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UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

Mail Stop 954, Federal Center, Box 25046
Denver, Colorado 80225

PRELIMINARY REPORT ON THE GEOLOGY AND GEOPHYSICS OF DRILL HOLE UE25a-1, YUCCA MOUNTAIN, NEVADA TEST SITE

By

Richard W. Spengler[1], D. C. Muller[1], and R. B. Livermore[2]

[1]U.S. Geological Survey, Denver, Colo.
[2]Fenix & Scisson, Inc., Mercury, Nev.

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ABSTRACT

A subsurface geologic study in connection with the Nevada Nuclear Waste Storage Investigations has furnished detailed stratigraphic and structural information about tuffs underlying northeastern Yucca Mountain on the Nevada Test Site. Drill hole UE25a-1 penetrated thick sequences of nonwelded to densely welded ash-flow and bedded tuffs of Tertiary age. Stratigraphic units that were identified from the drill-hole data include the Tiva Canyon and Topopah Spring Members of the Paintbrush Tuff, tuffaceous beds of Calico Hills, and the Prow Pass and Bullfrog Members of the Crater Flat Tuff.

Structural analysis of the core indicated densely welded zones to be highly fractured. Many fractures show near-vertical inclinations and are commonly coated with secondary silica, manganese and iron oxides, and calcite. Five fault zones were recognized, most of which occurred in the Topopah Spring Member. Shear fractures commonly show oblique-slip movement and some suggest a sizable component of lateral compression.

Graphic logs are included that show the correlation of lithology, structural properties, and geophysical logs. Many rock units have characteristic log responses but highly fractured zones, occurring principally in the Tiva Canyon and Topopah Spring Members, restricted log coverage to the lower half of the drill hole.

INTRODUCTION

As a participant in the Nevada Nuclear Waste Storage Investigations, the USGS (U.S. Geological Survey) is providing technical assistance to identify and characterize suitable rock masses for the safe storage of waste radionuclides on or near the NTS (Nevada Test Site). At the request of DOE (U.S. Department of Energy), an exploratory drilling project was initiated in July 1978, to evaluate subsurface characteristics of ash-flow and bedded tuffs in the vicinity of Yucca Mountain, Area 25, NTS (fig. 1). Drill hole UE25a-1 was sited along the northeastern flank of Yucca Mountain and cored to a depth of 2,500.6 feet (762.2 m). The specific objectives were to:

1. Closely examine the subsurface stratigraphy and lithologic variations,
2. determine the distribution and nature of structural discontinuities,
3. obtain borehole geophysical measurements and natural-state samples, and
4. collect limited hydrologic information, such as static water level and direction of head change.

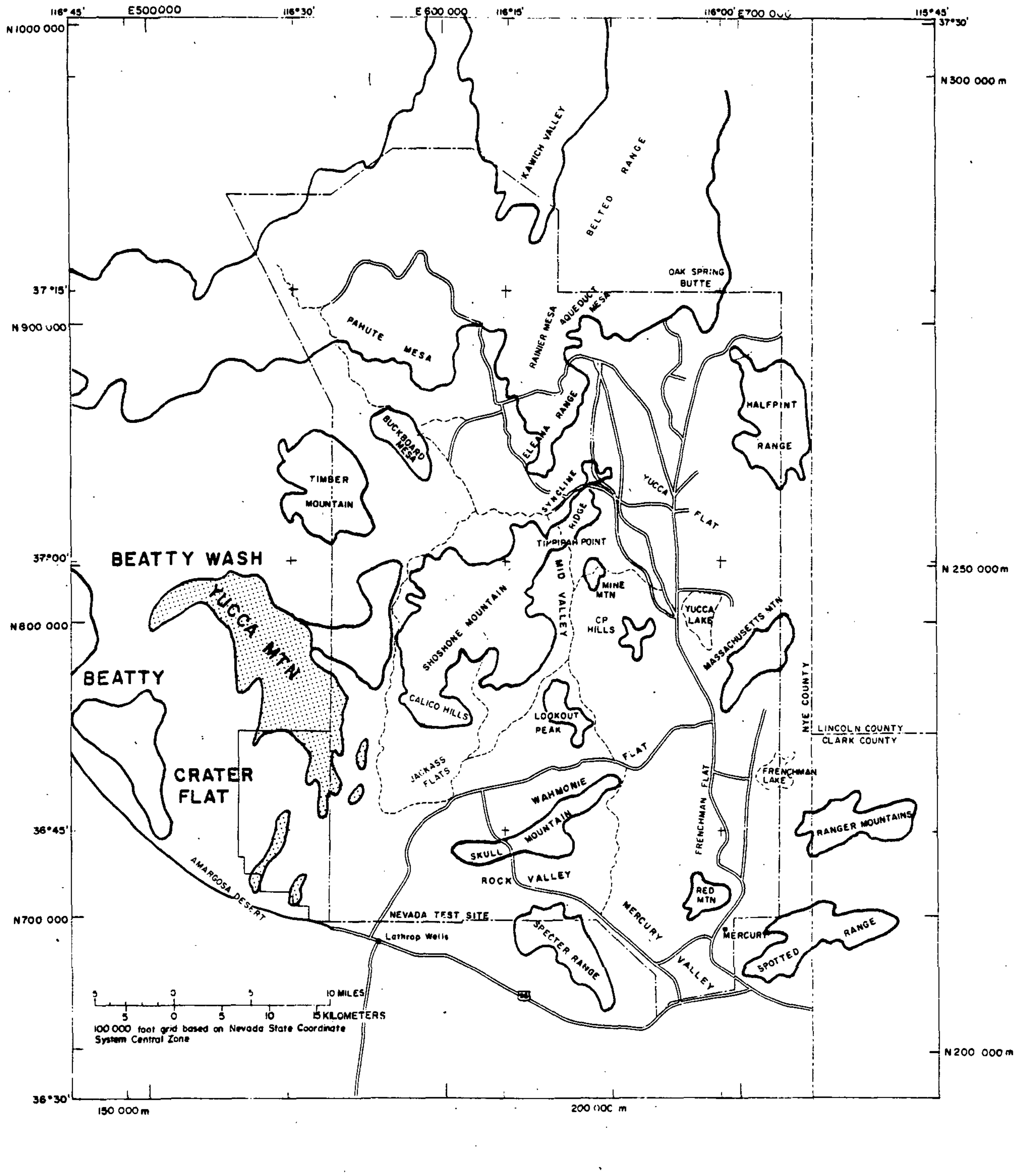

Figure 1.--Index map of the Nevada Test Site and vicinity showing the location of Yucca Mountain.

This report briefly summarizes some of the geologic aspects of Yucca Mountain and presents a compilation of geologic, hydrologic, and geophysical data derived from the drilling program.

ACKNOWLEDGMENTS

Appreciation is expressed for the assistance given by F. M. Byers, Jr., in examining selected thin sections taken from drill hole UE25a-1. J. Kibler was of assistance in providing digitized geophysical-log data. Acknowledgment is also given to geologists M. J. Baldwin, R. M. Beathard, M. P. Chornack, E. P. Eshom, J. N. Hodson, and T. Tomko of Fenix & Scisson, Inc., who monitored drill-hole operations. Critical and helpful reviews were provided by P. P. Orkild, W. J. Carr, and C. H. Miller.

GENERAL GEOLOGY OF YUCCA MOUNTAIN

Examination of the general physiographic features in or near the NTS (fig. 1) shows Yucca Mountain as one of the major highlands located along the western edge of the NTS. Along its northern limits, the highland extends northwestward to include Chocolate Mountain and low-lying hills southeast of Beatty Wash, most of which occurs on the adjoining Nellis Air Force Bombing and Gunnery Range.

This report is concerned principally with an area situated along or near the western NTS border, specifically, south of the inferred boundary of the Claim Canyon caldron segment (fig. 2). Bordered by Jackass Flats on the east and Crater Flat on the west, this area averages close to 6 miles (9.6 km) in width and 16 miles (25.7 km) in length and includes several isolated outcrops surrounded by alluvium along the eastern and southern flanks. Here, elevations range from 4,951 feet (1,509 m) near the central part of the highland to about 3,000 feet (914.4 m) near the southeastern flank.

Stratigraphy

Several widespread and voluminous ash-flow sheets are exposed in the Yucca Mountain area. Table 1 shows the stratigraphic relations of major units exposed in the area and designates those units encountered in the drill hole. These tuffs, which issued from source areas located within the nearby Claim Canyon caldron and the Oasis Valley caldera (Christiansen and others, 1977), form a cogenetic sequence designated as the Paintbrush Tuff (Orkild, 1965). This formation attains thicknesses over 1,000 feet (304.8 m), and in many places consists of four ash-flow members separated by thin ash-fall tuff beds.

The Tiva Canyon and Topopah Spring Members comprise the bulk of the Paintbrush Tuff and are made up of thick compound cooling units, in which zonal patterns deviate from those characteristic of uniform cooling (Smith, 1960). The members of the Paintbrush Tuff rocks are predominantly crystal poor, rhyolitic in composition, and contain several well-developed zones of dense welding which persist laterally as well as vertically. The thick welded zones commonly contain an inner core characterized by lithophysal cavities. Cavities are nearly spherical and, like the vesicles in basalt, are usually unconnected or poorly connected. Lithophysae are commonly lined with secondary minerals.

Table 1.--General stratigraphy of Yucca Mountain in the vicinity of drill hole UE25a-1

Era	System	Series	Formation	Member or unit
Cenozoic	Quaternary	Holocene and Pleistocene	Alluvium and colluvium[2]	
	Tertiary	Pliocene	Timber Mountain Tuff	Rainier Mesa Member
		Miocene	Paintbrush Tuff	Tiva Canyon Member[2]
				Yucca Mountain Member
				bedded tuff[2]
				Pah Canyon Member
				Topopah Spring Member[2]
			Tuffaceous beds of Calico Hills[1,2]	
			Crater Flat Tuff	Prow Pass Member[1,2]
				Bullfrog Member[1,2]

[1]Not exposed in the immediate vicinity of drill hole.

[2]Encountered in drill hole.

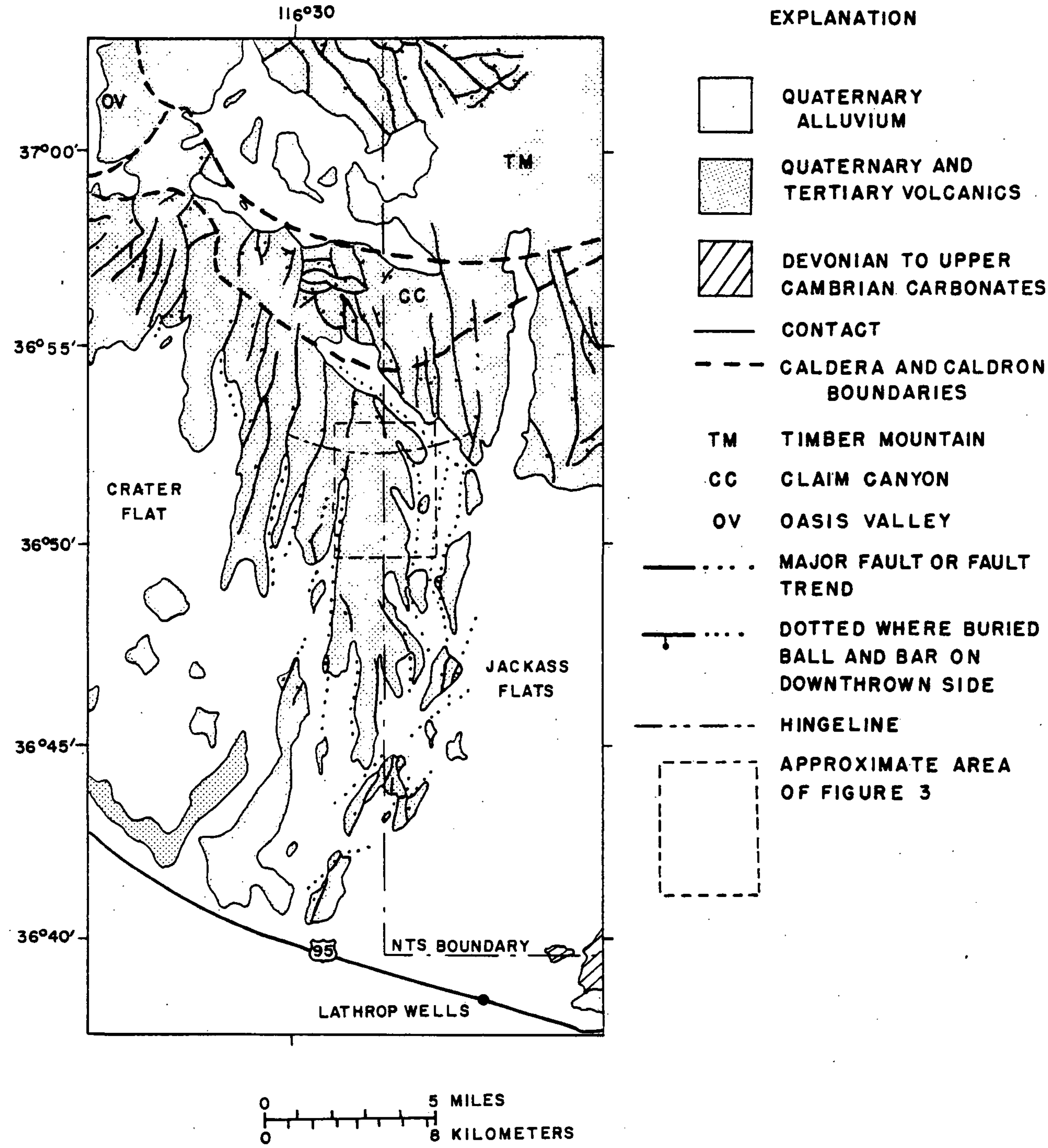

Figure 2.--Generalized structural map of Yucca Mountain.
[Modified from Carr, 1974]

The zones of dense welding are generally underlain and overlain by zones of partial welding which, in turn, are enclosed within nonwelded zones of variable thickness (Smith, 1960). Variations in welding characteristics are generally transitional, whereas the contacts between ash flows and underlying bedded tuffs are quite abrupt.

Two other ash-flow tuff members of the Paintbrush Tuff, the Yucca Mountain and Pah Canyon Members, occur locally between the Tiva Canyon and Topopah Spring Members (Lipman and Christiansen, 1964; Orkild, 1965). These two units are generally confined to the northern part of Yucca Mountain, where they wedge out in a southeasterly direction (Lipman and others, 1966; Lipman and McKay, 1965). In many places thick sequences of bedded tuffs underlie each member.

Unconformably overlying the Paintbrush Tuff, usually along the downthrown side of major faults, is the Rainier Mesa Member of the Timber Mountain Tuff. This tuff, which erupted from the Timber Mountain area, is relatively thin everywhere in the Yucca Mountain area.

Isolated exposures of both the tuffaceous beds of Calico Hills and underlying Crater Flat Tuff occur 5 miles (8 km) northwest of the drill-hole location directly south of the inferred boundary of the Claim Canyon caldron segment.

Structure

Yucca Mountain is composed of a series of north-trending structural blocks, most of which are tilted eastward. Along its eastern flank, rocks are fragmented into a system of horsts and grabens outlined by steeply dipping normal faults that are generally concealed beneath talus and stream gravels. Western fault-block margins display several prominent scarps, most of which are shown on figure 2. North-trending faults show a systematic variation in both displacement and concentration. Faults tend to decrease in number and displacement from the southern limit of Yucca Mountain northward to an east-west hinge line that coincides with lat 36°52' (Christiansen and others, 1977). North of the hinge line, the faults again increase in number and magnitude of displacement. Faulting is believed to have been active during a stage of broad doming of the area which preceded collapse of the Timber Mountain caldera about 11.3 m.y. ago (Byers and others, 1976).

A variation in structural style is evident immediately north in the inferred Claim Canyon caldron segment. Here, north- to northeastward-trending structural blocks are broken into a mosaic of smaller blocks by variously oriented faults. This style is inferred to be the result of subsidence and resurgence within the Claim Canyon caldron during eruption of the Paintbrush Tuff 12.5-13 m.y. ago (Byers and others, 1976).

On a regional scale, Yucca Mountain as well as most of the area incorporated within the limits of the NTS area lies along the projected trend of the Walker Lane and the Las Vegas Valley shear zone (Locke and others, 1940; Longwell, 1960), one of the major crustal features of the Basin and Range Province. Right-lateral deformation within the zone may have occurred before, during, and after evolution of the caldera complex.

