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Basic Data Report of Selected Samples Collected from Six Test Holes at Five Sites in the Great Salt Lake and Utah Lake valleys, Utah

By

Robert D. Miller, Harold W. Olsen, George S. Erickson, Carter H. Miller, and Jack K. Odum

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Introduction

As part of the Earthquake Hazard Reduction Program of the U.S. Geological Survey, five sites in Utah Lake and Great Salt Lake valleys were selected for drilling test holes as deep as 36 m in the fine-grained unconsolidated deposits believed to be typical of materials under the low-lying areas along the Wasatch Front, Utah. All of these sites are on materials deposited in Lake Bonneville; test holes penetrate these Lake Bonneville deposits and possibly pre-Lake Bonneville deposits. The purpose of the drilling was to obtain undisturbed samples for geotechnical testing, to make penetration tests, and to install casing for in-hole wave-velocity measurements to supplement other studies of the earth material at representative sites in a corridor of rapid urban development.

Geotechnical and geophysical data presented in this report are applicable to the study of ground response to natural phenomena such as earthquakes and to the evaluation of construction practices associated with urban development.

Acknowledgments

The authors appreciate the support and technical assistance of the following people during drilling and laboratory testing: H. D. Gomez, K. A. Hewitt, J. M. Leitner, T. J. Lindeman, Richard Van Horn, and M. C. Witmer, all of the Geological Survey. We also thank the landowners who gave us access to their land and permission to drill.

Site locations

The five sites selected for test drilling are indicated by triangles in figure 1.

In Utah Lake valley:

1. Lakeshore site (LS), Utah County. In the NW 1/4 SW 1/4 SW 1/4 sec. 9, T. 8 S., R. 2 E., Provo 7 1/2-minute quadrangle.

In the Great Salt Lake valley:

2. KSL transmitter site (KSL), Salt Lake County. In the SW 1/4 NW 1/4 sec. 32, T. 1 N., R. 2 W., Saltair 7 1/2-minute quadrangle.
3. Farmington siding site (FS-1, FS-2), Davis County. In the NE 1/4 SW 1/4 SE 1/4 sec. 14, T. 3 N., R. 1 W., Farmington 7 1/2-minute quadrangle.
4. Shepard Lane site (SL), Davis County. In the NE corner of sec. 15, T. 3 N., R. 1 W., Kaysville 7 1/2-minute quadrangle.
5. Malad River (MR) site, Box Elder County. In the SW corner of SE 1/4 sec. 3, T. 10 N., R. 3 W., Bear River City 7 1/2-minute quadrangle.

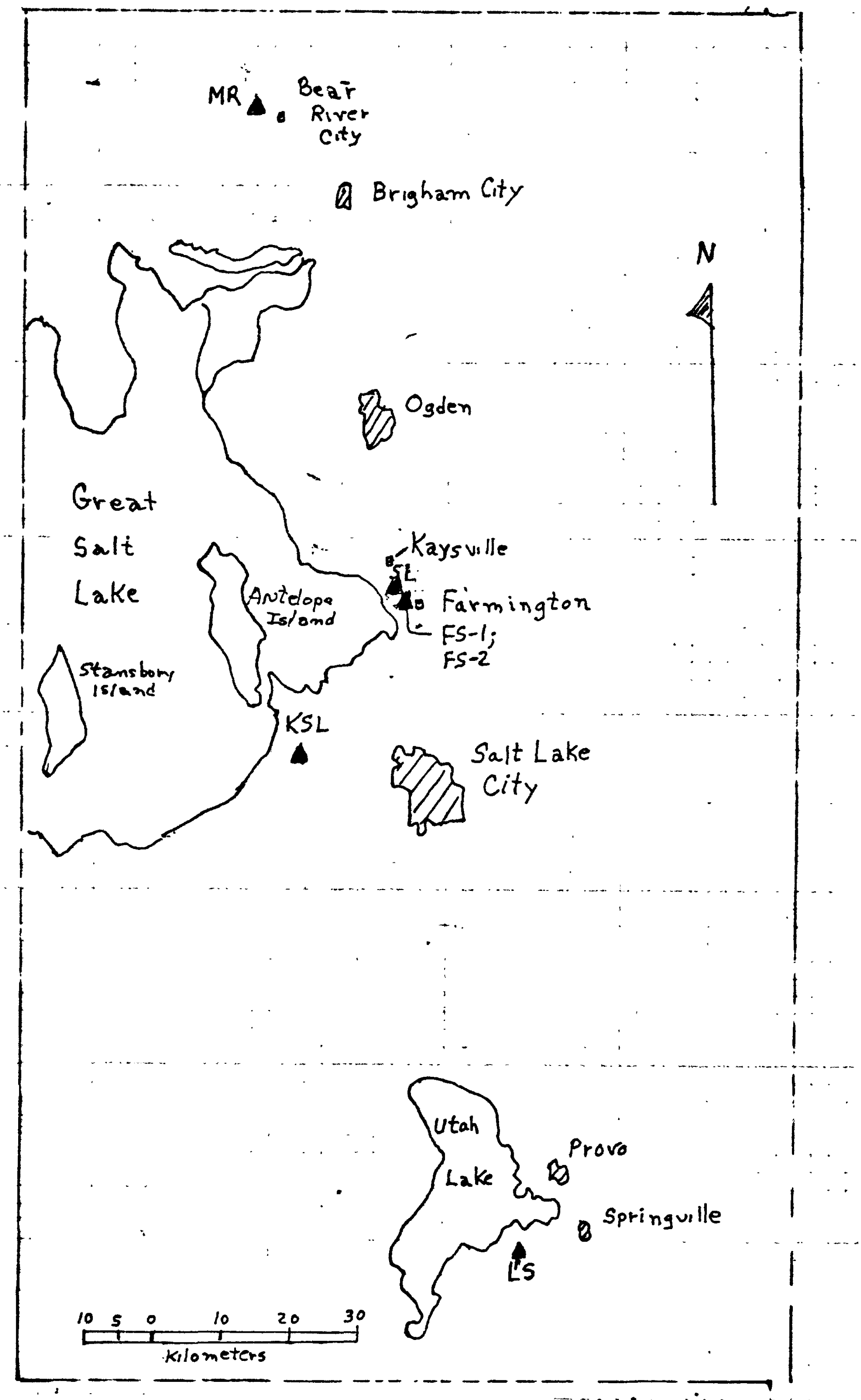


Figure 1.--Map showing the locations of five sites of six test holes. LS, Lake Shore site; KSL, KSL Transmitter site; FS-1, FS-2, Farmington Siding site, test holes 1 and 2; SL, Shepard Lane site; MR, Malad River site.

Procedures

Drilling, sampling, and casing installation

A truck-mounted Mobil B-52 auger/core drill rig was used to drill the holes, obtain undisturbed samples, conduct standard penetration tests, and install casing for in situ seismic wave-velocity measurements.

These operations were begun at each site with the use of CME' 3 1/4-in. i.d. hollow-stem augers. Samples were taken and standard penetration tests were run through and ahead of the auger. Undisturbed samples were obtained with a 3-in. o.d. Shelby tube sampler, and disturbed samples were obtained in the 2 1/2-in. o.d. heavy-wall split-tube sampler that was driven into the formation during the standard penetration test. This approach became unworkable when flowing sand was encountered about 9 m below the surface, because the sand moved into the hollow-stem auger and blocked the passage of the samplers through the auger to the formation below.

Additional depths were reached by rotary drilling with bentonite mud, weighted with barite where necessary to overcome artesian pressures. A 4 5/8-in.-diameter tricone bit was used for rotary drilling. At depths selected by examining the cuttings in the circulating mud, drilling was interrupted to obtain undisturbed Shelby tube samples and to run standard penetration tests.

Upon reaching the final depth at each site, preparations were made for velocity testing. The hole was flushed extensively with drill mud to remove loose material, and 3-in. plastic casing was placed in the hole. The bottom section of the casing was perforated and covered with fine-mesh screen to prevent sediment but allow water to flow between the casing and the formation. Water was flushed down through the casing and up through the annulus between the casing and the formation to remove the drill mud. Finally, 1/4- to 1/8-in. pea gravel was slowly poured into the annulus between the formation and the casing.

Logging

Logging of the test holes was accomplished by examining drill cuttings and selected samples in the field, and by studying the remainder of the samples in the laboratory. The extent of field logging was limited to that required for obtaining the "feel" for the material being penetrated, which was needed to select specific depths for undisturbed sampling and standard penetration tests. To the extent possible, the undisturbed samples in Shelby tubes were sealed in the field and transported to the U.S. Geological Survey geotechnical laboratory in Denver, where they were extruded, logged, and subsampled for geotechnical tests under controlled conditions.

In the field, limited logging was accomplished with the aid of a mobile laboratory truck equipped for extruding samples from Shelby tubes. Samples were visually examined with the aid of a hand lens or microscope, moisture content was obtained, and indicies of shear strength were measured with standard pocket penetrometer and torvane devices. The materials examined in the field were sealed in plastic and packed in core boxes to minimize drying and disturbance until they could be studied further under controlled conditions in the laboratory in Denver.

In the laboratory, logging was carried out in a controlled high-humidity room where the core could be studied in detail without damage from moisture loss. The operations involved in logging included: extruding the sample; comparing the length of material recovered with field data on the depth interval from which the sample was taken; scraping the surface of the core to remove the smeared surface and expose the undisturbed material; obtaining continuous colored photographs of the core; describing the composition and structure of the materials, including features such as laminations and dips and contortions; and selecting representative subsamples for laboratory geotechnical measurements.

Geotechnical measurements

The geotechnical measurements were run according to ASTM standards where available (American Society for Testing and Materials, 1978). The specific ASTM standards used are as follows:

		ASTM
1.	Dry preparation of soil samples for particle size and determination of soil constants.	D421
2.	Particle-size analysis	D422
3.	Liquid limit	D423
4.	Plastic limit	D424
5.	Specific gravity	D854
6.	Moisture content	D2216
7.	One-dimensional consolidation	D2435
8.	Unconfined compressive strength	D2166
9.	Standard penetration test	D1586

The standard penetration test provides a means to determine relative density for sand and silt, and consistency for clay (Terzaghi and Peck, 1948).

Relative density

Very loose--less than 4 blows per foot.
Loose--4-10 blows per foot.
Medium--10-30 blows per foot.
Dense--30-50 blows per foot.
Very dense--more than 50 blows per foot.

Consistency

Very soft--less than 2 blows per foot.
Soft--2-4 blows per foot.
Medium--4-8 blows per foot.
Stiff--8-15 blows per foot.
Very stiff--15-30 blows per foot.
Hard--more than 30 blows per foot.

Other measurements

Other measurements used, for which no ASTM standards exist, included: bulk densities of the material in each Shelby tube, pocket penetrometer resistance, and X-ray clay-mineral analysis. Bulk densities of the material in the Shelby tubes were obtained from measurements of the weight, volume, and moisture content of the material when the material was extruded from the tubes. The pocket penetrometer used is the model sold by Soiltest Inc. X-ray clay-mineral analyses to determine clay mineralogy were conducted and interpreted according to the procedures described by Schultz (1964).

Geophysical investigations

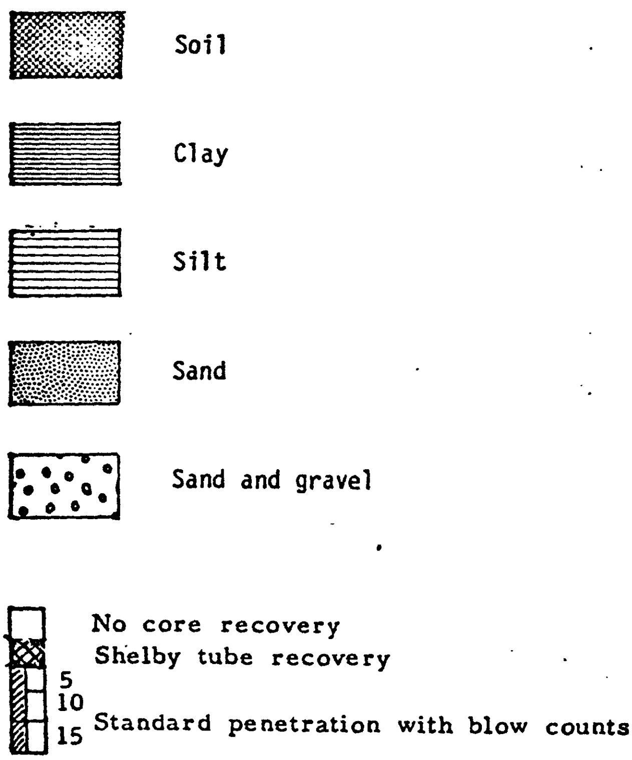
Compressional and shear-wave velocities were measured in boreholes at the five sites shown in figure 1 and the shear modulii, as well as the other elastic constants and Poisson's ratio, were computed from the inhole velocities and core densities. The downhole techniques employed at the five borehole sites produced strains of as much as 0.001 percent. The results of the measurements and computations by C. H. Miller and J. K. Odum are summarized in figure 2.

The compressional and shear waves were generated and recorded using techniques described by Gibbs and others (1975). Compressional waves were generated by a vertical impact of a sledge hammer on a steel plate and shear waves by horizontal impacts on a horizontally oriented structure. The shear-wave structure was impacted on both ends to obtain a phase reversal, which facilitated identification of the onset of shear waves. Dynamic shear modulii are proportional to the square of the shear-wave velocities, which are usually measured in situ.

Test hole data

Each test hole is described separately. The lithologic log and descriptions and the sample locations are related to hole depth in meters. Geophysical calculations, in separate figures, are also keyed to depth of the test hole.

Pattern symbols of the dominant lithology used on the lithologic log column



Material	Shear Wave Velocity (m/s) Mean	Standard Deviation
Clay-Silty Clay very soft-soft	88	22
Clay-Silty Clay medium-hard	186	22
Sandy Clay-Silt Loam Interbedded Coarse and Fine Sediment	265	32
Sand loose to dense	206	36
Sand dense to very dense	366	84
Gravel	504	138

Figure 2.-- Shear-wave velocities in geologic materials (modified from Borcherdt and others, 1979, table 1, p.23).

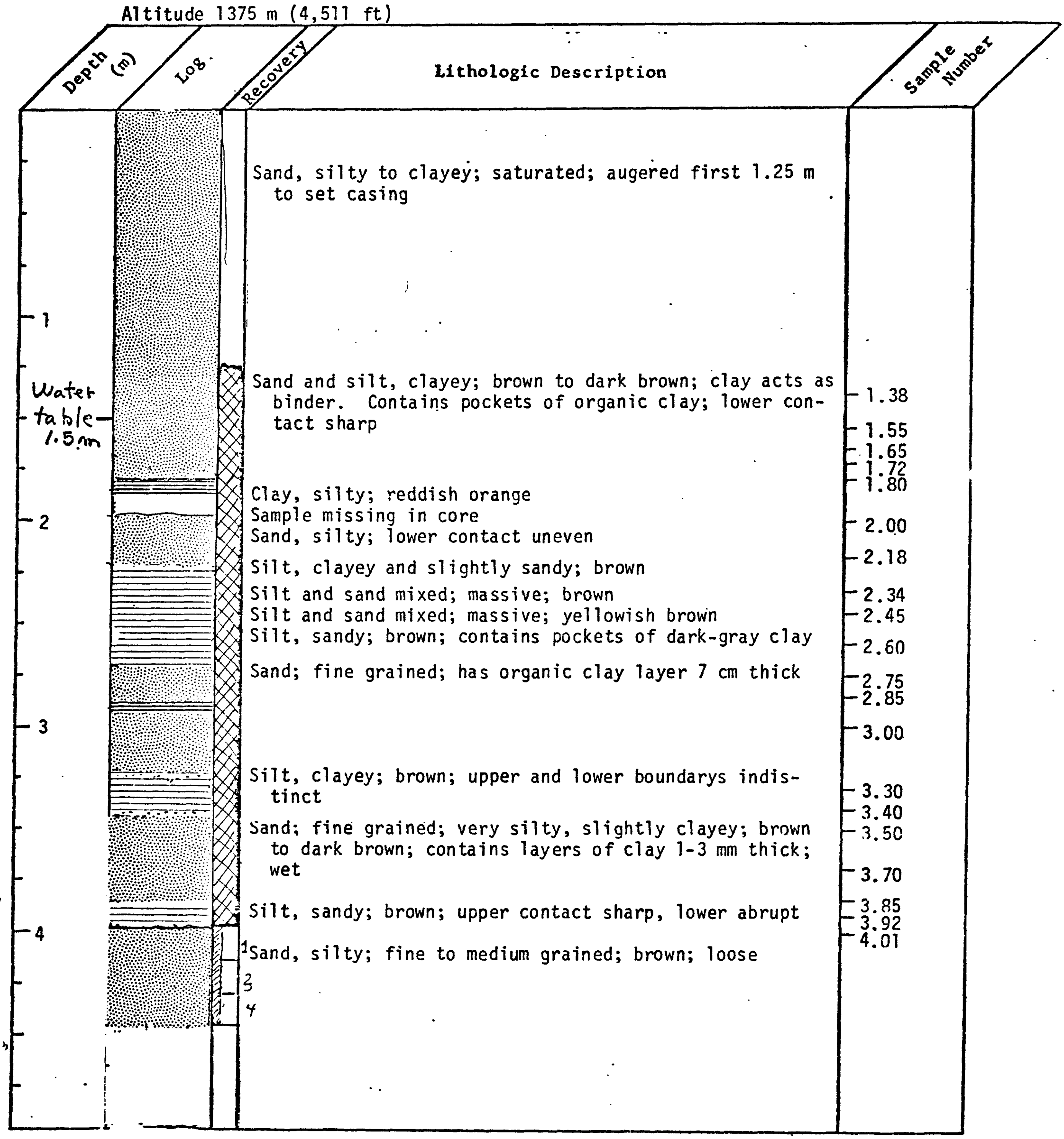
Lake Shore site (LS)

The Lake Shore site lies about 16 km southwest of Provo, Utah, and about 1 km north of the community of Lake Shore (fig. 1). The hole was drilled in the NW 1/4, SW 1/4, SW 1/4, sec. 9, T. 8 S., R. 2 E., Provo 7 1/2' quadrangle. This site was selected as a location that would provide samples believed to be typical of the deposits in the lowlands of Utah Lake valley. The site is about 2.5 km from the shore of Utah Lake, and is less than 7.5 m above the water level of the lake.

