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GEOLOGIC AND WELL-CONSTRUCTION DATA FOR THE H-7 BOREHOLE COMPLEX NEAR THE PROPOSED WASTE ISOLATION PILOT PLANT SITE, SOUTHEASTERN NEW MEXICO

PREPARED BY THE
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By S. L. Drellack, Jr. (Fenix and Scisson, Inc.)

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Albuquerque, New Mexico

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UNITED STATES DEPARTMENT OF THE INTERIOR

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All measurements related to the drill site are given in inch-pound units. These measurements include: The survey to locate the borehole (both horizontally and vertically), the drilling depths as provided by the driller, and the wire-line log recordings as provided by the logging company. Unless otherwise noted, altitude and depth measurements are referenced to ground level. The following table contains factors for converting to metric units.

Multiply inch-pound units	By	To obtain metric units
foot	0.3048	meter
inch	25.40	millimeter
pound	0.4536	kilogram
pound per square inch	0.006895	megapascal
mile	1.609	kilometer

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

The use of trade names in this report is for identification purposes only and does not imply endorsement by the U.S. Geological Survey.

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ABSTRACT

The H-7 borehole complex, a group of three closely spaced boreholes, is located 2 miles southwest of the proposed Waste Isolation Pilot Plant site in east-central Eddy County, New Mexico. The holes were drilled during September and October 1979 to obtain geologic and hydrologic data to better define the regional ground-water-flow system. The geologic data presented in this report are part of a site-characterization study for the possible storage of defense-associated radioactive wastes within salt beds of the Salado Formation of Permian age. The geologic data include detailed descriptions of cores, cuttings, and geophysical logs.

Each borehole was designed to penetrate a distinct water-bearing zone: H-7a (total depth 154 feet) was completed just below the Magenta Dolomite Member of the Rustler Formation of Permian age; H-7b (total depth 286 feet) was completed just below the Culebra Dolomite Member of the Rustler Formation; and H-7c (total depth 420 feet) was completed below the Rustler Formation-Salado Formation contact. The geologic units penetrated in borehole H-7c are surficial alluvium and dune sand of Holocene age (0-5 feet); the Gatuna Formation of Pleistocene age (5-57 feet); and the Dewey Lake Red Beds (57-87 feet), the Rustler Formation (87-283 feet), and part of the Salado Formation (283-420 feet), all of Permian age. The upper 122 feet of the Salado Formation penetrated by borehole H-7c is composed of residue from dissolution of halite and associated rocks, indicating that the eastward-moving dissolution front on top of the Salado, found just to the west of the WIPP site, has reached the H-7 site.

INTRODUCTION

The H-7 borehole complex (SE¼ NW¼ sec. 14, T. 23 S., R. 30 E.) was drilled in east-central Eddy County, New Mexico (fig. 1), at the request of the Waste Isolation Pilot Plant (WIPP) project office of the U.S. Department of Energy. Sandia National Laboratories is evaluating the WIPP site for the Department of Energy as a potential repository for the disposal of defense-associated transuranic wastes in Permian salt beds. The U.S. Geological Survey is assisting Sandia National Laboratories by developing information on the ground-water hydrology of the region, obtaining geologic borehole data, and conducting hydrologic tests in boreholes on and near the WIPP site. This report provides well-construction information and lithologic data about the Rustler and Salado Formations and the top of the salt interval within the Salado Formation at the H-7 borehole complex. The geologic information will provide a basis for determining the occurrence and movement of ground water in certain water-bearing zones above and below the salt. An understanding of the regional geology and hydrology is necessary for predicting the capability of the water-bearing zones to transport radionuclides to the biosphere in the event the storage facility is breached. Previous studies (Mercer and Orr, 1979, and Powers and others, 1978) indicate water-bearing zones within and at the lower contact of the Rustler Formation of Permian age probably require the most detailed study.

The H-7 borehole complex is one in a series of four complexes that has been drilled near the WIPP site for determining regional geologic and hydrologic characteristics. At each complex, a cluster of three boreholes (fig. 2) was completed in successively deeper water-bearing zones. The borehole designated "a" penetrated the Magenta Dolomite Member of the Rustler Formation, the "b" borehole penetrated the Culebra Dolomite Member of the Rustler Formation, and the "c" borehole penetrated the Rustler Formation-Salado Formation contact.

Data for the geologic section at the H-7 borehole complex are tabulated in plate 1 and table 1. Most of each borehole was drilled by the air-rotary method. Drill cuttings collected at 5-foot intervals and cores from selected intervals were used to describe the rocks penetrated in each borehole (tables 2-7). Wire-line geophysical logs (plate 1) were made in the H-7c borehole to: (1) aid in the recognition and correlation of rock units; (2) assist in identification of major lithologies; and (3) provide information about rock porosities for hydrologic evaluation.

