CONCENTRATED SUBSURFACE BRINES IN THE MOAB REGION, UTAH

Utah Geological and Mineralogical Survey

Special Studies 13

UTAH GEOLOGICAL AND MINERALOGICAL SURVEY

103 Civil Engineering Building
University of Utah
Salt Lake City, Utah 84112

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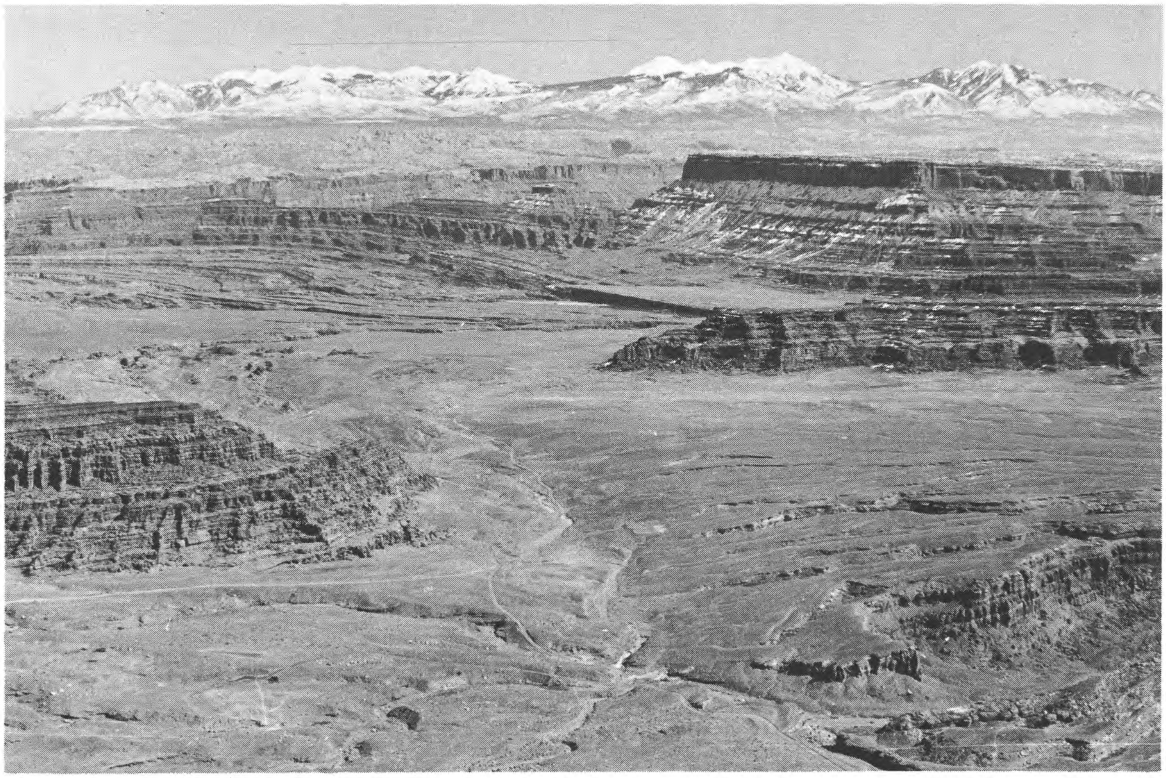
by E. Jay Mayhew
Edgar B. Heylmun



View east from Dead Horse Point.