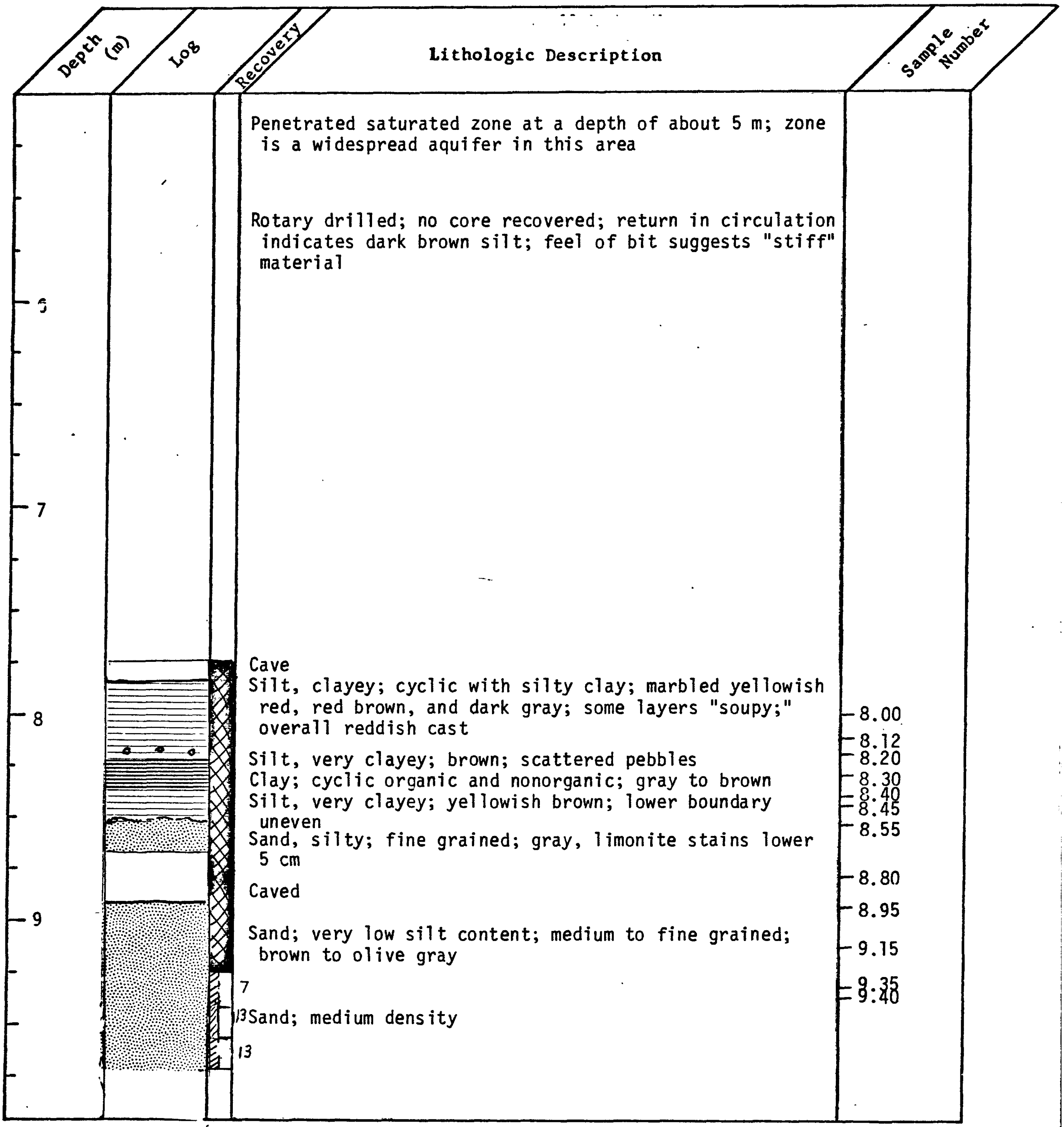
Deposits penetrated by the test hole are fine-grained silts, sands, and clays deposited in the waters of Lake Bonneville.

The test-hole log follows:

