3396

CARR

USGS-OFR86-175

USGS-OFR-86-175

SAI
T&MSS
LIBRARY

USGS-OFR86

HYDROLOGY DOCUMENT NUMBER 337

UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

Geology of drill hole UE25p#1: A test hole into pre-Tertiary rocks near Yucca Mountain, southern Nevada

by

Michael D. Carr
Sandra J. Waddell
Greg S. Vick
Joanne M. Stock
Susan A. Monsen
Anita G. Harris
Byron W. Cork
Frank M. Byers Jr.

Open-file Report 86-175

Prepared in cooperation with the
United States Department of Energy
(Interagency Agreement DE-AI08-78ET44802)

This report is preliminary and has not been edited or reviewed for conformity with United States Geological Survey editorial standards or stratigraphic nomenclature.

Menlo Park, California
1986

 USGS-OF-86-175

UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

Geology of drill hole UE25p#1: A test hole into pre-Tertiary rocks near Yucca Mountain, southern Nevada

by

Michael D. Carr[1]
Sandra J. Waddell[2]
Greg S. Vick[1]
Joanne M. Stock[1]
Susan A. Monsen[1]
Anita G. Harris[1]
Byron W. Cork[2]
Frank M. Byers Jr.[3]

SAI
T&MSS
LIBRAR

1 United States Geological Survey
2 Formerly with Fenix & Scisson, Inc.
3 Los Alamos National Laboratory

CONTENTS

LIST OF ILLUSTRATIONS

LIST OF TABLES

ABSTRACT

Yucca Mountain in southern Nye County, Nevada, has been proposed as a potential site for the underground disposal of high-level nuclear waste. An exploratory drill hole designated UE25p#1 was drilled 3 km east of the proposed repository site to investigate the geology and hydrology of the rocks that underlie the Tertiary volcanic and sedimentary rock sequence forming Yucca Mountain. Silurian dolomite assigned to the Roberts Mountain and Lone Mountain Formations was intersected below the Tertiary section between a depth of approximately 1244 m (4080 ft) and the bottom of the drill hole at 1807 m (5923 ft). These formations are part of an important regional carbonate aquifer in the deep ground-water system.

Tertiary units deeper than 1139 m (3733 ft) in drill hole UE25p#1 are stratigraphically older than any units previously penetrated by drill holes at Yucca Mountain. These units are, in ascending order, the tuff of Yucca Flat(?), an unnamed calcified ash-flow tuff, and a sequence of clastic deposits. The upper part of the Tertiary sequence in drill hole UE25p#1 is similar to that found in other drill holes at Yucca Mountain.

The Tertiary sequence is in fault contact with the Silurian rocks. This fault between Tertiary and Paleozoic rocks may correlate with the Fran Ridge fault, a steeply westward-dipping fault exposed approximately 0.5 km east of the drill hole. Another fault intersects UE25p#1 at 873 m (2863 ft), but its surface trace is concealed beneath the valley west of the Fran Ridge fault. The Paintbrush Canyon fault, the trace of which passes less than 100 m (330 ft) east of the drilling site, intersects drill hole UE25p#1 at a depth of approximately 78 m (255 ft). The drill hole apparently intersected the west flank of a structural high of pre-Tertiary rocks, near the eastern edge of the Crater Flat structural depression.

INTRODUCTION

Yucca Mountain in southern Nye County, Nevada (fig. 1), has been proposed as a site for the underground disposal of high-level nuclear waste. The U.S. Geological Survey is participating in geologic investigations of the Yucca Mountain site under an agreement with the U. S. Department of Energy (Nevada Nuclear Waste Storage Investigations Project).

Yucca Mountain comprises a series of north-trending, eastward-tilted structural blocks that are bounded by westward-dipping Cenozoic faults (figs. 2, 3). The blocks consist of a sequence of Miocene ash-flow tuff, tuff breccia, lava flows, and tuffaceous sedimentary units, which are known to be more than 1830 m (6000 ft) thick from previous drilling at Yucca Mountain. The Tertiary rocks were inferred to be as much as 3400+400 m thick under Crater Flat (fig. 3) to the west of Yucca Mountain by Snyder and Carr (1982) on the basis of their geophysical interpretations; the depth to pre-Tertiary rocks in Crater Flat was estimated as 3200 m (approx. 10,500 ft) on the basis of seismic reflection surveys (H. D. Ackerman, W. D. Mooney, D. B. Snyder, and V. Sutton, USGS, written commun., 1985).

Previous estimates of the lithology and distribution of pre-Tertiary rocks beneath Yucca Mountain all were based on the interpretation of geophysical and surface geologic data (Snyder and Carr, 1982; Bath and Jahren, 1984). The nearest exposures of pre-Tertiary rocks are 15 km or more from the Yucca Mountain site (fig. 1). Consequently, an exploratory drill hole, designated UE25p#1, was drilled to study the geology, hydrology, and geophysical properties of the rocks that make up the pre-Tertiary basement of Yucca Mountain.

SCOPE AND PURPOSE OF THE PROJECT

Pre-Tertiary rocks in the region surrounding Yucca Mountain mainly are: 1) Precambrian crystalline rocks, 2) upper Proterozoic and Paleozoic sedimentary and metasedimentary rocks, and 3) Mesozoic plutonic rocks. Upper Proterozoic and Paleozoic stratified rocks were considered most likely to form the pre-Tertiary basement at the Yucca Mountain site (Snyder and Carr, 1982; Bath and Jahren, 1984), but the possibility that a Mesozoic or Tertiary pluton lies beneath the north end of the site also was discussed by Snyder and Carr (1982) and Carr (1984).

Precambrian crystalline rocks occur in the Death Valley area, 60 km or more southwest of Yucca Mountain (fig. 1), but they are areally less significant in the region than other pre-Tertiary rock types. Rocks similar to the Precambrian crystalline rocks exposed in Death Valley form the stratigraphic basement for younger Precambrian and Paleozoic miogeoclinal strata throughout the region. The crystalline rocks were exposed by erosion where they were uplifted to shallow structural levels by Mesozoic and Cenozoic tectonism. It is unlikely that such rocks occur at the pre-Tertiary surface beneath Yucca Mountain, because structurally shallower upper Proterozoic and Paleozoic miogeoclinal rocks are exposed in nearby uplifted mountain ranges, and Yucca Mountain along with adjacent Crater Flat are situated within a structural depression involving these pre-Tertiary rocks.

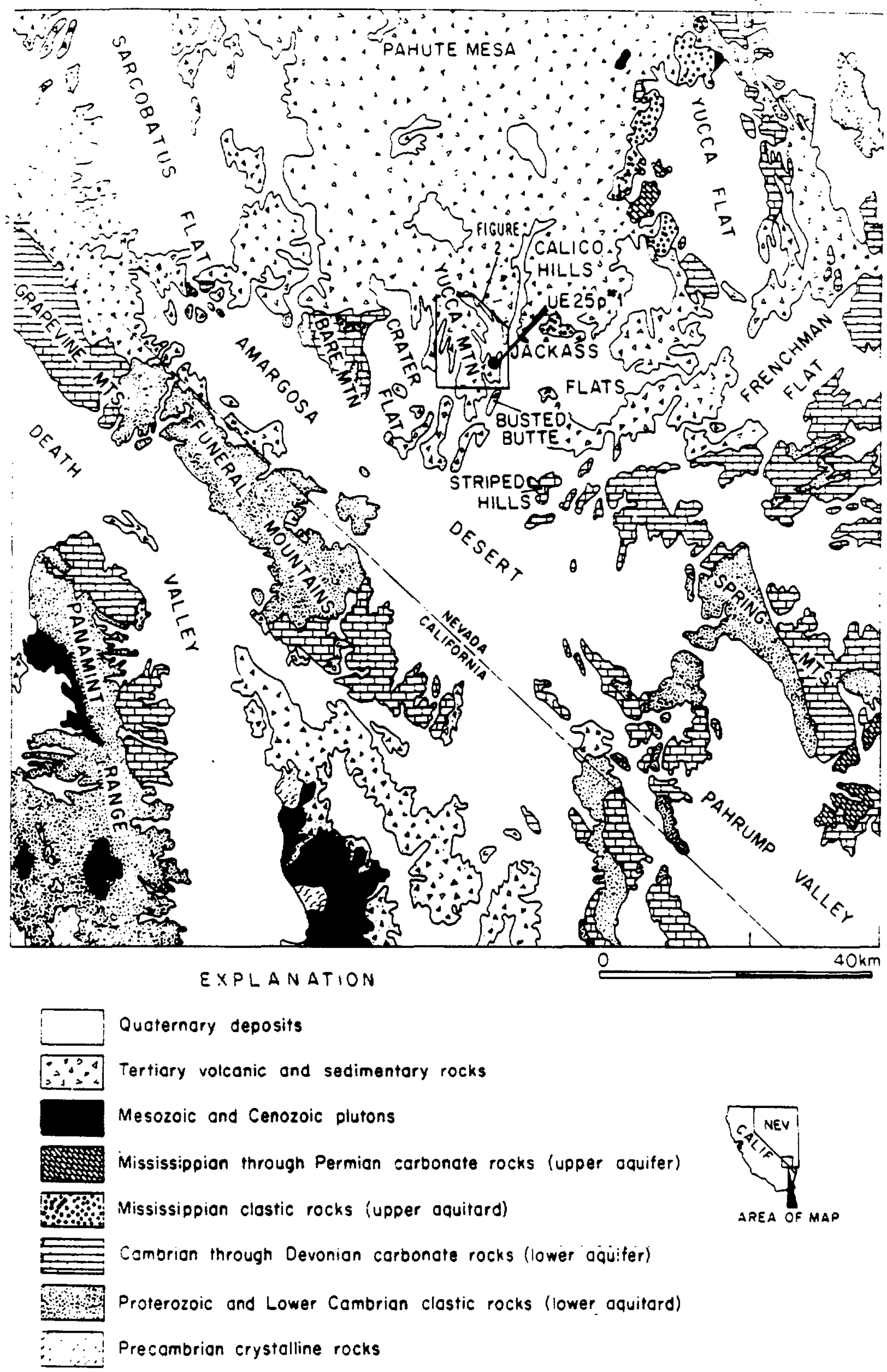


Figure 1. Generalized geologic map showing the major hydrogeologic units of Winograd and Thordarson (1975) in the region surrounding Yucca Mountain.

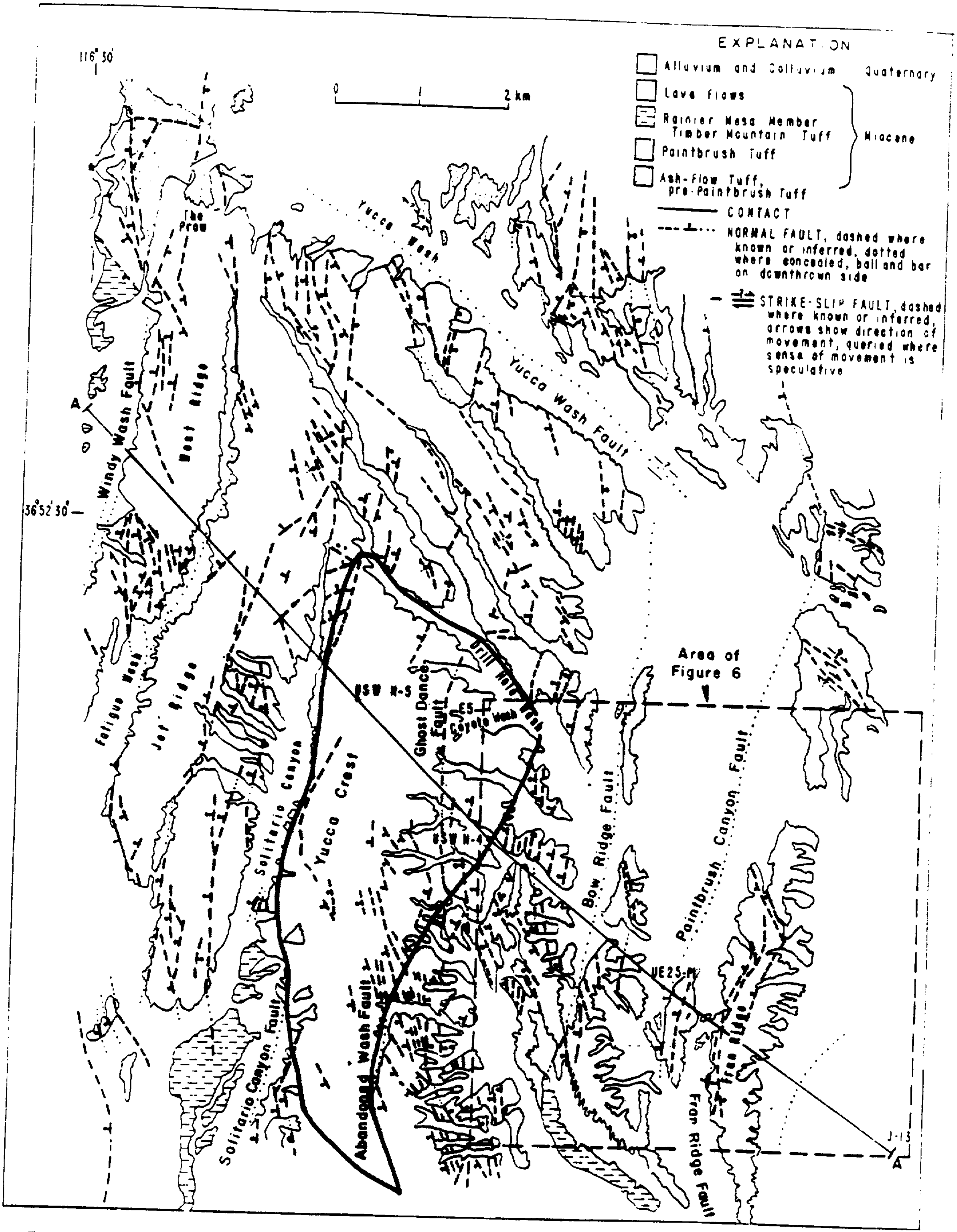


Figure 2. Generalized geologic map of Yucca Mountain. Proposed repository outlined by heavy line. Area of map corresponds to diagonally ruled area on figure 1. Modified after Scott and Castellanos (1984).

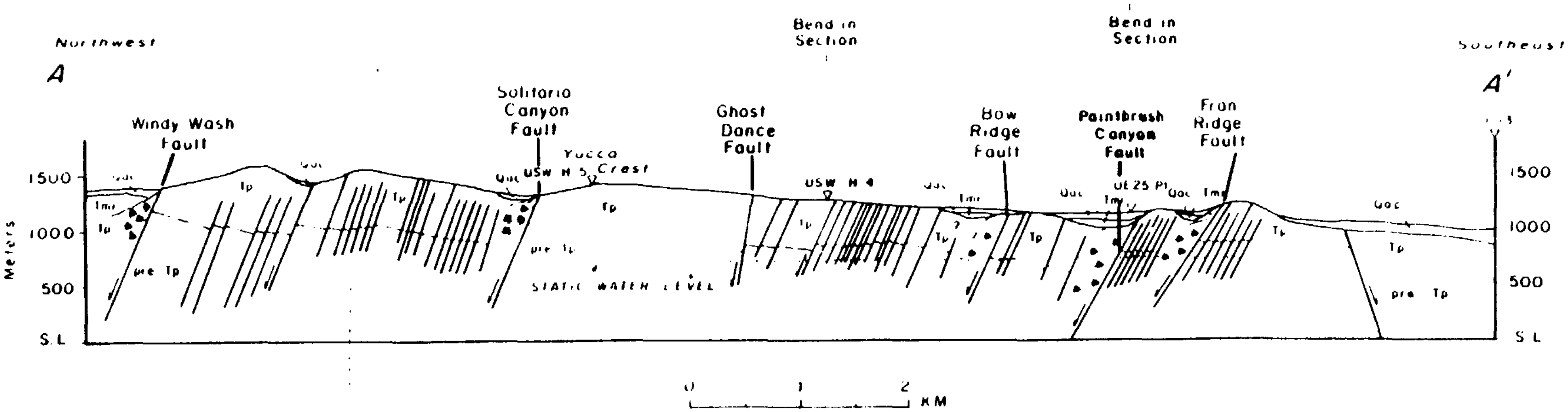


Figure 3. Geologic section across Yucca Mountain generalized from Scott and Bonk (1984) Section line shown on figure 2. Symbols: Qac--Quaternary deposits, Tm--Rainier Mesa Member, Tp--Paintbrush Tuff, pre-Tp--tuff units older than Paintbrush Tuff, S.L.--sea level, triangles indicate breccia zones, dashed lines indicate westward dipping strata in breccia zones.

Upper Proterozoic and Paleozoic strata in the region surrounding Yucca Mountain are part of a westward-thickening wedge of carbonate and terrigenous rocks that make up the Cordilleran miogeocline, a continental-shelf terrane extending the length of western North America. These rocks can be divided into four major lithologic sequences: 1) Upper Proterozoic and Lower Cambrian clastic rocks, 2) Middle Cambrian through Devonian carbonate rocks, 3) uppermost Devonian and Mississippian clastic rocks, and 4) Pennsylvanian and Lower Permian carbonate rocks. These four sequences form the framework for deep ground-water flow in most of the southern Great Basin; the clastic sequences are regional aquitards, and the carbonate sequences are regional aquifers (Winograd and Thordarson, 1975).

The hydrologic flow paths between a nuclear waste repository and the environment potentially accessible to man are one of the fundamental site characteristics that must be understood in order to insure safe waste isolation. It is important, therefore, to determine the lithology, distribution, and hydrology of the pre-Tertiary rocks in the vicinity of Yucca Mountain. The distribution of pre-Tertiary units beneath areas of thick Cenozoic cover, such as Yucca Mountain, is difficult to predict solely by interpreting geophysical and surface geologic information. The upper Precambrian and Paleozoic rocks in the southern Great Basin have been complexly redistributed from their original paleogeography by Mesozoic compressional and Cenozoic extensional tectonism; Mesozoic and Cenozoic plutonism also has modified the distribution of the older rocks. The pre-Cenozoic rocks are covered by thick Cenozoic volcanic and sedimentary sequences throughout much of the region.

Drill hole UE25p#1 was designed to provide direct information about the pre-Tertiary rocks at Yucca Mountain including the following objectives:

1) Determine the lithology, stratigraphy, and structural characteristics of the pre-Tertiary rocks.
2) Determine the depth to the pre-Tertiary surface and obtain physical properties data that will aid in the evaluation of depths to the pre-Tertiary surface elsewhere in the area as estimated on the basis of gravity data.
3) Determine the transmissivities of the saturated Tertiary and pre-Tertiary rocks.
4) Determine the distribution of hydraulic conductivity within the pre-Tertiary section and saturated section of the Tertiary rocks.
5) Determine hydraulic heads of the Tertiary and pre-Tertiary sections and in relatively permeable zones within the saturated Tertiary section.
6) Determine ages and chemical characteristics of groundwater in the Tertiary and pre-Tertiary sections.
7) Obtain data that will aid in the interpretation and accuracy of the geophysical modelling of data from gravity, aeromagnetic, seismic refraction, and seismic reflection surveys in the Yucca Mountain area.
8) Determine the lithology, stratigraphy, hydrologic and physical properties, and structure of units in the lower part of the Tertiary section that have not been penetrated by other drill holes at Yucca Mountain.

Geologic data from drill hole UE25p#1 are covered by this report; hydrologic data were reported by Craig and Johnson (1984) and Craig and Robison (1984) and borehole geophysical data were reported by Muller and Kibler (1984).

GEOLOGIC SETTING AND SELECTION OF THE DRILLING SITE

The general siting strategy for drill hole UE25p#1 was to select a site: (1) where the pre-Tertiary surface was predicted at a relatively shallow depth, optimizing the chance of successfully reaching pre-Tertiary rocks at minimal cost; (2) near enough to the proposed repository that data from the drill hole would be directly applicable to site evaluation but far enough from the site that drilling into pre-Tertiary rocks would not interfere with development of a repository; and (3) where information could be obtained with a single drill hole to test most existing predictions about the lithology and distribution of pre-Tertiary rocks beneath Yucca Mountain.

Previous Geophysical Interpretations

The principal data used to guide drill-site selection were gravity and magnetic surveys. Depths to the pre-Tertiary surface in the vicinity of Yucca Mountain were estimated by Snyder and Carr (1982), on the basis of gravity data, to be from approximately 1 km near Busted Butte (5 km south of the UE25p#1 site; fig. 4) to 3.4 km at the north end of Yucca Mountain and 4 km in Crater Flat. Uncertainty in the density contrasts used for gravity modeling made these estimates reliable only to within about ± 30 percent of the depth.

A positive gravity anomaly near Busted Butte extends northward toward the UE25p#1 site (fig. 4; Snyder and Carr, 1982); another positive anomaly coincides with exposures of Paleozoic rocks in the Calico Hills and connects northeastward with positive anomalies that coincide with other outcrops of Paleozoic rocks. Snyder and Carr (1982) interpreted these combined anomalies as the signature of a largely buried remnant-topographic ridge trending northeastward in the pre-Tertiary surface. They suggested that the ridge could be an eroded escarpment facing caldera depressions known to the northwest and hypothesized to the west. The gravity models preferred by Snyder and Carr suggested as much as 2 km of structural relief in the pre-Tertiary surface between Busted Butte and Crater Flat. They predicted the depth to the pre-Tertiary surface as 1 to 1.2 km at Busted Butte. A drilling site on the positive gravity anomaly north of Busted Butte appeared to provide the shallowest depth to the pre-Tertiary surface near the repository site. (Drill hole UE25p#1 intersected the pre-Tertiary surface at a depth of approximately 1.24 km.)

The lithology of the pre-Tertiary rocks beneath Yucca Mountain also was interpreted primarily on the basis of geophysical evidence. The gravity saddle between the anomaly near Busted Butte and the anomaly centered on the Calico Hills was suggested to represent a structural discontinuity areally coincident with Yucca Wash (Snyder and Carr, 1982). Snyder and Carr could not determine whether the fine-grained clastic rocks of Eleana Formation extended westward from the Calico Hills under the eastern part of Yucca Mountain or lower and middle Paleozoic carbonate rocks occurred south of the inferred structure in Yucca Wash.

The negative gravity anomaly near the center of the site (fig. 4) was interpreted by Snyder and Carr as part of the Crater Flat-Yucca Mountain volcano-tectonic depression, which they envisioned as a complex of sector grabens and caldera depressions filled with an estimated 3000 m of tuff. They could not, however, predict whether the floors of the calderas are underlain by upper Proterozoic and Paleozoic strata or younger intrusive rocks.

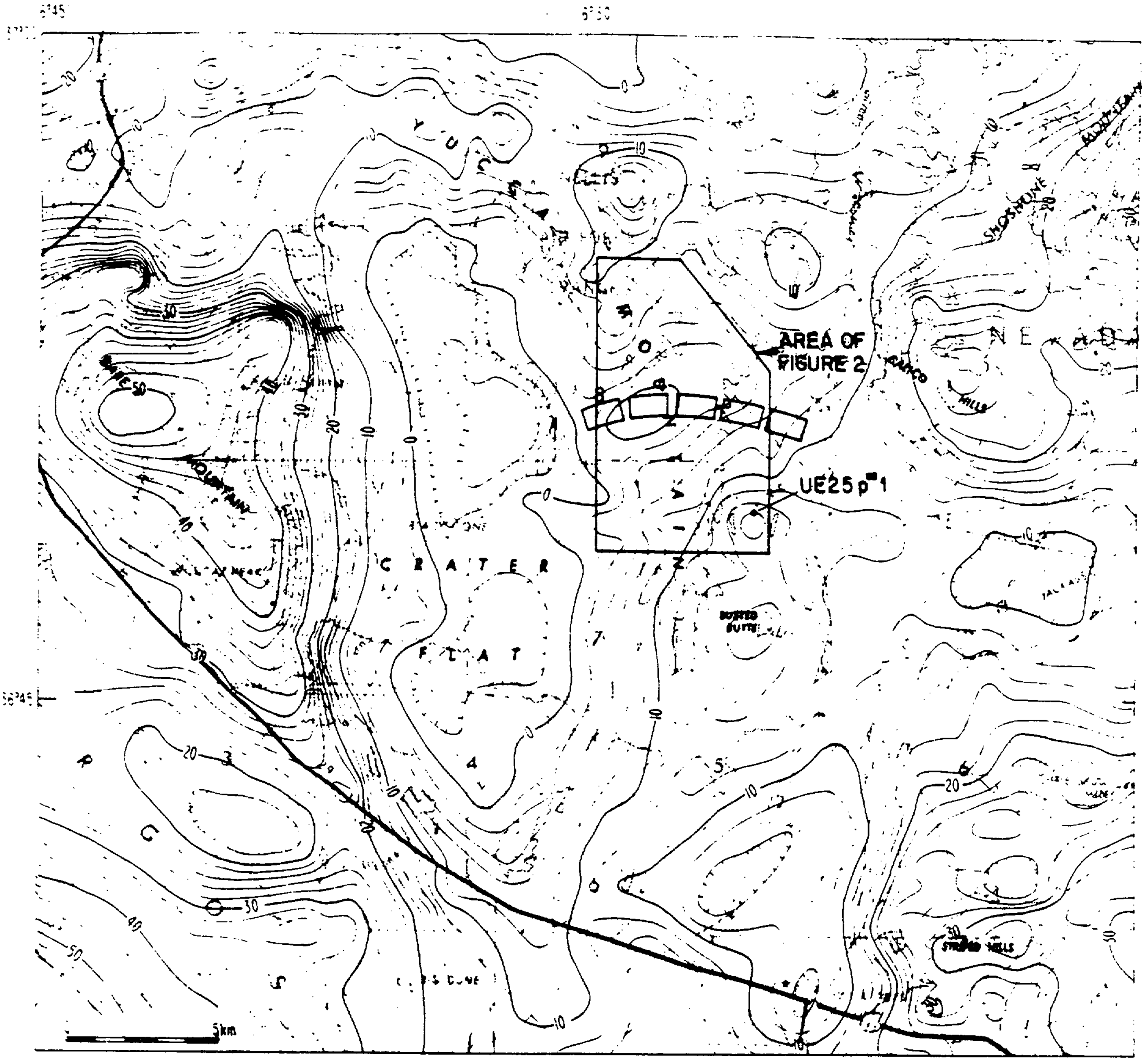


Figure 4. Residual gravity map of Yucca Mountain and vicinity. Contour interval 2 mGal. Reduction density is at 2.0 g/cm^3. Modified from Snyder and Carr (1982) after U.S. Geological Survey (1984). Line of open boxes marks approximate southern limit of buried Eleana Formation inferred from magnetic data by Bath and Jahren (1984).

An intermediate-altitude aeromagnetic survey in the vicinity of Yucca Mountain shows a distinct positive magnetic anomaly trending westward from the Calico Hills across Yucca Mountain (fig. 5). The positive magnetic anomaly near the Calico Hills was attributed to magnetized slightly metamorphosed Eleana Formation, which crops out there (Baldwin and Jahren, 1982). Continuity of the Calico Hills anomaly westward to Yucca Mountain led Bath and Jahren (1984) to suggest the existence of a tabular body of metamorphosed Eleana 2200 to 2400 m below the surface as the source of the anomaly at Yucca Mountain. They hypothesized a deep-seated intrusive body for which there was no direct geophysical evidence as the heat source for the metamorphism.

Geology of the Drill Site

Drill hole UE25p#1 is located near the north end of a cresent-shaped ridge approximately 3 km east of the proposed repository (fig. 6). A previously proposed drilling site located 250 m to the south-southwest was abandoned in order to preserve biological and archaeological resources.

The drilling site is in an area of northerly trending elongate ridges and valleys smaller than those that make up the principal ridges of Yucca Mountain. The Tiva Canyon Member of the Paintbrush Tuff underlies the ridges surrounding the UE25p#1 site, as well as those of Yucca Mountain. The Tiva Canyon primarily is composed of densely welded ash-flow tuff. It is a compound-flow, multiple cooling unit made up of ash flows erupted approximately 12.5 m.y. ago from the Claim Canyon caldera north of Yucca Mountain (Byers and others, 1976). The thickness of the Tiva Canyon Member ranges from 88 to 140 m in measured sections on Yucca Mountain (Scott and others, 1983). The Rainier Mesa Member of the Timber Mountain Tuff, 11.3 m.y. old† (Marvin and others, 1970), crops out in several isolated areas along the west side of the cresent-shaped ridge south of the UE25p#1 site and along the west side of Fran Ridge, the next ridge to the east (fig. 6).

Quaternary surficial deposits fill the narrow valleys near the UE25p#1 site. The drill hole was spudded in a poorly consolidated unit of alluvial, colluvial, eolian, and reworked aeolian deposits (Q2e of Hoover and others, 1981). This unit locally is covered by a thin veneer of Holocene colluvium derived from the adjacent volcanic ridges.

Two westward-dipping faults were considered in siting UE25p#1, the Paintbrush Canyon and Fran Ridge faults (fig. 6). The drill hole was situated near the trace of the Paintbrush Canyon fault in order to intersect that fault zone at a shallow level and case it to prevent further drilling problems. The hole was sited as near as possible to the Fran Ridge fault in an attempt to intersect that fault within the Tertiary volcanic sequence, allowing the possibilty that pre-Tertiary rocks would be intersected in the footwall through a depositional contact. Such a situation would have provided more complete stratigraphic information about the older tuff units in the area.

† 11.6 m.y. corrected for new decay constants (Carr, 1984).

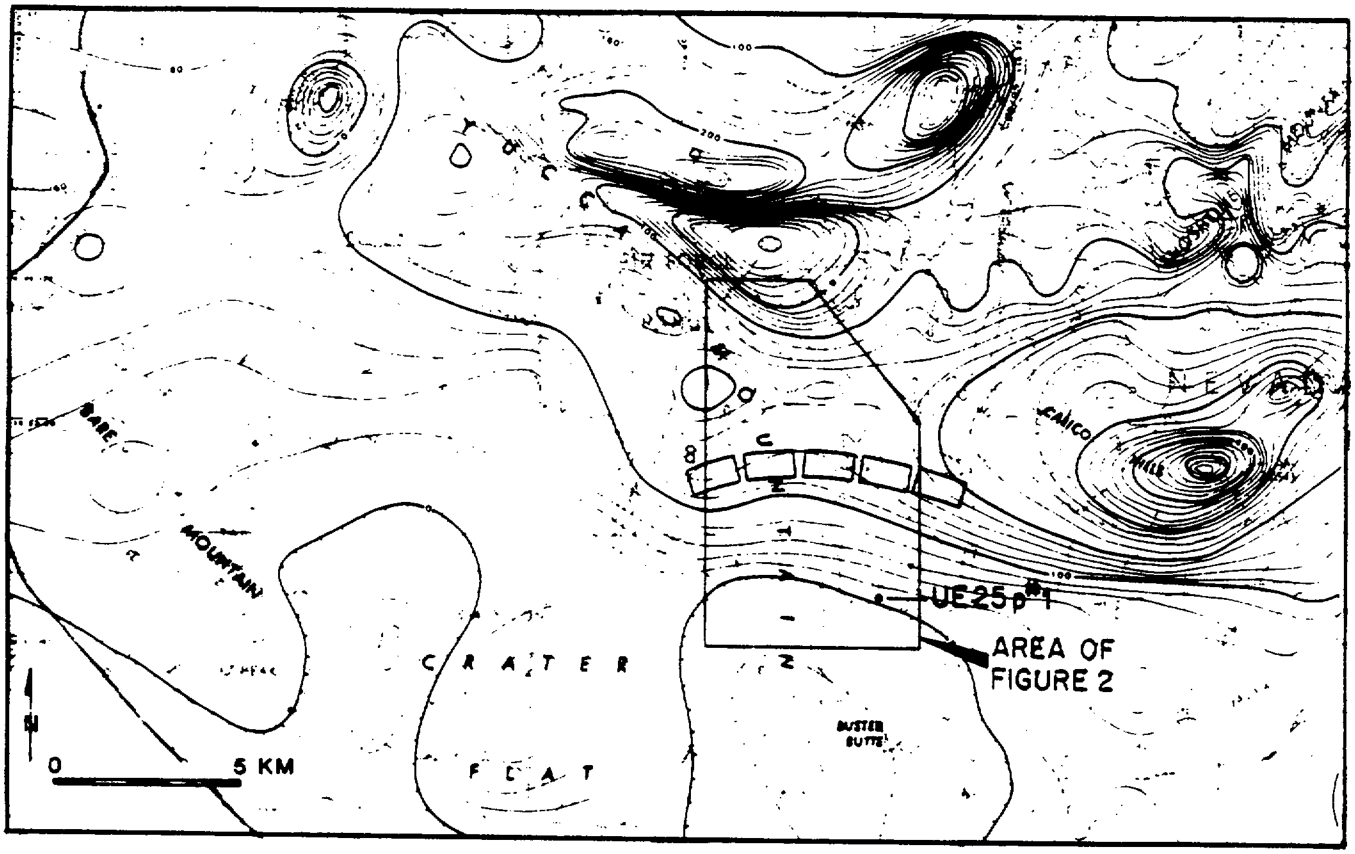


Figure 5. Aeromagnetic map of Yucca Mountain and vicinity. Contour interval 20 gammas. Measurements at 2450 m (8000 ft) above sea level. Compiled by G. D. Bath, U.S. Geological Survey. After U.S. Geological Survey (1984). Line of open boxes marks southern limit of buried Eleana Formation inferred from aeromagnetic data by Bath and Jahren (1984).