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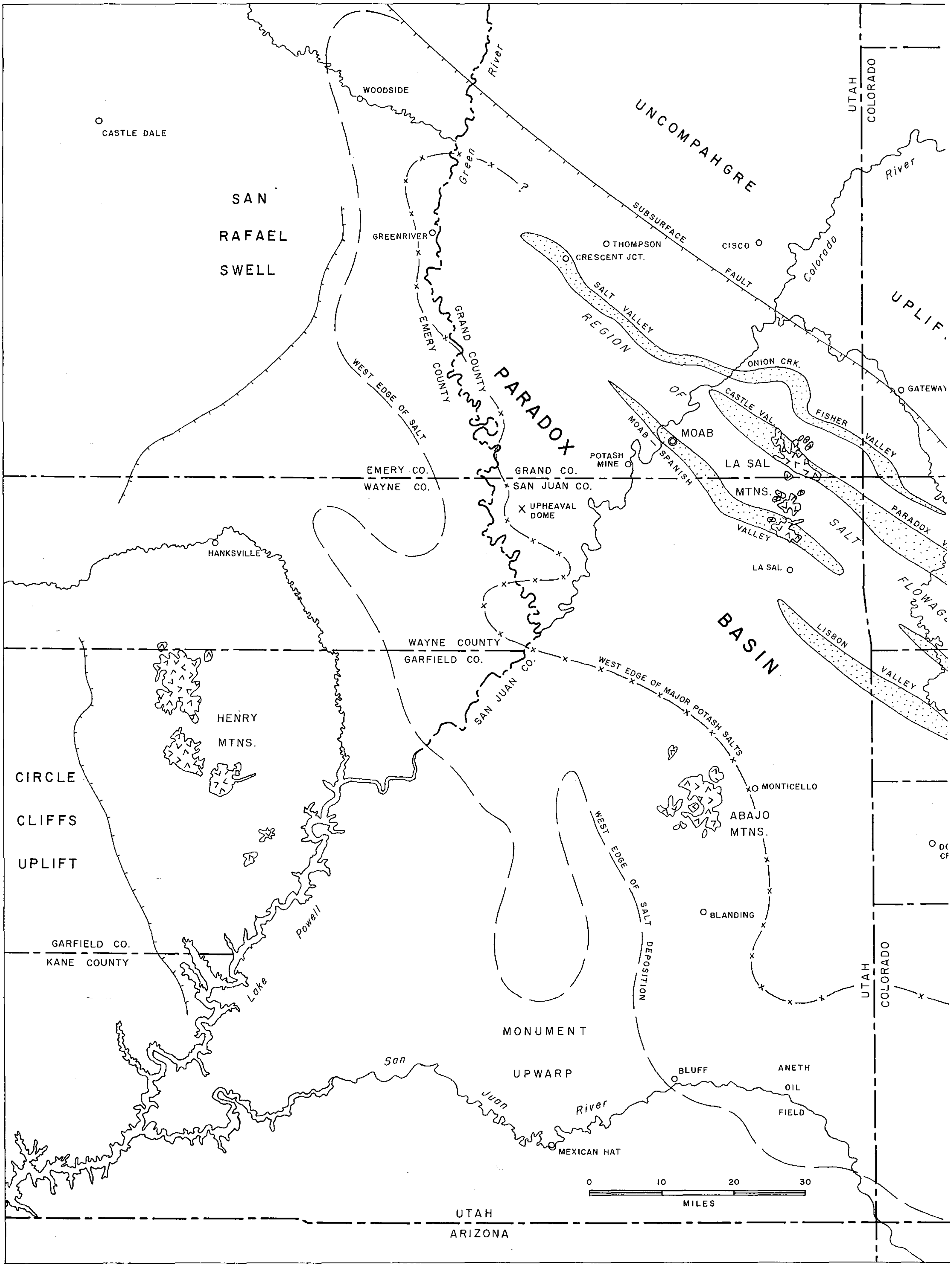

Figure 1. Regional map of southeastern Utah showing approximate edge of salt deposition.

CONCENTRATED SUBSURFACE BRINES IN THE MOAB REGION, UTAH

by E. Jay Mayhew[1] *and Edgar B. Heylmun*[2]

INTRODUCTION

Wells drilled for oil and gas in the Paradox Basin of Utah have encountered supersaturated brines in rocks of Pennsylvanian, Mississippian, and Devonian age. Analyses indicate commercial possibilities for the extraction of magnesium, potassium, bromine, boron, lithium, and other minerals from the brines, particularly in the central part of the basin. Partial analyses of over 200 brine samples from various wells drilled for oil, gas, and brine in southeastern Utah were used in formulating this report. The analyses were performed by chemists of the U. S. Geological Survey and of various oil company and consulting laboratories.