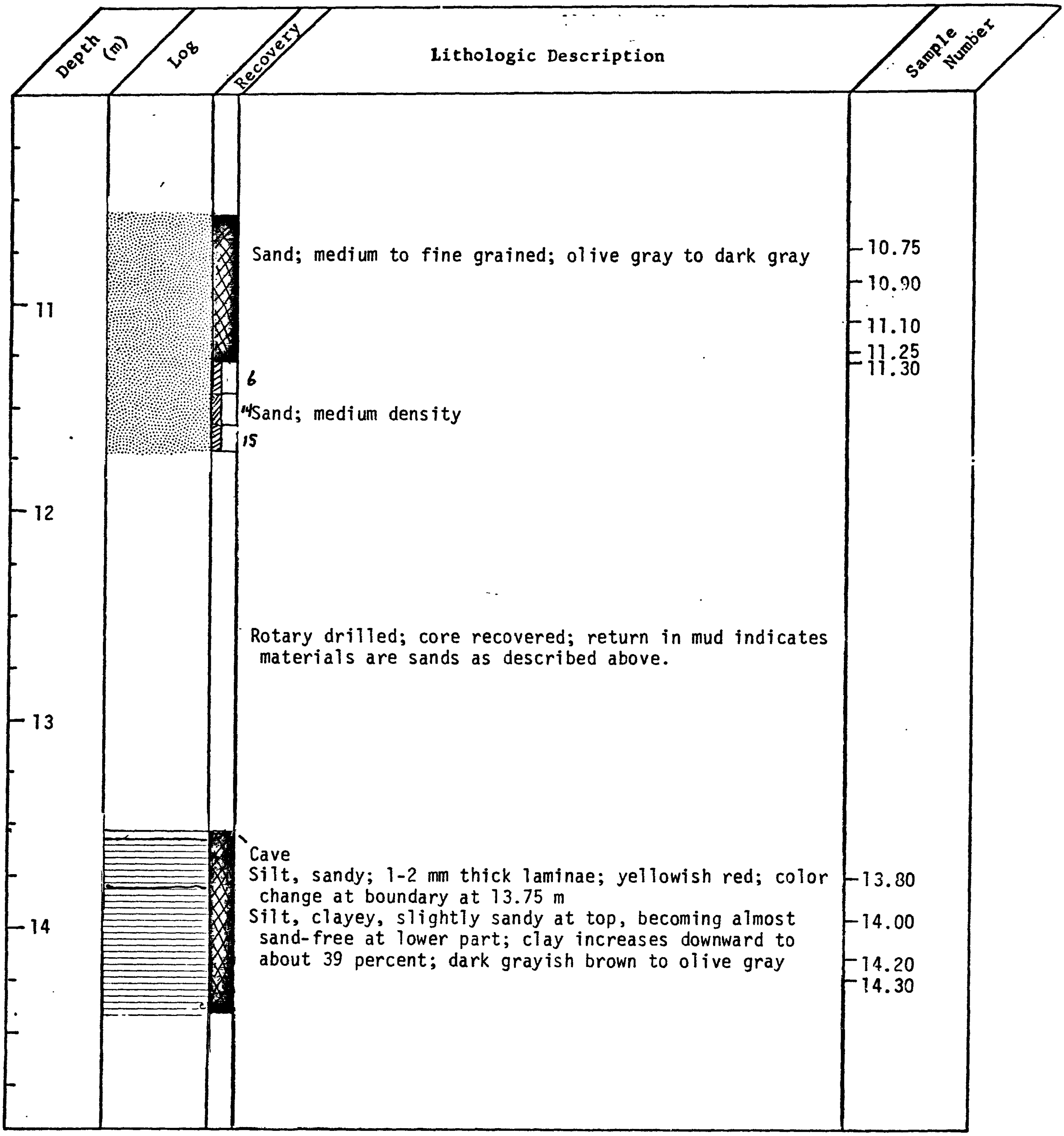
Lake Shore site



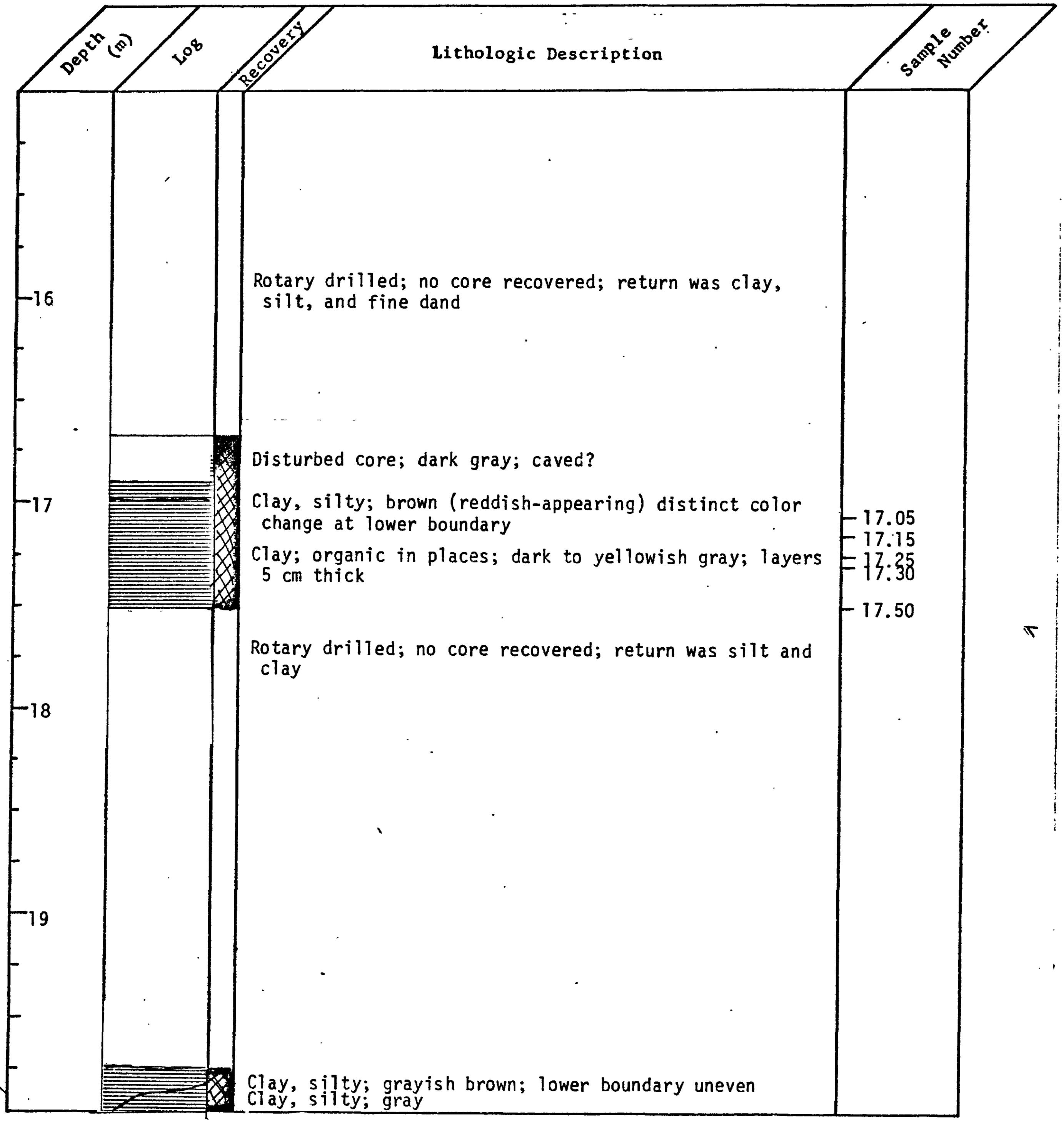
Lake Shore site



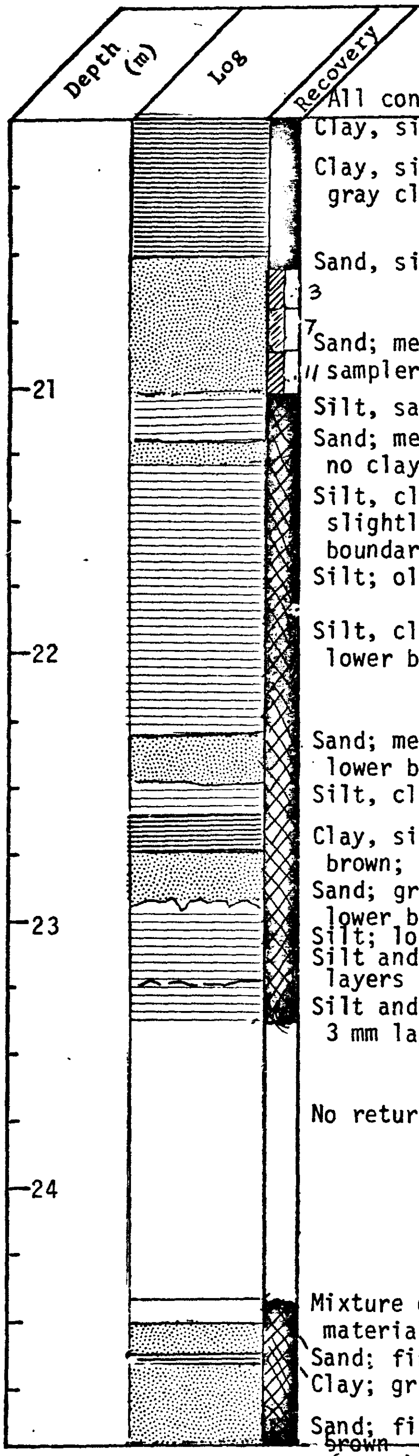
Lake Shore site



Lake Shore site



Lake Shore site

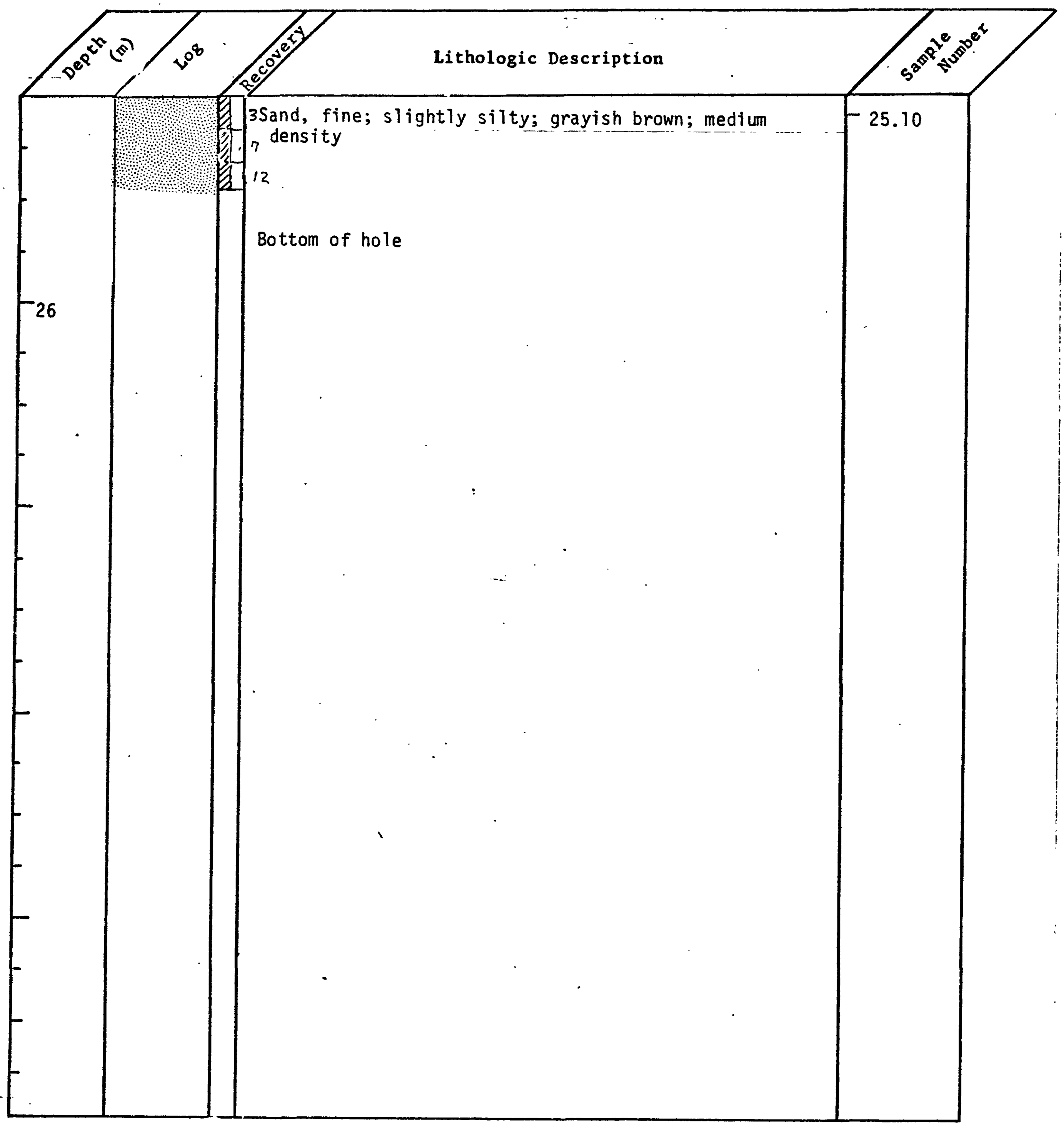


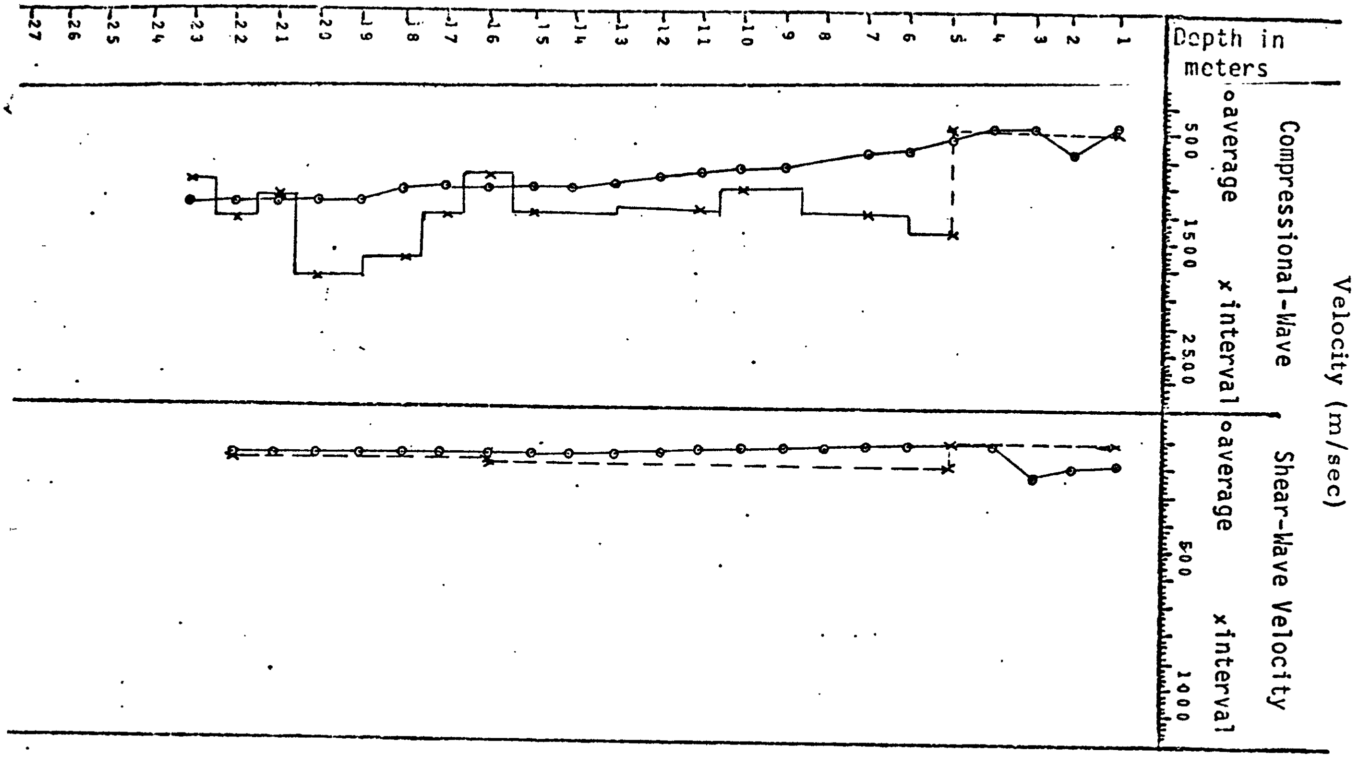
Lithologic Description

All contacts are gradational unless otherwise described

Lithologic Description	Sample Number
Clay, silty; grayish brown in uneven contact	20.05
Clay, silty; gray; organic; wavy layers of very dark gray clay 0.-]10 cm thick; sharp lower boundary	20.15 20.25 20.35
Sand, silty; fine grained; olive gray	20.55 20.59
Sand; medium to fine grained as seen in split tube sampler; medium density	
Silt, sandy; brown; sharp lower boundary	21.10
Sand; medium to fine grained; very dark brown; little to no clay	21.20 21.30
Silt, clayey; reddish brown; during extrusion dark gray slightly clayey silt oozed from tube at 21.55 m, at boundary with gray silt	21.50 21.55 21.60
Silt; olive gray; wet, fell out of tube at 21.79 m	21.70
Silt, clayey; brown to dark brown; gray below 22.10 m; lower boundary abrupt	21.95 22.05 22.20
Sand; medium to fine grained; grayish brown; distinct lower boundary	22.30 22.40
Silt, clayey; has stringers of fine sand and clay; brown	22.50
Clay, silty; intermixed with silt; brown to yellowish brown; lower boundary distinct	22.65 22.80
Sand; granules as large as 10 mm; olive gray; soil? lower boundary sharp and uneven	22.95 23.00
Silt; low in clay and sand; olive gray	
Silt and very fine sand; olive gray; alternates with layers of silty clay; lower boundary uneven	23.25
Silt and very fine sand; 2 cm layers alternate with 3 mm layers of clayey silt	
No return	
Mixture of clay, silt, and sand; brown and gray; caved material?	24.50
Sand; fine to very fine; dark gray; sharp boundarys	24.75
Clay; gray; layer 2.5 cm thick	
Sand; fine to very fine; slight amount of silt; grayish brown	24.90

Lake Shore site





Natural Bulk Density 1/ (measured)	Shear modulus $N/m^2 X 10^9$ (calculated)	Poisson's Ratio (calculated)	Young's modulus $N/m^2 X 10^9$ (calculated)	Bulk modulus $N/m^2 X 10^9$ (calculated)
2.11	0.0730	0.39	0.203	0.315
2.07 1.93	.0241 .0225	.48 .48	.071 .067	.511 .448
1.99	.0741	.49	.221	4.415
1.94	.0722	.49	.216	4.304
1.80	.0558	.49	.167	4.001
1.78	.0527	.49	.157	3.786
1.95	.0604	.49	.180	4.343

1/ from table 1

Figure 3.--In-hole compressional and shear-wave velocities from the Lake Shore site test hole, with measured densities and calculated moduli and ratios. Dashed lines are interpolated measurements.

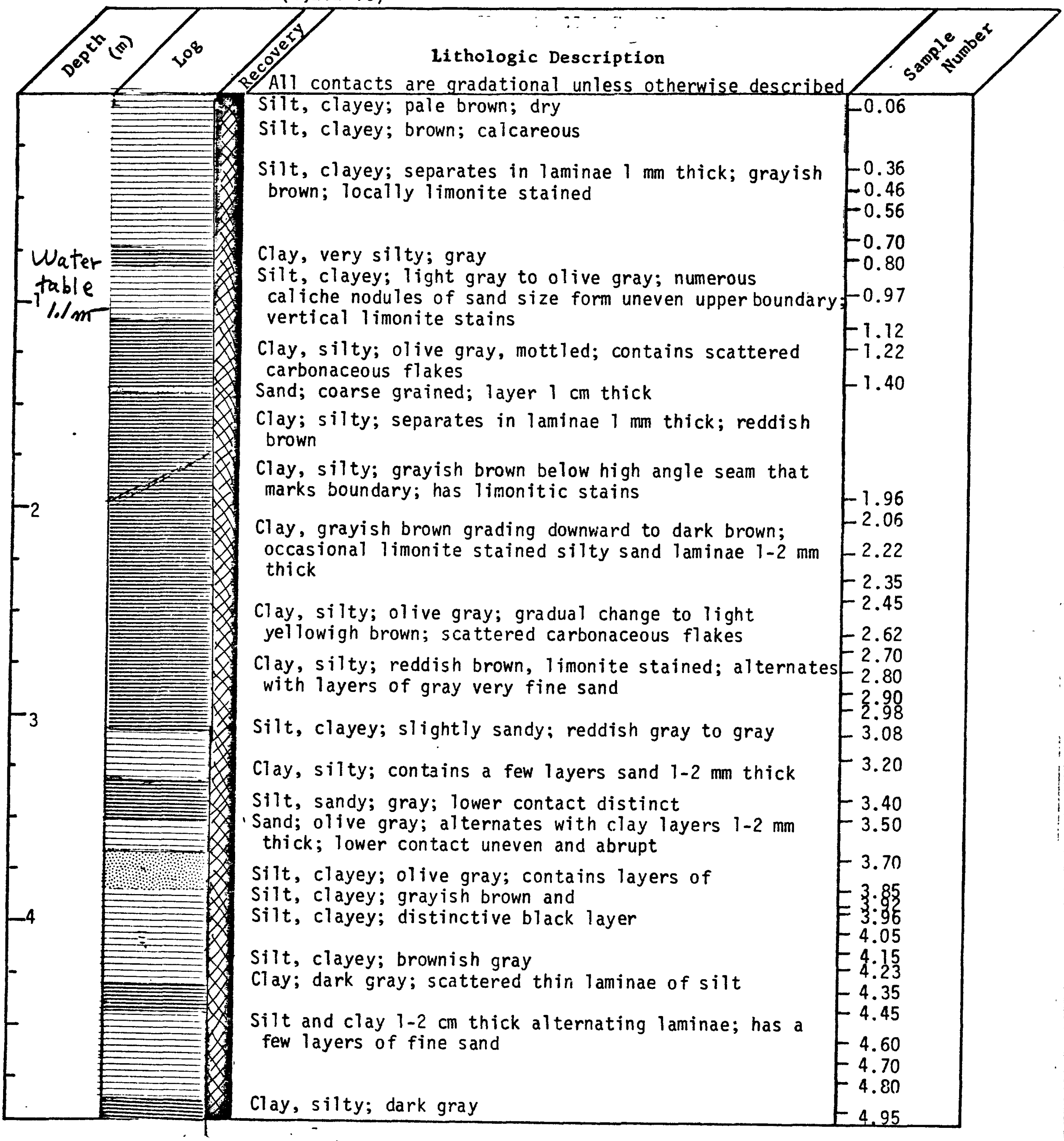
KSL Transmitter site (KSL)

The KSL Transmitter site is located about 18 km west of Temple Square, Salt Lake City, Utah. The hole is about 69 m northeast of the transmitter tower for radio KSL in the SW 1/4, NW 1/4, sec. 32, T. 1 N., R. 2 W., Saltair 7 1/2' quadrangle. The site was selected as being typical of wet fine-grained materials on the Jordan River delta. The delta underlies much of the urbanized part of western Salt Lake City and its environs. The ground level at the site is only 3.5 m above the level of Great Salt Lake (as shown on the U.S. Geological Survey topographic Saltair quadrangle, 1972 edition).

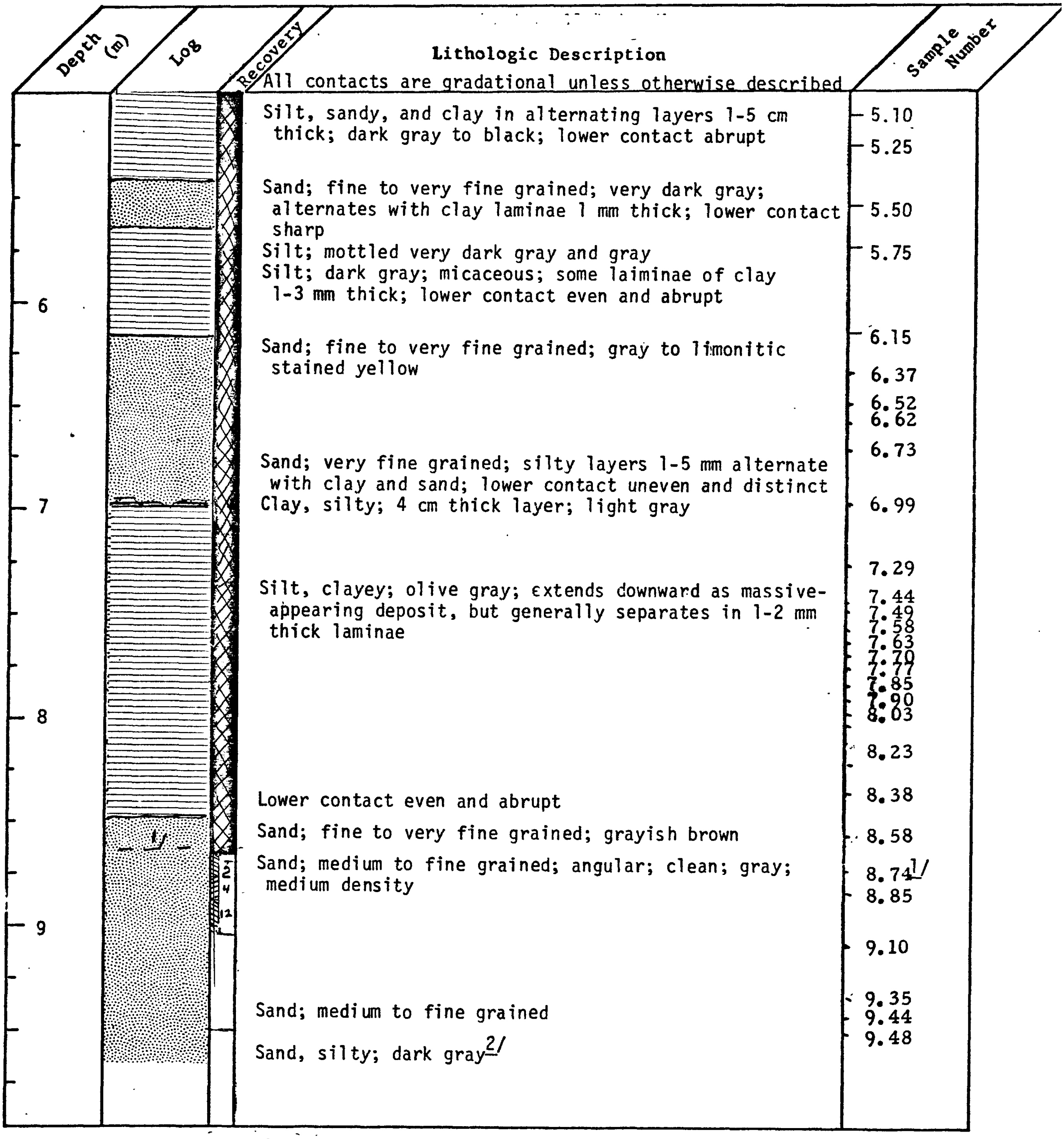
A test hole was augered and sampled with hollow-tube samplers to a depth of 6 m. After standing overnight, water stood in the hole at a depth of 1.1 m. After augering and sampling an additional 3 m, the tube bound in the hole and sheared. A new hole was started 3 m east of the first hole, and was rotary drilled with mud circulation to a depth of 9 m without sampling or logging; samples were collected from the second hole and logged below 9 m.

