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LITHOLOGIC LOG AND LITHIUM CONTENT OF SEDIMENTS PENETRATED IN A TEST BORING DRILLED ON WILLCOX PLAYA, COCHISE COUNTY, ARIZONA

by

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INTRODUCTION

The U.S. Geological Survey is engaged in drilling several test holes to test hypotheses for the occurrence and distribution of lithium in sedimentary basins and possibly to identify additional domestic resources of nonpegmatite lithium. As a byproduct, valuable experience is gained in the technology required to drill successfully in unconsolidated playa sediments. The purpose of this report is to describe the results of a test hole drilled into the unconsolidated sediments at Willcox Playa, Arizona. The location was selected to test the association of lithium with nonmarine evaporites and their associated residual brines. The primary target for drilling was the late Cenozoic sediments, which we thought might resemble the lithium-rich sediments and sedimentary rocks of the Lake Mead area, as described by Bohannon (1976) and by Brenner-Tourtelot and Glanzman (1978). A secondary target was the interstitial fluids of the sediments, which we thought might contain anomalous concentrations of lithium.

Interest in searching for new lithium resources stems from potential new uses for lithium in batteries for electric vehicles and from other applications (Chilenskas and others, 1976). Most lithium was derived from spodumene-bearing pegmatites until about 1967, when the Foote Mineral Company began recovery of lithium from a subsurface brine at Clayton Valley, Nevada, (Kunasz, 1975). Recent construction of facilities to recover lithium from brines at Salar de Atacama, Chile (Comer, 1978), suggests that production of lithium from brines may soon exceed that from pegmatites.

Paul Dunlevy of the U.S. Bureau of Land Management, Safford Arizona, helped us select a suitable drilling site and obtain permission to drill. Sediment samples were analyzed for lithium in the U.S. Geological Survey's Reston, Virginia, laboratory by J. Kane and A. Neuville under the direction of F. O. Simon. Water samples were analyzed in the Denver, Colorado, Laboratory by J. Crock under the direction of J. H. Cristie.

This work was performed under the terms of a cooperative agreement with the Division of Energy Storage Systems and the Division of Uranium Resources and Enrichment of the U.S. Department of Energy.

Previous geological studies in the Willcox Playa area include the ground-water report by Meinzer and Kelton (1913) and more recent ground-water investigations by Brown and others (1963), Kister and others (1966), and Brown and Schumann (1969). Sedimentologic studies by Prof. Joseph F. Schreiber, Jr., and his students from the University of Arizona, based in part on a 140-ft (43-m) core near the center of Willcox Playa, are described in a report by Schreiber and others (1972). A study of the ostracode succession of the upper playa sediments by Cameron and Lundin (1977) provides the basis for an interpretation of the environment of deposition. Davis and Meier (1976) report lithium analyses for several surface-sediment samples, water samples, and core samples from Willcox Playa.

LOCATION OF SITE AND DESCRIPTION OF DRILLING PROCEDURE

A test boring, identified on figure 1 as USGS W-1, was located on Willcox Playa about 5 1/2 mi (9 km) southwest of the town of Willcox in Cochise County, Arizona. The site is located near the center of sec. 34, T. 14 S., R. 24 E. about 100 ft (30 m) northwest of a service road adjacent to the Southern Pacific Railroad grade. The playa surface in the vicinity of the site is devoid of plant life and is beyond the zone of beach sands and sand dunes where endangered species of salt brush and possible archeological sites have been reported (Paul Dunlevy, personal commun. Sept. 1978).