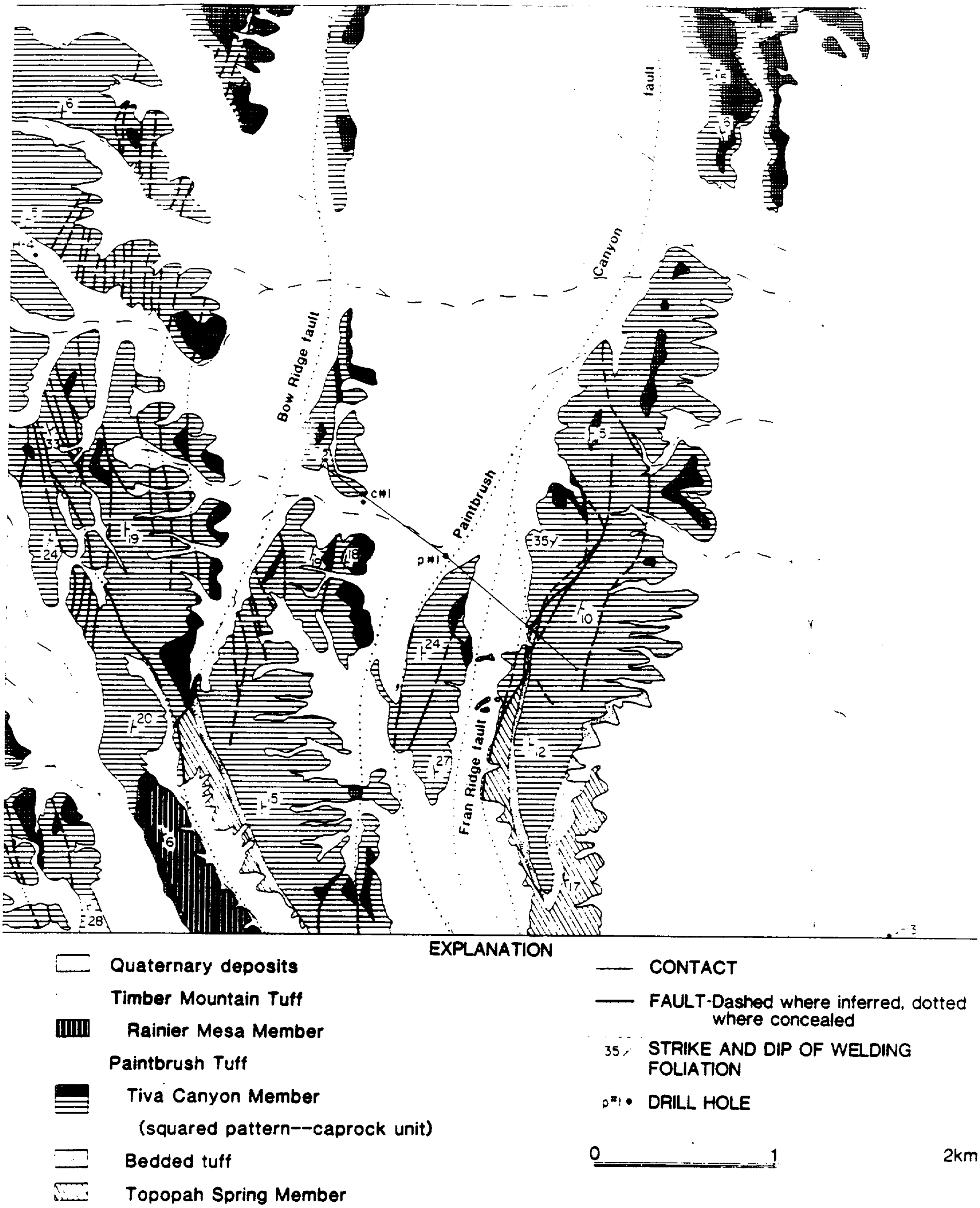


Figure 6. Geologic map of the area surrounding the UE25p#1 drilling site. Generalized after Scott and Bonk (1984). Area of map is located on figure 2.

DRILL HOLE HISTORY

The final site for drill hole UE25p#1 was located in October 1982 by Michael D. Carr of the U.S. Geological Survey. The location was surveyed by Holmes and Narver, Inc. in the Nevada Coordinate System at N. 756,171.20 ft (230,632 m); E. 571,484.52 ft (174,303 m). Ground level at the drill collar is 3654.63 ft (1115 m) above sea level. The drill hole was spudded on November 14, 1982, and reached a total depth of 5923 ft (1807 m) below ground level on May 1, 1983. A complete drill-hole history prepared by the drilling contractor is on file at the Nevada Test Site and is summarized in table 1. Drill hole construction is depicted on figure 7 and drill hole deviation is shown on figure 8. Appendix I summarizes the coring record for the drill hole.

ACKNOWLEDGMENTS

The pre-Tertiary test hole was a complex operation invoking a wide variety of expertise. The authors wish to express their appreciation to the drilling crews of the Reynolds Electrical and Engineering Company. Geologic and hydrologic sampling were monitored on site by geologists of Fenix & Sisson, Inc. Drilling operations were engineered and supervised by the Department of Energy Nevada Operations Office, Fenix & Scisson, Inc., and Reynolds Electrical and Engineering Company. D. B. Broxton of Los Alamos National Laboratory identified the zeolite minerals in the core. Several members of the U.S. Geological Survey participated in on-site monitoring of the scientific aspects of the project at the drilling site. The general drilling location was chosen by Wilfred J. Carr of the U.S. Geological Survey. The manuscript benefited from reviews by R. W. Spengler, E. H. Pampeyan, and W. J. Carr. Spengler also provided valuable advice for interpreting the Tertiary stratigraphy of the drill hole. We thank M. T. Brandon for his help in the statistical analysis of fracture data.

Table 1. Summary of drill hole history for drill hole UE25p#1.

HOLE NO.: UE-25p #1	W. O. NO.: 3404-151 A		I. D. NO.:
USER: USGS	TYPE HOLE: NNWSI Paleozoic Test Hole		
LOCATION: NTS	COUNTY: Nye	AREA: 25	
SURFACE COORDINATES: N 756,171.20' - E 571,484.52'			
GROUND ELEVATION:	PAD ELEVATION:	TOP CASING ELEVATION: 3654.63'	
RIG ON LOCATION: 11-09-82	SPUDDED: 11-13-82	COMPLETED: 05-24-83	
CIRCULATING MEDIA: Air foam - Water - Polymer - Air & Soap			
MAIN RIG & CONTRACTOR: BIR 800, Ideco 525 - REECo		NO. OF COMPRESSORS & CAPACITY: 1/IR-1500 3/Atlas-1200	

BORE HOLE RECORD			CASING RECORD							
FROM	TO	SIZE	I. D.	WT./FT.	WALL	GRADE	CPL'G.	FROM	TO	CU. FT. CMT
0'	42'	30"	23.25"		.375"			0'	36'	465
42'	338'	22"	15.125"	75#				0'	325'	1325
338'	341'	17-1/2"								
341'	1598'	14-3/4"	10.050"	40.50#				0'	1564'	125
1598'	4279'	9-7/8"	6.969"	26.40#				1487'	4256'	
4279'	4322'	6-7/8"								
4322'	5900'	6-3/4"								
5900'	5923'	6-1/8"								

TOTAL DEPTH: 5923' GL	AVERAGE MANDREL DEPTH:	FROM REFERENCE ELEVATION @
JUNK & PLUGS LEFT IN HOLE:		
SURVEYS PAGE:	CORING PAGE:	CU. FT. CMT. TOTAL IN PLUGS, ETC: **
LOGGING DATA: Caliper (14), Magnetometer (2), Density (6), Electric (5), *		
BOTTOM HOLE COORDINATES:		REFERENCE:

RIGS USED (Site Prep Rigs *)

RIG NO.	NAME	TYPE	CLASS	DAYS OPERATING	SECURED W CREW	SECURED W/O CREW	TOTAL DAYS ON LOC.
85132	BIR 800	Ideco 800	II	32.00	.04	4.17	36.21
85124	Ideco 525	525	II	142.93	.20	17.99	161.12

REMARKS: *Fluid density (13), Vibroseis (5), Epithermal neutron (3), 3-D velocity (4), Gamma ray (2), Temperature (7), Acoustic, Frac (4), Neutron (3), Spectrum (3), NCTL (5), Collar locator (6), NAIL (2), Spinner

** Hole plugged in 2 stages from 3947' to 3915' w./ 115 ft^3, 01-22-83, then redrilled.

Note: 1 ft = .305 m

UE25p1 7-5/8" O.D., 26.40#/ft. LINER

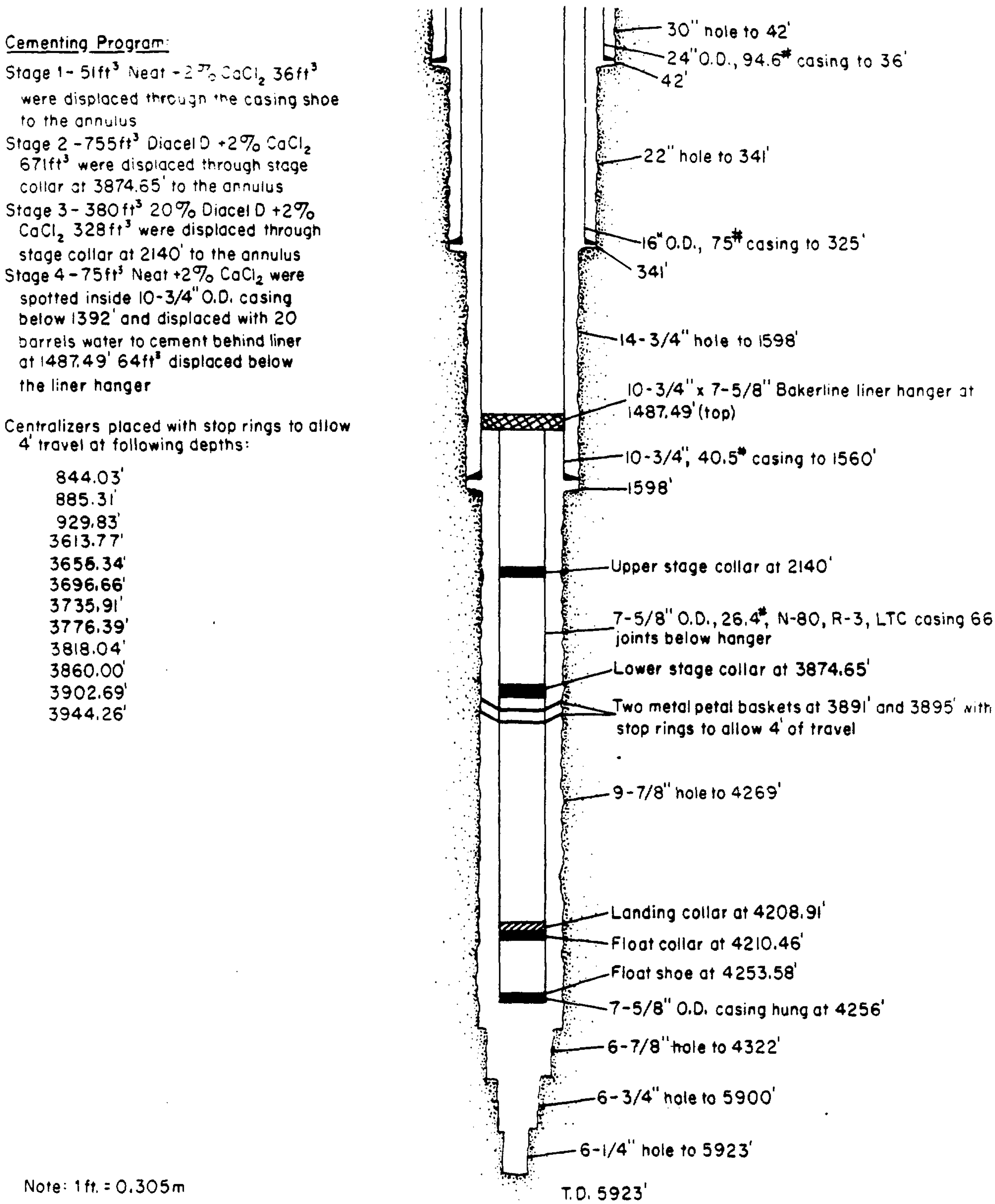


Figure 7. Schematic diagram showing the construction of drill hole UE25p#1.

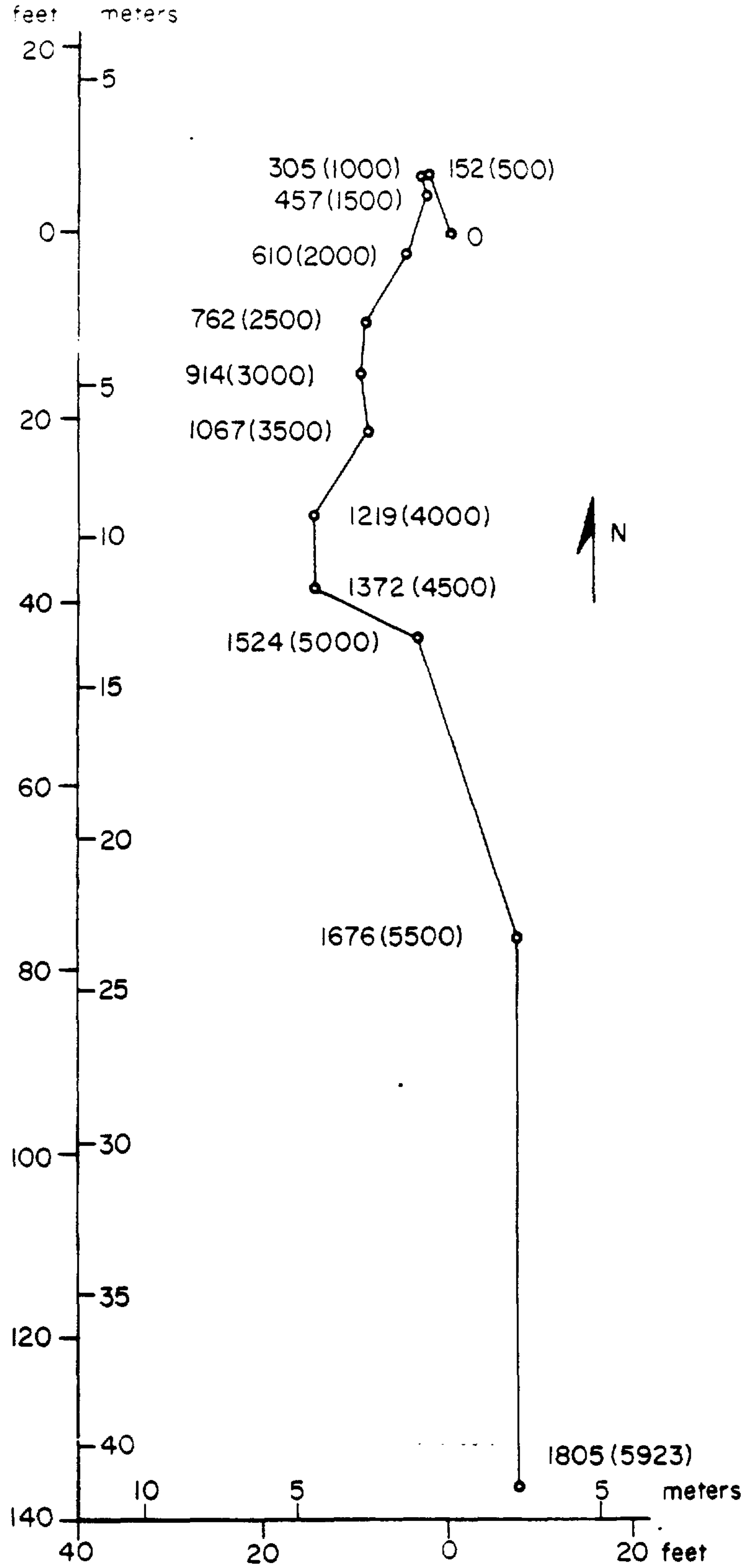


Figure 8. Horizontal projection of drill hole deviation in drill hole UE25p#1 derived from East Whipstock Gyroscopic Survey. Depths shown along drill hole trace are drilled depths in meters (feet). True vertical depth at 1676 m (5500 ft) is 1675 m (5498 ft) and at 1805 m (5923 ft) is 1803 (5917 ft). All other drilled depths are approximately equal to actual vertical depth.

PRE-CENOZOIC STRATIGRAPHY AND CORRELATION WITH A SILURIAN SECTION AT BARE MOUNTAIN

Drill hole UE25p#1 intersected pre-Tertiary rocks at approximately 1244 m (4080 ft) (pl. 1). The contact is interpreted as a fault. Approximately 563 m (1843 ft) of Paleozoic dolomite were penetrated; 213 m (700 ft) were cored and the remainder was drilled (table, 2; Appendix II). All of the dolomite is Late Silurian (most is middle Ludlovian and Pridolian) on the basis of conodont faunas (Appendix III). The rocks are lithologically and biostratigraphically similar to the Roberts Mountain Formation (Merriam, 1940) and Lone Mountain Dolomite (Merriam, 1940; Nolan and others, 1956) as described at Bare Mountain by Cornwall and Kleinhampl (1961).

ROBERTS MOUNTAIN FORMATION

The Roberts Mountain Formation was intersected between approximately 1668 m (5470 ft) and the bottom of the drill hole at 1807 m (5923 ft). The interval was cored from 1798 to 1807 m (5900 to 5923 ft); the remainder of the Roberts Mountain was drilled and bit cuttings were sampled.

The Roberts Mountain consists of dark gray to black, very finely crystalline dolomite. The unit is well bedded in core and appears in television camera logs to be well bedded throughout much of the drilled interval. Dark- and light-colored layers as much as a few centimeters thick appear on television camera logs in some intervals and are presumed to be chert layers. Dolomite beds appear on camera logs generally to be less than 0.3 m thick and are separated by chert layers, several centimeters thick. The dolomite beds contain parallel laminations in core samples. A 1-cm-thick layer of black chert separating dolomite layers at 1800 m (5904 ft) in the core is the only chert layer sampled in the drill hole. Poorly preserved fossil debris occurs in much of the cored interval.

The upper contact of the Roberts Mountain Formation with the Lone Mountain Dolomite is gradational. Bedding appears less distinct and brecciation is more common and more strongly developed in the upper part of the Roberts Mountain where observed on television camera logs. The upper contact of the Roberts Mountain is placed at approximately 1668 m (5470 ft), primarily on the basis of a change from dark-gray and grayish-black to light- and medium-gray dolomite. Gradational changes occur in the signature of some of the geophysical logs (e.g., slight upward decrease in density and increase in porosity) between approximately 1652 and 1687 m (5420 and 5535 ft). The true thickness of the Roberts Mountain Formation penetrated in the drill hole is estimated as 95 m (310 ft), on the basis of an average dip of approximately 40° northward determined from acoustic borehole televiewer logs for the interval from 1471 to 1474 m (4825 to 4835 ft) and accounting for drill hole deviation.

Thin sections of dolomite from the Roberts Mountain near the base of the drill hole are described in Appendix IV. In general, the cored interval consists of dolomicrite containing sparse allochems, which include fossil debris and pelletoids. Pelletoids only occur locally and are as much as 1 mm in diameter. Sparse quartz grains are scattered locally throughout the matrix. The groundmass consists of cloudy and clotted dolomicrite. Fine parallel lamination is preserved. Stylolites which occur parallel to layering vary in

Table 2. Major stratigraphic units and contacts in drill hole UE25p#1.

Unit	Depth of Interval meters (feet)	Thickness of Interval meters (feet)
Alluvium..................................	0-39 (0-128)	39 (128)
---------- unconformity ----------		
Timber Mountain Tuff		
Rainier Mesa Member......................	39-52 (128-170)	13 (42)
--------- unconformity ----------		
Paintbrush Tuff		
Bedded tuff..............................	52-55 (170-180)	3 (10)
Tiva Canyon Member......................	55-78 (180-255)	23 (75)
------------- fault -------------		
Topopah Spring Member....................	81-381 (267-1250)	300 (983)
Rhyolite of Calico Hills..................	381-436 (1250-1430)	55 (180)
Crater Flat Tuff		
Prow Pass Member........................	436-547 (1430-1792)	111 (362)
Bedded tuff.............................	547-558 (1792-1830)	11 (38)
Bullfrog Member.........................	558-683 (1830-2240)	125 (410)
Bedded tuff.............................	683-691 (2240-2265)	8 (25)
Tram Member.............................	691-873 (2265-2863)	182 (598)
------------- fault -------------		
Lithic Ridge Tuff........................	873-1064 (2863-3488)	191 (625)
Bedded tuff...............................	1064-1068 (3488-3502)	4 (14)
Older tuffs of drill hole USW G-1		
Unit A.................................	1068-1101 (3502-3610)	33 (108)
Unit C.................................	1101-1139 (3610-3733)	38 (123)
Sedimentary deposits.....................	1139-1172 (3733-3844)	33 (111)
Calcified tuff.........................	1172-1205 (3844-3950)	33 (106)
Tuff of Yucca Flat(?)..................	1205-1244 (3950-4080)	39 (130)
------------- fault -------------		
Lone Mountain Dolomite..................	1244-1668 (4080-5470)	424 (1390)
Roberts Mountain Formation...............	1668-1807 (5470-5923)	139 (453)

their abundance from sparse to common. Irregularly oriented calcite veinlets are common in some intervals and appear to be truncated by the stylolites.

Roberts Mountain Formation at Bare Mountain

A stratigraphic section of the Roberts Mountain Formation was measured at Bare Mountain, 15 km to the west of drill hole UE25p#1 (figs. 9 and 10), to provide a basis for interpreting stratigraphic information from the drill hole. The Roberts Mountain Formation at Bare Mountain was informally subdivided into three units by Cornwall and Kleinhampl (1961): (1) a lower unit, approximately 46 m (150 ft) thick, consisting of interstratified dark- and light-gray limestone and limy dolomite with intercalated chert layers locally; (2) a middle unit, approximately 122 m (400 ft) thick, consisting of medium to dark gray limestone and limy dolomite; and (3) an upper unit, approximately 61 m (200 ft), consisting of medium gray limy dolomite that grades upward into light gray partially recrystallized dolomite.

Cornwall and Kleinhampl (1961) defined the base of the Roberts Mountain as the base of a relatively persistent cherty medium-gray dolomite that weathers light gray in contrast to their darker-gray and more cherty Ely Springs Dolomite below. They also noted a 1-m (3-ft) thick limestone conglomerate bed that occurs discontinuously at the base of their middle unit of the Roberts Mountain. Our conodont studies in the Ely Springs Dolomite and Roberts Mountain Formation at Bare Mountain show that the lower 46 m (150 ft) of the Roberts Mountain as used by Cornwall and Kleinhampl (1961) contains Upper Ordovician (Richmondian and middle Maysvillian) faunas, and uppermost Lower to lowermost Middle Silurian conodonts occur less than 2 m (5 ft) above the base of the limestone conglomerate bed at the base of the middle unit of Cornwall and Kleinhampl (1961) (Appendix III, fig. 10). We, therefore, place the base of the Roberts Mountain Formation at the base of the conglomerate bed, and include the lower unit of the Roberts Mountain as used by Cornwall and Kleinhampl with the Ely Springs Dolomite. The base of the Roberts Mountain Formation at Bare Mountain is a disconformity.

Age and Correlation

The Roberts Mountain Formation in drill hole UE25p#1 is restricted to the Late Silurian on the basis of its conodont faunas and conodonts from the overlying Lone Mountain Dolomite. A fauna from core between 1802 and 1803 m (5911 to 5914 ft; USGS collection 10776-SD) restricts the base of the drill hole to no older than the CRASSA and probably no younger than the SILURICUS Zones in the Ludlovian Stage (early Late Silurian) (Appendix III, fig. 10). The base of the Roberts Mountain at its type locality and at most other places begins in the Llandovery (Mullens, 1980). In the section measured at Bare Mountain, the base of the Roberts Mountain was restricted to the latest Llandovery or earliest Wenlockian (fig. 10). Comparison with the section at Bare Mountain indicates that the bottom of drill hole UE25p#1 is in an interval 30 to 100 m (100 to 300 ft) above the base of the Roberts Mountain in the measured section at Bare Mountain. No conodonts were recovered from the upper part of the Roberts Mountain in drill hole UE25p#1; the age of the upper Roberts Mountain in the drill hole is only restricted by the presence of Late Silurian conodonts in the overlying Lone Mountain Dolomite.

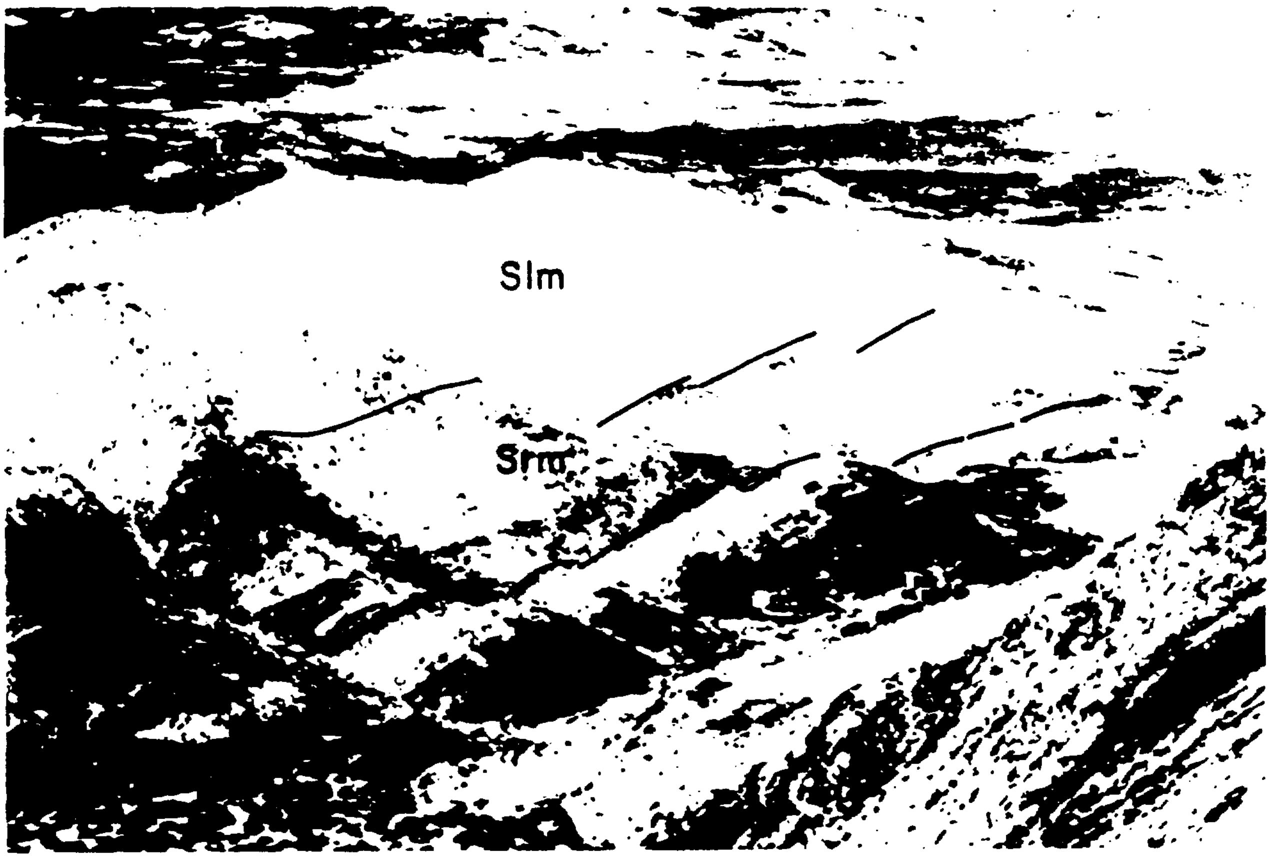


Figure 9. Stratigraphic section in Chuckwalla Canyon at Bare Mountain. View to the northeast showing Ordovician Ely Springs Dolomite (Oes), Silurian Roberts Mountain Formation (Srm), and Silurian Lone Mountain Dolomite (Slm). Silurian section at Bare Mountain is similar to that in drill hole UE25p#1.

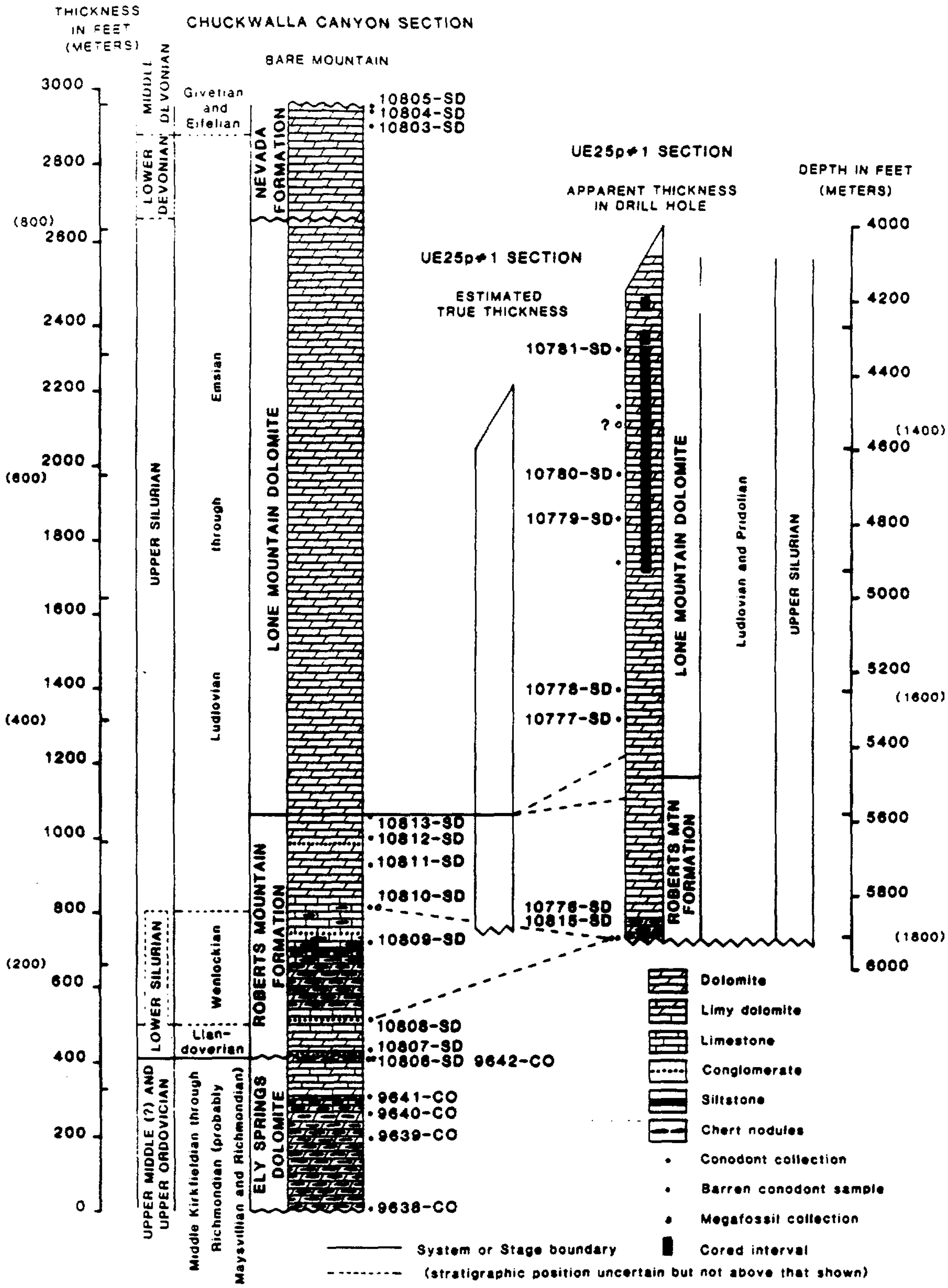


Figure 10. Stratigraphic correlation between Silurian rocks in drill hole UE25p#1 and the Silurian section in Chuckwalla Canyon at Bare Mountain.