STRATIGRAPHY

Surface rocks in the region are marine and continental deposits of Permian, Triassic, Jurassic, and Cretaceous age which have been eroded into the colorful canyonlands characteristic of southeastern Utah. In the subsurface, Pennsylvanian rocks are thick and well developed, dominated by the great mass of cyclically deposited halite, anhydrite, and potash salts in the Paradox Formation. Because of this thick salt development, geologists refer to the region as the Paradox Basin, although there is no surface expression of such a large and prominent basin (Figure 1). Depths to the base of the Paradox Formation range from 3,500 feet to over 15,000 feet, depending on the structural and topographic location. The Paradox Formation is restricted almost entirely to the subsurface, cropping out only in the cores of salt anticlines in the eastern part of the region and in Cataract Canyon along the Colorado River. The Paradox evaporite section in the central part of the basin ranges from less than 1,000 feet to over 11,000 feet in thickness, and contains much of the potential mineral wealth of the region. Figure 2 shows a typical gamma ray-neutron log of the Paradox salt section in the Moab region, with salt beds and clastic breaks numbered both according to Hite (1960) and to industry's usage.

A few score feet below the Paradox Formation are the widespread and homogeneous Mississippian limestones and dolomites which are noted for local porosity development. The Mississippian section offers an excellent reservoir for

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brine production, should such brines prove commercial. The lower part of the Paleozoic section, consisting of Devonian and Cambrian strata, has been penetrated by a number of wells. Only the McCracken Sandstone, the basal Devonian formation in the region, holds much interest for brine potential in the lower Paleozoic section. Most of the other units lack sufficient porosity and permeability to be adequate reservoirs for brine accumulation.

Formation tops in the Big Flat area, 12 miles west of Moab, are as follows:

Jurassic	Kayenta Fm.		Surface
	Wingate Ss.		230 feet
Triassic	Chinle Fm.		560
	Moenkopi Fm.		895
Permian	Cutler Fm.		1,410
	Rico Fm.		2,175
Pennsylvanian	Honaker Trail Fm.	Hermosa Group	2,700
	Paradox Salt	Hermosa Group	4,280
	Pinkerton Trail Fm.	Hermosa Group	7,321
Mississippian	Leadville and Madison Fms.		7,465
Devonian	Ouray, Elbert, and McCracken Fms.		7,675 est.
Cambrian	Unnamed Fms.		8,300 est.

Permian and Pennsylvanian strata vary widely in thickness and lithology. In the Pan American No. 1 Pace-State, section 12, T. 26 S., R. 25 E., Grand County, Permian and Pennsylvanian rocks consist mostly of arkosic sandstones, siltstones, and shales comprising the Cutler Formation, over 14,000 feet in thickness. The details of Permian and Pennsylvanian stratigraphy and sedimentation in this region are complex and not fully understood. Papers by Herman and Barkell (1957), Wengerd and Matheny (1958), Hite (1960), and O.B. Raup (U.S.G.S. in prep.) have added considerably to the knowledge of the Pennsylvanian, and particularly the most important unit, the Paradox Formation. Interested readers are referred to these papers for more detailed information concerning Pennsylvanian rocks of the region.

