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RESULTS OF THE EXPLORATORY DRILL HOLE Ue5n, FRENCHMAN FLAT, NEVADA TEST SITE

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FRENCHMAN FLAT, NEVADA TEST SITE

ABSTRACT

Exploratory hole Ue5n was drilled to a depth of 514 m in central Frenchman Flat, Nevada Test Site, as part of a program sponsored by the Nuclear Monitoring Office (NMO) of the Advanced Research Projects Agency (ARPA) to determine the geologic and geophysical parameters of selected locations with anomalous seismic signals. The specific goal of drilling Ue5n was to provide the site characteristics for emplacement sites U5b and U5e. We present here data on samples, geophysical logs, lithology and stratigraphy, and depth to the water table. From an analysis of the measurements of the physical properties, a set of recommended values is given.

INTRODUCTION

The exploratory hole Ue5n was drilled as part of a program sponsored by the Nuclear Monitoring Office (NMO) of the Advanced Research Projects Agency (ARPA) to determine the geologic and geophysical parameters of selected locations with anomalous seismic signals. The specific goal of drilling Ue5n was to provide the site characteristics for emplacement sites U5b and U5e.

LOCATION

Drill hole Ue5n is located about midway between holes U5b and U5e at Nevada state coordinates: N229,959.4 m; E215,315.3 m in Area 5 (Fig. 1). The ground elevation of the location is 948.60 m, and the hole was terminated at a depth of 514.2 m below the surface. This drill hole is in central Frenchman Flat; three of the ten underground nuclear tests in Frenchman Flat have been conducted nearby. The other seven have been in northern Frenchman Flat where other exploratory holes have been drilled. This is the only useful exploratory hole in central Frenchman Flat.

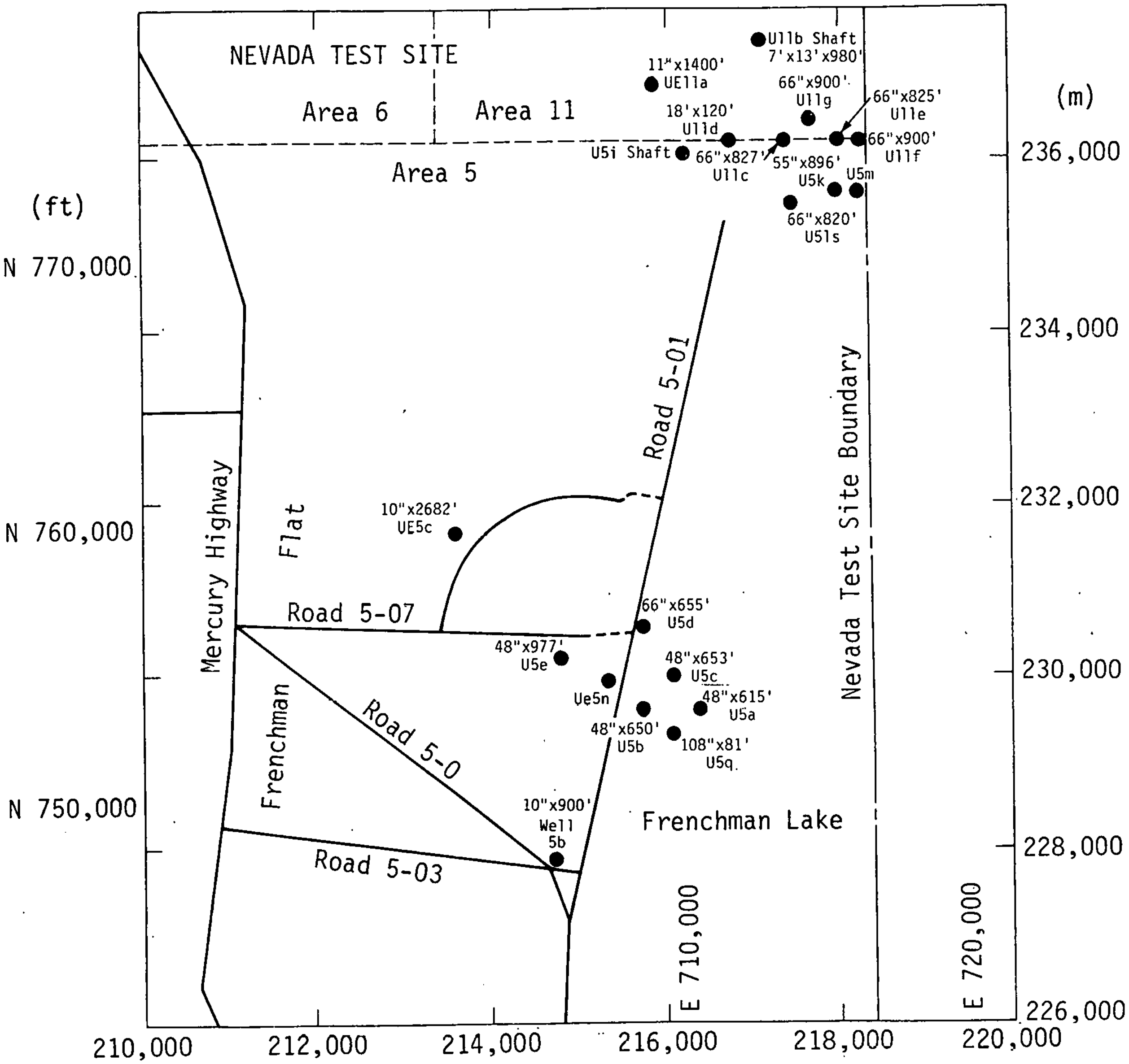

Fig. 1. Map of Frenchman Flat showing location of Ue5n and other drill holes.

SUMMARY DRILLING HISTORY

Appendix A gives an expanded drilling history. Exploratory hole Ue5n was planned as a 380-mm-diam hole to be drilled by using reverse circulation (mud/water with air assist) to a depth sufficient to penetrate ~30 m into Tertiary tuff. This depth was inferred to be 610 ± 122 m. Severe sloughing problems occurred below 450 m, and the maximum depth reached was 514 m.

Subsequent sloughing filled the hole to about 490-m depth. Repeated attempts to remove the fill were unsuccessful, and the hole was logged and sidewall sampled from 490 m to the surface. Then a string of 270-mm-o.d. casing was emplaced to 464.3 m. The purpose of this casing was to preserve access for use of a borehole gravimeter and, finally, to measure the water level.

SAMPLES

Standard cutting samples were taken at 3-m intervals from 25 to 514 m. In addition, Hunt sidewall samples were taken between 30.5 and 481.6 m (Table 1).

Four conventional core runs were made in the hole using the 190-mm Christiansen diamond bit and a 3.1-m rubber sleeve core barrel. Core recovery was as follows:

	Depth (m)	Recovery (m)
Core No. 1	191.1 - 197.2	2.1 (void spaces and undergauge section within rubber sleeve)
Core No. 2	293.2 - 293.8	0.6 plugged bit
Core No. 3	293.8 - 293.8	0 core barrel malfunction
Core No. 4	398.4 - 401.4	2.0 (undergauge sections within rubber sleeve)

Table 1. List of Hunt sidewall samples from Ue5n.

Sample depths					
(ft)	(m)	(ft)	(m)	(ft)	(m)
100	30.5	760	231.6	1360	414.5
125	38.1	780	237.7	1380	420.6
150	45.7	800	243.8	1400	426.7
175	53.3	820	249.9	1420	432.8
200	61.0	840	256.0	1440	438.9
225	68.6	860	262.1	1460	445.0
250	76.2	870	265.2	1480	451.1
275	83.8	880	268.2	1500	457.2
300	91.4	890	271.3	1520	463.3
325	99.1	903	275.2	1540	469.4
350	106.7	910	277.4		
375	114.3	920	280.4	1560	475.5
400	121.9	930	283.5	1580	481.6
425	129.5	940	286.5		
450	137.2	945	288.0		
475	144.8	950	289.6		
500	152.4	955	291.1		
510	155.4	960	292.6		
520	158.5	965	294.1		
530	161.5	970	295.7		
540	164.6	975	297.2		
550	167.6	980	298.7		
560	170.7	985	300.2		
570	173.7	990	301.8		
580	176.8	1000	304.8		
590	179.8	1010	307.8		
600	182.9	1020	310.9		
610	185.9	1030	313.9		
615	187.5	1040	317.0		
620	189.0	1050	320.0		
625	190.5	1060	323.1		
630	192.0	1080	329.2		
635	193.5	1100	335.3		
640	195.1	1120	341.4		
645	196.6	1140	347.5		
650	198.1	1160	353.6		
660	201.2	1180	359.7		
670	204.2	1200	365.8		
680	207.3	1220	371.9		
690	210.3	1240	378.0		
700	213.4	1260	384.0		
710	216.4	1280	390.1		
720	219.5	1300	396.2		
730	222.5	1320	402.3		
740	225.6	1340	408.4		

Despite the use of a rubber sleeve core-barrel, sloughing and fill created problems and core recovery was not as successful as hoped. However, some of this recovered core was of sufficiently high quality to attempt rock mechanics measurements. These results will be reported separately.

Figure 2 is a photograph of the remaining core. The white material at 194.5 to 195 m is an air-fall tuff. The U.S. Geological Survey (USGS) is attempting an age-determination on this material (see p. 18).

GEOPHYSICAL LOGGING

Two suites of geophysical logs were run: the first following coring to a depth of 293.8 m, and the second after the hole had attained its maximum depth of 514.2 m. In addition, the USGS ran a borehole gravimeter in the cased hole about five months after completion. Table 2 gives a summary of these logs, and they are discussed by type below.