KSL Transmitter site

Altitude 1284 m (4,212 ft)



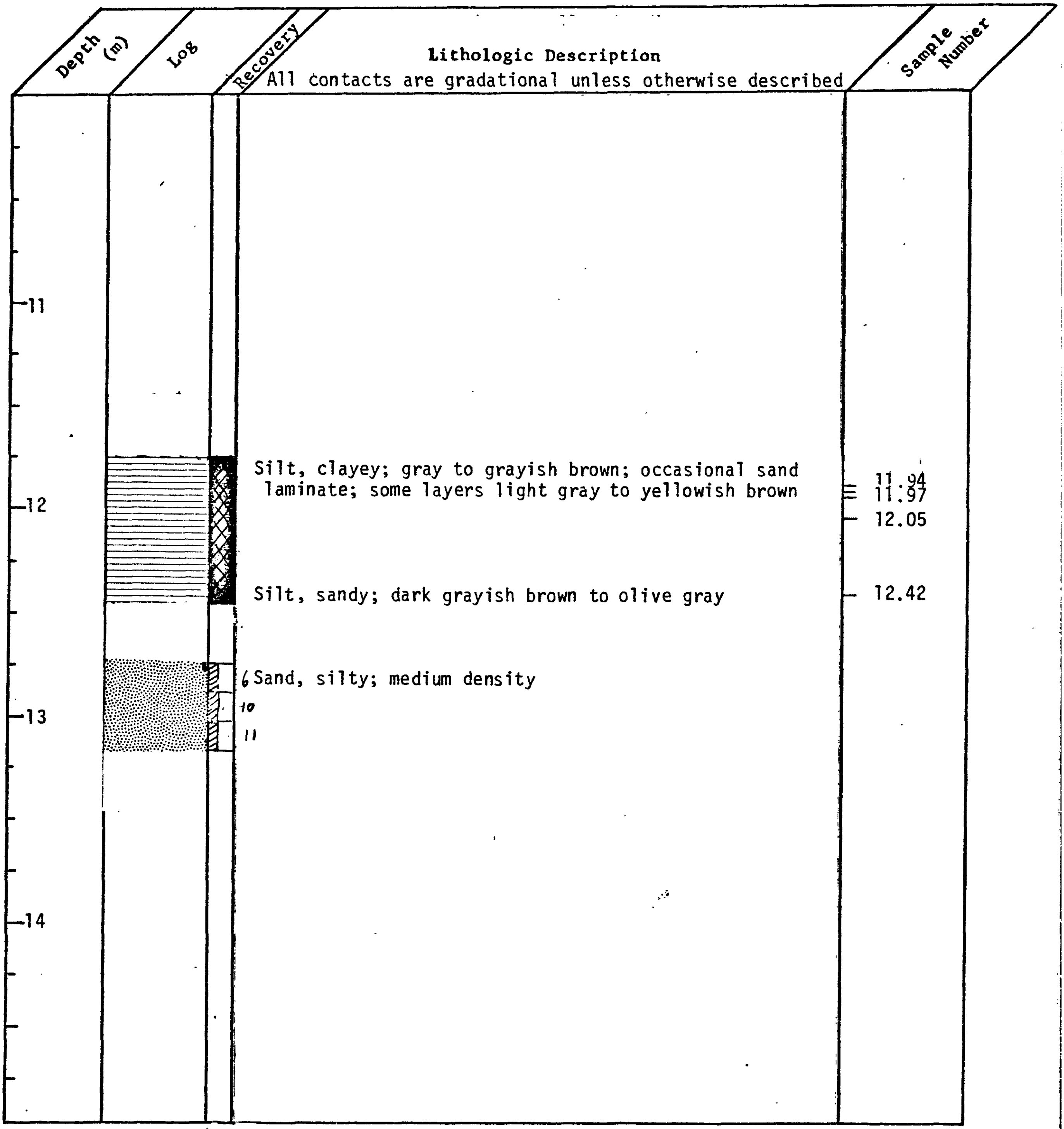
KSL Transmitter site



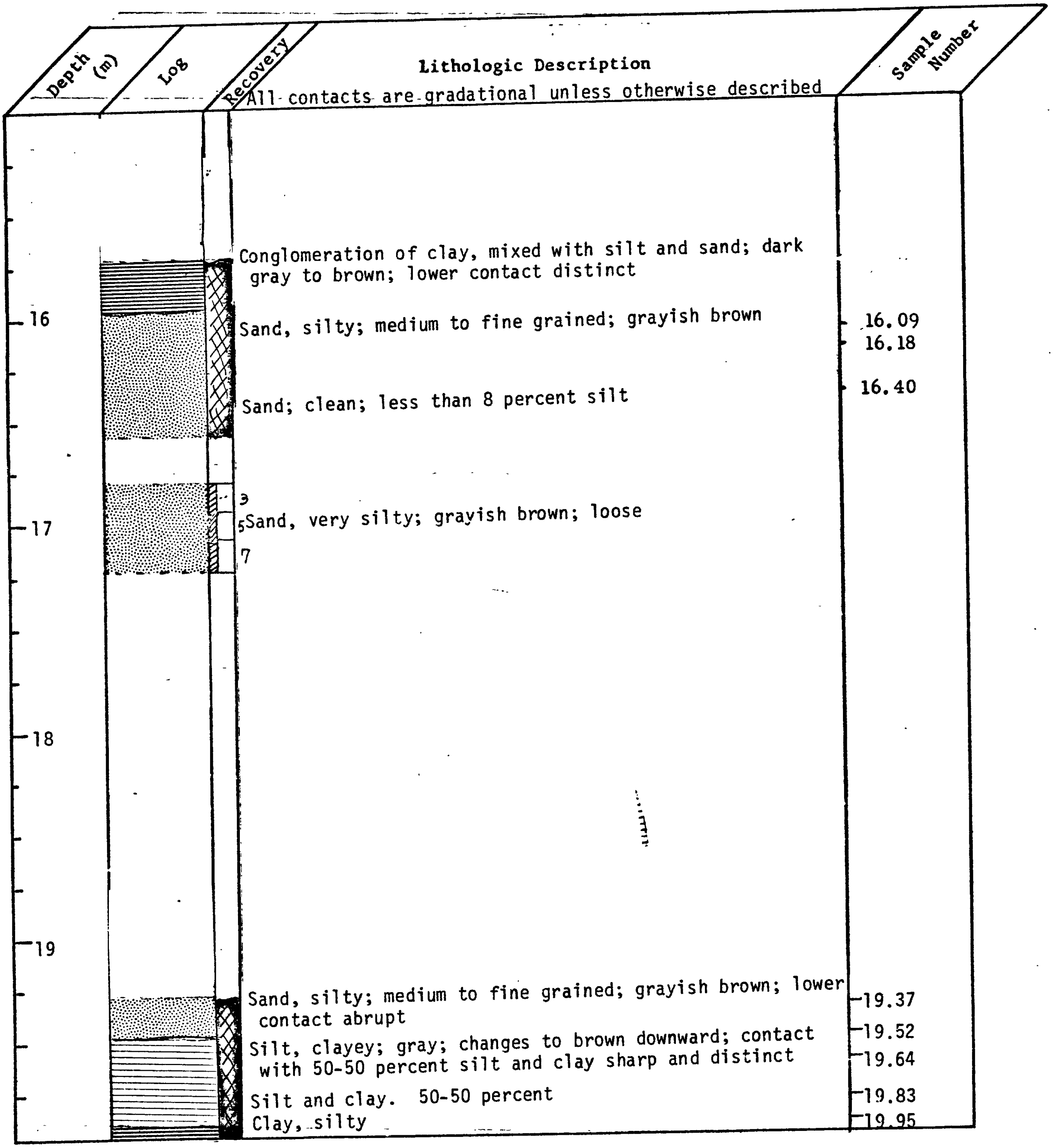
1/ Shelby tube bound; moved hole; rotary drilled to 8.7 m; blow counts in new hole

2/ Data from spoon sample in new test hole below 9.48 m

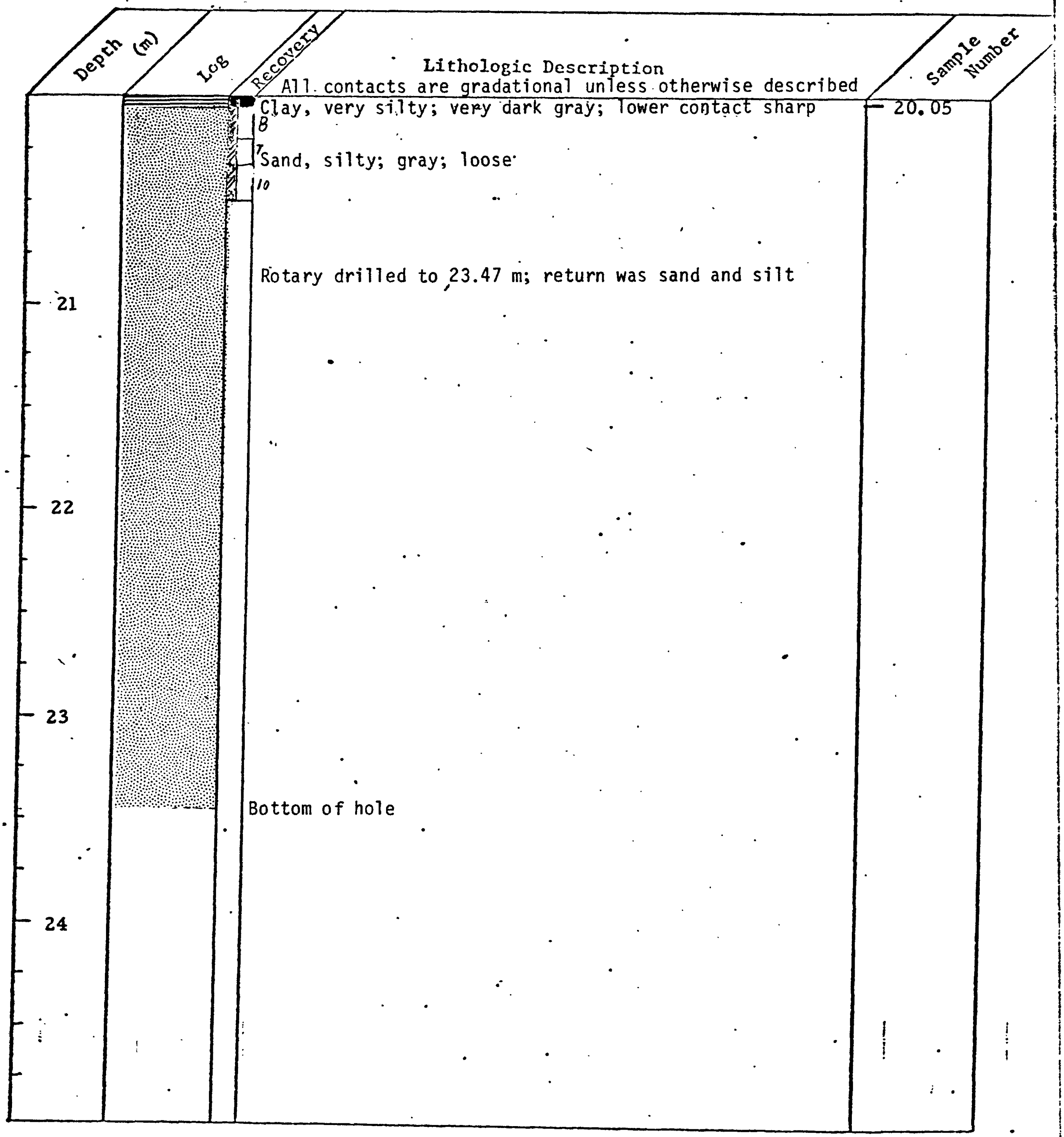
KSL Transmitter site

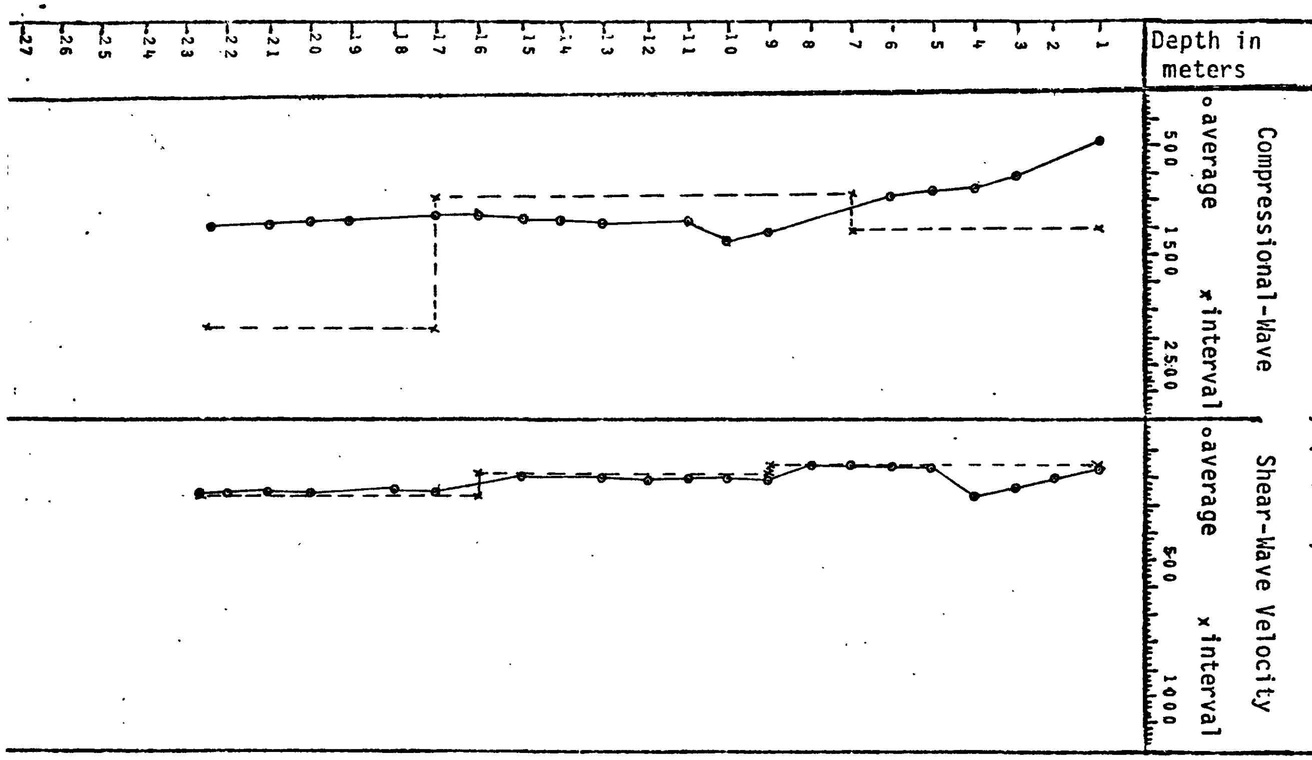


KSL Transmitter site



KSL Transmitter site





Natural Bulk Density 1/ (measured)	Shear modulus $N/m^2 X 10^9$ (calculated)	Poisson's Ratio (calculated)	Young's modulus $N/m^2 X 10^9$ (calculated)	Bulk modulus $N/m^2 X 10^9$ (calculated)
1.87	0.0600	0.42	0.1704	0.362
1.71	.1730	.46	.5068	2.425
1.91	.2545	.45	.7400	2.626
1.74	.5477	.37	1.504	1.971
2.08	.0526	.49	.1569	3.159
1.78	.0450	.49	.1343	2.704
1.93	.0488	.49	.1456	2.932
2.05	.0518	.49	.1547	3.114
1.97	.0498	.49	.1484	2.432
2.01	.0780	.48	.2302	1.546
1.86	.0950	.47	.2788	1.400
1.94	.1262	.49	.3768	9.395

1/ from table 3

Figure 4.--In-hole compressional and shear-wave velocities from the KSL Transmitter site test hole, with measured densities and calculated moduli and ratios. Dashed lines are interpolated measurements.

Farmington Siding site, test holes FS-1 and FS-2

Two test holes were drilled at the Farmington Siding site, which is located about 1.8 km northwest of the courthouse in Farmington, Utah. The site is on a large translatory slide described by Van Horn (1975) and Miller (1980). The first hole (FS-1, fig. 1) was started on top of a mound (altitude 1296 m) that was displaced during slide movement; the second hole (FS-2, fig. 1) was started on the slide at the base of the mound at the level of the general slide surface (altitude 1290 m). Both holes are in the NE 1/4, SW 1/4, SE 1/4, sec. 14, T. 3 N., R. 1 W., Farmington 7 1/2' quadrangle. The level of the Great Salt Lake is used here as 1280 m (4,200 ft) above sea level, the figure shown on published U.S. Geological Survey topographic maps.