Rocks lithologically equivalent to the Roberts Mountain Formation do not crop out east of drill hole UE25p#1. The Roberts Mountain in the drill hole corresponds in age with unit C and possibly parts of units A and D of the dolomite of the Spotted Range as mapped by Poole (1965) (fig. 11).

LONE MOUNTAIN DOLOMITE

The Lone Mountain Dolomite was intersected between approximately 1244 and 1668 m (4080 and 5470 ft). The formation was cored from 1276 to 1285 m (4185 to 4215 ft), 1302 to 1313 m (4273 to 4308 ft), and 1316 to 1501 m (4318 to 4924 ft); the remainder of the formation was drilled and bit cuttings were sampled.

The Lone Mountain predominantly consists of very light gray to medium-gray, fine- to medium-grained crystalline dolomite. Most of the formation is indistinctly bedded or nonbedded in core, and no distinct beds are visible on television camera logs. Most of the rock is massive, but sparse laminated intervals, intervals of pelletoidal dolomite, and intervals of possible sedimentary breccia, occur locally. Poorly preserved fossil debris (pelmatozoan?) occurs in some intervals. Much of the cored dolomite is tectonically brecciated, obliterating original sedimentary structure. Fine-grained, white to very light gray secondary dolomite commonly forms the matrix for brecciated intervals. Zones of intense brecciation commonly occur adjacent to fractures. Anastomosing veinlets of calcite and dolomite are common locally. Stylolites are well developed in some intervals; they typically dip gently and commonly truncate fractures, indicating that the stylolites formed after the fractures they cut.

An interval containing bands of medium-to dark-gray dolomite as much as 2 m thick occurs between 1415 and 1475 m (4642 and 4840 ft). Both above and below this interval, the dolomite is a more uniform lighter gray. The basal contact of the Lone Mountain Dolomite is gradational, the upper contact is a fault.

Indistinct bedding(?), which is oriented N.10°E., 35°NW., occurs in oriented core from approximately 1436 m (4710 ft). The true thickness of the Lone Mountain Dolomite in drill hole UE25p#1, calculated on the basis of a dip of 35° to 40° northward (determined from acoustic borehole televiewer logs) and accounting for drill-hole deviations, is approximately 326 m (1070 ft). The lower interval of uniform light-gray dolomite is 152 m (500 ft), the darker gray banded interval is 46 m (150 ft), and the upper light gray interval is 128 m (420 ft).

Age and Correlation

The Lone Mountain Dolomite in drill hole UE25p#1 is restricted to the late Silurian (middle Ludlovian through Pridolian) on the basis of two conodont faunas from the upper part of the cored interval and conodonts from the underlying Roberts Mountain Formation (fig. 10). OZARKODINA CONFLUENS (Branson and Mehl), which is restricted to the Ludlovian and Pridolian stages, occurs in two samples from 177 m (586 ft) and approximately 75 m (245 ft) below the top of the Lone Mountain in the drill hole. Ludlovian conodonts (restricted to CRASSA through SILURICUS zones) occur in the Roberts Mountain Formation approximately 122 m (400 ft) below the inferred base of the Lone Mountain Dolomite in the drill hole.

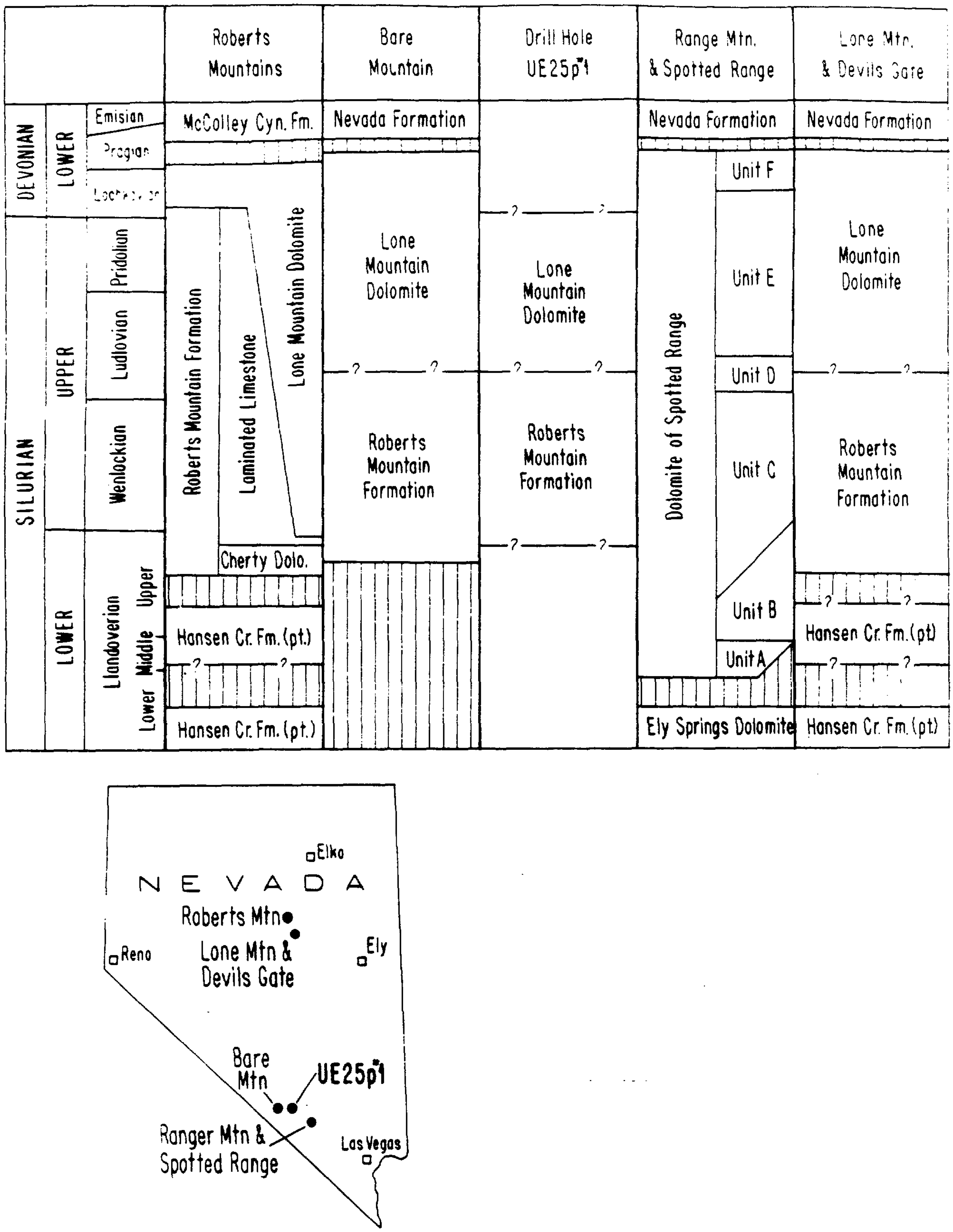


Figure 11. Correlation of Silurian units from drill hole UE25p#1 with Silurian sections in the surrounding region. Stratigraphy from the Roberts Mountains, Ranger Mountains--Spotted Range, and Lone Mountain--Devils Gate are from Poole and others (1977).

The lithology of Lone Mountain in the drill hole is similar to that of the Lone Mountain Dolomite exposed at Bare Mountain. Cornwall and Kleinhampl (1961) subdivided the formation at Bare Mountain into three informal units. Their lower unit, 60 to 90 m (200 to 300 ft) thick, consists of pitted light-gray, fine- to medium-grained dolomite, which becomes coarser upward in the section; it is indistinctly stratified, massive, and contains pelmatozoan debris. The middle unit, approximately 152 m (500 ft) thick, is a blotchy light- and dark-gray dolomite, mostly fine- to medium-grained with several sandy layers near the top. This unit also is poorly stratified and massive. It forms a distinctive dark-gray band on hillslopes comprised of Lone Mountain Dolomite. The upper unit, 245 m (800 ft) thick, consists of light-gray, non-stratified to faintly stratified, medium-grained, massive dolomite. The distinct interval of banded medium- and dark-gray dolomite recognized from approximately 1415 to 1475 m (4640 to 4840 ft) in core from UE25p#1 may correlate with part of the middle unit of the Lone Mountain as described by Cornwall and Kleinhampl (1961). The interval of uniformly lighter gray dolomite below the banded core interval would then correlate with the lower unit of Cornwall and Kleinhampl.

The Lone Mountain Dolomite in the drill hole also is lithologically similar to the dolomite of the Spotted Range (Poole, 1965) exposed in the Ranger Mountains and Spotted Range, 50 km to the east. The Lone Mountain in drill hole UE25p#1 corresponds in age with unit D and (or) the lower part of unit E of the dolomite of the Spotted Range (fig. 11; Poole and others, 1977).

NATURE OF THE PRE-TERTIARY SURFACE

The base of the Tertiary sequence is no deeper than 1244 m (4080 ft) on the basis of our interpretation of drill bit cuttings and geophysical logs. Tertiary volcanic rocks last appeared in drill-bit cuttings from the interval 1240 to 1244 m (4070 to 4080 ft). Cuttings and core below 1244 m (4080 ft) were dolomite. Logged density values stabilized between approximately 2.7 and 2.8 g/cm^3 beginning at 1244 m (4080 ft), remaining in that density range for the remainder of the drill hole (Muller and Kibler, 1984). Another interval of relatively high density (2.7 to 2.8 g/cm^3) occurs from approximately 1227 to 1231 m (4025 to 4040 ft), and may indicate the presence of carbonate rock higher in the drill hole than indicated by drill bit cuttings. The interval of lower density separating the upper high-density interval from the one beginning at 4080 ft might then represent a zone of sheared carbonate rock in a fault zone. Alternatively, the upper high density zone could represent a block of carbonate rock within the lower density Tertiary section or a Tertiary sedimentary unit rich in clasts of Paleozoic carbonate rock. We favor the interpretation that the Tertiary-Paleozoic contact is at 1244 m (4080 ft).

Several lines of negative evidence suggest that the contact between Tertiary and Paleozoic rocks is a fault. There is no evidence of any strongly weathered sedimentary rock, such as a talus or slope-wash deposit, between the last occurrence of ash-flow tuff and the first occurrence of dolomite in the drill hole. Such deposits commonly occur at the top of the Paleozoic rocks in drill holes in Yucca Flat and are considered to be evidence for unconformable sedimentary contacts. That Paleozoic rocks were exposed locally during the eruption of the older tuffs present in drill hole UE25p#1 is demonstrated by the presence of carbonate rock as clasts in conglomerate within the Tertiary section between 1139 and 1172 m (3733 and 3844 ft). The oldest ash-flow tuff unit in the drill hole, the tuff of Yucca Flat(?) (Carr and others, in press), is moderately welded throughout. The absence of partially to nonwelded material at the base of the unit suggests that the lower part of the cooling unit is missing. Moreover, nowhere else in southern Nevada is the tuff of Yucca Flat known to rest depositionally on pre-Cenozoic rocks; commonly a few hundred feet of volcanic or clastic sedimentary rocks separate the tuff of Yucca Flat from underlying pre-Cenozoic rocks.

There is no direct evidence to indicate the attitude of the fault interpreted at the Tertiary-Paleozoic contact. The contact occurs, however, at the approximate depth at which the projection of the Fran Ridge fault should intersect the drill hole if that fault is planar and dipping approximately 60° westward, as it is in surface exposures (fig. 12). Such a fault geometry is consistent with the characteristics of the large block-bounding faults at Yucca Mountain, however, other fault geometries also are permissible given such limited constraining data.

The unusual alteration of calcified ash-flow tuff between 1172 and 1204 m (3844 and 3950 ft) (Appendix II) may be further indirect evidence for a fault at the pre-Tertiary surface. The most likely source for the calcium carbonate-charged fluids that altered these tuffs is the Paleozoic carbonate sequence. Upward movement of calcium carbonate-rich solutions along a fault zone and into the partially welded ash-flow is a likely cause of alteration. (See Cenozoic Stratigraphy.)

Although the contact between Tertiary and Paleozoic rocks where intersected by the drill hole is interpreted as a fault, this contact is probably an angular unconformity under much of the Yucca Mountain area. As noted above, the presence of clasts of carbonate rock in sedimentary deposits interlayered with the older tuff sequence in the drill hole indicates that Paleozoic rocks were exposed locally during the deposition of the ash-flow tuffs. This relationship supports the interpretation of the gravity high along the east side of Yucca Mountain as a buried pre-Tertiary topographic high (Snyder and Carr, 1982). Parts of this ridge may have been exposed at least until the eruption of unit C of the older ash-flow tuffs of drill hole USW-G1 (Spengler and others, 1981), providing the source for carbonate clasts in the sedimentary strata below unit C.

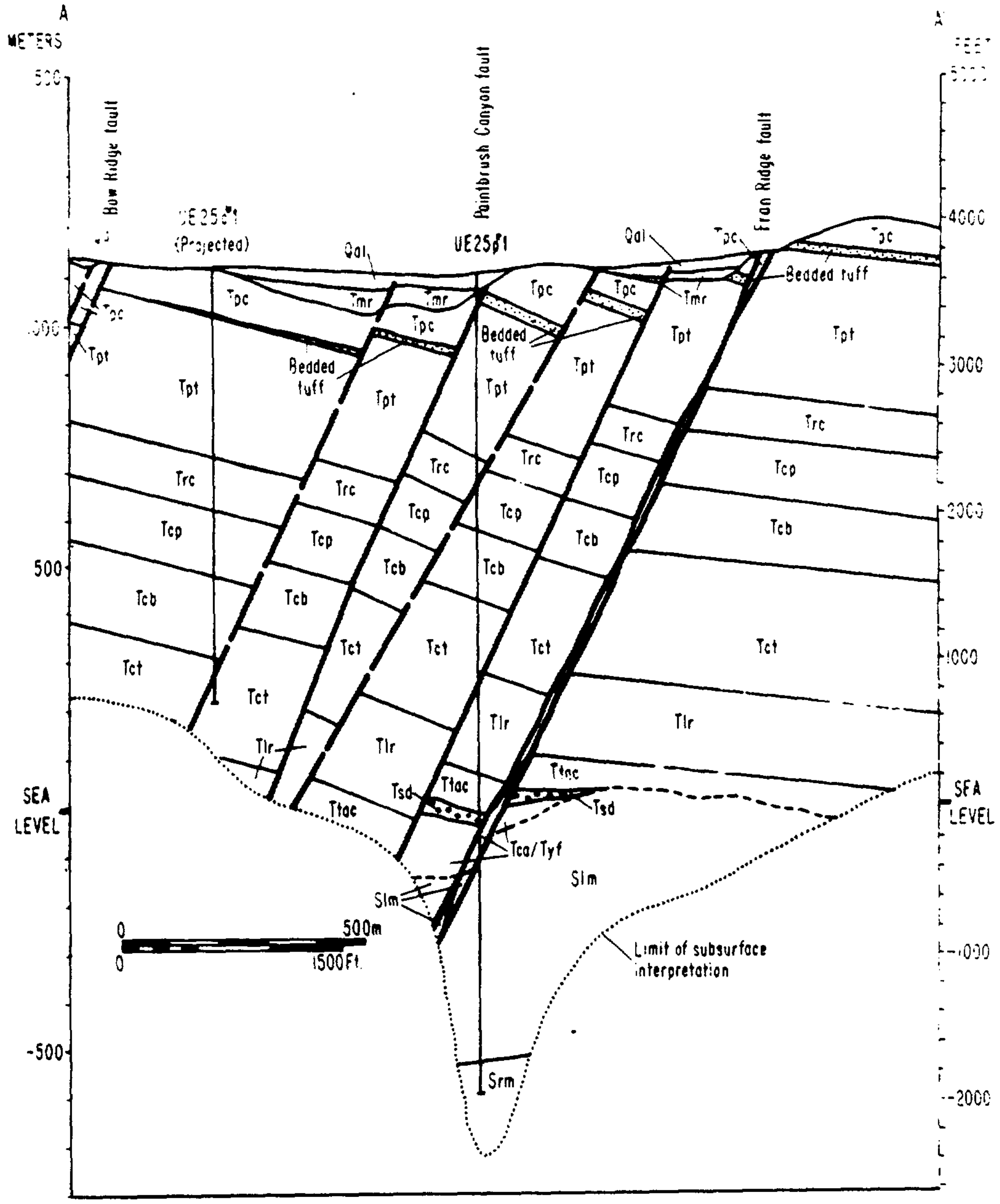


Figure 12. Interpretive geologic section in the vicinity of drill hole UE25p#1. Unit thicknesses not controlled by drill hole UE25p#1 were interpolated from thicknesses in UE25c#1 (R. W. Spengler, USGS, written commun., 1984) and well J-13 (Byers and Warren, 1983). Symbols: Qal--Quaternary deposits, Tmr--Rainier Mesa Member, Tpc--Tiva Canyon Member, Tpt--Topopah Spring Member, Trc--Rhyolite of Calico Hills, Tcp--Prow Pass Member, Tcb--Bullfrog Member, Tct--Tram Member, Tlr--Lithic Ridge Tuff, Ttac--Older tuffs of drill hole USW-G1, Tsd--sedimentary deposits, Tca/Tyf--calcified ash flow tuff and tuff of Yucca Flat(?), Slm--Lone Mountain Dolomite, Srm--Roberts Mountain Formation. See figure 6 for line of section.

CENOZOIC STRATIGRAPHY AND PETROGRAPHY

Drill hole UE25p#1 penetrated unconsolidated latest Tertiary(?) and Quaternary sedimentary deposits to a depth of 39 m (128 ft) (Appendix II). These deposits probably are unconformable on the underlying Tertiary volcanic rocks as they are in most localities at Yucca Mountain, but there are no data from the drill hole to confirm this relationship.

Tertiary ash-flow, ash-fall, and reworked tuff and sedimentary deposits were encountered from 39 to 1244 m (128 to 4080 ft) (table 2, Appendix II). The succession of ash-flow and bedded tuff units encountered to a depth of 1139 m (3733 ft) correlates with units of (1) the older tuffs of USW-G1 (Spengler and others, 1981), (2) the Lithic Ridge Tuff (Carr and others, in press), (3) the Crater Flat Tuff (Byers and others, 1976), (4) the rhyolite of Calico Hills (Christiansen and Lipman, 1965), (5) the Paintbrush Tuff (Byers and others, 1976), and (6) the Timber Mountain Tuff (Byers and others, 1976), all known from other drill holes at Yucca Mountain.

Volcanic and sedimentary units deeper than 1139 m (3733 ft) in UE25p#1 were not encountered previously in drill holes at Yucca Mountain. The oldest ash-flow tuff in drill hole UE25p#1 may correlate with the tuff of Yucca Flat (Carr and others, in press). The tuff of Yucca Flat(?) is overlain in UE25p#1 by an unnamed calcified tuff unit that is in turn overlain by a unit of Tertiary clastic sedimentary rocks, mostly conglomerate containing cobbles and boulders of carbonate rock. The Tertiary sequence is faulted against the Silurian dolomite section.

OLDER ASH-FLOW TUFFS AND SEDIMENTARY UNITS OF UE25p#1

Tuff of Yucca Flat(?) (Informal)

Carr and others (1984) informally designated a quartz-bearing ash-flow tuff unit present around and beneath Yucca Flat as the tuff of Yucca Flat. Earlier workers correlated the unit with the Crater Flat Tuff.

The tuff of Yucca Flat is widely distributed beneath Yucca Flat, Pahute Mesa, and Rainier Mesa (Orkild and others, 1968). The unit crops out to the east, west, and southeast of Yucca Flat and at Lithic Ridge. The tuff of Yucca Flat was not recognized previously in the southwestern part of the Nevada Test Site, including Yucca Mountain (Carr and others, in press).

The exposure of the tuff of Yucca Flat nearest to drill hole UE25p#1 is at Lithic Ridge approximately 19 km (12 mi) east-northeast of the drill hole, where the tuff underlies a thin quartz latitic tuff unit (not present in UE25p#1) that in turn underlies the Lithic Ridge Tuff (Carr and others, in press). At Lithic Ridge, the tuff of Yucca Flat is moderately welded and devitrified. The general phenocryst composition of the tuff of Yucca Flat is summarized on figure 13. Lithic fragments in the tuff predominantly are rhyolitic volcanic rock, which commonly are spherulitic. Sparse lava fragments of intermediate composition also are present. The presence of spherulitic rhyolite and sparsity of intermediate lava fragments distinguish the tuff of Yucca Flat from other pre-Crater Flat tuffs (Carr and others, in press).

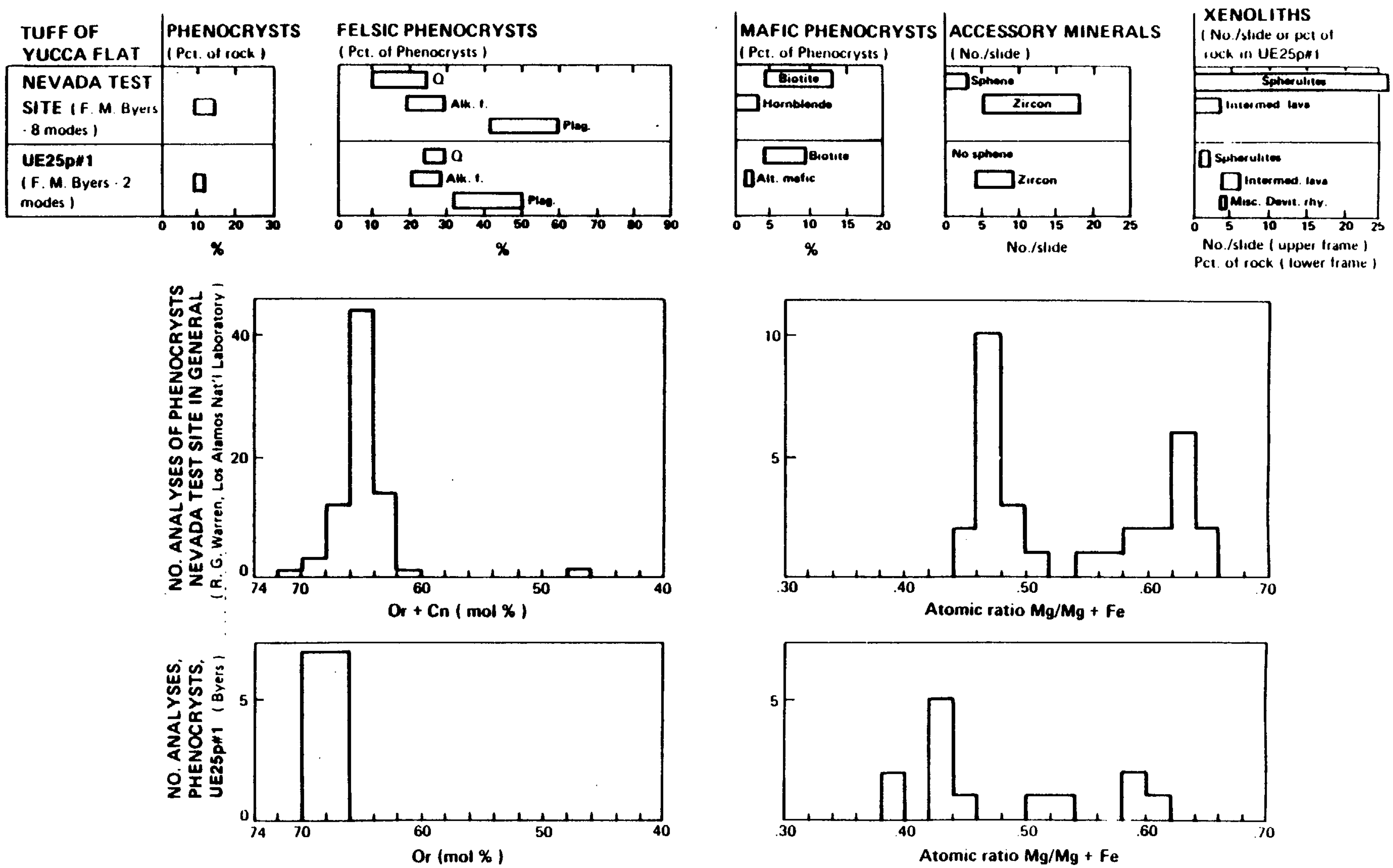


Figure 13. Comparison of phenocrysts between the tuff of Yucca Flat exposed at the Nevada Test Site and the tuff of Yucca Flat(?) in drill hole UE25p#1.

Drill hole UE25p#1 intersected 39 m (130 ft) of the tuff of Yucca Flat(?) between 1205 and 1244 m (3950 and 4080 ft). The lower contact with the Lone Mountain Dolomite is interpreted as a fault, as discussed previously. The tuff of Yucca Flat in the drill hole is moderately welded, containing 9 to 12 percent phenocrysts. Phenocryst composition and modal data for the drill hole, also summarized on figure 13, are similar to those generally determined for the tuff of Yucca Flat. Compositions of feldspar and biotite phenocrysts in the drill hole also are similar to those determined for the tuff of Yucca Flat in the Nevada Test Site area, in general. The tuff in the drill hole contains sparse lithic fragments, including both spherulitic rhyolite and intermediate composition lava. The sparse content of spherulitic rhyolite fragments in UE25p#1 is in striking contrast with the tuff of Yucca Flat elsewhere in the Nevada Test Site area where such lithic fragments are abundant (fig. 13). The oldest tuff unit in UE25p#1 tentatively is correlated with the tuff of Yucca Flat on the basis of 1) stratigraphic position, which Carr and others (1984) concluded was stratigraphically below older tuff units previously recognized at Yucca Mountain, and 2) general petrographic and compositional similarity with the tuff of Yucca Flat as known from surface exposures (fig. 13).

Calcified Ash-flow Tuff

Drill hole UE25p#1 intersected 33 m (106 ft) of calcified ash-flow tuff, between 1172 m and 1205 m (3844 and 3950 ft), conformably overlying the tuff of Yucca Flat(?). This ash-flow was not encountered previously in any other drill holes at Yucca Mountain, and no correlation with any unit exposed at the surface has been attempted.

The calcified tuff is partially welded. Phenocryst content is less than one percent, and the unit contains less than five percent lithic fragments. The sparsity of phenocrysts partly is due to the replacement of phenocryst minerals by secondary calcite, which locally comprises more than 50 percent of the total rock volume.

Preferential calcification of this unit in contrast to the underlying tuff of Yucca Flat(?) may have resulted from greater permeability in the calcified unit owing to its lesser degree of welding. The source of carbonate-charged fluid was probably ground water in the underlying Paleozoic carbonate rocks. The higher hydrostatic head in the Paleozoic rocks than in the Tertiary section observed in UE25p#1 (Craig and Johnson, 1984) could have provided an effective mechanism for the upward migration of carbonate-rich ground water along pathways such as the fault between the Tertiary and Paleozoic section, which continues upward through the Tertiary section to the surface. The carbonate-rich ground water could then have migrated laterally within the more permeable units in the Tertiary section.

Sedimentary deposits

Tertiary sedimentary deposits, conformably overlying the calcified ash-flow tuff, were intersected from 1139 to 1172 m (3733 to 3844 ft) in UE25p#1. A basal conglomerate containing boulder-size clasts is visible on acoustic borehole televiewer (fig. 14) and television camera logs. Some clasts are larger than the diameter of the borehole, which is approximately 28 cm (11 in) through the interval of sedimentary deposits. The conglomerate

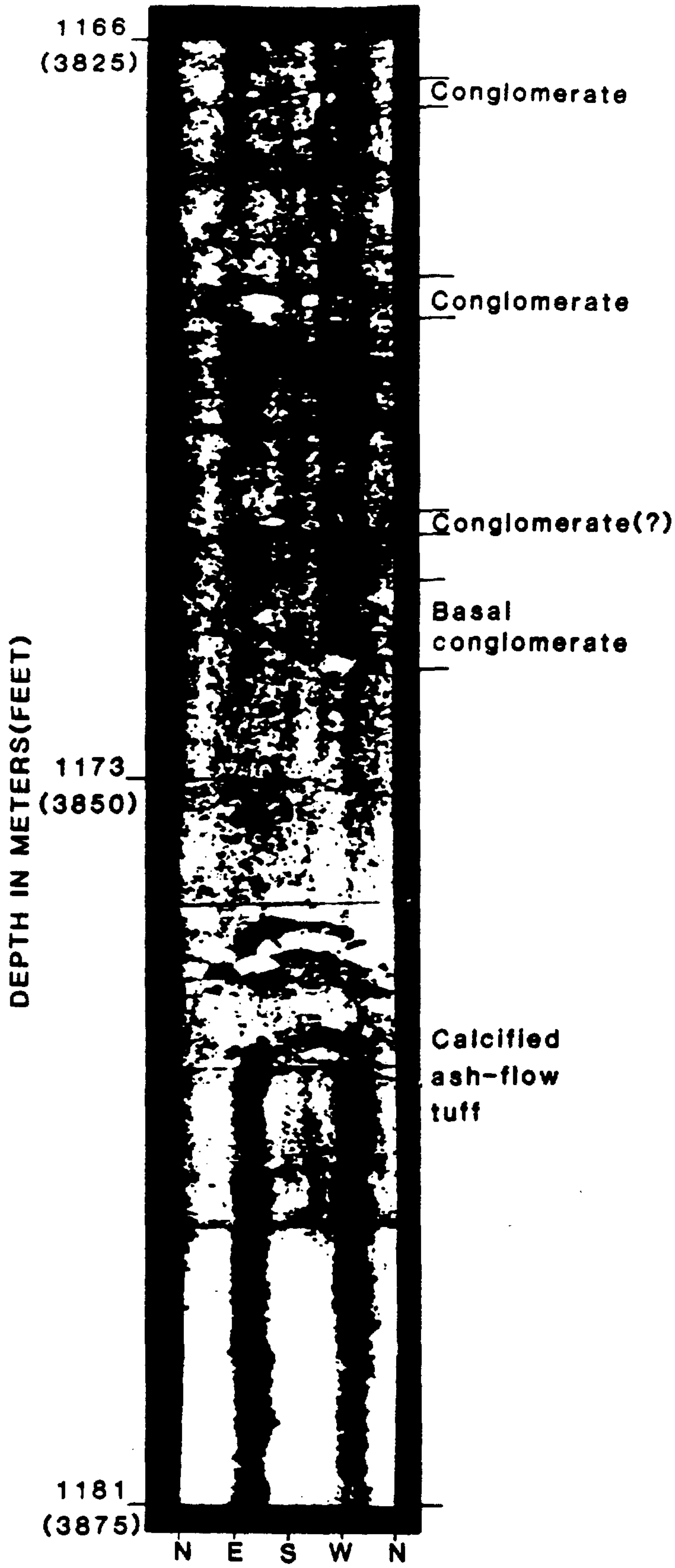


Figure 14. Part of an acoustic borehole televiewer log of drill hole UE25p#1 showing intervals interpreted as conglomeratic layers in the lower part of the Tertiary sedimentary deposits.

appears to be poorly sorted with angular clasts. The larger clasts are more reflective than other materials (fig. 14) and probably are light-colored carbonate rock. Upward from the coarse basal conglomerate, the deposits are finer grained, mostly sandstone(?) and some intercalated coarse, unsorted, conglomeratic layers. The finer grained material is well bedded locally. Judging from drill-bit cuttings, the conglomerate clasts include both carbonate rocks and argillite derived from the Paleozoic sedimentary sequence and ash-fall tuff derived from the Tertiary volcanic sequence. Conglomerate is the most conspicuous rock type in the Tertiary sedimentary deposits, but finer grained deposits appear to predominate on the basis of the television camera log observations. It was not possible to determine whether the fine-grained materials in the UE25p#1 succession include ash-flow and ash-fall tuff beds or limestone, which commonly are associated with some of the exposed Miocene sedimentary sequences in the area.