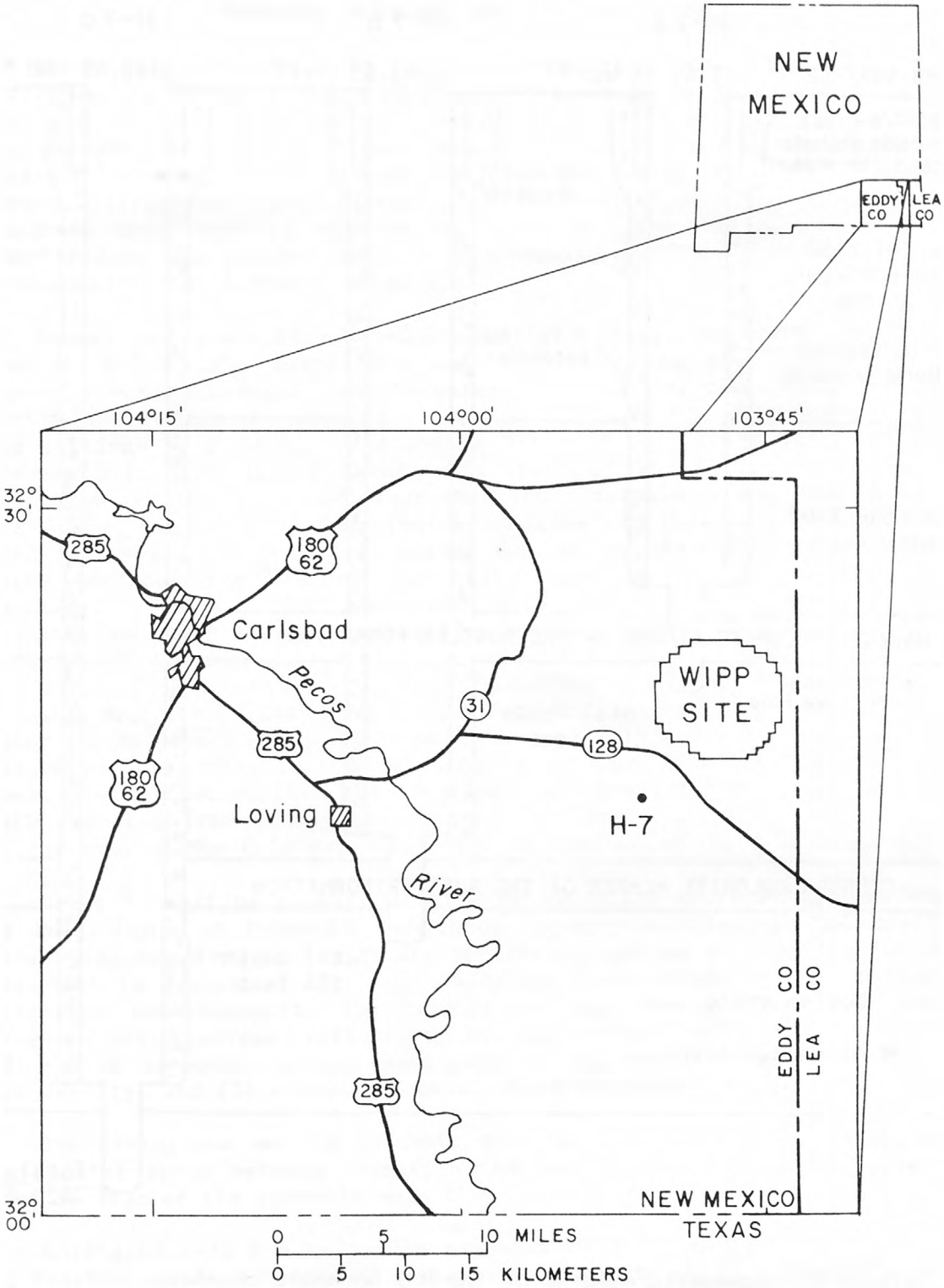

Figure 1.--Location of H-7 borehole complex with respect to the Waste Isolation Pilot Plant site.

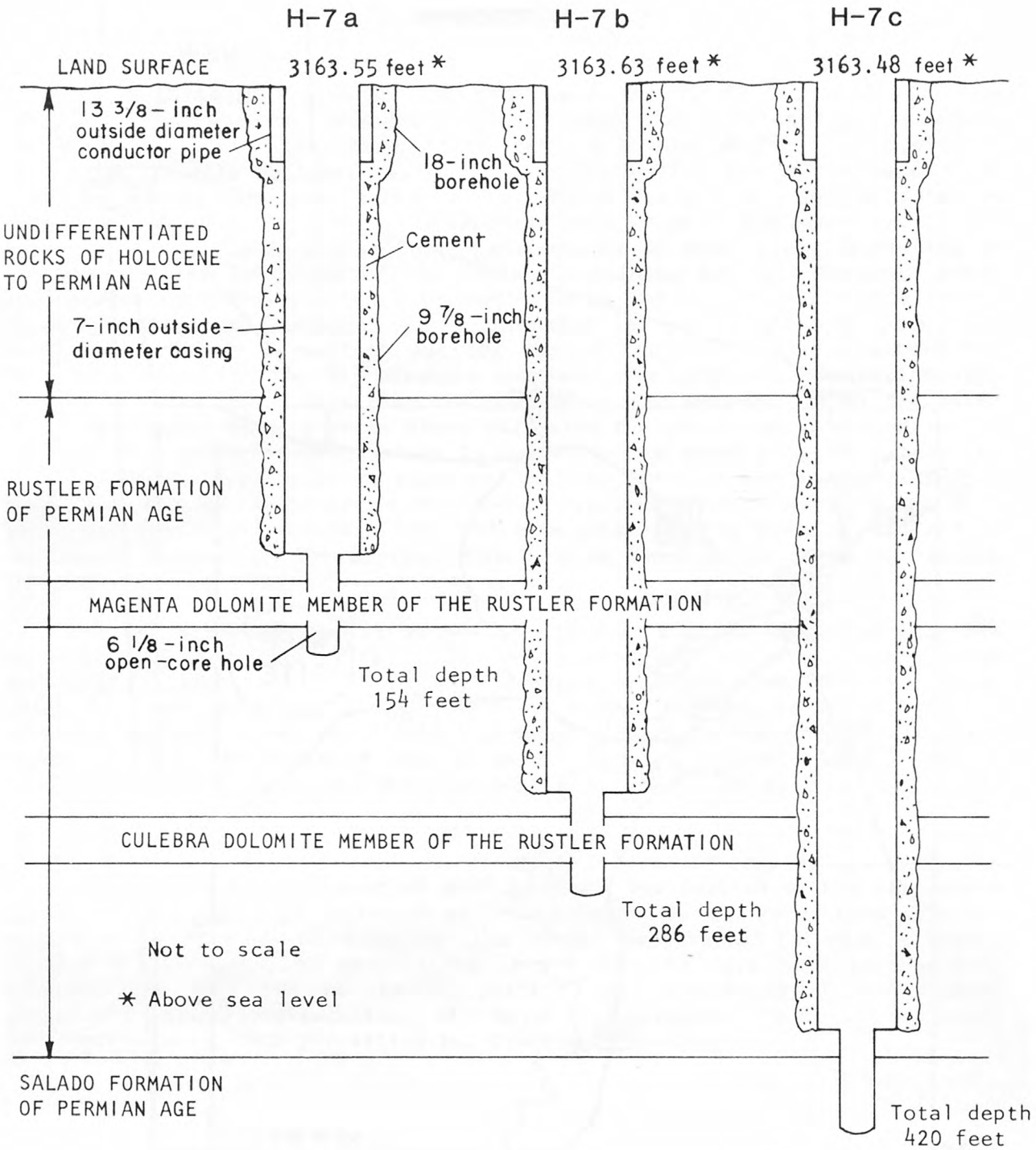

Figure 2.--Schematic diagram of the H-7 borehole complex.