SUBSURFACE GEOLOGY OF DRILL HOLE UE25a-1

Location

Drill hole UE25a-1 was sited in a northwest-trending valley near the northeastern flank of Yucca Mountain. This location is approximately 1,600 feet (488 m) southeast of the edge of an area where detailed surface mapping and preliminary surface geophysical studies indicate a relatively low density of faulting with maximum displacement generally on the order of a few tens of feet (fig. 3) (Lipman and McKay, 1965). The area of interest, encompassing approximately

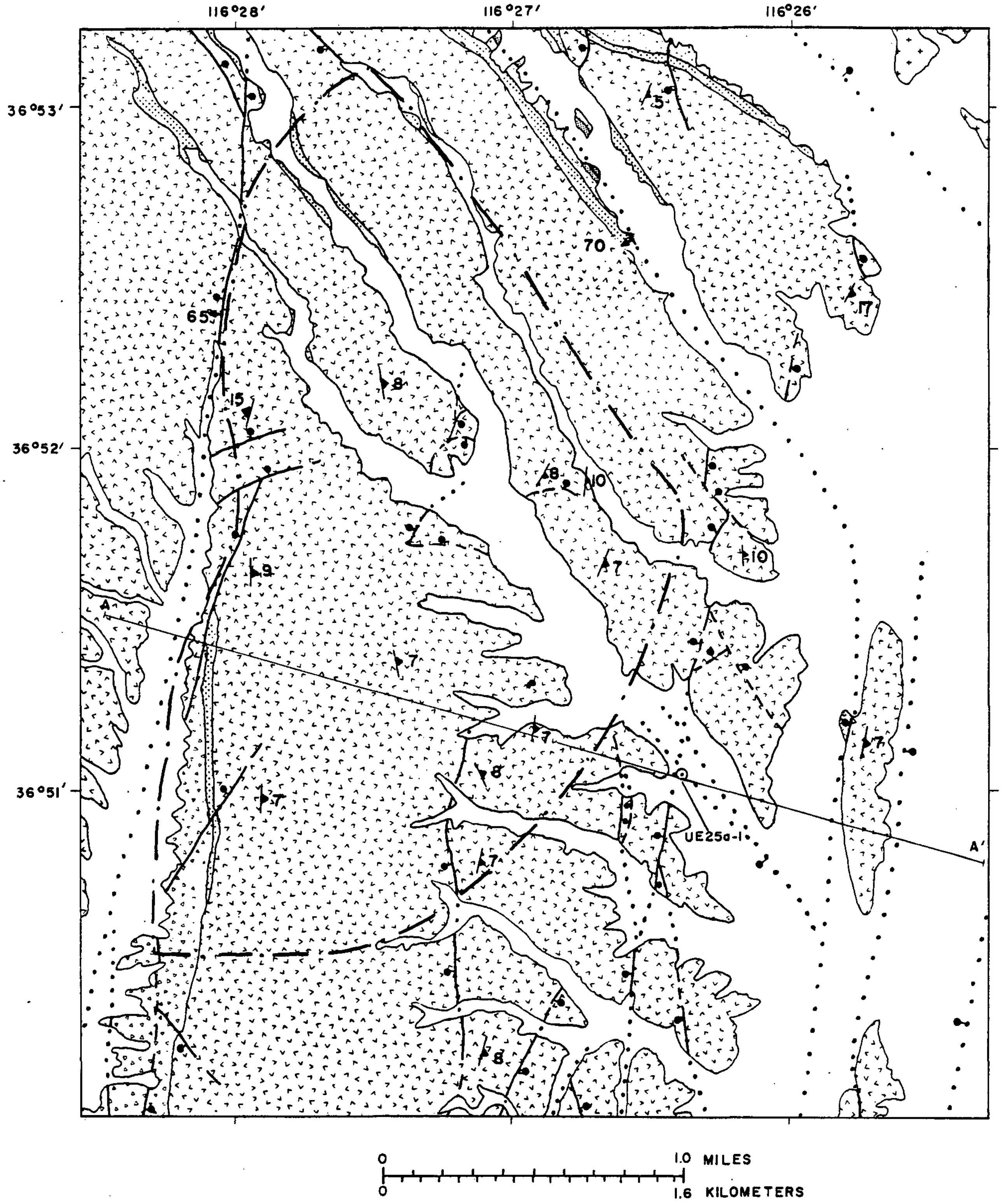

Figure 3.--Generalized geologic map of Yucca Mountain in the vicinity of drill hole UE25a-1. [Modified from Christiansen and Lipman, 1965; Lipman and McKay, 1965; and W. J. Carr, written commun., 1978]

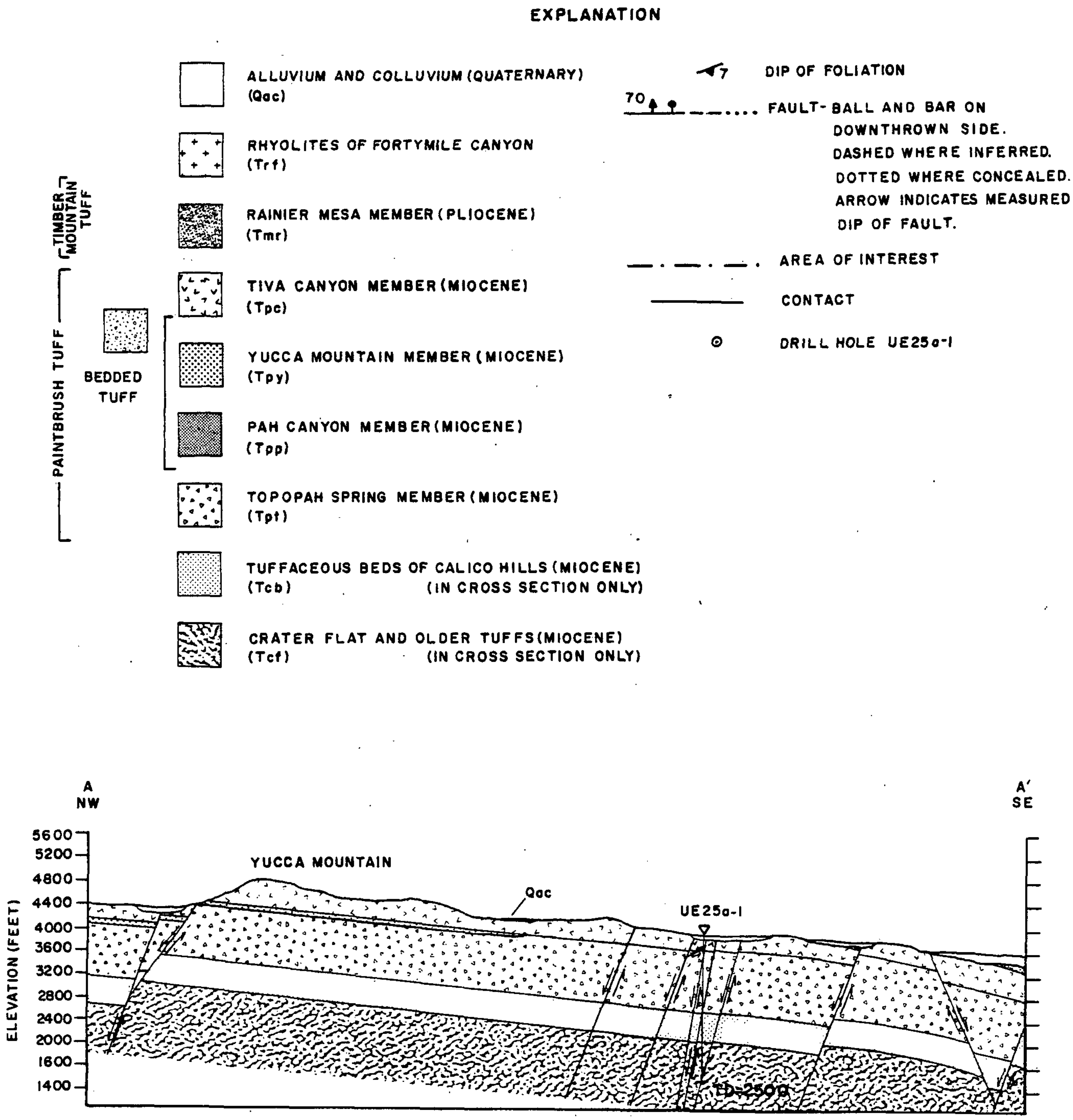

Figure 3.--Continued

4 square miles (10.4 km^2), is situated along the east-west hinge line, between major faults so as to avoid intersecting them at a depth above approximately 4,000 feet (1,219 m) (W. J. Carr, written commun., 1978). Here, as in much of northern Yucca Mountain, major outcrops consist of the upper portion of the Tiva Canyon Member. Topographic relief between the drill hole and the top of the ridge, 1.4 miles (2.2 km) west, is about 900 feet (274 m). Foliation in the rocks dips eastward from 7° to 10°.

Stratigraphy

The following section discusses a few of the salient features of major tuff units encountered in the drill hole. A more detailed description of the lithology is given in table 3. In descending order, stratigraphic units penetrated in the drill hole, along with their respective thicknesses, are as follows:

Alluvium and colluvium	30 feet (9.1 m)
Tiva Canyon Member of the Paintbrush Tuff	240 feet (73.2 m)
Topopah Spring Member of the Paintbrush Tuff	1,093.9 feet (333.4 m)
Tuffaceous beds of Calico Hills	471.8 feet (143.8 m)
Prow Pass Member of the Crater Flat Tuff	497.5 feet (151.6 m)
Bullfrog Member of the Crater Flat Tuff	167.4 feet (51.0 m)

Alluvium and Colluvium

Prior to coring, the hole was drilled to a depth of 54.0 feet (16.5 m) and casing was installed to the surface (table 2). Bit cutting samples, collected at 10-foot (3.1-m) intervals, show alluvial deposits extending to a depth of 30 feet (9.1 m) below the surface. This material is made up of gravel, sand, and silt consisting of tuff debris. Pebbles are commonly coated with secondary calcium carbonate.

Paintbrush Tuff

The Tiva Canyon and Topopah Spring Members comprise over 50 percent of the core recovered from the drill hole. The two units strongly resemble one another in lithology and petrography; both are compound cooling units compositionally zoned upward from rhyolite to quartz latite (Lipman and others, 1966).

Tiva Canyon Member.--The lower part of the Tiva Canyon Member, penetrated by the drill hole, consists of 165.0 feet (50.3 m) of moderately to densely welded tuff. Most of the unit is devitrified, although a few intervals show evidence of vapor-phase crystallization which consists of microscopic intergrowths of alkali feldspar and tridymite in the collapsed cavities of pumice lapilli.

The unit grades downward into 22.0 feet (6.7 m) of nonwelded to partially welded, shard-rich tuff. Within the interval, most of the pumice fragments appear pervasively altered to clay minerals.

Table 2.--Abridged drill-hole history of drill hole UE25a-1, Yucca Mountain, Nevada Test Site

Location: lat 36°51'05", long 116°26'24"

Nevada State Coordinates: N. 764,900 feet (233,142 m)
E. 566,350 feet (176,624 m)

Ground Elevation: 3,932.8 feet (1,198.7 m)

Drill Rig: Longyear L-44[1]

Drill Hole Size:	17.50 inches	0-28 feet (0-8.5 m)
	10.63 inches	28-54 feet (8.5-16.5 m)
	6.25 inches	54-86 feet (16.5-26.2 m)
	3.89 inches	86-1,297 feet (26.2-395.3 m)
	2.98 inches	1,297-2,501 feet (395.3-762.2 m)

Circulating Media: Bentonite mud, ASP 611 F[1](all-purpose liquid polymer by Nalco Chemical Co.[1]) added periodically for lubrication. Lost circulation material (Celloflake[1]) added when necessary.

Drilling Record: Spudded 6/25/78
Commenced coring 7/31/78 at a depth of 54.0 feet (16.5 m)
Completed coring 8/24/78 at a depth of 2,500.6 feet (762.2 m)
Completed logging 9/1/78

Remarks: HQ (3.89 in.) drill rods, outer core barrel, and core bit left in hole from 1,264.5 to 1,297.0 feet (385.4 to 395.3 m).

Well Site Geolcgists: M. J. Baldwin, R. M. Beathard, M. P. Chornack, E. P. Eshom, J. N. Hodson, and T. Tomko.

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[1]Use of brand names is for identification purposes only and does not constitute endorsement by the U.S. Geological Survey.

Table 3.--Lithologic log of drill hole UE25a-1

Stratigraphic and lithologic description	Thickness of interval feet (meters)	Depth to bottom of interval feet (meters)
Alluvium, gravel, sand, silt consisting of ash-flow and ash-fall tuff debris--	30.0 (9.1)	30.0 (9.1)
Paintbrush Tuff		
Tiva Canyon Member		
Tuff, ash-flow, grayish-red, densely welded; white to dark-gray pumice, devitrified, some vapor phase; 1-2 percent phenocrysts (sanidine,quartz,biotite)--	11.0 (3.4)	65.0 (19.8)
Tuff, ash-flow, grayish-red, densely welded; white to dark-gray pumice, devitrified; 1 percent sanidine, quartz,phenocrysts (contains sparse lithophysal)--------------------------	7.0 (2.1)	72.0 (22.0)
Tuff, ash-flow, grayish-red, densely welded; blackish-red pumice, devitrified; 1 percent sanidine,quartz,phenocrysts-----	18.0 (5.5)	90.0 (27.4)
Tuff, ash-flow, grayish-red pumice, densely welded, devitrified; grayish-pink to pale-red pumice, devitrified, 5 mm, some as large as 4 cm; 1 percent phenocrysts--------------------------	14.0 (4.3)	104.0 (31.7)
Tuff, ash-flow, grayish-red, densely welded, devitrified; light-gray to blackish-red pumice, devitrified (some vapor phase); 1-3 percent phenocrysts-------------------------	10.0 (3.0	114.0 (34.8)
Tuff, ash-flow, grayish-red, densely welded, devitrified; medium-light-gray to dark-gray pumice, devitrified (sparse vapor phase), 1-5 mm; 3 percent phenocrysts; sparse rhyolitic lithic fragments. Interval contains a zone from 152.0 to 164.6 feet (46.3-50.2 m) where several large pumice fragments have been altered to red-brown clay---	59.0 (18.0	173.0 (52.7)
Tuff, ash-flow, grayish-red, pale-red, light-brownish-gray, and medium-gray, moderately welded; pumice, vapor phase crystallization; 1-2 percent phenocrysts; 2-3 percent volcanic lithic fragments------------------------------	22.0 (6.7)	195.0 (59.4)
Tuff, ash-flow, moderate-yellow-brown, partially welded, vitric, partly argillized; white to yellow-brown pumice, argillized; 1 percent phenocrysts,black and red volcanic lithic fragments; contains yellow-brown glass shards-----------------------------	12.0 (3.7)	207.0 (63.1)
Tuff, ash-flow, moderate-yellow-brown, nonwelded to partially welded; grayish-orange-pink to pale-brown pumice, argillized; 1 percent sanidine and quartz phenocrysts; contains abundant yellow glass shards--	10.0 (3.0)	217.0 (66.1)

Table 3.--Lithologic log of drill hole UE25a-1--Continued

Stratigraphic and lithologic description	Thickness of interval feet (meters)	Depth to bottom of interval feet (meters)
Paintbrush Tuff--Continued:		
Tiva Canyon Member--Continued:		
Bedded tuff		
Tuff, reworked ash-fall, very light gray to light-gray, poorly consolidated; pumice, white to light-gray, argillized; less than 1 percent phenocrysts, sparse biotite, 1-3 percent pale-red volcanic lithic fragments	1.2 (0.4)	218.2 (66.5)
Tuff, ash-flow, pale-red, nonwelded; white to gray pumice, argillized, as large as 5 cm; 1-2 percent phenocrysts; minor glass shards and bronze biotite	18.0 (5.5)	235.0 (71.6)
Tuff, ash-flow, yellow-brown to pale-red-brown; yellow-brown pumice, vitric, slightly argillized; 3-8 percent phenocrysts, minor bronze biotite; rare red volcanic lithic fragments; sparse black glass shards	4.5 (1.4)	239.5 (73.0)
Tuff, ash-fall and reworked ash-fall, grayish-orange, thick-bedded, friable to partially indurated; white to light-brown pumice, vitric (some pumice altered to clay); 1-3 percent phenocrysts (quartz, sanidine, biotite); 1-2 percent red-brown volcanic lithic fragments	30.5 (9.3)	270.0 (82.3)
Topopah Spring Member		
Tuff, ash-flow, pale-yellowish-brown, nonwelded; 90 percent pale-yellowish-brown to grayish-orange pumice, vitric, blocky, 10 mm; less than 1 percent phenocrysts, 2-4 percent dark-gray to red-brown volcanic lithic fragments, lower 1.0 foot (0.3 m) grades into moderately welded glassy zone	5.6 (1.7)	275.6 (84.0)
Tuff, ash-flow, grayish-red, densely welded (quartz latitic caprock); vitric, contains 15-20 percent phenocrysts of sanidine, plagioclase, biotite, and hornblende	13.4 (4.1)	289.0 (88.1)
Tuff, ash-flow, grayish-red, moderately welded; moderate-red to grayish-red, vapor phase pumice; 5-8 percent phenocrysts, sparse biotite	5.0 (1.5)	294.0 (89.6)
Tuff, ash-flow, grayish-red, moderately to densely welded, devitrified; pumice, grayish-red and white, vapor phase; 3-5 percent phenocrysts; contains highly fractured and granulated zones at 301.4 and 304.7, 316.3-318.5, and 319.2-326.6 feet (91.9 and 92.9, 96.4-97.1, and 97.3-99.6 m) (zone of brecciation, with a slight indication of clay at 298.0-328.0 feet (90.8-100.0 m)	52.0 (15.8)	346.0 (105.5)

Table 3.--Lithologic log of drill hole UE25a-1--Continued

Stratigraphic and lithologic description	Thickness of interval feet (meters)	Depth to bottom of interval feet (meters)
Topopah Spring Member--Continued:		
Tuff, ash-flow, pale-red to grayish-red, densely welded, devitrified; very light gray to dark-gray and pale-red pumice, devitrified (subordinate vapor phase crystallization), as large as 5 cm in length; 8-10 percent phenocrysts-----	62.0 (18.9)	408.0 (124.4)
Tuff, ash-flow grayish-red, densely welded, devitrified; light-gray to pale-red pumice as large as 25 mm; contains lithophysae as large as 25 mm in diameter lined with quartz and feldspars (zone of highly broken and granulated core at 409.6-426.0 feet (124.8-129.8 m), slight indication of swelling clay)--	30.0 (9.1)	438.0 (133.5)
Tuff, ash-flow, medium-light-gray, densely welded, devitrified; very light gray to medium-light-gray and pale-brown pumice, devitrified; 1 percent quartz and sanidine phenocrysts----------	19.0 (5.8)	457.0 (139.3)
Tuff, ash-flow, grayish-red, densely welded, devitrified; pale-red and very light gray to medium-gray pumice, devitrified (some vapor phase crystallization); 1 percent phenocrysts; contains abundant lithophysae, as much as 5 cm in diameter, lined with quartz and feldspars (two highly granulated zones with a slight indication of clay at 581-521.0 and 525.0-529.0 feet (157.9-158.8 and 160.0-161.2 m)--	174.0 (53.0)	631.0 (192.3)
Tuff, ash-flow, very light gray to medium-light and grayish-red-purple and grayish-orange-pink (mottled), densely welded, devitrified; very light gray and pale-red pumice, devitrified; less than 1 percent phenocrysts, rare biotite; sparse lithophysae; sparse light-gray rhyolitic lithic fragments; highly granulated zone with a slight indication of clay at 665.8-672.4 and 708.9-718.4 feet (202.9-205.0 and 216.1-219.9 m) (highly brecciated at 718.4 ft (219.0 m))---------	87.4 (26.6)	718.4 (219.0)
Tuff, ash-flow, moderate-brown, densely welded, devitrified; grayish-orange-pink pumice, devitrified, 1 mm-1 cm: 1 percent phenocrysts: sparse medium-gray rhyolitic lithic fragments------	16.6 (5.1)	735.0 (224.0)