Table 2. Geophysical logs, Ue5n.

Log	Run date	Run no.	Logger	Logged interval (m)	
				Top	Bottom
Velocity					
Three-dimensional sonic velocity, 6-ft spacing	2-19-76	1	Birdwell	183	283
Three-dimensional sonic velocity, 12-ft spacing	2-19-76	2	Birdwell	30	282
Three-dimensional sonic velocity, 6-ft spacing	2-19-76	3	Birdwell	30	283
Three-dimensional sonic velocity, 12-ft spacing	2-25-76	4	Birdwell	198	487
Three-dimensional sonic velocity, 6-ft spacing	2-25-76	5	Birdwell	198	488
Three-dimensional sonic velocity, 18-ft spacing	2-27-76	6	Birdwell	183	482
Vibroseis sonic velocity	2-19-76	1	Birdwell	Surface	285
Density					
Dual-proximity density	2-18-76	1	Birdwell	0	287
Dual-proximity density	2-19-76	2	Birdwell	0	130
Dual-proximity density	2-26-76	3	Birdwell	310	471
Dual-proximity density	2-27-76	4	Birdwell	152	469
Borehole gravimeter	8-11-76	1	USGS	0	442
Other					
Caliper	2-18-76	1	Birdwell	0	288
Caliper	2-25-76	2	Birdwell	15	490
Caliper	2-27-76	3	Birdwell	0	487
Fluid locator	2-19-76	1	Birdwell	15	39
Fluid locator	2-27-76	2	Birdwell	168	204
Fluid locator	3-01-76	3	Birdwell	198	219
Electric log (wet hole)	2-25-76	1	Birdwell	213	489
Induction log (dry hole)	2-18-76	1	Birdwell	26	288

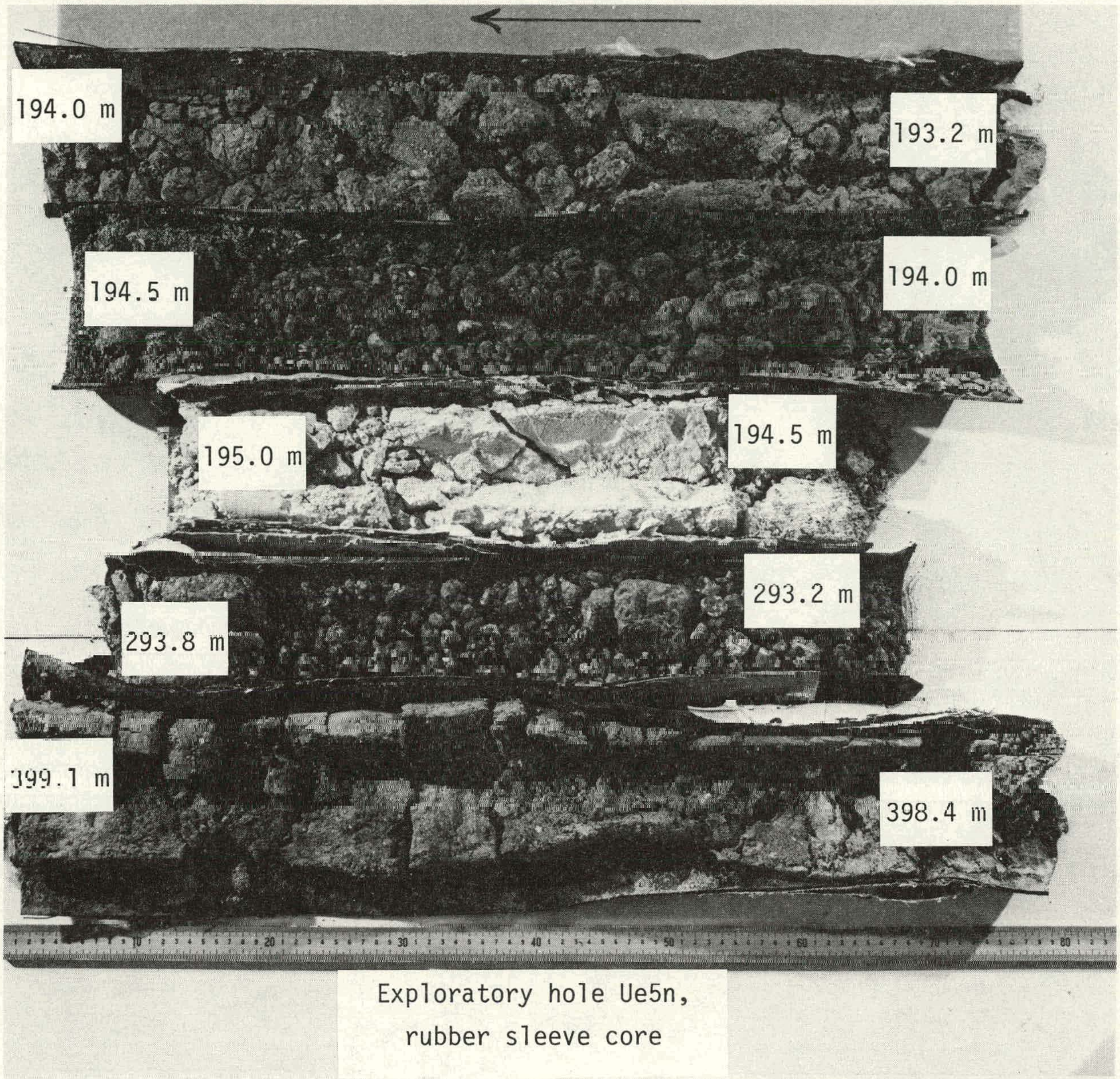

Fig. 2. Photograph of core from Ue5n.

Sonic Velocity Logs

The original work plan included running a series of dry hole logs above the water table, which is about 215 m below the surface. For construction reasons, these logs were delayed until the hole was about 80 m deeper than the water table. At that time, the fluid level was only 35 m below the surface. Therefore, in place of a dry hole acoustic log (DHAL), three-dimensional sonic velocity and vibroseis logs were run. Following the completion of the hole to total depth, only three-dimensional logs were run. These logs are shown in Figs. 3 and 4. Figure 3 is a standard plot of log and sample data used for containment evaluations. Figure 4 is a travel time versus depth plot from the vibroseis survey.

Three-Dimensional Logs — The three-dimensional logs have little interpretable data above 218 m, and Fig. 3 shows only data from runs 4 and 5, which give interpretable data only as high as 253 m. The overlapping intervals of data between the pairs 1-2 and 4-5, namely 253- to 283-m depth, disagree. The value from pair 1-2 is about 22% faster velocity than from pair 4-5. These data are obtained by a two-tool method in which the differential travel time is calculated by subtracting the travel time of the shorter tool from that of the longer tool and associating that time with the difference in tool lengths. In the case of pair 1-2, the digitized pick of the shorter tool is clearly a second arrival (the first is not clear enough to digitize). Although picking a second arrival by a single-tool method would give an erroneously low velocity, picking a second arrival on the shorter tool with the two-tool method would give an erroneously high velocity. Thus, the data from pair 4-5 were chosen as correct. As an independent verification of the above analysis, we compared the interval velocity from the vibroseis log and found it only about 3% faster than that from pair 4-5.

Although the fluid level was standing as high as 49 m below the surface in the drill hole at the time that runs 1, 2, and 3 were made, no data were recorded above 218 m on these sonic velocity logs. At that time, the caliper of the hole showed about a 410-mm minimum diameter. With a centralized 160-mm-diam tool, there is about a 125-mm average gap between the tool and rock. In such cases, the sonic velocity of the rock must be about 10% greater than the velocity of the fluid before the path through the rock