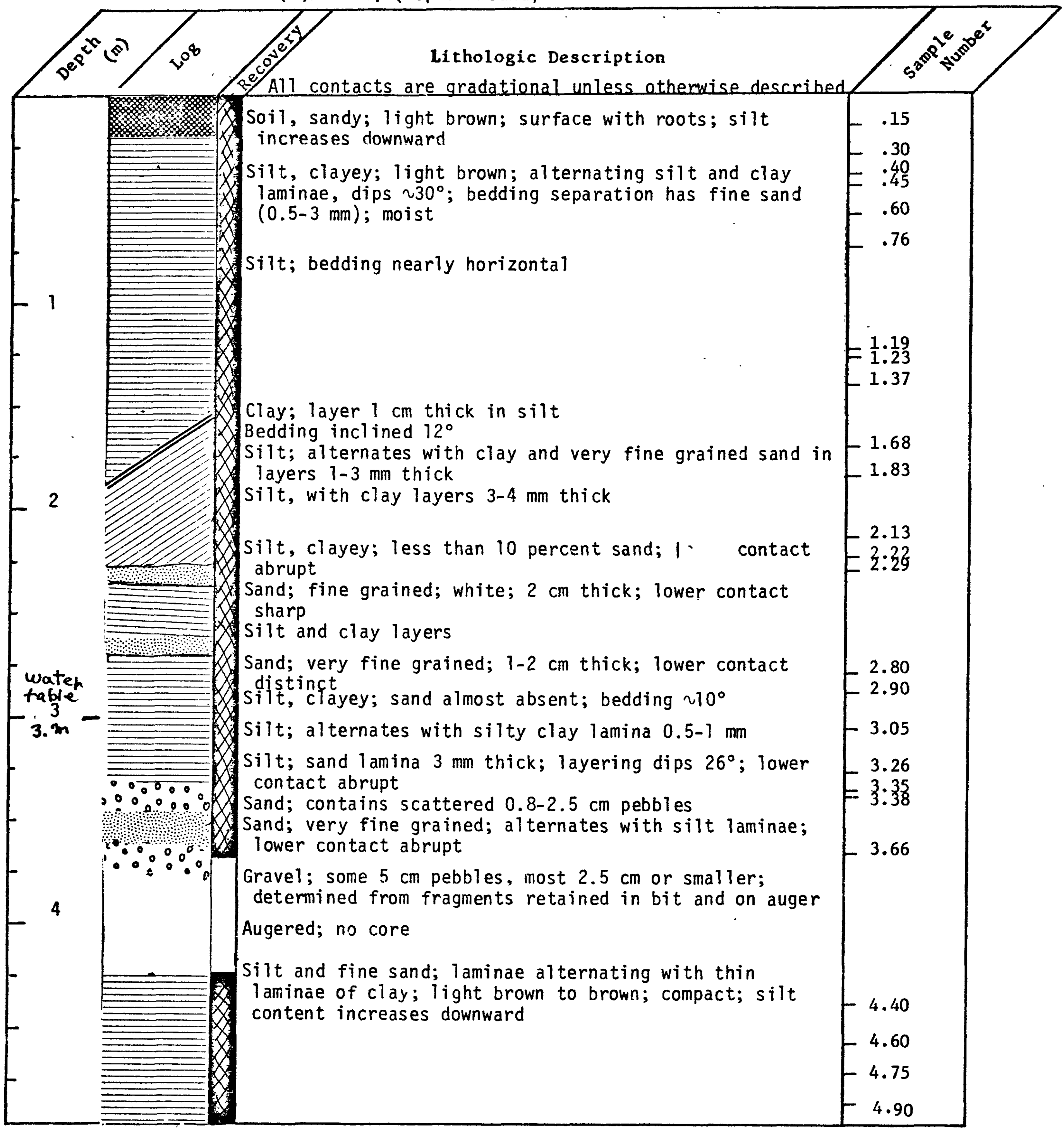
The hole emplaced on top of the mound was sampled to a depth of 8.7 m, and augered to a depth of 38 m, where the auger bound and was pulled from the hole. Plastic casing was placed in the hole to a depth of 29 m; bouyancy was sufficient to force the casing upward. Sand was used to pack the casing against the wall of the hole. The water level at the completion of drilling was 7.6 m below the top of the mound, but rose overnight to 3 m below the top of the mound. In-hole geophysics was applied to the cased 29 m of hole 1 and about 21 m of hole 2.

The drilling equipment was moved to the base of the mound and the second hole was augered to a depth of 21.6 m. Samples were taken intermittently in deposits that appeared to be uniform throughout.

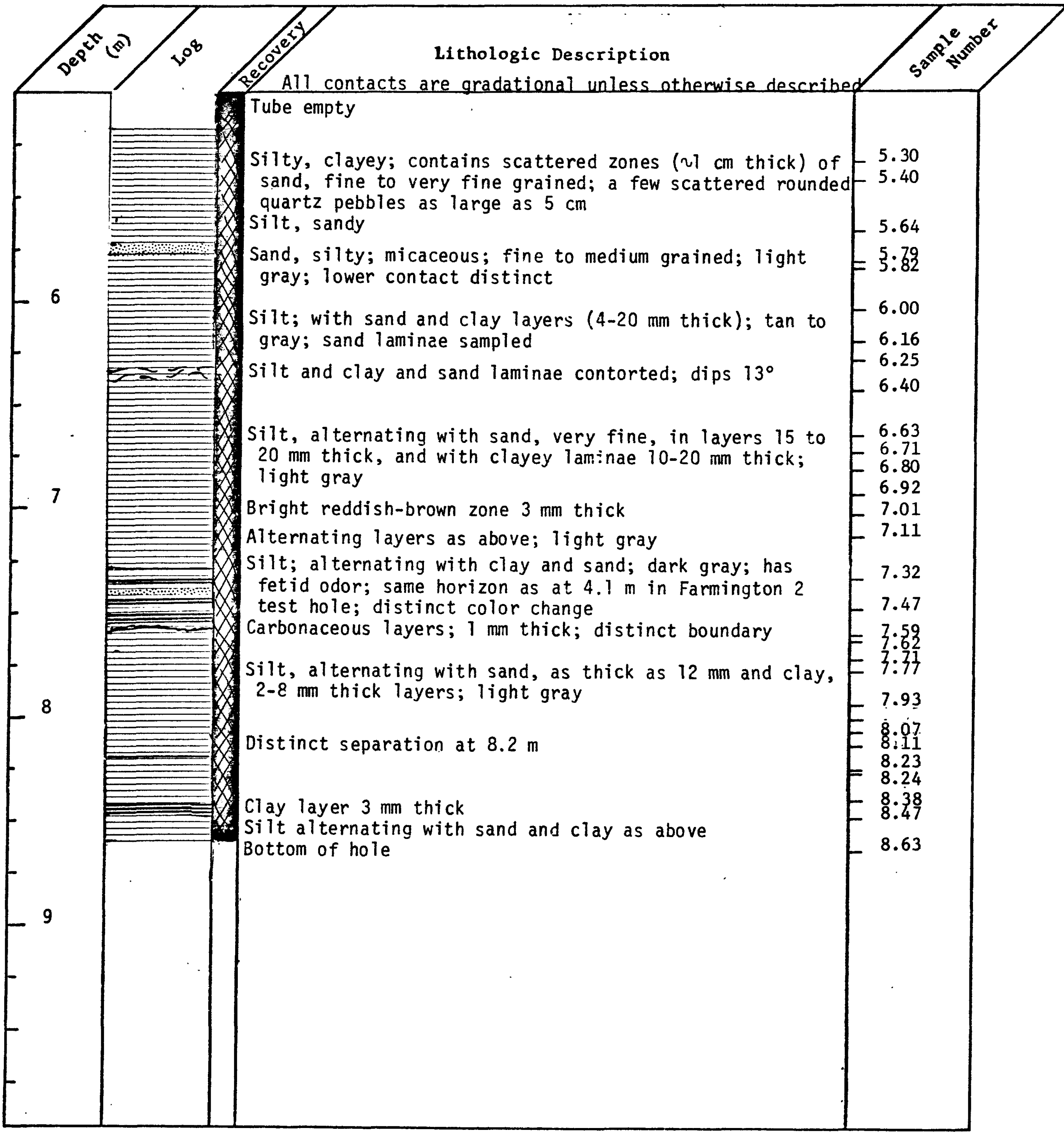
The log of these holes follow:

Farmington Siding site, Hole 1

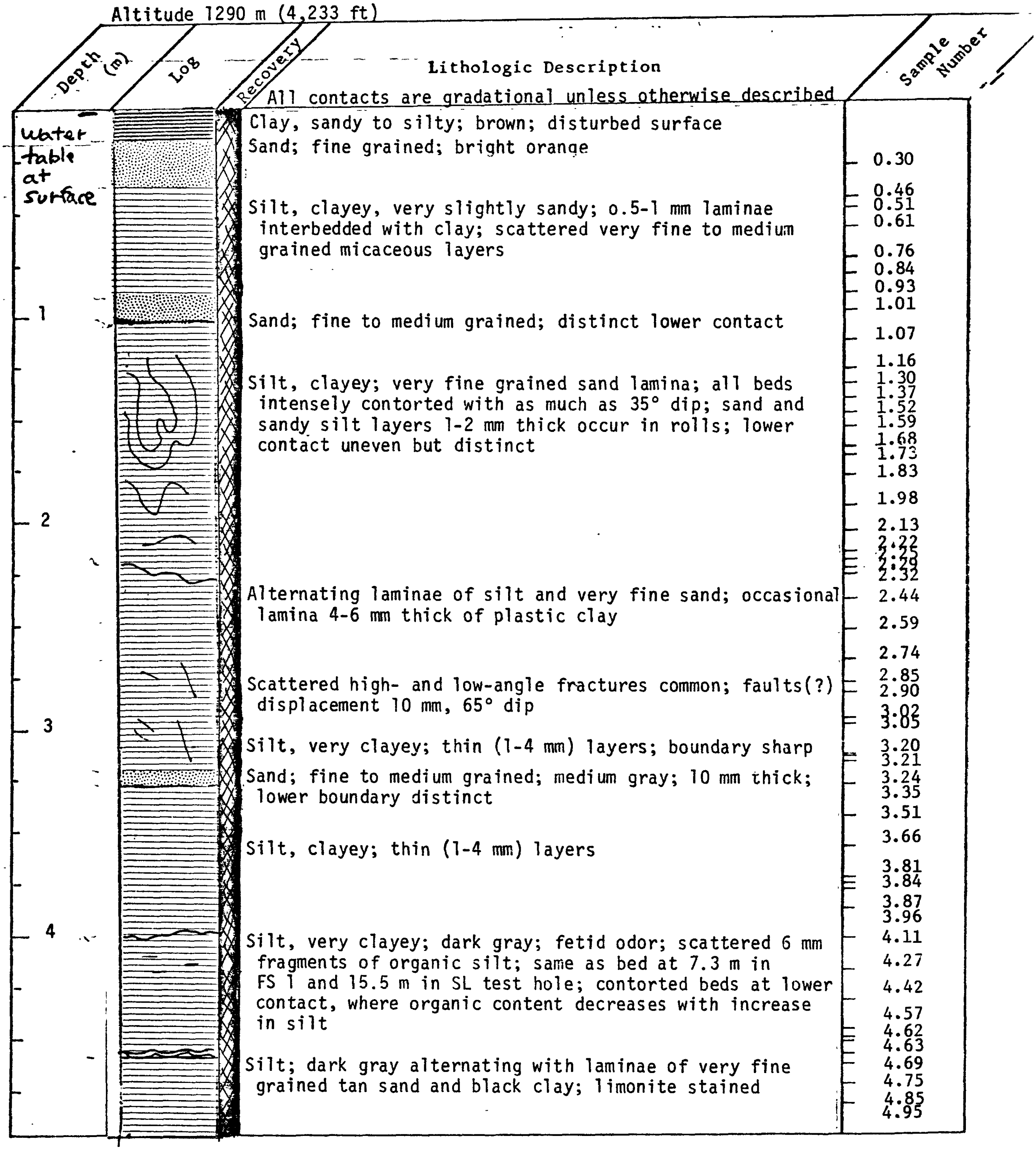
Altitude 1296 m (4,255 ft) (Top of mound)



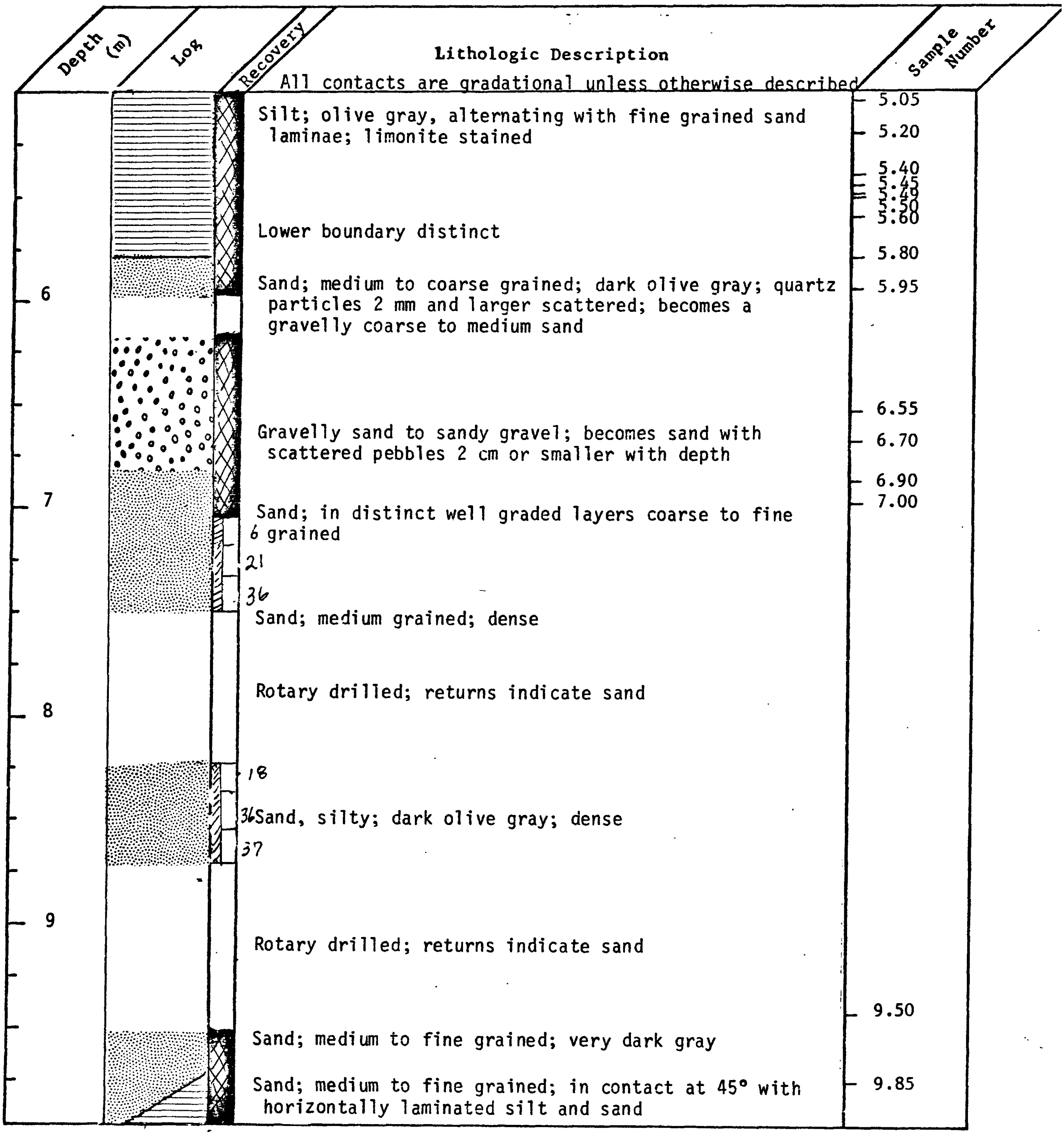
Farming Siding site. Hole 1



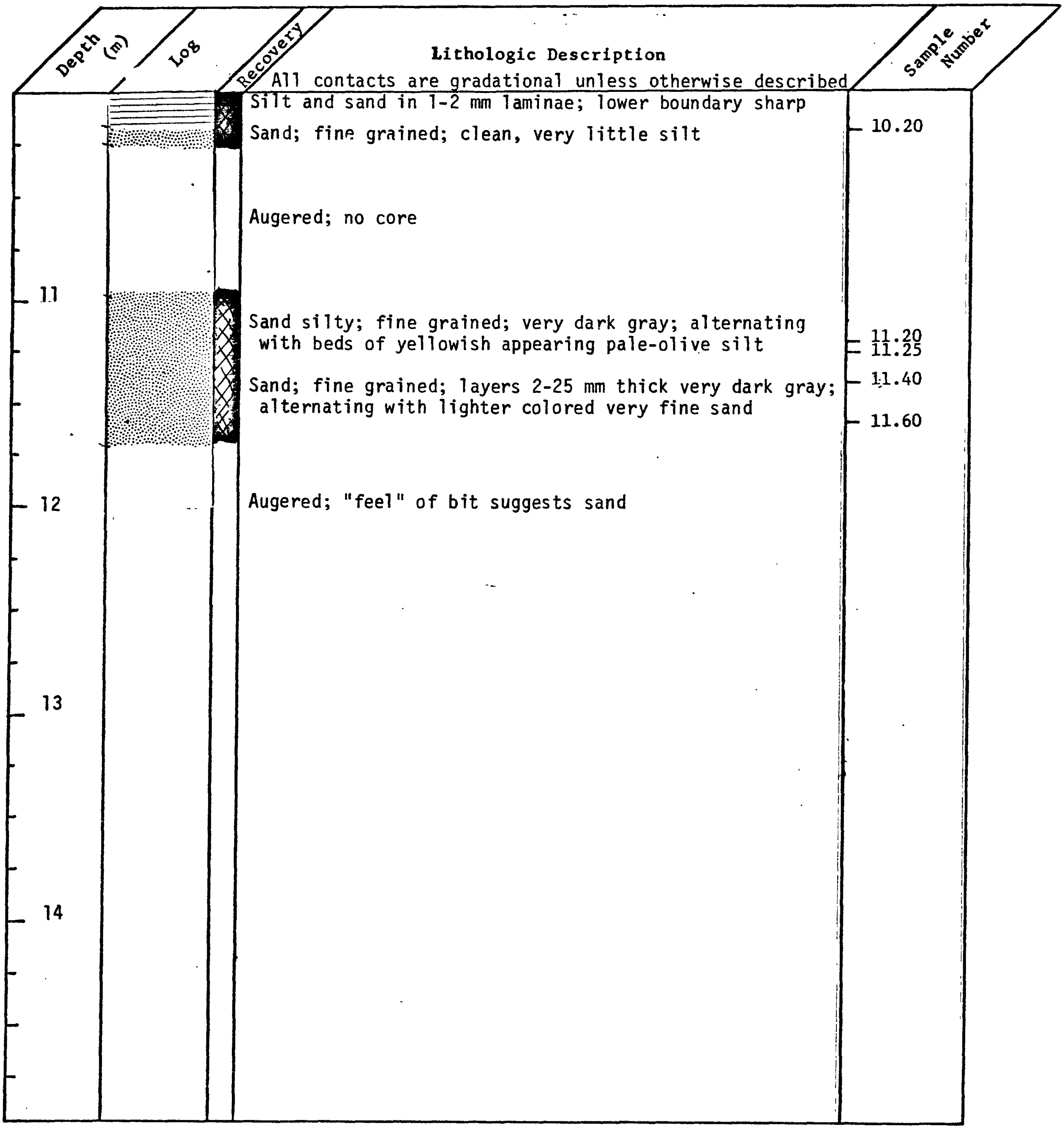
Farmington Siding site, Hole 2



Farmington Siding site, Hole 2



Farmington Siding site, Hole 2



Farmington Siding site, Hole 2

Depth (m)	Log	Recovery	Lithologic Description All contacts are gradational unless otherwise described	Sample Number
16			Gravel and sand; detected from feel and sound of rotary bit	
17			Rotary drilled	
18				
19				
			Gravel; detected from feel and sound of rotary bit; about 10 cm thick	