No widely accepted stratigraphy has been established for Tertiary sedimentary deposits in southern Nevada. The names Horse Spring Formation and rocks of Pavits Spring generally have been applied in the Nevada Test Site area for successions of intercalated sedimentary rocks and tuffs that unconformably overlie Paleozoic rocks but underlie the thick sequence of Miocene volcanic rocks derived from sources in southern Nevada (e.g. Hinrichs and McKay, 1965; Poole and others, 1965; Hinrichs, 1968; and Barnes and others, 1982). These successions contain tuff beds that have been correlated with Oligocene tuffs from sources northeast of the Nevada Test Site and are considered Oligocene and Miocene (Barnes and others, 1982). The Tertiary sedimentary deposits of drill hole UE25p#1 grossly correlate with these sedimentary successions, which generally are considered pre-Crater Flat Tuff in age, but no detailed correlation was possible.

UNIT C OF THE OLDER TUFFS OF USW-G1 (INFORMAL)

In drill hole USW-G1, unit C of the older tuffs succession consists of a thin sequence of moderately welded ash-flow tuffs intercalated with reworked tuffaceous sediments (Spengler and others, 1981). Phenocrysts comprise from 10 to 30 percent of the total rock volume of the unit, according to Spengler and others (1981), and consist of 83 percent plagioclase, a few percent each of quartz and potassium feldspar, and sparse hornblende, biotite, sphene and pyroxene. The unit also contains between 1 and 3 percent lithic fragments.

Drill hole UE25p#1 penetrated 38 m (123 ft) of tuff correlated with unit C between 1101 and 1139 m (3610 and 3733 ft). The lower contact with the conglomerate unit appears conformable. Unit C is a partially welded ash-flow tuff. The thin beds of reworked tuff typical of unit C in core from drill hole USW-G1 were not recognized in drill bit cuttings from UE25p#1. The unit contains 16 to 22 percent phenocrysts consisting predominantly of plagioclase, with 10 percent biotite, a few percent each of sanidine and quartz, and sparse hornblende and zircon.

The correlation with unit C in drill hole USW-G1 is made primarily on the basis of the plagioclase-rich and quartz-poor phenocryst assemblage. The suite of accessory minerals also is similar.

UNIT A OF THE OLDER TUFFS OF USW-G1 (INFORMAL)

Unit A of the older tuffs succession in drill hole USW-G1 consists of partially to moderately welded ash-flow tuff. The unit is devitrified, partially silicified, and contains approximately 17 percent phenocrysts. Phenocrysts consist of approximately 35 percent each potassium and plagioclase feldspars, 26 percent quartz, and sparse biotite, zircon, and sphene. The unit contains less than 5 percent lithic fragments (Spengler and others, 1981).

Drill hole UE25p#1 penetrated 33 m (108 ft) of quartz-rich tuff between 1067 and 1100 m (3502 and 3610 ft). The lower contact with unit C is concordant. The quartz-rich tuff in UE25p#1 is nonwelded to moderately welded and devitrified. The unit contains 15 to 18 percent phenocrysts including 25 to 27 percent quartz. In the lower 6 m (20 ft), the quartz-rich interval contains 40 percent plagioclase and 28 percent sanidine, but in the upper 27 m (88 ft) contains 20 percent plagioclase and 50 percent sanidine. Sparse biotite, zircon and sphene are also present.

The quartz-rich tuff is correlated with unit A of Spengler and others (1981) principally on the basis of quartz phenocryst content and stratigraphic position below the Lithic Ridge Tuff. Unit B of Spengler and others (1981) is distinguished from unit A by a decrease in the amount of quartz and an increase in plagioclase phenocrysts. No such decrease in quartz is noted in UE25p#1, but plagioclase content increases significantly in the lower 6 m. On the basis of plagioclase content, the lower 6 m of the quartz-rich tuff in UE25p#1 could be correlated with the transitional unit B. Because of its consistent quartz phenocryst content in sharp contrast to the quartz-poor, plagioclase-rich unit C, however, the entire quartz-rich interval in UE25p#1 is correlated with unit A. The thickness of unit A in UE25p#1 is less than a third of that found in USW-G1.

The older ash-flow and bedded tuffs of USW-G1 are overlain by 4 m (14 ft) of bedded and reworked tuff. This unit was not recognized in drill bit cuttings, but is evident on velocity, induction, and television camera logs, between the depths of 1064 and 1068 m (3488 and 3502 ft).

LITHIC RIDGE TUFF

The Lithic Ridge Tuff was defined formally by Carr and others (in press) from exposures at Lithic Ridge, 19 km (12 mi) east-northeast of drill hole UE25p#1. The unit, however, was previously recognized in drill hole USW-G1, where it informally was called the lithic-rich tuff by Spengler and others (1981). At its type locality, the Lithic Ridge was divided into two parts by Carr and others (in press). The lower part contains approximately 3 percent phenocrysts and a few percent lithic fragments. The upper part contains approximately 10 percent phenocrysts and 10 percent lithic fragments. The lithic fragments are mainly pilotaxitic lava and spherulitic rhyolite, which are distinct from fragments in the overlying Crater Flat Tuff. The Lithic Ridge also contains sphene and noticeably less quartz than the Crater Flat Tuff. In the drill holes at Yucca Mountain, the Lithic Ridge is partially welded, zeolitized, and argillized.

Drill hole UE25p#1 intersected 191 m (625 ft) of the Lithic Ridge Tuff from 873 m to 1064 m (2863 to 3488 ft). The lower contact is concordant. The Lithic Ridge in UE25p#1 is nonwelded to partially welded. The phenocryst content is 8 to 12 percent throughout the interval. Phenocrysts include less than 12 percent quartz except in the uppermost 24 m (77 ft), where the quartz content increases to 27 percent. The greater quartz phenocryst content of the uppermost interval, however, probably resulted from contamination of drill-bit cuttings with material from the overlying Tram Member of the Crater Flat Tuff. Sparse sphene (less than 1 percent) is also present. The content of lithic fragments gradually decreases downward from 11 percent at the top to 2 percent at the base. The greater content of lithic fragments at the top of the unit also may have resulted from contamination of samples. The interval is zeolitized and (or) argillized throughout. The atomic ratios Mg/Mg+Fe for biotite phenocrysts from the Lithic Ridge are distinctly higher than those for the predominant biotite phenocrysts of the overlying Tram Member of the Crater Flat Tuff (fig. 15). Some biotite with relatively high ratios Mg/Mg+Fe occurs in the Tram, but no biotite with low ratios occurs in the Lithic Ridge, distinguishing the two units (Byers and Warren, 1983).

Correlation of the Lithic Ridge section in UE25p#1 with the type section and with other Yucca Mountain drill holes is made on the basis of similar welding, alteration, and stratigraphic position. The relatively small content of quartz phenocrysts distinguishes the Lithic Ridge from enclosing units. The content of lithic fragments in UE25p#1 is not markedly different from that of the enclosing units. The atomic ratios of Mg/Mg+Fe and the presence of sphene in the Lithic Ridge are the principal criteria used to locate the upper contact of the Lithic Ridge with the Tram Member.

The upper contact of the Lithic Ridge with the overlying Tram Member is inferred to be a fault, primarily because the bedded tuff generally occurring between the two units in drill holes at Yucca Mountain is absent. There are no distinct stratigraphic criteria from the drill hole to establish the amount of dip separation on this fault.

CRATER FLAT TUFF

The Crater Flat Tuff (Byers and others, 1976; Carr and others, in press) consists of three members; from bottom to top, the Tram, Bullfrog, and Prow Pass Members. At Yucca Mountain, the members, which correspond to ash-flow units, typically are separated by relatively thin units of bedded and (or) reworked tuff.

Tram Member

The Tram Member, formerly known as the Tram unit, was formally designated by Carr and others (1984) from an exposed partial section. A complete section of the Tram Member was penetrated in drill hole USW G-1 (Spengler and others, 1981). The lower half of the Tram in USW G-1 is nonwelded to partially welded ash-flow tuff. Rhyolite, dacite lava, and quartz latite xenoliths comprise as much as 50 percent of the total rock volume. The upper half of the unit is partially welded, devitrified, and contains only 3 to 5 percent volcanic xenoliths (Spengler and others, 1981; Carr and others, in press).

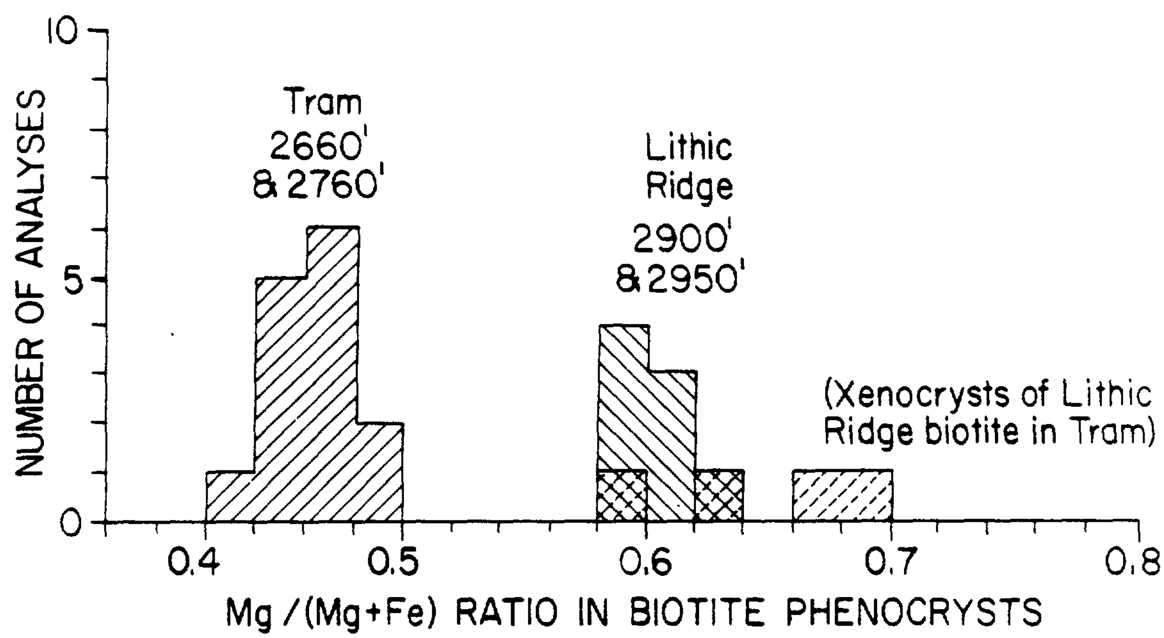


Figure 15. Comparison of Mg/Mg+Fe ratios for biotite pheno-
chrysts from the Tram Member and Lithic Ridge Tuff.

Drill hole UE25p#1 intersected 182 m (598 ft) of the Tram Member between 691 m and 873 m (2265 and 2863 ft). The Tram in UE25p#1 can be subdivided into an upper, partially to moderately welded lithic-poor interval, containing approximately 3 percent lithics, and a lower, nonwelded to partially welded lithic-rich interval, generally containing about 10 percent lithic fragments.

Correlation with the type Tram is based on stratigraphic position. In addition, the Tram in UE25p#1 can be subdivided into upper and lower zones, similar to those in the section in USW-G1, based on degree of welding and abundance of lithic fragments. The Tram Member is reversely magnetized, distinguishing it from the overlying Bullfrog and Prow Pass Members, which are normally magnetized. The magnetometer log from UE25p#1 shows distinctly different magnetic characteristics for the Bullfrog and the Tram Members (fig. 16) and served as a basis for distinguishing the units.

The Tram is separated from the ash-flow tuff of the overlying Bullfrog Member by 8 m (25 ft) of bedded and reworked tuff.

Bullfrog Member

The Bullfrog Member, now recognized as the middle member of the Crater Flat Tuff (Carr and others, in press), was named from exposures on Bullfrog Mountain approximately 10 km (6.2 mi) west-southwest of Beatty, Nevada (Byers and others, 1976). At its type locality, the Bullfrog Member consists of three parts. The lower part is brown and glassy, containing much more plagioclase than alkali feldspar; the middle part contains approximately equal amounts of the two feldspars; and the upper part is distinguished by the occurrence of vapor-phase pumice. Other distinguishing characteristics of the unit are the presence of biotite-bearing pumice and the abundance of quartz phenocrysts (Byers and others, 1976). Quartz from the Bullfrog Member in drill holes at Yucca Mountain is strongly to moderately resorbed (Carr and others, in press).

Drill hole UE25p#1 intersected 125 m (410 ft) of the Bullfrog Member from 558 m to 683 m (1830 ft to 2240 ft). The lower 27 m (90 ft) of the Bullfrog Member is non-welded to partially welded, partially zeolitized, and contains sparse glass shards. Zeolitization could account for the lesser glass content of this interval in the drill hole as compared to the type section. The content of plagioclase feldspar in the lower 27 m (90 ft) of the section is almost twice that of alkali feldspar. The middle 75 m (245 ft) is partially to moderately welded, pumice is devitrified, and plagioclase and alkali feldspar contents are approximately equal. The uppermost part of the Bullfrog exhibits sparse vapor-phase crystallization. Quartz is abundant throughout the interval and is moderately resorbed. In the overlying Prow Pass Member, quartz is strongly resorbed and in the underlying Tram it is slightly resorbed.

Correlation with the type Bullfrog is based on recognizing the three distinct zones, the abundance and degree of resorption of the quartz phenocrysts, and stratigraphic position.

The Bullfrog Member is separated from the overlying ash-flow tuff of the Prow Pass Member by 11 m (38 ft) of bedded tuff.

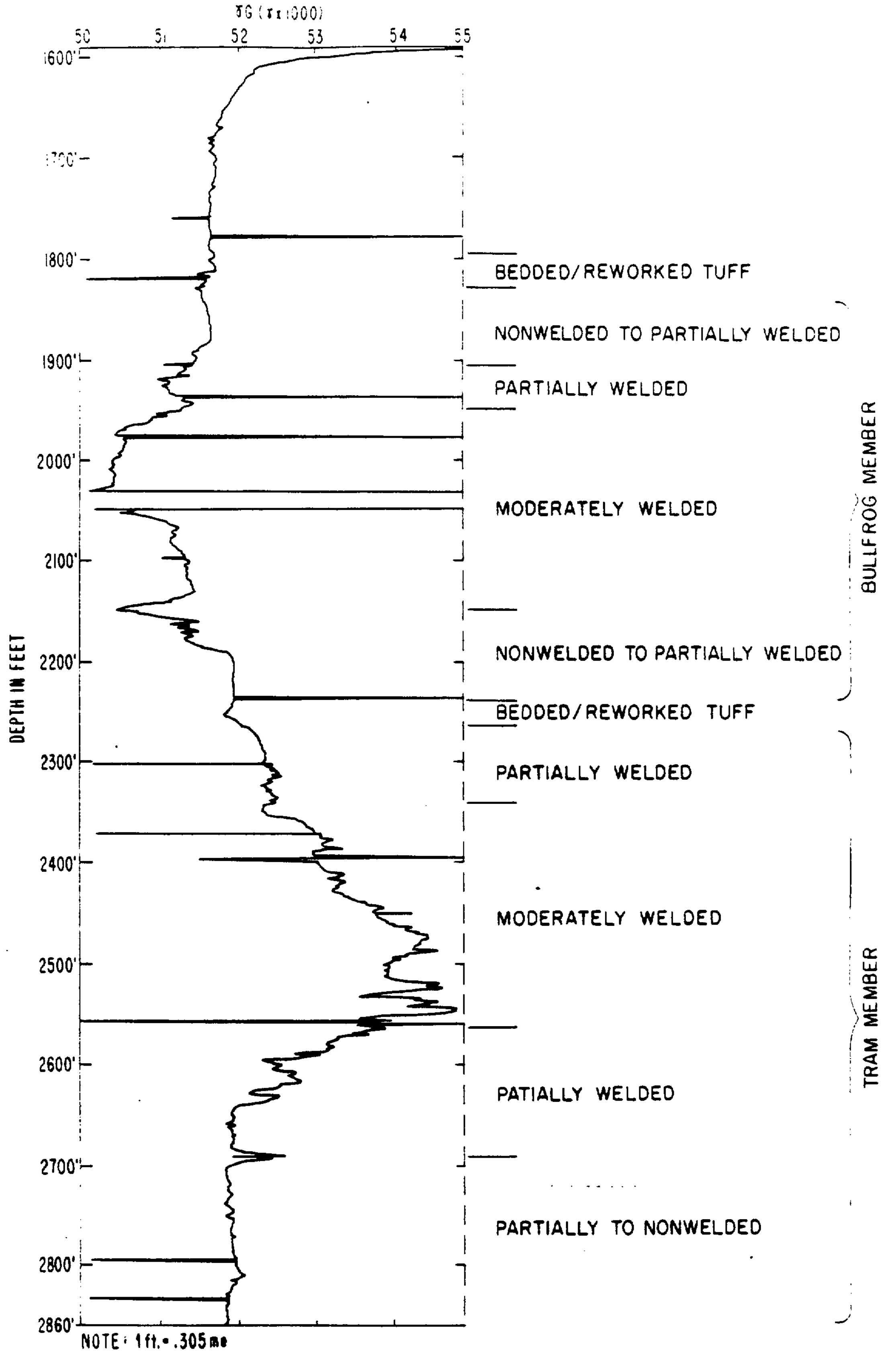


Figure 16. Magnetometer log of drill hole UE25p#1 from 485 to 872 m (1590 to 2860 ft). Shows distinct magnetic signatures for the Bullfrog and Tram Members. Casing at 483 m (1583 ft) affects uppermost part of log.

Prow Pass Member

The Prow Pass Member, the upper member of the Crater Flat Tuff, was defined by Byers and others (1976) from exposures at the north end of Yucca Mountain. The Prow Pass at its type locality is distinguished from the Bullfrog by 1) stronger resorption of quartz, 2) presence of orthopyroxene as the predominant mafic phenocryst, 3) absence of biotite, and 4) a lesser degree of welding in the Prow Pass (Byers and others, 1976). The potassium and plagioclase feldspar contents of the Prow Pass are approximately equal, whereas, the Bullfrog contains relatively more plagioclase. The Prow Pass also contains fragments of mudstone, absent from the Tram and sparse in the Bullfrog.

Drill hole UE25p#1 intersected 111 m (362 ft) of Prow Pass Member between 436 and 547 m (1430 and 1792 ft). The Prow Pass in UE25p#1 is partially welded and devitrified. The feldspars are approximately equal in abundance, and mudstone fragments occur throughout the interval.

The Prow Pass interval in UE25p#1 is correlated with the type section on the basis of stratigraphic position as well as: 1) the nearly equal feldspar content of alkali and plagioclase, 2) the small content of biotite, 3) the strong resorption of quartz phenocrysts, and 4) the presence of mudstone lithic fragments. The Prow Pass in UE25p#1 also exhibits partial welding throughout the unit.

A fault may be present at or near the conact between the Crater Flat Tuff and the overlying rhyolite of Calico Hills (see Structural Geology for discussion), but the exact position of the fault is not known.

RHYOLITE OF CALICO HILLS (INFORMAL)

The Prow Pass Member is overlain by the rhyolite of Calico Hills, an informal name applied to a sequence of extensively altered ash-flow and ash-fall tuff, rhyolitic lavas, tuff breccias, and tuffaceous sandstones between the Crater Flat Tuff and the Paintbrush Tuff (Christiansen and Lipman, 1965). The bedded and reworked tuff beds in this interval also have been discussed informally as the tuffaceous beds of Calico Hills (Spengler and others, 1981). In drill holes USW-G1 and UE25a-1, the Calico Hills consists of a relatively thick zone of nearly homogeneous, zeolitized, nonwelded ash-flow tuff intercalated with thin beds of ash-fall and reworked tuff (Spengler and others, 1981; 1979). The zeolite minerals clinoptilolite and mordenite constitute 60 to 80 percent of the rock.

Fourteen meters (45 ft) of bedded tuff overlies the Prow Pass in drill hole UE25p#1, forming the basal part of the rhyolite of Calico Hills. The bedded tuff interval is overlain, between 381 m (1250 ft) and 422 m (1385 ft) in the drill hole, by 41 m (135 ft) of nonwelded to partially welded and zeolitized tuff, containing less than 4 percent phenocrysts. The interval also contains 2 to 8 percent volcanic lithic fragments. The thin beds of ash-fall and reworked tuffs that typically occur in outcrop and core were not recognized in drill-bit cuttings from the upper part of the Calico Hills in drill hole UE25p#1.

The interval in UE25p#1 is correlated with the rhyolite (tuffaceous beds) of Calico Hills from other drill holes at Yucca Mountain on the basis of stratigraphic position, welding characteristics, and zeolitization. The lower phenocryst content of the Calico Hills aids in distinguishing it from the underlying Prow Pass.

The rhyolite of Calico Hills is overlain conformably by the Topopah Spring Member of the Paintbrush Tuff.

PAINTBRUSH TUFF

The Paintbrush Tuff was named by Orkild (1965) but was redefined by Byers and others (1976). It includes four members that are, from oldest to youngest, the Topopah Spring, Pah Canyon, Yucca Mountain, and Tiva Canyon Members. The Pah Canyon and Yucca Mountain Members of the Paintbrush Tuff are areally restricted; they thin southward from the Timber Mountain-Oasis Valley caldera complex immediately north of Yucca Mountain, and are absent under the southern part of Yucca Mountain (e.g., drill hole USW-G3/GU3, Scott and Castellanos, 1984). The Topopah Spring and Tiva Canyon Members are both widespread, densely welded ash-flow tuffs. The principal petrographic distinction between the two units is the relative abundance of alkali feldspar in the Tiva Canyon Member. More than 90 percent of the phenocrysts are alkali feldspar throughout much of the Tiva Canyon Member, whereas the Topopah Spring Member usually contains nearly equal amounts of alkali feldspar and plagioclase phenocrysts. The two members also are distinguished from one another by the presence of sphene found only in the Tiva Canyon Member. The Topopah Spring Member has normal thermal remnant magnetization, whereas the Tiva Canyon Member, together with the rest of the Paintbrush Tuff, has reverse remnant magnetization (Byers and others, 1976). The contact between the Topopah Spring and Tiva Canyon in drill hole UE25p#1 was not logged with a magnetometer.

Topopah Spring Member

The Topopah Spring Member was divided into four different depositional units in the Busted Butte area, approximately 5 km south-southeast of the UE25p#1 site, by Lipman and others (1966). The upper unit, a crystal-rich quartz-latitic caprock, overlies three units of crystal-poor rhyolite. The lower three units were subdivided according to variations in welding and crystallization.

Lithologic subunits also have been described within the Topopah Spring in drill hole USW-G1 (Spengler and others, 1981), as well as in other cored holes in the Yucca Mountain area. The lower part of the Topopah Spring in drill hole USW-G1 grades upward from nonwelded to moderately welded ash-flow tuff. The moderately welded ash-flow tuff is overlain by a lower vitrophyre unit. The vitrophyre is overlain by densely welded tuff containing subzones distinguished by their content of lithophysal cavities. This lithophysae-bearing zone is overlain by a zone of moderately welded tuff lacking lithophysae but distinguished by vapor-phase crystallization and a slight increase in phenocrysts. This zone is overlain by a crystal-rich quartz latitic caprock, that is in turn overlain by an upper vitrophyre unit that grades upward into nonwelded vitric tuff at the top. The Topopah Spring in other drill holes at Yucca Mountain is zoned similarly.

The UE25p#1 drill hole penetrated 300 m (983 ft) of the Topopah Spring Member between 81 and 381 m (267 and 1250 ft). The Topopah Spring in UE25p#1 can be divided into the same general stratigraphic subunits that were recognized in the other Yucca Mountain drill holes. The lowest subunit is a partially welded and partially zeolitized ash-flow tuff identified from 351 to 381 m (1153 to 1250 ft). The lower vitrophyre occurs from 334 to 351 m (1095 to 1153 ft). A thin nonlithophysal, devitrified zone from 290 to 334 m (950 to 1095 ft) is overlain by a lithophysal subzone from 197 to 290 m (645 to 950 ft). A devitrified zone occurs from 151 to 197 m (495 to 645 ft) and another lithophysal subzone occurs from 123 to 151 m (405 to 495 ft). Most of the lithophysae in the upper lithophysal subzone are open and coated with vapor-phase mineralization. The upper contact of this subzone is gradational. A vapor phase zone occurs from approximately 116 to 151 m (380 to 495 ft), and an uppermost nonlithophysal zone extends from 81 to 116 m (267 to 380 ft). Part of this nonlithophysal subunit and all of the crystal-rich, quartz latitic caprock, the upper vitrophyre, and the nonwelded top of the Topopah Spring apparently are missing in the drill hole. These subunits are inferred to be cut out by a fault at 81 m (267 ft). On the basis of the thicknesses of the upper nonlithophysal and overlying subunits of the Topopah Spring from drill holes H-4, USW G-1, UE25a-1, and UE25b-1, an estimated 31 m (100 ft) of the Topopah has been faulted from the section in UE25p#1.†

Correlation of the Topopah Spring in drill hole UE25p#1 with the type Topopah Spring Member and the Topopah Spring from other drill holes at Yucca Mountain is made on the basis of the similarity of the lithologic subunits, stratigraphic position above the tuffaceous beds of Calico Hills, and structural and inferred stratigraphic position below the Tiva Canyon Member.

The bedded and reworked tuff interval that typically occurs above the Topopah Spring, even in drill holes of southern Yucca Mountain such as USW-G3/GU3, also appears to be missing from the section in UE25p#1, further indicating a fault. Three meters (10 ft) of bedded tuff was intersected by drill hole UE25c#1, only 618 m (2028 ft) west of UE25p#1 (R. W. Spengler, written commun., 1984). The Pah Canyon and Yucca Mountain Members also are absent from UE25p#1, but this is a result of southward stratigraphic thinning of the units (Spengler and Rosenbaum, 1980) rather than faulting. Both the Pah Canyon and Yucca Mountain are also absent in UE25c#1, where the Topopah Spring and Tiva Canyon Members appear to be in normal stratigraphic succession (R. W. Spengler, written commun., 1984).

Tiva Canyon Member

The Tiva Canyon Member of the Paintbrush Tuff is composed of eight mappable subunits (Scott and others, 1983), which have been found in outcrop on

† R. W. Spengler (written communication, 1985) reports that part of the caprock unit and overlying bedded tuff may be present in the drill hole UE25p#1 based on his reexammination of drill bit cuttings. If so, then the displacement on the fault between the Topopah Spring and Tiva Canyon Members estimated herein may be too great. The conflicting interpretations of the drill bit cuttings were not resolved in time for this report and the problem remains to be solved.

Yucca Mountain. The basal unit of the Tiva Canyon is a nonwelded to partially welded, yellowish-brown tuff with black glass shards. A columnar subunit with abundant vertical joints overlies the basal unit; this subunit ranges from moderately to densely welded and from devitrified to vitrophyric. Above the columnar subunit is a zone with abundant hackly fracturing. The hackly subunit is overlain by a lithophysal zone, the lower of two lithophysal zones in the Tiva Canyon Member. A moderately to densely welded subunit with very few lithophysal cavities lies above this and is overlain by the upper lithophysal subunit. The upper lithophysal zone is overlain by a cliff-forming subunit known as the upper cliff. A crystal-rich quartz latite caprock lies above the upper cliff.

Drill hole UE25p#1 penetrated 23 m (75 ft) of the Tiva Canyon Member between 55 m and 78 m (180 and 225 ft). Based on a comparison with measured section #6, figure 5 of Scott and others (1983), an estimated 91 m (300 ft) of the Tiva Canyon is missing leaving only part of the upper cliff and crystal-rich caprock in fault contact with the underlying Topopah Spring Member.

The Tiva Canyon Member in UE25p#1 is a pale-red to moderate-brown, densely welded, ash-flow tuff containing 3 percent phenocrysts in the lower 3 m (9 ft) and 15 percent phenocrysts in the upper 23 m (76 ft). Sanidine, the most abundant phenocryst, composes between 85 and 95 percent of the total phenocryst content. Also present are plagioclase and bronze-colored biotite.

Correlation is on the basis of the abundance of phenocrysts and the presence of bronze-colored biotite, which are characteristic of the crystal-rich quartz latite caprock of the Tiva Canyon.

TIMBER MOUNTAIN TUFF

The Timber Mountain Tuff originally was named by Orkild (1965). It was later redefined by Byers and others (1976) to include all quartz-bearing ash-flow tuffs and thin ash-fall tuffs deposited in the Nevada Test Site area approximately 11 m.y. ago. Only the basal member, the Rainier Mesa, which crops out in the vicinity of the UE25p#1 drill site, was intersected by the drill hole.

Rainier Mesa Member

The Rainier Mesa Member was defined as the basal member of the Timber Mountain Tuff by Orkild (1965, p. A49). Within the Timber Mountain caldera and at the type section, the Rainier Mesa Member is a compositionally zoned compound cooling unit. At Yucca Mountain, it is interpreted as a single cooling unit by Lipman and Mckay (1965), who describe the unit as a pumiceous ash-flow tuff, which grades upward from pink to white nonwelded, glassy tuff near the base to light-gray, partially welded, and devitrified tuff at the top. The unit contains abundant quartz phenocrysts.

The UE25p#1 drill hole penetrated 13 m (42 ft) of the Rainier Mesa Member of the Timber Mountain Tuff between 39 m and 52 m (128 and 170 ft). At most localities at Yucca Mountain, the Rainier Mesa is areally restricted to structural depressions that post-date deposition of the Paintbrush tuff, and the basal contact is an angular unconformity (Scott and others, 1983). The basal contact of the Rainier Mesa in UE25p#1, therefore, is inferred to be unconformable. The Rainier Mesa in UE25p#1 consists of pinkish-gray nonwelded ash-flow or air-fall tuff. The unit is vitric, consisting of 97 percent pumiceous matrix. Quartz is the most abundant phenocryst, accounting for 55 percent of the total phenocryst content.

Correlation is based on stratigraphic position, abundance of quartz as phenocrysts, and general lithologic similarity with the Rainier Mesa known from surface exposures at Yucca Mountain. It is readily differentiated from the Paintbrush Tuff, which contains only sparse quartz phenocrysts.

QUATERNARY DEPOSITS

The upper 39 m (128 ft) of drill hole UE25p#1 intersected unconsolidated to poorly consolidated Quaternary deposits, which unconformably overlie the volcanic rocks. The lower 24 m (78 ft) of the Quaternary deposits consist of sandy pebble gravel, which is well sorted near the base but is poorly to moderately sorted higher in the unit. Sparse plates of carbonate-cemented fine sand occur throughout the interval. Most of the clasts are welded tuff. This interval is considered to be alluvial in origin and is tentatively correlated with unit QTa of Hoover and others (1981).

The upper 15 m (50 ft) of the Quaternary deposits consist of poorly to moderately sorted fine- to very coarse grained pebbly sand. Pebbles are mainly welded tuff. Hollow carbonate-cemented root casts are common throughout the interval, and laminated carbonate-cemented plates of fine- to medium-grained sand reworked from Stage IV calcrete are also present. Clasts of clay- and carbonate-cemented, moderately to well-sorted, fine- to medium-grained sand are probably eolian in origin. The deposit probably consists of reworked materials from unit Q2e of Hoover and others (1981), like that exposed at the surface near the drill hole.