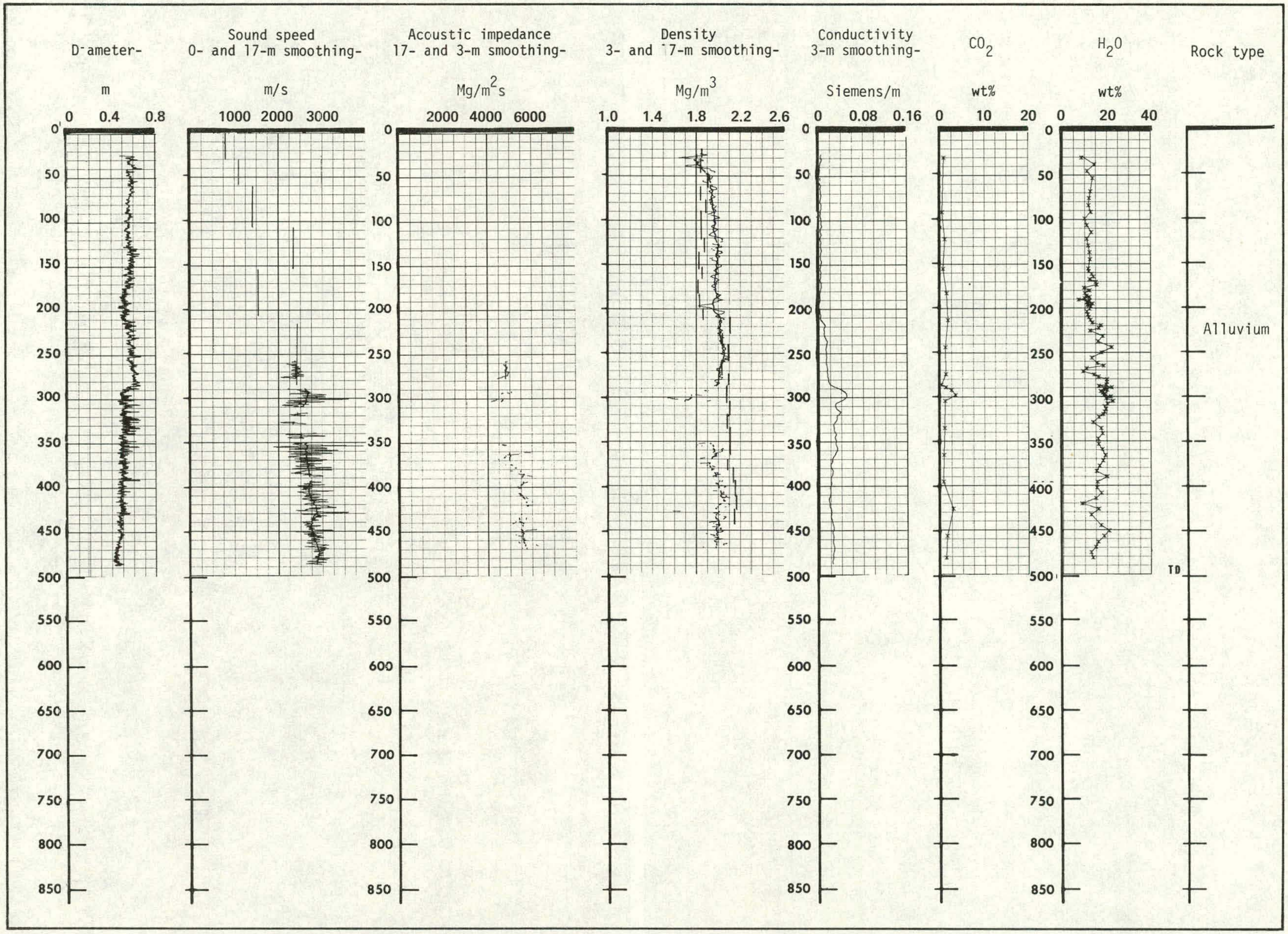

Fig. 3. Plot of sample and geophysical log data from Ue5n (caliper limit — 0.711 m; depths in meters; date — 5/6/76).

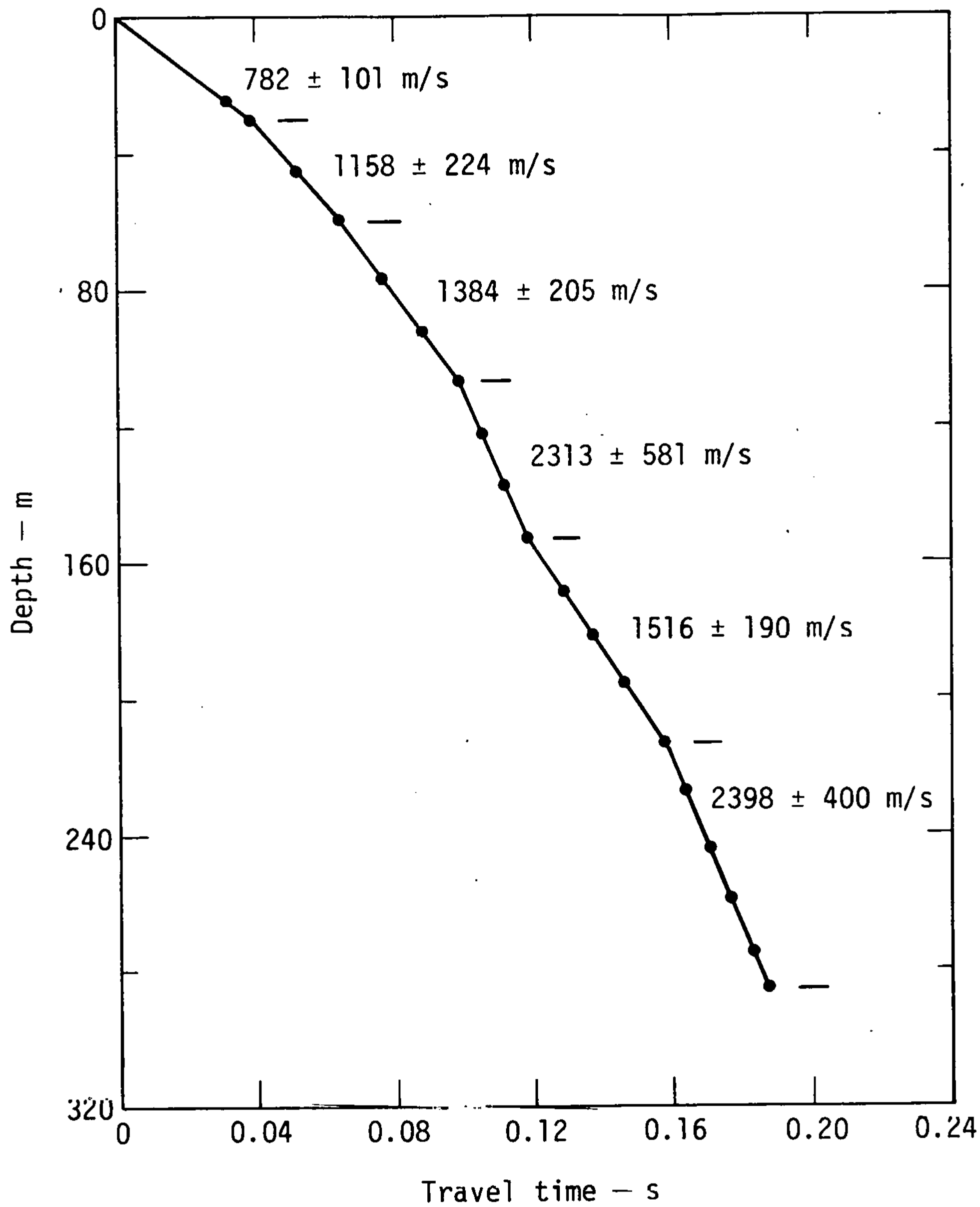

Fig. 4. Travel-time depth curve from vibroseis survey of Ue5n.

becomes the fastest route. By the time logs 4, 5, and 6 were run, the diameter of the hole was at about 560 mm, giving about a 200-mm gap. This requires a rock velocity about 20% faster than the fluid before a signal will take a path through the rock. When one considers these factors and the interval velocities from the vibroseis log, only some data in the interval 107-152 m would have been expected on the three-dimensional log above 218-m depth and none was seen even here.

Vibroseis Log — The vibroseis log generally gives very poor interval velocities because of the high possible error in reading the records. Under good circumstances, one arrival can be picked to about ±1 ms so that the potential error for an interval (two arrivals) is about ±2 ms at best. When the downhole signal is degraded, an error of ±5 ms for an interval travel time is the least we feel justified in using. Typical travel times for a 15-m interval in these rocks are from 5 to 15 ms (1016 to 3048 m/s); thus the potential error for a 15-m interval velocity is 13 to 40% at best, and 33 to 100% at worst. A full cycle covers about 16 ms at the frequency range of the vibroseis; thus an error due to missing the entire first cycle is obvious if the station interval is 15 m, as for the present log.

Because of the large possible error over 15-m intervals, direct use of vibroseis interval velocities is poor practice. Another way to reduce a vibroseis log is to zone the trace of the depth-travel time curve. Figure 4 is such a log, with the zones indicated. These zones are also plotted as vertical bars on the sound speed column in Fig. 3. For all the zones in Fig. 4, the potential travel-time error of 5 ms is less than 25% of the zone travel-time.

Density Logs

Four density logs were run, two in each suite. Portions of all of these were used for the composite trace in Fig. 3. There is little useful data in the interval from 290- to 350-m depth. Fortunately, this drill hole was logged with a borehole gravimeter (Table 3). Data derived from the gravimeter log are shown as vertical bars overplotted on the density trace in Fig. 3.

Table 3. Density data from borehole gravimeter, Ue5n.

Measured depth interval (m)	Interval density (Mg/m^3)	
	In run	
20.0 - 30.5	1.86	
30.5 - 45.7	1.85	
45.7 - 61.0	1.91	
61.0 - 76.2	1.85	
76.2 - 91.5	1.89	
91.5 - 106.6	1.86	
106.6 - 121.9	1.86	
121.9 - 137.2	1.88	
137.2 - 152.4	1.83	
152.4 - 167.6	1.86	
167.6 - 182.9	1.82	
182.9 - 199.6	1.84	
199.6 - 213.4	1.87	
214.0	Measured water level	
213.4 - 228.6	2.11	
228.6 - 243.9	2.04	
243.9 - 259.1	2.10	
259.1 - 274.3	2.04	
274.3 - 286.5	2.09	
286.5 - 307.8	2.08	
307.8 - 320.0	2.11	
320.0 - 335.3	2.08	
335.3 - 350.5	2.11	
350.5 - 365.8	2.11	
365.8 - 381.0	2.09	
381.0 - 396.3	2.14	
396.3 - 411.5	2.15	
411.5 - 426.8	2.16	
426.8 - 442.0	2.14	
	Out run	In run
20.0 - 152.4	1.862	1.864
152.4 - 307.8	1.975	1.985
307.8 - 442.0	2.117	2.120

There are several interesting aspects to the borehole-gravimeter data. The most pronounced is the fact that there is a distinct shift at the water table. The range of values above the water table is 1.86 ± .05 Mg/m^3; below the water table it is 2.10 ± 0.06 Mg/m^3. By contrast, there is only a small shift in the trace of the gamma-density log, from slightly less than 2.0 to slightly greater than 2.0 Mg/m^3.