BOREHOLE DRILLING AND SAMPLING METHODS

The H-7 borehole complex 2 miles southwest of the proposed WIPP site, drilled during September and October 1979, consists of three boreholes (H-7a, H-7b, and H-7c) located 100 feet apart in an equilateral triangle. Borehole H-7c was drilled first and penetrated the Rustler Formation-Salado Formation contact 137 feet above the total depth of 420 feet measured from a land-surface altitude of 3,163.48 feet above sea level. Borehole H-7b was drilled next to a total depth of 286 feet and penetrated the Culebra Dolomite Member. H-7a borehole was drilled last to a total depth of 154 feet and penetrated the Magenta Dolomite Member (fig. 2).

Rotary and air-rotary/air-mist drilling procedures were used to drill borehole H-7c. The air-rotary method facilitates the identification of unknown zones that might contain water by using dry compressed air to cool the bit and remove the cuttings. A standard rock bit was used for drilling when cuttings were being collected at 5-foot intervals in selected zones of borehole H-7c from ground level to a depth of 360 feet. Wire-line coring procedures were used at the other selected intervals to cut continuous cores at 140-161 feet, 203-292 feet (which includes the Culebra Dolomite Member at 237-273.5 feet and the Rustler-Salado contact at 283 feet), and 360-420 feet (which includes the top of the salt found in the Salado Formation at 405 feet). The cuttings and core were examined and described at the drillsite and then transported to the Sandia National Laboratories warehouse in Carlsbad, New Mexico, for storage.

The depth reported from cores for the base of the Culebra Dolomite Member is believed to be incorrect because of core loss. Sections of the Culebra probably were lost from one core but recovered in the next core and labelled with that depth. The core loss explains the discrepancy between the depth reported from geophysical logs (273.5 feet) and from cores (283 feet) for the base of the Culebra; 273.5 feet is considered to be correct.

Prior to setting casing, a suite of wire-line geophysical logs was made the full depth of borehole H-7c under open-hole, fluid-filled conditions. The logging was done to facilitate the identification and correlation of rock units and to provide a depth determination independent of that indicated by drill-pipe measurements. The geophysical logs include: (1) A gamma ray curve, which recorded variations in the content of potassium and other radioactive elements; (2) a gamma-gamma curve, which recorded variations in rock density; and (3) a neutron curve, which recorded porosity.

The casing was set in borehole H-7c to 356 feet below land surface and the annular space between formation and casing was filled with cement. The lower 64 feet of the borehole were then cored.

Boreholes H-7a and H-7b were air-mist drilled to just above the Magenta and Culebra Dolomite Members, respectively. Forty feet of borehole H-7a and 52 feet of borehole H-7b were cored after the casing was set and cemented to the surface, as in borehole H-7c. The holes were geophysically logged after the total depth of each hole was reached.

GEOLOGIC DATA

Borehole H-7c, with a total depth of 420 feet, is the deepest borehole at the H-7 complex. For this reason, the geologic section penetrated by borehole H-7c is summarized in table 1.

The geologic section includes continental sediments of Quaternary age and marine red beds and evaporites of Permian age. The Quaternary sediments include, in order of increasing age, unconsolidated alluvium and dune sand of Holocene age and the Gatuna Formation of Pleistocene age. The Permian rocks include, in order of increasing age, the Dewey Lake Red Beds, the Rustler Formation, and the upper 137 feet of the Salado Formation. The Permian rocks are present in the lower 363 feet of the geologic section penetrated by borehole H-7c.

The unconsolidated alluvium and dune sand are an informal unit that is 5 feet thick. The Gatuna Formation underlies the dune sand and consists of 52 feet of light orange and reddish-brown, friable, very fine to medium-grained, poorly sorted sandstone. Several conglomeratic zones that contain small chert and silicious pebbles are present near the base of the Gatuna Formation

Borehole H-7c penetrated the Dewey Lake Red Beds at 57 feet below land surface. The Dewey Lake Red Beds are reddish-brown, poorly to moderately consolidated sandstone and siltstone with greenish-gray reduction spots. Veins of fibrous selenite, commonly present in the formation, are missing. Their absence probably was caused by dissolution by ground water.

The Rustler Formation, from 87 to 283 feet below land surface, consists chiefly of gypsum, remnant anhydrite, and poorly to moderately consolidated clay and silt probably derived from argillaceous and silty halite. The formation also contains the Magenta and Culebra Dolomite Members and some well-consolidated siltstone. The rocks of the Rustler Formation at the H-7 borehole complex are notably more altered, fractured, and porous than those within the WIPP site boundary (Sandia National Laboratories and U.S. Geological Survey, 1980a,b). The formation probably has thinned from ground-water dissolution of all of the halite, part of the anhydrite and gypsum, and part of the dolomite. There are residual pods and other isolated remnants of anhydrite in much of the remaining gypsum. At the H-7 borehole complex, the Magenta is a friable, yellowish-gray, silty dolomite, and dolomitic silt; the Culebra is a fractured, pitted, light-olive-gray to yellowish-gray, finely crystalline dolomite.

The last 137 feet of section, between 283 and 420 feet below land surface, is part of the Salado Formation. At the H-7 borehole complex, the upper 122 feet of the Salado is a distinct halite-free interval of unconsolidated clay and silt interlayered at irregular intervals with shattered bands of gypsum. This interval is considered to be dissolution residue derived from halite and associated rocks that formerly were present. The lower salt-rich part of the Salado (405-420 feet) is halite and argillaceous halite with traces of polyhalite. A summary of the geologic units penetrated by borehole H-7c is presented in table 1.