Drilling was done from September 28 to October 7, 1978, under contract with Drilling Services Company of Tempe, Arizona, a division of Layne-Western Company, Inc. A reverse circulation technique was employed utilizing a 4 1/2-in.(11.4-cm)-diameter dual-wall drill stem and a mixture of air and water to flush the bit and bring samples to the surface. This technique minimizes contamination of samples by drilling additives and permits recovery of water or brine samples by simply maintaining air pressure after shutting off drilling water. In order to set casing, the first 50 ft (15.2 m) of the well were drilled with an 11-in. (27.9-cm)-diameter tricone bit using a mixture of air and water with a foaming agent to bring up the cuttings. Only a limited number of samples were recovered during this operation because of the foam. Several samples were collected, however, from the upper 10 ft (3 m) of a water pit. From 50 to 998 ft (15.2-304 m) drilling was done with a 5 1/8-in. (13-cm)-diameter drag bit having a 2-in. (5-cm)-diameter central opening, through which cuttings and pieces of core 40-45 mm in diameter and 10-50 mm long were returned to the surface via the inner annulus of the dual-wall drill stem. Beginning at 50 ft (15.2 m) sediment samples were collected at 5 ft (1.5 m) intervals from a cyclone designed to reduce the velocity of samples as they were ejected from the air return. The contractor also provided a sample splitter intended to provide