Farmington Siding site, Hole 2

Depth (m)	Log	Recovery	Lithologic Description All contacts are gradational unless otherwise described	Sample Number
21			Sand, pebbly; dark gray; becomes fine grained downward; boundary abrupt	21.00 21.15
			Clay; very dark gray at top, yellowish below; 10 cm thick; boundary abrupt	21.30 21.40
			Sand, black, and clay, yellowish, interlayered; dips 5-10°; sand layers 1 cm thick, clay layers 6 cm thick	21.60
			Bottom of hole	
22				

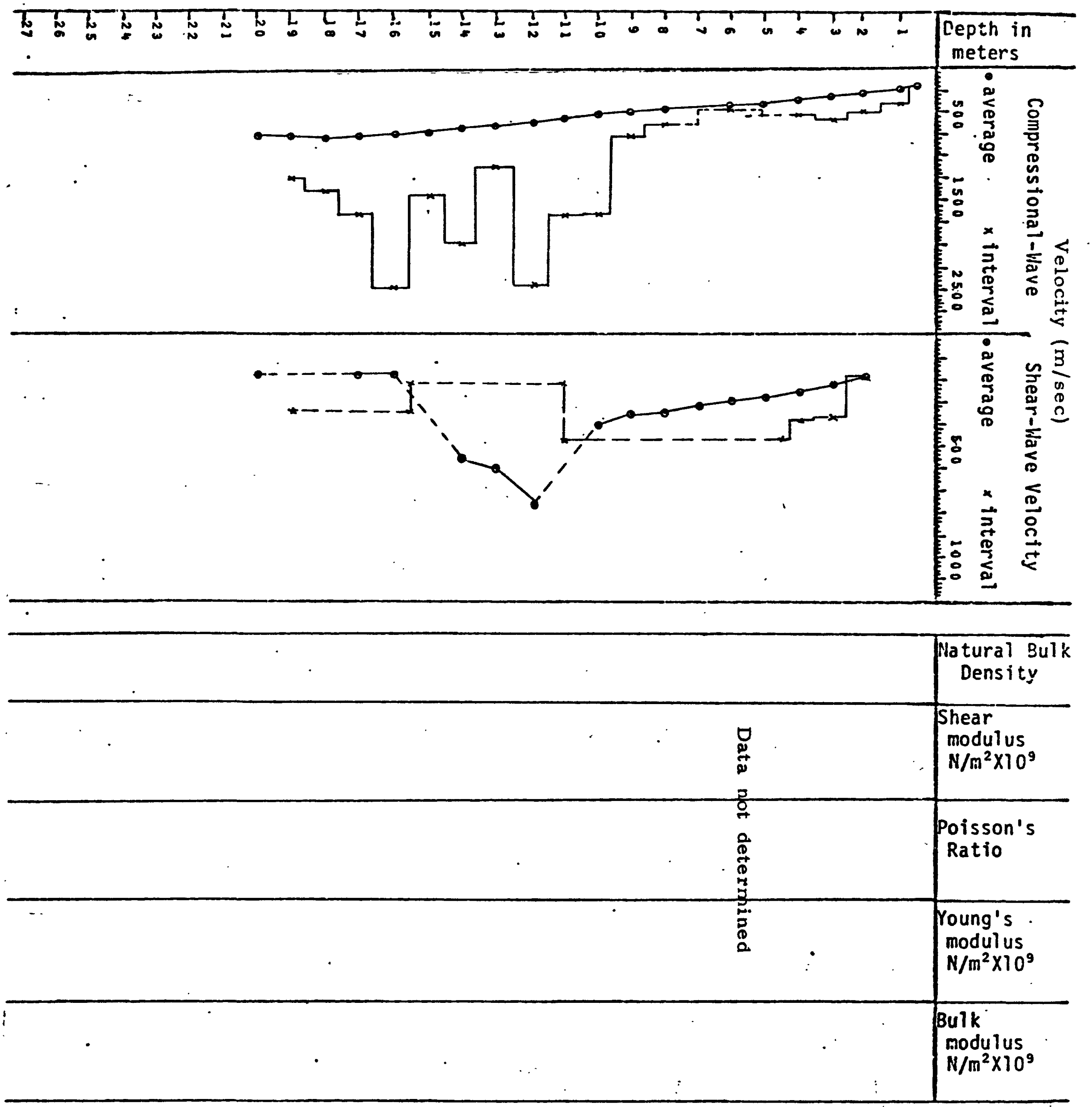
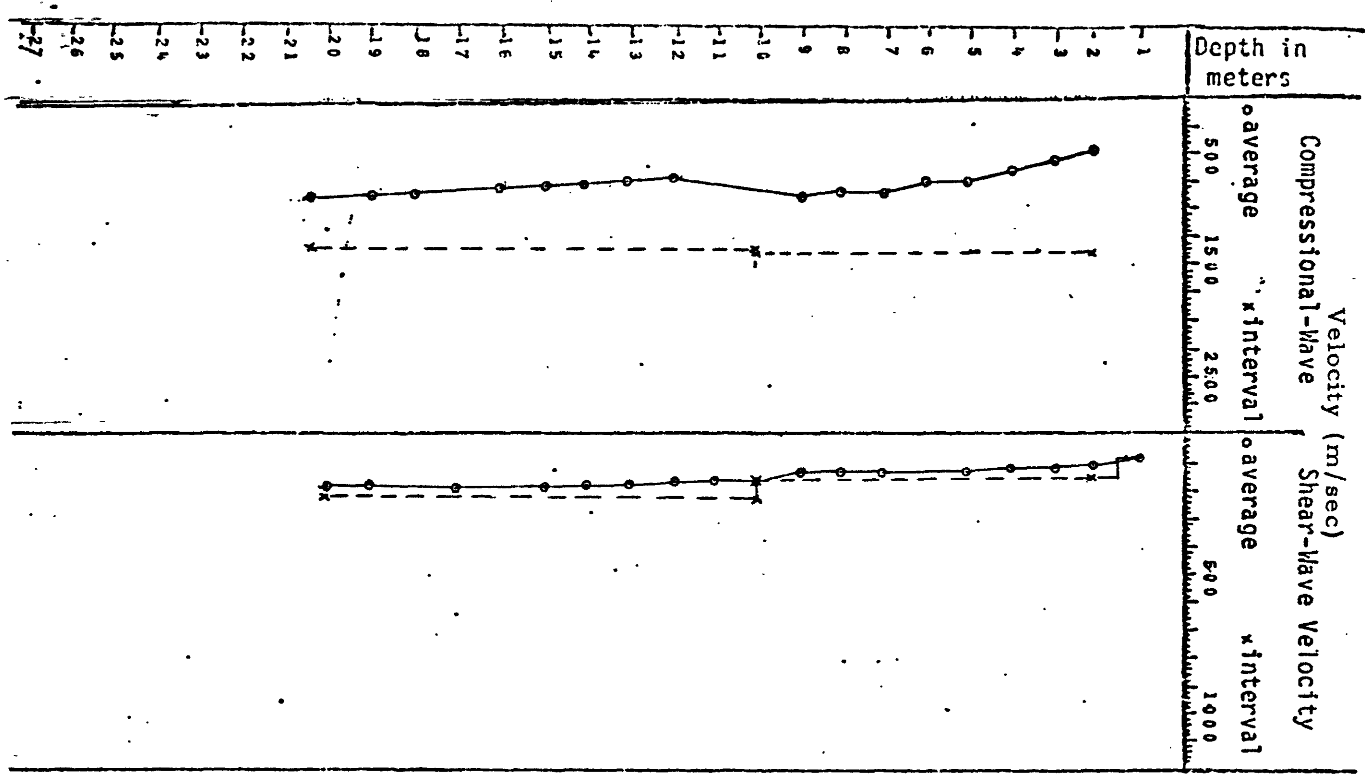


Figure 5.--In-hole compressional and shear-wave velocities from the Farmington Siding site, test hole 1. Dashed lines are interpolated measurements.



Natural Bulk Density 1/	1.97	2.09	1.86	1.86
Shear modulus $N/m^2 X 10^9$ (measured)	0.0437	.0464	.0413	.0860
Poisson's Ratio (calculated)	0.49	.49	.49	.48
Young's modulus $N/m^2 X 10^9$ (calculated)	0.1307	.1387	.1234	.2557
Bulk modulus $N/m^2 X 10^9$ (calculated)	3.842	4.076	3.442	3.201

1/ from table 7

Figure 6.--In-hole compressional and shear wave velocities from the Farmington Siding site, test hole 2, with measured densities and calculated moduli and ratios. Dashed lines are interpolated measurements.

Shepard Lane site (SL)

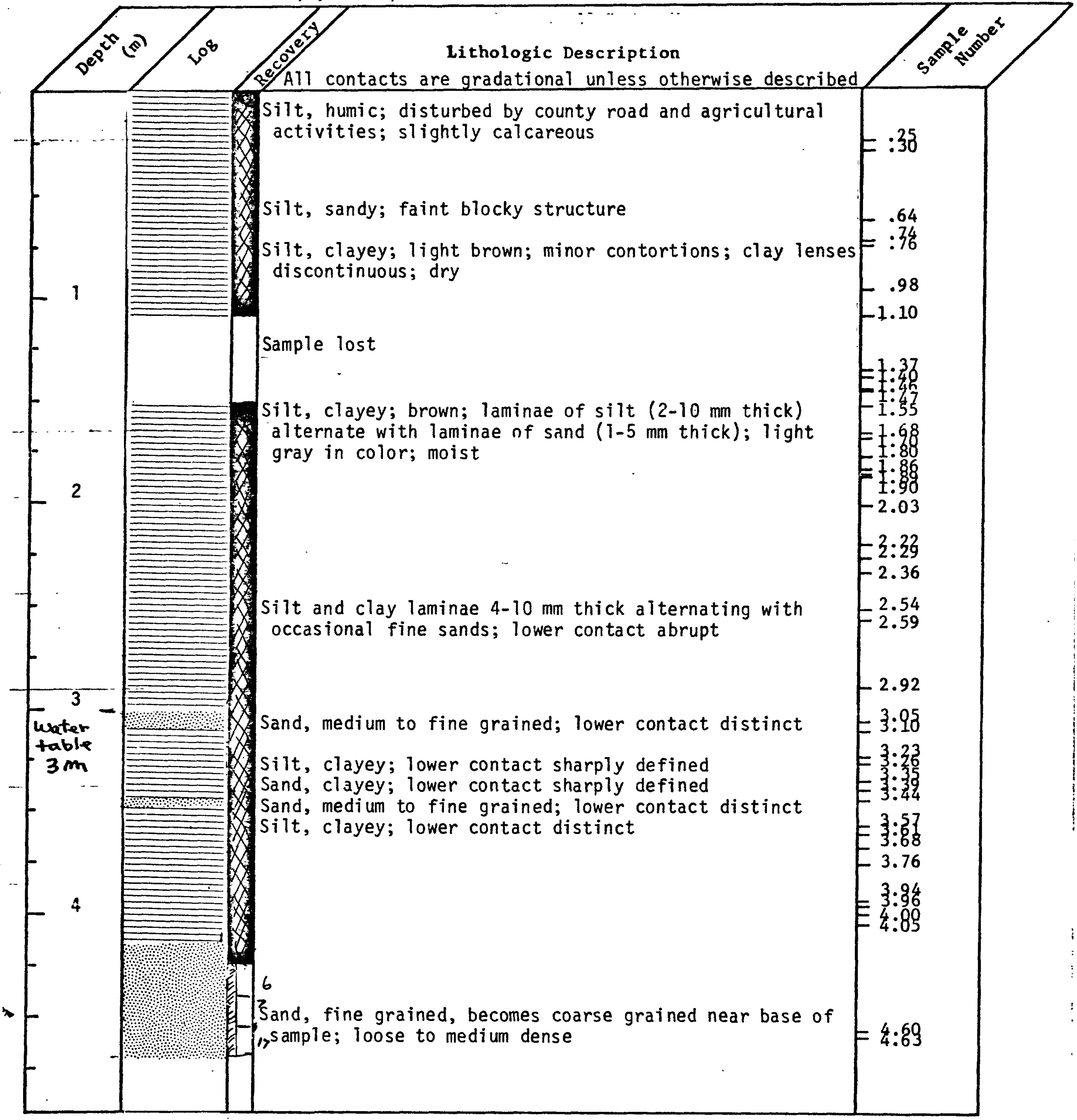
The Shepard Lane site lies about 3.5 km south-southeast of the courthouse in Kaysville, Utah (fig. 1). The site is on the lacustrine deposits of Lake Bonneville that were not involved with the Farmington Siding slide. It is located in the NE corner, sec. 15, T. 3 N., R. 1 W., Kaysville 7 1/2' quadrangle. The purpose of the samples and hole was, in addition to obtaining data on physical properties, to correlate beds under the deposits adjacent to the slide with the beds beneath the mound and low-lying ground on the Farmington Siding slide. A dark-gray silt, having a fetid odor, was penetrated at 15.3 m and correlated with a similar bed at the Farmington site. Much of this hole was advanced by rotary drill with mud circulation, the purpose being to sample only where distinct differences in materials appeared in the return circulation.

The log of the test hole follows:

GEOTECHNICAL MEASUREMENTS LABORATORY
SOIL SAMPLE TEST RESULTS

Shepard Lane site

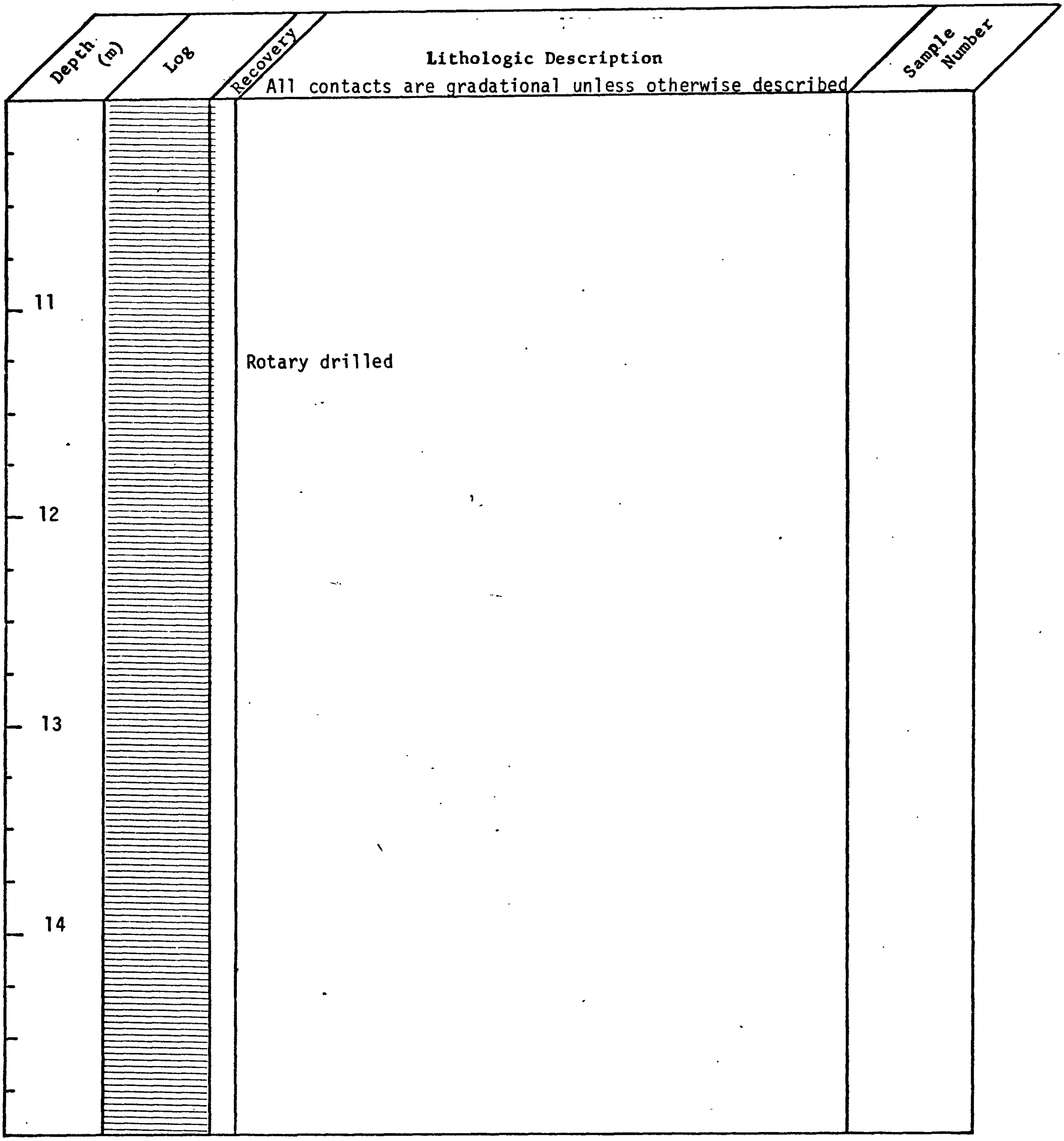
Altitude 1306 m (4,285 ft)