The lithologies penetrated by borehole H-7c are interpreted and correlated with selected geophysical logs in plate 1. Drilling and well-completion details of the H-7 boreholes are given in tables 2 through 4. Core descriptions from boreholes H-7a and H-7b are presented in tables 5 and 6, respectively, and the core and cuttings from borehole H-7c are described in table 7.

SUMMARY

The H-7 borehole complex, a group of three closely spaced boreholes, was drilled southwest of the WIPP site in east-central Eddy County, New Mexico, during September and October 1979. The boreholes were drilled to obtain geologic data and to conduct hydrologic tests to better define the regional ground-water-flow system. The H-7 complex was drilled as part of a site-characterization study for the possible storage of defense-associated wastes within salt beds of the Salado Formation of Permian age. Cores and cuttings from the borehole complex and geophysical logs from borehole H-7c were described or interpreted for this study.

Each borehole was completed just below a distinct water-bearing zone. Borehole H-7a (total depth 154 feet) penetrated the Magenta Dolomite Member, a light-olive-gray to yellowish-gray fractured dolomite of the Rustler Formation. Borehole H-7b (total depth 286 feet) penetrated the Culebra Dolomite Member, a light-olive-gray to yellowish-gray, finely crystalline, fractured and pitted dolomite of the Rustler Formation. Rocks penetrated by borehole H-7c (total depth 420 feet) at the Rustler-Salado contact consist of gray to reddish-brown mudstones at the base of the Rustler, which grade to gypsiferous mudstones and siltstones (dissolution residue), followed by the argillaceous halite, halite, and polyhalite interval of the Salado Formation. The dissolution residue is derived from halite and associated rocks that formerly were present.

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Table 1.--Summary of geologic units pentrated by borehole H-7c

Rock unit	Depth interval[1]/ (feet)
Holocene deposits[2]/	
Unconsolidated alluvium and dune sand	0-5
Pleistocene rocks	
Gatuna Formation	5-57
Permian rocks	
Dewey Lake Red Beds	57-87
Rustler Formation	87-283
Magenta Dolomite Member	117-140
Culebra Dolomite Member	237-273.5
Salado Formation	283-420
Dissolution residue	283-405
Top of salt interval	405
Total depth of borehole	420

[1]/Depth interval recorded from gamma-ray and bulk-density logs made by Dresser Atlas on September 9, 1979.

[2]/Includes artificial fill for drill pad.

Table 2.--Drilling and well-completion record of borehole H-7a

Location: Sec. 14, T. 23 S., R. 30 E.
2,495.04 feet from the north line
2,492.35 feet from the west line

Altitude (land surface) above sea level: 3,163.55 feet. Datum for depth measurements in drilling and logging operations.

Lithologic log prepared by: S. L. Drellack, Jr., J. L. Gonzales, A. F. McIntyre (Fenix and Scisson, Inc.), and K. F. Dennehy (U.S. Geological Survey)

Drilling contractor: Shortes Drilling Company

Drilling record:

Commenced drilling on September 18, 1979, and completed on September 22, 1979, at 154 feet below land surface.

Conductor pipe (13 3/8 inches outside diameter) set at 38 feet below land surface and cemented to surface.

Drilled with a rock bit to 110 feet below land surface, hole widened from 7 7/8 to 9 7/8 inches and 109 feet of 7-inch outside-diameter casing was set and cemented to surface.

24.5 feet of 3 1/2-inch outside-diameter core was recovered from 114 feet to a total depth of 154 feet, 15.5 feet of core not recovered (completed hole diameter was 6 1/8 inches). The hole was blown dry and made ready for hydrologic studies.

Core no.	Depth interval (feet) From	To	Revolutions per minute	Weight on bit (pounds)	Circulation medium	Feet cored	Feet recovered	Percent recovery
1	114	124	100	2,000	Air	10	3.3	33
2	124	134	100	2,000	Air	10	6.3	63
3	134	144	100	2,000	Air	10	4.8	48
4	144	154	100	2,000	Air	10	10.1	101

Table 3.--Drilling and well-completion record of borehole H-7b

Location: Sec. 14, T. 23 S., R. 30 E.
2,565.8 feet from north line
2,563.45 feet from west line

Altitude (land surface) above sea level: 3,163.63 feet. Datum for depth measurements in drilling and logging operations.

Lithologic log prepared by: S. L. Drellack, Jr., J. L. Gonzales, A. F. McIntyre (Fenix and Scisson, Inc.), and K. F. Dennehy (U.S. Geological Survey)

Drilling contractor: Shortes Drilling Company

Drilling record:

Commenced drilling on September 13, 1979, and completed on September 18, 1979, at 286 feet below land surface.

Conductor pipe (13 3/8 inches outside diameter) set at 38 feet below land surface and cemented to surface.

Drilled with a rock bit to 230 feet below land surface, hole widened from 7 7/8 to 9 7/8 inches and 230 feet of 7-inch outside-diameter casing was set and cemented to surface.

26.0 feet of 3 1/2-inch outside-diameter core was recovered from 234 feet to a total depth of 286 feet, 26.0 feet of core not recovered (completed hole diameter was 6 1/8 inches).

The hole was blown dry and made ready for hydrologic studies.

Core no.	Depth interval (feet) From	To	Revolutions per minute	Weight on bit (pounds)	Circulation pressure (pounds per square inch)	Feet cored	Feet recovered	Percent recovery
1	234	243	--	--	--	9	0.9	10
2	243	250	--	--	--	7	.5	7
3	250	259	--	--	--	9	6.1	68
4	259	268	80	7,000	150	9	6.7	74
5	268	277	80	7,000	150	9	2.6	29
6	277	286	80	7,000	150	9	9.2	102

Table 4.--Drilling and well-completion record of borehole H-7c

Location: Sec. 14, T. 23 S., R. 30 E.
2,467.51 feet from west line
2,591.93 feet from north line

Altitude (land surface) above sea level: 3,163.48 feet. Datum for depth measurements in drilling and logging operations.