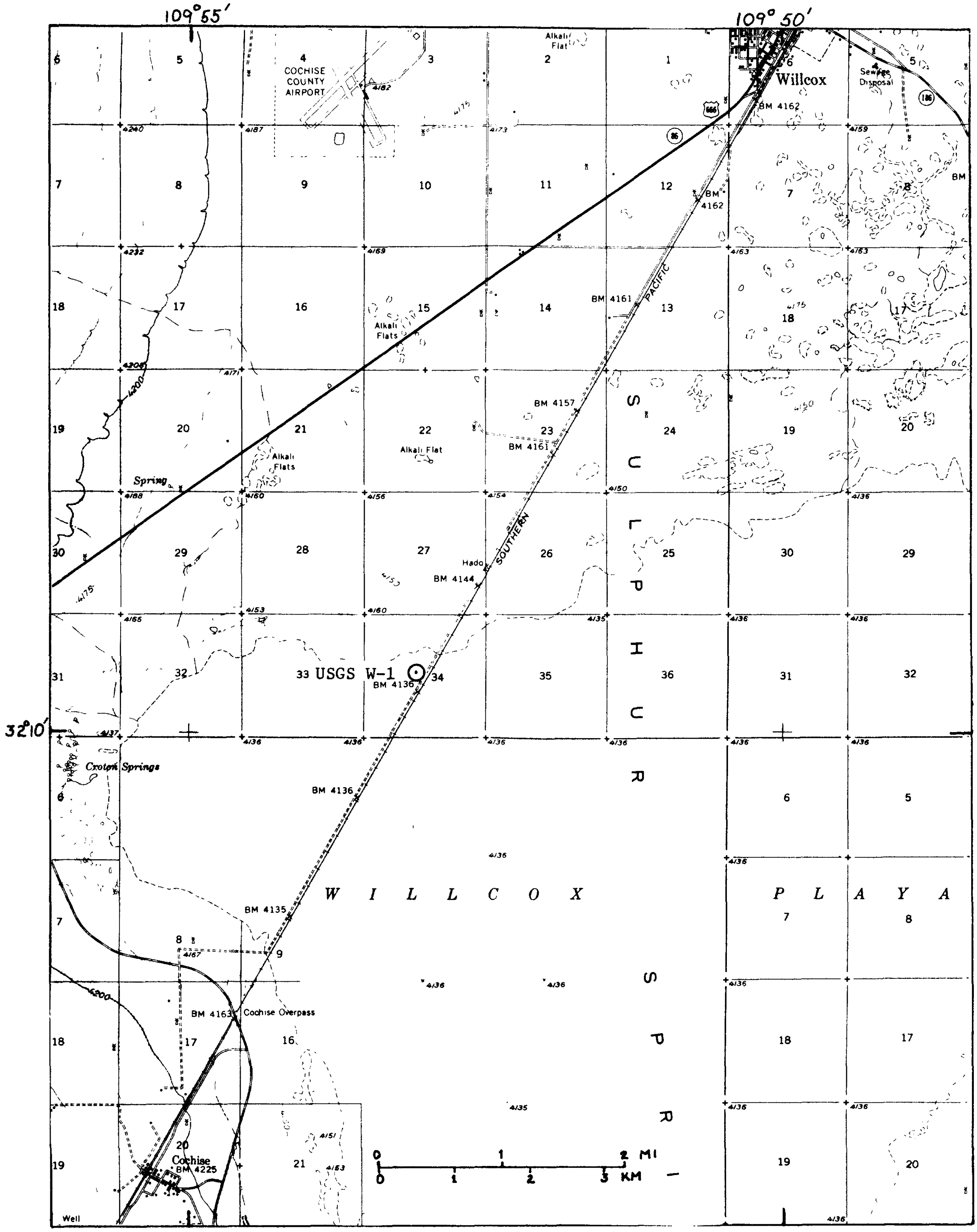

FIGURE 1.--Map of part of Cochise 15-minute quadrangle, Arizona, showing location of test boring USGS W-1

a continuous sample split of one-eighth of the material that came through the cyclone. However, most of the clays penetrated by the drill broke into sticky chunks too large to pass through the splitter and were collected in a hand-held sieve.

Artesian water was encountered in the first 50 ft (15.2 m) of drilling and welled up around the outside of the casing. An additional 15 ft (4.6 m) of casing was forced into the hole but failed to stop the flow of water, which continued throughout the time required to complete the test. This water had a pH of 9.5 and was nearly opaque black with dispersed iron hydroxide or humic acid, which could be flocculated by the addition of HCL. This black water, which was probably high in bicarbonate, contaminated all the samples and mixed with the clays to form a viscous black mud resembling grease. No other aquifiers of any consequence were encountered during the remainder of the drilling. Most of the sediments penetrated appeared to be dry on fresh fracture.

Some of the clays penetrated in drilling were sufficiently plastic to plug the bit whenever the driller allowed penetration to exceed a certain rate. The rate of penetration for the time actually spent drilling averaged about 50 ft (15 m) per hour on the first full day of drilling with the drag bit and decreased thereafter on successive days to 21, 20, 14, 10.5, and 5 ft (6.4, 6, 4.3, 3.2, and 1.5 m) per hour. The last 37 ft (11.3 m) were drilled in 3 hours with a tricone bit at a rate of about 12 ft (3.7 m) per hour, or only a little better than with the drag bit. Drilling was terminated at a depth of 1,035 ft (315.5 m) because of this slow rate of penetration, the lack of permeability, and the lack of a brine. Upon completion of drilling, the hole was plugged with concrete to a depth of 85 ft (25.9 m) to prevent water seepage.

DRILLING RESULTS

Water samples were collected from seven depths and submitted for analysis, as shown here:

Depth ft	Depth m	Lithium (mg/l)	Chloride (mg/l)	Specific conductance (millimhos/cm)
35	10.7	0.05	1,740	6.8
255	77.7	<0.02	5,000	39
415	126.5	0.42	7,860	60
595	181.4	0.48	8,820	66
855	260.6	0.48	11,400	82
977	297.8	0.88	12,700	84
1,035	315.5	0.06	4,380	32

The lithium content of these samples, ranging from <0.02 to 0.88 mg/l, is low considering the evaporative concentration in a lake or playa indicated by the large quantity of gypsum throughout some 650 ft (198 m) of the section. Moreover, the low values for lithium in the water contrast with anomalously high values for lithium in some of the sediment samples, as indicated on figure 2.

The types of sediments penetrated in the borehole are described in a lithologic log at the end of this report. In general, the upper third of the sequence is characterized by gray clays typical of a reducing environment. The lower two-thirds of the sequence is characterized by red-brown clays and gypsum typical of an oxidizing environment and an evaporative concentration of saline waters sufficient to precipitate calcium sulfate. These lithologies are illustrated on figure 2, along with analytical results of lithium contained in sediment samples.

