UNITED STATES DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY

LITHOLOGY AND LITHIUM CONTENT OF SEDIMENTS DRILLED IN A TEST HOLE ON RED LAKE, HUALAPAI VALLEY, MOHAVE COUNTY, ARIZONA

by

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OPEN-FILE REPORT 79-1439

1979

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INTRODUCTION

The U.S. Geological Survey has drilled several test holes in the southwestern United States to test hypotheses for the occurrence and distribution of lithium in sedimentary basins.

The demand for lithium, nature's lightest metal, in the United States is expected to rise sharply in the next few decades because of uses in electric storage batteries for electric vehicles, and for load-leveling in power plants. The United States' present domestic production of lithium is from the tin-spodumene belt of North Carolina, where two companies are mining the spodumene for its lithium content, and from the lithium-rich brine of Clayton Valley, Nevada (Kunasz, 1976). As demand for lithium increases, the United States may need to tap the resources of other sediments and brine fields to remain self-sufficient in lithium production. The U.S. Geological Survey's study of closed basins is aimed at identifying the origin and distribution of lithium in those basins, and at developing new techniques for drilling unconsolidated basin-fill sediments that involve minimum contamination to the sediments or to their associated ground waters or brines. This report describes the results and the techniques used for one such test hole located near Red Lake in Hualapai Valley, Mohave County, Arizona.

PREVIOUS GEOLOGIC STUDIES IN THE RED LAKE AREA

Hualapai Valley is the first Basin-and-Range province valley west of the Colorado Plateaus province in northern Arizona. In 1908 Willis T. Lee suggested that the Hualapai Valley was formed by downdropping and eastward tilting of a valley block against the Grand Wash Cliffs, and that the valley fill was greater than 700 ft (213 m) (1908, p. 49-50).

In 1959 Wilson and Moore published a geologic map at the scale of 1:375,000 of Mohave County, which includes Hualapai Valley. On this map the units and lithologies that make up the surrounding terrain of the Grand Wash Cliffs, Music Mountains, and Cerbat Mountains are delineated, but the valley fill and playa deposits are generalized.

Gillespie, Bentley, and Kam (1966) provided basic hydrologic data and driller's logs for Hualapai Valley, and Gillespie and Bentley (1971) reported on the hydrology of the valley and accompanied their report with a generalized geologic map of the basin and the surrounding rocks.

Koester (1971) reported the existence of a salt body in Hualapai Valley, based on driller's logs from three wells south of Red Lake drilled by Kerr-McGee Corporation and El Paso Natural Gas Company. He postulated that the body is a salt dome of possible Mesozoic age on the basis of at least 4000 ft (1220 m) of relatively pure halite drilled, the presence of an anhydrite caprock, the dips of the salt between wells, and paleontologic and K-Ar dating.

In 1972, Peirce, using geophysical gravity data, suggested that the salt body might be as much as 12 mi (19 km) long paralleling Hualapai Valley, as much as 5 mi (8 km) wide, and 2 mi (3.2 km) thick. He interpreted the salt body as a basin evaporite sequence, tabular in form, of Tertiary age, and related by proximity and elevation to the evaporites of the largely Pliocene Muddy Creek Formation in the Lake Mead region (Peirce, 1972, p. 5).

LOCATION OF TEST HOLE

Test hole USGS RL-1 (fig. 1) is located near the east edge of Red Lake, an ephemeral lake or playa in Hualapai Valley, about 35 mi (56 km) north of Kingman, Mohave County, Arizona, on the SW 1/4 SW 1/4 SW 1/4 SW 1/4 sec. 29, T. 27 N., R. 16 W. This site is managed by the U.S. Bureau of Land Management, Kingman Resource Area. The site was chosen by cooperative agreement by Ralph Korn of the Bureau of Land Management and James D. Vine, U.S. Geological Survey. Mitch Linne' of the U.S. Bureau of Land Management (Kingman)

