SUMMARY OF LITHOLOGIC LOGGING OF NEW AND EXISTING BOREHOLES AT YUCCA MOUNTAIN, NEVADA, JULY 1994 TO NOVEMBER 1994

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CONVERSION FACTORS AND VERTICAL DATUM

Multiply	By	To obtain
millimeter (mm)	0.03937	inch
centimeter (cm)	0.3937	inch
meter (m)	3.281	foot
kilometer (km)	0.6214	mile

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

Summary of Lithologic Logging of New and Existing Boreholes at Yucca Mountain, Nevada, July 1994 to November 1994

By Thomas C. Moyer, Jeffrey K. Geslin, *and* David C. Buesch

Abstract

This report summarizes lithologic logging of core and drill cuttings from boreholes at Yucca Mountain, Nevada, conducted from July 1994 to November 1994. Units encountered during logging include the Tiva Canyon Tuff, Yucca Mountain Tuff, Pah Canyon Tuff, Topopah Spring Tuff, and interbedded nonwelded pyroclastic and epiclastic deposits of the Miocene Paintbrush Group, the Miocene Calico Hills Formation, and the Prow Pass Tuff and Bullfrog Tuff of the Miocene Crater Flat Group. Logging results are presented as: (1) A table of contact depths for core from boreholes USW SD-9, USW SD-12 and the lower part of USW UZ-14, and for drill cuttings from the upper part of boreholes UE-25 NRG #4 and UE-25 NRG #5; and (2) graphical lithologic logs for core from boreholes USW SD-9, USW SD-12, USW UZ-N31, and USW UZ-N32.

INTRODUCTION

Yucca Mountain, Nevada, is being investigated as a potential site for a high-level radioactive waste repository. Boreholes drilled by continuous coring and air-hammer methods are an integral part of the site-characterization studies. The objectives of the U.S. Geological Survey (USGS) lithologic logging program are to characterize the stratigraphic units encountered in boreholes in the Yucca Mountain area, to determine the spatial distribution of these units, and to provide stratigraphic data for use in a preliminary three-dimensional lithostratigraphic model of the site area. The program also provides data that can be integrated into hydrologic studies at Yucca Mountain and applied to engineering and construction of the Exploratory Studies Facility.

The contents of this report include lithologic logs completed between July and November 1994 by the Yucca Mountain Project Branch of the USGS. Logging results are presented as a table-of-contact depths for core from boreholes USW SD-9, USW SD-12, and the lower part of USW UZ-14, and for drill cuttings from the upper part of boreholes UE-25 NRG #4 and UE-25 NRG #5; and as graphical lithologic logs for core from boreholes USW SD-9, USW SD-12, USW UZ-N31, and USW UZ-N32.

The boreholes logged from July to November 1994 are plotted on figure 1 and listed, with their location and elevation, in table 1. Table 1 also lists the Data Tracking Number (DTN) for stratigraphic data from each borehole that have been released to the Yucca Mountain Project, submitted to the USGS Local Records Center in Denver, Colorado, and stored in the Yucca Mountain Project Central Records Facility in Las Vegas, Nevada. Cores and drill cuttings from boreholes logged during this study are stored at the Yucca Mountain Project Sample Management Facility at the Nevada Test Site.

Lithostratigraphic units identified during logging include the Tiva Canyon Tuff, Yucca Mountain Tuff, Pah Canyon Tuff, Topopah Spring Tuff, and interbedded nonwelded pyroclastic and epiclastic deposits of the Miocene Paintbrush Group, the Miocene Calico Hills Formation, and the Prow Pass Tuff and Bullfrog Tuff of the Miocene Crater Flat Group. Radiometric ages determined for these units are reported in Sawyer and others (1994).

STUDY METHODS

The lithologic logs reported herein use the stratigraphic hierarchy and nomenclature defined by Sawyer and others (1994) for the Paintbrush Group, Calico Hills Formation, and Crater Flat Group. Sub-formation lithostratigraphic units follow the stratigraphic hierarchy and nomenclature defined by Buesch and others (in press) for the Paintbrush Group and by Moyer and Geslin (in press) for the Calico Hills Formation and Prow Pass Tuff (Crater Flat Group) (table 2). The criteria used to identify sub-formation contacts are described in Geslin and others (in press) for the Paintbrush Group and in Moyer and Geslin (in press) for the Calico Hills Formation and Prow Pass Tuff. Table 3

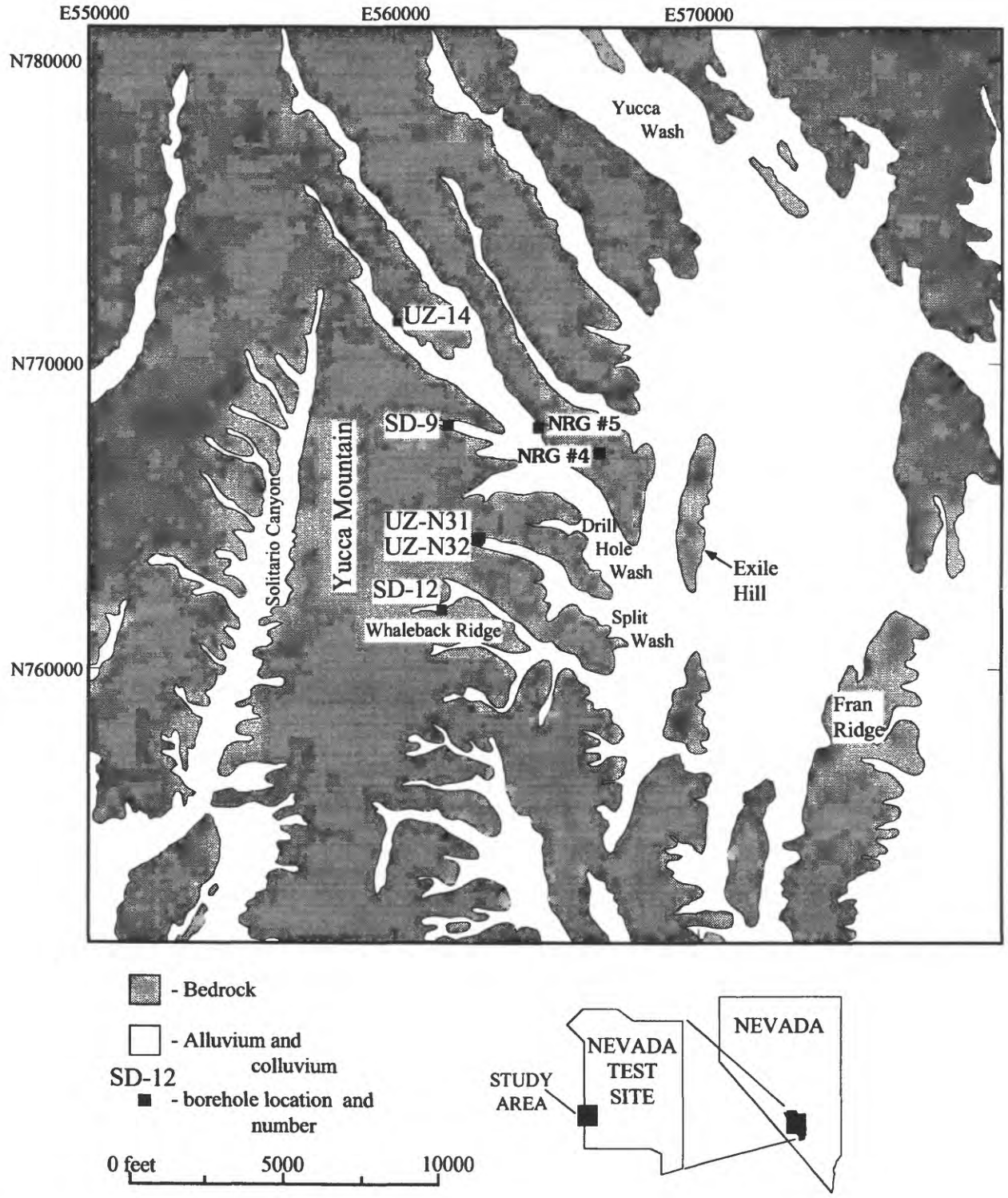


Figure 1. Borehole location map.

Table 1. Location and information for boreholes logged at Yucca Mountain, July 1994 to November 1994

[Northing, easting, and elevation data are from EG&G and were provided as information to the Yucca Mountain Project. Northing and easting are based on the Nevada State Coordinate System. 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. Locations and elevations are in feet. Locations for USW SD-9 and USW SD-12 are pre-drilling estimates.]

Borehole number	Northing	Easting	Elevation	Data tracking number
Identification of lithologic contacts (type 1 logging)				
USW UZ-14	771,309.4	560,141.3	4,426.2	GS940908314211.043
USW SD-9	767,988.6	561,818.0	4,272.5	GS941008314211.050
USW SD-12	761,956.6	561,605.7	4,343.0	GS940908314211.044
UE-25 NRG #4	767,080.2	566,820.0	4,099.7	GS941108314211.055
UE-25 NRG #5	767,889.6	564,769.9	4,106.7	GS941108314211.055
Detailed lithologic logging (type 2 logging)				
USW SD-9	767,988.6	561,818.0	4,272.5	GS941108314211.052
USW SD-12	761,956.6	561,605.7	4,343.0	GS940908314211.045
USW UZ-N31	764,245.7	562,751.9	4,101.0	GS941008314211.051
USW UZ-N32	764,302.6	562,799.6	4,156.2	GS941008314211.049

summarizes the stratigraphic intervals penetrated by the boreholes included in this report.

Lithologic logs that identify the depths of stratigraphic contacts are herein referred to as type 1 logs. The results of type 1 logging are reported to the Yucca Mountain Project as tables-of-contact depths. Type 1 logs were completed for core recovered from boreholes USW SD-9, USW SD-12, and the lower part of USW UZ-14, and for drill cuttings recovered from the upper part of boreholes UE-25 NRG #4 and UE-25 NRG #5 (table 4).

More detailed logs that identify the depths of contacts and provide detailed unit descriptions are herein referred to as type 2 logs. The results of type 2 logging are reported to the Yucca Mountain Project in graphical form. Type 2 lithologic logs (appendix 1) were created for core recovered from boreholes USW SD-9, USW SD-12, USW UZ-N31, and USW UZ-N32. These logs use the criteria of Buesch and others (in press) to identify the welding and crystallization zones in each unit. Accompanying lithologic unit descriptions include the phenocryst content and assemblage; lithophysae content and size; pumice content, size, and composition; lithic clast content, size and composition; and matrix color and content. The percentage of phenocrysts, lithic clasts, pumice clasts and lithophysae are visually estimated using charts included in the Munsell Soil Color Charts (Kollmorgen Instruments Corp., 1992). Phenocryst, pumice, and lithic clast types are identified with the aid of a hand lens or binocular microscope. The maximum and minimum dimensions of pumice, lithic clast, and lithophysae (void) sizes are measured along two perpendicular axes and recorded as either typical or maximum sizes observed. Pumice, lithic clast, and matrix colors are determined using Munsell Color Charts (Geological Society of America, 1991; Kollmorgen Instruments Corp., 1992). Other features of the core, including fracture geometry and morphology, fracture mineralization, and development and orientation of foliation (dip angle measured from a plane perpendicular to the core axis), also are recorded and included in unit descriptions.

Table 2. Lithostratigraphic nomenclature of the Paintbrush Group, Calico Hills Formation, and Prow Pass Tuff at Yucca Mountain (from Sawyer and others, 1994; Buesch and others, in press; Moyer and Geslin, in press)

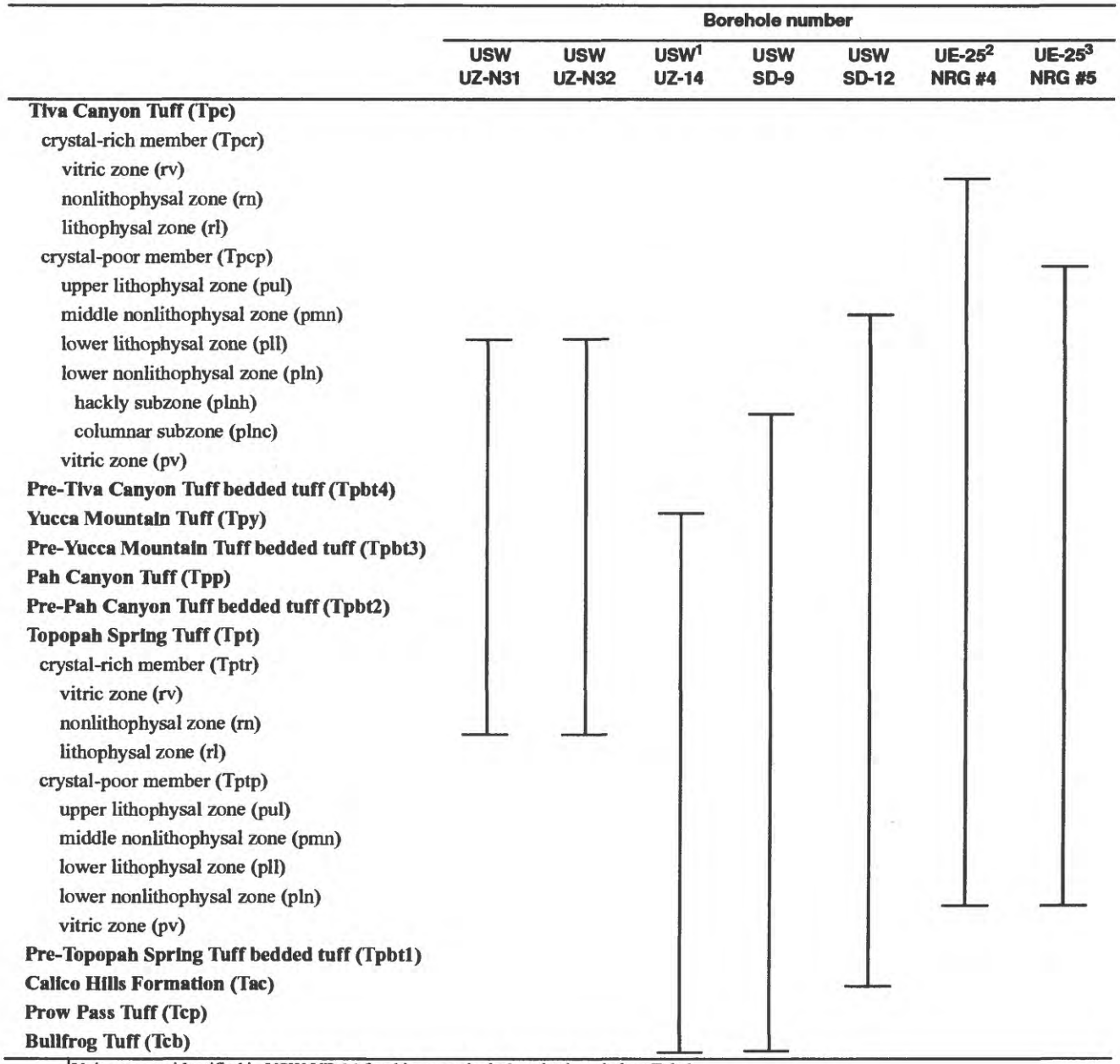
Tuff unit "x" (Tpkl)
Pre-Tuff unit "x" bedded tuff (Tpbt5)
Tiva Canyon Tuff (Tpc)
- crystal-rich member (Tpcr) (quartz latite)
  - vitric zone (rv)
    - non- to partially welded subzone (rv3)
    - moderately welded subzone (rv2)
    - densely welded subzone (rv1)
  - nonlithophysal zone (rn)
    - subvitrophyre transition subzone (rn4)
    - pumice-poor subzone (rn3)
    - mixed pumice subzone (rn2)
    - crystal transition subzone (rn1)
  - lithophysal zone (rl)
    - crystal transition subzone (rl1)
- crystal-poor member (Tpcp) (high-silica rhyolite)
  - upper lithophysal zone (pul)
    - spherulite-rich subzone (pul1)
  - middle nonlithophysal zone (pmn)
    - upper subzone (pmn3)
    - lithophysae-bearing subzone (pmn2)
    - lower subzone (pmn1)
  - lower lithophysal zone (pll)
  - lower nonlithophysal zone (pln)
    - hackly subzone (plnh)
    - columnar subzone (plnc)
      - spherulitic pumice interval (plnc3)
      - argillic pumice interval (plnc2)
      - vitric pumice interval (plnc1)
  - vitric zone (pv)
    - densely welded subzone (pv3)
    - moderately welded subzone (pv2)
    - non- to partially welded subzone (pv1)