STRUCTURAL GEOLOGY

The Tertiary strata in drill hole UE25p#1 are tilted and faulted. Judging from television camera logs and foliation of pumice in cores from the lower part of the Tertiary section, the Tertiary rocks are gently dipping. Pre-Tertiary strata dip more steeply than the Tertiary beds and are tilted northward or northwestward similar to the general attitudes of pre-Tertiary rocks exposed in nearby areas such as Bare Mountain and the Striped Hills (fig. 1). Dips of layering in the pre-Tertiary rocks vary, possibly indicating faulting and gentle folding within the section or error in the indirect methods used for determining dips. Televiewer logs indicate that layering in the Roberts Mountain Formation dips approximately 40° NNW between the depths of 1775 and 1778 m (5825 and 5835 ft) (fig. 17). The dips of layers in this interval are confirmed by the attitudes of laminations and chert layers in core. In core from the Lone Mountain Dolomite, layered and laminated intervals are inclined between 60 and 80° to the core axis, indicating dips in the range of 20 to 40° if beds are dipping northward. [Drill-hole deviation in that interval (fig. 8) is southward at less than 10° from vertical.] No unequivocal layering was recognized in any of the oriented core, although possible bedding was recognized in an oriented core of the Lone Mountain Dolomite dipping 35° westward.

FRACTURING AND BRECCIATION

Oriented fracture data from drill hole UE25p#1 are from two sources--oriented core and acoustic borehole televiewer logs. Only three cores were oriented successfully, and all were from the Paleozoic section. Televiewer logs were obtained from 493 to 1186 m (1618 to 3890 ft) in the Tertiary section and from 1298 to 1524 m (4260 to 5000 ft) in the Paleozoic section. The televiewer images were analyzed by J. M. Stock in conjunction with hydraulic fracturing experiments from UE25p#1. Only the major findings from analysis of the televiewer images are summarized herein.

Thirty-six fractures were recognized in oriented core (table 3). These are plotted in the upper left stereographic projection of figure 18, but contouring of these data by a method based on Kamb (1959) showed no regions of data that were significantly overpopulated in comparison to a random distribution of orientations.

Fractures recognized on televiewer images of the Paleozoic section define a preferred northwest to north-northwest strike and dip from 45 to 80o both eastward and westward (upper right, fig. 18). The statistical maximum surface is approximately N.30°W., 80°SW. Fractures recognized on the televiewer log from the Tertiary section (lower right, fig. 18) form a pattern similar to that for the Paleozoic section, however the statistical maximum surface, oriented approximately N.20°W., 60°NE., dips distinctly eastward. The televiewer fracture data from the Paleozoic and Tertiary sections in combination (lower left, fig. 18) yielded northeast- and southwest-dipping maxima that were statistically equal.

No data were collected from UE25p#1 core to analyze the density of fractures. Much of the core is strongly brecciated, as indicated in the lithologic log (Appendix II).

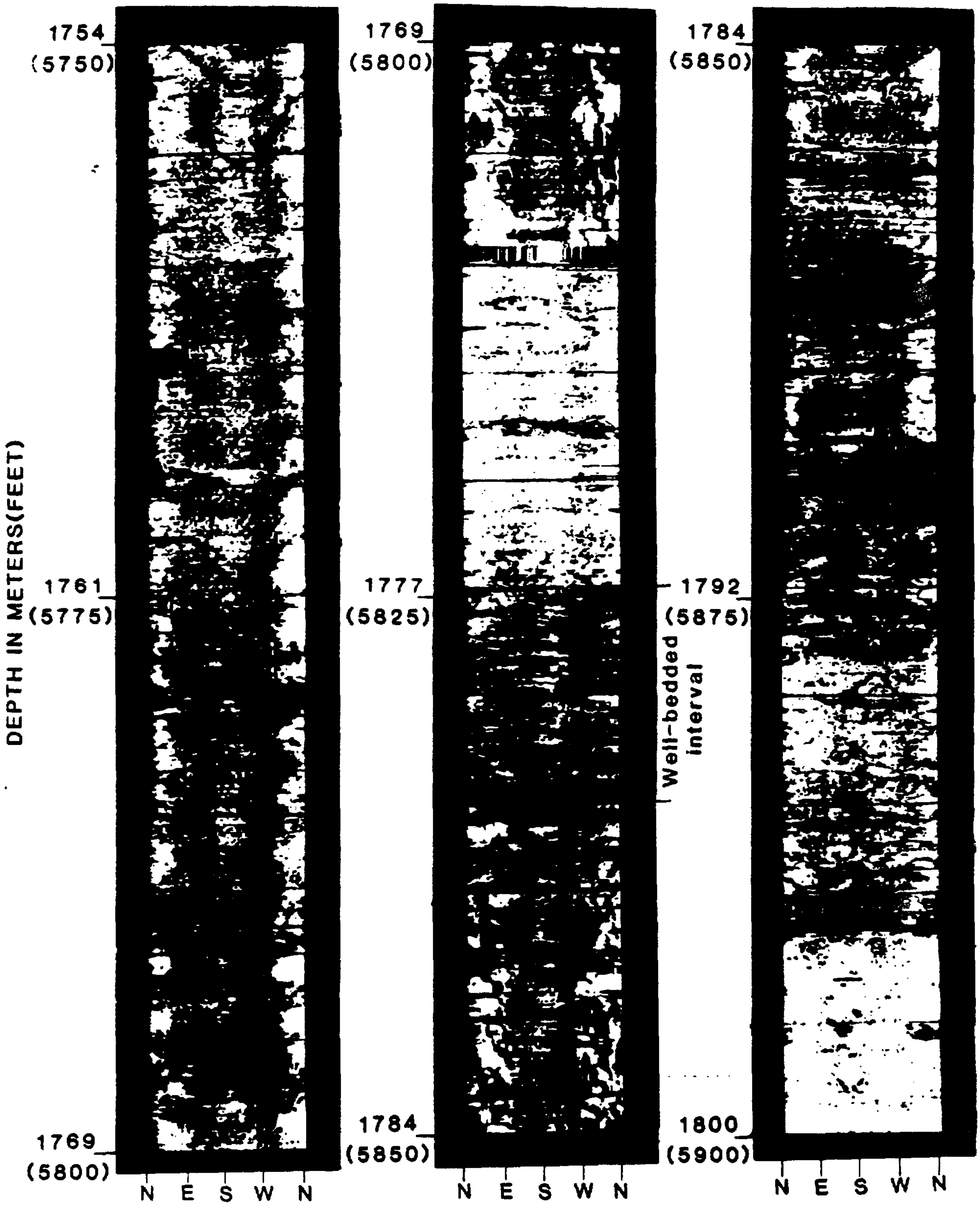
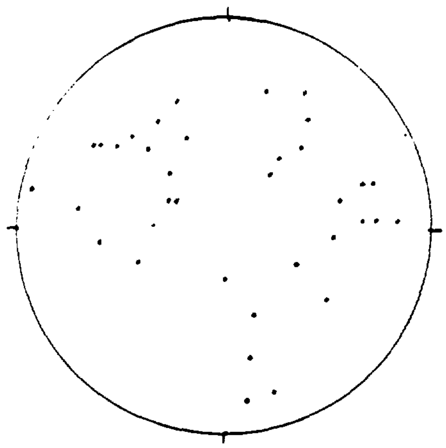


Figure 17. Acoustic borehole televiewer log of the Roberts Mountain Formation in drill hole UE25p#1. Drilling depths in meters (feet).

36 POLES TO FRACTURES

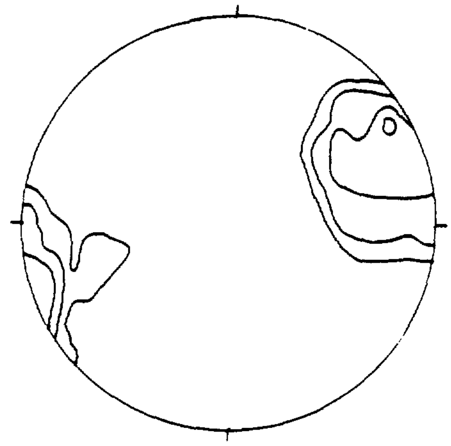
ORIENTED CORE



Contouring of these data by a method based on Kamb (1959) yielded no contours greater than or equal to two percent of points per one percent of area. Consequently no areas are overpopulated with respect to a ramdom distribution.

40 POLES TO FRACTURES

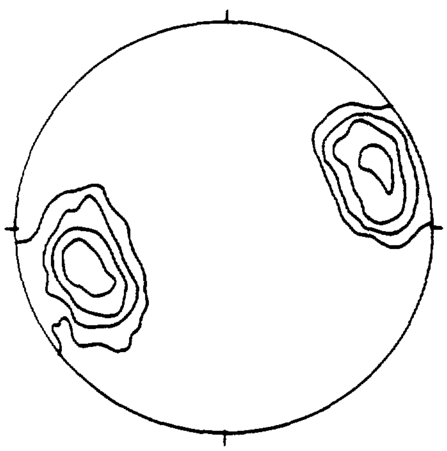
Interpreted from acoustic borehole televiewer log 1299 to 1525m (4260 to 5000ft.)



Contours: 2.0, 2.5, 3.0, 3.5
N= 40

90 POLES TO FRACTURES

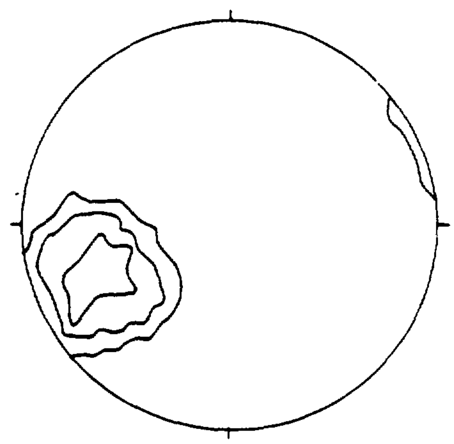
Interpreted from acoustic borehole televiewer logs Composite of all UE25p#1 data



Contours: 2.0, 2.5, 3.0, 3.5
N= 90

44 POLES TO FRACTURES

Interpreted from acoustic borehole televiewer log 493 to 1186m (1618 to 3890ft.)



Contours: 2.0, 2.5, 3.0, 3.5
N=44

Figure 18. Fracture orientations from core and acoustic borehole televiewer data from drill hole UE25p#1. Plots are lower hemisphere equal area projections. Contour method after Kamb (1959); contour program developed by M. T. Brandon. Contours are percent of points per one percent of net area.

Table 3. Description of Fractures in Oriented Core from Drill Hole UE25p#1

Depth in feet	Attitude	Remarks
CORE RUN #12		
4,346.0	N.37°E., 52°NW.	Brecciated surface
4,346.5	N.34°E., 63°SE.	"
4,342.0	N. 3°E., 73°SW.	
4,348.5	N. 5°W., 63°SW.	Open surface
4,348.7	N.70°E., 37°NW.	Planar surface
4,349.0	N.74°W., 59°SW.	
4,349.2	N. 2°W., 57°SW.	Open spaces along surface
4,349.8	N.17°W., 59°SW.	
4,350.3	N.26°E., 31°NW.	
4,350.9	N.59°W., 64°SW.	
4,351.7	N.51°W., 37°SW.	
4,351.9	N.49°W., 29°SW.	
4,352.1	N.51°W., 55°SW.	Brecciated surface
4,352.3	N.46°W., 46°SW.	Open surface
4,352.9	N.17°W., 64°SW.	"
4,354.5	N.14°W., 49°SW.	"
4,355.3	N.21°W., 38°NE.	Closed surface
CORE RUN #19		
4,442.6	N.89°E., 22°NW.	Closed fracture with breccia along surface
4,443.9	N.78°E., 55°NW.	"
4,448.0	N.69°E., 57°SE.	"
CORE RUN #52		
4,706.3	N. 1°E., 28°SE.	Closed surface
4,707.0	N.79°E., 58°NW.	Open surface
4,707.4	N.67°E., 40°SE.	"
4,707.5	N.37°E., 57°SE.	Closed surface
4,707.7	N.82°E., 80°NW.	Open surface
4,707.7	N.11°E., 85°SE.	"
4,708.5	N.32°E., 65°SE.	"
4,709.0	N.25°E., 25°SE.	"
4,709.1	N.44°E., 53°SE.	Closed surface
4,709.3	N.73°E., 75°NW.	Open surface
4,709.6	N.47°E., 32°SE.	Closed surface
4,709.9	N. 5°E., 44°NW.	Open surface
4,710.3	N. 9°E., 52°NE.	Closed surface
4,710.5	N.59°E., 51°SE.	Brecciated surface
4,710.8	N.26°E., 22°SE.	Open surface
4,710.9	N. 6°E., 62°SE.	"

MAJOR FAULTS

Three normal faults were recognized in UE25p#1 because they omit parts of the stratigraphic column. These form the contact between the Tiva Canyon and Topopah Spring Members of the Paintbrush Tuff (79 m), the contact between the Crater Flat and Lithic Ridge Tuffs (873 m), and the contact between Tertiary and Paleozoic rocks (1244 m). Other faults may occur at or near the base of the rhyolite of Calico Hills, in the lower part of the Lithic Ridge Tuff, and within the calcified tuff unit. Evidence suggesting that the Fran Ridge fault separates the Tertiary and pre-Tertiary section in the drill hole was discussed previously; the other faults are discussed below.

The fault between the Tiva Canyon and Topopah Spring Members is recognized on the basis of missing stratigraphic section and geophysical logs. Only the upper 24 m (80 ft) of the Tiva Canyon occurs in UE25p#1. The Tiva Canyon is approximately 140 m (460 ft) thick in the nearest surface section to UE25p#1 measured by Scott and others (1983), suggesting that as much as 116 m (380 ft) of Tiva Canyon is missing at the fault. The caprock and part of the underlying subunit of the Topopah Spring and the bedded tuff interval generally occurring between the Tiva Canyon and Topopah Spring are also absent, suggesting that approximately another 30 m (100 ft) of section is missing at the fault. The fault probably correlates with an event occuring on the induction log between 78 and 81 m (255 and 267 ft). We correlate this fault with the Paintbrush Canyon fault exposed south of the drill site (fig. 6). The correlation with surface exposures requires that the fault dips approximately 65° westward, which is consistent with dips measured along the surface trace. Considering the thickness of missing stratigraphic section, the geometry of the fault, and the attitude of layering in the vicinity of the drill hole, the dip separation on the fault is on the order of 150 m (500 ft) (fig. 12).

The fault between the Crater Flat and Lithic Ridge Tuffs correlates with events on the gamma-ray and neutron porosity logs at approximately 873 m (2863 ft). A westward dipping shear zone, 2 m wide, is visible on the televiewer log at approximately 878 m (2880 ft) (fig. 19). Discrepancy in depths is because the depths on the televiewer log are measured relative to the floor of the drilling platform while depths on other geophysical logs are relative to the drill-hole collar 3.7 m (12 ft) lower. It is difficult to estimate the amount of displacement along this fault because of poor control on the thicknesses of the Tram Member and Lithic Ridge Tuff beneath the eastern part of Yucca Mountain. The expected thickness of the Tram Member in drill hole UE25p#1 interpolated from the apparent thickness in drill holes USW-H4, [342.6 m (1124 ft), Whitfield and others, 1984] and J-13 [260 m (850 ft), Byers and Warren, 1983] is approximately 328 m (1000 ft). The drilled thickness of the Tram in UE25p#1 is only 183 m (600 ft), therefore, 100 m or more of the Tram may be missing at the fault. The bedded unit occurring between the Tram and Lithic Ridge in drill holes USW-H4 and J-13 is missing in UE25p#1 suggesting another 7.6 m (25 ft) of displacement. The Lithic Ridge was not entirely penetrated in other drill holes near UE25p#1, but the true thickness of the Lithic Ridge was estimated to be about 280 m (920 ft) in drill hole USW-G3, 4 km to the southwest (Scott and Castellanos, 1984). The apparent thickness of Lithic Ridge drilled in UE25p#1 is 190 m (625 ft), and true thickness could be as little as 165 m (545 ft), considering the steepest dips recorded at the surface in the area. As much as 100 m of Lithic Ridge may be missing because of faulting in UE25p#1, however some section could be cut out along faults within the Lithic Ridge. A conspicuous

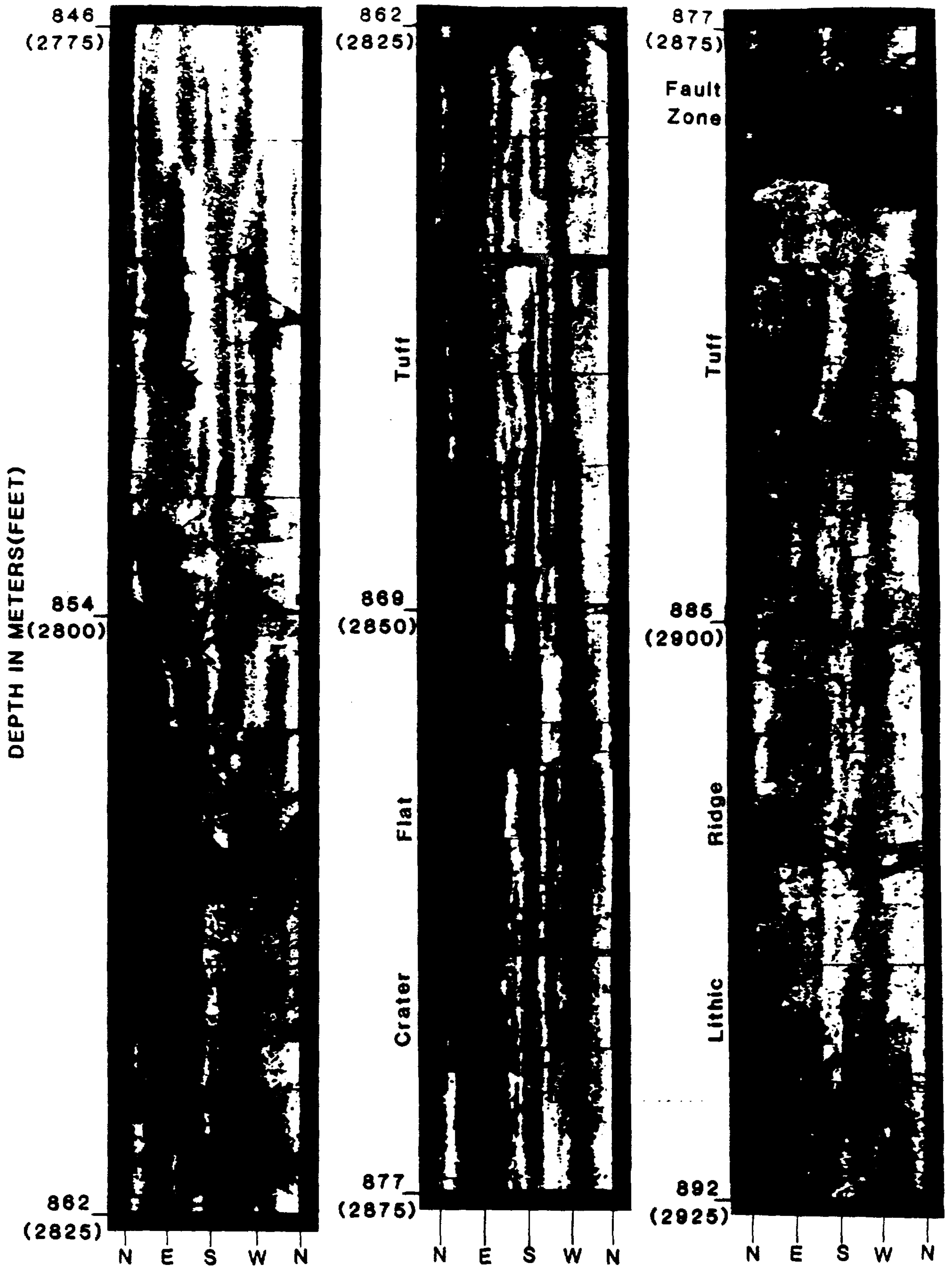


Figure 19. Acoustic borehole televiewer log of part of drill hole UE25p#1 showing faulted contact between Crater Flat and Lithic Ridge Tuffs.

shear zone evident on television camera logs at about 1012 m (3320 ft) could be a fault.

The minimum displacement on the fault at the base of the Tram probably is on the order of 100 m, but displacement could be as much as several hundred meters. This fault cannot be correlated with any exposed fault, but the trace may be buried beneath alluvial deposits in the valley west of the Fran Ridge fault.

The rhyolite of Calico Hills is thin in UE25p#1 relative to sections in nearby drill holes. The apparent thickness of the Calico Hills in UE25p#1 is 55 m (180 ft), whereas the unit is 110 m (360 ft) thick in UE25c#1 (R. W. Spengler, written commun., 1984) and 80.8 m (265 ft) in water well J-13 (Byers and Warren, 1983). Thinning could be stratigraphic, but more likely is due to faulting. Assuming a westward dip between 60° and 65°, a fault at or near the base of the Calico Hills in UE25p#1 could correlate with a fault mapped by Scott and Bonk (1984) on the ridge southeast of the drill hole (figs. 6 and 12), but this correlation is uncertain.

Another fault is inferred at a depth of 1197 m (3926 ft), near the base of the calcified ash-flow tuff to explain a sharp temperature inversion at that depth recorded on a temperature log measured in UE25p#1 on May 4, 1983; the temperature inversion was no longer evident on a log measured on June 23, 1983 (fig. 20). One interpretation of the temperature data is that relatively cool drilling fluid infiltrated the walls of the drill hole along a permeable fault zone at approximately 1197 m (3926 ft), and over the following month fluids equilibrated to background temperatures. Four meters (13 ft) of core were recovered in the interval between 1192 and 1198 m (3912 and 3929 ft); the upper part of the core was solid rock, but the lower part was strongly sheared, possibly indicating a fault. If the permeable zone at 1197 m (3926 ft) is a fault, then it probably is a splay of the Fran Ridge fault zone.

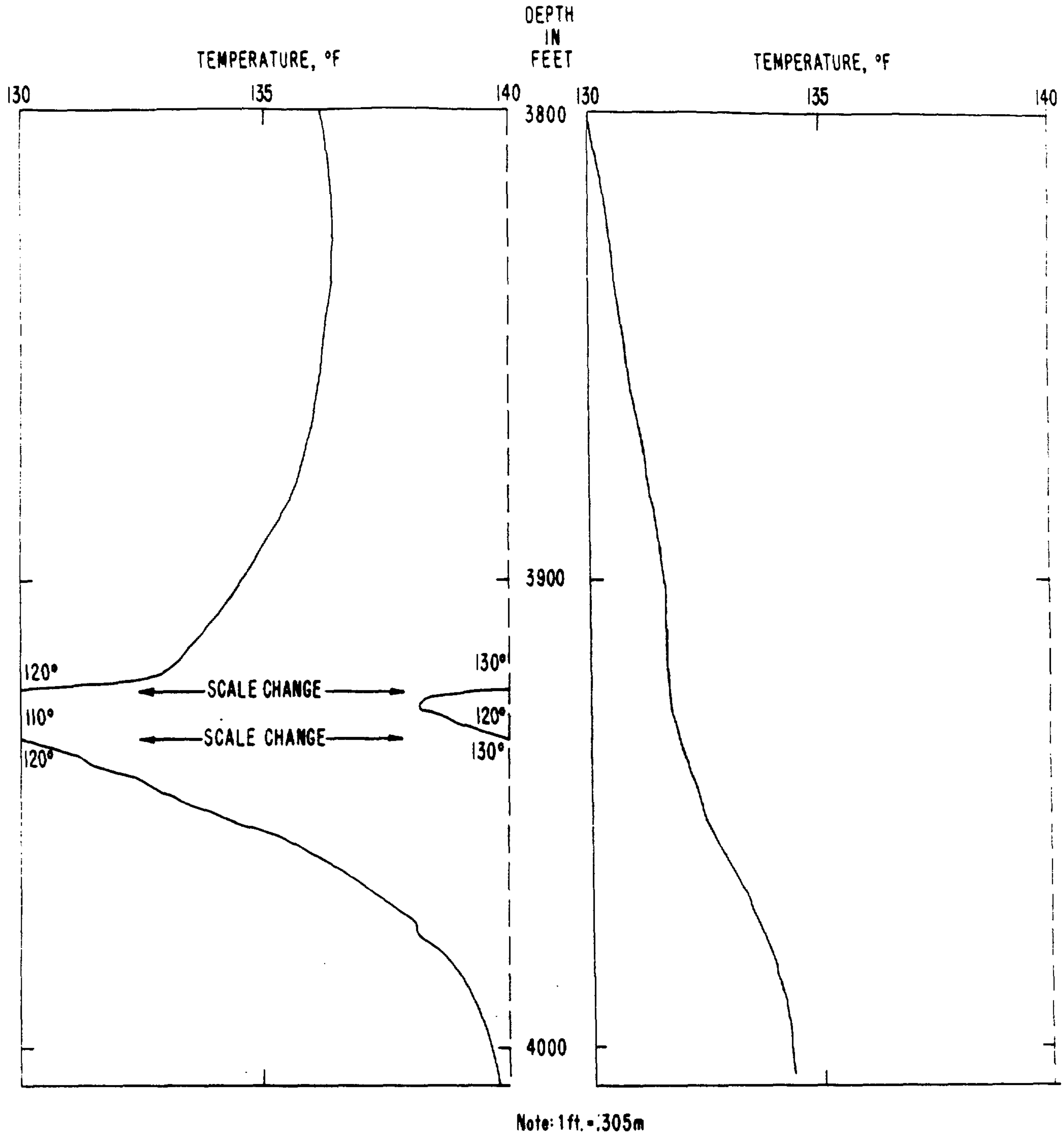


Figure 20. Temperature logs of drill hole UE25p#1 measured on May 4, 1983 (left) and June 23, 1983 (right).

DISCUSSION AND INTERPRETATION

Drill hole UE25p#1 provides a significant data point for interpreting the distribution of regionally important hydrogeologic units beneath the Yucca Mountain site. Silurian rocks belonging to the lower carbonate aquifer of Winograd and Thordarson (1975) form part of the pre-Tertiary basement at Yucca Mountain.

Predictions of the depth to pre-Tertiary rocks at the drilling site by Snyder and Carr (1982) on the basis of gravity studies are remarkably accurate. Their interpretation of the northward-trending positive gravity anomaly (on which the drilling site was located) as the signature of a high-standing block of Paleozoic rocks marking the eastern edge of the structural depression beneath Crater Flat and Yucca Mountain also is consistent with data from the drill hole. Drill hole UE25p#1 did not intersect shale of the Mississippian Eleana Formation, which Snyder and Carr predicted as most likely to form the Paleozoic basement of Yucca Mountain, but an interpretation of magnetic data by Bath and Jahren (1984) indicating that the Eleana underlies only the northern part of Yucca Mountain can be supported by the discovery of northward dipping Silurian rocks in drill hole UE25p#1.

Conodont alteration indices (Epstein and others, 1977) for all of the faunas from drill hole UE25p#1 are CAI=3, suggesting that the rocks in the drill hole have never been above a maximum temperature in the range 140° to 180°C. Such temperatures could easily be generated at normal burial depths for Silurian rocks in the Great Basin. If the northern part of the site is underlain by an intrusive body as suggested by Snyder and Carr (1982), this intrusion is sufficiently deep seated or areally removed to the north that it did not heat the Silurian rocks in the area of the drill hole.

DISTRIBUTION OF HYDROGEOLOGIC UNITS

Using gravity and magnetic models in combination with geologic data from Yucca Mountain, a model was constructed for the general subsurface distribution of Paleozoic rocks in the vicinity of Yucca Mountain. Figure 21 is an orthographic projection to the surface of the predicted traces of several important Paleozoic stratigraphic contacts on the pre-Tertiary surface hypothesized by Snyder and Carr (1982) for the vicinity of Yucca Mountain. Several assumptions (some of which clearly are erroneous, but not considered critical to the general reconstruction) have been made in order to simplify the orthographic reconstruction. These assumptions are:

(1) The attitude of the Paleozoic rocks in drill hole UE25p#1 (approximately N.80°E., 40°NW.) is typical for the entire Paleozoic section beneath Yucca Mountain. This assumption is reasonable in that Paleozoic rocks have similar attitudes at Bare Mountain and in Striped Hills.

(2) The lower and middle Paleozoic carbonate sequence is approximately 4000 m (13,115 ft) throughout the area of the reconstruction. This assumption is probably accurate within ±500 m (1640 ft).

(3) The depth to the pre-Tertiary surface in Crater Flat is between 3 and 4 km. A depth of 4 km is used in figure 21 to consider probable maximum structural relief. (Depth estimates are 3.4 km and 3.2 km on the basis of gravity and seismic refraction data, respectively.)

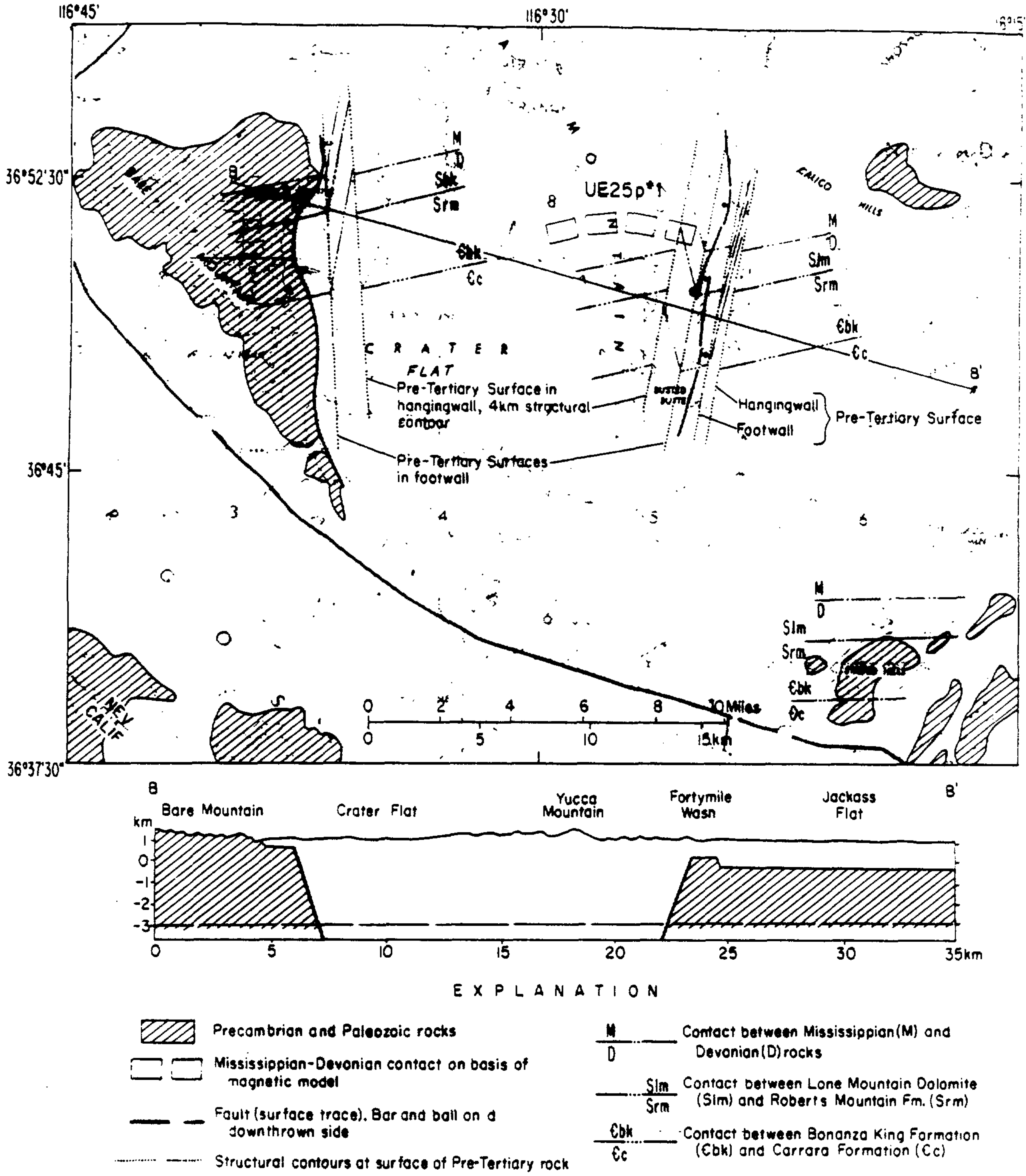


Figure 21. Orthographic reconstruction showing the subsurface distribution of Paleozoic carbonate rocks in the Crater Flat-Yucca Mountain structural depression. Shaded area interpreted as underlain by early and middle Paleozoic carbonate rocks.