Lithologic log prepared by: S. L. Drellack, Jr., J. L. Gonzales, A. F. McIntyre (Fenix and Scisson, Inc.), and K. F. Dennehy (U.S. Geological Survey)

Drilling contractor: Shortes Drilling Company

Drilling record:

Commenced drilling on September 6, 1979, and completed on September 13, 1979, at 420 feet below land surface.

Conductor pipe (13 3/8 inches outside diameter) set at 38 feet below land surface and cemented to surface.

Lost circulation at 63 feet below land surface.

Drilled with a rock bit to 357 feet below land surface (with two interim coring points at 140-161 and 203-292 feet), geophysical-wireline logs were made by Dresser Atlas.

Hole was widened from 7 7/8 to 9 7/8 inches and 356 feet of 7-inch outside-diameter casing was set and cemented to surface.

32.2 feet of 3 1/2-inch outside-diameter core was recovered from 360 feet to a total depth of 420 feet, 27.8 feet of core not recovered (completed hole diameter was 6 1/8 inches).

The hole was blown dry and made ready for hydrologic studies.

Table 4.--Drilling and well-completion record of borehole H-7c - Concluded

Core no.	Depth interval (feet) From	To	Revolutions per minute	Weight on bit (pounds)	Circulation pressure (pounds per square inch)	Feet cored	Feet recovered	Percent recovery
1	140	150	100	3,000	150	10	9.1	91
2	150	160	100	3,000	150	10	6.9	69
3	160	161	100	3,000	150	1	0	0
4	203	213	60-100	3,000-4,000	100	10	9.8	98
5	213	223	60-100	3,000-4,000	100	10	10.3	103
6	223	232	60-100	3,000-4,000	100	9	10.3	114
7	232	242	60-100	3,000-4,000	100	10	7.4	74
8	242	252	60-100	3,000-4,000	100	10	1.1	11
9	252	260	60-100	3,000-4,000	100	8	4.7	59
10	260	272	60-100	3,000-4,000	100	12	11.6	97
11	272	282	60-100	3,000-4,000	100	10	3.5	35
12	282	292	60-100	3,000-4,000	100	10	7.2	72
13	360	370	60-100	3,000-4,000	100	10	0	0
14	370	380	60-100	3,000-4,000	100	10	2.3	23
15	380	390	60-100	3,000-4,000	50	10	1.9	19
16	390	400	60-100	3,000-4,000	50	10	8.2	82
17	400	410	-	-	-	10	9.2	92
18	410	420	-	-	-	10	9.2	92

Table 5.--Lithology penetrated by borehole H-7a

[Color designation from Rock-Color Chart (Goddard and others, 1948). Depth interval refers to depth reported by driller.]

Lithologic description	Depth interval (feet)
No recovery	114.0-120.7
Dolomite, grayish-orange (10YR 7/4) to yellowish-gray (5Y 7/2), very silty, crumbly, some small scale cross-bedding, numerous 0.1- to 2-millimeter diameter pits	120.7-123.3
Dolomite, light-olive-gray (5Y 6/1) to yellowish-gray (5Y 7/2), crumbly, small-scale low-angle cross-bedding, laminae dip 3-5', numerous 0.1- to 2-millimeter diameter pits, well fractured	123.3-124.0
Silt, grayish-orange (10YR 7/4), some light-olive-gray (5Y 6/1), soft, friable, dolomitic	124.0-125.3
Dolomite, same as unit from 123.3 to 124.0 feet	125.3-130.3
No recovery	130.3-139.2
Note: Because top of core 4 (144 feet) and recovered intervals of core 3 are similar, core 3 loss was placed at top of core 3 interval	
Gypsum, light-olive-gray (5Y 6/1) to olive-gray (5Y 4/1), very finely crystalline, with wavy, thin, horizontal, light-olive-gray (5Y 6/1) dolomitic laminae	139.2-139.3
Gypsum, light-olive-gray (5Y 6/1) to olive-gray (5Y 4/1) and olive-black (5Y 2/1), very finely crystalline, "blotchy"	139.3-141.2
Gypsum, light-olive-gray (5Y 6/1) to olive-gray (5Y 4/1) and olive-black (5Y 2/1), very finely crystalline, well fractured, numerous rounded to subrounded pebble to cobble size fragments	141.2-141.8
Gypsum, same as unit from 139.3 to 141.2 feet	141.8-148.0
Anhydrite, olive-gray (5Y 4/1) and olive-black (5Y 2/1), mottled, very finely crystalline, gypsiferous in parts; slight "chicken wire" appearance; few isolated hairline fractures	148.0-153.4
Gypsum, same as unit from 139.3 to 141.2 feet	153.4-154.1
	Bottom of cored interval

Table 6.--Lithology penetrated by borehole H-7b

[Color designation from Rock-Color Chart (Goddard and others, 1948). Depth interval refers to depth reported by driller.]

Lithologic description	Depth interval (feet)
No core	234.0-242.1
Dolomite, light-olive-gray (5Y 6/1), very finely crystalline, pitted, dense, fractured and broken up into cobble size fragments	242.1-243.2
Oolitic dolomite, aggregate of 0.25-millimeter sized oolites; yellowish-gray (5Y 7/2), light-olive-gray (5Y 6/1), very porous; poorly consolidated	243.2-243.5
No core	243.5-250.0
Dolomite, same as unit from 242.1 to 243.2 feet, becoming denser with pits rare toward base; several 10- to 20-millimeter sized vugs, tendency of vugs to be slightly elongated horizontally, several nearly vertical fractures with traces of (small spots and dendrites) manganese dioxide on fracture surfaces	250.0-256.1
No core	256.1-259.0
Dolomite, same as unit from 250.0 to 256.1 feet; trace small pits, several 5- to 20-millimeter sized vugs scattered throughout, very finely crystalline, argillaceous, dense	259.0-265.7
No core	265.7-268.0
Dolomite, same as unit from 242.1 to 243.2 feet	268.0-269.2
Siltstone, light-olive-gray (5Y 6/1) and medium-gray (N5), poorly consolidated, slightly dolomitic	269.2-270.6
No core	270.6-277.0
Clay, medium-gray (N4), silty	277.0-277.3
Siltstone, medium-dark-gray (N6), hard, 32° dip	277.3-277.6