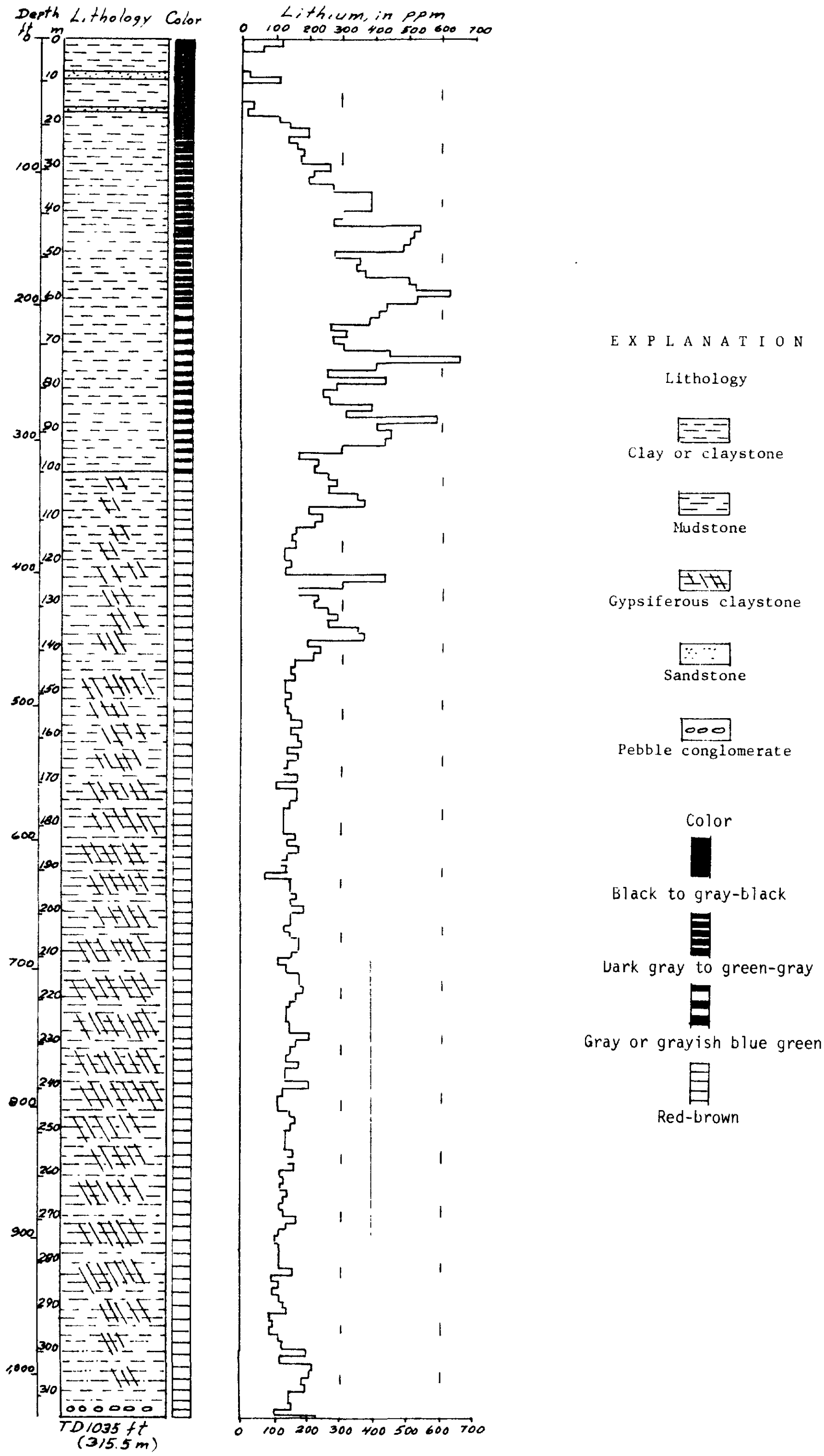

FIGURE 2.--Log of test boring USGS W-1 located on Willcox Playa near the center of sec. 34, T. 14 S., R. 24 E., Cochise County, Arizona