Table 3.--Lithologic log of drill hole UE25a-1--Continued

Stratigraphic and lithologic description	Thickness of interval feet (meters)	Depth to bottom of interval feet (meters)
Topopah Spring Member--Continued:		
Tuff, ash-flow, moderate-brown and pale-red-brown (mottled), densely welded, devitrified; medium-light-gray to medium-gray pumice, devitrified, 1-10 mm; 1 percent phenocrysts; minor light-gray rhyolitic lithic fragments----------------------	5.3 (1.6)	740.0 (225.6)
Tuff, ash-flow, moderate-brown (pale-red-purple along fractures), densely welded, devitrified; moderate-brown to pale-red-purple pumice; 1 percent phenocrysts; sparse moderate-orange-pink and very light gray volcanic lithic fragments; some lithophysae, as much as 8 cm in diameter, rich in biotite, some lithophysae filled with clay and (or) zeolites------------------	55.7 (17.0	796.0 (242.6)
Tuff, ash-flow, brownish-gray, partially to moderately welded, devitrified; light-gray pumice, less than 10 mm, vapor phase crystallization and devitrified (predominantly vapor phase); 1 percent phenocrysts---	1.5 (0.5)	797.5 (243.1)
Tuff, ash-flow, moderate-brown and grayish-red-purple (mottled), densely welded; light-gray and moderate-brown pumice, 1-5 mm, devitrified; 1 percent phenocrysts; contains some grayish-red-purple lithophysae, as much as 10 cm in diameter, some cavities lined with quartz, others partially filled with clay and (or) zeolites--	11.7 (3.6)	809.2 (246.6)
Tuff, ash-flow, grayish-red-purple, partially to moderately welded; grayish-red-purple pumice, 1-20 mm, devitrified and vapor phase crystallization; 1 percent phenocrysts; (interval appears partially brecciated)-------------------------	1.0 (0.3)	810.2 (247.0)
Tuff, ash-flow, moderate-brown and medium-light-gray (slightly mottled), densely welded, devitrified; medium-light-gray pumice, devitrified, 1-20 mm; 1 percent phenocrysts; contains sparse medium-light-gray lithophysae; increase in light-gray rhyolitic lithic fragments as much as 10 cm in length-----------	102.1 (31.1)	912.3 (278.1)
Tuff, ash-flow, pale-brown and light-brown (mottled), densely welded, devitrified; light-gray pumice, devitrified, 1-20 mm; 1 percent phenocrysts; 3-4 percent light-gray rhyolitic lithic fragments, as large as 3 cm in length; rare lithophysae, yellow brown, as much as 4 cm in diameter-----------------------	26.3 (8.0)	938.6 (286.1)

Table 3.--Lithologic log of drill hole UE25a-1--Continued

Stratigraphic and lithologic description	Thickness of interval feet (meters)	Depth to bottom of interval feet (meters)
Topopah Spring Member--Continued:		
Tuff, ash-flow, pale-brown and moderate-brown (mottled), densely welded, devitrified; light-gray and light-brown pumice, devitrified, as large as 1 cm; 1 percent phenocrysts; 3-4 percent light-gray rhyolitic lithic fragments, 1-5 mm; 5-10 percent lithophysae, pale yellowish brown, as much as 10 cm in diameter---	13.4 (4.1)	952.0 (290.2)
Tuff, ash-flow, pale-brown and moderate-brown (mottled), densely welded, devitrified; light-gray and light-brown pumice, devitrified, 1-10 mm; contains 20-30 percent lithophysae, pale yellowish brown, slightly argillized; 3-4 percent light-gray rhyolitic lithic fragments, commonly 1-2 cm in length, as large as 4 cm------------------------------------	124.0 (37.8)	1,076.0 (328.0)
Tuff, ash-flow, pale-brown to moderate-brown (mottled), densely welded, devitrified; light-gray to moderate-brown pumice, devitrified, 1-20 mm; 1 percent phenocrysts (sanidine and quartz); 4-5 percent rhyolitic lithic fragments, 1-5 mm, as large as 5 cm; rare lithophysae, pale yellowish brown, less than 5 cm in diameter; highly granulated zone with slight amount of clay at 1,118.0-1,123.5 feet (340.8-342.4 m)--	53.0 (16.2)	1,129.0 (344.1)
Tuff, ash-flow, light-brown and pale-brown (mottled), densely welded, devitrified; pale-brown to gray pumice, devitrified, 1-10 mm; 1 percent sanidine and quartz phenocrysts; 5-10 percent light-gray rhyolitic ash flow and reworked lithic fragments, 5-20 mm--	34.0 (10.4)	1,163.0 (354.5)
Tuff, ash-flow, pale-brown, moderately to densely welded, devitrified; pale-brown pumice (outer rims are moderate orange pink), devitrified (some vapor phase crystallization); 1 percent phenocrysts of sanidine and quartz; 2-4 percent light-gray rhyolitic and tuffaceous lithic fragments------------	71.6 (21.8)	1,234.6 (376.3)
Tuff, ash-flow, moderate-yellowish-brown, moderately to densely welded, devitrified; pale-brown to moderate-brown pumice, devitrified (occasional vapor phase), 2-30 mm; rare light-gray rhyolitic lithic fragments, 1-5 mm, as large as 3 cm---	27.4 (8.4)	1,262.0 (384.7)

Table 3.--Lithologic log of drill hole UE25a-1--Continued

Stratigraphic and lithologic description	Thickness of interval feet (meters)	Depth to bottom of interval feet (meters)
Topopah Spring Member--Continued:		
Tuff, ash-flow, dark-yellowish-brown to yellowish-orange (altered), moderately to densely welded, vitric, partially argillized, pale-reddish-brown pumice, 1-10 mm; 2-3 percent volcanic lithic fragments; contains abundant black glass shards in dark-yellowish-brown altered zones---	11.0 (3.4)	1,273.0 (388.0)
Tuff, ash-flow, black, vitrophyre, glassy conchoidal fracturing; contains abundant fractures; moderate-yellowish-brown clay gouge along some fractures (clay zone from 1,295.3 to 1,296.2 ft (394.8 to 395.1 m))--------------------------------	44.2 (13.5)	1,317.2 (401.5)
Tuff, ash-flow, light-brown, partially welded, vitric; moderate-brown pumice, devitrified or partially vitric, 1-20 mm; less than 1 percent phenocrysts (sanidine, quartz); abundant moderate-yellow glass shards; 2-3 percent moderate-dark-gray volcanic lithic fragments, less than 5 mm-------------------------------	7.4 (2.3)	1,324.6 (403.7)
Tuff, ash-flow, grayish-orange-pink to light-brown, nonwelded to partially welded, devitrified; pale-brown pumice, partially devitrified, less than 1 cm; less than 1 percent phenocrysts (sanidine, quartz); 2-3 percent dark-medium-gray volcanic lithic fragments; sparse dark-brown glass shards----------------------	15.4 (4.7)	1,340.0 (408.4)
Tuff, ash-flow, grayish-orange-pink, nonwelded; devitrified grayish-orange-pink pumice; contains volcanic lithic fragments as much as 6 cm in size--	10.1 (3.1)	1,350.1 (411.5)
Tuff, ash-flow, grayish-orange-pink to light-brown, nonwelded; grayish-orange-pink pumice, devitrified, 3-15 mm; 1 percent phenocrysts; 4-5 percent dark-brown rhyolitic lithic fragments as much as 20 mm-------------------------------------	9.9 (3.0)	1,360.0 (414.5)
Tuff, ash-fall and reworked, slightly indurated, upper 15 cm contains lithic fragments as much as 2 cm in diameter, grading downward in size and abundance--------------------------	3.9 (1.2)	1,363.9 (415.7)

Table 3.--Lithologic log of drill hole UE25a-1--Continued

Stratigraphic and lithologic description	Thickness of interval feet (meters)	Depth to bottom of interval feet (meters)
Tuffaceous beds of Calico Hills		
Tuff, ash-flow, light-brown to moderate-brown, moderate-reddish-orange, and pale-reddish-brown, nonwelded, devitrified; pumice, devitrified to slightly zeolitized, 5-40 mm; less than 1 percent phenocrysts (sanidine, plagioclase, quartz, biotite); less than 1 percent dark-reddish-brown volcanic lithic fragments; ash-flow tuff intercalated with thin ash-fall and bedded tuffs (slightly argillized and zeolitized) at 1,383.5-1,386.3, 1,492.0-1,508.0, 1,582.4-1,585.5, 1,762.6-1,764.0, and 1,775.1-1,775.9 feet (421.7-422.5, 454.8-459.6, 482.3-483.3, 537.2-537.7, and 541.0-541.3 m)--	425.1 (129.6)	1,789.0 (545.3)
Tuff, bedded and reworked, pale-brown, moderate-red, light-red, moderate-orange-pink, yellowish-gray, moderate-greenish-yellow, and pale-olive, moderately to highly indurated; occasionally silicified; interbedded ash flow, air fall, reworked and tuffaceous sandstone; thickness of beds ranges from 0.05 to 3.0 feet (0.02 to 0.9 m); white to gray and yellow pumice, slightly argillized and zeolitized; volcanic lithic fragments vary from 2-20 percent (iron stained from 1,819.4 to 1,832.0 feet (554.6 to 558.4 m))--	46.7 (14.2)	1,835.7 (559.5)
Crater Flat Tuff		
Prow Pass Member		
Tuff, ash-flow, light-brownish-gray and pale-yellowish-brown, nonwelded to partially welded, devitrified, gray to grayish-yellow pumice, (upper 20 ft, 61 m argillized) 5-25 mm; 6-9 percent phenocrysts (quartz, sanidine, plagioclase, biotite); 1 percent volcanic lithic fragments--	9.4 (2.9	1,845.1 (562.4)
Tuff, ash-flow, light-olive-gray and light-gray, partially welded; light-brownish-gray to brownish-gray pumice, devitrified, 3-25 mm; 7-10 percent phenocrysts (sanidine, plagioclase, quartz, trace of biotite); 1 percent dark-brown volcanic and red-brown mudstone lithic fragments--	51.9 (15.8)	1,897.0 (578.2)

Table 3.--Lithologic log of drill hole UE25a-1--Continued

Stratigraphic and lithologic description	Thickness of interval feet (meters)	Depth to bottom of interval feet (meters)
Crater Flat Tuff--Continued:		
Prow Pass Member--Continued:		
Tuff, ash-flow, grayish-pink to moderate-orange-pink and yellowish-gray, nonwelded to partially welded, slightly zeolitized; grayish-yellow and moderate-greenish-yellow pumice, devitrified, slightly argillized, 1-20 mm; 4-6 percent phenocrysts (plagioclase, sanidine, quartz); 2-6 percent red-brown mudstone and volcanic lithic fragments; lithic fragments increase toward base of interval; thin-bedded air-fall marks base of unit from 2,331.4 to 2,333.2 feet (710.6 to 711.2 m), light-brown and yellowish-gray, fine ash, devitrified, highly indurated----------------------------	45.2 (13.8)	2,333.2 (711.1)
Bullfrog Member		
Tuff, ash-flow, pale-yellow-brown to pale-brown, and light-olive-gray, partially to moderately welded, devitrified; grayish-orange-pink and medium-gray pumice, vapor phase crystallization 1-20 mm; 10-15 percent phenocrysts (quartz, sanidine, plagioclase, hornblende, black and bronze biotite); less than 1 percent volcanic lithic fragments-----------------	167.4 (51.0)	2,500.6 (762.2)
Total depth-----------		2,500.6 (762.2)

Table 3.--Lithologic log of drill hole UE25a-1--Continued

Stratigraphic and lithologic description	Thickness of interval feet (meters)	Depth to bottom of interval feet (meters)
Crater Flat Tuff--Continued:		
Prow Pass Member--Continued:		
Tuff, ash-flow, light-brownish-gray to medium-gray, nonwelded to partially welded, devitrified; pumice, white, vapor phase, 1-25 mm; 7-12 percent phenocrysts (quartz, sanidine, trace of biotite); less than 1 percent volcanic and red-brown mudstone lithic fragments----------------------------------	52.8 (16.1)	1,949.8 (594.3)
Tuff, ash-flow, pale-red-brown to moderate-red-brown (iron-oxide staining), moderately welded, devitrified; light-gray pumice with reddish-brown rims, vapor phase, 5-20 mm; 10 percent phenocrysts (sanidine, plagioclase, quartz, biotite; 2 percent black volcanic and red-brown mudstone lithic fragments--	64.2 (19.6)	2,014.0 (613.9)
Tuff, ash-flow, grayish-orange-pink and pale-greenish-yellow, partially welded, partially devitrified; pumice, 5-15 mm, devitrified; 9-10 percent phenocrysts (sanidine, plagioclase, quartz); 14 percent dark-brown volcanics and red-brown mudstone lithic fragments--------------	95.5 (29.1)	2,109.5 (643.0)
Tuff, ash-flow, yellowish-gray to dusky-yellow, moderately welded, vitric; white to light-gray and yellowish-gray pumice, 5-25 mm 10-15 percent phenocrysts (quartz,plagioclase, sanidine); 2 percent gray and red-brown volcanic and red-brown mudstone lithic fragments; interval is moderately silicified-------------------	12.5 (3.8)	2,122.0 (646.8)
Tuff, ash-flow, pale-greenish-yellow to yellowish-gray, partially welded, devitrified; white to grayish-yellow pumice, devitrified (slightly zeolitic), 5-20 mm; 10-15 percent phenocrysts (quartz, plagioclase, sanidine, trace of biotite); 2-3 percent dark volcanic and red-brown mudstone lithic fragments; interval is slightly to moderately silicified (zones at 2,125.4-2,126.3, 2,158.4-2,162.0, and 2,177.0-2,178.0 feet (647.8-648.1, 657.9-659.0, and 663.5-663.8 m) are highly silicified and partially vitric)--	166.0 (50.6)	2,288.0 (697.4)

About 53 feet (16.2 m) of ash-flow and bedded tuff separates the Tiva Canyon from the underlying Topopah Spring Member. In core Specimens, the unit is highly friable and thick bedded (table 3). As in the overlying nonwelded to partially welded ash flow, pumiceous material appears argillized. Two samples (1, 2, table 4) were selected from this interval and submitted for X-ray examination. Results showed that samples contain from 60 to 70 percent montmorillonite clay (10 to 20 percent were mixed layers of illite).

As previously mentioned, the Yucca Mountain and Pah Canyon Members occupy stratigraphic positions within the bedded sequence. The two units were not recognized in the drill hole, indicating that their depositional edge lies northwest of the drill-hole location.

Topopah Spring Member.--Like the Tiva Canyon, the Topopah Spring ash-flow sheet consists of a thick zone of dense welding enclosed within a nonwelded to partially welded glassy top and bottom. Lipman and others (1966) provide a detailed description of the lithologic variations within the member in the Yucca Mountain area.

Commonly referred to as "caprock," the uppermost unit is composed of a reddish-brown crystal-rich zone, which averages about 40 feet (12.2 m) in thickness over much of Yucca Mountain (Lipman and others, 1966). In the drill hole, only about 13 feet (4 m) of this zone was encountered.

Below the caprock, the member progressively grades downward into about 1,094 feet (333.4 m) of densely welded, rhyolitic, crystal-poor tuff. The zone contains a mixture of high- and low-silica pumice, and foliate structure due to the parallel flattening of pumice fragments and is generally well developed. Typical of many compound cooling units, there are several thin intercalated intervals where the rock appears less welded and pumice shows evidence of vapor-phase crystallization.

Near the central part of the densely welded devitrified zone three conspicuous subunits where lithophysae constitute as much as 30 percent of the volume of rock. Cavities are roughly spherical to lenticular and near the center of each subunit, cavities as much as 3 inches (7.5 cm) in diameter are not uncommon. Contacts of lithophysal units are transitional, exhibiting a decrease in size and abundance of cavities away from the center of the zones.

Secondary minerals lining cavities mainly consist of alkali feldspar, quartz, and cristobalite. X-ray examination of samples (3, 4, table 4) taken from the lowermost zone of lithophysae (pl. 1) shows that, in addition to the three major mineral components, the rock contains traces (<5 percent) of montmorillonite, illite, clinoptilolite, hematite, dolomite, and siderite(?).

Near the base of the ash flow, the member consists of a black (obsidianlike) densely welded vitrophyre, about 55 feet (16.8 m) thick. The upper 20 feet (6.1 m) of the zone, as well as the lower 11.0 feet (3.4 m) of the overlying crystalline zone, appear argillized, usually along fracture planes. X-ray analysis of two samples (5, 6, table 4) from this interval indicates that montmorillonite and clinoptilolite constitute 20-50 percent and 10-20 percent of the rock, respectively.

Within this zone, a 1-foot (0.3-m) interval from 1,295.3 to 1,296.4 feet (394.8 to 395.1 m) appears pervasively altered to clays and zeolites. It is noteworthy to mention that while coring through this interval the outer core barrel and bit became lodged within the formation, possibly due to the hydration of montmorillonite clays in contact with drilling fluids. Resumption of the coring could only be achieved by drilling through the HQ (3.89-in. O.D.) drill rod and core assembly with a smaller diameter (NX 2.98-in. O.D.) drill bit and rods. Most of the HQ drill rods were subsequently retrieved but a few of the HQ rods, outer core barrel, and coring bit remain (February 1979) in the drill hole from 1,264.5 to 1,297.0 feet (385.4 to 395.3 m).

Table 4.--X-ray analyses of selected samples from drill hole UE25a-1

[Analyst: P. D. Blackmon, U.S. Geological Survey. Estimated amounts of minerals present are reported as parts of 10, Tr, trace; leaders (---) indicate minerals not identified]

Sample No.	1	2	3	4	5	6	7	8	9
Depth									
Feet	217.7	224.6	990.0	1,093.8	1,274.4	1,295.0	1,440.0	1,720.3	2,310.3
Meters	66.4	68.5	301.8	333.4	388.4	394.7	438.9	524.4	704.2
Rock type	nonwelded ash flow (argillized)		densely welded ash flow (lithophysal)		vitrophyre (argillized)		nonwelded to partially welded ash flow (zeolitized)		
Montmorillonite	[1]7	[1]6	Tr	Tr	[1]5	2	---	---	Tr
Illite	[2]Tr	[2]Tr	---	Tr	[2]Tr	[2]Tr	Tr	---	Tr
Clinoptilolite	---	---	Tr	Tr	[3]2+	1	7+	[3]6+	4+
Quartz	Tr	Tr	3+	4	---	Tr	Tr	Tr	2+
Feldspar	2	1+	4+	4	Tr	<1	<1	<1	2
Cristobalite-opaline silica	<1	Tr	1+	1+	1+	1	<1	1+	---
Amorphous (ash)	<1	2	---	---	1	5	1	<1	1
Carbonate	[4]Tr	[4]Tr	---	---	---	---	---	---	---
Dolomite	---	---	Tr	Tr	---	---	Tr	---	Tr
Hematite	---	Tr	Tr	Tr	---	---	---	---	---
Siderite(?)	---	---	---	Tr	---	---	---	---	---

[1]About 10-20 percent illite mixed layers.
[2]Illite mica.
[3]Probable mordenite.
[4]Acid test.