At the time the gravimeter was run in the cased hole, the hole was filled with water to a depth of 7 m below the surface. Therefore, the gravimeter could not have been affected by a transition from air to water at 214-m depth. There was also no shut-down or interruption in the logging that might account for the difference in density above and below the 213.4-m station.

A possible explanation is that the gravimeter "sees" about 90% of its effect in a 76-m radius (equal to 5 times the station spacing) surrounding the borehole, whereas the depth of penetration of the gamma-density tool is less than 0.3 m. Therefore, it is possible that the gamma-tool was affected by a state of near or full saturation adjacent to the borehole, whereas the borehole gravimeter is more affected by the native state of the rock far from the borehole.

If the above explanation of the different values of density given by the gravimeter and the gamma log is true, it has some important implications for the standard logging techniques in use at NTS. Furthermore, we want to have the best values of density and porosity available for interpretation of seismic measurements. Therefore, we will analyze the reliability of the various estimates of density and related physical properties in a later section.

Other Logs

In addition to caliper and fluid locator logs, which we will not discuss, two electrical logs were run: a standard electrical log in the final group of logs, and a dry-hole induction log in the first group (the hole was not dry, but this log can be run in either a fluid-filled or dry hole). Figure 3 gives a composite plot of conductivity. The conductivity peak from 290- to 305-m depth correlates with increased CO_2, but there is no direct electrical effect possible from increased CO_2 alone. If increased clay or zeolite accompanies the higher CO_2, this would explain the conductivity increase. There is no significant increase in clay. Samples at 291.1-, 295.7-, and 298.7-m depth do show 30-40% zeolite (Table 4). However, a sample at 335.3 m has greater than 50% zeolite, and it has a lower conductivity. Thus we have no simple explanation for the conductivity peak at about 300-m depth.

Table 4. X-ray analyses on selected samples from Ue5n[a] (%).

	Sample depth (m)										
	91.4	137.2	182.9	274.3	291.1	295.7[b]	298.7	335.3	396.2	445.0	475.5
Minerals											
Montmorillonite	<10[c]	<10	tr[d]	<10	<10	10	<10	tr	<10	<10	tr
Illite-mica	<10	<10	tr	tr	tr	tr	tr	tr	<10	tr	<10
Clinoptilolite	tr	tr	tr	tr	40	30	>30	>50	tr	>10	tr
Quartz	>10	>10	10	20	10	10	10	<10	<10	tr	<10
Feldspar	60	>50	>50	>50	30	>30	30	>20	60	60	60
Cristobalite-opaline silica	<10	<10	10	<10	tr	tr	tr	tr	10	<10	10
Calcite	tr	tr	<10	tr	<10	<10	10	tr	tr	tr	tr
Dolomite	tr	tr	tr	tr	—	—	—	—	—	—	—
Amphibole	—	tr	—	tr	—	—	—	tr	tr	tr	tr
Iron oxide (goethite?)	—	tr	tr	tr	—	—	—	—	tr	tr	tr

[a]Analyst: P. Blackmon, USGS

[b]Analyzed by W. Beiriger, LLL

[c]<10 = 5-9%

[d]tr = trace = <5 percent

LITHOLOGY AND STRATIGRAPHY

General Comments

Table 5 gives a lithologic log of the drill hole. Despite differences in detail, the lithology is generally similar from top to bottom. As noted earlier, the hole was still in alluvial material at the total depth of 514 m. The expected depth to tuff was 610 m ± 20%.

Although there are currently outcrops of Paleozoic rock around Frenchman Flat, mainly to the south and east, the dominant lithology in the alluvium is clasts of Tertiary tuff and rhyolitic lava. There are rare clasts of quartzite and basalt. Other drill holes about 6 km north in Frenchman Flat have penetrated basalt flows, but none were encountered at Ue5n.

Figure 5 is a plot of the sieve and hydrometer analyses of sidewall samples given in Appendix B. It shows the relative proportions of pebbles, sand, and fine material. Although the fine material ranges from a few to

Table 5. Lithologic log of exploratory hole Ue5n.

Depth (m)	Description
0 - 6.1	Alluvium; tuffaceous sandstone, medium brown, silty with ≈10% small gravels of silicified welded tuff, moderately calcareous with common blebs of secondary calcite.
6.1 - 24.4	No samples of geophysical logs.
24.4 - ≈195.1	Alluvium; tuffaceous sediments, medium grey/brown, common interstratified sandy cobble-gravel beds. Clasts mainly silicified welded ash-flows/minor lavas of Timber Mountain, Wahmonie, and Topopah Springs units, minor clasts of Paleozoic quartzite, poorly indurated, very slight calcareous cementation with caliche coated clasts, matrix generally unaltered.
≈195.1 - ≈196.6	Tuff; rhyolitic ash-fall, stratigraphic unit unknown (late Pliocene/early Pleistocene), very fine volcanic dust, rare biotite, glassy.
≈196.6 - 286.5[a]	Alluvium; tuffaceous sediments, section same as 24.4-195.1-m interval with rare basalt clasts.
286.5 - 307.8	Alluvium; tuffaceous sediments, medium grey/brown sand/silt matrix zeolitized/slightly argillized, ≈30% clasts and semi-rounded pebbles of ash-flow tuffs (caliche coated), rare basalt and quartzite clasts; abrupt increase of induration at ≈287 m from bonding by particle alteration and increasing fines; matrix slightly calcareous.
307.8 - 481.6	Alluvium; tuffaceous sediments, medium grey/brown, increasing sand-silt-clay with decreasing cobbles, crudely stratified, partially zeolitized, slightly argillized matrix. Clasts mainly welded ash-flows of Timber Mountain, Wahmonie, and Topopah Spring units; clasts occasionally partially zeolitized, very slightly argillized, induration similar to 286.5-307.8-m interval, common caliche coated clasts; matrix slightly calcareous.
481.6 - 514.2[b]	Alluvium (cuttings); tuffaceous sediments, sand/silt matrix with clasts of semi-rounded to angular welded ash-flow tuffs (Timber Mountain, Wahmonie, Topopah Spring units), minor rounded quartzite pebbles, very poorly indurated, moderately calcareous.

[a]Static water level: 213.4 ± 1 m.

[b]Hole sloughing through this interval, cuttings contaminated with fill material.

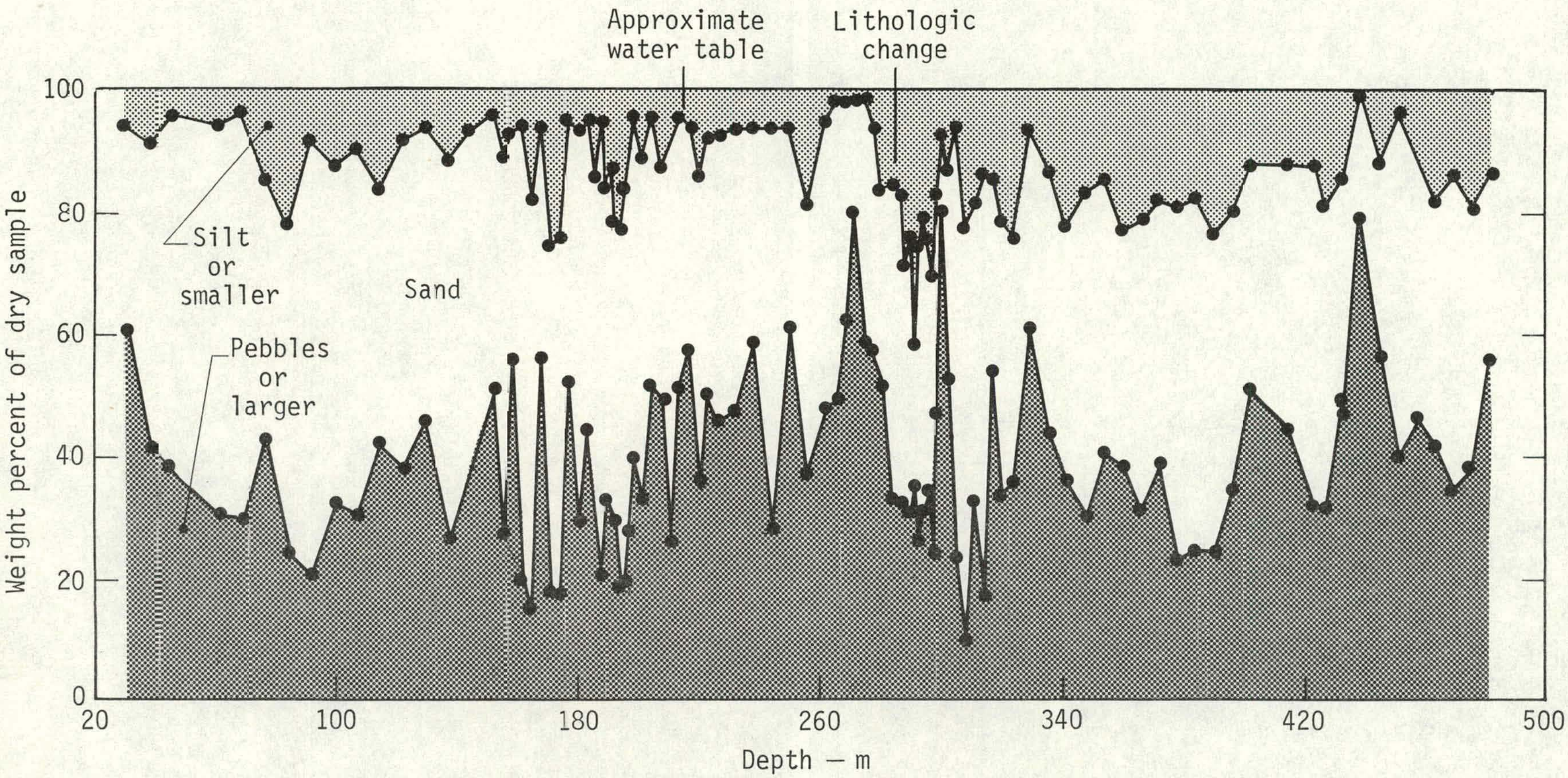

Fig. 5. Plot of sieve and hydrometer analyses of sidewall samples from Ue5n.