Pre Tiva Canyon Tuff bedded tuff (Tpbt4)
Yucca Mountain Tuff (Tpy)
Pre-Yucca Mountain Tuff bedded tuff (Tpbt3)
Pah Canyon Tuff (Tpp)
Pre-Pah Canyon Tuff bedded tuff (Tpbt2)
Topopah Spring Tuff (Tpt)
- crystal-rich member (Tptr) (quartz latite)
  - vitric zone (rv)
    - non- to partially welded subzone (rv3)
    - moderately welded subzone (rv2)
    - densely welded subzone (rv1)
  - nonlithophysal zone (rn)
    - crystal transition subzone (rn1)
  - lithophysal zone (rl)
    - crystal transition subzone (rl1)
- crystal-poor member (Tptp) (high-silica rhyolite)
  - upper lithophysal zone (pul)
    - cavernous lithophysae subzone (pul2)
    - small lithophysae subzone (pul1)
  - middle nonlithophysal zone (pmn)
    - upper subzone (pmn3)
    - lithophysae-bearing subzone (pmn2)
    - lower subzone (pmn1)
  - lower lithophysal zone (pll)
  - lower nonlithophysal zone (pln)
  - vitric zone (pv)
    - densely welded subzone (pv3)
    - moderately welded subzone (pv2)
    - non- to partially welded subzone (pv1)

Pre-Topopah Spring Tuff bedded tuff (Tpbt1)
Calico Hills Formation (Tac)
- pyroclastic unit 5 (Tac5)
- pyroclastic unit 4 (Tac4)
- pyroclastic unit 3 (Tac3)
- pyroclastic unit 2 (Tac2)
- pyroclastic unit 1 (Tac1)
- bedded tuff unit (Tacbt)
- basal sandstone unit (Tacbt)

Prow Pass Tuff (Tcp)
- unit 4 (Tcp4)
- unit 3 (Tcp3)
- unit 2 (Tcp2)
- unit 1 (Tcp1)
- bedded tuff unit (Tcpbt)

Table 3. Generalized lithostratigraphy of boreholes at Yucca Mountain, Nevada



[1]Unit contacts identified in USW UZ-14 for this report include only those below Tpbt1.

[2]Unit contacts identified in UE #25 NRG #4 for this report include only those above Tpbt3.

[3]Unit contacts identified in UE #25 NRG #5 for this report include only those above Tptrn.

Table 4. Summary of depths to basal contacts for boreholes at Yucca Mountain, Nevada

[Stratigraphic subdivisions follow the nomenclature defined by Sawyer and others (1994) and Buesch and others (in press); All depths in feet; N.A., no core, identification of contacts in drill cuttings was not attempted; N.P., not present]

UNIT	USW SD-9	USW SD-12	USW[1] UZ-14	UE-25[2] NRG #4	UE-25[2] NRG #5
Tiva Canyon Tuff (Tpc)					
crystal-rich member (Tpcr)					
nonlithophysal zone (rn)				[3]56	
lithophysal zone (rl)				64	
crystal-poor member (Tpcp)					
upper lithophysal zone (pul)				N.A.	[3]N.A.
middle nonlithophysal zone (pmn)		[3]93.4		N.A.	N.A.
lower lithophysal zone (pll)		129.5		N.A.	N.A.
lower nonlithophysal zone (pln)	[3]57.2	176.0		311	140
vitric zone (pv)					
moderately welded subzone (pv2)	61.0	256		323	154
non- to partially welded subzone (pv1)	92.4	263.7		335	164
Bedded tuff (Tpbt4)	95.9	268.3		342	170
Yucca Mountain Tuff (Tpy)	140.8	N.P.	*[3]78.2*	360	198
Bedded tuff (Tpbt3)	156.5	278.3	*102.1*	*381.0*	216
Pah Canyon Tuff (Tpy)	226.6±0.5	291.2	*240.4*	*458.0*	292
Bedded tuff (Tpbt2)	255.6	314.1	*258.6*	*468.1*	312±10
Topopah Spring Tuff (Tpt)					
crystal-rich member (Tpcr)					
vitric zone (rv)					
non- to partially welded subzone (rv3)	266.7	320.8	*280.9*	*N.P.*	N.A.
moderately welded subzone (rv2)	268.5	324.6±0.5	*282.5*	*485.0*	330
vitrophyre subzone (rv1)	272.2	330.7	*286.0*	*488.9*	332
nonlithophysal zone (rn)	439.2	436.4	*430.0*	*660.5*	N.A.
lithophysal zone (rl2)	447.3	439.0	*452.8*	*683±2*	N.A.
crystal transition subzone (rl1)	484.2	476.5	*468.0*	*710±2*	N.A.
crystal-poor member (Tpcp)					
upper lithophysal zone (pul)	736.8	663.7	*715.0*		*796.0*
middle nonlithophysal zone (pmn)	845.8	786.9	*828.0*		*901.5*
lower lithophysal zone (pll)	1185.8	1041.0	*1138.0*		N.A.
lower nonlithophysal zone (pln)	1365.0	1278.1±0.4	*1279.1*		N.A.
vitric zone (pv)					
vitrophyre subzone (pv3)	1418.4±0.3	1308.0	*1344.0*		
moderately welded subzone (pv2)	1425.7	1337.5±0.4	*1383.0*		
non- to partially welded subzone (pv1)	1464.1	1408.1	*1404.2*		
Bedded tuff (Tpbt1)	1479.9	1411.5±1.0	1420.2		
Calico Hills Formation (Tac)	1820.7		1750.2		
Prow Pass Tuff (Tcp)			2072.1		
Bullfrog Tuff (Tcb)					
Total depth	2223.1	1435.3	2206.7	*726.0*	*1350.0*

[1]Depths in italics are from Geslin and others (1995).

[2]Depths in italics are from Geslin and others (1995). Bit cuttings sampled at 5 ft intervals; contact depth is assigned by visually estimating the proportion of substrate material in the sample.

[3]The first unit encountered in the borehole.

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(p. 9 follows)

APPENDIX

APPENDIX 1. GRAPHICAL LITHOLOGIC LOGS FOR BOREHOLES AT YUCCA MOUNTAIN, NEVADA

Notes for Graphical Lithologic Logs

USW UZ-N31

1. This log contains a description of the crystal-poor lower lithophysal zone of Tiva Canyon Tuff (15.0–24.0 ft). This unit was not listed in the data package "Table of basal lithologic contacts in boreholes USW UZ-N31, USW UZ-N32 and USW UZ-N37" (data tracking number: GS940208314211.005) (Geslin and others, in press), and the contacts depths in this log are superseding data for borehole USW UZ-N31 in that data package.
2. Core from this borehole is stored in lexan tubing that retains moisture. Therefore, colors listed in this log may not correlate to colors listed in lithologic logs that describe dry core.

USW UZ-N32

1. This log contains a description of the crystal-poor lower lithophysal zone of Tiva Canyon Tuff (0.0–16.4 ft). This unit was not listed in the data package "Table of basal lithologic contacts in boreholes USW UZ-N31, USW UZ-N32 and USW UZ-N37" (data tracking number: GS940208314211.005) (Geslin and others, in press), and the contacts depths in this log are superseding data for borehole USW UZ-N32 in that data package.
2. Core from this borehole is stored in lexan tubing that retains moisture. Therefore, colors listed in this log may not correlate to colors listed in lithologic logs that describe dry core.

All Graphical Lithologic Logs

(v) - contacts depths designated with this symbol were identified using videotape of unstaged core intervals or downhole videotape.

Welding Definitions

Nonwelded = nondeformed pumice, no to slight sintering of matrix.

Partially welded = nondeformed pumice, sintered/ incipiently welded matrix (some macroscopic porosity).

Moderately welded = partial deformation of pumice (some macroscopic porosity), densely welded matrix (no porosity).

Densely welded = collapsed pumice (no macroscopic porosity), densely welded matrix.

Mineral Notation

qtz = quartz

san = sanidine

plag = plagioclase

feld = sanidine and plagioclase, undifferentiated

hbld = hornblende

cpx = clinopyroxene

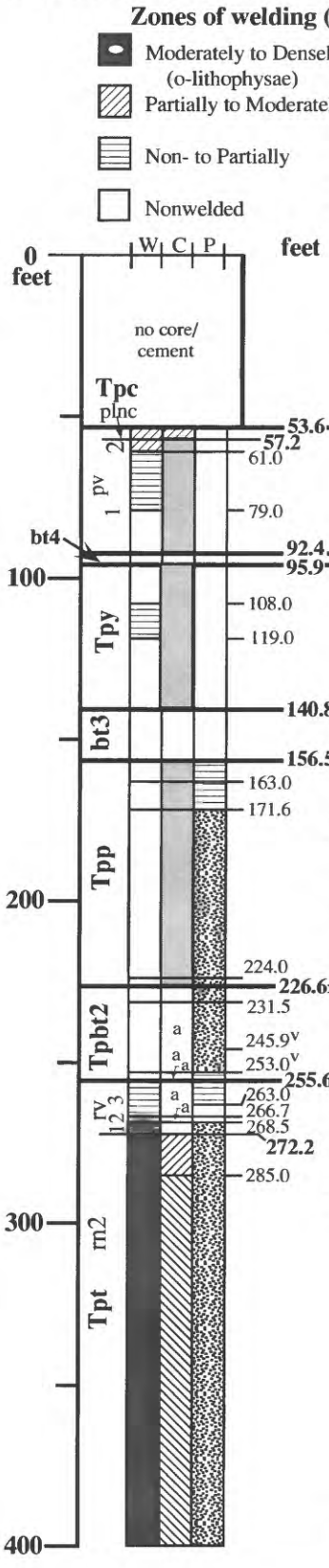
bio = biotite

(oxy)bio = partially oxidized biotite

oxybio = completely oxidized biotite

Graphical Lithologic Log of Borehole USW SD-9

DTN: GS941108314211.052 Compiled: 2 August, 1994



Tiva Canyon Tuff (Tpc)-

Crystal-poor lower nonlithophysal zone (pln) (53.6-57.2 ft):

53.6-57.2 ft columnar subzone (plnc)- Matrix is grayish orange-pink to grayish orange (5YR7/1 to 10YR7/4) with light brown to orange-brown (5YR6/6 to 5YR6/8), devitrified shards. Deformed pumice clasts (7 percent) are light brown (5YR5/4) or pale red (5R6/1, 5R7/2); the latter may contain spherulites. Phenocrysts (2 to 3 percent) are mostly feld; lithic clasts are less than 1 percent.

Crystal-poor vitric zone (pv) (57.2-92.4 ft):

57.2-61.0 ft moderately welded subzone (pv2)- Matrix is light brown (7.5YR6/4) with deformed, black (N1) glass shards. Pumice clasts (7 to 10 percent) are grayish pink (5R8/2), devitrified with minor vapor-phase alteration. Crystals (2 to 3 percent) are mostly feld; medium gray (N5) lithic clasts comprise 1 percent.

61.0-92.4 ft non -to partially welded subzone (pv1)- Matrix grades downward from pale yellowish brown (5YR6/2) to grayish orange-pink (5YR7/2) to very pale orange (10YR8/1) all with black glass shards. Pumice clasts (10 to 12 percent decreasing down to 7 to 10 percent) are grayish orange-pink (2.5YR7/2, 10R8/2), and vitric with minor vapor-phase alteration. Crystals and lithic clasts as above. Smooth fractures with black mineral coating are common. Basal 2 cm is well-sorted, crystal- and lithic-rich layer with sharp lower contact.

Bedded tuff (Tpbt4) - Pumiceous fallout. Light brown (5YR6/4) paleosol grades downward to white (N9), well-sorted pumice of 1 to 3 mm diameter.