Table 6.--Lithology penetrated by borehole H-7b - Concluded

Lithologic description	Depth interval (feet)
Mudstone, medium dark-gray (N3), hard, fissile, highly brecciated, residue; matrix of moderate-reddish-brown (10R 4/6) clay residue; rosettes and blades, chalky white (N9) selenite fragments from 278.3 to 278.6 feet	277.6-278.9
Clay, moderate-reddish-brown (10R 4/6), soft to hard residue; blades, chalky white (N9) selenite fragments; rounded, cobble-size, fragments chalky white (N9) gypsum at 279.1 and 280.3 feet	278.9-280.5
Gypsum, olive-gray (5Y 4/1) to olive-black (5Y 2/1); very finely crystalline anhydrite; numerous, irregular, olive black (5Y 2/1) gypsum "blotches" from 280.9 to 281.5 feet	280.5-281.8
Gypsum, moderate-red (5Y 4/6) to moderate-reddish-brown (10Y 4/6), very finely crystalline, mottled	281.8-282.8
Anhydrite, light-gray (N7) to medium-gray (N5), microcrystalline; numerous bands and veinlets, gypsiferous, olive-gray (5Y 4/1) anhydrite	282.8-286.0
	Bottom of cored interval

Table 7.--Lithology penetrated by borehole H-7c

[Color designation from Rock-Color Chart (Goddard and others, 1948). Depth interval refers to depth reported by driller except where lithologic and descriptive depths have been corrected to coincide with geophysical logging depths.]

Lithologic description	Depth interval (feet)
Cellar	0-5.0
Sandstone, moderate-reddish-brown (10R 4/6), fine- to medium-grained, rounded to subrounded, very poorly consolidated, calcareous; very small trace white (N9) caliche	5.0-15.0
Sandstone, pale-reddish-brown (10R 5/4) to moderate-reddish-brown (10R 4/6), medium- and coarse-grained, rounded to subrounded, unconsolidated, calcareous; trace white (N9) caliche	15.0-20.0
Sandstone, moderate-light-orange (10R 6/6) to pale-reddish-brown (10R 5/4), very fine- to medium-grained, poorly sorted, rounded to subrounded, calcareous; trace white (N9) sandy caliche	20.0-25.0
Sandstone (95 percent), same as unit from 20.0 to 25.0 feet; white (N9) caliche (5 percent)	25.0-38.0
No sample	38.0-40.0
Sandstone (95 percent), moderate-reddish-brown (10R 4/6), poorly sorted, rounded to subrounded, poorly consolidated, calcitic; rounded, medium-light-gray (N6), grayish-yellow (5Y 8/4) and white (N9) chert pebbles (5 percent); trace, white (N9) caliche, chert pebbles become fewer in lower 7 feet	40.0-57.0
Siltstone, moderate-reddish-brown (10R 4/6), moderately consolidated, with numerous greenish-gray (5GY 6/1) reduction spots	57.0-87.0
Siltstone (95 percent), same as unit from 57.0 to 87.0 feet; very finely crystalline, light-olive-gray (5Y 6/1) gypsum (5 percent)	87.0-95.0
Siltstone, same as unit from 57.0 to 87.0 feet; trace gypsum, same as unit from 87.0 to 95.0 feet	95.0-110.0
Siltstone (90 percent), same as unit from 57.0 to 87.0 feet; gypsum (10 percent), same as unit from 87.0 to 95.0 feet	110.0-115.0

Table 7.--Lithology penetrated by borehole H-7c - Continued

Lithologic description	Depth interval (feet)
Siltstone (90 percent), dark-reddish-brown (10R 3/4) to moderate-reddish-brown (10R 4/6), some grading to very fine-grained sandstone; well indurated to friable, greenish-gray (5GY 6/1) reduction spots; trace manganese dioxide as metallic greenish-black (5GY 2/1) spots with coating; very finely crystalline, light-olive-gray (5Y 6/1) gypsum (10 percent); possibly some anhydrite	115.0-117.0
Dolomite (90 percent), light-olive-gray (5Y 6/1), silty texture; siltstone (10 percent), same as unit from 115.0 to 117.0 feet; trace of gypsum, same as unit from 115.0 to 117.0 feet	117.0-140.0
Gypsum (85 percent), white (N9) and very light-gray (N8) to light-olive-gray (5Y 6/1), very finely crystalline; dolomite (15 percent), same as unit from 117.0 to 140.0 feet	140.0-150.0
Gypsum (95 percent), same as unit from 140.0 to 150.0 feet; siltstone (5 percent), same as unit from 115.0 to 117.0 feet; trace dolomite, same as unit from 117.0 to 140.0 feet	150.0-155.0
Gypsum, same as unit from 140.0 to 150.0 feet; trace siltstone, same as unit from 115.0 to 117.0 feet	155.0-160.0
Gypsum (60 percent), white (N9), very light-gray (N8), some light-olive-gray (5Y 6/1) tint, very finely crystalline, some soft, white (N9) and chalky; anhydrite (40 percent), very light-gray (N8) to light-olive-gray (5Y 6/1)	160.0-170.0
Gypsum (80 percent), same as unit from 160.0 to 170.0 feet, much soft, white (N9), chalky; anhydrite (20 percent), same as unit from 160.0 to 170.0 feet; trace of poorly to well indurated, moderate-reddish-brown (10R 4/6) mud and siltstone	170.0-175.0
Anhydrite (60 percent), and gypsum (40 percent), same as unit from 160.0 to 170.0 feet	175.0-180.0
Anhydrite (90 percent), same as unit from 160.0 to 170.0 feet, becoming light-gray (N7) to light-olive-gray (5Y 6/1) to olive-gray (5Y 4/1); gypsum (10 percent)	180.0-185.0