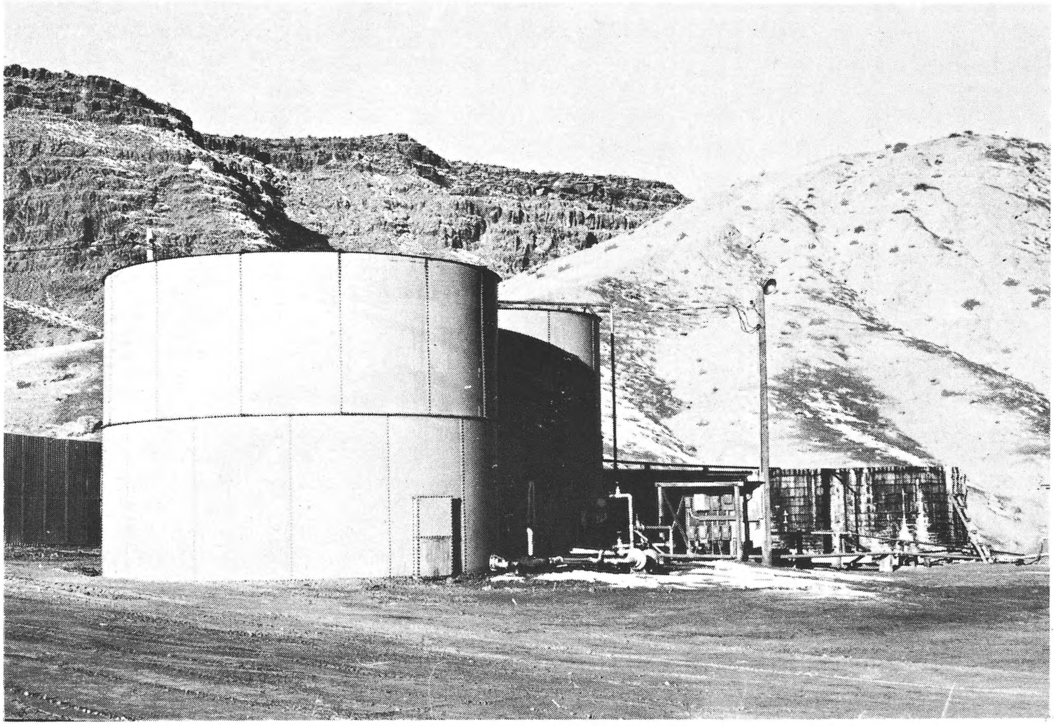
STRUCTURE

The northeastern part of the Paradox Basin is characterized by long, linear, salt-cored anticlines. These features trend in a northwest direction and were apparently caused by flowage of the relatively plastic salt beds in the Paradox Formation. The best known salt anticlines in the region are at Salt Valley, Castle Valley, Onion Creek-Fisher Valley, Moab-Spanish Valley, Lisbon Valley, and Paradox Valley (Figure 1). It is in the cores of the salt anticlines that Paradox salt beds come closest to the surface. Complex faulting is found in association with the salt anticlines. Stokes (1948) has demonstrated that as early as Late Pennsylvanian sufficient stresses were present within the mother salt horizons of the Paradox Formation to cause salt flowage, thus initiating the formation of the salt anticline complex.

Further, it can hardly be denied that the lineations of these anticlines are closely related to the structural trends within the basement complex, especially to the buttress effect of the Uncompahgre uplift. West of the zone of salt flowage, the region assumes characteristics typical of the Colorado Plateau province, i. e., flat-lying or gently dipping rocks with areas of gentle folds. Faulting is insignificant except in a few limited areas.

The broad Monument upwarp dominates the southern part of the region, and the Uncompahgre uplift, San Rafael Swell, and Circle Cliffs uplift buttress the Paradox Basin on the northeast and west. The Henry, Abajo (Blue), and LaSal Mountains, which are laccolithic igneous intrusions, form unique and dramatic features either flanking or within the Paradox Basin. Upheaval Dome, 23 miles southwest of Moab, is a circular feature two miles in diameter that might be a cryptovolcanic structure, a salt flowage feature, or the result of meteorite impact.

Figure 3 is a structure contour map of part of the Moab region, showing wells drilled for oil, gas, and brine. The structural geology of southeastern Utah has been discussed at length by Kelley (1955, 1958), Shoemaker, et al. (1958), and several others. Baker (1933), Dane (1935), and McKnight (1940) have done detailed work in the central part of the basin, and excellent structure contour maps accompany their reports.



Moab Brine Company operation Moab, Utah.

EVAPORITE MINERALS

Halite (NaCl), anhydrite ($CaSO_4$), carnallite ($KMgCl_3 \cdot 6H_2O$), and sylvite (KCl) are the most common evaporite minerals recognized in Paradox Formation. Halite, of course, is the most common salt, totaling several thousand feet of thickness in some wells. Anhydrite is also found throughout the Paradox Basin, often being intimately associated with dolomite and black shale in the clastic breaks which separate the salt beds.

There are thick and widespread occurrences of carnallite in the central part of the basin. Halite and carnallite are found interbedded through considerable intervals of the Paradox Formation, and the so-called "carnallite marker", found in Hite's salt bed 6, contains solid carnallite over 140 feet thick in the Cane Creek area. A carnallite zone over 80 feet thick has been encountered in the Seven Mile area at the top of Hite's salt bed 18. In the Defense Plant Corporation No. 1 Reeder well, section 4, T. 22 S., R. 19 E., Grand County, near Crescent Junction on the Salt Valley anticline, notable thicknesses of carnallite were cored, the shallowest zone being at 3,319 feet (Severy, et al., 1949). Carnallite is not generally considered a commercial potash mineral, but it does contain potentially commercial quantities of magnesium. The mineral is highly soluble. Another mineral occurring in the black shale of the clastic zones is fluorspar (CaF_2). These crystals are in low concentration and are about one millimeter in size.