Yucca Mountain Tuff (Tpy) -

Matrix with minor vapor-phase crystallization varies downward from grayish orange-pink (5YR7/1) to pale red (10R6/2) to pale yellowish brown (10YR6/1) to very light gray (N8). Glass shards with bubble-wall textures vary from colorless to gray or black (N1) and are slightly deformed from 108.0 to 119.0 ft. Vitric pumice clasts comprise from 5 to 7 percent, are typically smaller than 10 mm, and vary from very pale orange (10YR8/2; 10YR8/1) to grayish orange-pink (10R8/1) and moderate orange-pink (10R7/4). Phenocrysts (less than 1 percent) are mostly feld. Lower contact is depositional.

Bedded tuff (Tpbt3) - *140.8-143.1 ft:* pale yellowish brown (10YR7/2), possibly reworked deposit; *143.1-143.6 ft:* well-sorted, pumice- and lithic-rich fall deposit; *143.6-151.3 ft:* pale yellowish brown (5YR7/2), reworked deposit with mm-sized pumice; *151.3-155.1 ft:* grayish orange (10YR7/3), reworked deposit with cm-sized pumice; *155.1-156.5 ft:* very light gray to white (N8-N9), well-sorted, pumice-fall deposit (5 mm diameter clasts).

Pah Canyon Tuff (Tpp) -

Vitric, ashy matrix is moderate pink (2.5YR7/3, 2.5YR6/3; 5YR7/4), grayish orange-pink (5YR7/2) , moderate orange-pink (5YR8/3), pale yellowish brown (10YR7/2), or white (N9). Phenocrysts (10 to 15 percent) of feld, (oxy)bio, and cpx. Variations in pumice size, amount, and color indicate flow unit breaks at 163.0, 171.6, and 224.0 ft. Vitric pumice (typically 10 to 60 mm, but to greater than 80 mm) vary downward by flow unit: light gray (N7 to N8); light gray and grayish orange-brown (10YR6/4); pale red (2.5YR6/3) to dark yellowish orange (10YR6/6) with feld and bio; white (N9). Lithic clasts comprise 1 to 5 percent. Lower contact is in nonrecovered interval; upper 1 to 2 feet appear reworked or weathered.

Bedded tuff (Tpbt2) - *226.6±0.5-231.5 ft:* pale yellowish brown (10YR7/2), possibly reworked, with very light gray (N8) microvesicular pumice, moderate reddish orange (10R6/6) altered pumice, and lithic clasts of porphyritic obsidian. Basal 0.8 ft is reworked fallout with 1-cm-thick lithic-rich fallout at base. *231.5-253.0 ft:* fallout deposit; very pale orange (10YR8/2), slightly altered, vitric pumice of less than 15 mm comprise 70 to 80 percent. Lithic clasts comprise 5 to 15 percent and include devitrified lava(?), porphyritic obsidian and tuff. Pink fallout occurs at 245.9 ft on video. Lower contact determined from video. *253.0-255.6 ft:* dark yellowish orange (7.5YR6/6), strongly altered, with 10 percent very light gray (N8) pumice. Fallout at 255.6 ft is approximately 3-cm-thick, moderate orange-pink (10R7/4) ash with abundant lithic clasts.

Topopah Spring Tuff (Tpt) -

Crystal-rich vitric zone (rv) (255.6-272.2 ft) -

255.6-266.7 ft non- to partially welded subzone (rv3) - dark yellowish orange (7.5YR6/6), matrix-rich and altered above 262.6 ft; pumiceous and clast supported below, with very light gray (N8) to yellowish brown (7.5YR6/8), nondeformed pumice.

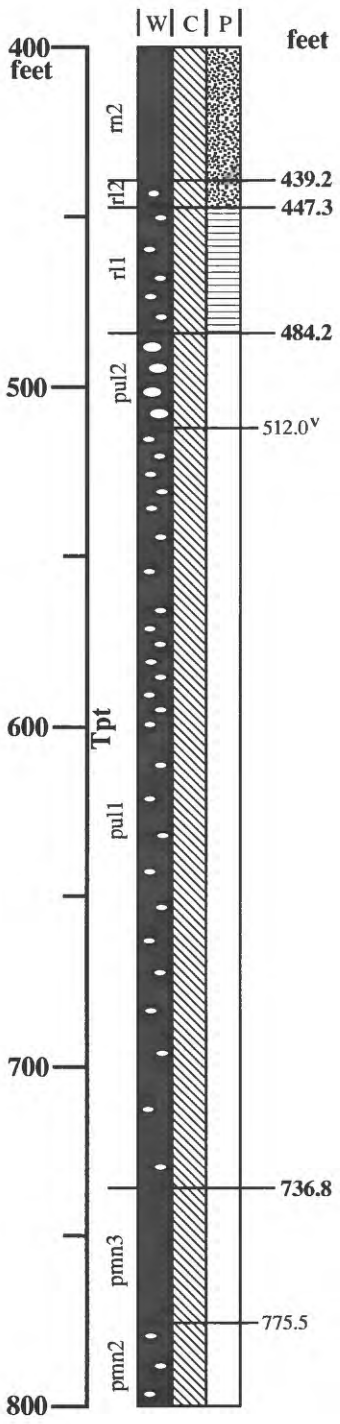
266.7-268.5 ft moderately welded subzone (rv2) - deformed, very light gray (N8) to yellowish brown (7.5YR6/8) vitric pumice, clast supported, with pale red (5R6/2) matrix. Lithic clasts of devitrified lava and porphyritic glass comprise 10 percent. Phenocrysts (3 to 5 percent) are predominantly feld with subordinate (oxy)bio.

268.5-272.2 ft densely welded subzone (rv1) - dark grayish red (10R3/2) to dark reddish brown (10R4/3) glass with black (N1) fiamme above 271.5 ft; grayish black (N2) glass below 271.5 ft. Phenocrysts of predominant feld with subordinate oxybio and cpx comprise 12 to 15 percent. Large, porphyritic pumice clast occurs at 268.7 ft.

Crystal-rich nonlithophysal zone (rn2) (272.2-439.2 ft) - see page 2.

Graphical Lithologic Log of Borehole USW SD-9

DTN: GS941108314211.052 Compiled: 3 August, 1994



Topopah Spring Tuff (Tpt) -

Crystal-rich nonlithophysal zone (rn2) (272.2-439.2 ft) - Devitrified matrix varies downward from grayish black (N2) to dark gray (N3) to dusky yellowish brown (10YR3/1) to reddish brown (2.5YR4/3) to moderate brown (5YR4/4) to light brown (5YR5/6). Vapor-phase alteration typically comprises 20 to 50 percent below 285.0 ft and is intense from 312.5 to 334 ft, with large pockets of coarsely crystalline vapor-phase minerals comprising 60 to 80 percent of the rock from 318 to 323 ft. Vapor-phase deposits vary from very dark gray (N3) to grayish red (10R4/3) to pale red (10R6/2) and form pockets, blebs, or streaks in the matrix. Pumice clasts comprise 10 to 20 percent, typically are medium gray (N5) and pale red (2.5YR6/2), or white (N9) and pale red (5R6/2) and contain vapor-phase minerals. Phenocrysts of feld, subordinate oxybio, and fresh to altered cpx comprise 12 to 15 percent. Lithic clasts comprise 1 percent or less.

Crystal-rich lithophysal zone (rl) (439.2-484.2 ft) -

439.2-447.3 ft crystal-rich lithophysal subzone (rl2) - Light brown (5YR5/6), devitrified matrix contains from 40 to 50 percent grayish pink (5R7/1), vapor-phase alteration as discrete blebs and rims on lithophysal cavities. Lithophysae (up to 30 mm diameter) comprise less than 2 percent. Pumice clasts (10 percent) are white (N9) and medium light gray (N6). Phenocrysts of feld, subordinate oxybio, and fresh to altered cpx comprise 12 to 15 percent. Lithic clasts comprise 1 percent or less.

447.3-484.2 ft crystal transition subzone (rl1) - Matrix grades from predominantly light brown (5YR5/6) above 455 ft to predominantly grayish red-purple (5RP5/2) below 460 ft. Vapor-phase alteration (40 to 60 percent) is very light gray (N8) to pinkish gray (5YR8/1), occurring as discrete spots (up to 40 mm diameter), blebs, streaks, and rims on lithophysae. Lithophysae (10 to 30 mm diameter) typically comprise less than 5 percent but locally are 7 to 10 percent (446-474 ft); lithophysae are subrounded (length/width of 1 to 2). Pumice clasts (8 to 10 percent decreasing downward to 5 to 7 percent) are moderate brown (5YR4/3), with 10 to 12 percent crystals of feld, oxybio, and altered cpx. Crystals decrease downward: 10 to 12 percent above 455 ft, 7 to 10 percent at 458 ft, 3 to 5 percent at 466 ft, 3 percent at 475 ft, 2 to 3 percent at 484.2 ft. (Oxy)bio and altered cpx decrease downward; cpx not observed below 474 ft.

Crystal-poor upper lithophysal zone (pul) (484.2-736.8 ft) -

484.2-512.0 ft cavernous lithophysae subzone (pul2) - Matrix is predominantly pale red-purple (5RP6/2) with vapor-phase alteration (40 to 60 percent) as very light gray (N8) to pinkish gray (10R8/2) spots and rims on lithophysae. Lithophysae vary from 10 to 25 percent of the core, typically are 10 to 30 mm in diameter, and subround (length/width of 1 to 2). Downhole video reveals abundant, large lithophysae with diameters that exceed borehole diameter. Large (to 50 mm), moderate brown (5YR5/3) pumice clasts that contain 10 to 12 percent phenocrysts of feld and oxybio comprise 10 to 15 percent. Crystals (2 percent) are predominantly feld with subordinate bio. Lithic clasts comprise less than 1 percent.

512.0-736.0 ft small lithophysae subzone (pul1) - Matrix is predominantly pale red-purple (5RP6/2) with variable, but generally subordinate, moderate orange-pink (10R7/4) to light brown (5YR6/4) colors mingled throughout; light brown locally dominates pale red-purple. Vapor-phase alteration is pinkish gray (5YR8/1) and varies from 15 to 30 percent, occurring as discrete spots, wisps, streaks, and rims on lithophysae. Lithophysae, which vary from 5 to 10 percent up to 10 to 25 percent, are typically smaller than 40 mm, but may exceed core width. They become increasingly elongate downward (length/width of 1 to 2 above 600 ft; 2 to 4 below 600 ft). Large lithophysae are rarely observed on downhole videos. Large (to greater than 80 mm), moderate brown (5YR5/3) pumice clasts that contain 10 to 12 percent phenocrysts of feld and oxybio comprise 5 to 15 percent above 541 ft. Pumice clasts decrease rapidly to less than 5 percent below 540 ft, where they are typically smaller than 15 mm and medium light gray (N6) with grayish brown (5YR3/2) borders. Crystals (1 to 2 percent) are predominantly feld with rare (oxy)bio. Lithic clasts, mostly light gray (N7) and pale reddish brown (10R5/3) foliated lava, comprise less than 1 percent. Fractures are typically irregular and rough above 715 ft but become gradually smoother from 715 to 736 ft. Some fractures from 680 to 700 ft are smooth and are enclosed in bands of vapor-induced alteration.

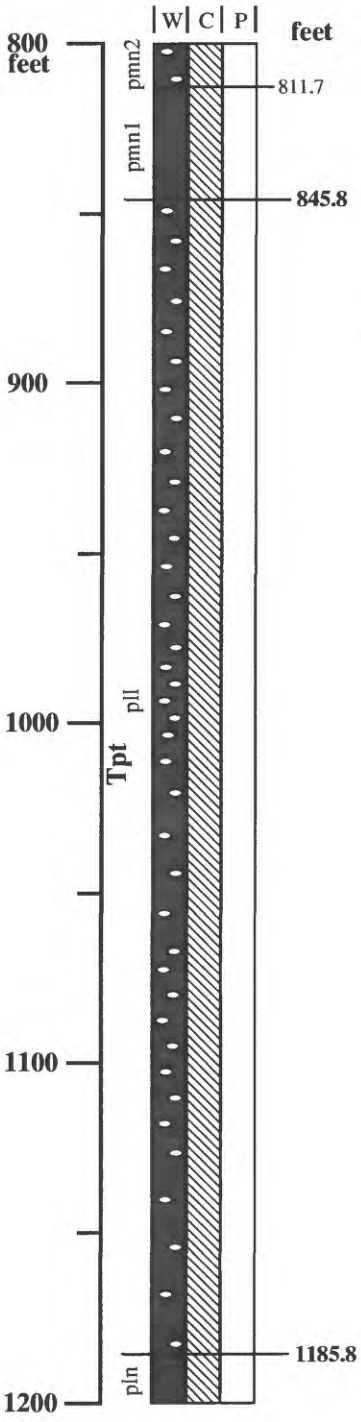
Crystal-poor middle nonlithophysal zone (pmn) (736.8-845.8 ft) -

736.8-775.5 ft upper nonlithophysal subzone (pmn3) - Matrix is light brown (2.5YR6/4), with 10 percent (locally greater) spots and wisps of pinkish gray (5YR7/1) vapor-phase alteration. Lithophysae are rare to absent. Pumice clasts comprise 1 to 2 percent, are typically smaller than 15 mm, and pinkish gray (5YR8/1) with dark brown borders. Crystals (1 to 2 percent) are predominantly feld with rare (oxy)bio. Lithic clasts of light gray (N7) lava and pale red (5R6/2) lava comprise 1 percent. Fractures are typically smooth, planar and moderately high-angle (dips of 50° to 60°).

775.5-811.7 ft middle lithophysae-bearing subunit (pmn2) - Matrix grades downward from light brown (2.5YR6/3) to grayish red-purple (5RP4/2) to moderate brown (5YR5/4) with 10 to 20 percent pinkish gray (5YR7/1) vapor-phase alteration as spots and rims on lithophysae. Lithophysae, typically smaller than 30 mm, vary downward: 1 to 2 percent above 792.0 ft, 2 to 3 percent from 792.0 to 805.6 ft, 1 to 2 percent 805.6 to 813.5 ft. Pumice clasts comprise 1 percent, are typically smaller than 25 mm, and pinkish gray (5YR8/1) with dark brown borders. Crystals (1 to 2 percent) are predominantly feld with rare (oxy)bio. Lithic clasts of very light gray to white (N8 to N9) hypabyssal(?) rock (euhedral feld, bio, and qtz(?) in a sugary matrix), comprise 1 percent and are smaller than 15 mm. Fractures are typically irregular; high-angle fractures are rare.