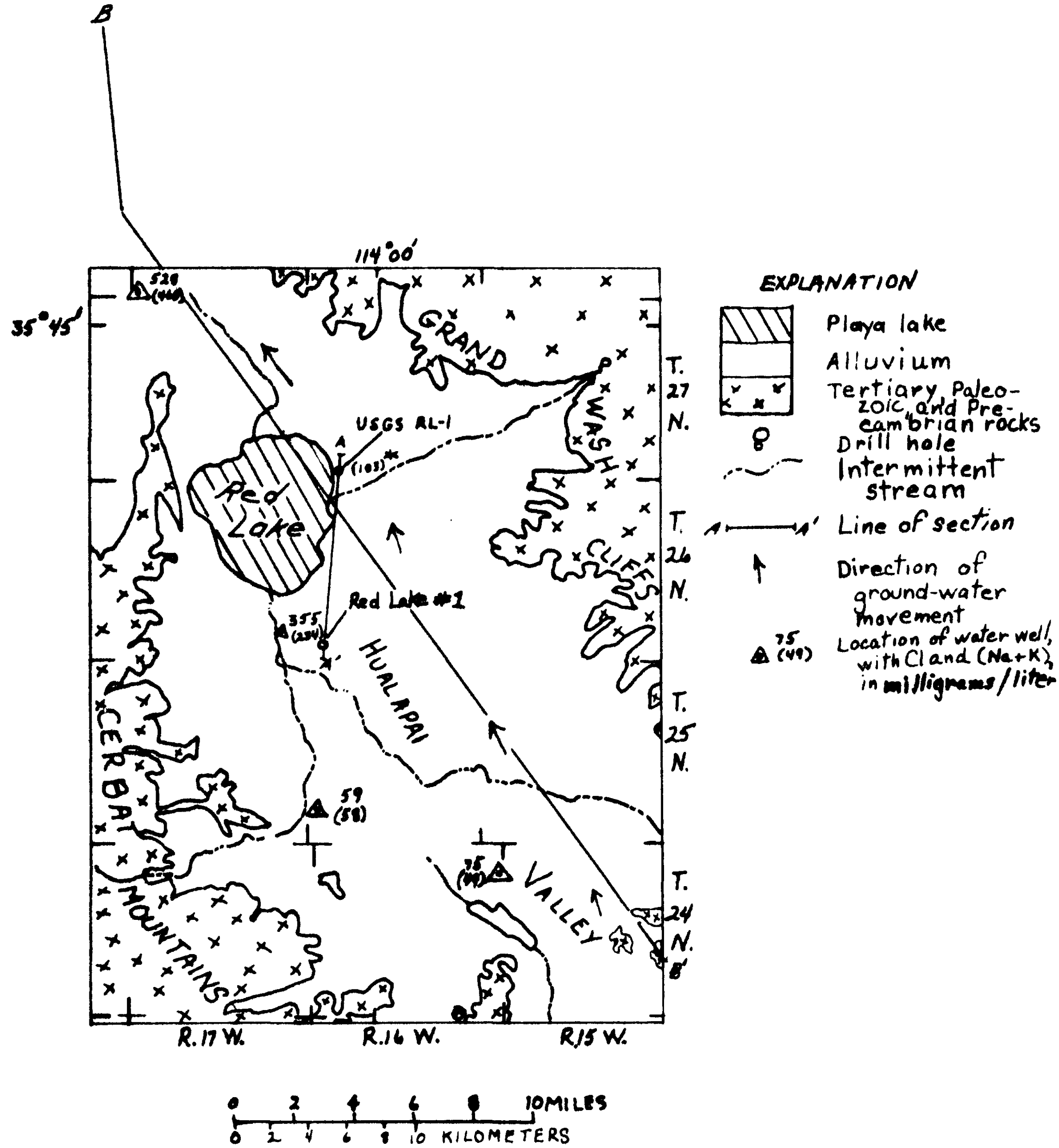

Figure 1.--Index map of Hualapai Valley, Mohave County, Arizona, showing generalized geology (modified from Gillespie, Bentley, and Kam, 1966, fig. 3). Starred value of (103) represents (Na + K) for bottom water of USGS RL-1, in mg/L.

performed the site inspections while drilling took place. We thank these U. S. Bureau of Land Management employees for their help and information.

The drilling site is located in the northeast part of the Mohave Desert; it is sparsely vegetated and dusty when dry. The only surface water in the area comes from small springs which are probably fed from buried alluvial-fan material. This water is collected and stored in stock tanks. The playa surface, nearly devoid of vegetation, is extensively mud-cracked. The cracks vary from irregular thin polygonal chips 2-10 in. (5-25 cm) across to giant desiccation features--polygons 15-30 ft (4.5-9 m) across and 6-8 in. (15-20 cm) thick. Repeated rainfall during the drilling of the test hole created shallow (less than 1 in. or 2.5 cm) ephemeral puddles on the playa, which, in a day or two, were floored with green-brown algae. As the puddles dried, the algae desiccated and turned the same tan as the playa sediments.