At the base, the cooling unit grades downward into a nonwelded to partially welded zone approximately 43 feet (13.1 m) thick, of which the lowermost intervals contain angular to sub-rounded volcanic lithic inclusions up to 2.4 inches (6 cm) in diameter. About 4 feet (1.2 m) of ash-fall and reworked tuff of variable sorting occurs at the base and separates the Paintbrush Tuff from the underlying tuffaceous beds of Calico Hills.

Tuffaceous Beds of Calico Hills

In outcrop, this interval includes a sequence of rhyolitic lavas, tuff breccias, ash flows, ash falls, and tuffaceous sandstones. The most extensive exposures occur near Calico Hills where much of the tuff has been hydrothermally altered (McKay and Williams, 1964).

Tuffs encountered in the drill hole were arbitrarily subdivided into two distinctive units based upon the frequency and thickness of bedded tuff intervals. The upper unit, about 425 feet (129.5 m) thick, consists of a relatively homogeneous, nonwelded ash flow intercalated with five thin ash-fall and reworked tuff units (table 3). X-ray examination of two samples (7, 8, table 4) at depths of 1,440.0 and 1,720.3 feet (438.9 and 524.4 m) shows that zeolites (clinoptilolite and mordenite) constitute 60 to over 70 percent of the rock.

The lower unit, approximately 47 feet (14.3 m) thick, is made up of thin, interbedded ash-flow and ash-fall tuffs, reworked tuffs, and tuffaceous sandstone. These beds are moderately to highly indurated and silicified. Thicknesses of individual beds range from 0.5 to 3.0 feet (0.15 to 0.91 m).

Crater Flat Tuff

Two members of the Crater Flat Tuff (Byers and others, 1976) recognized in the drill hole include the Prow Pass and the upper cooling unit of the Bullfrog. Both members are ash-flow tuff and, unlike other stratigraphic units encountered, contain an abundance of red-brown mudstone lithic inclusions believed to be derived from the Eleana Formation of Paleozoic age.

Prow Pass Member.--Three distinct lithologic subunits exist within the Prow Pass. The upper subunit consists mainly of a uniform nonwelded to partially welded, devitrified ash-flow tuff. Near its center, the ash-flow tuff is moderately welded. Pumice lapilli show evidence of vapor-phase alteration and appear red brown due to iron-oxide staining.

Underlying the top unit there occurs a conspicuous pale-greenish-yellow, nonwelded to moderately welded interval, most of which appears slightly to intensely silicified.

Beneath the silicified zone, about 43 feet (13.2 m) of nonwelded to partially welded tuff was encountered. In core specimens, most of the zone appears slightly zeolitized, and X-ray analysis of a sample (9, table 4) taken from the interval indicates that the rock contains approximately 40 percent clinoptilolite (and probably some mordenite). At the base, the contact between the Prow Pass and Bullfrog Members is marked by 2 feet (0.61 m) of thin-bedded ash-fall and reworked tuff.

Bullfrog Member.--About 167 feet (51.0 m) of the Bullfrog Member was encountered in the drill hole, all of which consisted of partially to moderately welded ash-flow tuff. In core specimens, the unit contains a conspicuous amount of black and bronze biotite within the matrix material. Pumice lenticles are usually white and show vapor-phase crystallization.

Structural Properties of the Core

Continuous core (95.3 percent recovered) provided a unique opportunity to study in detail the occurrence, frequency, and nature of fracturing in the drill hole. The core was carefully examined for layering attitudes, frequency, inclinations, and types of fillings of joints, and evidence of faults.

Stratification of bedded-tuff intervals in the upper part of the drill hole was commonly gradational and attitudes could not be obtained with any high degree of accuracy. One interval where measurements were taken occurred in the bedded horizon at the base of the Prow Pass Member where dips range from 10° to 15°. Dips taken on flattened pumice axes in the Topopah Spring generally were 12° to 19°, although dips as much as 45° were observed in fault zones. Alinement of pumiceous fragments in the Bullfrog Member consistently dip from 2° to 5°.

Joints

In this report, joints are defined as fracture planes along which differential movement was not apparent during megascopic examination of the core. Joint surfaces are usually planar, relatively smooth, and commonly partially lined with secondary minerals.

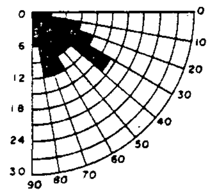
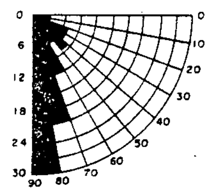
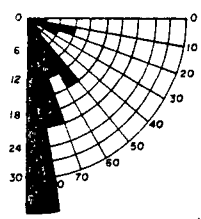
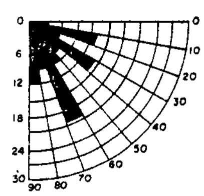
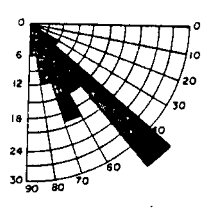
A total of 920 joints was examined in the core, corresponding to an average frequency of 3.8 joints per 10-foot (3.0-m) interval. In general, a study of the joint occurrence and distribution indicates that the densely welded ash flows are highly fractured, whereas bedded tuffs and nonwelded to moderately welded ash flows are less fractured (col. 4, pl. 1). Fracturing in the densely welded zones is likely to be underrepresented because of the frequent occurrence of badly broken intervals where accurate measurements of joint planes could not be obtained.

Figure 4 shows the distribution of joint inclinations (percent of joints in each 10° increment) for the five major stratigraphic units. Inclinations are expressed in degrees of dip as measured from the horizontal. As displayed, joints within the Tiva Canyon indicate a nearly random orientation ranging from 0° to 90°. The absence of a preferred inclination more than likely indicates masking of high-angle cooling joints by lower angle planes of weakness resulting from removal of overburden from prestressed rock.

In contrast to the Tiva Canyon, joint development in both the Topopah Spring and the underlying tuffaceous beds of Calico Hills show a conspicuous preferred inclination in the 80° to 90° range. In the Topopah Spring, the near-vertical trend of joints is believed to represent columnar joints generated in response to tensional forces active during cooling of the flow. Although described in more detail in later sections, it should also be noted here that fault planes, occurring within the same intervals, show coincident dips. Additional information, such as joint trends from oriented core samples, is needed to better understand this interrelationship and the mode of joint development.

Joints are relatively uncommon in the nonwelded parts of ash flows except where intervals are silicified. Most of the jointing in the tuffaceous beds of Calico Hills occurs near the top of the unit. These joints may represent propagation of preexisting planes of weakness in the overlying Topopah Spring, possibly caused by differential compaction or regional stresses.

Jointing in the Prow Pass shows a similar trend as that found in the Tiva Canyon Member, but joints in the underlying moderately welded Bullfrog Member exhibit a pronounced dip inclined between 40° and 50°. Based upon the abundance of shear fractures having similar inclinations (discussed in section on faults), the joint trend is probably related to tectonic processes.

INTERVAL FEET	INTERVAL METERS	PERCENT OF JOINTS PER 10° INCREMENT	NUMBER OF MEASURED JOINTS	PERCENT OF TOTAL JOINTS	AVERAGE NUMBER OF JOINTS PER 10-FOOT INTERVAL
54.0-270.0	16.5-82.3	TIVA CANYON MEMBER 	159	17.3	7.4
270.0-1,363.9	82.3-415.7	TOPOPAH SPRING MEMBER 	494	53.7	4.5
1,363.9-1,835.7	415.7-559.5	TUFFACEOUS BEDS OF CALICO HILLS 	46	5.0	.98
1,835.7-2,333.2	559.5-711.1	PROW PASS MEMBER 	181	19.7	3.6
2,333.2-2,500.6	711.1-762.2	BULLFROG MEMBER 	40	4.4	2.4

PERCENT OF FRACTURES

FIGURE 4.--STRUCTURAL DIAGRAMS SHOWING THE INCLINATIONS OF JOINTS FOUND WITHIN STRATIGRAPHIC UNITS

Circulation losses occurred repeatedly during coring of the highly fractured intervals, suggesting that many fractures are open and interconnected.

Careful examination of joint faces revealed that 79 percent were partially coated and (or) stained with secondary minerals. Of the remaining joint faces examined, 18 percent were open with no coating and 3 percent were closed with no apparent coating. In decreasing order of abundance, the types of joint fillings are as follows: silica (37 percent), manganese and (or) iron oxides (17 percent), calcite (13 percent), and manganese oxide and silica (12 percent).

Within the Tiva Canyon Member, over 50 percent of fracture planes were stained with manganese and (or) iron oxides (fig. 5). Silica and (or) manganese oxide accounted for over 58 percent of the joint fillings within the Topopah Spring Member. Many siliceous coatings in the member displayed a distinctive white chalky appearance. X-ray examination indicated the material principally contains quartz (40 percent), cristobalite (20 percent), and feldspar (20 percent). In addition to these major components, traces (5 percent) of montmorillonite, Clinoptilolite, and kaolinite and less than 10 percent amorphous ash were also detected (P. D. Blackmon, written commun., 1978). Both members of the Paintbrush Tuff were the only two stratigraphic units where noticeable amounts of calcite fracture fillings were observed. The deepest joint coated with calcite was reported at a depth of 1,242.4 feet (378.7 m), although a few fragments of broken core with calcite coatings were recognized at a depth of 2,004.3 feet (610.9 m), which is 462.7 feet (141.0 m) below the present water level. Three samples of calcite from depths of 286, 927.5, and 2,004.3 feet (87.2, 282.7, and 610.9 m) were submitted for dating by the uranium-series method. Analyses of all samples resulted in ages greater than 400,000 years (J. N. Rosholt, written commun., 1979).

Joints coated with silica accounted for 61 percent of the fractures examined in the tuffaceous beds of Calico Hills (30 percent had no coating). In the Prow Pass all types of fracture filling were observed except calcite. In contrast, only 23 percent of joints in the underlying Bullfrog Member were coated (silica and manganese and (or) iron oxide).

Faults

Evidence for faulting in the drill hole was based upon the recognition of: (1) brecciated core, (2) abrupt changes in the dip of pumice, (3) zones of granulation, and (4) striations and slickenside grooving on fracture surfaces. Due to the absence of any thin, well-defined marker beds, the magnitude of displacements within fault zones could not be established. Nonetheless, five dominant fault zones (designated as F1-F5) were recognized based upon the extent of disrupted core.

Plate 1 (col. V) shows the occurrence of granulated zones, frequency of fracture planes marked by striations, and five designated fault zones. In granulated zones, core has been comminuted to granules dominantly of gravel size (2-75 mm). Zones are uncemented, commonly friable and well defined in the caliper log (pl. 1) where they generally appear "washed out."

As previously mentioned, shear planes within all fault zones except F2 indicate coincident dips with preferred orientations of joints within their respective stratigraphic units, except in the lower half of fault zone F5 where steeper dips (70°-80°) were measured (fig. 6). The lower portion of fault zone F1 contained about 30 feet (9.1 m) of highly granulated core with the upper 1.0 foot (0.3 m) consisting of recemented breccia. Emphasis should be made that the thickness of granulated core does not represent the true thickness of granulation within the respective fault zone. For instance, if one assumes an apparent dip of 40° to 60° for fault zone F1, then the apparent thickness of the granulated zone is between 15 and 23 feet (4.6 and 7.0 m). No striations were recognizable along fracture faces in fault zone F2 but the core is also highly

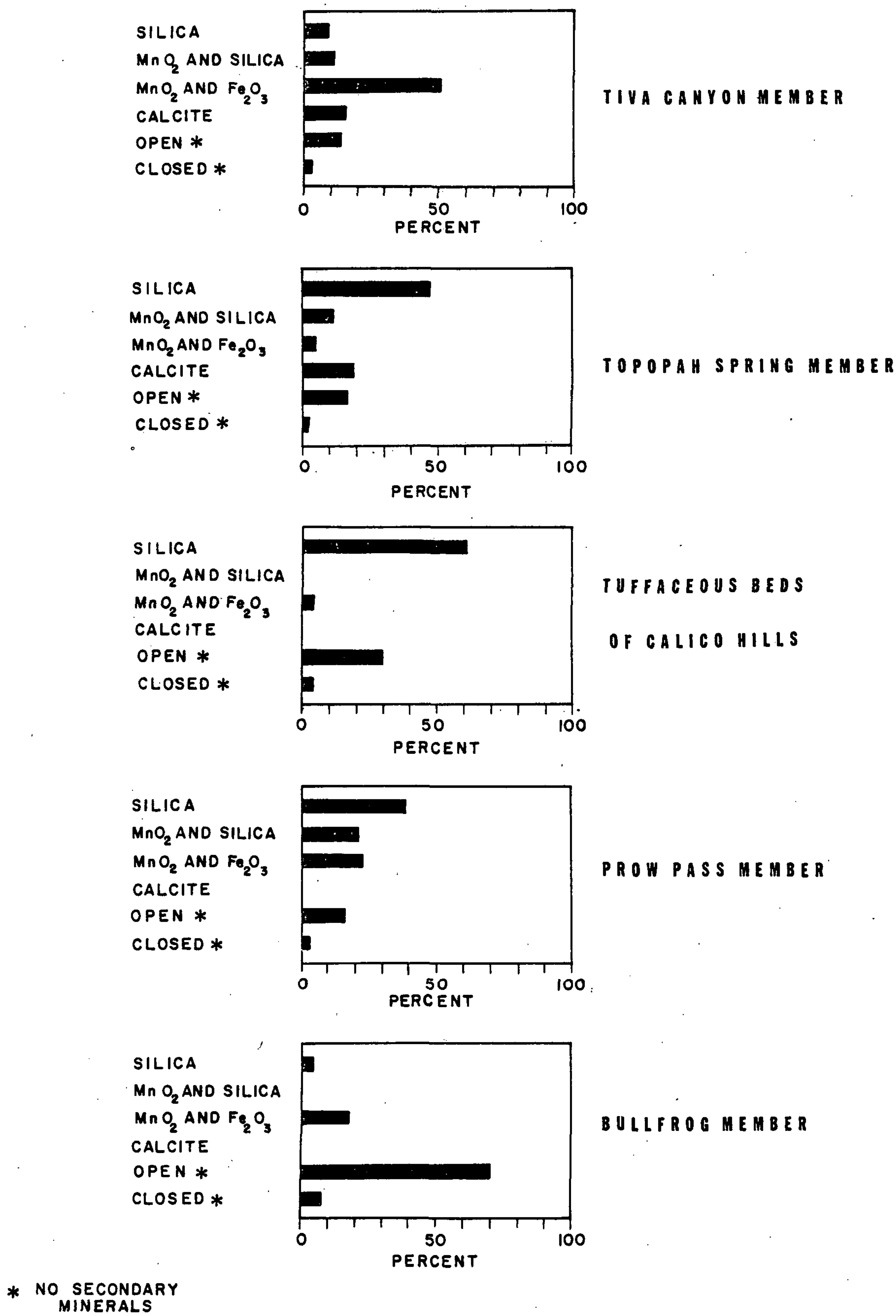


Figure 5.--Histograms showing the type and percent of joint fillings within respective stratigraphic units.

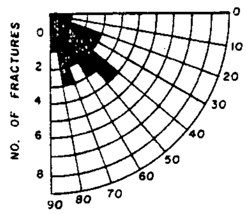
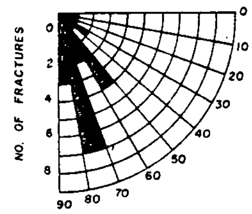
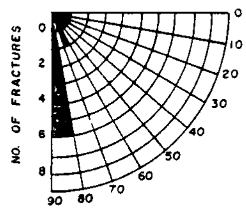
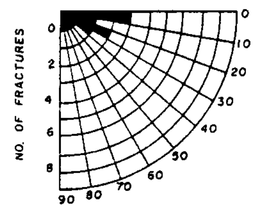
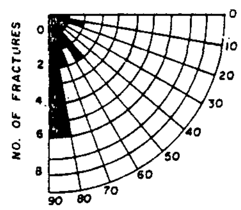
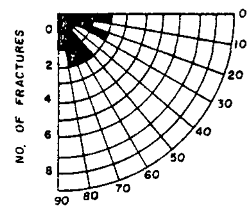
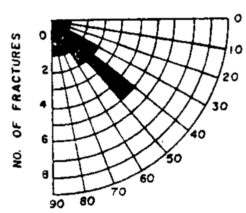
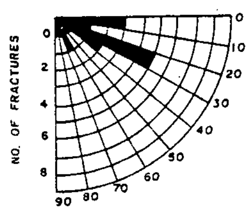
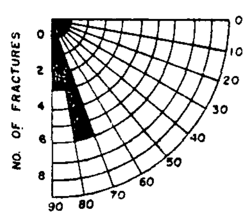
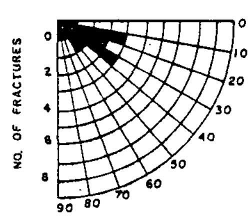
INTERVAL FEET	INTERVAL METERS	INCLINATION OF FAULT-PLANE SURFACES (10° INCREMENTS)	INCLINATION OF STRIAE ON FRACTURE FACES (RAKE)	FAULT NUMBER
225.4 - 270.4	68.7 - 82.4			F1
680.4 - 725.7	207.4 - 221.2			F3
1,224.8 - 1,361.8	373.3 - 415.1			F4
2,427.6 - 2,451.5	739.9 - 747.2			F5
2,465.1 - 2,498.3	751.4 - 761.5			F5

FIGURE 6.--STRUCTURAL DIAGRAMS SHOWING THE INCLINATIONS OF SHEAR FRACTURES AND CORRESPONDING STRIATIONS IN FAULT ZONES F1 AND F3-F-5

granulated. The upper 0.5 foot (0.2 m) of core, directly overlying the zone of granulation, shows the alinement of collapsed pumice lapilli dipping at about 45°. In fault zone F3, fault breccia occurs at a depth of 718.5 feet (219.0 m). Fragments are angular and recemented with calcite. In fault zones F4 and F5, yellow-brown and dark-brown clay gouge was commonly recognized along shear fractures.