Graphical Lithologic Log of Borehole USW SD-9

DTN: GS941108314211.052 Compiled: 3 August, 1994



Topopah Spring Tuff (Tpt) -

Crystal-poor middle nonlithophysal zone (pmn) (736.8-845.8 ft) -

811.7-845.8 ft lower nonlithophysal subzone (pmn1) - Matrix is moderate brown (5YR5/4), locally grayish red-purple (5RP4/2), with 5 to 10 percent very light gray (N8) to pinkish gray (5YR8/1) vapor-phase alteration as diffuse spots. Lithophysae are absent above 839 ft; less than 1 percent from 839 to 845.8 ft. Pumice clasts, typically pinkish gray (5YR7/1) with moderate brown (5YR5/4) rims, comprise 2 to 3 percent and are up to 35 mm in diameter. Crystals (1 to 2 percent) are predominantly feld with rare (oxy)bio. Lithic clasts (1 to 2 percent) include light gray to very light gray (N7 to N8) hypabyssal and grayish red (5R4/2) porphyritic lava. Fractures are commonly high-angle (dips of 50° to 90°), smooth to moderately rough, and planar to curviplanar.

Crystal-poor lower lithophysal zone (pll) (845.8-1185.8 ft) -

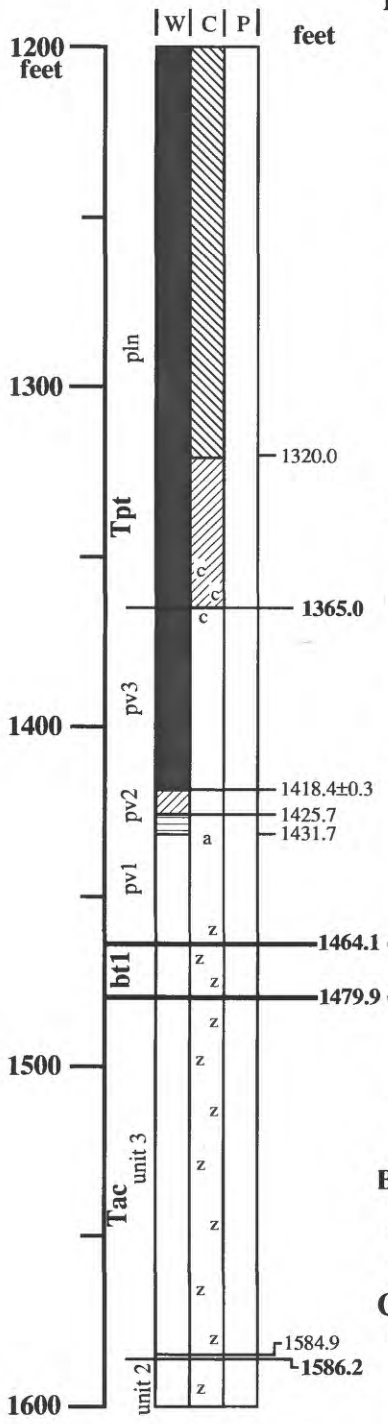
Matrix is a variable mix of moderate brown (5YR5/4) and pale red (10R6/2). Vapor-phase alteration, present as very light gray (N8) to pale grayish red (10R6/1) or grayish orange-pink (10R8/2) spots, blebs, streaks, wisps, and veinlets, comprises from 5 to 30 percent, typically 10 to 25 percent. Remnant shard texture is locally preserved below about 940 ft. Lithophysae typically comprise less than 5 percent (locally to 7 percent), but are difficult to estimate due to poor core recovery. Lithophysae are elongate (length/width of 3 to 5 or greater) with major axes commonly greater than 20 mm. Pumice clasts are light gray (N7) to pinkish gray (2.5YR7/1) with grayish brown (2.5YR3/2) rims. Pumice varies in abundance, comprising from 1 to 7 percent, with sizes typically less than 35 mm. Crystals (1 to 2 percent) are predominantly feld with rare (oxy)bio; possible qtz at 1092 ft. Lithic clasts increase downward from 1 to 2 percent to 7 to 10 percent (1040 to 1047 ft), then decrease to 2 to 5 percent. Lithic clasts include hypabyssal rock as above (common above 860 ft), very light gray to white (N8 to N9) and pale red (5R6/2) foliated lava, pale to dark yellowish brown (10YR6/2 to 10YR4/2), porphyritic lava, pale red (10R6/1), porphyritic lava, medium light gray (N6) lava, and rare, equigranular, cognate(?) clasts of feld and (oxy)bio. Most lithic clasts are smaller than 25 mm. Fractures are irregular to 1125 ft; smooth, high-angle, planar fractures are more common below 1125 ft. Vertical fracture with slickensides that dip at 5° occurs at 953.0 ft.

Crystal-poor lower nonlithophysal zone (pln) (1185.8-1365.0 ft) - see page 4.

Graphical Lithologic Log of Borehole USW SD-9

DTN: GS941108314211.052

Compiled: 4 August, 1994



Topopah Spring Tuff (Tpt) -

Crystal-poor lower nonlithophysal zone (pln) (1185.8-1365.0 ft) -

Matrix grades downward from pale red (10R6/1, 10R6/2) above 1286 ft to a mottled mix of pale red (10R6/1) and light brown (5YR6/6) below (where finely mottled the matrix has a grayish brown (5YR6/3) color); remnant shard texture occurs throughout. Vapor-phase alteration is present in minor amounts above 1320 ft as grayish orange-pink (10YR8/2) wisps and small, diffuse spots. Pumice clasts comprise from 3 to 10 percent, generally increasing downward, and are elongated with long axes of 20 to 40 mm. Pumice clasts have a mottled medium gray (N6) and moderate red (5R5/2) color, typically with thin, moderate reddish brown (10R5/6) or dusky yellowish brown (10YR2/2) rims; some clasts contain spherulites. Grayish black to dusky yellowish brown (N2 to 10YR2/2) borders preserved on some clasts below 1356 ft may be glassy. Grayish orange (10YR7/4) clay alteration occurs along pumice boundaries below 1352 ft, increasing in intensity downward until entire clasts are altered. Crystals (1 to 2 percent) are predominantly feld, with rare (oxy)bio and possible qtz. Lithic clasts increase from 1 to 3 percent above 1252 ft to 5 to 10 percent from 1273 to 1326 ft, then decrease to 3 to 5 percent below. Most clasts are white (N9), some with pale red (5R6/2) foliation; other lithic types include pale red (10R7/2) and pale yellowish brown (10YR6/2) porphyritic lava, medium gray (N6) lava, very light gray (N8) to very pale orange (10YR8/2) cognate clasts and very light gray (N8) hypabyssal clasts. Lithic clasts are typically 5 to 25 mm, but may occur up to 50 mm. Fractures are moderately smooth, with smooth, high-angle, curviplanar fractures common. Fractures at 1245.6 ft (dips at 15°) and 1318.9 ft (dips at 34°) have slickensides.

Crystal-poor vitric zone (pv) (1365.0-1464.1 ft) -

1365.0-1418.4±0.3 ft densely welded subzone (pv3) - Matrix is dark gray to black (N3 to N1), variably hydrated glass. Grayish orange (10YR7/4) clay alteration occurs in the upper 1.5 ft; pale red (5R6/2) spherulites comprise 2 to 3 percent above 1400 ft. Matrix texture is obliterated above 1411 ft but reappears below, becoming more pronounced downward as the degree of welding begins to decrease. Pumice clasts can be discerned as black (N1), glassy lumps below about 1385 ft. Crystals (1 to 2 percent) are mostly feld, with very rare (oxy)bio. Lithic clasts (3 to 6 percent decreasing to 2 to 4 percent) include white (N9) lava, grayish red (10YR5/2) and yellowish brown (10YR5/2) porphyritic lava, medium gray to light gray (N5 to N7) glass (below 1408 ft), and a possibly hypabyssal clast with a glassy matrix. Yellowish brown lava clasts dominate below 1380 ft. Lower contact is in nonrecovered interval.

1418.4±0.3-1425.7 ft moderately welded subzone (pv2) - Matrix is a mottled mix of grayish black (N2) and moderate yellowish brown (10YR5/4) glass shards that are deformed and fused. The rock fractures smoothly across shard boundaries. Pumice clasts (10 to 20 percent) are pale orange-pink (5YR8/3) to grayish brown (5YR6/2) and finely crystalline; some clasts are vitric below 1428 ft. Crystals and lithic clasts as in vitrophyre subzone.

1425.7-1464.1 ft non- to partially welded subzone (pv1) - Matrix contains grayish black (N2) to dark yellowish brown (10YR4/2) to colorless glass shards enclosed by very light gray (N8) to pinkish gray (5YR8/1), vitric ash. Shards are slightly aligned and deformed above 1431.7 ft; randomly oriented and nondeformed below. Shards are primarily cuspate, with some bubble-wall textures above 1432 ft. Matrix is altered from 1432.8 to 1436.7 ft with dark yellowish orange (10YR6/8) shards in a light brown (5YR6/4) matrix. Ash is altered to white (N9) or very pale orange (10YR8/2) zeolite(?) below 1457 ft; shards are altered to pale yellowish orange (10YR8/6) below 1460 ft. Pumice clasts (8 to 20 percent) are grayish orange-pink (5YR6/2) to light brown (5YR6/4). Crystals as above. Lithic clasts are generally less than 4 percent , except for the interval from 1431.5 to 1442.0 ft where they comprise 10 to 20 percent. Lithic types include those above plus prominent medium gray (N5) to light gray (N7) glass (yellowish gray (5Y8/1) where zeolitic); glassy lithic clasts dominate devitrified clasts from 1436.6 to 1442.0 ft. At the lower contact, a 10-mm-thick, pinkish gray (10YR8/1), fine-ash deposit rests on paleosol.

Bedded tuff (Tpbt1) - *1464.1-1479.9 ft:* white (N9) to pale pink-purple (5RP7/2) pumiceous fallout. Top is moderate brown (5YR6/4) paleosol. Pumice clasts are smaller than 5 mm. *1472.9-1477.0±0.7 ft:* light brown (5YR6/4), poorly sorted, nonwelded pyroclastic-flow deposit or reworked interval. *1477.0±0.7-1478.7±0.4 ft:* white to pale pink-purple, pumiceous fallout; pumice clasts are smaller than 15 mm. *1478.7±0.4-1479.9 ft:* lithic-rich fallout; lithic clasts are smaller than 3 mm and comprise 20 to 30 percent.

Calico Hills Formation (Tac) -

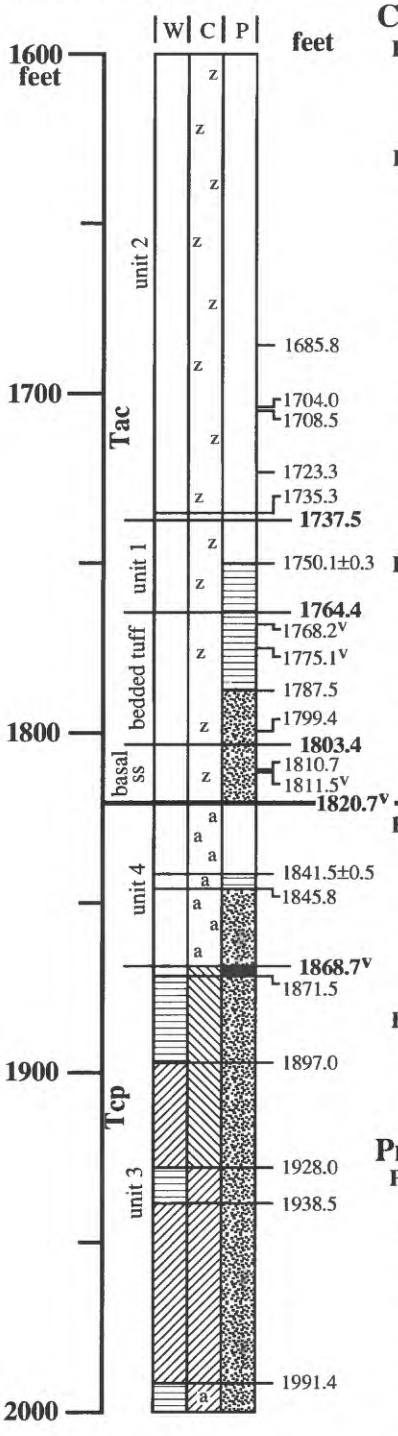
Pyroclastic unit 3 (Tac3) (1479.9-1586.2 ft) -

1479.9-1584.9 ft pyroclastic-flow deposit - Altered matrix varies downward from light brown (5YR6/3) to grayish orange-pink (5YR7/2) to grayish orange (10YR7/3) to pale yellowish brown (10YR7/2). Pumice clasts (15 to 40 percent) are pinkish gray (5YR8/1), grayish orange-pink (10R8/2), yellowish gray (5Y8/1), or moderate greenish yellow (10Y8/3) and typically smaller than 20 mm. Crystals of feld, qtz and minor bio compose 1 to 2 percent. Lithic clasts (4 to 10 percent) are aphyric or porphyritic lava in shades of brown (5YR3/2, 5YR4/4, 5YR6/4), red (5R4/2, 10R4/2, 10R3/4), or grayish black (N2) and moderate reddish orange (10R6/6) tuff. Lithic clasts are typically smaller than 15 mm; a zone of large clasts (20 to 35 mm) occurs from 1572.9-1573.9 ft.

Graphical Lithologic Log of Borehole USW SD-9

DTN: GS941108314211.052

Compiled: 21 October, 1994



Calico Hills Formation (Tac) -

Pyroclastic unit 3 (Tac3) (1479.8-1586.2 ft) -

1584.9-1586.2 ft lithic-rich fall deposit - Clast supported fallout with bedding break at 1585.8 ft. Lithic clasts, mostly 3-7 mm, but to 20 mm, compose 15 to 35 percent; types as in overlying pyroclastic-flow deposit. Pumice clasts, mostly 5 to 15 mm compose 65 to 85 percent.