The test hole was drilled to determine the lithology and lithium values of the late Cenzoic sediments and brines thought to be associated with a buried salt body underlying Hualapai Valley, where Red Lake is located (fig. 1). The origin of the salt body is uncertain but may be similar to that of the gypsum and halite found in the lithium-rich sediments of the Lake Mead area (Bohannon, 1976; Brenner-Tourtelot and Glanzman, 1978).

Drilling Services Company of Tempe, Arizona, drilled the test hole from October 17 to October 24, 1978. The first 50 ft (15.2 m) were drilled with an 11-in. (27.9-cm) diameter tricone bit to allow about 35 ft (10.7 m) of surface casing to be set. Below 50 ft, the drillers used a reverse-circulation drilling technique. This method minimizes contamination of sediments and water samples with drilling fluids or caving of walls by pumping a mixture of water and air down the outer wall of a 4.5-in.(11.4-cm) dual-wall drill stem and then forcing that mixture and the sediments drilled past the bit and up the inner annulus of the drill stem. The drill bit was a carbide-tipped drag bit having an outside diameter of 5 1/8 in. (13 cm) and an inside diameter (the opening through which the plugs and cuttings passed) of 2 in. (5.4 cm). Beginning at 55 ft (16.8 m), sediment samples were taken at 5-ft (1.5-m) intervals and were described and bagged for analyses.

LITHOLOGY AND LITHIUM CONTENTS

The types of sediments penetrated in the test hole are described in the lithologic log at the end of this report, and the lithium values of the sediments are given on figure. 2, which also serves as a generalized