Shepard Lane site

Depth (m)	Log	Recovery	Lithologic Description All contacts are gradational unless otherwise described	Sample Number
			Rotary drilled, sand returned to 9 m	
6				
7				
8				
9				
			Rotary drilled, silt, dark gray to gray return to 15.2 m	

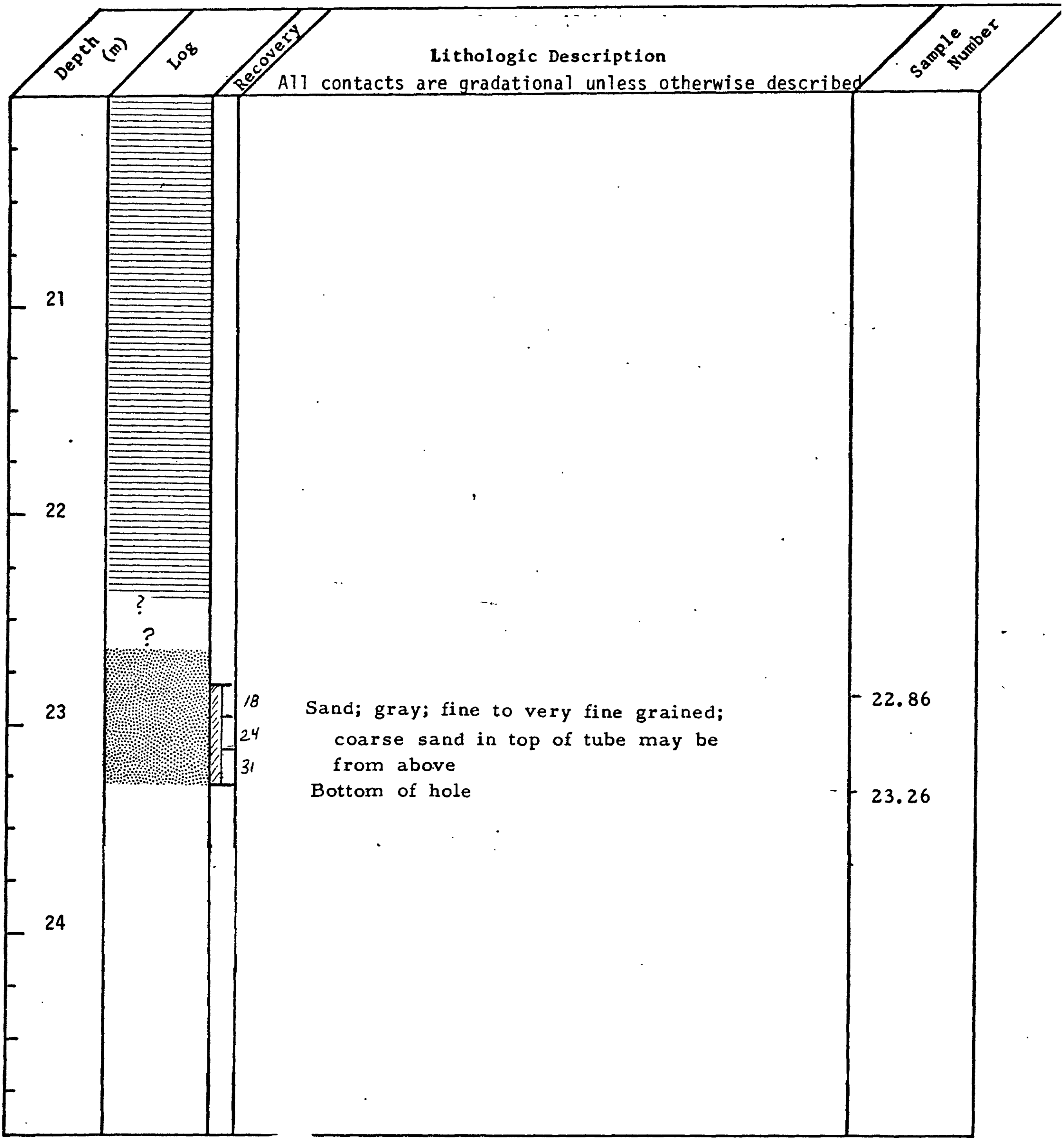
Shepard Lane site



Shepard Lane site

Depth (m)	Log	Recovery	Lithologic Description All contacts are gradational unless otherwise described	Sample Number
			3 Clay, dark gray, silty, organic; very soft	15.50
			4	
			4 Silt, clayey; gray to olive gray; has fetid odor. This is apparently the same bed that is present at 7.3 m in the Farmington 1 hole, and at 4 m in the Farmington 2 hole; loose	15.75
16				
			Rotary drilled; silt and clayey silt returned to about 22.25 m	
17				
18				
19				

Shepard Lane site



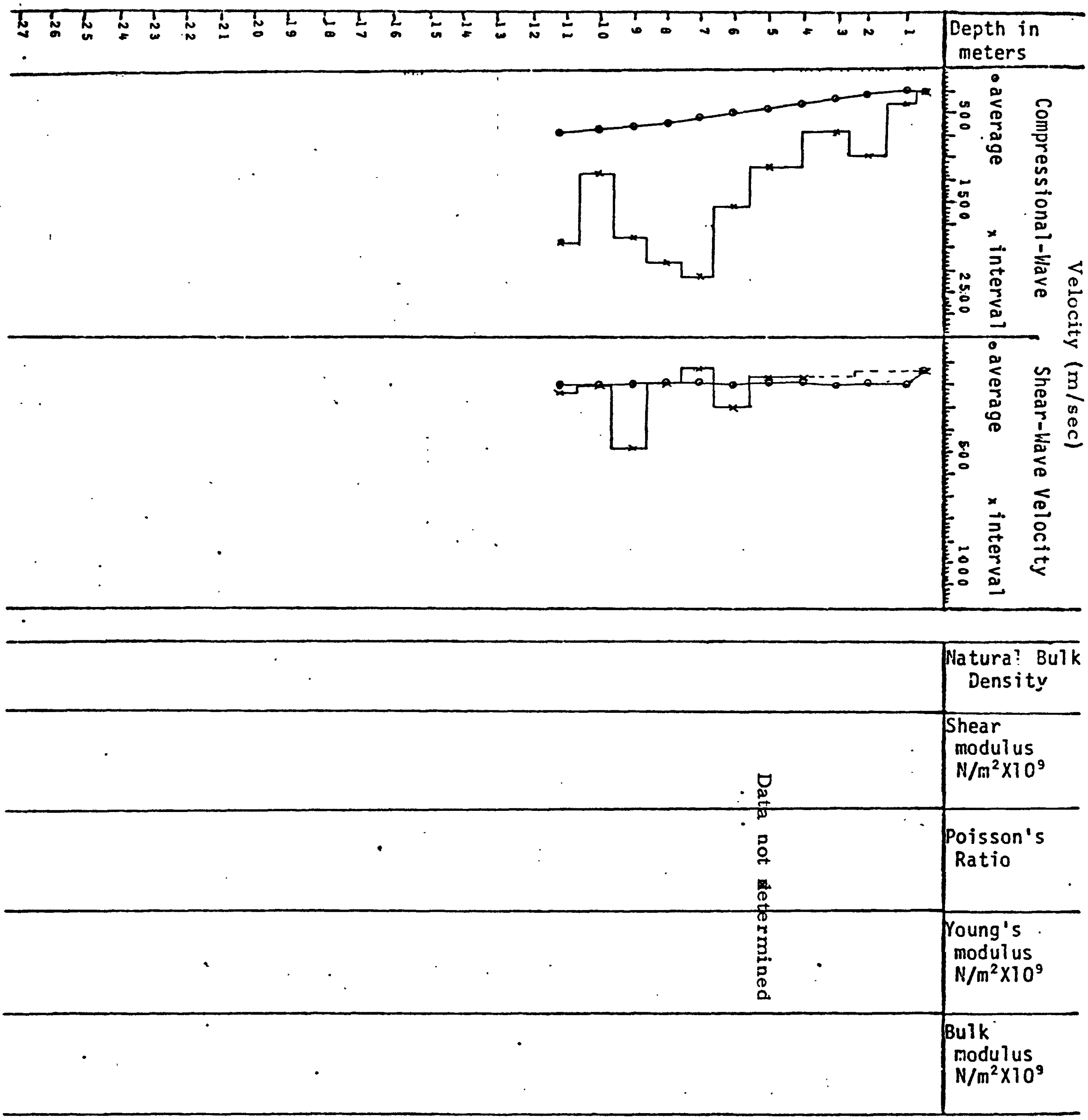


Figure 7.--In-hole compressional and shear-wave velocities from the Shepard Lane site test hole. Dashed lines are interpolated measurements.

Malad River site (MR)

The Malad River site is located on the edge of the Malad River 3.5 km northwest of the center of Bear River City, Utah (fig. 1). The hole was drilled in the SW corner, SE 1/4, sec. 3, T. 10 N., R. 3 W., Bear River City 7 1/2' quadrangle. The drill was sited on shallow-water deposits of dark, shell-rich silts and sands overlying typical deeper water buff-colored deposits, principally silts and clays of Lake Bonneville. The Malad River flows in a channel entrenched in these materials to a depth of 12 m.

Rotary drilled to emplace plastic casing. Lost circulation between 1.8 and 4 m. Poured concrete down hole; drilled through concrete and drove tube sampler at 6.4 m and sampled at 6.86 m. Rotary drilled to 9.7 m, lost circulation; filled with concrete and let set overnight. Drilled through the concrete next morning; the concrete successfully sealed the hole to prevent loss in circulation.

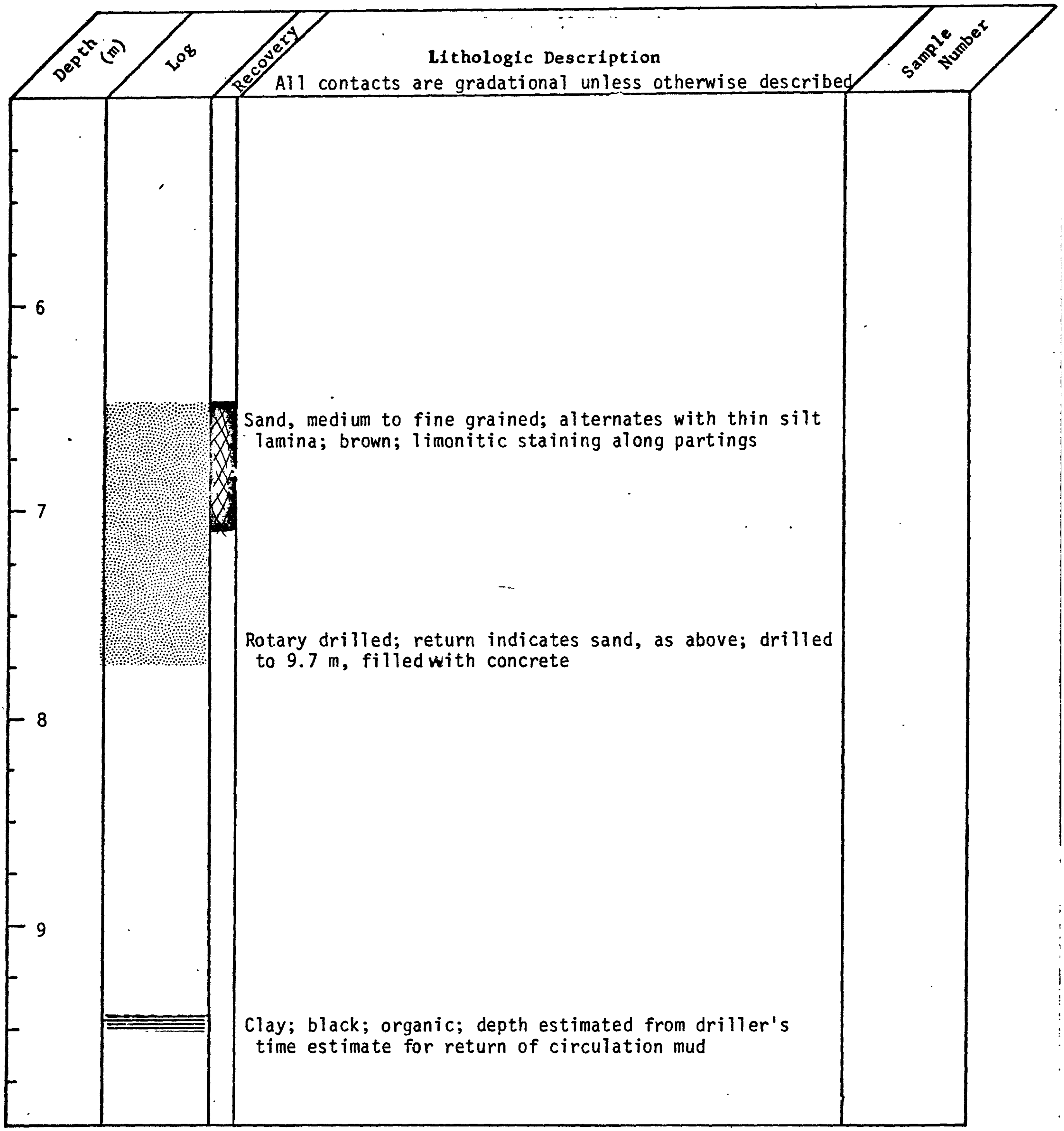
The log of the test hole follows:

Malad River site

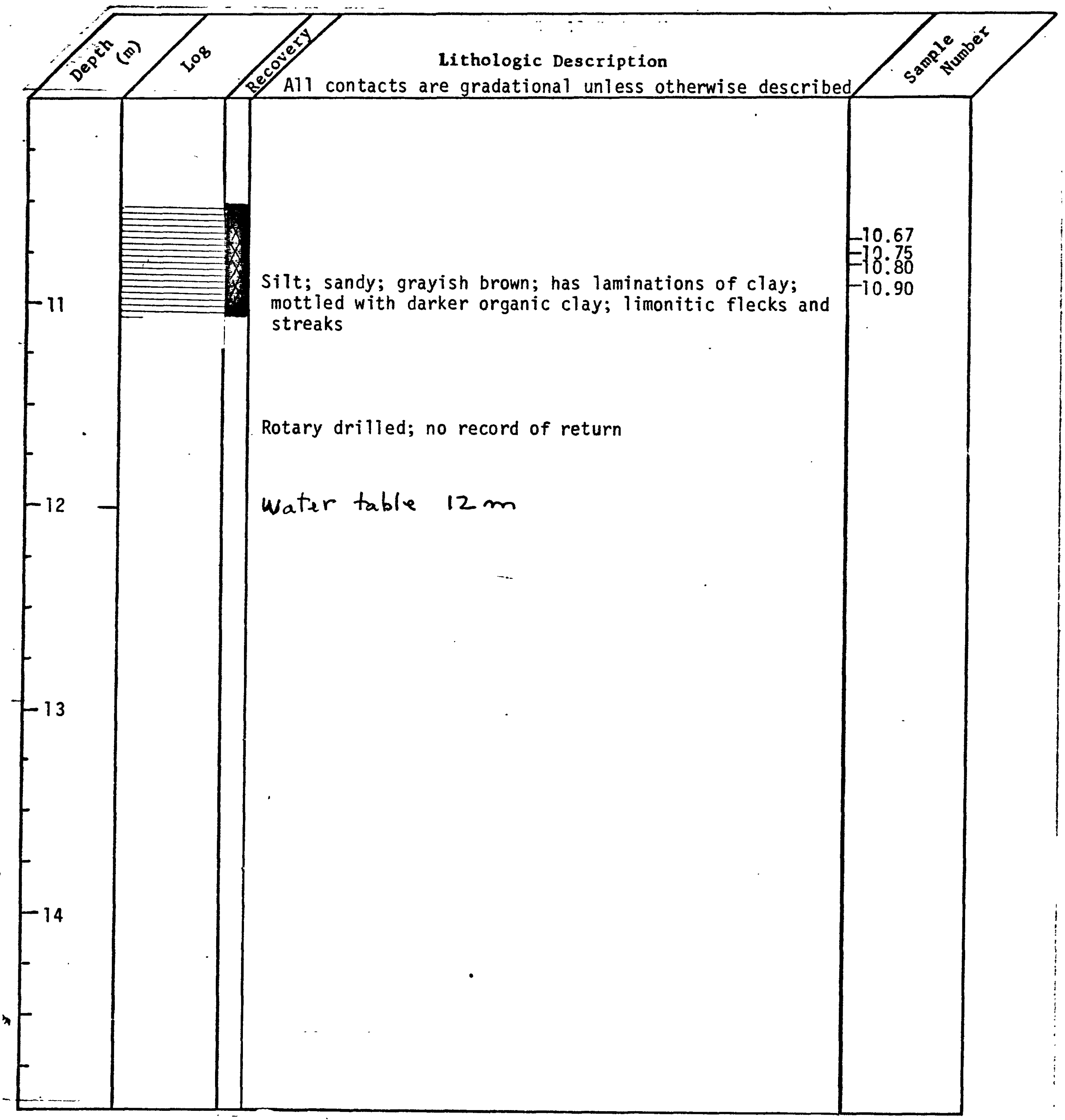
Altitude 1295 m (4,250 ft)