Pyroclastic unit 2 (Tac2) (1586.2-1737.5 ft) -

1586.2-1735.5 ft pyroclastic-flow deposits - Bedding breaks defined by thin (few cm) pumice- or ash-fall deposits at 1685.8, 1704.4, 1708.5, and 1723.3 ft. Altered matrix varies downward from grayish orange-pink (5YR8/2) to moderate orange-pink (10R7/4). Pumice clasts (15 to 30 percent) are very pale orange (10YR8/2) or, locally, yellowish gray (5Y8/2; 5Y8/1) or grayish orange-pink (10R8/2), and typically smaller than 15 mm (but up to 65 mm). Phenocrysts of feld, qtz, and subordinate bio compose from 1 to 2 percent above about 1600 ft, and from 2 to 4 percent below. Lithic clasts compose from 2 to 5 percent above 1723.3 ft and from 3 to 7 percent below. Lithic clasts are typically smaller than 5 mm, but vary up to 15 mm, and are mostly moderate brown (5YR3/4) and blackish red (5R2/2) aphyric or porphyritic lava, with minor grayish black (N2) or medium light gray (N6) lava and moderate reddish orange (10R6/6) porphyritic tuff.

1735.3-1737.5 ft pyroclastic-fall deposits - Ash-fall and pumice-fall deposits with bedding thicknesses of a few cm. Ash deposits have a porcelaneous texture and vary from grayish orange-pink (5YR7/2) to pale yellowish brown (10YR7/2). Pumice-fall deposits are clast supported and have very pale orange (10YR8/2) to pinkish gray (5YR8/1) pumice clasts of less than 15 mm diameter. Lithic clasts compose from 3 to 5 percent up to 7 to 10 percent of the fall units.

Pyroclastic unit 1 (Tac1) (1737.5-1764.4 ft) -

Pyroclastic-flow deposits with a bedding break at 1750.1 ft ?? Altered matrix is grayish orange-pink (5YR8/2). Pumice clasts compose 15 to 25 percent above 1750.1 ft and 20 to 30 percent below, are yellowish gray (5Y8/1), and typically smaller than 20 mm. Crystals of feld, qtz, and subordinate bio compose 3 to 5 percent above 1750.1 ft and 7 to 10 percent below. Lithic clasts (3 to 5 percent above 1750.1 ft, 10 to 15 percent below) are mostly moderate reddish brown (10R4/4) and moderate brown (5YR3/4) porphyritic lava, with minor light gray (N7) or dark gray (N3) aphyric lava, and rare, moderate orange-pink (10R7/4) porphyritic tuff. Lithic clasts are typically smaller than 5 mm (but up to 18 mm) above 1750.1 ft and smaller than 8 mm (but up to 20 mm) below. Basal 1 cm is a grayish orange-pink (10YR8/2) ash.

Bedded tuff unit (Tacbt) (1764.4-1803.4 ft) -

Primarily pumice- or ash-fall deposits with bedding thicknesses of less than 0.1 ft to greater than 3.0 ft. *1764.4-1768.2 ft* - pyroclastic-flow deposit, pale yellowish brown (10YR7/2) with 7 to 10 percent white (N9) pumice clasts. *1768.2-1775.1 ft* - fine- to medium-grained pumice-fall deposits, pinkish gray to yellowish gray (5R8/1 to 5Y8/1) pumice clasts; base is a porcelaneous ash. *1755.1-1787.5 ft* - medium- to coarse-grained pumice-fall deposits; top may be reworked; thinly bedded from 1776.7 to 1778.6 ft. *1787.5-1799.4 ft* - medium- to coarse-grained pumice-fall deposits; top 6.3 ft is reworked; bio content increases sharply below 1793.8 ft. 1799.4-1803.4 ft - poorly sorted pumiceous fallout; top is reworked.

Basal sandstone unit (Tacbs) (1803.4-1820.7 ^{v} ft) -

Immature, tuffaceous sandstone with abundant bio. *1803.4-1810.7^{v} ft* - pale reddish brown (10R5/4) to light brown (5YR6/4) sandstone with intervals of reworked pumice. *1810.7-1811.5^{v} ft* - dark reddish brown (10R4/4) sandstone; top is deformed by loading. *1811.5^{v}-1820.7^{v} ft* - pale reddish brown (10R5/4) to pale yellowish brown (10YR7/2) sandstone with 5 to 15 percent altered pumice.

Prow Pass Tuff (Tcp) -

Pyroclastic unit 4 (Tcp4) (1820.7^{v}-1868.7^{v} ft) -

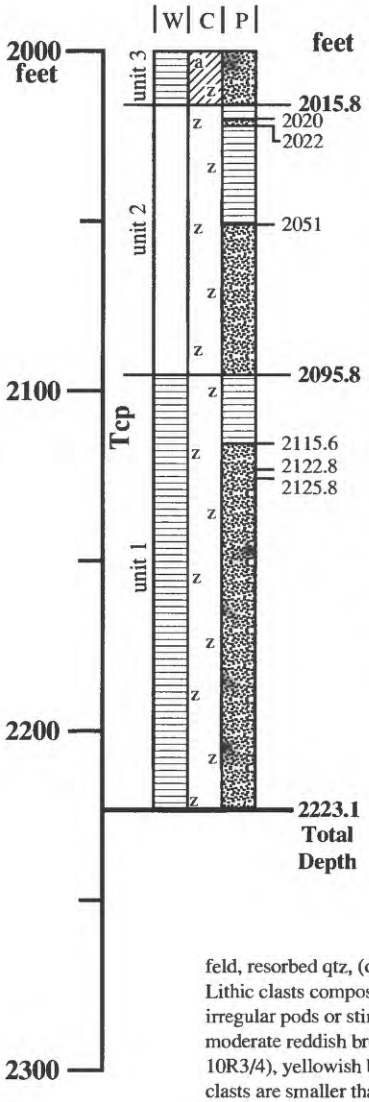
1820.7^{v}-1841.1±0.5 ft upper subunit - Fine-grained, altered pyroclastic-flow deposit. Matrix is grayish orange-pink (5YR8/2), yellowish gray (5Y8/2) or grayish orange-pink (10R8/2) with yellowish gray (5Y7/2) mottling. Upper 2.3 ft appear weathered. Pumice clasts (2 to 3 percent) are white (N9), rarely light brown (5YR7/4), and smaller than 10 mm. Phenocrysts of feld with minor qtz, (oxy)bio and pseudomorphs of px, compose 3 to 5 percent. Lithic clasts (2 to 3 percent) are smaller than 3 mm. Ash partings occur at 1832.7, 1835.8, and 1836.0 ft. Irregular high-angle fractures occur from 1820.7 to 1837 ft.

1841.1±0.5-1845.8 ft middle subunit - Altered matrix is light brown (7.5YR7/3) with white (N9) remnant shards. Pumice clasts (7 to 10 percent) are very pale orange (10YR8/2) and smaller than 15 mm. Crystals of feld, minor qtz, (oxy)bio, and px pseudomorphs compose 5 to 7 percent. Lithic clasts (2 to 3 percent) of lava are light brown (5YR6/4), grayish brown (5YR3/2), or grayish red (10R3/2), may be porphyritic, and are smaller than 5 mm (but rarely to 15 mm). Upper and lower contacts are gradational over 1 ft.

1845.8-1868.7v ft lower subunit - Altered matrix is very pale orange (10YR8/2) to medium light gray (N6) to very light gray (N8). Pumice clasts (15 to 25 percent) are 5 to 50 mm in size (typically 20 mm), porphyritic with feld, bio, and rare px, and light brown (5YR6/4 to 5YR6/6). Phenocrysts as above compose 10 to 12 percent. Lithic clasts as above plus moderate reddish brown (10R4/6) siltstone compose 2 to 3 percent, and are typically 3 to 5 mm in diameter.

Graphical Lithologic Log of Borehole USW SD-9

DTN: GS941108314211.052 Compiled: 3 November, 1994



Prow Pass Tuff (Tcp) -

Pyroclastic unit 3 (Tcp3) (1868.7^{V}-2015.8 ft) -

Note: Contacts within this unit commonly are gradational over distances of 1 to 3 feet.

1868.7^{V}-1871.5 ft vapor-phase altered subunit - Matrix is very pale orange (10YR8/1) and strongly altered to vapor-phase minerals. Pumice clasts (10 to 20 percent) are grayish orange-pink (5YR7/2) and smaller than 15 mm. Phenocrysts compose 5 to 7 percent; lithic clasts compose 1 to 2 percent.

1871.5-1897.0 ft upper non- to partially welded subunit - Matrix, which varies downward from very pale orange (10YR8/1) to very light gray (N8), is less altered than above. Pumice clasts (10 to 20 percent) vary from grayish orange-pink (5YR7/2) to pale red (10R6/2) to light gray (N7) and contain vapor-phase minerals. Most clasts are from 5 to 20 mm diameter, but a zone of larger clasts (to 65 mm) occurs from 1882.0 -1884.5 ft); 1 to 5 percent of pumice clasts are pale red and biotite-rich. Phenocrysts of feld, qtz, (oxy)bio and subordinate px pseudomorphs compose from 7 to 10 percent to 10 to 12 percent. Some feld are chatoyant. Lithic clasts (1 to 2 percent) of siltstone (grayish red to moderate reddish brown [10R4/2 to 10R4/6) and volcanic rocks (grayish brown [5YR3/2]) are mostly smaller than 5 mm diameter.

1897.0-1928.0 ft upper moderately welded subunit - Matrix is very light gray (N8). Pumice clasts (15 to 25 percent) are very light gray (N7) to white (N9) and slightly to moderately flattened, typically with long dimensions of 10 to 20 mm (but to 30 mm). Pumice clasts (15 to 25 percent) are rarely biotite-rich. Phenocrysts as in the overlying subunit. Angular lithic clasts smaller than 10 mm include types listed above plus dark reddish brown (10R3/4) volcanic rock. Flattened pumice impart a weak foliation; high angle fractures occur from 1908 to 1914 ft.

1928.0-1938.5 ft middle non- to partially welded subunit - Matrix is pinkish gray to grayish orange-pink (5YR8/1 to 10YR8/1). Pumice clasts vary from white (N9) to pale red (5R7/2) and are non- to slightly flattened. Phenocrysts and lithic clasts as above; siltstone lithic clasts may contain rings of discoloration.

1938.5-1991.4 ft lower moderately welded subunit - Matrix varies from very pale orange (10YR8/2) to pale red or grayish orange-pink (10R7/2, 10R8/2). Pumice clasts (15 to 25 percent) vary from white to medium light gray (N9 to N6), and are moderately flattened, imparting a moderately well developed foliation. Pumice clasts contain comparatively coarse vapor-phase minerals from 1938 to 1940 ft. Phenocrysts as above; px has brownish alteration rims below 1948 ft. Lithic clasts compose from 2 to 4 percent from 1978 to 1982 ft (typically 3 to 15 mm diameter, but to 30 mm) and from 1 to 3 percent elsewhere (typically smaller than 7 mm, but to 15 mm). Clast types include those described above plus grayish red (10R4/2) and dark yellowish brown (10YR4/2) feld- and bio-phyric volcanic rock, pale reddish brown to grayish orange (10R5/4 to 10YR7/4) tuff, and siltstone that may be pale reddish brown (10R5/4) to grayish black (N2).

1991.4-2015.8 ft lower non- to partially welded subunit - Matrix colors vary from pinkish gray (5YR8/1) to a mottled mix of very pale orange (10YR8/1) and moderate orange-pink (10R7/4) to grayish orange pink (5YR7/2) to very pale orange (10YR7/2). Spots of light olive brown (5Y5/6) alteration occur below 2012 ft. Nondeformed pumice clasts are locally corroded and vary from pale yellowish brown (10YR7/2) to shades of very light gray (N7 to N9) or grayish pink (5R8/2). Lithic clasts compose from 1 to 3 percent above 2003 ft; 2 to 4 percent below 2003 ft. Siltstone lithic clasts have indistinct margins below 1994 ft.

Pyroclastic unit 2 (Tcp2) (2015.8-2095.8 ft) -

Matrix varies from very pale orange (10YR8/1, 10YR8/2) to pinkish gray (5YR8/1) with 1 to 5 percent of spots of moderate to light olive brown (5Y4/4 to 5Y5/6) alteration in the matrix and along lithic clast margins. Nondeformed pumice clasts, vary from white (N9) to pinkish gray (5YR8/1) or very pale orange (10YR8/1), compose from 20 to 40 percent, and are typically from 4 to 15 mm in diameter. Phenocrysts of feld, resorbed qtz, (oxy)bio and rare px (as pseudomorphs) compose from 5 to 10 percent above 2051 ft and 10 to 12 percent below. Lithic clasts compose from 3 to 7 percent of the unit except from 2020-2022 ft where they compose 7 to 10 percent and occur in irregular pods or stingers. Clasts include siltstone in shades of grayish brown to moderate brown (5YR3/2 to 5YR3/4) or dark to moderate reddish brown (10R3/4 to 10R4/6); feld- and bio-phyric lava in shades of grayish red to dark reddish brown (10R4/2 to 10R3/4), yellowish brown (10YR4/2, 10YR5/1, 10YR3/1), and grayish orange-pink (5YR7/2); and pale red (10R6/2) tuff. Most clasts are smaller than 10 mm (but may be up to 20 mm) except from 2020-2022 ft where they are typically 5 to 15 mm (up to 30 mm). Lower contact is indistinct and determined by relatively abrupt change in core texture.

Pyroclastic unit 1 (Tcp1) (2095.8-2223.1 ft) -

Matrix is very pale orange (10YR8/2 to 10YR8/1) to white (N9) with 5 to 10 percent spots of moderate to light olive brown (5Y4/4 to 5Y5/6) alteration. Secondary porosity, partially infilled with spherical masses of zeolite, increases downward. Matrix becomes yellowish gray to grayish yellow (5Y8/1 to 5Y8/4) below 2220 ft. Fibrous pumice clasts are grayish orange to dark yellowish orange (10YR7/4 to 10YR6/6; interiors may be white) or light brown (5YR6/6 where silicified), contain 3 to 5 percent crystals of feld, and are non- to slightly deformed. Pumice clasts, which compose from 15 to 25 percent above 2122.8 ft and from 20 to 40 percent below, are typically from 10 to 50 mm (but may exceed core width of 60 mm). Phenocrysts of feld, minor qtz (resorbed), and rare (oxy)bio compose from 7 to 10 percent above 2115.6 ft; from 8 to 12 percent below. Lithic clasts of siltstone (grayish brown [5YR3/2] or dark to moderate reddish brown [10R3/4 to 10R4/6]) and volcanic rocks (grayish red [10R4/2, 5R4/1], yellowish brown [10YR4/2], or moderate red [10R7/4]) typically are smaller than 7 mm, compose from 1 to 3 percent. Ash partings at 2122.8 and 2125.8 ft mark flow boundaries. Minor fractures at 2178.9 and 2182.2 ft dip at 30° to 35°.