Seven stratigraphic intervals with a combined thickness of 75 ft (23 m) exceed 500 ppm lithium, as follows:

Depth of interval (ft)	(m)	Average Li content (ppm Li)
140-160	43-49	505
180-200	55-61	540
240-245	73-75	650
285-290	87-88	580
300-310	91-94	505
335-340	102-104	555
375-385	114-117	515

The high-lithium intervals appear in a rhythmic or cyclic pattern suggestive of changes in water chemistry such as fluctuations in pH and salinity. Such changes are perhaps more characteristic of climatic variations like those of the Pleistocene than of changes in sedimentary processes such as rates of deposition. Thus, the deposition of lithium in Willcox Playa sediments may be climatically controlled.

The significance of the lithium values from Willcox Playa sediments can best be understood by a comparison with the mean lithium content of 99 ppm (Davis, 1976, table 48) from a reconnaissance of 41 playas and 156 sediment samples from the Great Basin region. These data suggest, moreover, that values greater than about 300 ppm Li can be regarded as anomalous if the threshold is placed at two standard deviations above the mean. By this standard, the Willcox Playa samples from the interval 115-450 ft (35-137 m), which contain a number of high values and average 365 ppm Li, may be regarded as anomalous.

The significance of the low concentration of lithium in water samples from Willcox Playa is complicated by the probable contamination of most of the samples with the black artesian water encountered in the upper part of the hole, which is represented by the water analysis from 35 ft (10.7 m) depth. However, the high-chloride samples ranging up to 12,700 mg/l Cl represent formation waters from the depths indicated, even though no obviously permeable zones were recognized in the lithologic log. Clearly a chemical mechanism for the preferential partition of lithium into the solid rather than the aqueous phase is indicated by the inverse relation between lithium in the sediment samples and lithium in the water samples. Whether this mechanism results in the formation of a stable lithium mineral, such as hectorite or cookeite, or is a sorption phenomenon has not been determined. However, the apparent effectiveness of the mechanism would seem to favor formation of a stable mineral phase.

LITHOLOGIC LOG OF TEST HOLE USGS W-1

Test hole located on the northwest side of Willcox Playa near the center of sec. 34, T. 14 S., R. 24 E., Cochise County, Arizona. Surface elevation 4,135 ft (1,260 m

Description of interval to depth listed from previous depth listed	Depth ft	Depth m
DESCRIPTION OF SEDIMENTS IN WATER PIT		
	0	0
Clay, red-brown to green-gray; sandy near surface of mud pit	5	1.5
Clay, green-gray at the top; black in lower part of mud pit	10	3
No record was kept of sediments penetrated in this interval as hole was drilled with tricone bit and foam to set casing. Cuttings were mostly black sand and clay. Artesian flow of black water with a pH of 9.5 occurred.	50	15.2

Description--continued	Depth ft	m
DESCRIPTION OF SEDIMENTS IN TEST HOLE DRILLED USING DRAG BIT		
Clay, dark-gray, slightly silty, slightly calcareous	55	16.8
Clay, dark-gray, silty; and coarse-grained, arkosic sandstone; grains are coated with black material	60	18.3
Clay, medium-gray, soft; and hard black clay	65	19.8
Clay, black and dark-green-gray	70	21.3
Clay, green-gray, silty; and medium-dark-gray, coarse, feldspathic sand	80	24.4
Clay or claystone, green-gray and gray-black, mottled, silty, calcareous; contains ostracodes; locally plastic but generally hard and dry	205	62.5
Clay, green-gray, light green-gray, and medium dark-gray, laminated, silty, calcareous; the lighter colored laminae are more calcareous	215	65.5
Claystone, light green-gray to green-gray and medium dark-gray, laminated, calcareous	255	77.7
Claystone, blue-gray, slightly calcareous, slightly silty	265	80.8
Claystone, grayish blue-green, slightly calcareous	280	85.3
Claystone, grayish blue-green, with black color mottling less than 2 mm across	285	86.9
Claystone, grayish blue-green, mottled with blebs of carbonate-cemented claystone; locally laminated	305	93.0