Depth (m)	Log	Recovery	Lithologic Description All contacts are gradational unless otherwise described	Sample Number
			Rotary drilled; lost circulation between 1.8 and 4 m	
1			First sample at 6.86 m	
2				
3				
4				

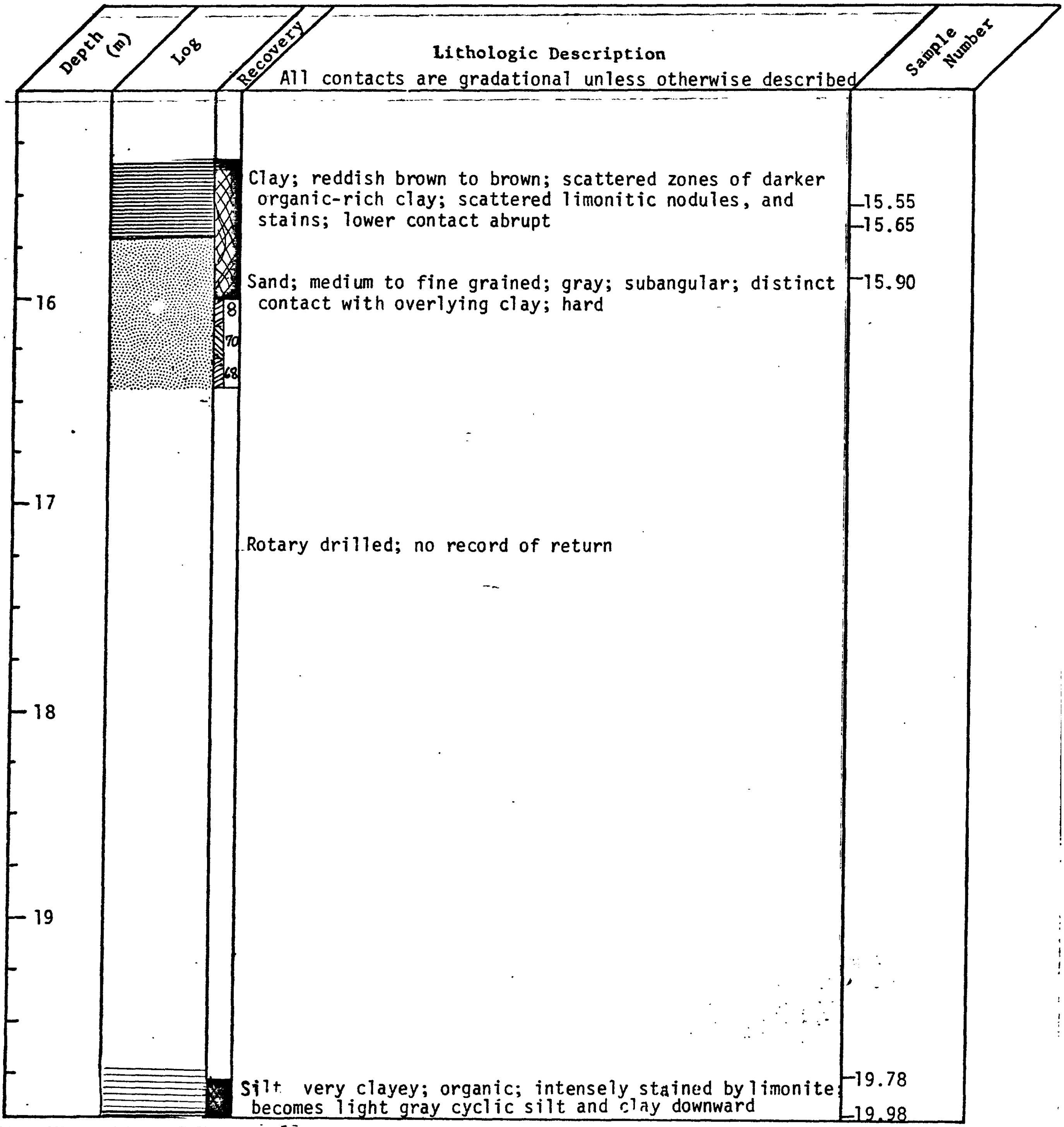
Malad River site



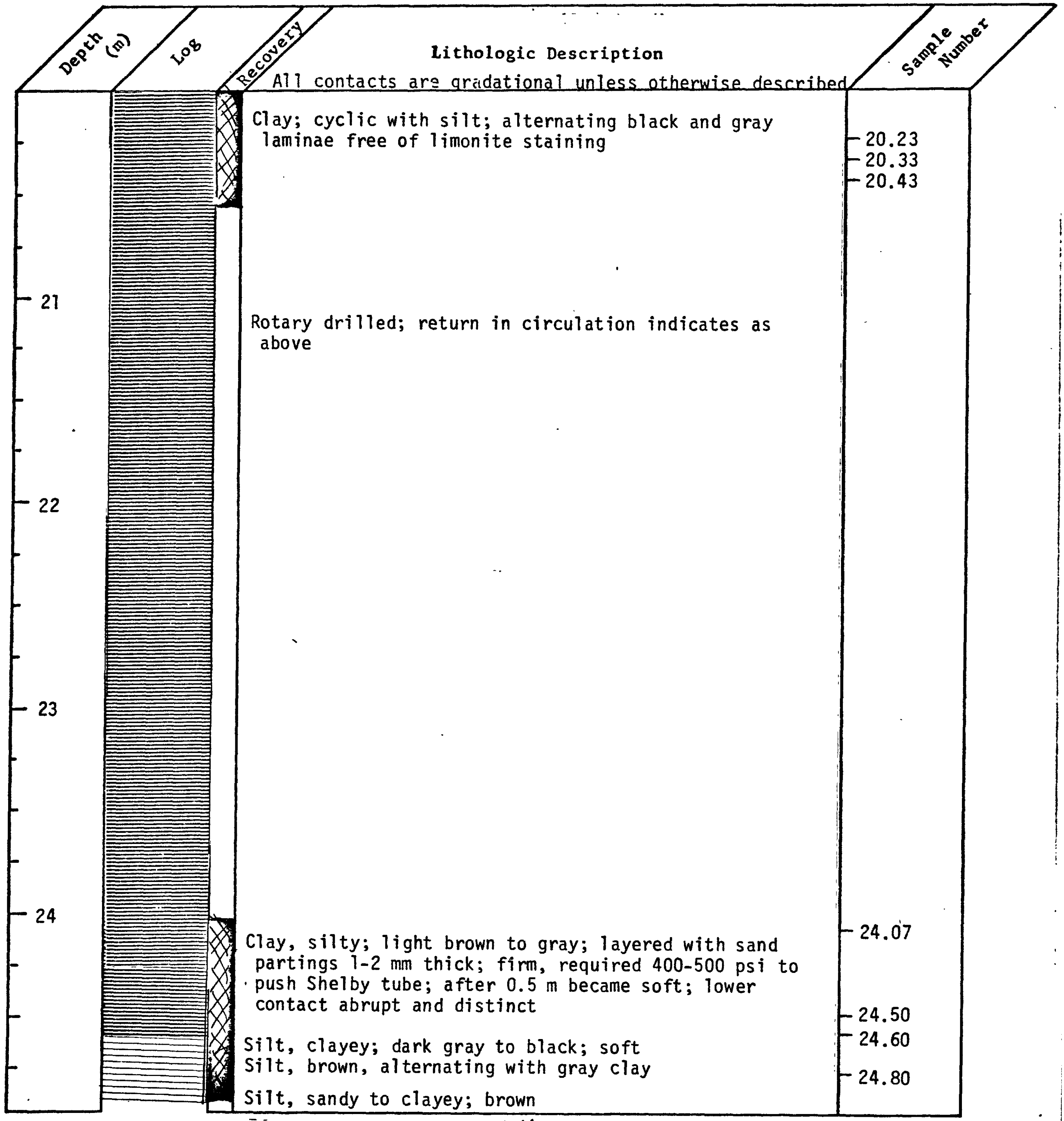
Malad River site



Malad River site



Malad River site



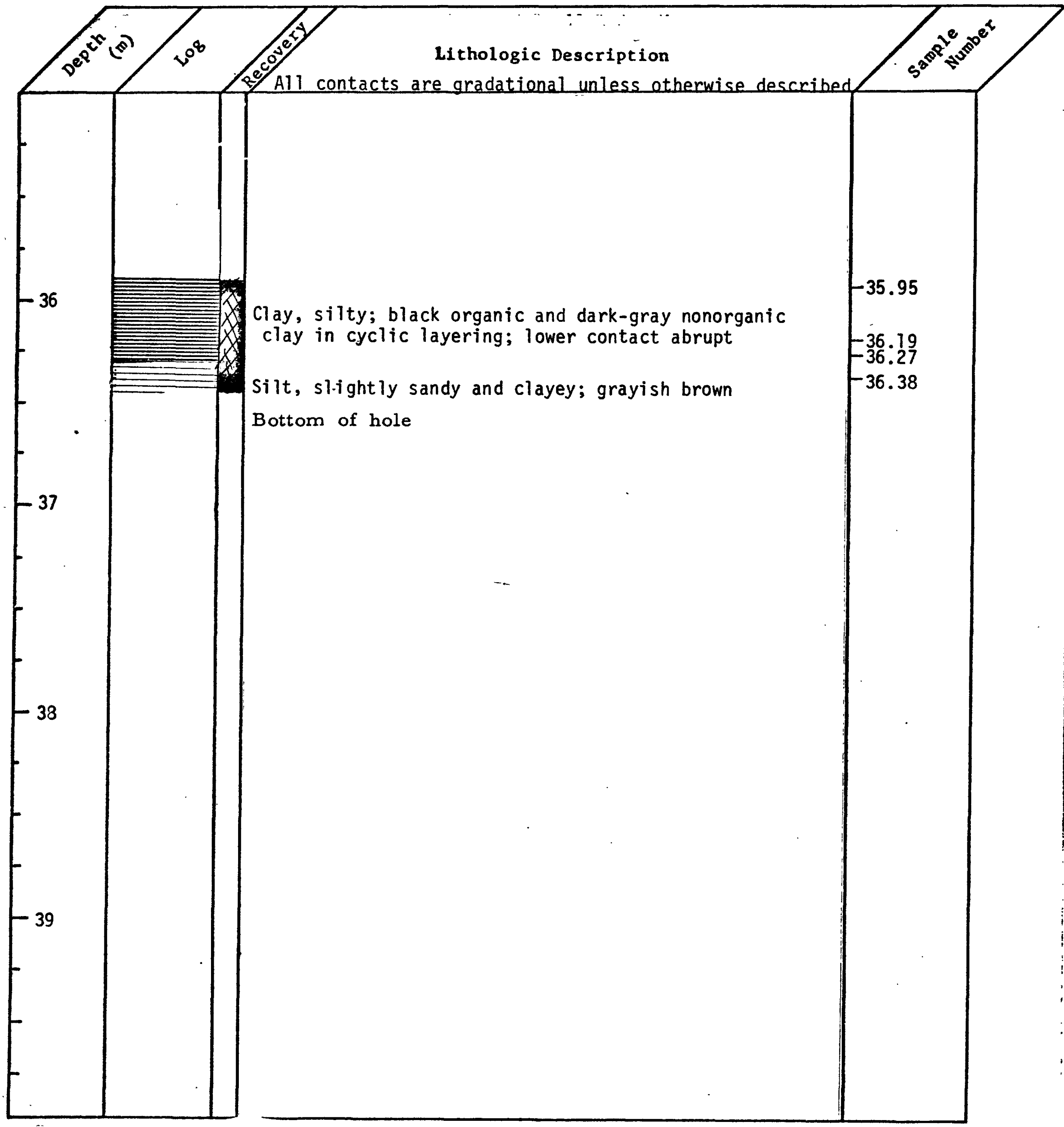
Malad River site

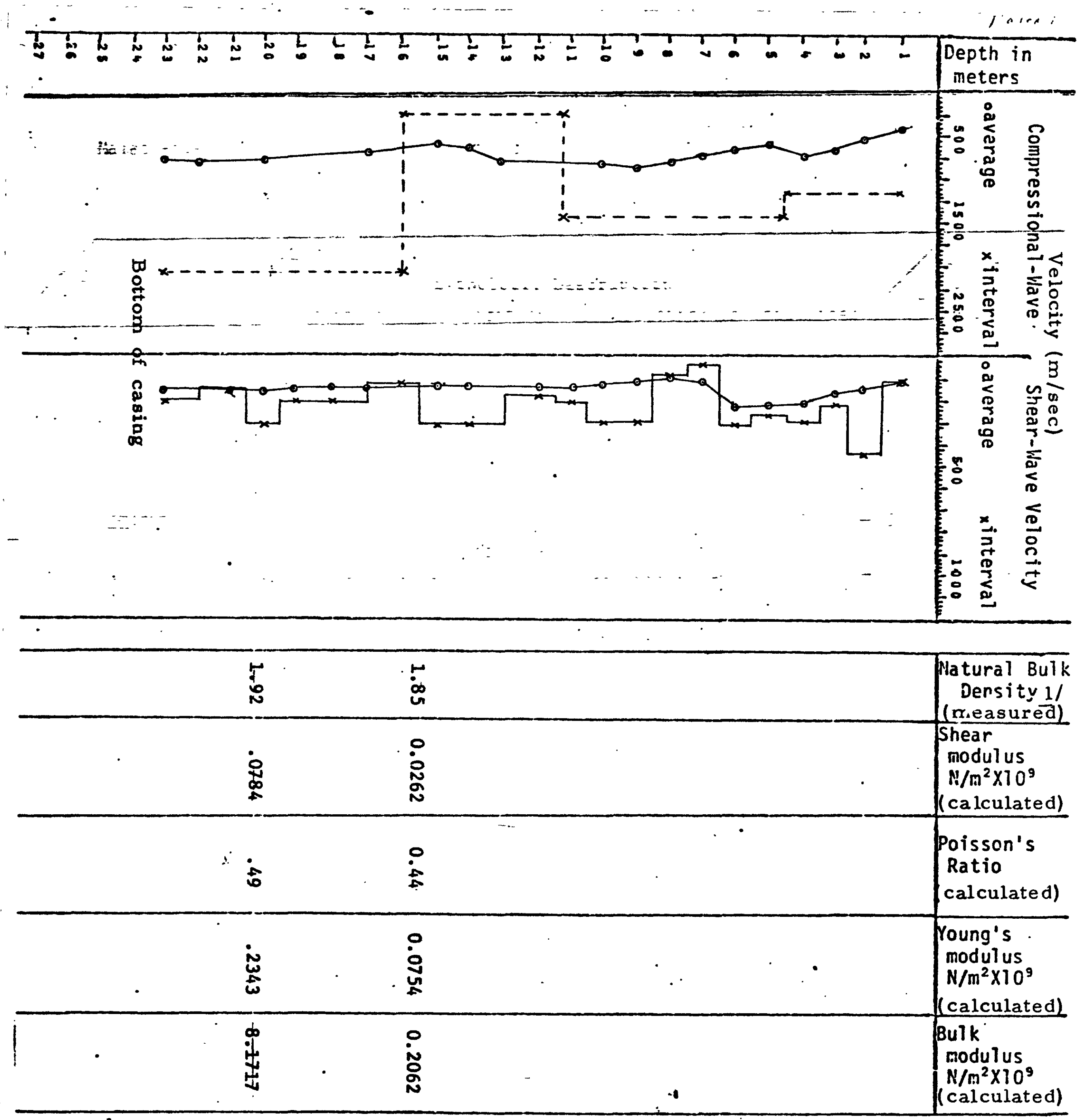
Depth (m)	Log	Recovery	Lithologic Description All contacts are gradational unless otherwise described	Sample Number
			Rotary drilled to 36 m; no record of return	
26				
27				
28				
29				

Malad River site

Depth (m)	Log	Recovery	Lithologic Description All contacts are gradational unless otherwise described	Sample Number
31			Rotary drilled to 36 m; no record of return	
32				
33				
34				

Malad River site





1/ from table 11

Figure 8.--In-hole compressional and shear-wave velocities from the Malad River site test hole, with measured densities and calculated moduli and ratios. Dashed lines are interpolated measurements.

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