Graphical Lithologic Log of the Paintbrush Group in Borehole USW SD-12

DTN: GS940908314211.045

Zones of welding (W)

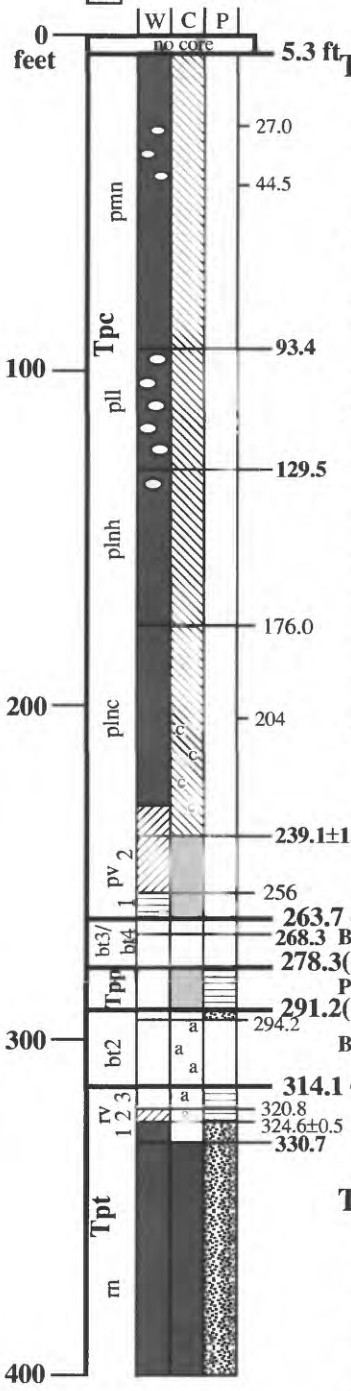
- Moderately to Densely (o-lithophysae)
- Partially to Moderately
- Non- to Partially
- Nonwelded

Zones of crystallization (C)

- Devitrified / Devit. + vapor-phase mins.
- Vitric / Vitric + vapor-phase mins.
- Altered (a) / to clay (c) / to zeolite (z)

Phenocryst content (P)

- greater than 10 percent
- 5 - 10 percent
- less than 5 percent



Tiva Canyon Tuff (Tpc)-

Crystal-poor middle nonlithophysal zone (pmn) (5.3-93.4 ft): Matrix is pale brown (5YR5/2) grading downward to pale red (5R6/2) then to grayish red (10R4/2). Matrix contains abundant white (N9) streaks of vapor-phase minerals. Lithophysae (1 to 2 percent) between 27.0 and 44.5 ft may represent the lithophysae bearing subzone; less than 1 percent lithophysae elsewhere. Less than 1 percent light gray (N7) volcanic lithic clasts, less than 10 mm. Pumice clasts (1 to 2 percent) are medium light gray (N6) and less than 12 mm (long axis). Phenocrysts (2 to 3 percent) include felds and very rare hbld.

Crystal-poor lower lithophysal zone (pll) (93.4-129.5 ft): Matrix is grayish red (10R4/2) with very light gray (N8) spots and rims on lithophysae, and streaks of vapor-phase minerals. Lithophysae comprise 7 to 10 percent; lithophysae plus spots and rims comprise 15 to 20 percent. Lithophysae average 20 to 30 mm diameter, up to 60 mm. Less than 1 percent light gray (N7) volcanic lithic clasts, most less than 5 mm. Pumice clasts (1 to 5 percent) are light gray to light brownish gray (N7 to 5YR6/1) and mostly less than 5 mm. Phenocrysts (1 to 2 percent) include feld and very rare hbld. Lower contact is gradational from about 125 to 134.5 ft and was based on the increase in hackly fractures.

Crystal-poor lower nonlithophysal zone (pln) (129.5-239.1±1.0 ft): *129.5-176.0 hackly subzone (plnh)* - Well developed hackly fractures at 128 to 134 and 167 to 176 ft; carbonate coated high-angle fractures from about 158 to 162 ft. Matrix is pale red (10R5/2). Pumice clasts (3 to 5 percent) are medium light gray to grayish red (N6 to 5R4/2), vapor-phase altered or spherulitic, most less than 20 mm (long axis), up to 40 mm. Phenocrysts (1 to 2 percent) include feld and very rare hbld. Lithophysae from 129.5 to 134.5 ft (1 to 2 percent), and from 165 to 170 ft (less than 1 percent). Lower contact gradational from about 165 to 176 ft and was called on the increase in smooth high-angle fractures. *176.0-239.1±1.0 columnar subzone (plnc)*- Matrix is grayish red (5R4/2) grading downward to light brownish gray (5YR6/1). Lithic clasts (1 to 2 percent) are light gray, light grayish brown, and white (N7, 5YR6/1, N9), mostly 5 to 10 mm. Pumice clasts comprise 3 to 5 percent, with swarms to 10 percent at 206.8 and 225.4 ft; most clasts are less than 20 mm. Pumice clasts are mostly gray (N6) to dark yellowish brown (10YR4/2), devitrified and spherulitic above about 204 ft, and are mostly moderate pink (5R7/4) and argillic below. Phenocrysts (2 percent) including feld and very rare oxybio. Moderately welded with remnant shard texture at base of unit.

Crystal-poor vitric zone (pv) (239.1±1.0-263.7 ft): *239.1±1.0-256 moderately welded subzone (pv2)*- Glass shards, moderate brown to black (5YR6/4 to N1), in a grayish orange (10YR7/4) partly devitrified matrix. Volcanic lithic clasts (2 percent) are gray (N6), less than 10 mm. Pumice clasts (3 to 5 percent) are grayish orange pink (5YR7/2), altered, and mostly less than 5 mm (up to 15 mm). One to 2 percent feld phenocrysts. Welding decreases downward. *256-263.7 non- to partially welded subzone (pv1)*- Black to dark yellowish orange (N1 to 10YR6/6) bubble-textured glass shards in grayish orange (10YR7/4) vitric to partly devitrified matrix. Lithic clasts, pumice clasts, phenocrysts as above.

Bedded tuffs (Tpbt4/bt3)

Bedded tuff (Tpbt4) (263.7-268.3 ft) - White pumiceous fallout deposit above 266.4 ft grading upward into light brown paleosol. Pumiceous, lithic-rich fallout deposit with black (N1) obsidian and very light gray (N8) perlitic glass below 266.4.

Bedded tuff (Tpbt3) (268.3-278.3 ft) - At least four beds including: fallout deposit (268.3-272.0 ft), multiple reworked fallout deposits (272.0-273.7 ft), reworked tuffaceous material (273.7-277.7 ft), and a fallout deposit (277.7-278.3).

Pah Canyon Tuff (Tpp)

Bedded tuff (Tpbt2)

Matrix is moderate orange pink (10R7/4) grading downward to grayish orange pink (10R8/2) and vapor-phase altered. Pumice clasts (20 to 25 percent) are yellowish gray, grayish orange and grayish orange pink (5Y7/2, 10YR7/4, 10R8/2), up to 60 mm and inversely graded. Phenocrysts (2 to 3 percent) including feld and (oxy) bio. Reworked with porphyritic obsidian clasts above 294.2 ft. Red argillic layer 294.2 to 295.0 ft. Altered and/or reworked below 295.0 with bedding breaks at 297.7, and 308.1 ft.

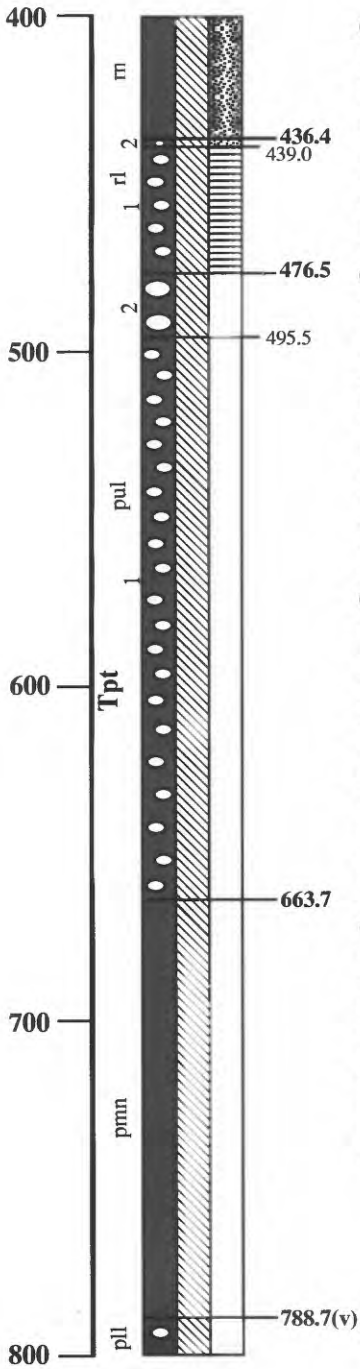
Topopah Spring Tuff (Tpt) -

Crystal-rich vitric zone (rv) (314.1-330.7 ft): *314.1-320.8 non- to partially welded subzone (rv3)* - 10 to 15 percent brownish gray (5YR4/1) devitrified, rarely vitric, volcanic lithic clasts. Vitric to altered pumice clasts (75 to 80 percent) are light gray (N8) and light grayish brown (5YR6/1). Phenocrysts (7 to 10 percent) include feld, (oxy)bio, and cpx. *320.8-324.6±0.5 moderately welded subzone (rv2)* - Slightly deformed, vitric to altered, pumice clasts (80 percent), moderate brown (5YR4/4) to light gray (N7). Seven to 10 percent phenocrysts as above. *324.6±0.5-330.7 densely welded subzone (rv1)* - Black to dark reddish brown (N1 to 10R3/4) glass with moderate brown (5YR4/4) vitric pumice clasts. Ten to 15 percent phenocrysts as above.

Crystal-rich nonlithophysal zone (rn) (330.7-436.4 ft): - see page 2

Graphical Lithologic Log of the Paintbrush Group in Borehole USW SD-12

DTN: GS940908314211.045



Crystal-rich nonlithophysal zone (rn) (330.7-436.4 ft):
Matrix grades downward from pale red (5R6/2) to pale brown (5YR5/2) to light brownish gray (5YR6/1), with abundant white (N9) streaks of vapor-phase minerals. Zones of intense vapor-phase alteration from 330.7 to 338.5 ft and 414.0 to 436.4 ft (vapor-phase alteration increases from about 398 to 414.0 ft). Less than 1 to 2 percent very light gray (N8) volcanic lithic clasts. Vapor-phase altered pumice clasts (5 to 7 percent) are corroded. Average pumice clast size increases downward in unit from mostly less than 10 mm to mostly less than 30 mm, local large clasts throughout unit (up to 55 x greater than 60 mm, width of core). Pumice clasts are very light gray, grayish red and light brownish gray (N8, 5R3/2, 5YR6/1), with pale brown to pale red (5YR5/2 to 5R6/2) porphyritic clasts below 422 ft. Phenocrysts (10 to 15 percent) include feld, oxybio, rare hbld and cpx. Moderately developed foliation, dipping approximately 5° to 15°, at about 350 and 420 ft.

Crystal-rich lithophysal zone (rl) (436.4-476.5 ft):
436.4-439.0 crystal-rich lithophysal subzone (rl2) - Matrix is light brownish gray (5YR6/1) with abundant white (N9) streaks of vapor-phase minerals. Lithophysae (3 to 5 percent) are up to 40 x 20 mm. Rare (less than 1 percent) very light gray (N8) volcanic lithic clasts. Vapor-phase altered pumice clasts (about 10 percent) are corroded, mostly less than 35 mm, and very light gray (N8) and pale brown (5YR5/2). Phenocrysts (10 to 15 percent) include feld and oxybio.
439.0-476.5 crystal transition subzone (rl1) - Matrix is light brownish gray (5YR6/1) above about 466 ft and medium light gray (N6) below, with abundant vapor-phase minerals. Lithophysae (3 to 5 percent) are mostly less than 35 mm (up to greater than 60 x 45 mm), and have very light gray (N8) rims. Pumice clasts (5 to 7 percent), mostly less than 25 mm (up to greater than 60 x 16 mm), are very light gray (N8) and porphyritic and pale brown (5YR5/1). Very light gray pumice clasts are corroded and filled with vapor-phase minerals; pale brown clasts increase in abundance downward. Phenocrysts decrease downward from 10 percent to 2 to 3 percent, and include feld and oxybio. There is an abrupt decrease in phenocryst content at about 460 to 468 ft.