(4) All of the structural subsidence of the Crater Flat structural depression is accomplished on the Bare Mountain rangefront and Painthbrush Canyon-Fran Ridge fault zones. This assumption obviously is incorrect for Yucca Mountain where the section incrementally is displaced downward to the west across numerous faults spaced from 1 to 2 km apart. Accurate reconstruction of offsets across each of the faults, however, does not appreciably change the position of the contacts in the structurally highest hanging wall block beneath Crater Flat from that reconstructed assuming that all of the displacement is on a single fault.

(5) All of the displacement on the graben-bounding faults is dip slip. In light of the results of the orthographic projection, it is unlikely that this assumption is correct. We interpret the belt of Paleozoic carbonate rocks, bounded by the Mississippian-Devonian contact on the north and the Bonanza King-Carrara contact on the south, as continuous, although incrementally displaced by numerous north-trending faults, between drill hole UE25p#1 and exposures of such Paleozoic carbonate rocks at Bare Mountain. If this interpretation is correct, then the faults that form the Crater Flat depression have a significant component of right-lateral strike slip, as well as a component of dip slip.

The general area that we interpret to be underlain by carbonate rocks is depicted by a stippled pattern on figure 21. The belt of carbonate rocks trends west-northwest connecting the surface exposures of Paleozoic carbonate rocks at Bare Mountain with the Paleozoic rocks in drill hole UE25p#1. On the basis of the fault geometry at Yucca Mountain, we hypothesize that this west-northwest trending belt is the composite of a series north-northwest dipping fault-bounded blocks that are displaced along faults of the northward-trending set at Yucca Mountain. Under this hypothesis, each block forming part of the carbonate belt successively should be dropped down to the west and displaced northward in a right-lateral sense from east to west across the northward-trending faults. A component of right-lateral strike slip approximately equal to the component of dip-slip displacement is required along the northward-trending faults at Yucca Mountain to explain the mismatch of the carbonate belt across Crater Flat that results from the reconstruction on figure 21, which only accounts for dip slip.

The hypothesized belt of carbonate rocks generally corresponds in position with a lobe in the 12 mGal gravity contour projecting eastward from the UE25p#1 site toward Jackass Flats (fig 4). The belt also corresponds with lobes in the 0 to 8 mGal contours projecting westward into Crater Flat. The positive gravity anomaly traversing central Crater Flat was interpreted by Snyder and Carr (1982) as the signature of a ridge or septum of relatively dense Paleozoic rocks separating two calderas filled with less dense volcanic rocks in northern and southern Crater Flat. An alternative hypothesis is that both the weak positive gravity anomaly projecting eastward from the UE25p#1 site and the anomaly projecting westward into Crater Flat are signatures of the west-northwest trending belt of carbonate rocks hypothesized herein. Such a carbonate belt could produce the observed anomalies because of its higher density relative to the shales of the Eleana Formation, which should overly the carbonate rocks to the north, and the upper Proterozoic and lower Paleozoic clastic rocks, which are stratigraphically below the carbonate rocks on the south. The carbonate rocks forming the west-northwest trending belt also tend to be more resistant to erosion than the enveloping Paleozoic clastic rocks. The carbonate rocks, therefore, could have formed a ridge in the pre-Tertiary surface that, now buried beneath Tertiary volcanic rocks in the vicinity of Yucca Mountain, would contribute to the gravity signature.

The hypothesized belt of carbonate rocks and the weak positive gravity anomaly both project eastward toward a gravity depression in western Jackass Flats, between the Calico Hills and Striped Hills (figs. 4 and 21). If the carbonate rocks in drill hole UE25p#1 are an offset continuation of the exposed Paleozoic carbonate sequence in the Striped Hills, then a northward-trending structure with significant right-lateral strike-slip displacement should separate the Striped Hills block from the Yucca Mountain block.

Clearly, more complex models for the structure and distribution of pre-Tertiary units in the vicinity of Yucca Mountain are permissible in terms of the general geologic framework (see for example Carr, 1984; Robinson, 1985). The structural model present herein is perhaps the simplest interpretation that is consistant with geologic and geophysical data from the vicinity of Yucca Mountain. The similarity of structural style between Bare Mountain and the Striped Hills, however, seems to justify a simple interpretation of the local struture in the intervening terrane. The geophysical data and limited subsurface data from Yucca Mountain appear consistant with the simple model.

The lower carbonate aquifer (Middle Cambrian through Devonian carbonate rocks) of Winograd and Thordarson (1975) underlies at least part of the southern half of the Yucca Mountain site, with the lower clastic aquitard (Upper Proterozoic and Lower Cambrian clastic rocks) of Winograd and Thordarson possibly underlying it and bounding it to the south. The upper clastic aquitard (Eleana Formation) may overlie and bound the lower carbonate aquifer under the northern part of the Yucca Mountain site. Whether the carbonate rocks that underlie the site directly contact the belt of carbonate rocks exposed in the Striped Hills is not known, because the position the contact between the carbonate sequence and shale of the Eleana Formation is concealed beneath Jackass Flats, as is the structural relationship between Yucca Mountain and the Striped Hills.

REFERENCES CITED

Baldwin, M.J. and Jahren, C.E., 1982, Magnetic properties of drill core and surface samples from the Calico Hills area, Nye County, Nevada: U.S. Geological Survey Open-File Report 82-536, 27 p.

Barnes, Harley, Ekren, E.B., Cleaves, L.R., and Hedlund, D.C., 1982, Geologic and tectonic maps of the Mercury quadrangle, Nevada: U.S. Geological Survey Micellaneous Geologic Investigations Series Map I-1197, scale 1:24,000.

Bath, G.D., and Jahren, C.E., 1984, Interpretations of magnetic anomalies at a potential repository site located in the Yucca Mountain area, Nevada Test Site: U.S. Geological Survey Open-File Report, 84-120, 40 p.

Byers, F.M., Jr., Carr, W.J., Orkild, P.P., Quinlivan, W.D., and Sargent, K.A., 1976, Volcanic suites and related cauldrons of Timber Mountain-Oasis Valley caldera complex, southern Nevada: U.S. Geological Survey Professional Paper 919, 70 p.

Byers, F.M., Jr., and Warren, R.G., 1983, Revised volcanic stratigraphy of drill hole J-13, Fortymile Wash, Nevada, based on petrographic modes and chemistry of phenocrysts: Los Alamos National Laboratory LA-9652-MS, Los Alamos, New Mexico, 23 p.

Carr, W.J., 1984, Regional structural setting of Yucca Mountain, southwestern Nevada, and late Cenozoic rates of tectonic activity in part of the southwestern Great Basin, Nevada and California: U.S Geological Survey Open-file Report 84-854, 109 p.

Carr, W.J., Byers, F.M., Jr., and Orkild, P.P., in press, Stratigraphic and volcano-tectonic relations of Crater Flat Tuff and some older volcanic units, Nye County, Nevada: U.S. Geological Survey Professional Paper (formerly U.S. Geological Survey Open-File Report 84-144, 42 p.).

Christiansen, R.L., and Lipman, P.W., 1965, Geologic map of the Topopah Spring NW quadrangle, Nye County, Nevada: U.S. Geological Survey Geological Quadrangle Map GQ-444, scale 1:24,000.

Cornwall, H.R. and Kleinhampl, F.J., 1961, Geology of the Bare Mountain quadrangle, Nevada: U.S. Geological Survey Geological Quadrangle Map GQ-157, scale 1:62,500.

Craig, R.W. and Johnson, K.A., 1984, Geohydrologic data for test well UE25p#1, Yucca Mountain area, Nye County, Nevada: U.S. Geological Survey Open-File Report 84-450, 63 p.

Craig, R.W. and Robison, J.H., 1984, Geohydrology of rock penetrated by test well UE25p#1, Yucca Mountain area, Nye County Nevada: U.S. Geological Survey Water Resources Investigation Report 84-4248, 57 p.

Epstein, A.G., Epstein, J.B., and Harris, L.D., 1977, Conodont color alteration--an index to organic metamorphism: U.S. Geological Survey Professional Paper 995, 27 p.

Hinrichs, E.N., 1968, Geologic structure of Yucca Flat area in Eckel, E.B., ed., Nevada Test Site: Geological Society of America Memoir 110, p. 239-246.

Hinrichs, E.N., and McKay, E.J., 1965, Geologic map of the Plutonium Valley quadrangle, Nye and Lincoln counties Nevada: U.S. Geological Survey Geologic Quadrangle Map GQ-384, scale 1:24,000.

Hoover, D.L., Swadley, W C, and Gordon, A.J., 1981, Correlation characteristics of surficial deposits with a description of surficial stratigraphy in the Nevada Test Site region: U.S. Geological Survey Open-File Report 81-512, 27 p.

Kamb, W.B. 1959, Ice petrofabric observations from Blue Glacier, Washington, in relation to theory and experiment: Journal of Geophysical Research, v. 64, p. 1891-1909.

Klapper Gilbert, and Murphy, M.A., 1974, Silurian-Lower Devonian conodont sequence in the Roberts Mountains Formation of central Nevada: University of California Publications in Geological Sciences, v. 111, 62 p.

Lipman, P.W., Christiansen, R.L., and O'Conner, J.T., 1966, A compositionally zoned ash-flow sheet in southern Nevada: U.S. Geological Survey Professional Paper 524-F, p. F1-F47.

Lipman, P.W., and McKay, E.J., 1965, Geologic map of the Topopah Spring SW quadrangle, Nye County, Nevada: U.S. Geological Survey Geologic Quadrangle Map GQ-439, scale 1:24,000.

Marvin, R.F., Byers F.M. Jr., Mehnert, H.H., Orkild, P.P., and Stern,T.N., 1970, Radiometric ages and stratigraphic sequence of volcanic and plutonic rocks, southern Nye and western Lincoln Counties, Nevada: Geological Society of America Bulletin, v.81, p. 2657-2676.

Merriam C.W., 1940, Devonian stratigraphy and paleontology of the Roberts Mountains region, Nevada: Geological Society of America Special Paper 25, 114 p.

Mullens, T.E., 1980, Stratigraphy, petrology, and some fossil data of the Roberts Mountain Formation, north-central Nevada: U.S. Geological Survey Professional Paper 1063, 67 p.

Muller, D.C. and Kibler, J.E., 1984, Preliminary analysis of geophysical logs from drill hole UE25p#1, Yucca Mountain, Nye County, Nevada: U.S. Geological Survey Open-File Report 84-649.

Nolan, T.B., Merriam, C.W., and Williams, J.S., 1956, The stratigraphic section in the vicinity of Eureka, Nevada: U.S. Geological Survey Professional Paper 276, 77 p.

Orkild, P.P., 1965, Paintbrush Tuff and Timber Mountain Tuff of Nye County, Nevada: U.S. Geological Survey Bulletin 1224-A, p. A44-A51.

Orkild, P.P., Byers, F.M., Jr., Hoover, D.L., and Sargent, K.A., 1968, Subsurface geology of Silent Canyon caldera, Nevada Test Site, Nevada, in Eckel, E.B., ed., Nevada Test Site: Geological Society of America Memoir 110, p. 77-86.

Poole, F.G., 1965, Geologic map of the Frenchman Flat quadrangle, Nye, Lincoln, and Clark Counties, Nevada: U.S. Geological Survey Geologic Quadrangle Map GQ-456, scale 1:24,000.

Poole, F.G., Carr, W.J., and Elston D.P., 1965, Salyer and Wahmonie Formations of southeastern Nye County, Nevada: U.S. Geological Survey Bulletin 1224-A, p. A36-A44.

Poole, F.G., Sandberg, C.A., and Boucot, A.J., 1977, Silurian and Devonian paleogeography of the western United States: in Stewart, J.H., Stevens, C.H., and Fritsche, A.E., eds., Paleozoic Paleogeography of the Western United States: Society of Economic Paleontologists and Mineralogists Pacific Coast Paleogeography Symposium 1, p 39-66.

Robinson, G.D., 1985, Structure of pre-Cenozoic rocks in the vicinity of Yucca Mountain, Nye County, Nevada--A potential nuclear-waste disposal site: U.S. Geological Survey Bulletin 1647, 22 p.

Scott, R.B. and Bonk, Jerry, 1984, Preliminary geologic map of Yucca Mountain with geologic sections, Nye County, Nevada: U.S. Geological Survey Open-File Report 84-494, scale 1:12,000.

Scott, R.B. and Castellanos, Mayra, 1984, Stratigraphic and structural relations of volcanic rocks in drill holes USW-GU3 and USW-G3, Yucca Mountain, Nye County, Nevada: U.S. Geological Survey Open-File Report 84-491, 121 p.

Scott, R.B., Spengler, R.W., Diehl, S., Lappin, A.R., Chornack, M.P., 1983, Geologic character of tuffs in the unsaturated zone at Yucca Mountain, southern Nevada in Mercer, J.W., Rao, E.S.C., and Marine, I.W., eds., The Role of the Unsaturated Zone in Radioactive and Hazardous Waste Disposal: Ann Arbor Science, Ann Arbor Michigan, p. 289-335.

Snyder, D.B., and Carr, W.J., 1982, Preliminary results of gravity investigations at Yucca Mountain and vicinity, southern Nye County, Nevada: U.S. Geological Survey Open-File Report 82-701, 36 p.

Spengler, R.W., Byers, F.M., Warner, J.B., 1981, Stratigraphy and structure of volcanic rocks in drill hole USW-G1, Yucca Mountain, Nye County, Nevada: U.S. Geological Survey Open-File Report 81-1349, 50 p.

Spengler, R.W., Muller, D.C., Livermore, R.B., 1979, Preliminary report on the geology and geophysics of drill hole UE25a-1, Yucca Mountain, Nevada Test Site: U.S. Geological Survey Open-File Report 79-1244, 43 p.

Spengler, R.W., and Rosenbaum, J.G., 1980, Preliminary interpretations of results obtained from boreholes Ue25a-4, -5, -6, -7, Yucca Mountain, Nevada Test Site: U.S. Geological Survey Open-File Report 80-929, 35 p.

U.S. Geological Survey, 1984, A summary of geological studies through January 1, 1983, of a potential high-level radioactive waste repository site at Yucca Mountain, southern Nye County, Nevada: U.S. Geological Survey Open-File Report 84-792, 103 p.

Whitfield, M.S., Jr., Thordarson, William, and Eshom, E.P., 1984, Geohydrologic and drill-hole data for test well USW H-4, Yucca Mountain, Nye County, Nevada: U.S. Geological Survey Open-File Report 84-449, 39 p.

Winograd, I.J., and Thordarson, William, 1975, Hydrogeologic and hydrochemical framework, south-central Great Basin, Nevada-California, with special reference to the Nevada Test Site: U.S. Geological Survey Professional Paper 712-C, p. C1-C126.

Appendix I.

Core record for drill hole UE-25p#1

[All measurments on this table are in feet as reported by driller and on-site geologist. Multiply by 0.305 to convert to meters.]

Core No.	Depth of Interval	Feet Cored	Feet Recovered	Percent Recovery	Comments
1	3445 - 3462	17	16.1	95	
2	3913 - 3929	16	13.0	81	
3	4185 - 4215	30	30.0	100	
4	4273 - 4289	16	16.7	104	
5	4289 - 4291	2	2.0	100	
6	4291 - 4293	2	2.1	105	
7	4293 - 4303	10	8.3	83	
8	4318 - 4322	4	2.7	68	
9	4322 - 4327	5	7.6	152	
10	4327 - 4345	18	7.2	40	
11	4345 - 4346	1	1.5	150	
12	4346 - 4356	10	10.0	100	Oriented
13	4356 - 4374	18	17.6	98	
14	4374 - 4392	18	18.0	100	
15	4392 - 4409	17	15.3	90	
16	4409 - 4415	6	6.8	113	
17	4415 - 4424	9	9.8	109	
18	4424 - 4442	18	18.2	101	
19	4442 - 4452	10	10.0	100	Oriented
20	4452 - 4460	8	8.0	100	
21	4460 - 4469	9	9.0	100	
22	4469 - 4478	9	9.0	100	
23	4478 - 4484	6	6.0	100	
24	4484 - 4494	10	10.0	100	
25	4494 - 4503	9	9.0	100	
26	4503 - 4513	10	10.0	100	
27	4513 - 4527	14	14.0	100	
28	4527 - 4545	18	18.0	100	
29	4545 - 4556	11	11.5	105	
30	4556 - 4565	9	7.75	86	
31	4565 - 4565	0	2.0	--	Rubble
32	4565 - 4573	8	8.8	110	
33	4573 - 4578	5	5.0	100	
34	4578 - 4583.5	5.5	4.5	82	
35	4583.5 - 4588.5	5	5.0	100	
36	4588.5 - 4589.5	1	1.0	100	
37	4589.5 - 4593.5	4	3.8	95	
38	4593.5 - 4598	4.5	3.4	.76	
39	4598 - 4601	3	3.3	110	
40	4601 - 4608.5	7.5	7.5	100	
41	4608.5 - 4621	12.5	9.5	76	
42	4621 - 4631	10	10.0	100	
43	4631 - 4642	11	12.0	109	
44	4642 - 4652	10	7.9	79	

Core record for drill hole UE-25p#1--Continued

Core No.	Depth of Interval	Feet Cored	Feet Recovered	% Recovery	Comments
45	4652 - 4660	8	8.0	100	
46	4660 - 4666	6	6.0	100	
47	4666 - 4666	0	3.0		Fill
48	4666 - 4675	9	1.0	11	
49	4675 - 4676	1	0	0	
50	4676 - 4686.5	10.5	10.5	100	
51	4686.5 - 4704	17.5	16.4	94	
52	4704 - 4712.5	8.5	10.0	118	Oriented
53	4712.5 - 4724	11.5	11.0	96	
54	4724 - 4742	18	18.0	100	
55	4742 - 4761	19	19.0	100	
56	4761 - 4762	1	0.3	30	
57	4762 - 4766	4	3.5	88	
58	4766 - 4772	6	6.0	100	
59	4772 - 4783	11	10.8	98	
60	4783 - 4794	11	9.9	90	
61	4794 - 4802	8	7.8	98	
62	4802 - 4813	11	10.2	93	
63	4813 - 4831	18	1.5	8	
64	4831 - 4840	9	0.25	3	
65	4840 - 4850	10	11.5	115	
66	4850 - 4862	12	12.0	100	
67	4862 - 4863	1	0.5	50	
68	4863 - 4872	9	9.2	102	
69	4872 - 4875	3	2.0	67	
70	4875 - 4883	8	6.0	75	
71	4883 - 4893	10	10.0	100	
72	4893 - 4902	9	9.0	100	
73	4902 - 4906	4	3.2	80	
74	4906 - 4912	6	3.0	50	
75	4912 - 4920	8	8.1	101	
76	4920 - 4924	4	4.0	100	
77	5900 - 5902	2	2.0	100	
78	5902 - 5909	7	4.0	57	
79	5909 - 5914	5	4.5	90	
80	5914 - 5923	9	4.0	44	

Lithologic log for drill-hole UE25p#1 -- Revised 04-21-84

Depth of interval m (feet)	Thickness of interval m (feet)	Stratigraphic assignment and lithology
		QUATERNARY DEPOSITS
0-15 (0-50)	15 (50)	Colluvium, alluvium, and eolian sand; poorly to moderately sorted, fine- to very coarse grained pebbly sand. Unit contains clay and carbonate cemented clasts of very pale brown (10YR 7/4) to yellowish-brown (10YR 5/4), moderate- to well-sorted, fine to medium sand, probably eolian. Hollow carbonate-cemented root casts as much as 2.6 cm long common throughout interval. White (10YR 8/2) laminated carbonate cemented plates of fine- to medium-grained sand reworked from Stage IV calcrete also are present. Partial carbonate coatings occur on 25 percent to 50 percent of pebble and sand casts. Pebbles mainly are welded tuffs.
15-39 (50-128)	24 (78)	Alluvium; poorly to moderately sorted, coarse-grained sandy pebble gravel. Becomes well-sorted below approximately 27 m (90 ft). Pebbles angular to subround. Most clasts are welded tuff, but as much as 35 percent of clasts are white (10YR 8/1) pumice, and rare vitrophyre clasts also are present. A few laminated carbonate-cemented fine-sand plates persist through the interval.
		TIMBER MOUNTAIN TUFF
		Rainier Mesa Member
39-52 (128-170)	13 (42)	Tuff; ash-flow or ash-fall, pinkish-gray (5YR 8 [illegible]), vitric. Pumiceous matrix contributes approximately 97 percent of rock volume. Phenocrysts consist of quartz (55 percent of total phenocryst), sanidine (20 percent), plagioclase (20 percent), biotite (4 percent), hornblende (1 percent). Also contains sparse fragments of moderate-yellowish-brown (10YR 5/4) and moderate-reddish-brown (10R 4/6) silicic volcanic rock. Base of interval located on the basis of drill-bit cuttings.
		---UNCONFORMITY---

		Bedded tuff
52-55 (170-180)	3 (10)	Tuff; ash-fall, grayish-orange-pink (5YR 8/1); argillized matrix. Contains abundant white (N9) to pinkish-gray (5YR 8/1) pumice. Phenocrysts are approximately 4 percent of rock volume and consist of sanidine (60 percent), plagioclase (30 percent), biotite and opaques (3 percent), hornblende (1 percent), and sparse sphene and quartz. Also contains sparse fragments of dusky-red (5R 3/4), very dark red (5R 3/4), and medium-bluish-gray (5B 5/11) silicic volcanic rock. Base of interval located on the basis of drill-bit cuttings.
		Tiva Canyon Member
55-67 (180-220)	12 (40)	Tuff; ash-flow, moderate-brown (5YR 4/4), devitrified, densely welded. Contains vapor phase crystallization. Commonly contains grayish-red-purple (5RP 4/2) pumice; less commonly contains yellowish-gray (5Y 7/2) pumice. Phenocrysts are approximately 15 percent of rock volume and consist of sanidine (85 percent), plagioclase (5 percent), biotite (3 percent), clinopyroxene (2 percent), opaque oxides (1 percent), sparse perrierite and hornblende, and trace of zircon. Also contains 1 percent fragments of very light gray (N8) silicic volcanic rock. Base of interval located on the basis of drill-bit cuttings.
67-76 (220-250)	9 (30)	Tuff; ash-flow, pale-red (5YR 6/2), devitrified, densely welded. Contains vapor phase crystallization. Commonly contains medium-gray (N5) pumice; less commonly contains yellowish-gray (5Y 7/2) pumice. Phenocrysts are approximately 15 percent of rock volume and consist of sanidine (90 percent), plagioclase (6 percent), biotite (2 percent), opaque oxides (1 percent), and clinopyrox (1 percent). Also contains 1 percent fragments of very light gray (N8) silicic volcanic rock. Base of interval located on the basis of drill-bit cuttings.
76-78 (250-255)	2 (5)	Tuff; ash-flow, pale-red (10R 6/2) to grayish-red (10R 4/2), devitrified, densely welded. Contains sparse medium light gray (N6) to very light gray (N8) pumice. Phenocrysts are 3 percent of rock volume and consist of sanidine (95 percent), a few percent each of biotite and opaque oxides, and traces of zircon. Also contains very sparse fragments of light-gray (N7)

		silicic volcanic rock. Base of interval located on the basis of induction log.†
78-81 (255-267)	3 [illegible]	Fault zone; inferred on the basis of geophysical logs and missing stratigraphic sequence.
		Topopah Spring Member
81-116 (267-380)	35 (113)	Tuff; ash-flow, grayish-red (5R 4/2), devitrified, densely welded. Contains sparse white (N9), medium-gray (N5), and pale-red (5R 6/2) pumice. Phenocrysts are approximately 2 percent of rock volume and consist of sanidine (50 percent), plagioclase (40 percent), biotite (5 percent), opaque oxides (4 percent), and quartz (1 percent). Also contains less than 1 percent fragments of light-gray (N7) silicic volcanic rocks. Base of interval located on the basis of drill-bit cuttings.
116-153 (380-500)	37 (120)	Tuff; ash-flow, grayish-red-purple (5RP 4/2), devitrified, moderately welded. Contains sparse white (N9) and medium light gray (N6) pumice. Phenocrysts are approximately 1 percent of rock volume and consist of sanidine (50 percent), plagioclase (40 percent), biotite (5 pecent), opaque oxides (4 percent), and quartz (1 percent). Also contain less than 1 percent fragments of light-gray (N7) silicic volcanic rocks. Base of interval located on the basis of drill-bit cuttings and density log. Upper lithophysal zone extends from 123 to 151 m (403 to 495 ft) on the basis of television camera and density logs (upper and lower contacts are gradational).
153-204 (500-670)	51 (170)	Tuff; ash-flow, moderate-brown (5YR 3/4), light-brown (5YR 5/6) and moderate-yellowish-brown (10YR 5/4) mottled, devitrified, moderately welded. Phenocrysts are less than 1 percent of rock volume and consist of sanidine (50 percent), plagioclase (40 percent), quartz (5 percent), opaque oxides (5 percent), and traces of biotite, zircon, and apatite. Also contains less than 1 percent fragments of very light gray silicic volcanic rock. Silica and manganese coated surfaces are common; the degree to which coatings are developed increases with increasing depth. Base of interval located on the basis of drill-bit cuttings.

† See Muller and Kibler (1984) for published borehole geophysical logs.

204-275 (670-900)	71 (230)	Tuff; ash-flow, light-brown (5YR 5/6), moderate-brown (5YR 3/4) and light-brown (5YR 5/4) mottled, devitrified, moderately welded. Commonly contains light-gray (N7), pale-red-purple (5RP 6/2), and grayish-orange (10YR 7/4) pumice (listed in decreasing order of abundance). Phenocrysts are approximately 1 percent of rock volume and consist of subequal amounts of sanidine and plagioclase, traces of biotite, opaque oxides, and apatite. Also contains less than 1 percent fragments of very light gray silicic volcanic rock. Silica, manganese, and vapor phase crystals commonly coat surfaces throughout interval. Base of interval located on the basis of drill-bit cuttings.
275-287 (900-940)	12 (40)	Tuff; ash-flow, grayish-red (5R 4/2) and dark-yellowish-orange (10YR 6/5) mottled, devitrified, densely welded; commonly contains dark-yellowish-orange (10YR 7/4), grayish-red-purple (5RP 4/2), light-gray (N7), and grayish-orange-pink (10R 8/2) pumice; phenocrysts are approximately 1 percent of rock volume and consist of plagioclase (approximately 60 percent), sanidine (40 percent), and traces of biotite, allanite, and apatite; also contains less than 1 percent fragments of very light gray (N8) and yellowish-gray (5Y 7/2) silicic volcanic rock; hairline fractures and surfaces coated with silica, manganese, chalcedony, clay and fluorite occur thoughout interval; base of interval located on the basis of drill-bit cuttings.
287-334 (940-1,095)	47 (155)	Tuff; ash-flow, moderate-brown (5YR 3/4) and dark-yellowish-orange (10YR 6/6) mottled, devitrified, moderately to densely welded. Contains common grayish-orange-pink (5YR 7/2), light-brown (10YR 6/4), and light-gray (N7) pumice. Phenocrysts are approximately 1 percent of rock volume and consist of subequal amounts of sanidine and plagioclase, sparse quartz, a few percent each of opaque oxides and biotite, and traces of apatite and zircon. Also contains less than 1 percent fragments of very light gray (N8), yellowish-gray (5YR 7/2), moderate-reddish-brown (10R 4/6) silicic volcanic rock. Silica, manganese and clay coated surfaces common thoughout interval. Contains zeolite minerals mordenite and heulandite, probably along fracture surfaces. Base of interval located on the basis of drill-bit cuttings and induction and spectral logs.

Lower lithophysal zone extends from 197 to 290 m (646 to 952 ft) on the basis of television camera and density logs.

334-352 (1,095-1,153)	18 (58)	Tuff; ash-flow, grayish-black (N2) and light-brown (5YR 5/6) mottled, densely welded, vitrophyric. Contains sparse moderate-reddish-orange (10R 6/6) pumice. Phenocrysts are 2 percent of rock volume and consist of plagioclase(40 percent), sanidine (approximately 30 percent), quartz (20 percent), biotite (7 percent), and traces of apatite. Also contains less than 1 percent fragments of very light gray (N8) and moderate-reddish-orange (10R 6/6) silicic volcanic rocks. Calcite and clay veinlets fill perlitic conchoidal fractures throughout the interval; calcite also occurs on fracture surfaces. Television camera log shows mottled vitrophyre from 334 to 342 m (1,095 to 1,120 ft), vitrophyre from 342 to 345 m (1,120 to 1,130 ft), and mottled vitrophyre from (1,130 to 1,153 ft). Base of interval located on the basis of spectral log.
352-381 (1,153-1,250)	29 (97)	Tuff; ash-flow, dark-yellowish-orange (10YR 6/6), partially zeolitized, partially welded. Contains sparse moderate-orange-pink (10R 7/4) and light-gray (N7) argillized pumice. Phenocrysts are approximately 1 percent of rock volume and consist of sanidine (45 percent), plagioclase (40 percent), quartz (5 percent), biotite (5 percent), opaque oxides (5 percent). Also contains 5 percent fragments of very light gray (N8), very dusky red purple (5RP 7/2) and moderate-reddish-brown (10R 4/6) silicic volcanic rock. Base of interval located on the basis of drill-bit cuttings and density log.

RHYOLITE OF CALICO HILLS

381-397 (1,250-1,300)	16 (50)	Tuff; ash-flow, grayish-orange (10YR 7/4), zeolitized, nonwelded. Contains abundant yellowish-gray (5Y 7/2) grayish-pink (5R 8/2), and moderate-reddish-orange (10R 4/6) pumice, some argillized. Phenocrysts are 2 to 3 percent of rock volume and consist of sanidine (18 to 43 percent), quartz (11 to 65 percent), plagioclase (6 to 52 percent), biotite (5 to 9 percent), opaque oxides (trace to 6 pecent), and traces of apatite and zircon. Also contains 8 percent fragments of grayish-red (5R 4/2), grayish-red-purple 5R 4/2), grayish-purple (5P 4/2), and dark-yellowish-brown (10YR 4/2) silicic volcanic rock; fragments contain abundant shards replaced by clinoptilolite/heulanite. Base of interval located on the basis of drill-bit cuttings.

397-422 (1,300-1,385)	25 (85)	Tuff; ash-flow, pale-yellowish-orange (10YR 8/6), zeolitized, partially welded. Contains abundant moderate-yellow-green (5GY 7/4) moderate-orange-pink (10R 7/4), and white (N9) pumice. Phenocrysts are 1 percent of rock volume and consist of plagioclase (60 percent), quartz (32 percent), sanidine (4 percent), biotite (4 percent), and traces of apatite, opaque oxides, and zircon. Contains abundant pseudomorphs of clinoptilolite/heulandite after shards. Also contains 2 percent fragments of medium light gray (N6), moderate-yellowish-brown (10YR 5/4), dark-reddish-brown (10R 3/4), and moderate-red (5R 4/6) silicic volcanic rock. Base of interval located on the basis of drill-bit cuttings and density log.
		Bedded Tuff
422-436 (1,385-1,430)	14 (45)	Tuff; bedded/reworked, dark-reddish-brown (10R 3/4), moderately to well indurated, zeolitized. Contains abundant moderate-orange-pink (10R 7/4) partly argillized pumice. Phenocrysts are approximately 22 percent of rock volume and consist of plagioclase (36 to 44 percent), quartz (32 to 37 percent), sanidine (11 to 18 percent, biotite (8 to 9 percent), opaque oxides (trace to 4 percent), and traces of zircon and apatite. Also contains 1 to 13 percent fragments of medium-dark-grey (N4) and dark-reddish-brown (10R 3/4) silicic volcanic rock. Base of interval located on the basis of drill-bit cuttings and density log.
		CRATER FLAT TUFF
		Prow Pass Member
436-479 (1,430-1,570)	43 (140)	Tuff; ash-flow, very light gray (N8), devitrified, partially welded. Commonly contains white (N9) and grayish-yellow (5Y 8/4) slightly argillized pumice. Phenocrysts are 11 percent of rock volume and consist of sanidine (38 percent), plagioclase (36 percent), quartz (22 percent), opaque oxides (3 percent), biotite (less than 1 percent), and traces of zircon, apatite, and perrierite(?). Also contains 1 percent fragments of grayish-red (5R 4/2) and moderate-brown (5YR 3/4) silicic volcanic rock and dark-reddish-brown (10R 3/4) and moderate-red (5R 5/4) mudstone. Base of interval located on the basis of drill-bit cuttings and gamma ray and spectral logs.