Where obtainable, the angle between the trace of striations or slickenside grooving and a horizontal plane, was measured along the fracture plane (rake) (fig. 6; table 5). In all but fault zone F2, they are commonly alined obliquely to the dip of the fractures. Striations in fault zones F3 and F5 reflect a sizable component of lateral movement.

Core Index

The CI (core index) number is a summation of the joint frequency, core loss, and broken core (core less than 4 in. (10 cm) in length) into one significant number (J. R. Ege, written commun., 1975). This number reflects the engineering characteristics of the core per drilled interval (pl. 1). The equation used to obtain the CI is expressed as:

$$CI=\frac{(\text{ft broken})+(\text{ft core loss})+(1/3\text{ joints})}{(\text{drilled interval, ft})} \times 100$$

In effect, an increasing value indicates a corresponding increase in joint frequency, core loss, and broken core and, therefore, decreasing structural competency. A value greater than 50 is arbitrarily chosen for incompetent rock. As shown in plate 1, for UE25a-1 an increase in degree of welding generally corresponds to a decrease in competency of the rock.

Physical Properties

Of the 2,328.0 feet (709.6 m) of core recovered from the drill hole, 22.8 percent (531.4 ft, 162.0 m) was wrapped in heavy-gauge alluminum foil and sealed in beeswax, a method widely accepted at NTS to preserve "in situ" moisture content of the core. Natural-state samples were subsequently distributed to various testing laboratories (Las Alamos Scientific Laboratory, Sandia Laboratories, and Holmes & Narver, Inc.) to determine physical and sorptive properties of the core. As of January 1979, six samples had been measured, the values of which are presented in table 6.

HYDROLOGY

Yucca Mountain occurs within the Pahute Mesa ground-water system. Ground water migrates in a southerly direction toward discharge areas near Ash Meadows about 30 miles (48 km) southeast of the Yucca Mountain area.

As of 1966, the welded tuff of the Topopah Spring Member was the sole aquifer used for water supply in Jackass Flats where it occurs within the zone of saturation (Winograd and Thordarson, 1975). Here, the static water level ranges in altitude from 2,387 to 2,404 feet (727.6 to 732.7 m). After completion of UE25a-1 (Sept. 2, 1978), four measurements of the depth to water were taken. The results are as follows:

Table 5.--Inclinations of shear fractures and striations exclusive of fractures within designated fault zones

Depth Feet	Depth Meters	Dip of fractures (°)	Rake of striations (°)
942.1	287.2	87	10
967.7	295.0	88	3
970.5	295.8	85	5
988.0	301.1	80	4
1,050.8	320.3	80	2
1,053.7	321.2	85	2
1,126.8	343.4	63	85
1,957.1	596.5	72	36
2,036.8	620.8	83	80
2,066.2	629.8	40	85
2,072.1	631.6	62	57
2,211.6	674.1	90	60
2,367.4	721.6	88	20

Date	Depth to water	
	Feet	Meters
9/13/79	1,534.2	467.6
10/05/78	1,541.2	469.8
12/C8/78	1,542.3	470.1
1/10/79	1,541.6	469.9

The average depth to water corresponds to a static water altitude of 2,391.1 feet (728.8 m).

GEOPHYSICAL LOGS

Geophysical logs from UE25a-1 were interpreted to obtain correlations with lithology and geology and to provide "in situ" quantitative physical properties for lithologic characterizations. The suite of logs plotted on plate 1 were run by Birdwell Division of Seismograph Service Corp. the prime geophysical logging contractor at NTS. Table 7 shows the data from these logs digitized on a 5-foot (1.5-m) interval, which is suitable for lithologic and geologic correlations. Additional log data from these logs digitized on a 5-foot (1.5-m) interval, which is suitable for lithologic and geologic correlations. Additional log data was collected by USGS (J. Daniels of Branch of Petrophysics and Remote Sensing) for experimental purposes and to obtain physical properties needed to interpret surface geophysical surveys and will be reported separately.

Logging Conditions and Procedures

At the time of logging, the mud level was at a depth of 1,407 feet (428.9 m), which limited the coverage of those logs which require fluid coupling to the formation. Attempts to raise the mud level by circulating high-viscosity mud with lost-circulation additives were unsuccessful.

The Sperry Sun directional survey was run first inside the drill rods to protest the tool in the event of hole collapse (fig. 7). The total horizontal displacement between the collar and the bottom of the hole is 141.4 feet (43.1 m) and in the direction of S. 50°56' W. As can be seen on figure 7, most of the deviation occurs below 1,050 feet (320 m).

After Sperry Sun completed their survey, the inner string of drill rods was pulled out of the drill hole. The USGS then logged the hole from 1,297 to 2,500 feet (395.3 to 762.0 m) with the section above 1,297 feet (395.3 m) cased with the outer string of drill rods. The outer string of drill rods were then pulled out of the drill hole so the USGS could log the upper section of the drill hole. Owing to deteriorating drill-hole conditions during logging operations, complete coverage with all logs was not obtained. Repeated attempts to keep the drill hole open by circulating mud to stabilize the borehole walls, after reopening the drill hole with the drill rods, were unsuccessful.

Following completion of USGS logging operations the drill hole was reopened to total depth with the drill rods, and personnel of Sperry Sun Inc. repeated the directional survey, because no data was obtained from the first directional survey. The inner string of drill rods was pulled out of the hole and Birdwell logged the lower section from 1,297 to 2,500 feet (395.3 to 762.0 m) with the section above 1,297 feet (395.3 m) cased with the outer string of drill rods. The outer string of drill rods were then pulled so that Birdwell could log the upper section of drill hole. The drill-hole walls, however, deteriorated too rapidly for Birdwell to obtain complete coverage.

Table 6.--Summary of measured physical properties of samples from drill hole UE25a-1

[Testing performed by Holmes & Narver, Inc., Mercury, Nev. Results reported by A. Lappin, written commun., 1979, Sandia Laboratories, Albuquerque, N. Mex.]

Unit	Rock type	Depth Feet	Depth Meters	Natural-state density (Mg/m^3)	Grain density (Mg/m^3)	Water content (weight percent)	Porosity (percent) Calculated	Porosity (percent) Measured
Tuffaceous beds of Calico Hills	nonwelded zeolitized	1,555	474.0	1.94	2.46	14.9	32.6	28.0
Tuffaceous beds of Calico Hills	nonwelded zeolitized	1,561	475.8	1.95	2.48	15.6	33.5	30.3
Prow Pass Member	partially welded	1,949	594.0	2.32	2.63	7.5	18.4	18.6
Prow Pass Member	moderately welded	1,978	602.9	2.34	2.62	6.9	16.9	17.0
Bullfrog Member	moderately welded	2,423	738.5	2.23	2.62	10.3	23.6	23.7
Bullfrog Member	moderately welded	2,432	741.3	2.33	2.64	7.5	18.2	18.1

Table 7.--Digitized values of geophysical logs from drill hole UE25a-1

[Conversion factors: meter X 3.28=foot; centimeter X 0.3937=inch. Leaders (---) indicate no data available]

Depth (meters)	Caliper (cm)	Density (Mg/m³)	Resistivity (ohmmeters) 16-in. normal	Resistivity (ohmmeters) 64-in. normal	Velocity (m/s)	Acoustic impedance (10⁶ Rayls)	Neutron log (API units)	Gamma-ray log (API units)
.2740e 2	.1110e 2	---	---	---	---	---	.5700e 4	.3155e 3
.2900e 2	.1141e 2	---	---	---	---	---	.5540e 4	.3280e 3
.3050e 2	.1128e 2	---	---	---	---	---	.5457e 4	.3264e 3
.3200e 2	.1145e 2	---	---	---	---	---	.5373e 4	.3178e 3
.3350e 2	.1138e 2	---	---	---	---	---	.5234e 4	.2969e 3
.3510e 2	.1206e 2	---	---	---	---	---	.5510e 4	.3094e 3
.3660e 2	.1107e 2	---	---	---	---	---	.5741e 4	.3132e 3
.3810e 2	.1083e 2	---	---	---	---	---	.5399e 4	.3240e 3
.3960e 2	.1128e 2	---	---	---	---	---	.5383e 4	.3154e 3
.4110e 2	.1058e 2	---	---	---	---	---	.5379e 4	.3227e 3
.4270e 2	.1097e 2	---	---	---	---	---	.5340e 4	.3159e 3
.4420e 2	.1085e 2	---	---	---	---	---	.5302e 4	.3090e 3
.4570e 2	.1118e 2	---	---	---	---	---	.5331e 4	.3216e 3
.4720e 2	.1106e 2	---	---	---	---	---	.5360e 4	.3041e 3
.4880e 2	.1076e 2	---	---	---	---	---	.5467e 4	.3185e 3
.5030e 2	.1092e 2	---	---	---	---	---	.5485e 4	.3134e 3
.5180e 2	.1028e 2	---	---	---	---	---	.5424e 4	.3083e 3
.5330e 2	.2064e 2	---	---	---	---	---	.5262e 4	.2821e 3
.5490e 2	.1124e 2	---	---	---	---	---	.5571e 4	.2788e 3
.5640e 2	.1134e 2	---	---	---	---	---	.4959e 4	.2737e 3
.5790e 2	.1841e 2	---	---	---	---	---	.5281e 4	.2704e 3
.5940e 2	.1397e 2	---	---	---	---	---	.6075e 4	.2653e 3
.6100e 2	.1752e 2	---	---	---	---	---	.5766e 4	.2373e 3
.6250e 2	.1799e 2	---	---	---	---	---	.7347e 4	.2234e 3
.6400e 2	.2121e 2	---	---	---	---	---	.7230e 4	.2025e 3
.6550e 2	.2270e 2	---	---	---	---	---	.7090e 4	.2186e 3
.6710e 2	.2424e 2	---	---	---	---	---	.6816e 4	.2100e 3
.6860e 2	.2614e 2	---	---	---	---	---	.6147e 4	.1678e 3
.7010e 2	.2653e 2	---	---	---	---	---	.7300e 4	.2175e 3
.7160e 2	.2669e 2	---	---	---	---	---	.7531e 4	.2618e 3
.7320e 2	.2518e 2	---	---	---	---	---	.7583e 4	.2673e 3
.7470e 2	.2517e 2	---	---	---	---	---	.7668e 4	.2746e 3
.7620e 2	.2511e 2	---	---	---	---	---	.7674e 4	.2678e 3
.7770e 2	.2510e 2	---	---	---	---	---	.7535e 4	.2397e 3
.7920e 2	.2583e 2	---	---	---	---	---	.7696e 4	.2206e 3
.8080e 2	.2738e 2	---	---	---	---	---	.7447e 4	.2190e 3
.8230e 2	.1988e 2	---	---	---	---	---	.7296e 4	.1857e 3
.8390e 2	.1572e 2	---	---	---	---	---	.7460e 4	.2406e 3
.8530e 2	.1589e 2	---	---	---	---	---	.6400e 4	.2867e 3
.8690e 2	.2083e 2	---	---	---	---	---	.5910e 4	.2958e 3
.8840e 2	.1459e 2	---	---	---	---	---	.6726e 4	.2301e 3
.8990e 2	.1348e 2	---	---	---	---	---	.5979e 4	.2750e 3
.9140e 2	.1376e 2	---	---	---	---	---	.6435e 4	.2770e 3
.9300e 2	.2621e 2	---	---	---	---	---	.7431e 4	.3214e 3
.9450e 2	.2694e 2	---	---	---	---	---	.7371e 4	.3022e 3
.9600e 2	.1967e 2	---	---	---	---	---	.7387e 4	.2724e 3
.9750e 2	.2041e 2	---	---	---	---	---	.7249e 4	.2814e 3
.9910e 2	.1717e 2	---	---	---	---	---	.6928e 4	.2723e 3
.1006e 3	.1359e 2	---	---	---	---	---	.5316e 4	.2730e 3
.1021e 3	.2528e 2	---	---	---	---	---	.5592e 4	.2339e 3
.1036e 3	.1080e 2	---	---	---	---	---	.5025e 4	.2770e 3
.1052e 3	.1079e 2	---	---	---	---	---	.5020e 4	.2843e 3
.1067e 3	.1049e 2	---	---	---	---	---	.5027e 4	.2880e 3
.1082e 3	.1077e 2	---	---	---	---	---	.5031e 4	.2883e 3
.1097e 3	.1053e 2	---	---	---	---	---	.5039e 4	.2956e 3
.1113e 3	.1046e 2	---	---	---	---	---	.5147e 4	.2852e 3
.1128e 3	.1115e 2	---	---	---	---	---	.5333e 4	.2960e 3
.1143e 3	.1063e 2	---	---	---	---	---	.5120e 4	.3048e 3
.1158e 3	.1575e 2	---	---	---	---	---	.5277e 4	.2924e 3
.1173e 3	.1062e 2	---	---	---	---	---	.6110e 4	.2959e 3
.1139e 3	.1070e 2	---	---	---	---	---	.5176e 4	.3030e 3
.1204e 3	.1465e 2	---	---	---	---	---	.5412e 4	.2995e 3
.1219e 3	.1078e 2	---	---	---	---	---	.6009e 4	.3047e 3
.1234e 3	.1348e 2	---	---	---	---	---	---	---
.1250e 3	.1129e 2	---	---	---	---	---	---	---
.1265e 3	.1486e 2	---	---	---	---	---	---	---
.1280e 3	.1393e 2	---	---	---	---	---	---	---
.1295e 3	.2039e 2	---	---	---	---	---	---	---
.1311e 3	.1179e 2	---	---	---	---	---	---	---
.1326e 3	.1778e 2	---	---	---	---	---	---	---
.1341e 3	.1195e 2	---	---	---	---	---	---	---
.1356e 3	.2152e 2	---	---	---	---	---	---	---
.1372e 3	.1108e 2	---	---	---	---	---	---	---
.1387e 3	.1085e 2	---	---	---	---	---	---	---
.1402e 3	.1067e 2	---	---	---	---	---	---	---
.1417e 3	.1130e 2	---	---	---	---	---	---	---
.1433e 3	.1089e 2	---	---	---	---	---	---	---
.1448e 3	.1100e 2	---	---	---	---	---	---	---
.1463e 3	.1100e 2	---	---	---	---	---	---	---
.1478e 3	.1088e 2	---	---	---	---	---	---	---
.1494e 3	.1185e 2	---	---	---	---	---	---	---
.1509e 3	.1150e 2	---	---	---	---	---	---	---
.1524e 3	.1484e 2	---	---	---	---	---	---	---
.1539e 3	.1380e 2	---	---	---	---	---	---	---
.1554e 3	.1276e 2	---	---	---	---	---	---	---
.1570e 3	.1114e 2	---	---	---	---	---	---	---
.1585e 3	.1339e 2	---	---	---	---	---	---	---
.1600e 3	.1315e 2	---	---	---	---	---	---	---
.1615e 3	.1205e 2	---	---	---	---	---	---	---
.1631e 3	.1066e 2	---	---	---	---	---	---	---
.1646e 3	.1083e 2	---	---	---	---	---	---	---
.1661e 3	.1037e 2	---	---	---	---	---	---	---
.1676e 3	.1336e 2	---	---	---	---	---	---	---
.1692e 3	.1566e 2	---	---	---	---	---	---	---
.1707e 3	.1110e 2	---	---	---	---	---	---	---
.1722e 3	.1167e 2	---	---	---	---	---	---	---
.1737e 3	.1057e 2	---	---	---	---	---	---	---
.1753e 3	.1103e 2	---	---	---	---	---	---	---
.1768e 3	.1097e 2	---	---	---	---	---	---	---
.1783e 3	.1062e 2	---	---	---	---	---	---	---
.1798e 3	.1090e 2	---	---	---	---	---	---	---
.1814e 3	.1073e 2	---	---	---	---	---	---	---
.1829e 3	.1061e 2	---	---	---	---	---	---	---
.1844e 3	.1049e 2	---	---	---	---	---	---	---
.1859e 3	.1031e 2	---	---	---	---	---	---	---
.1875e 3	.1030e 2	---	---	---	---	---	---	---
.1890e 3	.1065e 2	---	---	---	---	---	---	---
.1905e 3	.1087e 2	---	---	---	---	---	---	---
.1920e 3	.1052e 2	---	---	---	---	---	---	---
.1935e 3	.1035e 2	---	---	---	---	---	---	---
.1951e 3	.1011e 2	---	---	---	---	---	---	---
.1966e 3	.1039e 2	---	---	---	---	---	---	---

Table 7.--Digitized values of geophysical logs from drill hole UE25a-1--Continued