40%, it commonly makes up less than 10% of the sample above about 286 m and commonly more than 10% below that depth. There are no similar consistent correlations as a function of depth with either the amount of pebbles or sand, or the pebble:sand ratio.

For samples taken below the fluid level in a hole, there is a possibility of loss of fines during the sample process. During sampling at Ue5n, this level lay between 196- and 214-m depth. There is no evidence from the data in Fig. 5 itself to suggest such a loss of fines for Ue5n.

Figure 5 is based on samples to a depth of 482 m, but the hole penetrated to 514 m. We conclude from the drilling records and cuttings that induration is poor below about 487 m. The material near the bottom of the hole appeared to be a poorly indurated gravel with a very high inflow of fresh water (inferred from dilution of drilling mud).

Table 6 contains measured data for grain density, weight percent of water content on a "wet" basis, and CO_2 content of Hunt sidewall samples from Ue5n. These data were all processed by standard methods used by LLL for reports to the ERDA-NV Containment Evaluation Panel. The grain density and CO_2 values are straightforward measurements. We will give additional evaluation of the water-content data in a later section.

Lithologic Change at 286-meter Depth

In northern Frenchman Flat, there is commonly a lithologic contact at about 180-m depth between an upper alluvium and an older, indurated alluvium. The indurated alluvium has distinctly greater sonic velocity and density. No similar discontinuities in sonic velocity and density are found in Ue5n, although there are possible stratigraphic correlations with the contact at 286.5 m in Ue5n. Below 286 m in Ue5n, the rock is significantly more indurated. This induration seems to correlate with zeolitization (Table 4) and an increased amount of fine material (Fig. 5). Neither the standard density log nor the borehole gravimeter show an increase in density (Fig. 3). However, there is about a 10% increase in sonic velocity below the 286-m level.

Some additional information about the lithologic break at 286 m can be seen in the log and sample analysis plot, Fig. 3. Below about 286 m, there is a distinct increase in both conductivity and CO_2. The increased conductivity is accompanied by increased water content. An increase in

Table 6. Water content, grain density, and CO_2 content for samples from Ue5n.

Sample depth (m)	Water content (wt%)	Grain density (Mg/m^3)	CO_2 content (wt%)	Sample depth (m)	Water content (wt%)	Grain density (Mg/m^3)	CO_2 content (wt%)
30.5	8.56	2.59	0.81	268.2	10.83	2.56	
38.1	14.43	2.61		271.3	9.17	2.66	
45.7	11.11	2.63		275.2	14.15	2.64	1.20
53.3	13.67	2.65		277.4	16.22	2.59	
68.6	12.67	2.61		280.4	20.08	2.59	
76.2	11.92	2.61		283.5	19.97	2.59	
83.8	11.81	2.63		286.5	19.71	2.60	0.17
91.4	12.80	2.63	0.44	288.0	16.42	2.65	
99.1	9.93	2.59		289.6	22.21	2.79	1.20
106.7	11.02	2.61		291.1	18.58	2.66	
114.3	13.07	2.59		292.6	20.11	2.63	2.50
121.9	10.93	2.61	0.96	294.1	17.17	2.65	
129.5	11.54	2.63		295.7	18.25	2.72	
137.2	12.28	2.63		297.2	19.12	2.61	
144.8	12.43	2.62		298.7	18.52	2.63	3.40
155.4	11.55	2.61	0.61	300.2	21.77	2.63	
158.5	11.72	2.62		301.8	19.58	2.62	
161.5	13.23	2.62		304.8	22.85	2.64	0.99
164.6	14.03	2.62		307.8	20.27	2.64	
167.6	12.23	2.59		310.9	19.00	2.66	
170.7	15.00	2.64		313.9	19.66	2.60	
173.7	15.48	2.64		317.0	18.98	2.66	
176.8	9.59	2.55		320.0	18.31	2.65	
179.8	12.11	2.56		323.1	16.30	2.66	
182.9	10.04	2.58	1.40	329.2	13.77	2.66	
185.9	10.83	2.57		335.3	17.43	2.60	0.93
187.5	12.24	2.58		341.4	18.07	2.66	
189.0	10.05	2.59		347.5	15.91	2.68	
190.5	7.19	2.56		353.6	16.10	2.62	
192.0	12.30	2.59		359.7	17.88	2.67	
193.5	11.04	2.59		365.8	19.16	2.63	0.74
195.1	13.61	2.51		371.9	18.26	2.67	
196.6	11.15	2.58		378.0	16.68	2.66	
198.1	12.78	2.56		384.0	15.12	2.67	
201.2	12.24	2.55		390.1	20.04	2.59	
204.2	11.06	2.56		396.2	15.68	2.66	0.60
207.3	11.45	2.60		402.3	15.41	2.65	
210.3	11.73	2.60		408.4	17.41	2.65	
213.4	12.64	2.56	1.70	414.5	14.91	2.67	
216.4	13.41	2.57		420.6	8.61	2.66	
219.5	17.44	2.59		426.7	16.19	2.67	2.80
222.5	16.37	2.57		432.8	12.88	2.64	
225.6	12.50	2.56		445.0	17.15	2.65	
231.6	18.12	2.60		451.1	20.79	2.64	
237.7	16.03	2.56		457.2	18.52	2.66	1.40
243.8	22.20	2.63	1.10	463.3	15.98	2.64	
249.9	17.54	2.59		469.4	14.73	2.65	
256.0	13.21	2.62		475.5	12.75	2.67	
262.1	15.67	2.61		481.6	13.50	2.66	1.20
265.2	18.56	2.61					

grain density, from about 2.60 Mg/m^3 above the contact to about 2.65 below (Table 6), reflects the increased CO_2. X-ray analyses of samples from Ue5n (Table 4) show increased zeolite content below 286-m depth but no increase in clay content. The increased CO_2 (due to caliche stringers and not primary carbonate pebbles), difference in grain size distribution, and the sharpness of the break at 286 m suggest a stratigraphic discontinuity that might be comparable to that between the older and younger alluvium at 180 m in northern Frenchman Flat.

Air-Fall Tuff at 195-meter Depth

There is an air-fall tuff at about 195-m depth that may be of high stratigraphic significance. The tuff is vitric, distinctively white (see core photograph, Fig. 2), and is marked by high porosity, low grain density, very low conductivity, and low *in situ* density. The exact thickness and depth are not precisely known. The two side-wall cores at 195.1- and 196.6-m depth were from this unit. Core No. 1, which had about 2.1-m recovery in the interval 191.1 to 197.2 m, showed 0.5 m of tuff at the bottom of the recovered sample. The standard depth uncertainty of the sidewall samples is ±0.6 m. Excursions on log traces that are related to this unit occur on the density log between 195.1 and 197.5 m, and on the induction log between 193.6 and 199.6 m. The caliper log shows this material to be less eroded than the adjacent alluvium; a ledge occurs in the interval 193.6 to 196.6 m. To recapitulate, at least 0.5 m of this tuff occurs above 197.2-m depth, and it occurs at least as high as 195.7 m. It is possibly as thick as 2.5 or 3 m.

The possible significance of this tuff lies in the fact that it is clearly an air-fall that may be related to a datable volcanic eruption in the western U.S. The USGS is currently attempting to obtain a radiometric age date. If the material can be correlated, then (1) an excellent stratigraphic marker for both Frenchman and Yucca Flats will be established, and (2) through inferred rate of deposition, quite a bit of tectonic information can be derived.

WATER TABLE DEPTH

During the drilling and logging activities, the only measurement of fluid level that might approximate the water table was at 01:30 h, March 1, 1976, at which time it was 214.0 m below ground level. About 72 h had passed since the last drilling activity. Given the ground elevation of 948.6 m, the water level was at an elevation of 734.6 m.

After logging with the borehole gravimeter, we perforated the casing over a 3-m interval centered on 221-m depth. The perforation took place on November 4, 1976. Before the perforation, the fluid level stood in the casing at 6.7-m depth. By November 19, it had declined to 150.3 m, and on December 3, the (apparently stable) level was 215.3 m below the casing top or 214.3 m below the ground elevation. This is a water-table elevation of 734.3 m above sea level.

The water table at the Ue5n site about 564 m to the west is at an elevation of close to 735 m. This is also the reported elevation for the northern Frenchman Flat test area, based on four locations. This small difference, considering uncertainties in the other measurements and the variable penetration of the aquifer, is negligible. It is likely that the water-table elevation at Ue5n would be 735 m if the well penetrated only a few meters below the water table, and that is our recommended value.

EVALUATION OF PHYSICAL PROPERTIES DATA

We have earlier noted the discrepancy between the density measurement by the borehole gravimeter and the gamma log. As an aid in deciding which of the two logs should be accepted, we constructed Table 7.

We should note at the outset that the gamma log received a grade* of D below 290 m, so that one would not expect reliable results. Even above 290 m, the gamma log was only rated C. On the other hand, the gravimetry measurements had good closure (see Table 3, in and out runs) and the measurement of free-air gradient used in the calculations also had good closure and was verified on two separate occasions.