Table 7.--Lithology penetrated by borehole H-7c - Continued

Lithologic description	Depth interval (feet)
Gypsum (70 percent), same as unit from 160.0 to 170.0 feet; soft, white (N9), chalky gypsum; anhydrite (30 percent), same as unit from 160.0 to 170.0 feet	185.0-190.0
Gypsum (60 percent) and anhydrite (40 percent), same as unit from 160.0 to 170.0 feet	190.0-195.0
Gypsum (50 percent) and anhydrite (50 percent), same as unit from 160.0 to 170.0 feet	195.0-200.0
NOTE: End of cutting descriptions; core descriptions follow.	
Gypsum, light-olive-gray (5Y 6/1), olive-gray (5Y 4/1) and olive-black (5Y 2/1), very finely crystalline, mottled; some blotchy zones of recrystallized, olive-black (5Y 2/1) gypsum; wavy, horizontal, 10 to 15 millimeters thick, fibrous, translucent to transparent gypsum at 140.7 feet	140.0-146.5
Anhydrite, medium-light-gray (N6), very finely crystalline, numerous minute to small gypsum blebs and irregular, vertical fractures healed with olive-gray (5Y 4/1) gypsum; "chicken wire" gypsum from 146.5 to 147.0 feet	146.5-149.1
Unrecovered core	149.1-150.0
Gypsum, same as unit from 140.0 to 146.5 feet	150.0-151.7
Anhydrite, medium-light-gray (N6), remnant rounded nodules 3 to 20 millimeters in size within a well-developed "chicken wire" network of olive-black (5Y 2/1) gypsum	151.7-152.4
Gypsum, same as unit from 140.0 to 146.5 feet	152.4-155.7
Anhydrite, same as unit from 151.7 to 152.4 feet	155.7-156.1
Gypsum, same as unit from 140.0 to 146.5 feet	156.1-156.5
Unrecovered core	156.5-156.8
Gypsum, same as unit from 140.0 to 146.5 feet	156.8-157.2

Table 7.--Lithology penetrated by borehole H-7c - Continued

Lithologic description	Depth interval (feet)
Unrecovered core	157.2-161.0
No samples	161.0-203.0
Gypsum, dark-yellowish-brown (10YR 4/2), dusky-yellowish-brown (10YR 2/2), finely crystalline, some argillaceous, light-olive-gray (5Y 6/1), faintly laminated; two gypsum-healed fractures from 200.0 to 201.0 feet, 4-millimeter wide, dipping 75°, trace of vug porosity along fracture at 203.2 feet, more argillaceous with depth	203.0-204.6
Gypsum, light-olive-gray (5Y 6/1), some dark-yellowish-brown (10YR 4/2), some medium-light-gray (N6) tint, mottled, finely crystalline, laminated, dipping less than 13°; few continuous and discontinuous selenite laminae and light-olive-gray (5Y 6/1) argillaceous laminae, several selenite-healed fractures dipping 40-50°; trace of vug porosity associated with fractures, nearly vertical fracture at 207.5 feet, light-olive-gray (5Y 6/1) to olive-gray (5Y 4/1) laminated 20-millimeter wide mud-filled fracture dipping 45° at 209.3 feet	204.6-209.8
Recovered in next core	209.8-210.0
Gypsum, same as unit from 204.6 to 209.8 feet	210.0-212.1
Gypsum, olive-black (5Y 2/1) to greenish-black (5GY 2/1), some dusky-yellowish-brown (10YR 2/2), mottled, finely crystalline, with olive-black (5Y 2/1) to greenish-black (5GY 2/1) mud; several very irregular mud-filled fractures dipping 36-44°, as much as 0.1 foot thick, mud-fill has wavy laminae; some selenite veins parallel to mud-filled fractures; some angular gypsum inclusions; few selenite veins as wide as 10 millimeters, dipping 15°	212.1-214.3
Gypsum, light-olive-gray (5Y 6/1), with light-gray (N7) tint, finely crystalline, laminated, some wavy light-olive-gray (5Y 6/1) argillaceous laminae dipping less than 3°; few parallel, 1- to 4-millimeter thick cross-fibrous selenite laminae; few irregularly spaced 10- to 20-millimeter thick selenite-filled fractures, low angle to 47° dip; frequently with thin, medium-light-gray (N6) mud seam at top and bottom of selenite-filled fractures, some vug porosity associated with higher angle fractures	214.3-221.0

Table 7.--Lithology penetrated by borehole H-7c - Continued

Lithologic description	Depth interval (feet)
Gypsum and mud: gypsum, blocks and bands as much as 0.3 foot thick, also as fragments of selenite veins and crystal aggregates; gypsum, similar to unit from 214.3 to 221.0 feet; mud, moderate-reddish-brown (10R 4/6) to moderate-brown (5YR 3/4), trace of greenish-gray (5G 6/1), firm to hard, some mud as matrix and some as inclusions	221.0-223.3
Mud with gypsum: mud, same as unit from 221.0 to 223.3 feet, as a matrix with gypsum fragments, selenite veins and crystal aggregates, major selenite vein dipping 30-48°; pale-reddish-brown (10R 5/6) to moderate-reddish-brown (10R 4/6) and light-olive-gray (5Y 6/1), mottled, finely crystalline gypsum fragments at 226.0 feet, other gypsum fragments, same as unit from 214.3 to 221.0 feet	223.3-227.3
Gypsum, similar to unit from 214.3 to 221.0 feet, but no argillaceous laminae, finely to medium crystalline	227.3-231.0
Mud, olive-gray (5Y 4/1), with medium-gray (N5) tint, firm, slightly calcareous; 1 to 3 millimeter selenite veins dipping 30°	231.0-231.5
Gypsum, light-olive-gray (5Y 6/1), olive-gray (5Y 4/1), dark-yellow-brown (10YR 4/2), mottled, very fine to finely crystalline, argillaceous in parts, laminated, low angle dip at 30°, few gypsum-healed fractures, dipping as much as 30°, several 5-millimeter thick olive-black (5Y 2/1), soft mud seams dipping 16° from 231.5 to 231.8 feet	231.5-237.0
Dolomite, yellowish-gray (5Y 7/2) to light-olive-gray (5Y 6/1), clayey (altered), very finely crystalline, with porous texture, pinpoint porosity; laminations in denser streaks dipping 10°	237.0-239.4
No core	239.4-242.0
Dolomite, light-olive-gray (5Y 6/1), very finely crystalline, very hard, numerous pits 1 to 2 millimeters in diameter; core broken into rounded, cobble size fragments	242.0-243.1
No core	243.1-252.0
Dolomite, same as unit from 237.0 to 239.4 feet	252.0-254.5