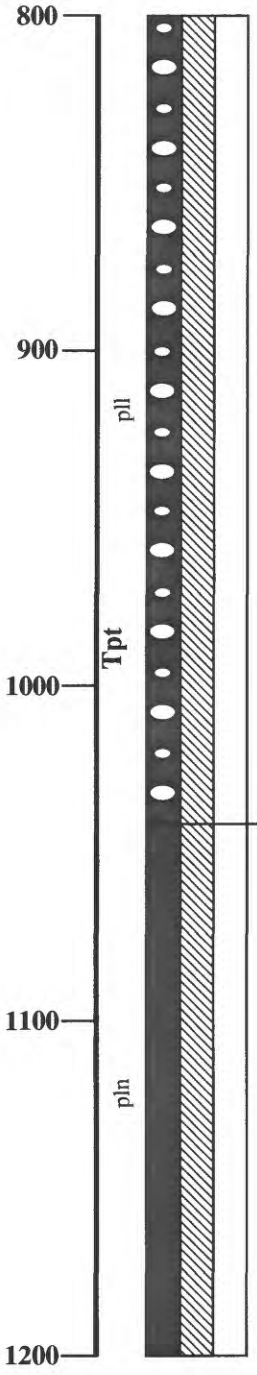
Crystal-poor upper lithophysal zone (pul) (476.5-663.7 ft):
476.5-495.5 Cavernous lithophysae subzone (pul2) - Core contains 3 to 5 percent visible lithophysae. Downhole videotape reveals numerous cavernous lithophysae (greater than about 10 cm). Other attributes as below.
495.5-663.7 Small lithophysae subzone (pul1) - Matrix grades downward from medium light gray (N6) above about 525 ft, to a mixture of pale red to light brown (5R6/2 to 5YR6/4) and red purple to moderate red (5RP5/2 to 5R5/2). Lithophysae content in core varies downward: 10 to 12 percent from about 495.5 to 550 ft; 15 to 25 percent from about 550 to 610 ft; 10 to 12 decreasing to 3 to 5 percent from about 610 to 663.7 ft. Lithophysae are mostly less than 30 mm (several are 40 to 50 mm, maximum 55 x 20 mm), with grayish pink (5R8/2) rims. Up to 10 percent grayish pink (5R8/2) spots in matrix. Pumice clast content decreases downward from 3 to 5 percent (above about 540 ft), to 1 to 3 percent (about 540 to 630 ft), to less than 1 percent (below about 630 ft). Pumice clasts are mostly less than 10 to 15 mm (up to greater than 60 x 55 mm). Pumice clast types include porphyritic pale brown (5YR5/2) above 543 ft, and very light gray to light brownish gray (N8 to 5YR6/1) throughout unit. Phenocrysts (1 to 3 percent) include feld and very rare (oxy)bio.

Crystal-poor middle nonlithophysal zone (pmn) (663.7-788.7 ft):
Matrix is a mixture of light brown (5YR6/4 to 5YR6/2) and red purple (5RP5/2). The abundance of red purple generally decreases downward. Matrix has 3 to 5 percent grayish pink (5R8/1) spots above about 680 ft, 1 to 2 percent spots below about 680 ft, and vapor-phase minerals in streaks and veinlets. The lithophysae-bearing subzone typically found in the middle of the zone was not observed in core or downhole videotape. Rare (less than 1 percent) lithophysae above 671 ft. Volcanic lithic clasts (1 to 3 percent) are very light gray to light brownish gray (N8 to 5YR6/1), most less than 10 mm, with a small swarm of clasts (5 percent) at about 735 ft (up to 34 x 32 mm). Pumice clasts (1 to 4 percent) are vapor-phase altered and light gray (N7), pale brown (5YR5/2), pale red (5R6/2), grayish orange pink (5YR7/2), and spherulitic and light brownish gray or grayish pink (5YR6/1 or 5R8/2). Phenocrysts (1 to 2 percent) include feld, rare bio, and very rare altered cpx.

Crystal-poor lower lithophysal zone (pll) (788.7-1041 ft): - see page 3

Graphical Lithologic Log of the Paintbrush Group in Borehole USW SD-12

DTN: GS940908314211.045



Crystal-poor lower lithophysal zone (pll) (788.7-1041 ft):

The upper and lower contacts of this unit were identified using downhole videotape and plots of unrecovered intervals, rubbled core and lithophysae visible in core. Above 960 ft matrix is light brown (5YR6/4 to 5YR5/3); below 960 ft matrix is a mixture of light brown (5YR6/4 to 5YR6/6) and red purple to moderate red (5RP5/2 to 10R5/2 or 5R4/2). Lithophysae visible in core at depths of 788.7 to about 840 ft (1 to 2 percent), about 880 to 930 ft (less than 1 percent), and about 960 to 965 ft (less than 1 percent); the lowest lithophysae visible in core is at about 1029 ft. These lithophysae are mostly less than 30 mm (maximum 55 x 37 mm), with grayish pink (5R8/2) rims; lithophysae in downhole videotape are larger than the diameter of the core (60 mm). Grayish pink (5R8/2) spots in matrix and rims on lithophysae (spots plus rims equal up to 5 percent). Volcanic lithic clasts comprise 2 to 5 percent and are mostly less than 10 to 15 mm, some 20 to 30 mm, maximum 80 x 55 mm (at 1028 ft). Volcanic lithic clast types include very light gray to white and pale reddish brown (N8 to N9 and 10R5/4), flow banded white and pale brown (N9 and 5YR5/2), and rare porphyritic pale red (5R6/2). Pumice clasts (2 to 5 percent) are mostly less than 20 mm (up to 15 cm x greater than 60 mm), and are very light gray (N8) and light brownish gray (5YR6/1). Phenocrysts (1 to 3 percent) include feld and rare (oxy)bio and altered cpx, and very rare qtz (?) below 940 ft.

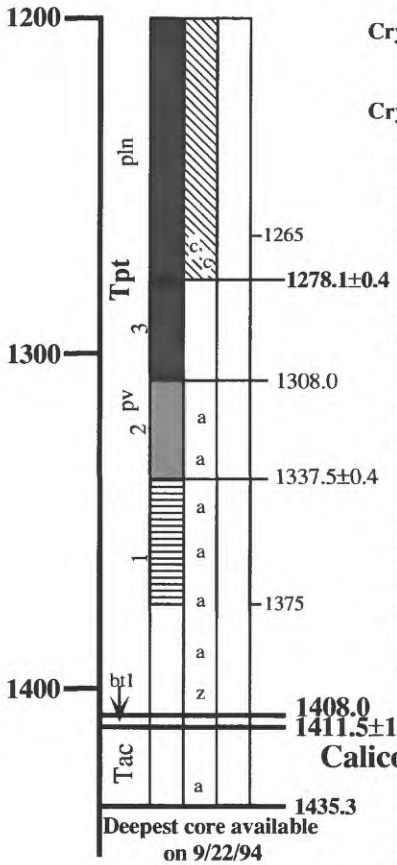
1041(v)

Crystal-poor lower nonlithophysal zone (pln) (1041-1278.1±0.4):

Matrix is a mixture of light brown (5YR6/6 to 5YR6/4) and grayish red or pale red (10R5/2, 5R4/2, or 10R6/2). Grayish red and pale red in matrix is replaced by red purple (5RP5/2) above about 1060 ft, and by dark yellowish brown (10YR4/2) below about 1240 ft. Lithic-clast content varies throughout the unit, and several swarms of lithic clasts are present. Lithic clasts comprise 2 to 5 percent from 1041 to about 1150 ft, with swarms of clasts (10 to 25 percent) at about 1098, 1116, 1134, and 1153 ft. Lithic clast content varies: 5 to 7 percent at about 1150 to 1170 ft; 2 to 3 percent at about 1170 to 1190 ft; 5 to 7 percent at about 1190 to 1220 ft; and 2 to 3 percent below 1220 ft. Lithic clasts are very light gray to white (N8 to N9), grayish brown (5YR4/2), rarely porphyritic and pinkish grey (5YR8/1), rarely porphyritic and pale red (5R6/2), or rarely light olive gray (5Y5/2). Lithic clasts are mostly less than 10 to 15 mm (up to 55 x 34 mm). Pumice clasts comprise 1 to 3 percent above about 1260 ft and 3 to 5 percent below. Pumice clasts above about 1265 ft have dark yellowish brown (10YR3/2) rims with grayish orange pink (10R8/2) vapor-phase altered cores, and locally contain light brown (5YR6/4) spherulites. Below about 1265 ft pumice clasts are dominantly argillically altered and pale yellowish orange (10YR8/6). Pumice clasts are mostly less than 15 mm (up to 42 x 7 mm). Phenocrysts (1 to 2 percent) include feld and rare bio.

Graphical Lithologic Log of the Paintbrush Group in Borehole USW SD-12

DTN: GS940908314211.045



Crystal-poor lower nonlithophysal zone (pln) (1041-1278.1±0.4) - see page 3:

Crystal-poor vitric zone (pv) (1278.1±0.4-1408.0):

1278.1±0.4-1308.0 densely welded subzone (pv3) - Matrix is perlitic glass, black grading downward to medium grey (N1 to N5). Lithic clasts (2 to 3 percent) are very light gray (N8), rarely moderate brown (5YR4/4) and porphyritic or grayish red (5R4/2), most less than 15 mm (up to 51 x 16 mm). Black (N1) fiamme (3 to 5 percent) visible below about 1300 ft. Phenocrysts (1 to 2 percent) include feld. Grayish blue (5PB5/2) fracture-lining minerals.

1308.0-1337.5±0.4 moderately welded subzone (pv2) - Matrix is grayish orange (10YR7/4) with black (N1) glass shards. Pumice clasts (3 to 5 percent) are vitric (perlitic) and black (N1) or dusky yellowish brown (10YR2/2) above about 1318 ft, and altered and dark yellowish orange or moderate yellowish brown (10YR6/6 or 10YR5/4) below 1318 ft. Most pumice clasts are less than 20 mm. Lithic clasts (3 to 5 percent) are very light gray (N8), rarely moderate brown (5YR4/4) and porphyritic or grayish red (5R4/2). Most lithic clasts are less than 15 mm with many 1 to 2 mm. Phenocrysts (1 to 2 percent) include feld. Lower contact is gradational from about 1334 to 1338 ft.

1337.5±0.4-1408.0 non- to partially welded subzone (pv1) - Matrix is grayish orange (10YR7/4) with grayish black (N1) glass shards above about 1377 ft, and altered and grayish pink (10R8/2) below 1381 ft. Pumice clasts (5 to 10 percent) are argillic (?) and grayish orange (10YR7/4) with rare remnant black (N1) glass shards in top of unit, and mostly zeolitic (?) and grayish pink (10YR8/2) in base. Most pumice clasts are less than 10 to 15 mm (up to 60 x 15 mm). Lithic clasts (2 to 7 percent) are vitric and dark gray to very light gray (N3 to N8), or devitrified and very light gray, grayish brown, and moderate brown (N8, 5YR3/2, 5YR4/4). Lithic clasts are mostly less than 10 mm (up to 25 x 16 mm) and reverse graded in lowest two feet of unit. Phenocrysts (1 to 2 percent) include feld and rare bio.

Bedded tuff (Tpbt1) (1408.0-1411.5±1.0):

Pumiceous fallout deposit. Pumice clasts (80 to 90 percent) are white (N9) or moderate pink (5YR7/2), most are 1 to 2 mm.

Calico Hills Formation (Tac) -

Pyroclastic flow deposit (unit 3 of Moyer and Geslin, 1994, USGS Open-File Report 94-460). Matrix is grayish orange pink to moderate orange pink (5YR7/2 to 5YR8/4) and dominantly vitric with minor amounts of zeolite minerals. Pumice clasts (5 to 7 percent) are light gray (N7) and vitric or grayish orange pink to very pale orange (10R8/2 to 10YR8/2) and altered (zeolitic?), most less than 15 to 20 mm (up to 35 x 55 mm). Lithic clasts (12 to 15 percent) are dark gray or medium light gray (N3 or N6) glass, black and dark yellowish orange (N1 and 10YR6/6) altered glass, and grayish red and moderate brown (5R4/2 and 5YR4/4) devitrified. Most lithic clasts are less than 10 to 15 mm. Phenocrysts (3 to 5 percent) include feld, qtz, and (oxy)bio.

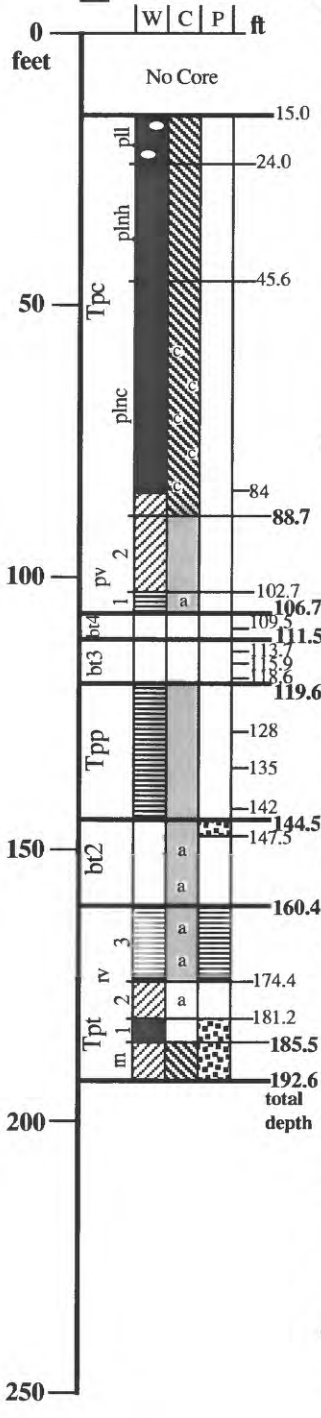
Graphical Lithologic Log of Borehole USW UZ-N31

DTN: GS941008314211.051

Zones of welding (W)
- Moderately to Densely (○- lithophysae)
- Partially to Moderately
- Non- to Partially
- Nonwelded

Zones of crystallization (C)
- Devitrified / Devit. + vapor-phase mins.
- Vitric / Vitric + vapor-phase mins.
- Altered (a) / to clay (c) / to zeolite (z)

Phenocryst content (P)
- greater than 10 percent
- 5 - 10 percent
- less than 5 percent



Tiva Canyon Tuff (Tpc) -

Crystal-poor lower lithophysal zone (pll) (15.0-24.0 ft):
Matrix is pale red (10R6/2) with 3 to 5 percent very light gray (N8) spots and rims on lithophysae and streaks in matrix. Lithophysae (1 to 2 percent), up to 19 x 58 mm. Devitrified volcanic lithic clasts (1 to 2 percent) are very light gray (N8), less than 10 mm. Pumice clasts (2 to 3 percent) are medium gray (N6) with very light gray (N8) vapor-phase minerals. Two to 3 percent feld phenocrysts. Hackly fractures below about 16 ft.

Crystal-poor lower nonlithophysal zone (pln) (24.0-88.7 ft):
24.0-45.6 hackly subzone (plnh) - Matrix is pale red (10R6/2) with 3 to 5 percent very light gray (N8) streaks of vapor-phase minerals. Devitrified volcanic lithic clasts (1 to 2 percent) are very light gray (N8), less than 10 mm. Pumice clasts (2 to 3 percent) are medium light gray (N6) with very light gray (N8) vapor-phase minerals, and mostly less than 20 mm. Phenocrysts (2 to 3 percent) include feld. Hackly fractures poorly developed between about 25 and 43 ft.