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*A letter grade of A to F is assigned to all or portions of logs during processing. Logs assigned a grade lower than C generally do not give reliable data.

Table 7. Comparison of various methods of obtaining porosity and saturation for thick zones in Ue5n.

	Depth interval in Ue5n (m)	
	20.0-152.4 (above water table)	307.8-442.0 (below water table)
Measured parameters		
Density from borehole gravimeter (Mg/m^3)	1.86	2.12
Density from gamma log (Mg/m^3)	1.94	1.93
Grain density (Mg/m^3)	2.62	2.65
Water content (wt%)	11.9	16.8
Calculated parameters		
Water content, BHG (wt%)[a]	—	15.2
Water content, gamma log (wt%)[a]	—	22.8
Porosity from borehole gravimeter (vol%)	37	33
Porosity from gamma log (vol%)	35	40
Porosity from BHG, calc. H_2O (vol%)[a]	—	32
Saturation from BHG (vol%)	59	106
Saturation from gamma log (vol%)	66	82
Gas porosity from BHG (vol%)	15	-2
Gas porosity from gamma log (vol%)	12	7
Recommended values		
Bulk density (Mg/m^3)	1.86	2.12
Water content (wt%)	10.0	15.2
Porosity (vol%)	36	32
Saturation (vol%)	52	100
Gas porosity (vol%)	17	0

[a]Calculated using bulk density and grain density and assuming saturation

$$W = \frac{\rho_g - \rho_o}{\rho_g \rho_o - \rho_o} \quad , \ \phi = \rho_o W \ .$$

In Table 7, the gamma log density above the water table deviates from the borehole gravimeter density by only 4% of the 1.86 Mg/m^3 gravimeter value. This results in a 5% deviation in the porosity, 12% deviation in the saturation, and 20% in the gas-filled porosity; all calculations assumed the same grain density and porosity. On the other hand, the deviation in density below the water table is 9%, giving a 21% deviation in porosity, a 23% deviation in saturation, and a 450% deviation in gas-filled porosity; all deviations refer to the value derived from gravimetry. Note also that the calculation below the water table with the borehole gravimeter data leads to oversaturation (106%), which is physically impossible.

Of the parameters used to calculate porosity and saturation (grain density, bulk density, and water content), the one most likely to be in error is water content. Above the water table, the drilling fluid saturates the rock immediately surrounding the borehole. Use of sidewall samples for water content gives only a maximum water content unless a period of months elapses between drilling and sampling. Below the water table, there is also a tendency to force additional water into the sample. This reduces it to a disaggregated mud.

It is clear that below the water table, the bulk density is best estimated by the borehole gravimeter. If we accept this estimate for the bulk density, use the grain density, and assume 100% saturation of the rock, then we can calculate water content: 15.2 wt%. This is 10% less than the measured water content, 16.8%. If we make the same calculation using the gamma density value, we obtain a water content of 22.8%, which is unreasonably high for these rocks. Use of the 15.2% water content leads in turn to a calculated porosity of 32%, which is the recommended value.

Very little data exist for comparison of the true *in situ* water content with that measured on sidewall cores from a fluid-invaded hole. Table 8 gives some data from two holes, 15 m apart. For the two 6-m zones for which data on both air-drilled core and sidewalls in a fluid-invaded hole were available, the water content in the air-drilled core is 15% and 22% less than that in the "wet" sidewalls.

Table 8. Comparison of water content (wt%) of conventional core versus that of sidewall core at U10aq and U10aq-1.[a]

Depth (ft)	U10aq-1 conventional core (air-drilled)	U10aq sidewall core (water-foam drilled)
920		15.9
924-924.3	11.8	
929-929.4	15.1	
930		19.0
938-938.3	20.2	
940		20.3
Mean 920-940	15.7	18.4
1000		17.0, 18.6
1000-1000.3	12.4	
1009-1009.3	15.2	
1010		18.8
1019-1019.3	13.9	
1019.3-1019.6	15.8	
1020		18.3
Mean 1000-1020	14.3	18.3

[a]These holes are 50 ft apart. Data taken April 1971.

Table 9 gives data for a small area in Area 2, Yucca Flat, in which the geology is laterally uniform. One drill hole, Ue2a-1, was sampled nearly five years after drilling. Although the data are not conclusive, there is a tendency for the "natural state" samples to give lower values of water content. This is particularly marked in the upper part of the hole, where compaction has not reduced the pore size as much as it has deeper in the hole. (With sufficient compaction and reduction in pore size, water will not flow out of the rock under the force of gravity, and the rock will be nearly 100% saturated even though above the water table; this is the case at Rainier Mesa, for example.)

Table 9. Alluvium water content comparisons — Area 2.

Depth (ft)	Ue2a-1,[b] 4 y, 11 m (natural state)	U2D1,[c] 5 d	U2DM-1, 2 d	U2DM-2, at 125°C, 34 d	U2DP, 11 d	U2DK, 13 d
	Water content (%)[a] in drill holes at indicated sampling delay					
100-200			(3)9.5 ± 1.1	(2)9.6	(4)14.7 ± 2.5	
200-300	4.2 (300)		(4)8.0 ± 1.3	(3)9.2 ± 1.3	(5)10.8 ± 4.9	(5)11.7 ± 3.6
300-400	5.0 (375)		(4)8.5 ± 2.3	(2)7.1	(5)9.5 ± 1.5	(5)10.4 ± 2.6
400-500	1.5 (400)		(5)10.1 ± 2.5	(5)9.2 ± 1.2	(5)10.0 ± 1.9	(5)10.2 ± 2.0
500-600	2.9 (500)		(5)9.5 ± 1.8	(5)8.1 ± 1.2	(6)8.6 ± 2.0	(5)8.5 ± 1.2
600-700	3.8 (600)		(11)8.6 ± 1.4	(5)7.6 ± 1.4	(6)8.9 ± 1.8	(5)8.1 ± 2.0
700-800	4.4 (700)	8.2(750)	(11)9.1 ± 1.7	(5)9.5 ± 1.7	(6)9.2 ± 2.0	(5)9.5 ± 1.2
800-900	5.3 (800)	(2)7.2	(11)9.3 ± 1.6	(5)10.1 ± 2.8	(8)10.2 ± 2.7	(5)10.2 ± 1.9
900-1000	(5)8.2 ± 1.2	(4)10.8 ± 0.2	(14)9.4 ± 1.8	(10)10.2 ± 3.0	(8)10.2 ± 2.7	(11)10.6 ± 2.0
1000-1100	(17)10.8 ± 2.3	(15)12.4 ± 1.7	(16)11.1 ± 2.9	(11)12.2 ± 2.6	(17)9.6 ± 1.6	(17)10.7 ± 2.1
1100-1200	(12)11.9 ± 2.6	(11)13.4 ± 2.0			(10)10.7 ± 3.5	(10)11.8 ± 2.5

[a]Values in parentheses to left are number of samples for average; in parentheses to right, the specific depth of a single sample. The ± values are one standard deviation.

[b]Ue2a-1 gave two samples (20.9% H_2O at 990 ft and 30.2% H_2O at 1145 ft) that were not included in the averages, but that must be essentially "natural" state water content.

[c]U2DI gave two samples (20.5% H_2O at 1065 ft and 25.7% H_2O at 1145 ft) that were not included in the averages but may be realistic values in light of Ue2a-1 experience.

Given the data in Tables 8 and 9, we constructed Table 10 to illustrate the effect of various reductions in the water content above the water table at Ue5n. After evaluating the data in Tables 8 and 9, we decided that the most reasonable reduction in water content is about 15% of the measured value, so we transferred the values based on 10 wt% water back to Table 7 as recommended values.

Table 10. Effect of various assumed water contents on calculated properties above water table, Ue5n.[a]

Water content (wt%)	Porosity (vol%)	Saturation (vol%)	Gas porosity (vol%)
11.9 (measured)	37.2	59.4	15.1
11.0 (- Δ8%)	36.6	56.0	16.1
10.0 (- Δ16%)	35.9	51.9	17.3
9.0 (- Δ24%)	35.2	47.6	18.4
8.0 (- Δ33%)	34.5	43.2	19.6

[a]The depth zone 20.0-152.4 m (Table 7) was used for this calculation; the grain density is 2.62, and the bulk density 1.86.

We then constructed Table 11. The parameters were first calculated by using the gravimetric density and the measured water content. Below the water table, we assumed a saturation of 100% to adjust the water content and porosity; the adjusted values are shown in brackets. Above the water table, we used a calculation with an arbitrary 15% reduction in water content to produce the values shown in brackets. We recommend the use of the values in brackets as the best estimates available.

Table 11. Physical properties of depth zones measured by borehole gravimetry, Ue5n.