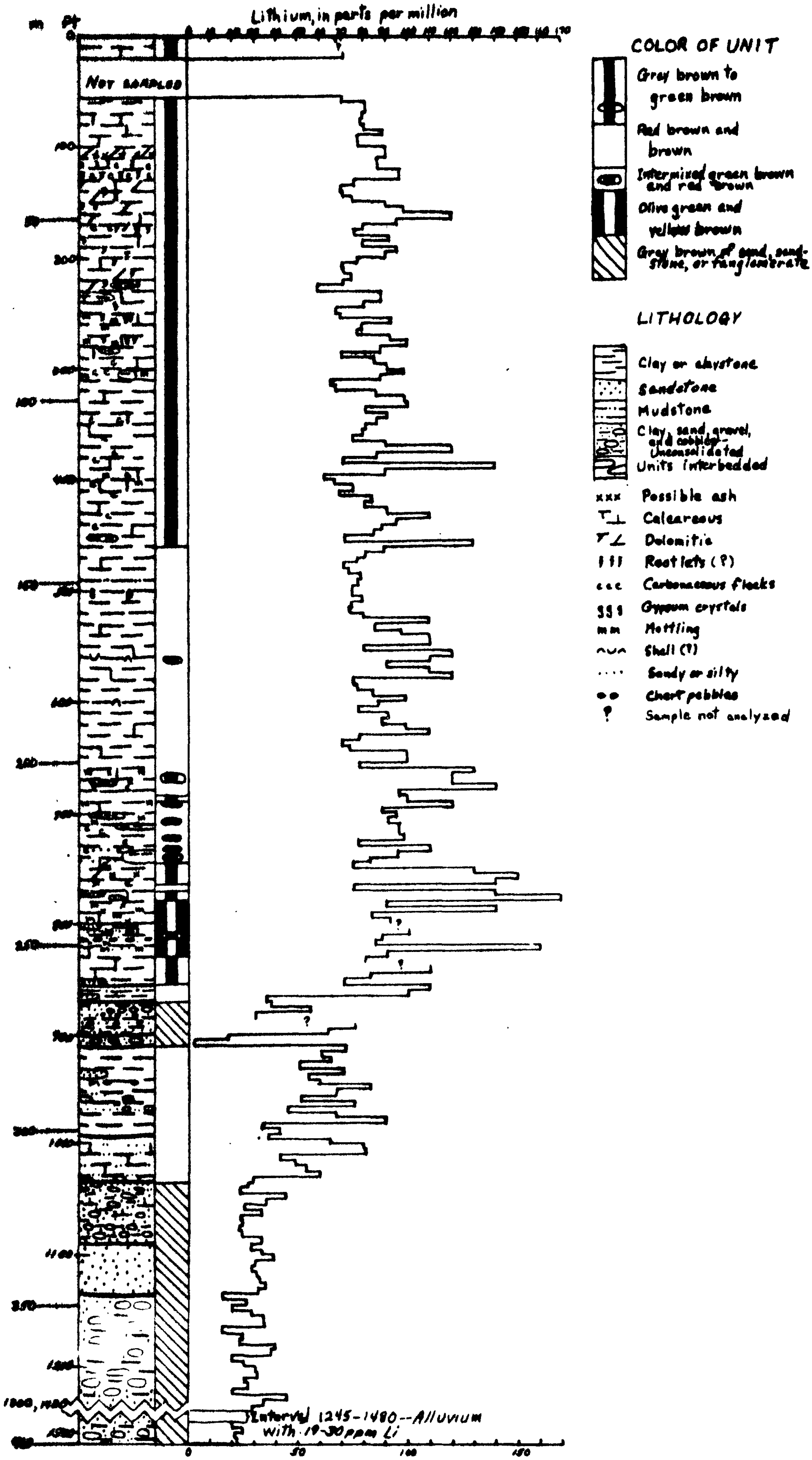

Figure 2.--Lithologic log and lithium content of sediments in USGS RL-1 drill hole, Red Lake.

lithologic log. Lithium analyses in the sediments were performed by A. Neuville and R. Moore, U.S. Geological Survey analytical laboratories, Reston, Virginia. The analytical method used was flame atomic absorption spectrography.

The lithium values (fig. 2) are in the normal range for the types of sediments sampled. One hundred fifty-six surface samples collected by other Survey geologists from more than 40 structural basins in the western Basin and Range province yielded an arithmetic mean of 99 ppm (parts per million) Li and a standard deviation of 86 ppm Li (Davis, 1976, p. 107). Considering only the 155 Li values from the claystones drilled at Red Lake (the samples thought to have been deposited in a playa), the arithmetic mean is 90.1 ppm Li, and the standard deviation is 19.8 ppm Li. The lithium values for the fanglomerates are 15 to 50 ppm.

The lithium values of the sediments show a correlation with the predominant color of sediment. Gray-brown, green-brown, olive-green, and yellow-brown sediments have higher lithium values than the red or red-brown sediments (fig. 2). Vine and others (1979, fig. 2) found the same correlation between color and lithium content. Apparently, the lithium content of clays, claystones, and mudstones is related to the oxidation state of the sediments; green and gray sediments suggest that reducing conditions have higher lithium values than red or brown oxidized sediments.
Thus far, we do not know the chemical processes by which lithium is held in the sediments, or whether lithium can be mobilized by a shift in the oxidation state of the sediments by ground-water flow.

Although USGS RL-1 is only 6 mi (9.6 km) north of the El Paso Natural Gas Company's test hole (fig. 1, Red Lake No. 1), correlation of lithologic units between the two holes is difficult. There is no evidence of the salt body or its associated gypsum and anhydrite cap at USGS RL-1; however, a thick deposit of generally unconsolidated gravel, sand, and clay was encountered at the depth where salt might have been (fig. 3). Gypsum was recognized between 250 and 300 ft (76-92 m), but it occurs only as small crystals or discontinuous chalky-looking areas in the claystone. Halite was not positively identified, and the rocks tasted only mildly salty, suggesting that evaporative concentration of brine was never very high at this site.

ANALYSES OF WATER

Samples of formation water were taken after the drilling water supply was shut off, drilling stopped, the drill stem cleared of sediment, and the air was forcing only formation water to the surface. Samples were taken in unused plastic bottles and sealed.

Formation waters were not encountered in the first 450 ft (151 m) of drilling, but a small water sample was taken from the light reddish-brown, moderately calcareous, micaceous, silty, and salty-tasting claystone at 450 ft (151 m).

At 855-870 ft (261-265 m), the micaceous calcareous silty claystone ~~is~~ was interbedded with lenses of clayey well-indurated calcareous sandstone, and the unit produced water (sample RL-870). From there downward, formation waters were taken from unindurated mixed clay, sand, and gravel similar to those currently found on alluvial fans and in small stream beds that encircle the playa (fig. 3).

C. Gent, U.S. Geological Survey analytical Laboratories, Lakewood, Colorado performed the lithium, sodium, and potassium analyses on the formation waters. Sample numbers correspond to drilling depths from surface in feet (10 ft equal 3.05 m).