45.6-88.7 columnar subzone (plnc)- Matrix is pale brown (5YR5/2) grading downward to grayish orange (10YR7/4). Lithic clasts (1 percent) are very light gray and light brown (N8, 5YR6/4), mostly 5 to 10 mm. Pumice clasts comprise 2 to 3 percent and are mostly less than 20 mm, except for a pumice swarm at about 84 to 86 ft (3 to 4 percent, up to 14 x greater than 60 mm). Pumice clasts above about 71 ft and below about 79 ft are mostly medium gray to moderate brown (N5, 5YR3/4), devitrified and spherulitic, with rare argillic moderate reddish orange (10R6/6) clasts. Pumice clasts between about 71 and 79 ft are mostly argillic and moderate reddish orange (10R6/6). Pumice clasts are vitric just above basal contact. Phenocrysts (2 to 3 percent) include feld. Moderately welded with remnant shard texture below about 84 ft.

Crystal-poor vitric zone (pv) (88.7-106.7 ft):
88.7-102.7 moderately welded subzone (pv2)- Moderate brown glass shards in a grayish orange (10YR7/4) partly altered matrix. Argillic (?) alteration at 92.5-93.0 ft. Volcanic lithic clasts (1 percent) are medium gray, very light gray and dark yellowish orange (N5, N8, 10YR6/6), less than 10 mm. Pumice clasts (1 to 2 percent) are black (N2) and vitric, mostly less than 10 mm (up to 22 mm). Two to 3 percent feld phenocrysts. Welding decreases downward.

102.7-106.7 non- to partially welded subzone (pv1)- Black to dark yellowish orange bubble-textured glass shards in a grayish orange (10YR7/4) vitric to partly altered matrix. Lithic clasts, pumice clasts, phenocrysts as above.

Bedded tuffs (Tpbt4) (106.7-111.5 ft)-

White (N9) pumiceous fallout deposit above 109.5 ft grading upward into pale red (5R6/2) paleosol. Pumiceous, lithic-rich fallout deposit with 5 to 10 percent distinctive black (N1) obsidian and medium light gray (N6) perlitic glass lithic clasts below 109.5 ft.

Bedded tuffs (Tpbt3) (111.5-119.6 ft)-

At least four beds including: lithic-rich fallout deposit containing gray perlitic glass and devitrified volcanic lithic clasts (111.5-113.7±0.8 ft), reworked pumiceous fine-grained fallout deposit (113.7±0.8-115.9±0.1 ft), reworked poorly-sorted fallout deposit (115.9±0.1-118.6 ft), and coarse-grained pumiceous fallout deposit (below 118.6 ft).

Pah Canyon Tuff (Tpp) (119.6-144.5 ft)-

Matrix is moderate reddish orange (10R6/6) grading downward to pale reddish brown (10R5/4) to moderate orange pink (10R7/4), and sintered. Pumice-clast swarms suggests flow boundaries at about 128, 135 and 143 ft. Pumice clasts comprise 15 to 20 percent at the tops of flows, grading downward to 3 to 5 percent. Pumice clasts are pinkish gray and grayish orange (5YR8/1, 10YR7/4), up to 80 mm and inversely graded. Phenocrysts (5 to 8 percent) include feld, hbld and (oxy)bio.

Bedded tuffs (Tpbt2) (144.5-160.4 ft)-

Reworked lithic-rich and crystal-rich tuff above 147.5 ft with several bedding breaks. Top of poorly-developed red argillic layer at 147.5 ft, with altered fallout deposit below. Thin very fine-grained fallout deposit at 160.4 ft.

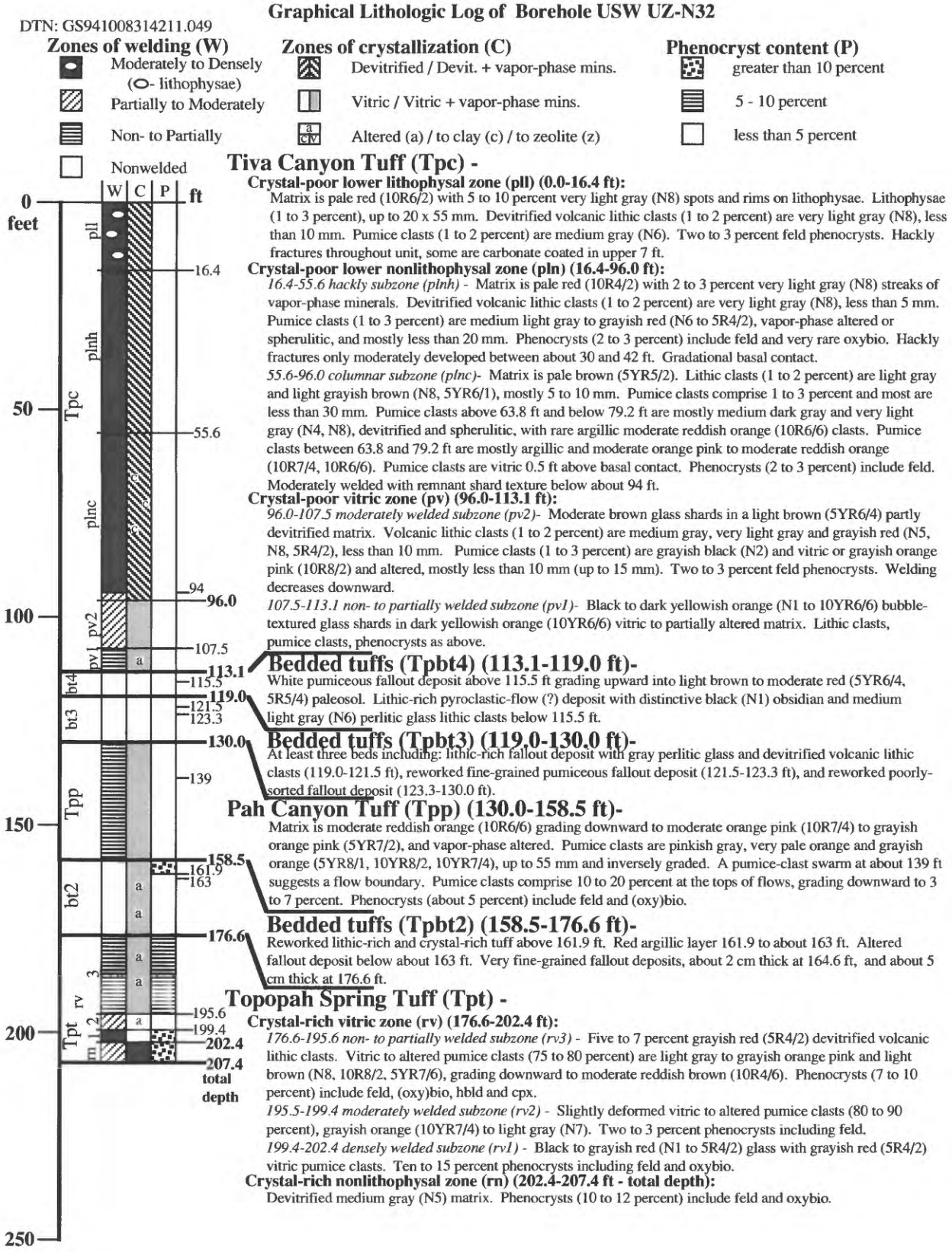
Topopah Spring Tuff (Tpt) -

Crystal-rich vitric zone (rv) (160.4-185.5 ft):
160.4-174.4 non- to partially welded subzone (rv3) - Seven to 10 percent black (N1) vitric, and pale red (5R6/2) devitrified volcanic lithic clasts. Vitric to altered pumice clasts (75 to 80 percent) vary in color from light gray to grayish orange pink (N8, 10R8/2). Phenocrysts include feld and (oxy)bio. Alteration increases downward with a dark reddish brown (10R3/4) matrix developed at base.

174.4-181.2 moderately welded subzone (rv2) - Slightly deformed vitric to altered pumice clasts (80 to 90 percent), light gray (N7). Unit appears altered with a dark yellowish brown (10YR4/2) matrix.

181.2-185.5 densely welded subzone (rv1) - Dusky red to grayish red (5R3/4 to 5R4/2) glass with black (N1) vitric pumice clasts. Ten to 15 percent phenocrysts including feld, hbld, oxybio and cpx.

Crystal-rich nonlithophysal zone (rn) (185.5-192.6 ft - total depth):
Devitrified medium dark gray to grayish red (N4, 5R4/1) matrix. Phenocrysts (10 to 12 percent) include feld and oxybio.



Tiva Canyon Tuff (Tpc) -

Crystal-poor lower lithophysal zone (pll) (0.0-16.4 ft):
Matrix is pale red (10R6/2) with 5 to 10 percent very light gray (N8) spots and rims on lithophysae. Lithophysae (1 to 3 percent), up to 20 x 55 mm. Devitrified volcanic lithic clasts (1 to 2 percent) are very light gray (N8), less than 10 mm. Pumice clasts (1 to 2 percent) are medium gray (N6). Two to 3 percent feld phenocrysts. Hackly fractures throughout unit, some are carbonate coated in upper 7 ft.

Crystal-poor lower nonlithophysal zone (pln) (16.4-96.0 ft):
16.4-55.6 hackly subzone (plnh) - Matrix is pale red (10R4/2) with 2 to 3 percent very light gray (N8) streaks of vapor-phase minerals. Devitrified volcanic lithic clasts (1 to 2 percent) are very light gray (N8), less than 5 mm. Pumice clasts (1 to 3 percent) are medium light gray to grayish red (N6 to 5R4/2), vapor-phase altered or spherulitic, and mostly less than 20 mm. Phenocrysts (2 to 3 percent) include feld and very rare oxybio. Hackly fractures only moderately developed between about 30 and 42 ft. Gradational basal contact.

55.6-96.0 columnar subzone (plnc)- Matrix is pale brown (5YR5/2). Lithic clasts (1 to 2 percent) are light gray and light grayish brown (N8, 5YR6/1), mostly 5 to 10 mm. Pumice clasts comprise 1 to 3 percent and most are less than 30 mm. Pumice clasts above 63.8 ft and below 79.2 ft are mostly medium dark gray and very light gray (N4, N8), devitrified and spherulitic, with rare argillic moderate reddish orange (10R6/6) clasts. Pumice clasts between 63.8 and 79.2 ft are mostly argillic and moderate orange pink to moderate reddish orange (10R7/4, 10R6/6). Pumice clasts are vitric 0.5 ft above basal contact. Phenocrysts (2 to 3 percent) include feld. Moderately welded with remnant shard texture below about 94 ft.

Crystal-poor vitric zone (pv) (96.0-113.1 ft):
96.0-107.5 moderately welded subzone (pv2)- Moderate brown glass shards in a light brown (5YR6/4) partly devitrified matrix. Volcanic lithic clasts (1 to 2 percent) are medium gray, very light gray and grayish red (N5, N8, 5R4/2), less than 10 mm. Pumice clasts (1 to 3 percent) are grayish black (N2) and vitric or grayish orange pink (10R8/2) and altered, mostly less than 10 mm (up to 15 mm). Two to 3 percent feld phenocrysts. Welding decreases downward.

107.5-113.1 non- to partially welded subzone (pv1)- Black to dark yellowish orange (N1 to 10YR6/6) bubble-textured glass shards in dark yellowish orange (10YR6/6) vitric to partially altered matrix. Lithic clasts, pumice clasts, phenocrysts as above.

Bedded tuffs (Tpbt4) (113.1-119.0 ft)-

White pumiceous fallout deposit above 115.5 ft grading upward into light brown to moderate red (5YR6/4, 5R5/4) paleosol. Lithic-rich pyroclastic-flow (?) deposit with distinctive black (N1) obsidian and medium light gray (N6) perlitic glass lithic clasts below 115.5 ft.

Bedded tuffs (Tpbt3) (119.0-130.0 ft)-

At least three beds including: lithic-rich fallout deposit with gray perlitic glass and devitrified volcanic lithic clasts (119.0-121.5 ft), reworked fine-grained pumiceous fallout deposit (121.5-123.3 ft), and reworked poorly-sorted fallout deposit (123.3-130.0 ft).

Pah Canyon Tuff (Tpp) (130.0-158.5 ft)-

Matrix is moderate reddish orange (10R6/6) grading downward to moderate orange pink (10R7/4) to grayish orange pink (5YR7/2), and vapor-phase altered. Pumice clasts are pinkish gray, very pale orange and grayish orange (5YR8/1, 10YR8/2, 10YR7/4), up to 55 mm and inversely graded. A pumice-clast swarm at about 139 ft suggests a flow boundary. Pumice clasts comprise 10 to 20 percent at the tops of flows, grading downward to 3 to 7 percent. Phenocrysts (about 5 percent) include feld and (oxy)bio.

Bedded tuffs (Tpbt2) (158.5-176.6 ft)-

Reworked lithic-rich and crystal-rich tuff above 161.9 ft. Red argillic layer 161.9 to about 163 ft. Altered fallout deposit below about 163 ft. Very fine-grained fallout deposits, about 2 cm thick at 164.6 ft, and about 5 cm thick at 176.6 ft.

Topopah Spring Tuff (Tpt) -

Crystal-rich vitric zone (rv) (176.6-202.4 ft):
176.6-195.6 non- to partially welded subzone (rv3) - Five to 7 percent grayish red (5R4/2) devitrified volcanic lithic clasts. Vitric to altered pumice clasts (75 to 80 percent) are light gray to grayish orange pink and light brown (N8, 10R8/2, 5YR7/6), grading downward to moderate reddish brown (10R4/6). Phenocrysts (7 to 10 percent) include feld, (oxy)bio, hbld and cpx.

195.5-199.4 moderately welded subzone (rv2) - Slightly deformed vitric to altered pumice clasts (80 to 90 percent), grayish orange (10YR7/4) to light gray (N7). Two to 3 percent phenocrysts including feld.

199.4-202.4 densely welded subzone (rv1) - Black to grayish red (N1 to 5R4/2) glass with grayish red (5R4/2) vitric pumice clasts. Ten to 15 percent phenocrysts including feld and oxybio.

Crystal-rich nonlithophysal zone (rn) (202.4-207.4 ft - total depth):
Devitrified medium gray (N5) matrix. Phenocrysts (10 to 12 percent) include feld and oxybio.

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