Depth interval (m)	Grain density[a] (Mg/m^3)	Gravimeter density (Mg/m^3)	Water content (wt%)[b]	Porosity (vol%)[b]	Saturation (vol%)[b]	Gas-filled porosity (vol%)[b]
20.0-30.5	2.59(1)	1.86	8.56[7.3]	34[33]	46[41]	18[20]
30.5-45.7	2.62(2)	1.85	12.77[10.8]	38[37]	62[54]	15[17]
45.7-61.0	2.65(1)	1.91	13.67[11.6]	38[36]	69[61]	12[14]
61.0-76.2	2.61(2)	1.85	12.30[10.5]	38[37]	60[53]	15[17]
76.2-91.5	2.63(2)	1.89	12.30[10.5]	37[36]	63[56]	14[16]
91.5-106.6	2.60(2)	1.86	10.48[8.9]	36[35]	54[48]	16[18]
106.6-121.9	2.60(2)	1.86	12.00[10.2]	37[36]	60[53]	15[17]
121.9-137.2	2.63(2)	1.88	11.91[10.1]	37[36]	60[53]	15[17]
137.2-152.4	2.62(1)	1.83	12.43[10.6]	39[38]	59[52]	16[18]
152.4-167.6	2.61(5)	1.86	12.55[10.7]	38[36]	62[55]	14[16]
167.6-182.9	2.59(5)	1.82	12.44[10.6]	38[37]	59[52]	16[18]
182.9-199.6	2.57(9)	1.84	11.20[9.5]	36[35]	57[50]	16[18]
199.6-213.4	2.57(5)	1.87	11.82[10.0]	36[34]	62[54]	14[16]
213.4-228.6	2.57(4)	2.11	14.93[13.9]	30[29]	104[100]	-1[0]
228.6-243.9	2.60(3)	2.04	18.78[17.2]	36[35]	106[100]	-2[0]
243.9-259.1	2.60(2)	2.10	15.38[14.9]	32[31]	102[100]	-1[0]
259.1-274.3	2.61(4)	2.04	13.56[17.4]	32[35]	85[100]	5[0]
274.3-286.5	2.60(5)	2.09	18.03[15.3]	34[32]	110[100]	-4[0]
286.5-307.8	2.66(12)	2.08	19.57[16.8]	37[35]	110[100]	-4[0]
307.8-320.0	2.64(4)	2.11	18.99[15.3]	35[32]	113[100]	-5[0]
320.0-335.3	2.64(3)	2.08	15.83[16.4]	34[34]	98[100]	-1[0]
335.3-350.5	2.67(2)	2.11	16.99[15.9]	34[34]	104[100]	-1[0]
350.5-365.8	2.64(3)	2.11	17.71[15.3]	34[32]	109[100]	-3[0]
365.8-381.0	2.66(2)	2.09	17.47[16.4]	35[34]	104[100]	-1[0]
381.0-396.3	2.64(3)	2.14	16.95[14.2]	33[30]	111[100]	-4[0]
396.3-411.5	2.65(2)	2.15	16.41[14.1]	32[30]	110[100]	-3[0]
411.5-426.8	2.67(3)	2.16	13.24[14.1]	30[30]	96[100]	1[0]
426.8-442.0	2.64(1)	2.14	12.88[14.2]	29[30]	94[100]	2[0]

[a]Number of samples used for grain density and water content averages shown in parentheses.

[b]The values shown in brackets are recommended as the best estimates (see text).

SUMMARY

Exploratory hole Ue5n was drilled to a depth of 514 m. Because of sloughing, logs and samples were obtained only to a depth of 490 m. The hole was cased for borehole gravimetry measurements. It has been perforated, and the USGS is monitoring the water level (about 214 m below ground surface).

In addition to standard cutting and sidewall core samples, there were four conventional core runs, three of which obtained core. One core fortuitously contained an air-fall tuff in the alluvium section. This may allow radiometric age dating of this horizon.

Standard sonic velocity, density, and electrical logs were run. In addition, the USGS logged the hole with a borehole gravimeter.

At the total depth of 514 m, the rock material was still alluvium. The dominant alluvium lithology is clasts of Tertiary tuff and rhyolitic lava, with rare clasts of quartzite and basalt. Although drill holes in northern Frenchman Flat have penetrated basalt flows, there are none in Ue5n.

There is a lithologic break at 286 m, with the rock showing increased induration, conductivity, CO_2, zeolitization, and proportions of fine materials below the break. There is, however, little effect on density or sonic velocity.

An evaluation of the data leads to the conclusion that the density from borehole gravimetry is correct. We then used the water contents calculated from simple assumptions to calculate porosity (and, above the water table, saturation and gas-filled porosity). We recommend use of these adjusted values, but we give both measured and adjusted values.

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The field costs were funded out of ARPA Order 838. The analysis has been carried out as part of the Seismic Monitoring Research Program of the ERDA Special Test Detection Program.

APPENDIX A: HISTORY OF HOLE Ue5n

Spudded: 2-9-76 Completed: 3-1-76

Circulating media: Reverse air-water to 293.2 m, air-mud to 514.2 m

Pad elevation: 948.60 m Elevation of top of 0.27-m casing: 949.63 m

Bore hole record			Casing record			
Depth (m) From	To	Size (m)	Size o.d. (m)	Weight kg/m	Depth (m) From	To
0	1.52	1.63	1.22	580.4	0	1.52
1.52	24.99	0.91	0.51	139.9	0	24.23
24.99	514.20	0.38	0.27	80.4	0	464.21

Drilling log

2-7-76 Moved-in Auger rig.

2-9-76 Rig secured from 2-7-76 to 0800 h, 2-9-76. Drilled 1.63-m hole to 1.52 m. Set 1.22-m wall casing at 152 m, and cemented annulus.

2-10-76 Drilled 0.91-m hole from 1.52 to 25.0 m. Moved-out rig.

2-11-76 Moved-in BIR 800 at 1600 h, started rigging-up.

2-12-76 Completed rigging-up. Ran 0.51-m o.d. casing to 24.2 m, and cemented annulus. Lost Dyna-Drill in hole.

2-13-76 Recovered Dyna-Drill, drilled mouse hole, and picked up 0.38-m drilling assembly.

2-14-76 Drilled-out cement and 0.38-m hole from 25.0 to 67.1 m, using dual-string reverse circulation: air/water.

2-15-76 Drilled 0.38-m hole from 67.1 to 191.1 m.

2-16-76 Cut core No. 1 from 191.1 to 197.2 m, using 0.19-m Christensen diamond bit and a rubber sleeve core barrel, recovered ≈1.2 m of contaminated and possibly washed alluvium plus ≈0.6 m of air-fall tuff.

2-17-76 Drilled 0.38-m hole from 210.3 m to 293.2 m. Tripped in hole with core barrel, cleaned out 1.8 m of fill, cut core No. 2 from 293.2 to 293.8 m, plugged bit from hole sloughing.

2-18-76	Tripped back in hole for core No. 3, circulated through fill from 286.5 to 293.8 m; string partially plugged, unable to clear core head. Pulled out of hole and started geophysical logging. Caliper log to 288.3 m, induction log to 288.0 m, density log to 286.8 m.
2-19-76	Continued logging, fluid density log with level at 34.7 m, vibroseis survey, started running three-dimensional velocity logs (2- and 4-m spacings).
2-20-76	Completed logging; cleaned fill from 284.4 and 293.8 m, and drilled 0.38-m hole from 293.8 to 381.9 m using reverse circulation with air and mud.
2-21-76	Drilled 0.38-m hole from 381.9 to 398.4 m. Cut core No. 4 from 398.4 to 401.4 m, recovered ≈2.7-m rubber sleeve core.
2-22-76	Cleaned fill from 391.7 to 398.4 m, reamed core hole, and drilled 0.38-m hole from 398.4 to 451 m.
2-23-76	Drilled 0.38-m hole from 451 to 464 m. Hole caved. Pulled out of hole checking for pipe leaks, repaired swivel, and cleaned-out fill in drill collars.
2-24-76	Tripped in hole, and cleaned fill from 446 to 464 m. Drilled 0.38-m hole from 464 to 514.2 m. Hole caving on connections.
2-25-76	Pulled-up the hole, and stuck pipe at 503.5 m. Worked free, and cleaned-out fill to 508.1 m. Unable to maintain pressure, pulled out of hole, checking for drill pipe leaks. Ran Birdwell caliper log to 490.1 m. Started running 2- and 4-m spacing three-dimensional logs, which indicated a fluid level of 214.3 m.
2-26-76	Completed running three-dimensional logs to 487.7 m, electric log to 488.9 m, density log to 470.6 m. Ran 0.38-m bit in hole, and attempted to clean-out fill from 476.4 to 495 m.
2-27-76	Hole continued to cave in interval from 490 to 495 m. Decision made to complete hole at this depth. Ran Birdwell caliper to 487 m, density log to 469.3 m; a fluid density log gave a fluid level at 196.3 m. A 6-m spacing three-dimensional log was run to 482.2 m. Started taking Hunt sidewall samples at a maximum depth of 481.6 m.

2-28-76 and 2-29-72	Continued taking sidewall samples from 481.6 to 30.5 m. Ran Birdwell fluid density sonde to 464.8 m. Fluid level at 214.0 m.
3-1-76	Laid down sampling tools, ran 0.27-m o.d. casing to 464.3 m. Cemented lower annulus with 7.08 m^3 of neat cement (annulus cemented below about 445-m depth).