479-512 (1,570-1,680)	33 (110)	Tuff; ash-flow, medium-light-gray (N6), devitrified, partially welded, vapor phase crystallization. Commonly contains very light gray (N8) and moderate-orange-pink (5YR 8/4) slightly argillized pumice. Phenocrysts are 12 to 15 percent of rock volume and consist of sanidine (36 to 46 percent), plagioclase (33 to 43 percent), quartz (16 to 21 percent), biotite (1 to 2 percent), and traces of opaque oxides, zircon, and apatite. Also contains 1 to 3 percent fragments of dark-yellowish-brown (10YR 4/2) and grayish-red (5R 4/2) silicic volcanic rock and pale-reddish-brown (10R 5/4), dark-reddish-brown (10R 3/4) and dusky-red (5R 3/4) mudstone. Base of interval located on the basis of drill-bit cuttings and events on all geophysical logs.
512-540 (1,680-1,770)	28 (90)	Tuff; ash-flow, dusky-yellow (5Y 6/4), devitrified, partially welded. Contains abundant moderate-orange-pink (5YR 8/4) pumice. Phenocrysts are 13 percent of rock volume and consist of sanidine (64 percent), plagioclase (24 percent), quartz (10 percent), biotite (1.5 percent), and traces of opaque oxides, perrierite(?), and zircon. Also contains 2 percent fragments of black (N1), grayish-red (5R 4/2), and olive-gray (5Y 3/2) silicic volcanic rock and dark-reddish-brown (10R 3/4) and moderate-reddish-brown (10R 4/6) mudstone. Base of interval located on the basis of drill-bit cuttings.
540-547 (1,770-1,792)	7 (22)	Tuff; ash-flow, grayish-orange (10YR 7/4) to moderate-reddish-orange (10R 6/6), zeolitized, partially welded. Contains abundant pale-greenish-yellow (10Y 8/2) to moderate-yellow-green (5GY 7/4) pumice. Phenocrysts are approximately 9 percent of rock volume and consist of sanidine (approximately 54 percent), plagioclase (41 percent), quartz (2.5 percent), opaque oxides (2 percent fragments of reddish-brown rimmed black (N1) silicic volcanic rock and dark-reddish-brown (10R 3/4) and moderate-reddish-brown (10R 4/6) mudstone. Base of interval located on the basis of drill-bit cuttings and gamma ray, magnetometer and induction logs.
		Bedded tuff
547-558 (1,792-1,830)	11 (38)	Tuff; bedded/reworked, moderate-reddish-brown (10R 4/6), zeolitized. Commonly contains moderate-yellow-green (5GY 7/4) zeolitic pumice and grayish-orange-pink (10R 8/2) argillized pumice. Phenocrysts are approximately 7 percent of rock volume and consist of sanidine (approximately 35 percent), quartz (30 percent), plagioclase (25 percent), and biotite (10 percent). Base of interval located on the basis of drill-bit cuttings and density log.

558-581 (1,830-1,905)	23 (75)	Tuff; ash-flow, pale-brown (5YR 5/2) to light-brownish-gray (5YR 6/1), devitrified, non- to partly welded. Commonly contains white (N9) to very light gray (N8) pumice and less commonly pale-yellowish-brown (10YR 6/2) to dark-yellowish-brown (10R 4/2) and yellowish-gray (5Y 8/1) pumice with some vapor phase crystallization near the top of the interval. Phenocrysts are approximately 12 percent of rock volume and consist of sanidine (approximately 50 percent), quartz (30 percent), plagioclase (12 to 15 percent), biotite (3 to 6 percent), opaque oxides (2 percent), and traces of zircon and apatite. Also contains as much as 5 percent fragments of olive-gray (5Y 4/1) or olive-black (5Y 2/1) silicic volcanic rock. Base of interval located on the basis of drill-bit cuttings and density log.
581-595 (1,905-1,950)	14 (45)	Tuff; ash-flow, moderate-brown (5YR 3/4), devitrified, partially welded. Commonly contains very light gray (N8) pumice and dark-yellowish-orange (10YR 6/6) and grayish-purple (5P 4/2) devitrified pumice. Phenocrysts are 20 percent of rock volume and consist of plagioclase (42 percent), sanidine (35 percent), quartz (18 percent), biotite (5 percent), opaque oxides (less than 1 percent), and traces of zircon and apatite. Also contains less than 1 percent fragments of grayish-red (5R 4/2) silicic volcanic rock and 0.5 percent calcite. Base of interval located on the basis of drill-bit cuttings, and porosity, epithermal neutron, induction, magnetometer, gamma ray, and spectral logs.
595-656 (1,950-2,150)	61 (200)	Tuff; ash-flow, light-brown (5YR 5/6), pale-brown (5YR 5/2), mottled, devitrified, moderately welded. Contains abundant light-brown (5YR 5/6) pumice. Phenocrysts are 23 percent of rock volume and consists of plagioclase (38 percent), sanidine (37 percent), quartz (22 percent), biotite (2 percent). Also contains fragments of dusky brown (5YR 2/2), dark-reddish-brown (10R 3/4), and blackish-red (5R 2/2) silicic volcanic rock. Base of interval located on the basis of drill-bit cuttings and induction and epithermal neutron logs (events on density and porosity logs occur at 2,160 ft (659 m).
659-683 (2,150-2,240)	27 (90)	Tuff; ash-flow, grayish-orange (10YR 7/4) to dark-yellowish-orange (10YR 6/6), zeolitized, non- to partially welded. Commonly contains pale-orange, (10 YR 8/2), light-brown (5YR 6/4), and moderate-olive-brown (5Y 4/4) pumice. Phenocrysts are 9 percent of rock volume and consist of plagioclase (42 percent), sanidine (27 percent), quartz (18 percent), biotite

		9 percent), opaque oxides (4 percent), rare zircon and traces of apatite. Also contains less than 1 percent fragments of dusky red (5 R 3/4), pale-reddish-brown (10R 5/4) and grayish-red (5R 4/2) silicic volcanic rock. Base of interval located on the basis of drill-bit cuttings and induction, magnetometer, and spectral logs.
		Bedded Tuff
683-691 (2,240-2,265)	8 (25)	Tuff; bedded/reworked, moderate-yellowish-brown (10YR 5/4), grayish-orange (10YR 7/4), and moderate-reddish-brown (10R 4/6), zeolitic. Contains abundant white (N9), very pale orange (10YR 8/2), and moderate-yellow-green (5GY 7/4) zeolitic pumice. Phenocrysts are 12 percent of rock volume and consist of quartz (41 percent), sanidine (31 percent), plagioclase (23 percent), biotite (2 percent), opaque oxides (2 percent), and traces of apatite and zircon. Also contains 3 percent fragments of grayish-red (10R 4/2) and dark-reddish-brown (10R 3/4) silicic volcanic rock. Base of interval located on the basis of drill-bit cuttings and density log.
		Tram Member
691-714 (2,265-2,340	23 (45)	Tuff; ash-flow, moderate-reddish-orange (10R 6/6), zeolitized (analcime), partially to moderately welded. Contains abundant moderate-orange-pink (10R 7/4) pumice. Phenocrysts are 12 percent of rock volume and consist of plagioclase (33 percent), sanidine (31 percent), quartz (28 percent), biotite (5 percent), opaque oxides (3 percent), and traces of zircon and apatite. Also contains fragments of grayish-red (10R 4/2) and rare dark-yellowish-brown (10YR 4/2) silicic volcanic rocks. Base of interval located on the basis of drill-bit cuttings and induction, gamma ray, velocity and epithermal neutron logs.
714-778 (2,340-2,550)	64 (210)	Tuff; ash-flow, light-gray (N7), light-brownish-gray (5YR 6/1), and grayish-orange-pink (5YR 7/2) with gradational color changes, devitrified, moderately welded grading downward to partially welded. Commonly contains very light gray (N8) pumice. Phenocrysts are 13 to 16 percent of rock volume and consist of sanidine (26 to 39 percent), quartz (25 to 41), plagioclase (25 to 29 percent), biotite (5 to 6 percent), opaque oxides (0.5 to 2 percent), and traces of apatite and zircon. Also contains 3 percent fragments of pale-brown (5YR 5/2), dusky yellowish-brown (10YR 2/2), dusky red (5R 3/2), black (N1), and medium-light-gray (N6) silicic volcanic rock. Base of interval located on the basis of drill-bit cuttings and epithermal neutron, porosity, spontaneous potential, and gamma ray logs.

778-805 (2,550-2,640)	27 (90)	Tuff; ash-flow, pale-red (5R 6/2), devitrified, partially welded. Commonly contains white (N9) and less commonly light-red (5R 6/6) pumice. Phenocrysts are 14 to 16 percent of rock volume and consist of sanidine (36 to 40 percent), plagioclase (25 to 32 percent), quartz (23 to 27 period), biotite (5 to 8 percent), opaque oxides (1 percent), and traces of zircon. Also contains 3 to 11 percent fragments of dark-reddish-brown (10R 3/4), grayish-red (5 R 4/2), and dark-yellowish-brown (10YR 4/2) silicic volcanic rock and sparse calcite veinlets. Base of interval located on the basis of drill-bit cuttings and magnetometer. Contact between upper lithic fragment-poor (0 to 3 percent lithic fragments) and lower lithic fragment-rich (7 to 12 percent lithic fragments) subunits of the Tram Member located between 787 and 805 m (2,580 and 2,640 ft) in this interval on basis of modal analysis of thin sections.
805-820 (2,640-2,690)	15 (50)	Tuff; ash-flow, light-brownish-gray (5YR 6/1) to grayish-orange-pink (5YR 7/2), zeolitized (sparse clinoptilolite), partially welded. Commonly contains very light gray (N8) pumice; less commonly contains grayish-red-purple (5RP 4/2) pumice with some vapor phase crystallization; sparse light-brown (5YR 6/4) pumice also is present. Phenocrysts are 11 percent of rock volume and consist of plagioclase (37 percent), sanidine (29 percent), quartz (26 percent), biotite (4 percent), opaque oxides (4 percent), and traces of zircon. Also contains 12 percent fragments of grayish-red (5R 4/2), very dusky red (10R 2/2), blackish-red (5R 2/2), and pale-yellowish-brown (10YR 6/2) silicic volcanic rock and less than 1 percent calcite; base of interval located the basis of drill-bit cuttings and events on all geophysical logs.
820-873 (2,690-2,863)	53 (173)	Tuff; ash-flow, light-brownish-gray (5YR 6/1) to pale-red (10R 6/2) with gradational color changes, zeolitized (clinoptilolite), partially welded grading downward to nonwelded. Commonly contains very light gray (N8) to white (N9) pumice, generally less than 3 mm in diameter. Phenocrysts are 13 percent of total rock volume and consist of quartz (40 percent), plagioclase (28 percent) sanidine (27 percent), biotite (3.5 percent), opaque oxides (2 percent), and traces of zircon. Also contains 7 percent fragments of very dusky red (10R 2/2), dark-reddish-brown (10R 3/4) grayish-red (10R 4/2), medium-bluish-gray (5P 5/1), and olive-gray (5Y 3/2) silicic volcanic rock. Base of the interval located on the basis of drill-bit cuttings and neutron porosity and gamma ray logs. Disturbed zone at faulted base of unit approximately 2 m (6 ft) thick.

---Fault---

LITHIC RIDGE TUFF

873-897 (2,863-2,940)	24 (77)	Tuff; ash-flow, yellowish-gray (5Y 8/1), zeolitized (clinoptilolite), nonwelded to partially welded. Contains sparse white (N9) devitrified pumice. Phenocrysts are 10 percent of rock volume and consist of plagioclase (33 percent), sanidine (33 percent), quartz (27 percent), biotite (4 percent), opaque oxides (2 percent), and traces of apatite, zircon, and hornblende(?); also contains 11 percent fragments of light-brown (5YR 5/4), olive-black (5Y 2/1), and light-brown (5YR 5/6) silicic volcanic rock and dark-reddish-brown (10R 3/4) mudstone. Some fragments near the base have silica coatings. Contains less than 1 percent calcite. Base of interval located on the basis of drill-bit cuttings and velocity log.
897-926 (2,940-3,035)	29 (95)	Tuff; ash-flow, moderate-yellowish-brown (10YR 5/4), zeolitized (analcime), nonwelded to partially welded. Contains sparse very light gray (N8) to white (N9) pumice. Phenocrysts are 7 percent of rock volume and consist of plagioclase (55 percent), sanidine (31 percent), quartz (4 percent), biotite (5 percent), opaque oxides (3 percent) and traces of zircon. Also contains 13 percent fragments of lighter-brown (5YR 5/6), dark-yellowish-brown (10YR 4/2), and olive-black (5Y 2/1) silicic volcanic rock and moderate-reddish-brown (10R 4/6) mudstone. Contains less than 1 percent calcite. Base of interval located on the basis of drill-bit cuttings.
926-939 (3,035-3,080)	13 (45)	Tuff; ash-flow, pale-yellowish-brown (10YR 6/2), zeolitized (analcime), nonwelded to partially welded. Contains abundant argillized white (N9), very pale orange (10YR 8/2), and grayish-pink (5R 8/2) pumice. Phenocrysts are approximately 10 percent of rock volume and consist of equal amounts of plagioclase and sanidine (45 percent each) with quartz (3 percent), biotite (5 percent), and opaque oxides (2 percent). Also contains approximately 7 percent fragments of moderate-brown (5YR 4/4), moderate-olive-brown (5Y 4/4), light-brown (5YR 5/6), medium dark gray (N4), and grayish-purple (5P 4/2) silicic volcanic rock and pale-reddish-brown (10R 5/4) and dark-reddish-brown (10R 3/4) mudstone. Base of interval located on the basis of drill-bit cuttings and density, velocity, and spectral gamma ray (potassium) logs.

939-952 (3,080-3,120)	13 (40)	Tuff; ash flow, pale-red (5R 6/2), zeolitized, partially welded. Contains abundant argillized white (N9), grayish-pink (5R 8/2), very pale orange (10YR 8/2), and dark-yellowish-green (10GY 4/4) pumice. Phenocrysts are approximately 10 percent of rock volume and consist of subequal amounts of plagioclase and sanidine (42 percent each), biotite (6 percent), opaque oxides (3 percent), hornblende (1 percent), and quartz (6 percent). Also contains approximately 7 percent fragments of grayish-red (5R 4/2), moderate-brown (5YR 3/4), dusky red (5R 3/4), and medium dark gray (N4) silicic volcanic rock. Base of interval located on the basis of drill-bit cuttings and density, velocity, and spectral gamma ray (potassium) logs.
952-1,013 (3,120-3,320)	61 (200)	Tuff; ash-flow, grayish-red (5R 4/2), zeolitized (analcime and sparse clinoptilolite), partially welded. Contains argillized, zeolitized pumice, which is commonly white (N9), less commonly moderate-yellowish-green (10GY 6/4), and least commonly moderate-orange-pink (5YR 8/4). Phenocrysts are 9 to 12 percent of the rock volume and consist of plagioclase (49 to 57 percent), sanidine (28 to 30 percent), quartz (7 to 12 percent), biotite (4 to 7 percent), opaque oxides (2 percent), and traces of zircon and apatite. Also contains 3 to 6 percent fragments of moderate-reddish-brown (10R 4/6), pale-reddish-brown (10R 5/4), grayish-red (10R 4/2), and blackish-red (5R 2/2) silicic volcanic rock and 1 percent calcite. Base located on the basis of drill-bit cuttings.
		----Fault(?)--- Sheared zone on television camera log.
1,013-1,032 (3,320-3,385)	19 (65)	Tuff; ash-flow, dark-reddish-brown (10R 3/4), zeolitized, partially welded. Commonly contains argillized very light gray (N8) and a moderate-orange-pink (10R 2/4) pumice. Phenocrysts are 10 percent of rock volume and consist of plagioclase (53 percent), sanidine (31 percent), quartz (9 percent), biotite (5 percent), opaque oxides (2 percent), and traces of zircon, apatite, and hornblende(?). Also contains 5 percent fragments of pale-yellowish-brown (10YR 6/2), dark-yellowish-brown (10YR 4/2), and light-olive (10Y 5/4) silicic volcanic rocks and less than 1 percent calcite. Base of interval approximately located on the basis of drill-bit cuttings and density [event at 1,032 m (3,385 ft)], velocity [event from 1,032 to 1,034 m (3,385 to 3,390 ft)], induction [event at 1,034 m (3,390 ft)], electric [event at 1,034 m (3,390 ft)], and neutron [event at 1,032 m (3,385 ft)] logs.

1,032-1,043 (3,385-3,420)	11 (35)	Tuff; ash flow, pale-olive (10Y 6/2), zeolitized, partially welded. Contains argillized white (N9), very light gray (N8), and pale-greenish-yellow (10Y 8/2) pumice. Phenocrysts are approximately 10 percent of rock volume and consist of subequal amounts of plagioclase and sanidine (40 percent each), quartz (10 percent), and biotite (10 percent). Also contains approximately 5 percent fragments of dusky brown (5YR 2/2), moderate-yellowish-brown (10YR 5/4), moderate-reddish-brown (10R 4/6), and medium dark gray (N4) silicic volcanic rock. Base of interval located on the basis of drill-bit cuttings.
1,043-1,064 (3,420-3,488)	21 (68)	Tuff; ash-flow, pale-olive (10Y 6/2), zeolitized (analcime) and albitized, partially welded. Commonly contains fragments of pale-yellowish-green (10GY 7/2) pumice, which generally are 0.5 to 1.5 cm in diameter; some pumice is argillized and unflattened; also contains some argillized, strongly flattened dusky blue (5PB 3/2) pumice fragments as long as 4 cm. Phenocrysts are 7 percent of rock volume and consist of sanidine (18 percent), plagioclase (70 percent), quartz (3 percent), biotite (4 percent), opaque oxides (5 percent), and traces of zircon. Also contains 11 percent fragments of moderate-brown (5YR 3/4), grayish-brown (5YR 3/2), dusky-yellowish-brown (10YR 2/2), moderate-reddish-brown (10R 4/6), and very dusky red (10R 2/2) silicic volcanic lithic fragments, which are generally less than 1.0 cm in diameter. Base of interval located on the basis of velocity, induction and television camera logs.
		Bedded Tuff
1,064-1,068 (3,488-3,502)	4 (14)	Tuff; bedded/reworked/ash-flow(?). Unit evident on velocity, induction, and television camera logs but not evident in drill-bit cuttings.

OLDER TUFFS OF USW-G1

Unit A

1,068-1,095 (3,502-3,590)	27 (88)	Tuff; ash-flow, pale-reddish-brown (10R 5/4), devitrified, sparse zeolitization (analcime) in upper part and sparse authigenic albite, partially to moderately welded. Commonly contains slightly argillized very light gray (N8) pumice. Phenocrysts are 18 percent of rock volume and consists of sanidine (approximately 50 percent), quartz (25 percent),

		plagioclase (20 percent), a few percent biotite and opaque oxides. Also contains less than 1 percent fragments of grayish-red-purple (5RP 4/2) and grayish-red (10R 4/2) silicic volcanic rocks. Base of interval approximately located on the basis of drill-bit cuttings.
1,095-1,101 (3,590-3,610)	6 (20)	Tuff; ash-flow, pale-olive (10Y 6/2), devitrified, argillized, albitized, nonwelded to partially welded. Contains abundant argillized white (N9), grayish-orange-pink (10R 8/2), and pale-green (5G 7/2) pumice. Phenocrysts are 15 percent of rock volume and consist of plagioclase (40 percent), sanidine (28 percent), quartz (27 percent), opaque oxides (3 percent), biotite (2 percent), and traces of zircon. Also contains 4 percent fragments of moderate-reddish-brown (10R 4/6) and blackish-red (5R 4/2) silicic volcanic rocks and less than 1 percent calcite. Base of interval located on the basis of drill-bit cuttings and all geophysical logs.
		Unit C
1,101-1,139 (3,610-3,733)	38 (123)	Tuff; ash-flow, light-gray (N7), argillized and calcitized, partially welded. Contains sparse very light gray (N8) and pale-green (5G 7/2) pumice. Phenocrysts are 16 to 22 percent of rock volume and predominantly consist of plagioclase with biotite (10 percent), a few percent each of sanidine, quartz, and opaque oxides, and traces of hornblende(?), zircon and apatite. Also contains 8 to 12 percent fragments of grayish-red-purple (5RP 4/2), moderate-brown (5YR 3/4), and medium dark gray (N4) silicic volcanic rock and approximately 5 percent calcite. Base of interval located on the basis of drill-bit cuttings and all geophysical logs.
		CONGLOMERATE
1,139-1,150 (3,733-3,770)	11 (37)	Conglomerate. Consists of clasts of gray carbonate, sandstone, siltstone, argillite, ash-flow tuff, and altered ash-flow tuff in a matrix of claystone. Base of interval located on the basis of drill-bit cuttings.
1,150-1,159 (3,770-3,800)	9 (30)	Conglomerate. Consists of clasts of argillite, gray carbonate rock, and altered grayish-green (5G 5/2) volcanic rocks in a chloritized(?) claystone matrix. Clasts of volcanic rock are more angular than the sedimentary rock clasts. Base of interval located on the basis of drill-bit cuttings.

1,159-1,172 (3,800-3,844)	13 (44)	Conglomerate. Consists of clasts of light- to and dark-gray carbonate rocks argillite, sandstone/siltstone, ash-flow tuff, and altered ash-flow tuff in matrix of claystone. Base of interval located on the basis of drill-bit cuttings and all geophysical logs.

CALCIFIED ASH-FLOW TUFF

1,172-1,196 (3,844-3,921)	24 m (77)	Tuff; ash-flow, light-brownish-gray (5YR 6/1), devitrified, partially welded, extensive carbonate alteration. Commonly contains pale-green (10G 8/2) to pale-green (5G 7/2) argillized pumice as long as 1.5 cm (some pumices are flattened, and the planes of flattening are inclined between 75^{0} and 90^{0} to the core axis but define no constant foliation). Phenocrysts are 1 percent of rock volume and consist of calcite pseudomorphs after plagioclase(?) (39 percent), sanidine (28 percent), quartz (22 percent), "bleached" biotite (6 percent), opaque oxides and traces of sphene pseudomorphs and zircon. Also contains less than 1 percent subrounded to angular fragments of light-brown (5YR 6/4), dusky brown (5YR 2/2), and moderate-reddish-orange (10R 6/6) silicic volcanic rock. Contains 7 percent calcite. Base of interval located on the basis of drill-core and gamma ray log.
1,196-1,205 (3,921-3,950)	9 m (29)	Tuff; ash-flow, light-gray (N7), strongly calcified, partially welded. Commonly contains white (N9), argillized, unflattened pumice less than 2 mm in diameter and less common medium light gray (N6), argillized, flattened pumice as long as 8 cm. Phenocrysts are 2 percent of rock volume and consist of quartz, opaque oxides, sanidine, calcite pseudomorphs after plagioclase and traces of sphene. Also contains 4 percent subangular to angular fragments of medium light gray (N6), dark-gray (N3) and grayish-black (N2) carbonate rock and mudstone, which are less than 0.5 cm in diameter; contains more than 50 percent calcite.

TUFF OF YUCCA FLAT(?)

1,205-1,244 (3,950-4,080)	39 (130)	Tuff; ash-flow, pale-red (5R 6/2), moderately welded. Commonly contains white (N9), partially arigillized pumice. Phenocrysts are 10 to 13 percent of rock volume and consist of plagioclase (32 to 50 percent), quartz (24 to 30 percent), sanidine (20 to 28 percent), biotite (4 to 9 percent), pseudomorphs of mafic minerals (2 percent), and 1 percent opaque oxides. Also contains 6 to 11 percent fragments of dusky brown (5YR 2/2), moderate-brown (5YR 4/4), and grayish-red-purple (5RP 4/1) silicic volcanic rock including spherulitic rhyolite; abundance of volcanic rock fragments increases with greater depth. Base of interval located on the basis of drill-bit cuttings and porosity, density, and temperature logs.
		---Fault---

LONE MOUNTAIN DOLOMITE

1,244-1,278 (4,080-4,191)	34 (111)	Dolomite; light- olive-gray (5Y 6/1) dry, olive-gray (5Y 4/1) wet, non-bedded to poorly bedded, aphanitic to very finely crystalline, moderately to strongly brecciated[1]. Veinlets of dolomitic rock flour commonly form breccia matrix and fracture fillings; open vugs and vugs partially or completely filled with sparry dolomite are common along fracture surfaces and boundaries of breccia clasts. Also contains sparse stylolites oriented to 50°to 90° from the core axis (bit cuttings to 4,185 ft, core from 4,185.3 ft to base of interval).
1,278-1,279 (4,191-4,195)	1 (4)	Dolomite; very-light-gray (N8) to light-gray (N7) dry, medium-light-gray (N6) wet, non-bedded to poorly bedded, pelloidal (oval-shaped pellets as much as 3 to 4 mm in diameter), slightly brecciated. Commonly fractured with openings as large as 1 cm x 0.5 cm x 0.1 cm along fractures; slickensides observed on one fracture surface (cored).
1,279-1,285 (4,195-4,214)	6 (19)	Dolomite; very-light-gray to (N8) to yellowish-gray (5Y 8/1) dry, light-olive-gray (5Y 6/1) to light-gray (N7) wet, non-bedded to poorly bedded, finely crystalline, slightly to intensely brecciated (intense brecciation in 10 to 20 percent of core). Fractures inclined 60° to 90° from the core axis

1244
40

1807
1244
563

		common throughout interval; fracture with slickensides at 1,283 m (4,208 ft). Sparse stylolites inclined 70° to 90° from the core axis generally truncate fractures. Vugs as large as 2 cm x 0.5 cm x 0.05 cm common and are filled with laminated silty (?) dolomite locally [1,285 m (4,212 ft)]. Anastomosing veinlets of white calcite common.
1,285-1,303 (4,214-4,273)	18 (59)	Drilled interval. Cuttings contaminated; approximately 70 percent of cuttings are volcanic rocks from higher in the drill hole, 30 percent of cuttings are dolomite.
1,303-1,314 (4,273-4,308)	11 (35)	Dolomite; very-light-gray (N8) dry, light-olive-gray (5Y 6/1) wet, non-bedded to poorly bedded, finely to medium crystalline; moderately to intensely brecciated (approximately 90 percent of interval moderately to strongly brecciated. Zones of intense brecciation occur near fractures inclined 0° to 30° from core axis). Contains irregular clots and abundant anostomosing veinlets of white calcite and dolomite. Faint pellets occur at 1,309 m (4,291 ft) (cored).
1,314-1,317 (4,308-4,318)	3 (10)	Dolomite, fine- to medium-grained, light-olive-gray (5Y 6/1) to brownish-gray (5YR 4/1). Sparse brecciated material (drilled).

DESCRIPTIONS FOR INTERVAL 1,316.1 TO 1,500.8 m (4,318.0 to 4,924.0 ft) ON BASIS OF CORE

1,317-1,329 (4,318-4,356)	12 (38)	Dolomite; very-light-gray (N8) dry, medium-light-gray (N6) wet, non-bedded to poorly bedded, finely to medium crystalline; slightly to intensely brecciated. Intense brecciation occurs in discrete zones as much as several centimeters wide along fractures. Sparse 5 mm x 1 mm vugs filled with sparry calcite occur throughout interval, generally along fractures. Core commonly broken along mineralized fractures. Faintly developed stylolites are common and are oriented between 20° and 40° from the core axis.
1,329-1,333 (4,356-4,370)	4 (14)	Dolomite; white (N9) to very-light-gray (N8) dry, very-light-gray (N8) wet, non-bedded, aphanic to finely crystalline, strongly to intensely brecciated. Commonly as much as 80 percent of breccia consists of secondary matrix and breccia clasts, generally are less than 0.5 mm in diameter. Core commonly splits along steeply dipping mineralized fractures; stylolites oriented between 10° and 45° from the core axis are common and in many instances bound intervals with contrasting degrees of brecciation.
1,333-1,338	5	Dolomite; medium-light-gray (N6) dry, to medium-gray (N5) wet, mottled,

(4,370-4,386)	(16)	non-brecciated to moderately brecciated. Sparse steeply dipping fractures. Stylolites oriented 80° to 90° from core axis are common. Discontinuous veinlets less than 0.5 mm long of white dolomite occur thoughout interval.
1,338-1,347 (4,386-4,415)	9 (29)	Dolomite; medium-light-gray (N6) to medium-gray (N5) dry, medium-gray (N5) wet, mottled, non-bedded, finely to medium crystalline, slightly to intensely brecciated. Less than 10 percent of core is intensely brecciated, and intense brecciation is confined to several discrete zones between 1,342 and 1,346 m (4,400 and 4,415 ft), which commonly are bounded by fractures. Irregular masses and veinlets of white dolomite are common throughout interval. Stylolites are common and typically are gently dipping.
1,347-1,354 (4,415-4,438)	7 (23)	Dolomite; very-light-gray (N8) to light-gray (N7) dry, light-gray (N7) to medium light gray (N6) wet, non-bedded to poorly bedded, faint layering oriented 60° to 70° from core axis, very finely crystalline, non-brecciated to slightly brecciated with several discrete zones of intense brecciation. Commonly contains vugs and veins filled with calcite.
1,354-1,376 (4,438-4,511)	22 (73)	Dolomite; medium-light-gray (N6) to medium-gray (N5) dry, medium-gray (N5) wet, non-bedded, medium crystalline, strongly to intensely brecciated with several zones of slight to moderate brecciation. Vugs as large as 2 cm x 1.5 cm x 1 cm are moderately common and preferentially occur along fractures; calcite commonly fills fractures; blebs and veins of white sparry dolomite comprise 25 percent of rock. Contains sparse stylolites.
1,376-1,379 (4,511-4,522)	3 (11)	Dolomite; very-light-gray (N8) dry, medium-light-gray (N6) wet, non-bedded, finely to medium crystalline, intensely brecciated. Contains several fractures oriented approximately 70° from the core axis and having slickensides in the direction of dip. Vugs are sparse. Stylolites are common and have both gentle and steep dips.
1,379-1,381 (4,522-4,527)	2 (5)	Dolomite; light-gray (N7) dry, medium-light-gray (N6) wet, non-bedded, medium crystalline, slightly to moderately brecciated. Fractures common and generally are steeply dipping. Vugs as large as 3 cm x 2 cm x 1 cm are common.
1,381-1,381 (4,527-4,529)	0 (2)	Dolomite; light-olive-gray (5Y 6/1) to olive-gray (5Y 4/1) dry or wet, non-bedded, medium crystalline, strongly brecciated with several zones of intense brecciation. Commonly contains vugs as large as 1 cm x 1 cm x 0.5 cm. Stylolite at base of interval separates intervals contrasting in intensity of brecciation.