Sylvite, the most important potash mineral, is also found throughout the central part of the Paradox Basin. The richest sylvite beds are frequently found near the top of the various salt units, as depicted in Figure 2. The mineral was apparently deposited as an end phase in many of the evaporite cycles. The ore mined at the Texas Gulf Sulphur Cane Creek mine is dominantly sylvite from a zone at a depth of approximately 3,000 feet.

In addition to the aforementioned evaporite minerals, many other minerals, including polyhalite ($2CaSO_4 \cdot MgSO_4 \cdot K_2SO_4 \cdot 2H_2O$), syngenite ($CaSO_4 \cdot K_2SO_4 \cdot H_2O$), kieserite ($MgSO_4 \cdot H_2O$), and gypsum ($CaSO_4 \cdot 2H_2O$) are probably present. Because of the presence of rare elements in the brines, there is reason to believe that rare and exotic minerals might have been deposited during certain end phases of the evaporite cycles.

BRINE ZONES

Brines, saturated with various salts, have been encountered in Pennsylvanian, Mississippian, and Devonian rocks in almost every well that penetrated these units. Saturated brine has been found in porous dolomites and limestones of Mississippian age in a number of wells, and in the Lisbon oil field (T. 30 S., R. 24-25 E., San Juan County) the McCracken Sandstone of Devonian age contains saturated brine. From the standpoint of reservoirs for brine accumulation, the Mississippian rocks may hold as much promise as the overlying Pennsylvanian units. Mississippian limestones and dolomites range from 200 to 800 feet in thickness in southeastern Utah, and are noted for vuggy and intercrystalline porosity, although locally they are hard and tight. The possibilities for encountering concentrated brines in Mississippian and Devonian rocks are excellent, especially where they have been faulted against Paradox salt beds. The top of the Mississippian ranges in depth from 3,500 to over 16,000 feet, depending on the structural and topographic location.