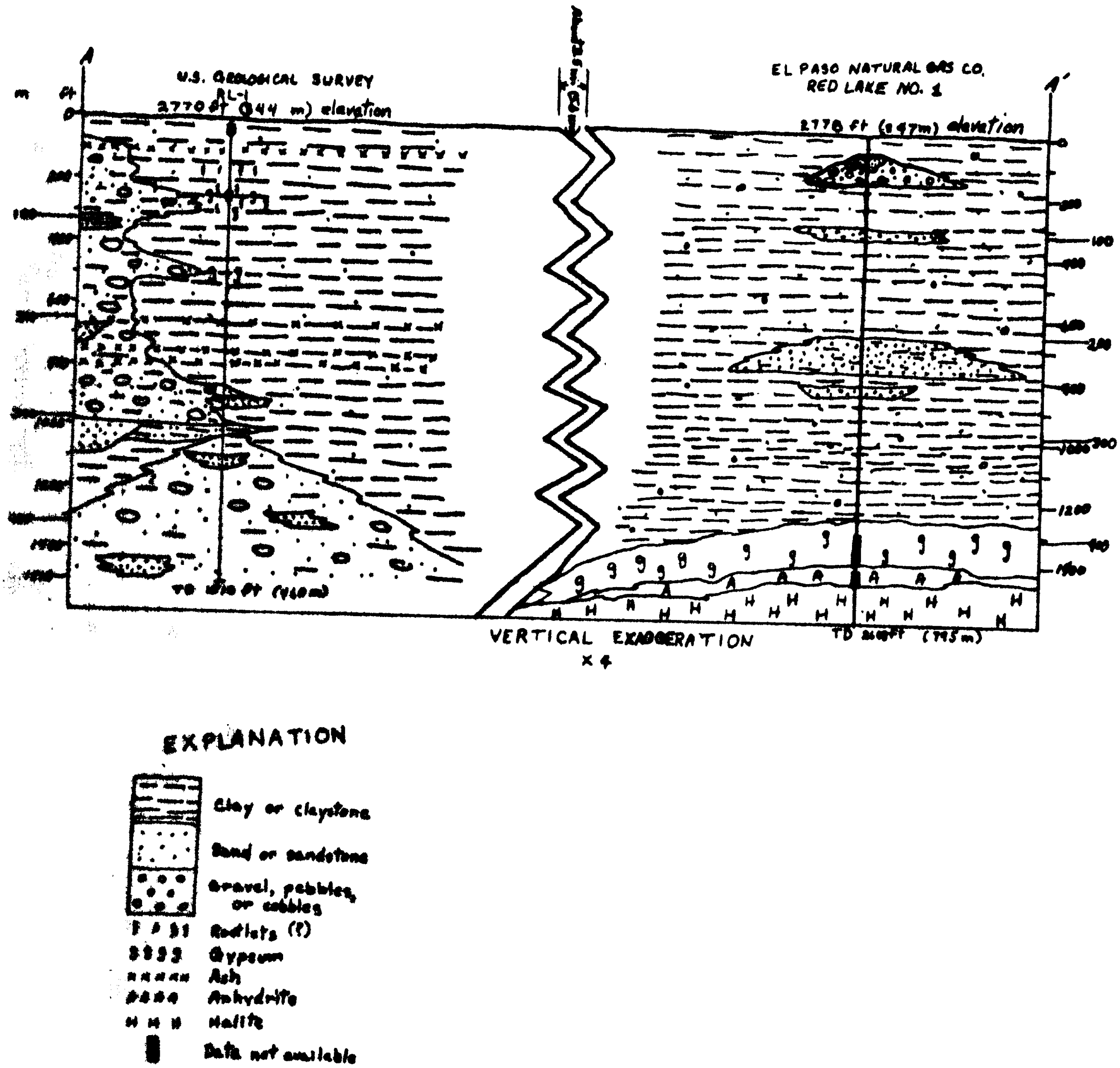

Figure 3.--Interpretive cross sections comparing lithologies and postulated environments of deposition for USGS RL-1 and Red Lake No.1.

Table 1.--Chemical analyses of water samples from U.S. Geological Survey RL-1 test hole

Sample number	Element, in mg/L of solution Li	Na	K	Ratios Li/Na	Li/K	K/Na
RL-450	2.7×10^{-2}	2246	13.9	1.2×10^{-5}	1.9×10^{-3}	6.2×10^{-3}
870	7.8	2684	23.7	2.9	3.3	8.8
890	13.8	3758	29.9	3.8	4.6	8.0
1150	.6	202	3.77	3.0	1.6	18.7
1156	2.0	1118	7.93	1.8	2.5	7.1
1175	.6	258	4.71	2.3	1.3	18.3
1190	2.0	1401	11.9	1.4	1.7	8.5
1210	1.3	953	6.41	1.7	2.0	6.7
1220	.6	117	4.86	5.1	1.2	41.5
1250	1.3	241	4.87	5.4	2.7	20.2
1270	3.4	1806	13.0	1.9	2.6	7.2
1290	1.3	218	4.53	6.0	3.0	20.8
1370	.6	153	4.32	3.9	1.4	28.2
1510	.6	155	4.13	3.9	1.5	26.6
Drilling water	2.0	263	9.13	7.6	2.2	34.6
			Mean-----------	3.5×10^{-5}	2.2×10^{-3}	17.4×10^{-3}
			Standard deviation----	0.5×10^{-5}	0.4×10^{-3}	11.3×10^{-3}