1,381-1,386 (4,529-4,544)	5 (15)	Dolomite; light-gray (N7) to medium-light-gray (N6) dry or wet, non-bedded, very finely to medium crystalline, moderately to strongly brecciated with several zones of intense brecciation. Commonly contains steeply dipping fractures filled by 0.2 to 0.3 cm thick veins of carbonate rock flour. Vugs as large as 2 cm x 1 cm x 0.5 cm occur throughout interval and generally are lined with sparry dolomite.
1,386-1,389 (4,544-4,554)	3 (10)	Dolomite; dark-gray (N3) to medium-light-gray (N6) dry or wet, non-bedded, finely to medium crystalline, sightly to moderately brecciated, fractured. Contains anastomosing veinlets of white sparry dolomite as fracture and vug filling; vugs generally are approximately 1 cm x 1 cm x .5 cm and occur throughout interval. Contains poorly preserved pelmatozoan(?) debris. Possible chert nodule at 1,386.1 m (4,544.5 ft).
1,389-1,392 (4,554-4,565)	3 (11)	Dolomite; very-light-gray (N8) to medium-light-gray (N6) dry or wet, non-bedded, very finely to medium crystalline, moderately to strongly brecciated with zones of slight and intensely brecciated rock. Commonly contains fractures that separate intervals having contrasting degrees of brecciation and that are filled with white carbonate-rock flour. Commonly contains stylolites. Vugs are sparse and typically are coated with sparry dolomite.
1,392-1,394 (4,565-4,571)	2 (6)	Dolomite; very-light-gray (N8) to medium-light-gray (N6) dry and wet, non-bedded, very finely to medium crystalline, strongly to intensely brecciated. Fractures oriented 10° to 30° from core axis are common; white carbonate rock flour occurs along fractures, which separate intervals having contrasting degrees of brecciation. Vugs are sparse.
1,394-1,397 (4,571-4,579	3 (8)	Dolomite; light-gray (N7) dry, medium-gray (N6) to brownish-gray (5YR 4/1) wet, non-bedded to poorly bedded with faint color banding near 1,394 m (4,572 ft), finely to medium crystalline, slightly to intensely brecciated. Commonly contains fractures and discrete zones of intensely brecciated rock oriented approximately 20° from core axis. Commonly contains anatomosing veinlets of carbonate rock flour. Sparse vugs are coated with sparry dolomite.
1,397-1,407 (4,579-4,612)	10 (33)	Dolomite; very-light-gray (N8) to medium-light-gray (N6) dry or wet, non-bedded to poorly bedded, non-brecciated to moderately brecciated with several discrete zones of strongly to intensely brecciated rock. Commonly contains fractures oriented approximately 20° from core axis.

1,407-1,416 (4,612-4,642)	9 (30)	Dolomite; medium-dark-gray (N8) to medium-light-gray (N6) dry or wet, non-bedded, intensely brecciated. Fractures are steeply dipping and contain veins of carbonate rock flour. Contains sparse stylolites.
1,416-1,435 (4,642-4,704)	19 (62)	Dolomite; medium-dark-gray (N4) to dark-gray (N3) dry, medium-gray (N5) to grayish-black (N2) wet, non-bedded to poorly bedded with intervals of possible conglomerate or sedimentary breccia at 1,423 m and 1,433 m (4,664 and 4,698 ft) and faint layering at 1,432 m (4,696 ft), very finely to medium crystalline, non-brecciated to strongly brecciated with several discrete zones of intense brecciation. Commonly contains steeply dipping fractures throughout interval; some low-angle (oriented more than 80° from core axis) fractures coated with clay gouge occur in the lower 12m (40 ft) of interval; vugs as large as 1 cm x 1 cm x .5 cm occur along fractures; some fractures filled by secondary dolomite; some fracture surfaces marked by slickensides. Irregular masses of white sparry dolomite a few millimeters in diameter are common. Contains poorly preserved pelmatozoan(?) debris. Contains sparse stylolites.
1,435-1,476 (4,704-4,840)	41 (136)	Dolomite; light-gray (N7) to medium-gray (N6) wet, very light gray (N8) to light-gray (N7) dry with dark-gray (N3) to grayish-black (N2) bands approximately two meters thick, non-bedded to poorly bedded [intervals of possible intraforamational conglomerate at 1,436 m (4,708 ft) and several intervals of faint layering from 1,436 to 1,458 m (4,708 to 4,780 ft)], finely to medium crystalline, non-brecciated to strongly brecciated in intervals in lower 18 m (60 ft). Brecciated zones are separated from unbrecciated zones by fractures. Commonly contains anatomosing veinlets of calcite. Fractures commonly mineralized with calcite. Contains sparse vugs increasing in abundance near base of interval. Sparse stylolites with irregular orientation.
1,476-1,479 (4,840-4,848)	3 (8)	Dolomite; medium-gray (N5) wet, medium-light-gray (N6) dry, non-bedded, medium crystalline. Sedimentary breccia with subangular clasts, as much as 3 cm in length, of light-brownish-gray (5YR 6/1) and light-gray (N7) dolomite in a matrix of medium-gray (N5) dolomite. Commonly contains fractures oriented more than 80° from core axis. Commonly contains stylolites. Breaks usually occur along fractures or stylolites and commonly are coated with medium dark gray (N4) clay gouge. Vugs are common between 1,479 m and 1,480 m (4,848 and 4,851 ft) and typically are partially filled with calcite.

1,479-1,502 (4,848-4,924)	23 (76)	Dolomite; medium-gray (N5) to medium-light-gray (N6) wet, medium-light-gray (N6) to light-gray (N7) dry, non-bedded, medium crystalline, non-brecciated to strongly brecciated with several discrete zones of intense brecciation. Some of the brecciated zones at the top and bottom of this interval may be tectonically disrupted sedimentary breccias or conglomerates. Steeply dipping fractures are common. Vugs are uncommon, but where they occur they cut fractures or separate breccia zones.
1,502-1,502 (4,924-4,925)	0 (1)	Drilled interval, no sample.

DESCRIPTIONS FOR INTERVAL 1,501 TO 1,798 m (4,925 to 5,900 ft) ON BASIS OF BIT CUTTINGS

1,502-1,580 (4,925-5,180)	78 (255)	Dolomite; medium-light-gray (N6) dry, medium crystalline. Contains sparse brecciated material. Also contains white opaque, secondary calcite (possibly as fracture coatings), calcite coatings contain slickensides in some samples. Contains sparse vugs with sparry calcite filling.
1,580-1,610 (5,180-5,280)	30 (100)	Dolomite; medium-dark-gray (N4) dry, finely to medium crystalline. Contains sparse to moderate amounts of brecciated material. Also contains sparse secondary calcite and rare pyrite.
1,610-1,668 (5,280-5,470)	58 (190)	Dolomite; light-gray (N7) to medium-dark-gray (N4) dry, predominantly medium-gray (N5), finely to medium crystalline. Contains sparse brecciated material. Also contains sparse secondary calcite.

ROBERTS MOUNTAIN FORMATION

(GRADATIONAL CONTACT FROM 1,653 to 1,688 m (5420 to 5,536 ft)

1,668-1,678 (5,470-5,500)	10 (30)	Dolomite; medium-dark-gray (N4) dry, finely to medium crystalline. Contains sparse brecciated material. Also contains sparse secondary calcite
1,678-1,693 (5,500-5,550)	15 (50)	Dolomite; dark gray (N3) dry, finely crystalline. Contains abundant brecciated material. Pyrite and flourite common in sample from 1,687 to 1,690 m (5,530 to 5,540 ft). Also contains sparse secondary calcite.
1,693-1,711 (5,550-5,610)	18 (60)	Dolomite; dark-gray (N3) dry, finely crystalline. Contains sparse brecciated material. Also contains sparse pyrite, flourite, and secondary calcite.

1,711-1,748 (5,610-5,730)	37 (120)	Dolomite; dark-gray (N3) to grayish-black (N2) dry, finely crystalline. Contains no brecciated material, but contains sparse to moderate secondary calcite.
1,748-1,800 (5,730-5,900)	52 (170)	Dolomite; grayish-black (N2) dry, finely crystalline. Contains no brecciated material. Contains sparse secondary calcite and grayish-black (N2) to black (N1) chert. Sparse slickensides occur in samples from 1,748 to 1,759 m (5,730 to 5,750 ft).

DESCRIPTIONS FOR INTERVAL FROM 1,798 to 1,895 m (5,900 to 5,923.0 ft) ON BASIS OF CORE

1,800-1,806 (5,900-5,922)	6 (22)	Dolomite; dark-gray (N3) dry, black (N1) wet, very finely crystalline, laminated (laminae oriented 70^{0} from core axis), non-brecciated. Contains black (N1) chert layers as much as 2 cm thick inclined 70^{0} from core axis. Also contains disrupted layering.
1,806-1807 (5,922-5,923)	1 (1)	Dolomite; mottled, black (N1) and dark-gray (N3), medium crystalline. Commonly contains wavy mottled laminae. Also contains poorly preserved pelmatozoan debris, sparse breccia, and fractures. Breccia clasts commonly surrounded by calcite. Anastomosing veinlets of calcite are common.

---

[1] Definition of relative adjectives modifying the degree of brecciation as used in this appendix

Intense: Clasts from <1 mm to 2 mm (average size <5 mm); clasts supported by secondary matrix of rock flour; matrix as much as 50 percent of rock volume.

Strong: Clasts generally larger than 1 cm in diameter (average 1.0 to 1.5 cm); secondary matrix approximately 10 percent of total rock volume.

Moderate: Clasts larger than 2 cm in diameter; matrix less than (5 percent of total rock volume).

Slight: Strongly fractured but discsrete clasts not developed; no secondary matrix.]

APPENDIX III.

List of conodont faunas from drill hole UE25p#1

Depth of sample below drill hole collar meters (feet)	U.S.G.S collection number	Description of fauna
1802.8 to 1803.8 (5911.0 to 5914.0)	19776-SD	

Three feet of core rubble of fine-grained grayish-black weakly brecciated dolomite. 5.32 kg of dolostone was processed for conodonts (394 g of +20 mesh insoluble residue) and yielded:

3 Pa elements of KOCKELELLA AMSDENI Barrick
1 Pa elements of KOCKELELLA VARIABILIS Walliser

OULODUS sp. indet.
2 Pa elements
1 Pb element

OZARKODINA EXCAVATA EXCAVATA (Branson & Mehl)
32 Pa elements
15 Pb elements
15 M elements
27 Sa elements
13 Sb elements
47 Sc elements

3 Pa elements of OZARKODINA SAGITTA BOHEMICA (Walliser)
1 PANDERODUS UNICOSTATUS Branson & Mehl
3 PSEUDOONEOTODUS BECKMANNI (Bischoff & Sannemann)
2 PSEUDOONEOTODUS BICORNIS Drygant

PTEROSPATHODUS AMORPOGNATHOIDES Walliser
1 Pa elements
2 Pb elements
1 Sb elements

4 Pa elements of PTEROSPATHODUS CELLONI (Walliser)
458 WALLISERODUS sp. elements
238 indet. bar, blade, platform, and simple cone elements

This sample contains conodonts of several late Early, Middle, and early Late Silurian conodont zones mixed together. In its type locality and most other places, the base of the Roberts Mountains Formation begins in the latest Llandovery (in the AMORPHOGNATHOIDES Zone). The youngest conodonts in this sample, representatives of KOCKELELLA VARIABILIS, indicate the sample is no older than the CRASSA Zone (earliest Ludlow) and probably no younger than the SILURICUS Zone (late Ludlow). Conodonts from higher in the drill hole are all of Ludlovian or Pridolian age.

At its type locality in the Roberts Mountains, KOCKELELLA VARIABILIS first occurs 206 m (675 ft) above the base of the Pete Hanson Creek II section of Klapper and Murphy (1974). Rocks of this age (Ludlow) first occur at 56 m above the base of the Hidden Valley Dolomite (56 m (184 ft) above top of Ely Springs Dolomite) at a section collected by A. G. Harris and J. McAllister in the NW 1/4 sec. 10, T.3E., R.26N., Ryan 15-min. quadrangle, Inyo County California.

Age: No older than CRASSA and probably no younger than SILURICUS Zone (equivalent to Ludlovian or early Late Silurian)
CAI*=3 (indicating host rock reached 140° to 180°C).

1802.3 to 1802.6 (5909.3 to 5910.1) — 10815-SD

Thinly bedded fine-grained dark-gray dolostone. 1.2 kg of rock processed for conodonts (82 g of +20 mesh insoluble residue) and yielded:

OZARKODINA EXCAVATA EXCAVATA (Branson and Mehl)
1 Pa, 1 Sa, 2 Sc elements
6 indet. bar fragments

Conodonts from samples above and below this level in the drill hole restrict the age of this sample to the Late Silurian (OZARKODINA EXCAVATA EXCAVATA ranges from the early Wenlockian through Emsian--from base of Middle Silurian to near top of Early Devonian).

AGE: Late Silurian
CAI=3 (indicating host rock reached 140° to 180°C).

1622.6 to 1625.7 (5320.0 to 5330.0) — 10777-SD

Cuttings of medium- to dark-gray fine-grained dolomite. 3.8 kg of cuttings was processed (46 g of +20 mesh insoluble residue) and yielded:

1 Sc element of OULODUS sp. indet.

OZARKODINA EXCAVATA EXCAVATA (Branson & Mehl)
4 Pa elements
1 Pb element
5 Sa elements
2 Sc elements

* CAI is the abbreviation for Color Alteration Index of conodonts as defined by Epstein and others (1977). Epstein and others have interpreted color alteration of conodonts as a function of the maximum temperature reached by the host rock during its metamorphic history and have experimentally determined temperature ranges for various stages of color alteration, which is classified by the Color Alteration Index (CAI).

9 PANDERODUS spp. elements
40 indet. bar, blade, platform and simple cone fragments

OZARKODINA EXCAVATA EXCAVATA is one of the most common Middle and Late Silurian conodont species but ranges through the Lower Devonian as well. The age of this collection can be restricted to the Late Silurian, however, on the basis of conodonts from sub- and suprajacent samples.

Age: Late Silurian (correlative with unit D or E of dolomite of Spotted Range)
CAI=3 (indicating host rock reached 140° to 180°C).

1598.2 to 1601.3 10778-SD
(5240.0 to 5250.0)

Cuttings of medium- to dark-gray fine-grained dolostone. 4.9 kg of cuttings was processed (53 g of +20 mesh insoluble residue) and yielded:

OZARKODINA EXCAVATA EXCAVATA (Branson & Meho)
1 Sa element
1 Sb element

2 PANDERODUS UNICOSTATUS Branson & Mehl
6 indet. bar, blade and platform fragments

AGE: Late Silurian (based on conodonts in supra and sub-jacent samples); correlative with unit D or E of dolomite of Spotted Range.
CAI=3 (indicating host rock reached 140° to 180°C).

1494.5 to 1495.1
(4900.0 to 4902.0)

3.7 kg of core was processed (94 g of +20 mesh insoluble residue): NO CONODONTS WERE RECOVERED.

1458.8 to 1459.4 10779-SD
(4783.0 to 4785.0)

Core of medium- to dark-gray fine-grained dolostone. 3.5 kg of core was processed (78 g of +20 mesh insoluble residue) and yielded:

LIGONODINA? CONFLUENS Jeppsson
1 Pa element
1 Pb element
1 Sb? element
6 indet. bar, blade, and platform fragments

Age: Late Silurian (based on range of LIGONODINA? CONFLUENS)
CAI=3 (indicating host rock reached 140° to 180°C).

1423.1 10780-SD
(4666.0)

Fine-grained medium- to dark-gray dolostone. 3.7 kg of rock was processed (91 g of +20 mesh insoluble residue) and yielded:

OZARKODINA CONFLUENS (Branson & Mehl)
4 Pa elements
2 Sc elements

3 PANDERODUS UNICOSTATUS Branson & Mehl
12 indet. bar, blade, and platform fragments

OZARKODINA CONFLUENS is restricted to the Upper Silurian Ludlovian and Pridolian. Correlative with units D or E of the dolomite of the Spotted Range.

Age: Late Silurian
CAI=3 (indicating host rock reached 140° to 180°C).

1367.0 to 1367.6
(4482.0 to 4484.0)

Fine-grained medium- to dark-gray dolostone. 3.8 kg of core was processed (15 g of +20 mesh insoluble residue): NO CONODONTS WERE RECOVERED.

1319.1 to 1319.7 10781-SD
(4325.0 to 4327.0)

Fine-grained medium- to dark-gray dolostone. 2.9 kg of core was processed (117 g of +20 mesh insoluble residue) and yielded:

1 Pa element of OZARKODINA CONFLUENS (Branson and Mehl)
1 indet. bar fragment

AGE: Late Silurian; correlative with unit D or E of the dolomite of the Spoted Range
CAI=3 (indicating host rock reached 140° to 180°C).

APPENDIX IV.

Description of thin sections of Paleozoic rocks from drill hole UE25p#1

Depth of sample meters (feet)	Description
1283.9 (4209.6)	Medium crystalline dolomite. No allochems are recognizable. Dolomite varies from very cloudy to cloudy with some transparent coarsely crystalline patches. These patches may have been allochems recrystallized prior to dolomitization. Fractures are common and are filled with aphanocrystalline carbonate.
1308.6 (4290.7)	Sparse dolopelbiomicrite. Dolomite is unzoned, medium crystalline, generally cloudy, and mottled. Preserved allochems include pelletoids (as long as 1 mm), coral(?), and unidentified fossil fragments. Original matrix not recognizable. Fractures are common. Veins are rare and consist of carbonate and quartz.
1309.2 (4292.5)	Unsorted dolopelsparite. Dolomite ranges from medium to coarsely crystalline, cloudy to clear. Abundant preserved pelletoids are elipsoidal to round and range in diameter from 0.25 mm to 2 mm. Pelletiods are surrounded by relatively clear coarsely crystalline dolomite, suggesting that they were orginally cemented with sparry calcite.
1319.9 (4327.7)	Dolobiomicrite. Dolomite is medium crystalline and varies from clear to cloudy. Pelletoids, other allochems, and ghosts of allochems are outlined by micritic rims. Locally brecciated. Breccia clasts bounded by well developed stylolites, which are highlighted by opaque minerals. Sparse patches of quartz occur within fractures.
1329.0 (4357.5)	Strongly fractured and brecciated, medium-crystalline dolomite. Dolomite crystals typically are twinned and grain boundaries are sutured. No recognizable depositional textures are preserved. Breccia zones occurs along fractures and range from 0.25 mm to 4.0 mm in width. Anastomosing fractures are abundant, and commonly merge into breccia zones and fractures filled with breccia. Breccia clasts range from 0.1 mm to 5 mm and are enclosed by a matrix of cloudy very finely crystalline carbonate. Opaque minerals are distributed throughout the rock and compose less than 1% of the rock volume.

1335.9 (4379.9) Sparse dolobiopelmicrite with rare quartz grains. Dolomite is medium crystalline and generally cloudy and clotted. Ghosts of allochems, including pelletoids, crinoids(?), and unidentified fragments, are commonly outlined by micritic rims.

Stylolites and fractures are common. Stylolites are subparallel to one another, except where numerous stylolites and fractures occur together. Fractures are both truncated by and truncate stylolites.

1348 (4421) Sparse dolopelmicrite with sparse quartz grains. The only preserved allochems are pelletoids. The dolomite is medium crystalline, cloudy, and mottled. Fractures and stylolites are sparse.

1370a (4491a) Brecciated coarsely crystalline dolomite. Dolomite crystals are cloudy and twinned, with irregular (sutured) grain boundaries. Breccia clast range from minute (0.10 mm), angular, anhedral dolomite crystals to polycrystalline dolomite clasts as large as 10 mm in diameter. The martix is aphanocrystalline to very finely crystalline dolomite. Clasts greater than 2 mm in diameter are generally fractured. Fractures are commonly marked by a thin (0.3 mm) breccia zones. Stylolites are sparse.

1370b (4491b) Brecciated coarsely crystalline dolomite. Dolomite crystals are cloudy and twinned, with irregular (sutured) grain boundaries. Breccia clasts range from 0.10 mm, angular, anhedral, dolomite crystals to very-fine polycrystalline dolomite. Clasts greater than 2 mm in diameter are strongly fractured. Boundaries between larger clasts and matrix are sharp and commonly marked by concentrations of opaque minerals.

Fractures are very common. Well developed stylolites cut across the breccia truncating both clasts and matrix. A residue of opaque minerals as large as 0.5 mm thick highlights the stylolites. The abundant twinned grains; small, anhedral, angular dolomite grains in the matrix; and abundant fracturing in large clasts suggest that this is a tectonic breccia.

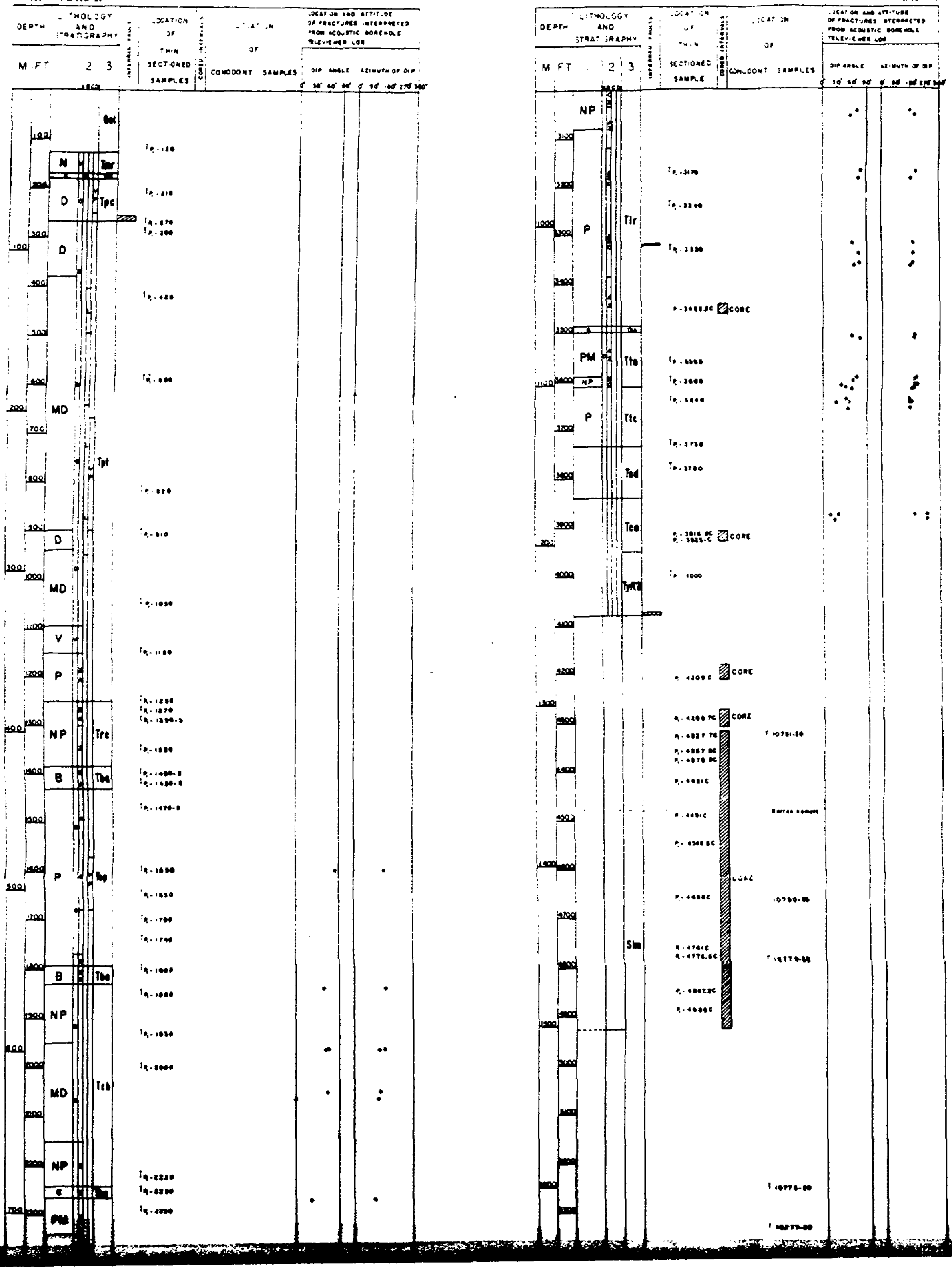
1387.3 (4548.5) Dolopelmicrite. Original micrite has been replaced by medium to coarse crystalline dolomite. Ghosts of allochems including pelletoids and possible fossil fragments are recognized by their micritic rims. Fractures are abundant as are moderately well developed stylolites.

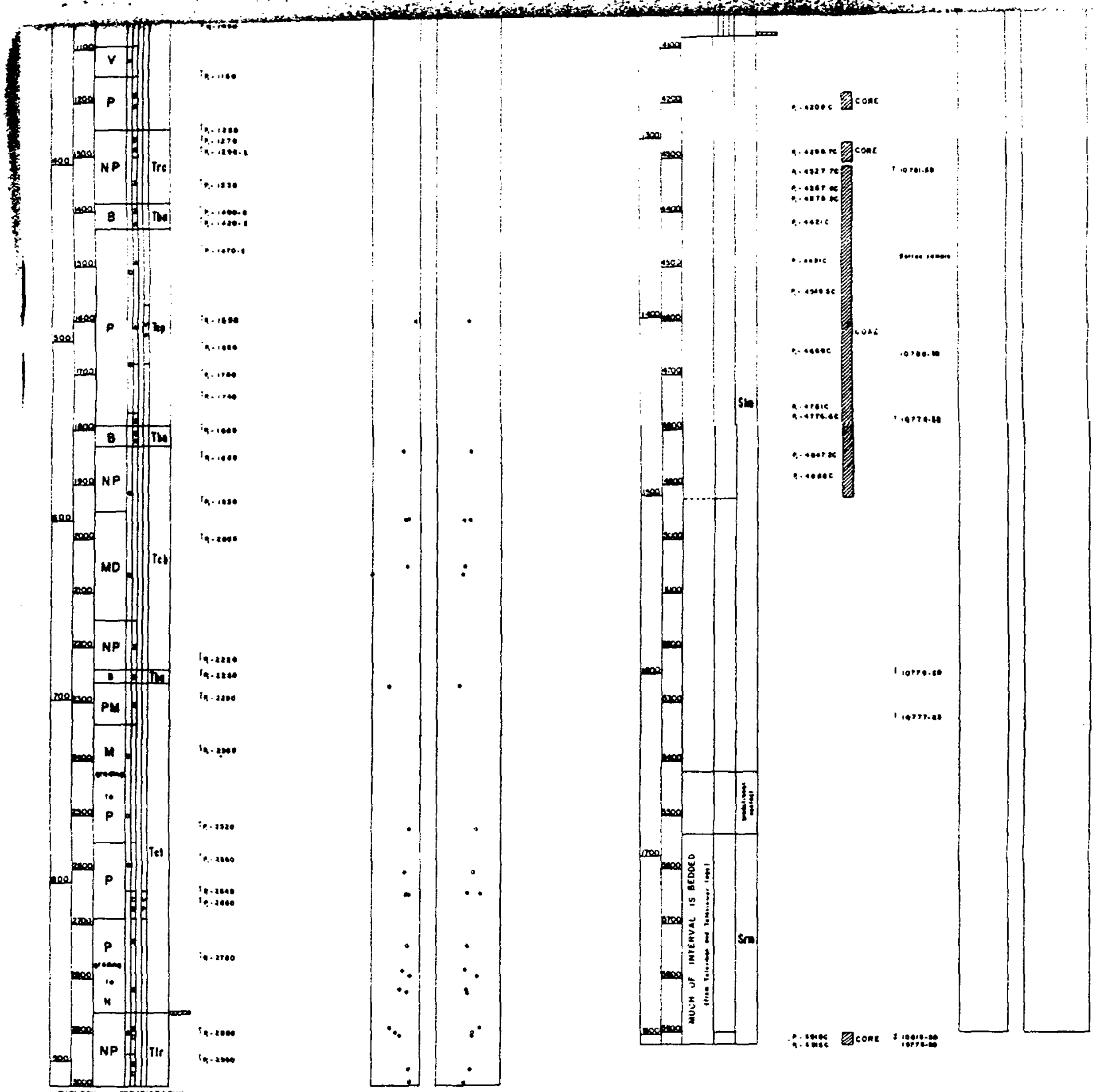
1421 (4660) Dolobiopelmicrite. Medium crystalline dolomite containing ghosts of pelletoids and possibly intraclasts(?). Dolomite generally is cloudy, but some ellipsoidal patches contain coarsely crystalline zoned dolomite rhombs that are clear to moderately cloudy. Fractures and stylolites are rare.

1452 (4761)	Medium crystalline dolomite with no recognizable allochems. Sedimentary layering is preserved. The dolomite is cloudy with clotted areas that may be replaced pelletoidal micrite. Dolomite rhombs are untwinned and unzoned. Stylolites are sparse and parallel layering.
1457.5 (4778.6)	Medium crystalline dolomite with no recognizable depositional features. Dolomite is clotted and cloudy suggesting that it replaced micrite. Fractures and stylolites are abundant (spaced every 3 to 5 mm). Stylolites both cut and are cut by fractures.
1478.4 (4847.2)	Coarse to medium crystalline dolomite, consisting of a medium-grained crystalline groundmass of cloudy, clotted dolomite enclosing patches of relatively clear, coarse, zoned dolomite rhombs. The rhombs are as large as 0.5 mm long and commonly have interpenetrating grain boundaries. Compositional layering is recognizable.
	Fractures highlighted by opaque minerals and orange hematite(?) cut rock in an anastomosing pattern.
1491 (4888)	Medium crystalline dolomite, with no recognizable depositional features. Dolomite is cloudy and clotted. Fractures and stylolites are sparse, and stylolites are poorly developed.
1803 (5910)	Sparse dolobiopelmicrite. Allochems include pelletoids, crinoids, and unidentified fossil fragments. Pelletoids are the most abundant allochem and are as large as 1 mm in diameter. The matrix consists of cloudy, clotted, fine- to medium-grained crystalline dolomite. Fine parallel lamination are preserved. Sparse stylolites are highlighted by concentrations of insoluble material and generally parallel layering. Fractures are rare.
1804 (5915)	Sparse dolobiopelmicrite. Allochems make up less than 1% of the total rock, and consist of unidentified fossil fragments (brachiopods?). Quartz grains are scattered throughout the matrix but constitute less than 1% of rock. Dolomite matrix is very finely to finely crystalline, cloudy, and clotted. Layering indicated by parallel laminations. Stylolites are common and parallel layering. Randomly oriented calcite veins are common and appear to be crosscut by the stylolites.

DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY

OPEN FILE REPORT 90-175
PLATE 1 of 1





LITHOLOGY and STRATIGRAPHY

(1) WELDED and BEDDED ZONES

N= Nonwelded
NP= Nonwelded to Partially Welded
P= Partially Welded
PM= Partially to Moderately Welded
M= Moderately Welded
MD= Moderately to Densely Welded
D= Densely Welded
V= Vitrophyre
B= Bedded
D/V= Partially Vitric

(2) PRIMARY CRYSTALLIZATION AND SECONDARY ALTERATION IN VOLCANIC SECTION

A. Crystallinity. V= Vitric, D= Devitrified
B. Alteration. A= Clay, Z= Zeolites, C= Calcite
C. Lithophysae. L= Zones Equal to Lithophysae
D. Vapor Phase. VP= Vapor Phase Crystallization Present

(3) STRATIGRAPHIC UNITS

Qal- Alluvium
Tmr- Rainier Mesa Member of the Timber Mountain Tuff
Tbe- Bedded Tuff
Tpc- Tiva Canyon Member of the Paintbrush Tuff
Tpt- Topopah Spring Member of the Paintbrush Tuff
Trc- Rhyolite of Calico Hills
Tcp- Prow Pass Member of the Crater Flat Tuff
Tcb- Bullfrog Member of the Crater Flat Tuff
Tct- Tram Unit of the Crater Flat Tuff
Tlr- Lithic Ridge Tuff
Tla- Older tuffs of drill hole USW-G1, unit a
Tlc- Older tuff of drill hole USW-G1, unit c
Tsd- Sedimentary deposits
Tca- Calcified ash-flow tuff
Ty(?)- Tuff of Yucca Flat(?)
Slm- Lone Mountain Dolomite
Srm- Roberts Mountain Formation

(4) LOCATION OF SAMPLES

^{T}P-270 Thin sectioned sample, dot indicates depth of sample from core, dot with bar indicates depth range of sample from drill bit cuttings, sample number indicates depth and letter suffix indicates type of sample (s= sidewall core, c= drill core, samples with no suffix are drill bit cuttings)

^{f}10776-SD Conodont sample, dot and bar symbols same as for thin section samples, sample number is U.S. Geological Survey Collection number and corresponds to fauna descriptions in appendix III. Collections are preserved at U.S. National Museum, Washington, D.C.

This report is preliminary and has not been reviewed for conformity with U.S. Geological Survey editorial standards and stratigraphic nomenclature

GRAPHIC LOG OF LITHOLOGIC FEATURES IN DRILL HOLE UE25P 1