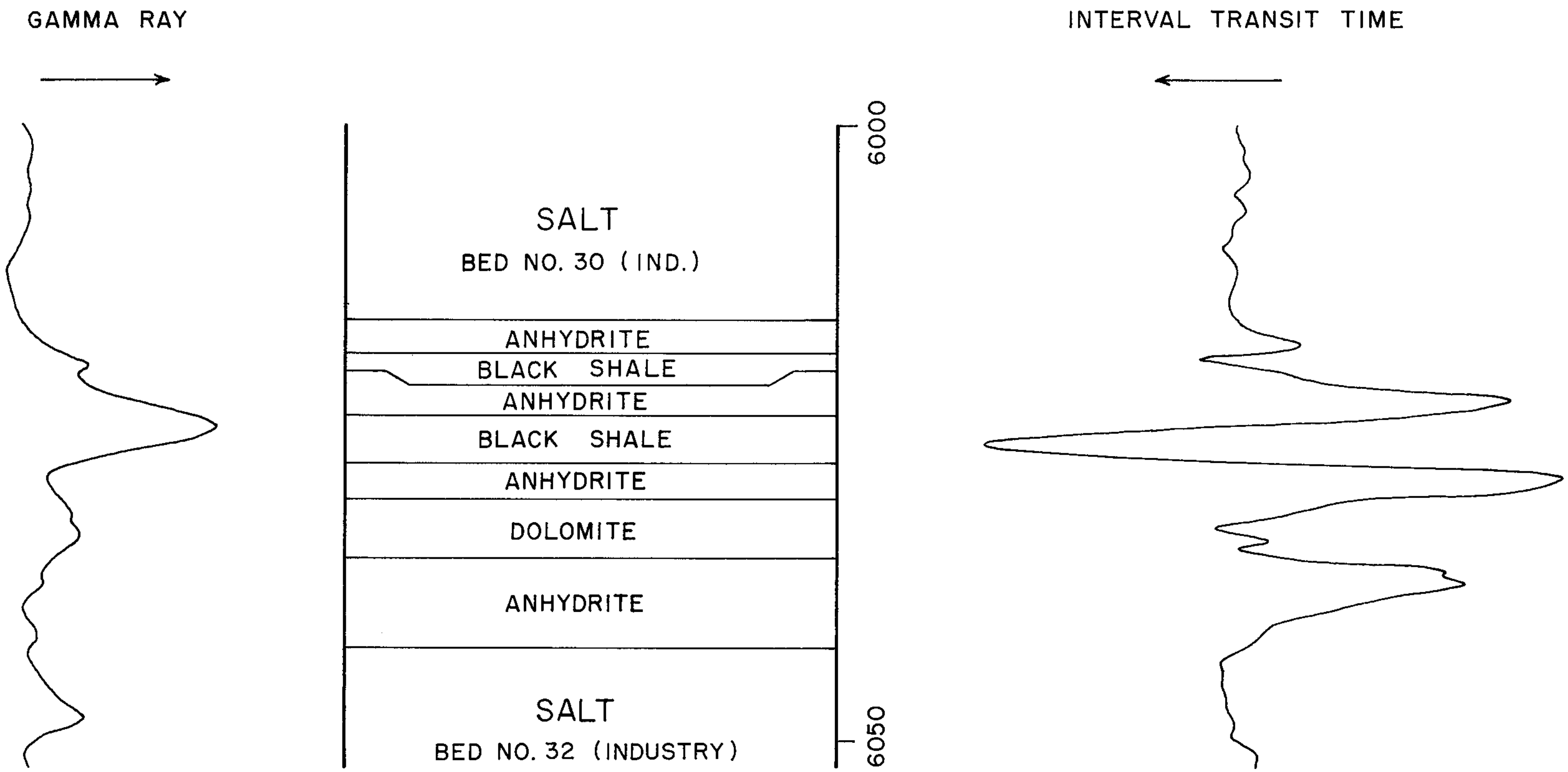
The most concentrated brines to date have been found in Pennsylvanian rocks, especially in the thin clastic breaks which separate the salt beds in the Paradox Formation (Figures 2 and 4). The clastic breaks consist of black, fetid shale, siltstone, dolomite, anhydrite, and some fine-grained sandstone. The beds are frequently brecciated. Whereas a number have been responsible for brine flows, clastic break 31, between Hite's salt bed 15 and salt bed 16, has been consistently responsible for flows of supersaturated brine in the Big Flat-Long Canyon area (Glen Ruby, personal communication). Clastic zone 17, between Hite's salt beds 8 and 9, is responsible for a brine flow in the Pure Oil No. 1 Hobson-U.S.A., section 30, T. 26 S., R. 20 E., Grand County. In a few of the Big Flat wells, the drilling fluid was not weighted enough, and blowouts occurred upon striking high pressure zones. Such blowouts were prevented in other wells by drilling with properly weighted mud. Other brine zones are present in the Paradox Formation and could be produced simultaneously with the main and more consistent zones. In some cases, oil occurs along with the brine in the clastic breaks, and two wells are currently producing sweet oil from the Cane Creek Marker, a well developed clastic break between Hite's salt beds 21 and 22, near the base of the formation.

BRINE FLOWS

One of the primary problems in developing a commercial brine operation is establishing a large and sustained brine flow from a reservoir of sufficient size. For this reason, the porous Mississippian dolomites and limestones appear to offer promise, especially where they have been faulted into contact with rich Paradox salt beds. Such faulting has probably occurred at Lisbon Valley, Moab Valley, Salt Wash, and elsewhere along the edge of the region of salt flowage. No gauges of brine flow are available from wells penetrating Mississippian beds. Drill-stem tests were conducted at several wells in the region which recovered several thousand feet of brine in the drill pipe, indicating that quantities of brine are present but that pumping might be required in order to produce them. Most wells have been drilled on surface or subsurface anticlinal highs in search of oil and gas, and it remains to be seen what kind of brine flow could be obtained from wells drilled in syn-

DETAIL LOG OF CLASTIC ZONE 31

SONIC LOG



SOUTHERN NATURAL GAS No. 1 LONG CANYON

SEC. 9 T. 26 S., R. 20 E.

GRAND COUNTY, UTAH

clinal areas where the hydrodynamic drive might be greater. The richest brines have specific gravities between 1.13 and 1.4, and might be expected to migrate into synclinal areas.