Depth (meters)	Caliper (cm)	Density (Mg/m³)	Resistivity (ohmmeters)		Velocity (m/s)	Acoustic impedance (10^6 Rayls)	Neutron log (API units)	Gamma-ray log (API units)
			16-in. normal	64-in. normal				
.1981e 3	.1062e 2	---	---	---	---	---	---	---
.1996e 3	.1137e 2	---	---	---	---	---	---	---
.2012e 3	.1489e 2	---	---	---	---	---	---	---
.2027e 3	.1046e 2	---	---	---	---	---	---	---
.2042e 3	.1418e 2	---	---	---	---	---	---	---
.2057e 3	.1698e 2	---	---	---	---	---	---	---
.2073e 3	.1032e 2	---	---	---	---	---	---	---
.2088e 3	.1069e 2	---	---	---	---	---	---	---
.2103e 3	.1043e 2	---	---	---	---	---	---	---
.2118e 3	.1012e 2	---	---	---	---	---	---	---
.2134e 3	.1014e 2	---	---	---	---	---	---	---
.2149e 3	.1041e 2	---	---	---	---	---	---	---
.2164e 3	.1061e 2	---	---	---	---	---	---	---
.2179e 3	.1346e 2	---	---	---	---	---	---	---
.2195e 3	.1061e 2	---	---	---	---	---	---	---
.2210e 3	.1052e 2	---	---	---	---	---	---	---
.2225e 3	.1015e 2	---	---	---	---	---	---	---
.2240e 3	[illegible]	---	---	---	---	---	---	---
.2256e 3	.1026e 2	---	---	---	---	---	---	---
.2271e 3	.1022e 2	---	---	---	---	---	---	---
.2286e 3	.1014e 2	---	---	---	---	---	---	---
.2301e 3	.1012e 2	---	---	---	---	---	---	---
.2316e 3	.1049e 2	---	---	---	---	---	---	---
.2332e 3	.1024e 2	---	---	---	---	---	---	---
.2347e 3	.1049e 2	---	---	---	---	---	---	---
.2362e 3	.1035e 2	---	---	---	---	---	---	---
.2377e 3	.1043e 2	---	---	---	---	---	---	---
.2393e 3	.1749e 2	---	---	---	---	---	---	---
.2408e 3	.1049e 2	---	---	---	---	---	---	---
.2423e 3	.1537e 2	---	---	---	---	---	---	---
.2438e 3	.1061e 2	---	---	---	---	---	---	---
.2454e 3	.1018e 2	---	---	---	---	---	---	---
.2469e 3	.1014e 2	---	---	---	---	---	---	---
.2484e 3	.1017e 2	---	---	---	---	---	---	---
.2499e 3	.1014e 2	---	---	---	---	---	---	---
.2515e 3	.1035e 2	---	---	---	---	---	---	---
.2530e 3	.1023e 2	---	---	---	---	---	---	---
.2545e 3	.1036e 2	---	---	---	---	---	---	---
.2560e 3	.1032e 2	---	---	---	---	---	---	---
.2576e 3	.1018e 2	---	---	---	---	---	---	---
.2591e 3	.1038e 2	---	---	---	---	---	---	---
.2606e 3	.1035e 2	---	---	---	---	---	---	---
.2621e 3	.1061e 2	---	---	---	---	---	---	---
.2637e 3	.1056e 2	---	---	---	---	---	---	---
.2652e 3	.1076e 2	---	---	---	---	---	---	---
.2667e 3	.1067e 2	---	---	---	---	---	---	---
.2682e 3	.1035e 2	---	---	---	---	---	---	---
.2697e 3	.1038e 2	---	---	---	---	---	---	---
.2713e 3	.1058e 2	---	---	---	---	---	---	---
.2728e 3	.1043e 2	---	---	---	---	---	---	---
.2743e 3	.1052e 2	---	---	---	---	---	---	---
.2758e 3	.1139e 2	---	---	---	---	---	---	---
.2774e 3	.1055e 2	---	---	---	---	---	---	---
.2789e 3	.1046e 2	---	---	---	---	---	---	---
.2804e 3	.1090e 2	---	---	---	---	---	---	---
.2819e 3	.1069e 2	---	---	---	---	---	---	---
.2835e 3	.1055e 2	---	---	---	---	---	---	---
.2850e 3	.1052e 2	---	---	---	---	---	---	---
.2865e 3	.1072e 2	---	---	---	---	---	---	---
.2880e 3	.1046e 2	---	---	---	---	---	---	---
.2896e 3	.1084e 2	---	---	---	---	---	---	---
.2911e 3	.1081e 2	---	---	---	---	---	---	---
.2926e 3	---	---	---	---	---	---	---	---
.2941e 3	---	---	---	---	---	---	---	---
.2957e 3	---	---	---	---	---	---	---	---
.2972e 3	---	---	---	---	---	---	---	---
.2987e 3	---	---	---	---	---	---	---	---
.3002e 3	---	---	---	---	---	---	---	---
.3018e 3	---	---	---	---	---	---	---	---
.3033e 3	---	---	---	---	---	---	---	---
.3048e 3	---	---	---	---	---	---	---	---
.3063e 3	---	---	---	---	---	---	---	---
.3078e 3	---	---	---	---	---	---	---	---
.3094e 3	---	---	---	---	---	---	---	---
.3109e 3	---	---	---	---	---	---	---	---
.3124e 3	---	---	---	---	---	---	---	---
.3139e 3	---	---	---	---	---	---	---	---
.3155e 3	---	---	---	---	---	---	---	---
.3170e 3	---	---	---	---	---	---	---	---
.3185e 3	---	---	---	---	---	---	---	---
.3200e 3	---	---	---	---	---	---	---	---
.3216e 3	---	---	---	---	---	---	---	---
.3231e 3	---	---	---	---	---	---	---	---
.3246e 3	---	---	---	---	---	---	---	---
.3261e 3	---	---	---	---	---	---	---	---
.3277e 3	---	---	---	---	---	---	---	---
.3292e 3	---	---	---	---	---	---	---	---
.3307e 3	---	---	---	---	---	---	---	---
.3322e 3	---	---	---	---	---	---	---	---
.3338e 3	---	---	---	---	---	---	---	---
.3353e 3	---	---	---	---	---	---	---	---
.3368e 3	---	---	---	---	---	---	---	---
.3383e 3	---	---	---	---	---	---	---	---
.3399e 3	---	---	---	---	---	---	---	---
.3414e 3	---	---	---	---	---	---	---	---
.3429e 3	---	---	---	---	---	---	---	---
.3444e 3	---	---	---	---	---	---	---	---
.3459e 3	---	---	---	---	---	---	---	---
.3475e 3	---	---	---	---	---	---	---	---
.3490e 3	---	---	---	---	---	---	---	---
.3505e 3	---	---	---	---	---	---	---	---
.3520e 3	---	---	---	---	---	---	---	---
.3536e 3	---	---	---	---	---	---	---	---
.3551e 3	---	---	---	---	---	---	---	---
.3566e 3	---	---	---	---	---	---	---	---
.3581e 3	---	---	---	---	---	---	---	---
.3597e 3	---	---	---	---	---	---	---	---
.3612e 3	---	---	---	---	---	---	---	---
.3627e 3	---	---	---	---	---	---	---	---
.3642e 3	---	---	---	---	---	---	---	---
.3658e 3	---	---	---	---	---	---	---	---
.3673e 3	---	---	---	---	---	---	---	---

Table 7.--Digitized values of geophysical logs from drill hole UE25a-1--Continued

Depth (meters)	Caliper (cm)	Density (Mg/m³)	Resistivity (ohmmeters) 16-in. normal	Resistivity (ohmmeters) 64-in. normal	Velocity (m/s)	Acoustic impedance (10⁶ Rayls)	Neutron log (API units)	Gamma-ray log (API units)
.5395e 3	.7030e 1	.1930e 1	.6718e 2	.7711e 2	.3166e 4	.6123e 1	.6103e 3	.2433e 3
.5410e 3	.7160e 1	.1960e 1	.1107e 3	.6251e 2	.3261e 4	.6391e 1	.6259e 3	.2271e 3
.5425e 3	.7169e 1	.1950e 1	.1238e 3	.1065e 3	.3592e 4	.7011e 1	.6414e 3	.2287e 3
.5441e 3	.7036e 1	.1980e 1	.1285e 3	.7980e 2	.3617e 4	.7166e 1	.7696e 3	.2444e 3
.5456e 3	.6902e 1	.2100e 1	.7681e 2	.9713e 2	.3791e 4	.7969e 1	.7176e 3	.2849e 3
.5471e 3	.6982e 1	.2030e 1	.9858e 2	.7413e 2	.3562e 4	.7914e 1	.7707e 3	.2546e 3
.5486e 3	.6921e 1	.2070e 1	.6714e 2	.5504e 2	.3464e 4	.7158e 1	.7112e 3	.2419e 3
.5502e 3	.7000e 1	.2080e 1	.5368e 2	.7882e 2	.3381e 4	.7021e 1	.8019e 3	.2453e 3
.5517e 3	.7080e 1	.2100e 1	.1179e 3	.4321e 2	.3869e 4	.8140e 1	.7874e 3	.2114e 3
.5532e 3	.7090e 1	.2070e 1	.7439e 2	.1237e 3	.3433e 4	.7115e 1	.8322e 3	.2080e 3
.5547e 3	.7027e 1	.2320e 1	.1327e 3	.7087e 2	.4173e 4	.9669e 1	.1018e 4	.2094e 3
.5563e 3	.7108e 1	.2240e 1	.4409e 2	.4563e 2	.3408e 4	.7640e 1	.7327e 3	.1930e 3
.5578e 3	.6976e 1	.2110e 1	.2170e 2	.3467e 2	.3336e 4	.7054e 1	.8520e 3	.2033e 3
.5593e 3	.7054e 1	.2050e 1	.2523e 2	.3127e 2	.3235e 4	.6519e 1	.7159e 3	.2206e 3
.5608e 3	.7062e 1	.1980e 1	.8502e 2	.5252e 2	.3330e 4	.6602e 1	.6174e 3	.2325e 3
.5624e 3	.7001e 1	.2090e 1	.1223e 3	.6789e 2	.3543e 4	.7492e 1	.8115e 3	.2605e 3
.5639e 3	.7009e 1	.2140e 1	.1130e 3	.1184e 3	.3269e 4	.6987e 1	.7657e 3	.2689e 3
.5654e 3	.6948e 1	.2150e 1	.9866e 2	.9695e 2	.3298e 4	.7098e 1	.7948e 3	.2632e 3
.5669e 3	.6956e 1	.2150e 1	.9383e 2	.6723e 2	.3239e 4	.6971e 1	.8163e 3	.2557e 3
.5685e 3	.7107e 1	.2170e 1	.6643e 2	.6999e 2	.3270e 4	.7111e 1	.8605e 3	.2500e 3
.5700e 3	.7400e 1	.2200e 1	.6857e 2	.6548e 2	.3273e 4	.7195e 1	.8746e 3	.2461e 3
.5715e 3	.7127e 1	.2200e 1	.9074e 2	.7245e 2	.3449e 4	.7579e 1	.8885e 3	.2634e 3
.5730e 3	.6921e 1	.2210e 1	.1043e 3	.8697e 2	.3422e 4	.7557e 1	.8952e 3	.2488e 3
.5745e 3	.6928e 1	.2210e 1	.1061e 3	.9674e 2	.3393e 4	.7486e 1	.9243e 3	.2538e 3
.5761e 3	.6942e 1	.2200e 1	.1051e 3	.1001e 3	.3367e 4	.7415e 1	.9234e 3	.2498e 3
.5776e 3	.7082e 1	.2210e 1	.9855e 2	.1003e 3	.3446e 4	.7620e 1	.9449e 3	.2406e 3
.5791e 3	.7080e 1	.2190e 1	.1060e 3	.9972e 2	.3514e 4	.7711e 1	.9590e 3	.2278e 3
.5806e 3	.6795e 1	.2210e 1	.1021e 3	.9072e 2	.3568e 4	.7875e 1	.9505e 3	.2345e 3
.5822e 3	.6864e 1	.2200e 1	.9569e 2	.8732e 2	.3336e 4	.7354e 1	.9571e 3	.2464e 3
.5837e 3	.6791e 1	.2120e 1	.9693e 2	.7636e 2	.3343e 4	.7100e 1	.9411e 3	.2390e 3
.5852e 3	.7073e 1	.2230e 1	.7427e 2	.6877e 2	.3573e 4	.7958e 1	.9928e 3	.2562e 3
.5867e 3	.6859e 1	.2240e 1	.6804e 2	.6257e 2	.3512e 4	.7857e 1	.1014e 4	.2505e 3
.5883e 3	.6857e 1	.2200e 1	.6544e 2	.6001e 2	.3398e 4	.7458e 1	.9533e 3	.2360e 3
.5898e 3	.6855e 1	.2170e 1	.6784e 2	.6966e 2	.3545e 4	.7706e 1	.1019e 4	.2338e 3
.5913e 3	.6853e 1	.2240e 1	.9282e 2	.8263e 2	.3874e 4	.8678e 1	.1131e 4	.2387e 3
.5928e 3	.7277e 1	.2280e 1	.1473e 3	.1425e 3	.4035e 4	.9190e 1	.1280e 4	.2489e 3
.5944e 3	.7346e 1	.2340e 1	.1574e 3	.1814e 3	.3952e 4	.9240e 1	.1302e 4	.2521e 3
.5959e 3	.7203e 1	.2300e 1	.1621e 3	.2174e 3	.3863e 4	.8873e 1	.1233e 4	.2534e 3
.5974e 3	.7414e 1	.2280e 1	.1694e 3	.2788e 3	.4002e 4	.9137e 1	.1368e 4	.2405e 3
.5989e 3	.7412e 1	.2320e 1	.2075e 3	.3008e 3	.4408e 4	.1020e 2	.1560e 4	.2552e 3
.6005e 3	.7339e 1	.2340e 1	.2344e 3	.3537e 3	.4470e 4	.1046e 2	.1658e 4	.2576e 3
.6020e 3	.7409e 1	.2350e 1	.2281e 3	.4023e 3	.4361e 4	.1024e 2	.1703e 4	.2642e 3
.6035e 3	.7336e 1	.2370e 1	.2365e 3	.4020e 3	.4496e 4	.1064e 2	.1912e 4	.2515e 3
.6050e 3	.7334e 1	.2390e 1	.3034e 3	.5136e 3	.4509e 4	.1008e 2	.2271e 4	.2500e 3
.6066e 3	.7403e 1	.2410e 1	.3592e 3	.5441e 3	.4590e 4	.1104e 2	.2128e 4	.2507e 3
.6081e 3	.7330e 1	.2350e 1	.2478e 3	.4457e 3	.4516e 4	.1062e 2	.1531e 4	.2431e 3
.6096e 3	.7399e 1	.2350e 1	.2395e 3	.1316e 3	.4524e 4	.1062e 2	.1473e 4	.2463e 3
.6111e 3	.8391e 1	.2260e 1	.2062e 3	.1677e 3	.4442e 4	.1006e 2	.1532e 4	.2266e 3
.6126e 3	.7325e 1	.2340e 1	.1070e 3	.1113e 3	.4152e 4	.9685e 1	.1516e 4	.2314e 3
.6142e 3	.7394e 1	.2310e 1	.1423e 3	.2310e 2	.3561e 4	.9468e 1	.1064e 4	.2221e 3
.6157e 3	.7251e 1	.2230e 1	.4014e 2	.6600e 2	.3592e 4	.7797e 1	.9463e 3	.2100e 3
.6172e 3	.7320e 1	.2150e 1	.9945e 2	.3460e 2	.3316e 4	.7139e 1	.7627e 3	.2319e 3
.6187e 3	.7318e 1	.2110e 1	.8723e 2	.7206e 2	.3567e 4	.7526e 1	.9370e 3	.2316e 3
.6203e 3	.7174e 1	.2120e 1	.9671e 2	.7062e 2	.3309e 4	.7198e 1	.7686e 3	.2312e 3
.6218e 3	.7314e 1	.2130e 1	.9281e 2	.6307e 2	.4108e 4	.8949e 1	.8876e 3	.2343e 3
.6233e 3	.7242e 1	.2210e 1	.9534e 2	.8119e 2	.3974e 4	.8779e 1	.8341e 3	.2321e 3
.6248e 3	.7169e 1	.2150e 1	.8148e 2	.7248e 2	.3799e 4	.8152e 1	.7957e 3	.2318e 3
.6264e 3	.7522e 1	.2080e 1	.7501e 2	.9849e 2	.3958e 4	.8213e 1	.1027e 4	.2394e 3
.6279e 3	.7378e 1	.2200e 1	.1708e 3	.5756e 2	.3953e 4	.8690e 1	.9364e 3	.2203e 3
.6294e 3	.7447e 1	.2110e 1	.1179e 3	.9842e 2	.3208e 4	.6766e 1	.7403e 3	.2323e 3
.6309e 3	.7446e 1	.2080e 1	.1096e 3	.6926e 2	.3827e 4	.7979e 1	.7619e 3	.2089e 3
.6325e 3	.7018e 1	.2110e 1	.1097e 3	.8407e 2	.3926e 4	.8285e 1	.8661e 3	.2173e 3
.6340e 3	.7229e 1	.2180e 1	.1237e 3	.7059e 2	.3642e 4	.7922e 1	.7376e 3	.2311e 3
.6355e 3	.7227e 1	.2090e 1	.1293e 3	---	.3836e 4	.7999e 1	.6765e 3	.2236e 3
.6370e 3	.7155e 1	.2060e 1	.1322e 3	.8332e 2	.3690e 4	.7587e 1	.6755e 3	.2339e 3
.6386e 3	.7437e 1	.2050e 1	.1378e 3	.1166e 3	.3579e 4	.7342e 1	.6373e 3	.2176e 3
.6401e 3	.7577e 1	.2040e 1	.1351e 3	.1163e 3	.3513e 4	.7177e 1	.6306e 3	.2264e 3
.6416e 3	.7504e 1	.2050e 1	.1324e 3	.1103e 3	.3560e 4	.7300e 1	.7565e 3	.2398e 3
.6431e 3	.7573e 1	.2190e 1	.1910e 3	.1610e 3	.6111e 4	.1336e 2	.1520e 4	.2281e 3
.6447e 3	.7501e 1	.2320e 1	.7286e 3	.1055e 4	.5626e 4	.1304e 2	.1736e 4	.2476e 3
.6462e 3	.7499e 1	.2270e 1	.4279e 3	.2190e 3	.4470e 4	.1016e 2	.8715e 3	.2457e 3
.6477e 3	.7497e 1	.2150e 1	.1327e 3	.2545e 2	.4121e 4	.8870e 1	.6896e 3	.2191e 3
.6492e 3	.7495e 1	.2020e 1	.5143e 2	.5483e 2	.2686e 4	.5417e 1	.5303e 3	.2244e 3
.6507e 3	.7565e 1	.2030e 1	.5757e 2	.7216e 2	.3004e 4	.6093e 1	.5288e 3	.2208e 3
.6523e 3	.7492e 1	.2000e 1	.8042e 2	.9940e 2	.3260e 4	.6515e 1	.4895e 3	.2314e 3
.6538e 3	.7490e 1	.1990e 1	.5703e 2	.1047e 3	.3007e 4	.5976e 1	.5254e 3	.2190e 3
.6553e 3	.7417e 1	.2060e 1	.8294e 2	.1127e 3	.3438e 4	.7075e 1	.5987e 3	.2172e 3
.6568e 3	.7557e 1	.2070e 1	.1219e 3	.1124e 3	.5051e 4	.1046e 2	.9196e 3	.2242e 3
.6584e 3	.7485e 1	.2220e 1	.2613e 3	.1989e 3	.4455e 4	.9869e 1	.7078e 3	.2241e 3
.6599e 3	.7696e 1	.2090e 1	.1583e 3	.1873e 3	.4566e 4	.9552e 1	.7512e 3	.2223e 3
.6614e 3	.7552e 1	.2110e 1	.2196e 3	.1282e 3	.4549e 4	.9585e 1	.7945e 3	.2134e 3
.6629e 3	.7533e 1	.2130e 1	.2308e 3	.2735e 3	.5120e 4	.1091e 2	.7627e 3	.2187e 3
.6645e 3	.7598e 1	.2110e 1	.1975e 3	.3207e 3	.3631e 4	.7665e 1	.7311e 3	.2204e 3
.6660e 3	.7522e 1	.2120e 1	.2059e 3	.2167e 3	.4285e 4	.9063e 1	.7519e 3	.2206e 3
.6675e 3	.7730e 1	.2120e 1	.2116e 3	.1940e 3	.5104e 4	.1082e 2	.8705e 3	.2257e 3
.6690e 3	.7653e 1	.2170e 1	.2033e 3	.1684e 3	.4758e 4	.1034e 2	.8985e 3	.2203e 3
.6706e 3	.7506e 1	.2160e 1	.1755e 3	.1513e 3	.4266e 4	.9194e 1	.8369e 3	.2096e 3
.6721e 3	.7359e 1	.2130e 1	.1588e 3	.1341e 3	.4127e 4	.8782e 1	.7525e 3	.2131e 3
.6736e 3	.7425e 1	.2100e 1	.1645e 3	.1422e 3	.3930e 4	.8239e 1	.7435e 3	.1954e 3
.6751e 3	.7632e 1	.2110e 1	.1618e 3	.1502e 3	.4177e 4	.8826e 1	.8017e 3	.1936e 3
.6767e 3	.7485e 1	.2110e 1	.1618e 3	.1499e 3	.4103e 4	.8675e 1	.7852e 3	.2148e 3
.6782e 3	.7479e 1	.2070e 1	.1619e 3	.1468e 3	.4011e 4	.8292e 1	.7459e 3	.2236e 3
.6797e 3	.7687e 1	.2070e 1	.1536e 3	.1464e 3	.3650e 4	.7539e 1	.6617e 3	.2200e 3
.6812e 3	.7540e 1	.2040e 1	.1676e 3	.1460e 3	.3737e 4	.7619e 1	.7649e 3	.2235e 3
.6828e 3	.7464e 1	.2090e 1	.1677e 3	.1485e 3	.3961e 4	.8278e 1	.7634e 3	.2146e 3
.6843e 3	.7387e 1	.2100e 1	.1705e 3	.1649e 3	.4283e 4	.8989e 1	.7615e 3	.2269e 3
.6858e 3	.7524e 1	.2100e 1	.1734e 3	.1477e 3	.4389e 4	.9226e 1	.8275e 3	.2251e 3
.6873e 3	.7235e 1	.2110e 1	.1676e 3	.1372e 3	.4026e 4	.9490e 1	.7658e 3	.2286e 3
.6888e 3	.7443e 1	.2130e 1	.1652e 3	.1259e 3	.4700e 4	.1001e 2	.8317e 3	.2303e 3
.6904e 3	.7295e 1	.2130e 1	.1657e 3	.1286e 3	.3826e 4	.8139e 1	.7474e 3	.2356e 3
.6919e 3	.7432e 1	.2100e 1	.1605e 3	.1398e 3	.3776e 4	.7930e 1	.7532e 3	.2285e 3
.6934e 3	.7427e 1	.2110e 1	.1638e 3	.1509e 3	.3849e 4	.8123e 1	.7592e 3	.2214e 3
.6949e 3	.8556e 1	.2120e 1	.1670e 3	.1621e 3	.4005e 4	.8501e 1	.7798e 3	.2231e 3
.6965e 3	.7628e 1	.2140e 1	.1730e 3	.1704e 3	.3890e 4	.8314e 1	.7556e 3	.2266e 3
.6980e 3	.7198e 1	.2120e 1	.1902e 3	.1843e 3	.3828e 4	.8116e 1	.7689e 3	.2336e 3
.6995e 3	.7334e 1	.2130e 1	.1990e 3	.1843e 3	.4244e 4	.9039e 1	.8349e 3	.2247e 3
.7010e 3	.7471e 1	.2180e 1	.1827e 3	.1786e 3	.4196e 4	.9144e 1	.8192e 3	.2353e 3
.7026e 3	.7394e 1	.2170e 1	.1749e 3	.1449e 3	.4034e 4	.8760e 1	.8099e 3	.2353e 3
.7041e 3	.7460e 1	.2190e 1	.1474e 3	.8604e 2	.4023e 4	.8821e 1	.7998e 3	.2299e 3
.7056e 3	.7597e 1	.2210e 1	.1228e 3	.9851e 2	.4030e 4	.8904e 1	.8357e 3	.2102e 3
.7071e 3	.7449e 1	.2190e 1	.1065e 3	.9234e 2	.3934e 4	.8616e 1	.8263e 3	.2351e 3
.7087e 3	.7444e 1	.2190e 1	.9307e 2	.7637e 2	.3948e 4	.8638e 1	.8547e 3	.2209e 3