Table 7.--Lithology penetrated by borehole H-7c - Continued

Lithologic description	Depth interval (feet)
Dolomite, same as unit from 242.0 to 243.1 feet, pits more numerous, increasing in size, 1-3 millimeter; large vug at 256.5 feet, 20 by 30 millimeters and approximately 60 millimeters deep	254.5-256.7
No core	256.7-260.0
Dolomite, same as unit from 242.0 to 243.1 feet, numerous high angle fractures, numerous lense shaped vugs as much as 30 millimeters long, vertical fracture from 261.4 to 264.0 feet	260.0-269.6
No core	269.6-270.0
Dolomite, same as unit from 242.0 to 243.1 feet, core becoming more vuggy and core more broken and fractured towards bottom; vugs range from 10 to 40 millimeters in diameter, dark-yellowish-orange (10YR 6/6) stain on some fracture surfaces	270.0-273.5
No core	273.5-280.0
Dolomite, light-olive-gray (5Y 5/2), very finely crystalline to argillaceous, brecciated and then rehealed; few cobbles of light-olive-gray (5Y 6/1) dolomite with 1 to 2-millimeter sized pits and dendritic manganese dioxide crystal growth on fracture surfaces; probably lost core from earlier intervals	280.0-283.0
Mud as residue, light-olive-gray (5Y 6/1)-(5Y 5/2), soft dolomitic, some medium-gray (N5), firm laminations dipping 10°; scattered light-olive-gray (5Y 5/2) dolomite fragments	283.0-283.1
Mud as residue, olive-gray (5Y 4/1) to olive-black (5Y 2/1), firm; softer mud "laminae"	283.1-283.2
Mud as residue, moderate-brown (5YR 4/4) to dark-reddish-brown (10R 3/4), firm; mottled gypsum veins, bands, and crystal aggregates	283.2-284.3
Gypsum, light-olive-gray (5Y 6/1), medium-light-gray (N6), mottled, with moderate-brown (5YR 4/4) mud, laminated, numerous selenite crystals and crystal aggregates in residue mud matrix from 284.7 to 285.0 feet	284.3-285.0

Table 7.--Lithology penetrated by borehole H-7c - Continued

Lithologic description	Depth interval (feet)
Mud as residue, gypsum fragments, and selenite crystals; crystal aggregates and veins, same as unit from 283.2 to 284.3 feet; dark-greenish-gray (5G 4/1) mud from 285.7 to 286.0 feet	285.0-289.2
No core	289.2-292.0
No samples	292.0-360.0
No core	360.0-370.0
Mud with clay, dark-greenish-gray (5G 4/1) to dark-gray (N3), soft, broken up, plastic in texture	370.0-372.0
Siltstone, medium-dark-gray (N6) to greenish-gray (5GY 6/1), hard; some thin laminae	372.0-372.3
No core	372.3-380.0
Siltstone, same as unit from 372.0 to 372.3 feet	380.0-380.4
Mudstone, dark-reddish-brown (10R 3/4) and medium-dark-gray (N8), soft, thin stringers of gypsum; 0.2-foot thick, irregular, broken band of dusky-yellowish-brown (10YR 2/2) gypsum at 381.0 feet	380.4-381.5
Mudstone, dark-reddish-brown (10R 3/4), firm; few thin short stringers of gypsum and some medium-dark-gray (N4) mud near top	381.5-381.9
No core	381.9-390.0
Mudstone and siltstone fragments, in soft friable dark-reddish-brown (10R 3/4) to moderate-brown (5YR 3/4) mud and silt matrix; angular, firm, dark-greenish-gray (5GY 4/1) siltstone inclusions as much as 0.5 foot in size, some approaching mudstone; mottled, moderate-reddish-brown (10R 4/6), grayish-red (10R 4/2), very light-gray (N8), argillaceous gypsum fragments from 390.5 to 392.0 feet	390.0-398.2
No core	398.2-400.0
Loose rubble of siltstone, mudstone, and gypsum fragments, same lithologies as unit from 390.0 to 398.2 feet	400.0-400.8

Table 7.--Lithology penetrated by borehole H-7c - Concluded

Lithologic description	Depth interval (feet)
Gypsum, moderate-reddish-brown (10R 4/6), light-olive-gray (5Y 6/1) and very light-gray (N8), mottled, finely crystalline	400.8-401.2
Halitic mud with silt, soft, moderate-reddish-brown (10R 4/6)	401.2-405.0
Argillaceous halite, transparent to translucent, finely crystalline, moderate-reddish-brown (10R 4/6) interstitial clay	405.0-406.0
Halite, transparent to translucent, very light-gray (N8) tint, medium crystalline, slightly argillaceous, moderate-reddish-brown (10R 4/6) interstitial clay; trace of polyhalite	406.0-409.2
No core	409.2-410.0
Argillaceous halite, same as unit from 406.0 to 409.2 feet; torquing of core barrel dislodged loose rubble of siltstone, mudstone, mud and silt, same lithologies as unit from 390.0 to 398.2 feet	410.0-411.3
Halite, same as unit from 406.0 to 409.2 feet; heavier trace of moderate-reddish-brown (10R 4/6) polyhalite	411.3-416.25
Argillaceous halite, transparent to translucent, very fine to medium crystalline, moderate-reddish-brown (10R 4/6) to dark-reddish-brown (10R 3/4) interstitial clay, trace of greenish-gray (5GY 6/1) clay from 416.5 to 417.0 feet	416.25-418.4
Halite, same as unit from 406.0 to 409.2 feet	418.4-419.2
No core	419.2-420.0
	Bottom of cored interval

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