Description--continued	Depth ft	m
Claystone, grayish blue-green and light-green, laminated, calcareous; carbonate-rich laminae locally have a sandy texture	315	96.0
Claystone, light-green and green-gray, laminated; and light brown-gray calcareous claystone	320	97.5
Claystone, gray-brown; in part interlaminated with gray-green calcareous claystone	325	99.1
Claystone, red-brown, calcareous; and gray-green claystone mottled with red-brown; contains thin gypsum laminae	330	100.6
Claystone, red-brown, slightly calcareous; and green-gray claystone with a few scattered crystals of gypsum	335	102.1
Claystone, red-brown, slightly silty, slightly calcareous; laminated or mottled in part with gray-green claystone; gypsum occurs as laminae and small crystals; calcite occurs as cement in light-green mottled areas and as small crystals; thin seams of black carbonaceous(?) matter and green glauconite(?) present	380	115.9
Claystone, red-brown and gray-green, gypsiferous	385	117.3
Claystone, gray-green to red-brown, very slightly calcareous	390	118.9
Claystone, red-brown, unbedded, very slightly silty and calcareous	405	123.4

Description--continued	Depth ft	m
Claystone, red-brown; interlaminated or mottled with gray-green;scattered gypsum and calcite crystals	415	126.5
Claystone, brown-gray and red-brown, unbedded; euhedral gypsum crystals as much as 4 mm long	445	135.6
Claystone, olive-gray, in part mottled with red-brown; contains gypsum laminae 2-4 mm thick and a few gray-green laminae that are crinkly and disrupted	450	137.2
Claystone, red-brown, partly calcareous; contains scattered euhedral crystals of gypsum and gypsum veinlets--some beds contain 30 percent gypsum	495	150.9
Claystone, red-brown, calcareous; contains euhedral gypsum crystals throughout	515	157.0
Claystone, red-brown, calcareous; euhedral gypsum crystals; gray claystone and thin green seams (possibly glauconite) locally present	535	163.1
Claystone, red-brown, calcareous; contains scattered gypsum crystals 1-10 mm long that locally comprise half the bed	595	181.4
Claystone, red-brown, with occasional thin gray laminae, calcareous; contains scattered gypsum crystals as much as 10 mm across	655	199.6
Claystone, red-brown, calcareous; contains scattered gypsum crystals as much as 10 mm across and a few layers as much as 30 mm thick of nearly pure gypsum	695	211.8

Description--continued	Depth ft	m	
Claystone, red-brown, calcareous; some layers contain 10-50 percent gypsum in crystals as much as 20 mm across; calcite crystals occur locally in vugs or on gypsum crystals. Probably includes some thin beds of gypsum that are fragmented by the drill	765	233.2	
Claystone, red-brown, in part calcareous; contains gypsum crystals 1-30 mm across that comprise 10-50 percent of some beds--unit tastes salty	955	291.1	
Claystone, sandy mudstone, and sandstone; all red-brown, calcareous, and gypsiferous; sandstone is arkosic	965	294.1	
Claystone, red-brown, gypsiferous	980	298.7	
Mudstone, red-brown, sandy, gypsiferous; sand grains are poorly sorted, angular, lithic and feldspathic; sand grains comprise as much as 30 percent of the rock in some beds	995	303.3	
Mudstone, red-brown, sandy; contains 1-mm-size gypsum crystals and calcite veinlets. Changed to tricone bit at 998 ft (304 m)	1,000	304.8	
Mudstone, red-brown, sandy	1,010	307.8	
Mudstone, red-brown; grains of coarse sand and pebbles are scattered throughout. Pebbles are as much as 30 mm across and composed of volcanic rock fragments	1,035	315.5	T.D.

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