Table 7.--Digitized values of geophysical logs from drill hole UE25a-1--Continued

Depth (meters)	Caliper (cm)	Density (Mg/m^3)	Resistivity (ohmmeters)		Velocity (m/s)	Acoustic impedance (10^6 Rayls)	Neutron log (API units)	Gamma-ray log (API units)
			16-in. normal	64-in. normal				
.3688e 3	---	---	---	---	---	---	---	---
.3703e 3	---	---	---	---	---	---	---	---
.3719e 3	---	---	---	---	---	---	---	---
.3734e 3	---	---	---	---	---	---	---	---
.3749e 3	---	---	---	---	---	---	---	---
.3764e 3	---	---	---	---	---	---	---	---
.3780e 3	---	---	---	---	---	---	---	---
.3795e 3	---	---	---	---	---	---	---	---
.3810e 3	---	.2960e 1	---	---	---	---	---	---
.3825e 3	---	.2910e 1	---	---	---	---	.2937e 4	.2440e 3
.3840e 3	---	.2730e 1	---	---	---	---	.2606e 4	.2452e 3
.3856e 3	---	.2760e 1	---	---	---	---	.2710e 4	.2499e 3
.3871e 3	---	.2690e 1	---	---	---	---	.1485e 4	.2282e 3
.3886e 3	---	.2550e 1	---	---	---	---	.2392e 4	.2099e 3
.3901e 3	---	.2830e 1	---	---	---	---	.1746e 4	.2235e 3
.3917e 3	---	.2880e 1	---	---	---	---	.1294e 4	.1999e 3
.3932e 3	---	.2980e 1	---	---	---	---	.1676e 4	.2064e 3
.3947e 3	---	.2510e 1	---	---	---	---	.2741e 4	.2182e 3
.3962e 3	---	.2110e 1	---	---	---	---	.3197e 4	.2548e 3
.3978e 3	---	.2340e 1	---	---	---	---	.2753e 4	.2595e 3
.3993e 3	---	.2150e 1	---	---	---	---	.2902e 4	.2377e 3
.4008e 3	---	.2110e 1	---	---	---	---	.3014e 4	.2141e 3
.4023e 3	.8468e 1	.1970e 1	---	---	---	---	.3846e 4	.2029e 3
.4039e 3	.1017e 2	.1900e 1	---	---	---	---	.3815e 4	.2167e 3
.4054e 3	.1039e 2	.1870e 1	---	---	---	---	.2778e 4	.2142e 3
.4069e 3	.8271e 1	.1970e 1	---	---	---	---	.2709e 4	.2154e 3
.4084e 3	.7566e 1	.2180e 1	---	---	---	---	.3188e 4	.2484e 3
.4100e 3	.7359e 1	.2240e 1	---	---	---	---	.3120e 4	.2602e 3
.4115e 3	.7222e 1	.2090e 1	---	---	---	---	.2556e 4	.2136e 3
.4130e 3	.7512e 1	.2060e 1	---	---	---	---	.2584e 4	.2095e 3
.4145e 3	.7588e 1	.2070e 1	---	---	---	---	.2546e 4	.2125e 3
.4161e 3	.7451e 1	.2070e 1	---	---	---	---	.2582e 4	.2119e 3
.4176e 3	.7456e 1	.2020e 1	---	---	---	---	.2566e 4	.2166e 3
.4191e 3	.7320e 1	.2020e 1	---	---	---	---	.2475e 4	.2099e 3
.6206e 3	.7112e 1	.1960e 1	---	---	---	---	.2399e 4	.2102e 3
.4221e 3	.7331e 1	.2010e 1	---	---	---	---	.2510e 4	.1937e 3
.4237e 3	.7690e 1	.1910e 1	---	---	---	---	.2337e 4	.2020e 3
.4252e 3	.7625e 1	.1980e 1	---	---	---	---	.1795e 4	.1943e 3
.4267e 3	.7276e 1	.2000e 1	---	---	---	---	.4954e 3	.1796e 3
.4282e 3	.8487e 1	.1990e 1	---	---	---	---	.5694e 3	.1914e 3
.4298e 3	.7712e 1	.1980e 1	.1214e 3	.9154e 2	.3252e 4	.6437e 1	.5232e 3	.1837e 3
.4313e 3	.8002e 1	.1890e 1	.1125e 3	.8815e 2	.3082e 4	.5822e 1	.5297e 3	.1831e 3
.4328e 3	.7865e 1	.1950e 1	.1175e 3	.7524e 2	.3232e 4	.6312e 1	.5586e 3	.1878e 3
.4343e 3	.7374e 1	.1950e 1	.1142e 3	.8081e 2	.3139e 4	.6115e 1	.6023e 3	.1820e 3
.4359e 3	.7521e 1	.1970e 1	.1053e 3	.7210e 2	.3167e 4	.6223e 1	.5337e 3	.1956e 3
.4374e 3	.7526e 1	.1930e 1	.8902e 2	.7796e 2	.3214e 4	.6203e 1	.6001e 3	.1861e 3
.4389e 3	.7531e 1	.1940e 1	.9426e 2	.7149e 2	.3176e 4	.6149e 1	.5540e 3	.1821e 3
.4404e 3	.7395e 1	.1930e 1	.8334e 2	.7398e 2	.3174e 4	.6137e 1	.5905e 3	.1903e 3
.4420e 3	.7329e 1	.1980e 1	.1006e 3	.6639e 2	.3339e 4	.6602e 1	.6644e 3	.1969e 3
.4435e 3	.7547e 1	.2010e 1	.8602e 2	.6188e 2	.3101e 4	.6238e 1	.5656e 3	.2158e 3
.4450e 3	.7623e 1	.1910e 1	.7315e 2	.6605e 2	.2997e 4	.5735e 1	.6396e 3	.2169e 3
.4465e 3	.7416e 1	.1990e 1	.7309e 2	.6154e 2	.3078e 4	.6113e 1	.6235e 3	.2111e 3
.4481e 3	.7492e 1	.1980e 1	.7889e 2	.6515e 2	.3220e 4	.6367e 1	.6899e 3	.2087e 3
.4496e 3	.7640e 1	.2010e 1	.8858e 2	.5952e 2	.3241e 4	.6516e 1	.6738e 3	.2352e 3
.4511e 3	.7503e 1	.2000e 1	.6847e 2	.6678e 2	.3245e 4	.6687e 1	.7177e 3	.2166e 3
.4526e 3	.7579e 1	.2000e 1	.9236e 2	.7487e 2	.3283e 4	.6577e 1	.7315e 3	.2247e 3
.4542e 3	.7443e 1	.2030e 1	.1015e 3	.6224e 2	.3329e 4	.6742e 1	.7154e 3	.2241e 3
.4557e 3	.7377e 1	.2050e 1	.6523e 2	.6361e 2	.3340e 4	.6940e 1	.7464e 3	.2298e 3
.4572e 3	.7524e 1	.2050e 1	.9471e 2	.4678e 2	.3674e 4	.7532e 1	.7359e 3	.2265e 3
.4597e 3	.7529e 1	.1990e 1	.6401e 2	.7196e 2	.3162e 4	.5301e 1	.6146e 3	.2179e 3
.4602e 3	.7463e 1	.1950e 1	.6563e 2	.5596e 2	.3066e 4	.5991e 1	.5999e 3	.2165e 3
.4618e 3	.7549e 1	.1950e 1	.6864e 2	.5650e 2	.3179e 4	.6109e 1	.5977e 3	.2150e 3
.4633e 3	.7473e 1	.1940e 1	.7554e 2	.6235e 2	.3123e 4	.5969e 1	.5735e 3	.2153e 3
.4648e 3	.7267e 1	.1930e 1	.8134e 2	.7155e 2	.3161e 4	.6100e 1	.5475e 3	.2147e 3
.4663e 3	.7435e 1	.1930e 1	.1164e 3	.6006e 2	.3359e 4	.6620e 1	.6532e 3	.2142e 3
.4679e 3	.7490e 1	.1970e 1	.8651e 2	.7655e 2	.3261e 4	.6423e 1	.6290e 3	.2168e 3
.4694e 3	.7567e 1	.1960e 1	.8590e 2	.5776e 2	.3175e 4	.6217e 1	.6294e 3	.2259e 3
.4709e 3	.7430e 1	.1970e 1	.6960e 2	.6417e 2	.3171e 4	.6249e 1	.6600e 3	.2257e 3
.4724e 3	.7649e 1	.2000e 1	.7855e 2	.5658e 2	.3320e 4	.6627e 1	.6091e 3	.2229e 3
.4740e 3	.7795e 1	.1980e 1	.6680e 2	.5628e 2	.3179e 4	.6299e 1	.6536e 3	.2280e 3
.4755e 3	.7658e 1	.2000e 1	.6313e 2	.5232e 2	.3121e 4	.6239e 1	.6392e 3	.2190e 3
.4770e 3	.7522e 1	.1970e 1	.5472e 2	.4838e 2	.3151e 4	.6296e 1	.6397e 3	.2064e 3
.4785e 3	.7669e 1	.1990e 1	.5912e 2	.4723e 2	.3152e 4	.6275e 1	.6178e 3	.2326e 3
.4801e 3	.7817e 1	.1930e 1	.5851e 2	.5644e 2	.3160e 4	.6119e 1	.6494e 3	.2219e 3
.4816e 3	.7396e 1	.1980e 1	.8964e 2	.5725e 2	.3351e 4	.6632e 1	.7615e 3	.2287e 3
.4831e 3	.7543e 1	.2050e 1	.4335e 2	.3678e 2	.3271e 4	.6709e 1	.6570e 3	.2320e 3
.4846e 3	.7619e 1	.1980e 1	.6669e 2	.5132e 2	.3175e 4	.6290e 1	.6125e 3	.2194e 3
.4862e 3	.7554e 1	.1940e 1	.9114e 2	.6389e 2	.3119e 4	.6060e 1	.5831e 3	.2103e 3
.4877e 3	.7700e 1	.1920e 1	.1006e 3	.8711e 2	.3212e 4	.6176e 1	.6211e 3	.2048e 3
.4892e 3	.7711e 1	.1930e 1	.8240e 2	.7952e 2	.3263e 4	.6313e 1	.6819e 3	.2064e 3
.4907e 3	.7507e 1	.2000e 1	.9990e 2	.6129e 2	.3131e 4	.6253e 1	.5697e 3	.2096e 3
.4923e 3	.7586e 1	.1920e 1	.6335e 2	.7499e 2	.2985e 4	.5726e 1	.6304e 3	.2289e 3
.4938e 3	.7595e 1	.1970e 1	.9950e 2	.6180e 2	.3099e 4	.6090e 1	.5484e 3	.1862e 3
.4953e 3	.7532e 1	.1930e 1	.9415e 2	.8305e 2	.3124e 4	.6040e 1	.5564e 3	.1984e 3
.4968e 3	.7329e 1	.1910e 1	.9827e 2	.8022e 2	.3106e 4	.5931e 1	.5569e 3	.1999e 3
.4983e 3	.7551e 1	.1920e 1	.9821e 2	.8467e 2	.3102e 4	.5947e 1	.5350e 3	.1909e 3
.4999e 3	.7489e 1	.1930e 1	.9816e 2	.8493e 2	.3006e 4	.5792e 1	.5205e 3	.2066e 3
.5014e 3	.7426e 1	.1910e 1	.1148e 3	.9022e 2	.3135e 4	.5973e 1	.5887e 3	.2045e 3
.5029e 3	.7436e 1	.1930e 1	.1059e 3	.8459e 2	.3324e 4	.6401e 1	.5667e 3	.2097e 3
.5044e 3	.7515e 1	.1900e 1	.1081e 3	.9408e 2	.3370e 4	.6407e 1	.5748e 3	.2130e 3
.5060e 3	.7311e 1	.1920e 1	.1075e 3	.9546e 2	.3443e 4	.6604e 1	.5978e 3	.2057e 3
.5075e 3	.7462e 1	.1930e 1	.1097e 3	.8815e 2	.3341e 4	.6447e 1	.5759e 3	.2214e 3
.5090e 3	.7187e 1	.1920e 1	.1064e 3	.9008e 2	.3095e 4	.5911e 1	.5316e 3	.2229e 3
.5105e 3	.7551e 1	.1900e 1	.9191e 2	.8725e 2	.3175e 4	.6033e 1	.5946e 3	.2121e 3
.5121e 3	.7417e 1	.1930e 1	.1025e 3	.7966e 2	.3314e 4	.6399e 1	.5776e 3	.1995e 3
.5136e 3	.7285e 1	.1920e 1	.1047e 3	.8019e 2	.3289e 4	.6322e 1	.5782e 3	.2099e 3
.5151e 3	.7506e 1	.1940e 1	.9120e 2	.8298e 2	.3192e 4	.6179e 1	.5562e 3	.2150e 3
.5166e 3	.7443e 1	.1890e 1	.9398e 2	.8239e 2	.3069e 4	.5805e 1	.5647e 3	.2271e 3
.5182e 3	.7240e 1	.1900e 1	.1003e 3	.8263e 2	.3248e 4	.6165e 1	.5873e 3	.2119e 3
.5197e 3	.7604e 1	.1910e 1	.9372e 2	.8064e 2	.3116e 4	.5949e 1	.5429e 3	.2196e 3
.5212e 3	.7399e 1	.1880e 1	.9341e 2	.8901e 2	.3058e 4	.5763e 1	.5735e 3	.2141e 3
.5227e 3	.7409e 1	.1910e 1	.9275e 2	.8168e 2	.3202e 4	.6109e 1	.5991e 3	.2280e 3
.5243e 3	.7346e 1	.1920e 1	.9961e 2	.7773e 2	.3398e 4	.6530e 1	.6122e 3	.2154e 3
.5258e 3	.7213e 1	.1940e 1	.9757e 2	.7405e 2	.3239e 4	.6281e 1	.5902e 3	.2187e 3
.5273e 3	.7151e 1	.1910e 1	.9022e 2	.7562e 2	.3191e 4	.6105e 1	.5907e 3	.2273e 3
.5288e 3	.7302e 1	.1930e 1	.7564e 2	.6698e 2	.3158e 4	.6099e 1	.6063e 3	.2466e 3
.5304e 3	.7169e 1	.1940e 1	.7415e 2	.6498e 2	.3177e 4	.6157e 1	.5919e 3	.2411e 3
.5319e 3	.7390e 1	.1920e 1	.9189e 2	.6075e 2	.3135e 4	.6034e 1	.5950e 3	.2390e 3
.5334e 3	.7187e 1	.1920e 1	.8539e 2	.7052e 2	.3159e 4	.6061e 1	.5955e 3	.2406e 3
.5349e 3	.7266e 1	.1920e 1	.8752e 2	.6544e 2	.3224e 4	.6205e 1	.5861e 3	.2368e 3
.5364e 3	.7275e 1	.1940e 1	.7545e 2	.8222e 2	.3112e 4	.6026e 1	.6017e 3	.2225e 3
.5380e 3	.7142e 1	.1890e 1	.9633e 2	.5138e 2	.2719e 4	.5131e 1	.5647e 3	.2382e 3