Semiquantitative spectrographic analysis by the U.S. Geological Survey Denver, Colorado, was performed on water sample 1510 (460 m). Results are reported from the detection limit to the upper concentration limit in steps of 1, 3, 5, 7, and 10 (table 2). Due to this rounding technique, the results are estimates with one significant figure.

Table 2.--Dissolved elements, in mg/L, in water sample RL-1510, test hole USGS RL-1

[<, less than]

Al	<0.05	Cu	0.01	K	3.00
Sb	.03	Ga	.07	Si	.01
Ba	.01	Ge	.05	Ag	.01
Be	.001	Fe	.07	Na	100.00
Bi	<1000.00	Pb	.05	Sr	.03
B	.1	Li	.01	Sn	.1
Cd	.003	Mg	3.00	Ti	.005
Ca	5.00	Mn	.007	V	.01
Cr	.05	Mo	.03	Zn	.005
Co	.01	Ni	.07	Zr	.01

Using these data, we find that Li/Na is $1X10^{-4}$, Li/K is $3.3X10^{-3}$, and K/Na is $3X10^{-2}$. Compare these values to those given in table 1, sample RL-1510.

The mean Li/Na ratio of $3.5X10^{-5}$ of the formation waters below Red Lake is much lower than that given in White, Thompson, and Fournier (1976, p. 59) for evaporite brines in other closed basins such as Clayton Valley, Nevada ($5.7X10^{-3}$) and Searles Lake, California ($7X10^{-4}$); but it is close to that of seawater ($1.6X10^{-5}$) (Hem, 1970, table 2). Likewise, the mean K/Na ratio in these test-hole waters is $1.74X10^{-2}$, a ratio similar to that given for seawater ($3.62X10^{-2}$) (Hem, 1970, table 2). If the potassium and sodium in the waters of the alluvial fanglomerates at Red Lake were derived by dissolution of Paleozoic marine rocks, such a ratio might be logical. However, most of the waters below Red Lake tasted fresh and are postulated to be from alluvial-fan and stream deposits (fig. 3). If the deposits sampled have or had hydrologic communication to the drainage from the Grand Wash Cliffs, the lithologies making up those cliffs may reduce the Li/Na and K/Na ratios of the ground water. Alluvial fans on the northeast side of Red Lake are fed from Precambrian granites, gneisses, and schists, and from Cambrian units such as the Tapeats Sandstone, Bright Angel Shale, and Muav Limestone (Gillespie and Bentley, 1971, pl. 1). The Pennsylvanian and Permian Supai Group probably has been eroded from the top of the Grand Wash Cliffs, but it is present nearby on the north side of the Grand Canyon (E. D. McKee, oral commun., 1979).

SURFICIAL AND GROUND WATER

Surface-water movement through Hualapai Valley is limited, and it is interrupted by a topographic sill or barrier about 60 ft (18 m) high about 3 mi (4.8 km) north of Red Lake (fig. 4) (Gillespie and Bentley, 1971, p. 1). However, ground-water underflow is apparently not interrupted significantly by this barrier (see water-table line, fig. 4). J. D. Vine has suggested that the shallow basin containing Red Lake may have formed by partial collapse by dissolution of salt from the buried salt body south of Red Lake.

The salinities of various aquifers encountered in drilling USGS RL-1, as expressed by the sodium content, vary widely from sample to sample (table 1). Such rapid variation suggests that a relatively fresh-water aquifer such as that at 1175 ft (358 m) may not be in hydrologic communication with the aquifer providing the water at 1190 ft (363 m). Perhaps thin lacustrine clay interbeds separate alluvial sequences and, isolate the aquifers.