APPENDIX B: GRADATION AND HYDROMETER ANALYSIS FOR Ue5n SIDEWALL SAMPLES*

UE5N EMPLACEMENT HOLE, I.D.130003

DEPTH FT.	M	SAMP. TYPE	G.D. G/CC	PERCENT H2O,DRY	PERCENT PEBBLES	PERCENT SAND	PERCENT SILT	PERCENT CLAY	PERCENT COLLOIDS
250	76.2	SIDEWALL	0.00	*00.0	43.0	42.0	8.2	3.5	3.4
275	83.8	SIDEWALL	0.00	*00.0	24.0	53.5	13.1	5.4	4.0
375	114.3	SIDEWALL	0.00	*00.0	41.9	41.6	8.6	3.6	4.3
540	164.6	SIDEWALL	0.00	*00.0	13.5	69.3	12.1	3.2	1.9
560	170.7	SIDEWALL	0.00	*00.0	17.6	56.7	17.5	5.1	3.1
570	173.7	SIDEWALL	0.00	*00.0	17.0	58.2	13.2	6.3	5.3
610	185.9	SIDEWALL	0.00	*00.0	24.7	60.5	9.6	2.3	2.8
620	189.0	SIDEWALL	0.00	*00.0	32.2	52.0	9.7	2.2	3.9
630	192.0	SIDEWALL	0.00	*00.0	29.0	49.2	14.6	4.3	2.9
635	193.5	SIDEWALL	0.00	*00.0	19.3	57.5	13.3	5.8	4.1
680	207.3	SIDEWALL	0.00	*00.0	49.4	37.3	7.1	3.9	2.3
720	219.5	SIDEWALL	0.00	*00.0	34.4	50.6	9.3	2.6	3.2
840	256.0	SIDEWALL	0.00	*00.0	36.7	44.0	11.1	3.4	4.7
920	280.4	SIDEWALL	0.00	*00.0	51.2	32.4	8.1	5.1	3.2
930	283.5	SIDEWALL	0.00	*00.0	32.4	51.4	7.9	4.7	3.5
940	286.5	SIDEWALL	0.00	*00.0	31.9	50.1	9.5	3.4	5.2
945	288.0	SIDEWALL	0.00	*00.0	31.0	39.8	13.2	6.9	9.1
955	291.1	SIDEWALL	0.00	*00.0	34.0	24.9	17.0	10.5	13.5
960	292.6	SIDEWALL	0.00	*00.0	26.0	48.8	11.2	4.4	9.7
965	294.1	SIDEWALL	0.00	*00.0	31.3	46.5	10.7	4.0	7.5
970	295.7	SIDEWALL	0.00	*00.0	34.1	40.0	7.9	4.8	13.1
975	297.2	SIDEWALL	0.00	*00.0	25.5	43.5	14.1	5.1	11.9
980	298.7	SIDEWALL	0.00	*00.0	46.9	35.5	6.5	3.4	7.6
985	300.2	SIDEWALL	0.00	*00.0	81.1	11.9	3.4	1.4	2.2
990	301.8	SIDEWALL	0.00	*00.0	52.4	34.1	6.0	3.0	4.5
1020	310.9	SIDEWALL	0.00	*00.0	32.3	48.5	12.1	3.9	3.1
1040	317.0	SIDEWALL	0.00	*00.0	53.2	32.1	5.3	3.0	6.3
1050	320.0	SIDEWALL	0.00	*00.0	33.5	44.0	11.3	5.9	5.3
1060	323.1	SIDEWALL	0.00	*00.0	35.7	40.0	12.3	6.3	5.6
1100	335.3	SIDEWALL	0.00	*00.0	43.8	42.9	7.1	3.3	2.9

*Computer sheets provided by Holmes and Narver, Inc.

UE5N EMPLACEMENT HOLE, I.D.13000B

DEPTH FT.	M	SAMP. TYPE	G.D. G/CC	PERCENT H20,DRY	PERCENT PEBBLES	PERCENT SAND	PERCENT SILT	PERCENT CLAY	PERCENT COLLOIDS
1120	341.4	SIDEWALL	0.00	*00.0	35.2	42.1	14.4	5.2	3.1
1160	353.6	SIDEWALL	0.00	*00.0	39.9	44.9	9.1	3.1	3.0
1180	359.7	SIDEWALL	0.00	*00.0	38.7	37.6	11.4	5.3	7.1
1200	365.8	SIDEWALL	0.00	*00.0	31.0	47.4	12.9	4.6	4.0
1220	371.9	SIDEWALL	0.00	*00.0	38.5	42.7	9.0	4.7	5.0
1240	378.0	SIDEWALL	0.00	*00.0	22.8	57.7	12.4	3.7	3.4
1260	384.0	SIDEWALL	0.00	*00.0	24.5	57.3	11.8	2.9	3.5
1280	390.1	SIDEWALL	0.00	*00.0	24.2	51.8	17.5	3.1	3.4
1300	396.2	SIDEWALL	0.00	*00.0	34.9	44.7	14.2	3.8	2.4
1320	402.3	SIDEWALL	0.00	*00.0	50.5	37.0	8.8	1.3	2.4
1360	414.5	SIDEWALL	0.00	*00.0	44.4	43.1	8.8	2.0	1.8
1390	423.7	SIDEWALL	0.00	*00.0	31.6	55.2	10.5	1.9	.9
1400	426.7	SIDEWALL	0.00	*00.0	31.6	48.5	12.7	3.8	3.4
1420	432.8	SIDEWALL	0.00	*00.0	48.3	36.9	9.8	3.0	1.9
1460	445.0	SIDEWALL	0.00	*00.0	56.4	31.6	8.3	2.4	1.3
1500	457.2	SIDEWALL	0.00	*00.0	45.8	41.8	8.8	1.9	1.8
1520	463.3	SIDEWALL	0.00	*00.0	41.3	40.5	13.8	2.5	1.8
1540	469.4	SIDEWALL	0.00	*00.0	34.4	51.1	11.0	1.8	1.7
1580	481.6	SIDEWALL	0.00	*00.0	55.7	30.4	9.7	3.0	1.2

GRAIN DENSITY (G.D.) ON PULVERIZED -200 MATERIAL BY WATER PYCNOMETER 24 HOUR SOAK METHOD.

MOISTURE CONTENT IN ACCORDANCE WITH ASTM D 2216-71.

PERCENT PEBBLES, SAND, SILT, CLAY AND COLLOIDS IN ACCORDANCE WITH ASTM D 422-63 (1972).

WTW/11/mla

UE5n - GRADATIONS

% PASSING SIEVE

Depth Ft.	Depth Mt.	#4	#10	#30	#50	#100	#200
100	30.5	52.6	39.5	28.1	23.0	13.9	6.2
125	38.1	72.3	58.1	41.8	31.2	17.8	9.2
150	45.7	79.2	62.6	54.5	19.8	9.6	4.3
200	61.0	85.4	69.8	42.1	24.6	11.7	5.8
225	68.5	85.9	70.3	35.2	16.8	7.3	4.3
300	91.4	89.2	79.9	62.3	33.6	16.1	8.7
325	99.1	80.8	67.7	48.1	29.2	17.5	13.1
350	106.7	79.2	70.3	53.5	32.0	15.8	9.6
400	121.9	75.6	62.2	40.6	27.5	14.9	8.4
425	129.5	64.8	54.7	37.6	24.2	12.3	6.5
450	137.2	86.3	74.5	52.2	37.4	21.3	12.2
475	144.8	73.5	61.4	36.6	21.2	10.4	6.8
500	152.4	61.2	49.0	32.2	15.1	6.7	4.2
510	155.4	84.6	72.2	51.6	35.7	19.2	10.9
520	158.5	52.2	44.7	35.1	25.8	13.2	7.6
530	161.5	87.1	79.7	50.9	27.6	10.8	6.3
550	167.6	52.9	43.6	30.5	20.9	11.8	7.3
580	176.8	63.2	48.0	28.9	18.1	9.8	5.4
590	179.8	79.4	71.1	56.3	37.9	14.9	7.3
600	182.9	70.2	57.5	38.4	24.6	10.8	5.5
615	187.5	78.5	63.6	39.0	22.9	11.0	6.4
625	190.5	79.7	67.9	46.1	31.6	20.0	13.3
640	195.1	91.9	79.9	51.5	40.9	25.9	16.4
645	196.6	82.0	71.6	54.1	36.7	17.3	9.5

UE5n - GRADATIONS(cont.)

Depth Ft.	Mt.	#4	#10	#30	#50	#100	#200
650	198.1	71.8	58.7	35.0	18.6	7.9	4.4
660	201.2	79.9	67.1	48.7	33.5	18.7	12.0
670	204.2	60.3	48.6	30.5	17.5	8.2	5.0
690	210.3	80.8	73.0	56.7	41.4	20.5	9.1
700	213.4	60.9	48.7	31.2	18.6	9.0	5.2
710	216.4	54.2	42.3	26.3	16.6	9.2	5.7
730	222.5	65.5	50.2	32.3	21.4	12.6	8.2
740	225.6	64.7	54.9	39.1	25.5	13.6	8.1
760	231.6	62.5	53.0	40.2	26.1	11.8	6.7
780	237.7	55.5	41.6	27.3	19.1	10.7	6.5
800	243.8	80.3	72.1	46.5	25.9	11.6	6.5
820	265.2	47.0	39.6	30.4	21.1	11.8	7.1
860	262.1	61.7	52.1	32.9	20.8	10.2	5.5
870	265.2	68.6	51.3	26.4	13.0	4.5	1.8
880	268.2	48.4	37.4	25.0	15.9	6.2	1.8
890	271.3	28.0	20.1	13.1	9.1	4.5	1.5
903	275.2	54.3	42.0	28.2	16.6	5.2	1.5
910	277.4	49.6	43.3	31.3	21.3	11.4	6.4
950	289.6	81.3	69.5	54.1	43.2	32.0	24.6
1000	304.8	80.4	77.0	64.3	39.3	15.2	6.3
1010	307.8	95.0	90.6	78.0	57.2	34.5	22.7
1030	313.9	87.3	82.5	62.8	41.0	23.2	14.3
1080	329.2	46.0	38.6	29.1	19.2	10.7	6.8
1140	347.5	75.9	70.1	50.2	41.2	25.0	17.3
1440	438.9	21.6	13.0	6.0	4.2	2.5	1.3
1480	451.1	86.0	60.0	30.8	19.3	10.2	4.8
1560	475.5	73.6	62.0	46.2	38.0	28.6	20.0

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