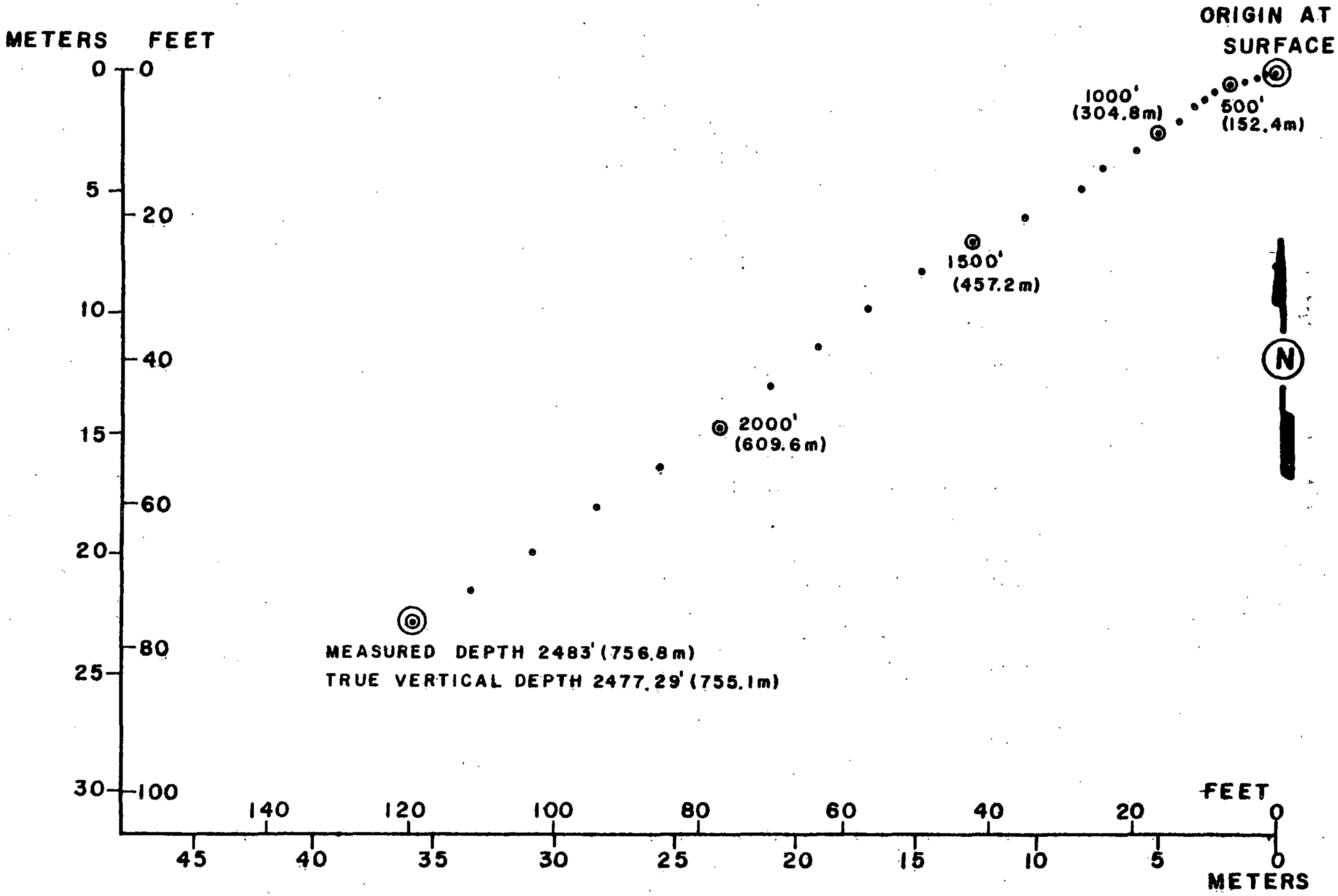


Figure 7.--Plot of Sperry Sun, Inc. hole deviation of drill hole UE25a-1.

Table 7.--Digitized values of geophysical logs from drill hole UE25a-1--Continued

Depth (meters)	Caliper (cm)	Density (Mg/m³)	Resistivity (ohmmeters) 16-in. normal	Resistivity (ohmmeters) 64-in. normal	Velocity (m/s)	Acoustic impedance (10⁶ Rayls)	Neutron log (API units)	
.7102e 3	.7439e 1	.2200e 1	.5057e 2	.6264e 2	.3772e 4	.8285e 1	.8081e 3	.1961e 3
.7117e 3	.7646e 1	.2170e 1	.1580e 3	.2986e 2	.3832e 4	.8312e 1	.9638e 3	.2865e 3
.7132e 3	.7499e 1	.2200e 1	.1362e 3	.1417e 3	.3726e 4	.8183e 1	.9322e 3	.2599e 3
.7148e 3	.7636e 1	.2220e 1	.1199e 3	.8276e 2	.3652e 4	.8109e 1	.9757e 3	.2597e 3
.7163e 3	.7418e 1	.2200e 1	.1176e 3	.8110e 2	.3354e 4	.7376e 1	.9964e 3	.2561e 3
.7178e 3	.7341e 1	.2220e 1	.1152e 3	.8193e 2	.3611e 4	.8008e 1	.1039e 4	.2596e 3
.7193e 3	.7407e 1	.2210e 1	.1240e 3	.8389e 2	.3624e 4	.8006e 1	.1038e 4	.2489e 3
.7209e 3	.7402e 1	.2220e 1	.1273e 3	.9536e 2	.3665e 4	.8153e 1	.1067e 4	.2577e 3
.7224e 3	.7397e 1	.2240e 1	.1388e 3	.9644e 2	.3757e 4	.8423e 1	.1124e 4	.2430e 3
.7239e 3	.7675e 1	.2250e 1	.1336e 3	.1272e 3	.3710e 4	.8331e 1	.1085e 4	.2426e 3
.7254e 3	.7598e 1	.2250e 1	.1313e 3	.1271e 3	.3849e 4	.8650e 1	.1128e 4	.2387e 3
.7269e 3	.7593e 1	.2230e 1	.1345e 3	.1130e 3	.3911e 4	.9718e 1	.1150e 4	.2419e 3
.7285e 3	.7588e 1	.2260e 1	.1211e 3	.8776e 2	.3749e 4	.8473e 1	.1127e 4	.2274e 3
.7300e 3	.7725e 1	.2220e 1	.1271e 3	.7089e 2	.3754e 4	.8340e 1	.1164e 4	.2235e 3
.7315e 3	.7577e 1	.2250e 1	.1248e 3	.5962e 2	.3917e 4	.8821e 1	.1171e 4	.2339e 3
.7330e 3	.7501e 1	.2260e 1	.1280e 3	.6796e 2	.3831e 4	.8676e 1	.1208e 4	.2335e 3
.7346e 3	.7566e 1	.2270e 1	.1284e 3	.6790e 2	.3945e 4	.8944e 1	.1177e 4	.2402e 3
.7361e 3	.7561e 1	.2260e 1	.1289e 3	.6502e 2	.3840e 4	.8663e 1	.1146e 4	.2346e 3
.7376e 3	.7627e 1	.2280e 1	.1237e 3	.6216e 2	---	---	.1191e 4	.2325e 3
.7391e 3	.7621e 1	.2300e 1	.1270e 3	.6438e 2	---	---	.1603e 4	.2463e 3
.7407e 3	.7687e 1	.2340e 1	.1219e 3	.7042e 2	---	---	.1422e 4	.2566e 3
.7422e 3	.7610e 1	.2290e 1	.1223e 3	.1012e 3	---	---	.1159e 4	.2280e 3
.7437e 3	.7463e 1	.2240e 1	.1339e 3	.1123e 3	---	---	.1234e 4	.2489e 3
.7452e 3	.7529e 1	.2290e 1	.1483e 3	.1262e 3	---	---	.1248e 4	.2344e 3
.7468e 3	.7595e 1	.2300e 1	.1497e 3	.1626e 3	---	---	.1278e 4	.2446e 3
.7483e 3	.7592e 1	.2280e 1	.1492e 3	.1541e 3	---	---	.1277e 4	.2516e 3
.7498e 3	.7535e 1	.2290e 1	.1468e 3	.1597e 3	---	---	.1286e 4	.2404e 3
.7513e 3	.7549e 1	.2290e 1	.1306e 3	.1456e 3	---	---	.1239e 4	.2419e 3
.7529e 3	.7634e 1	---	.1338e 3	.1143e 3	---	---	.1200e 4	.2433e 3
.7544e 3	.7507e 1	---	.1315e 3	.1342e 3	---	---	.1260e 4	.2465e 3
.7559e 3	.7591e 1	---	.1236e 3	.1230e 3	---	---	.1214e 4	.2355e 3
.7574e 3	.7322e 1	---	.1240e 3	.1229e 3	---	---	.1026e 4	.2618e 3
.7590e 3	.7194e 1	---	.1129e 3	.1172e 3	---	---	.1085e 4	.2544e 3
.7605e 3	.7279e 1	---	---	---	---	---	.1025e 4	---

The relatively small diameter (4 in. or 10 cm) of the drill hole limits the number of logging tools available through commercial logging companies. Each of the logs shown on plate 1 will be discussed individually in the following sections as to calibration, coverage, operating procedures, and geologic correlations.

Caliper Log

Calipering was done with Birdwell's small-diameter three-arm tool which measures average hole diameter. The tool is calibrated with rings of known diameter before and after logging the drill hole. The interval 960-1,320 feet (292.6-402.3 m) was not logged due to obstructions in the drill hole from hole collapse.

The interval 90-1,320 feet (27.4-292.6 m) exhibits considerable amounts of hole enlargement, and has a CI of greater than 50. Much of the hole enlargement also appears to be associated with fracture zones, fault zones, and associated breccia intervals.

The lower interval from 1,320 to 2,500 feet (402.2 to 762.0 m) is nearly in gage throughout. Again, hole enlargements appear to be associated with fractured intervals, fault zones, and intervals where the CI is greater than 50.

Density Log

Densities were obtained within the interval 1,300-2,500 feet (396.2-762.0 m) with Birdwell's small-diameter decentralized tool. This tool is calibrated before and after logging with aluminum and magnesium blocks. The response of the tool in these blocks is plotted versus equivalent block densities for the particular hole diameter to obtain a calibration curve for converting the log response to density.

The densities from the density log agree within 5 percent with the core densities shown in table 6. The average difference is less than 1 percent. The plot of densities on plate 1 shows a general increase of density with depth. The local variations in density are primarily the result of changes in welding, porosity, and mineralization or alteration at or near lithologic boundaries.

Resistivity Logs

Birdwell did not have a standard resistivity tool small enough to fit into this hole. The resistivity log was obtained by taping lead electrodes on a "pigtail" to conform to spacings of a 16-inch (41-cm) short normal log and a 64-inch (163-cm) long normal log. Because the electric log requires fluid coupling to the formation, the coverage was limited to the interval 1,410-2,490 feet (429.8-759.0 m).

Electric logs record apparent resistivity which is based on geometric factors calculated from the electrode spacings. The short normal reading can be considered true resistivity where it is less than about 100 ohmmeters. Above 100 ohmmeters both spacings give apparent resistivities higher than true resistivity.

The densely welded tuffs generally exhibit resistivities that are higher than those of partially welded or bedded tuffs. The contacts between the tuff units often show a low-resistivity "spike" of 20 ohmmeters, or less, which is characteristic of alteration and argillization of tuff contacts. The low-resistivity spikes often correspond to low-density spikes at the contact, as can be seen at 1,820 and 2,120 feet (555 and 646 m).

Spontaneous Potential Log

Because of fresh formation water and fresh muds used in drilling, the SP (Spontaneous Potential) log has limited usefullness in volcanic rocks at NTS. It is included on plate 1 because it was run as a standard item with the resistivity logs. Some of the formation contacts are apparent as deflections on the SP log (pl. 1). However, the experience at NTS has been that the SP log cannot be relied on to exhibit similar character to SP logs from other drill holes in the same area.

Velocity Logs

Two velocity surveys were made: a 3-dimensional log and a downhole vibroseis geophone survey. The 3-dimensional log is Birdwell's continuous-trace sonic log; arrival times are recorded over 3- and 6-feet (0.9- and 1.8-m) spacings between transmitter and receiver. The first arrivals from both receivers are digitized and velocity is computed from the difference in spacing divided by the difference in time of first arrivals. An advantage of the 3-dimensional log is that the shear-wave velocity can sometimes be determined and used to calculate the dynamic moduli. However, shear waves are not apparent on the logs from this drill hole.

The vibroseis geophone survey was accomplished with a surface vibroseis unit to generate seismic energy, and a clamping geophone to detect the seismic signal downhole at different levels. The average velocity trace on plate 1 is the average velocity from the recording depths to the surface. The interval velocity trace is the interval velocity between recording levels. The velocities (table 8) are computed from the times of arrival of the seismic signal at the geophone and the geophone depths. The geophone spacing is 50 feet (15 m) below 300 feet (396 m) in the drill hole. Above 1,300 feet (396 m) the recording intervals were varied because of drill-hole conditions.

Because of the nature of the vibroseis data, a detailed correlation with other logs and with stratigraphy cannot be made. The data indicate, however, a general increase in interval velocity with depth within a typical range of velocities for tuffs of the types found in this drill hole.

The 3-dimensional velocity log requires fluid for coupling to the formation, which limits the coverage to below the fluid level in the drill hole. The 3-dimensional velocities agree quite well with the vibroseis velocities where there is overlapping data. This indicates that the velocities from the 3-dimensional logs, which sample a smaller volume of material near the borehole wall than does the vibroseis technique, are representative of the bulk of the formation. The 3-dimensional log, however, indicates higher velocities than does the vibroseis technique in the densely welded tuffs.

Table 8.--Inhole vibroseis velocity data from drill hole UE25a-1

Depth (meters)	Average velocity (m/s)	Interval velocity (m/s)
7.6	1137	1137
15.2	1303	1524
22.9	1191	1016
30.5	1205	1249
38.1	1172	1058
45.7	1239	1732
53.3	1304	1905
61.0	1286	1192
86.9	1401	1775
99.1	1407	1451
106.7	1449	2381
114.3	1488	2381
121.9	1505	1814
128.0	1541	2903
133.5	1549	1770
144.8	1584	2169
150.6	1546	965
167.6	1648	3970
182.9	1696	2498
190.5	1718	2458
198.1	1755	3810
396.2	2135	2725
411.5	2159	3048
426.7	2182	3048
442.0	2203	3048
457.2	2224	3048
472.4	2243	3048
487.7	2261	2988
502.9	2268	2540
518.2	2296	3810
533.4	2312	3048
548.6	2328	3048
563.9	2343	3048
579.1	2367	3810
594.4	2380	3048
609.6	2403	3810
640.1	2436	3349
659.9	2464	3962

Acoustic Impedance

The acoustic-impedance log on plate 1 is computed from the density and 3-dimensional velocity-log data. There are no apparent acoustical boundaries in the logged interval which are significant in terms of surface seismic methods.

Neutron Log

The neutron log is run with a thermal-neutron centralized tool. The major change in count rate at 1,400 feet (426.7 m) is at the fluid level in the drill hole. Above 1,400 feet (426.7 m), there is considerable variation in count rate through the faulted and fractured interval labeled F4 on plate 1. Below 1,400 feet (426.7 m), the count rate and character of the curve are suppressed due to the effect of the fluid in the borehole. Since the neutron log responds primarily to formation water content, the increase in count rate through the more densely welded intervals indicates a decrease in water content. This is compatible with a corresponding decrease in porosity, which is indicated by the relatively high densities, resistivities, and velocities in these intervals. The general trend with depth is an increase in count rate that apparently corresponds to a decrease in porosity with depth, which also causes the general increases in density, resistivity, and velocity with depth. Because of the nature of the neutron log, in a dry hole, the interval from 100 to 400 feet (30 to 122 m) responds primarily to hole-size effects, indicated by the caliper log.

Gamma-ray Log

The gamma-ray log is a measure of the level of natural gamma-ray radiation in the formation. All of the volcanic tuffs at NTS exhibit relatively high-level gamma-ray activity, which is comparable to that of sedimentary shales. Because of the high gamma-ray level and a considerable variation in intensity throughout the tuff sequences, the gamma-ray log rarely correlates well with lithology or other logs. The signature on the gamma-ray log at 2,330 feet (710 m), the base of the Prow Pass Member, however, correlates with the electric and SP logs. Gamma-ray logs from future drilling might confirm this as a lithologic indicator.

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