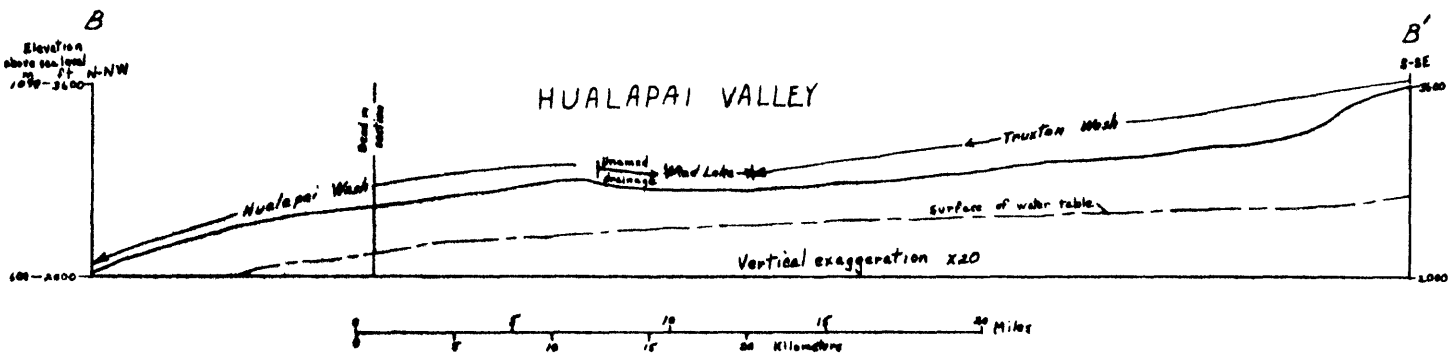

Figure 4.--Longitudinal profile of Hualapai Valley showing the surface of the water table and Red Lake in its slight topographic basin (modified from Gillespie and Bentley, 1971, plate 1).

Concentrations of Cl and (Na+K) however, are greater, at the water well just west of the Red Lake No. 1 (fig. 1), and the concentrations rise significantly in the well at the northwest edge of the map, area north of the topographic lip. Perhaps the (Na+K) value given for USGS RL-1 water at 1510 ft (461 m) represents the value for one of these isolated, rather fresh aquifers, whereas the generally rising values of (Na+K) to the north through the valley represent the ground-water flow past the salt body.

OTHER ANALYSES

Eight salt samples from the El Paso Natural Gas Company Red Lake No. 1 drill hole (fig. 1) were analyzed for lithium and sodium, using the atomic absorption method (H. W. Peirce, written commun., 1970). The calculated Li/Na ratios of seven of these samples are given in table 3.

Table 3.--Lithium and sodium contents for halite samples, Red Lake No.1 drill hole

[Depths in ft (m), element values in parts per million]

	Depth below surface						
	4047 (1234)	4077 (1243)	4106 (1252)	5015 (1529)	5041 (1536)	5059 (1542)	5086 (1550)
	Element						
Li	4.2	9.3	1.5	6.3	3.4	12.00	3.5
Na	346,000	352,000	356,000	361,000	357,000	355,000	363,000
	Li/Na ($X10^{-5}$)						
	1.2	2.6	0.4	1.7	0.95	3.3	0.96

The lithium may be in liquid inclusions of the original brine in the salt. Because such inclusions comprise only a fraction of the total in the original brine salt, analyses of salt and its associated inclusions containing even a few parts per million of lithium may represent an anomalously high concentration of lithium. The Red Lake salt samples in table 3 have lower lithium contents than salt samples from Salar de Uyuni, Bolivia (Ericksen, Vine, and Ballon, 1971, table 1), where the salt is associated with a high-lithium brine.

Thirty-one samples of the upper fine-grained playa-sequence sediments were submitted for paleontologic analysis to determine the age of the sediments and the salinity of the playa waters when the sediments were deposited. Juvenile candonid (probably freshwater) ostracodes, and fragments thereof, were reported from only three intervals: 115-120 ft (31-47 m), 225 ft (69 m), and 785 ft (239 m). A few unidentified seeds were found at 115-120 ft (31-47 m) (R. Forester, oral commun., 1979). The few juvenile candonids may represent downhole contamination; thus, no age or depositional environment determination could be made.

CONCLUSIONS

The upper 1035 ft (316 m) of sediment in RL-1 probably represent deposition of playa sediments, high on the edge of the playa, near the distal parts of streams and (or) alluvial fans. The sediments below 1035 ft are mud and sandstone of possibly fluvial origin that grade downward into sands and gravels of alluvial fans.

Because U. S. G. S. RL-1 did not encounter a salt body, the presence of an associated (lithium-rich) brine cannot be confirmed. The large vertical extent of alluvium encountered, the difficulties associated with drilling the alluvium, and the absence of salty-tasting water or evaporite mineralization resulted in our terminating drilling at 1510 ft (461 m).

LITHOLOGIC LOG OF TEST HOLE USGS RL-1

Test hole located on the SW 1/4 SW 1/4 SW 1/4 SW 1/4 sec. 29, T. 27 N., R. 16 W., Mohave County, Arizona. Surface elevation 2758 ft (840.6 m).

The depth listed corresponds to the base of the described interval. [Mineralogy in brackets was determined by X-ray diffraction]	Depth ft	Depth m
SEDIMENTS IN MUD PIT	0	0
Clay, medium red-brown, slightly silty and salty	5.2	1.6
NO RECORD OF INTERVAL DRILLED WITH TRICONE BIT TO SET CASING	50	15.2
SEDIMENTS IN TEST HOLE DRILLED WITH DRAG BIT		
Clay to claystone, red-brown to gray-brown, calcareous, silty and salty. [Quartz, calcite, feldspar, illite, dolomite]	60	18.3
Clay to claystone, olive-green-brown to red-brown, calcareous, slighty silty and salty; portions contain black (carbonaceous?) flecks and blebs 2-5 mm long, black rootlet traces, 1 mm dolomite nodules, and traces of dolomite. [Quartz, calcite, illite, feldspar, dolomite]	165	150.3
Clay to claystone, red-brown, calcareous, slightly silty and salty; contains black flecks and rootlets, and traces of mica. [Quartz, illite, calcite, feldspar]	220	67.
Clay to claystone, red-brown to gray-brown; micaceous to very micaceous; portions calcareous and (or) dolomitic; some cores have stringers of sand and light-gray clay. Black flecks and rootlets scattered throughout. Core from 255 ft (83.6 m) contains small (<1 mm) halite (?) or gypsum crystals. [Quartz, calcite, feldspar, illite, dolomite (?)]	310	94.5
Claystone, alternating red-brown, green-brown, and chocolate-brown, nonmicaceous to slightly micaceous, slightly silty and salty; contains swirls and mottles of (more calcareous ?)	460	140.2

	ft	m
lighter colored material. [Quartz, calcite, dolomite, illite, smectite, feldspar]		
Clay and claystone, red-brown, calcareous to noncalcareous, some dolomitic, slightly silty and salty, nonmicaceous to micaceous; contains swirls and mottles of (more calcareous?) green-gray brown clay; some intervals contain less than 1 percent black flecks. [Quartz, calcite, illite, feldspar, dolomite, analcime]	675	205.7
Claystone, interbedded and mottled red-brown and green-brown, silty, salty, slightly calcareous, slightly to very micaceous; contains black flecks or light mottles of (more calcareous?) material, or is silty. [Quartz, calcite, illite, feldspar, dolomite]	780	237.7
Clay or claystone, light-gray to olive-green to yellow-brown, calcareous, micaceous; mottled with pink-gray carbonate areas. Interbedded with thin lenses of very fine grained carbonate-cemented sand and chert pebbles. [Quartz, calcite, kaolinite, 10-Å clay(?)]	855	260.6
Claystone, brown, micaceous, silty, calcareous; contains clayey sand lenses with grains as large as 4 mm.	870	265.1
Sandstone, well-indurated, calcareous cement; contains grains of feldspar, quartz, and mica. Claystone, gray-brown, calcareous, micaceous. Sand and pebbles of granite, feldspar, hornblende(?), mica; sometimes held together by soft clay matrix. [Feldspar, quartz, 10-A clay, dolomite, kaolinite, montmorillonite, hornblende(?)]	910	277.4
Claystone to mudstone, olive-brown to brown, micaceous, calcareous, with calcite stringers, silty to sandy. Contains chunks of sandstone, limestone, and gravel. [Quartz, calcite, feldspar, illite, dolomite, kaolinite, smectite]	990	301.7
Mudstone, brown, calcareous, micaceous; contains sand laminae and pebbles of quartz and chert as much as 1 cm across	1035	315.5
Conglomerate and sandstone, brown, muddy, calcareous,	1090	332.2

	ft	m
micaceous; contains clasts of quartzite and basalt as great as 2 cm across		
Sandstone, brown, poorly sorted, angular; contains biotite flakes	1135	345.9
Sand, pebbles, gravel, and clay; poorly sorted, angular to well rounded; quartzite, chert, limestone, biotite, feldspar, gneiss, gray-brown clay; some fragments of caliche-cemented gravel. Gravels as large as 2-3 cm across. Proportions of size fractions vary through section	1510	460.2

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