In the Big Flat-Long Canyon area, brine flowed to the surface from clastic breaks in the Paradox salt at several wells. At the Murphy No. 1 Little Valley well, section 29, T. 26 S., R. 20 E., Grand County (Figure 3), a flow of 280 barrels (11,760 gallons) per hour of brine and some oil was obtained on a drill-stem test of clastic zone 39 at a depth of approximately 6,800 feet. The shut-in (formation) pressure in that interval was 3,370 psi. In the same well, a drill-stem test of clastic break 31 at a depth of approximately 6,025 feet, produced a flow of 168 barrels (7,056 gallons) per hour through 2 3/4-inch choke with a flow pressure of 175 psi.

The Pure Oil No. 1 Big Flat well, section 14, T. 26 S., R. 19 E., Grand County, tested brine in clastic zone 31 that was under a formation pressure of 4,570 psi. In the Pure Oil No. 3 Big Flat well, one-fourth of a mile to the southeast, saturated brine flowed to the surface during a drill-stem test of the same zone. The shut-in pressure was 3,940 psi. At the Pure Oil No. 2 Big Flat well, section 11, T. 26 S., R. 19 E., Grand County, clastic zone 31 produced a flow to the surface which was estimated at 50 barrels (2,100 gallons) per hour. Concentrated brine flowed to the surface from the same clastic break at the Southern Natural Gas No. 1 Long Canyon well, section 9, T. 26 S., R. 20 E., Grand County. The zone is approximately 26 feet thick in the Southern Natural well, the top lying at a depth of 6,016 feet.

The main brine zone (clastic break 31) has rarely been cored, but it has been adequately sampled and logged. Figure 4 shows a portion of the sonic log for the Southern Natural No. 1 Long Canyon, section 9, T. 26 S., R. 20 E., Grand County. This log reveals, from top to bottom, three feet of anhydrite, one foot of black shale, four feet of anhydrite, four feet of black shale, three feet of anhydrite, six feet of dolomite, and seven feet of anhydrite. The dolomite is quite porous and permeable, whereas the anhydrite and black shale is crushed and broken. Usually the fractures are filled with salt. However, where brine is present no salt filling occurs. In the Roberts brine well, which offsets the Southern Natural No. 1 Long Canyon, brine started to flow when the top anhydrite was penetrated, and increased so much by the time the underlying black shale was penetrated that no further drilling was done. The dolomite zone was not drilled. Vertical porosity, permeability, and communication are indicated. Brine flows have been encountered in clastic zone 31 over a distance of six miles north-south and eight miles east-west, and it remains to be proved if brine is present and the zone is communicable over a much larger area.

One reason for the presence of supersaturated brine in the clastic breaks is that the clastic beds frequently overlie rich potash and magnesium zones. In the classical concept of the evaporite cycle, the most soluble compounds are the last to precipitate. Therefore, the clastic units often overlie the end products of the preceding evaporite cycle. Potassium and magnesium chlorides and certain complex evaporite minerals can be found among the end products of evaporation.

The fractured clastic zones form an excellent reservoir for brines derived from underlying evaporite units. The fracturing is caused by salt flowage, and it is possible that, when brine is removed from these zones, salt will flow into voids from which brine has been removed. This would help maintain high reservoir pressure and assist in a high ultimate recovery of brine. Cores have exhibited fractures filled with salt when brine has not been present.

BRINE PRODUCTION

The Moab Brine Company operates two brine wells within the city limits of Moab, and they produce brine by pumping fresh water into the massive salt beds, dissolving the salt. The brine is produced only for its sodium chloride content, of which it contains about 310,000 ppm. The brine also contains approximately 1,200 ppm of calcium sulfate. Sodium carbonate is added to the brine, which precipitates $CaCO_3$. The latter compound would be a contaminant in the uranium process at the Atlas Minerals mill in Moab, where the brine is used. Between 400 and 3,000 barrels of brine are produced daily.

One of the problems in sustaining a brine flow is the fact that the brine is supersaturated, and the slightest pressure drop or lowering of temperature causes precipitation to occur. The precipitated solids soon clog tubing and other production equipment, seriously hampering or preventing brine production. The acid nature of the brine also has a deleterious effect on production equipment.

The brine is interesting but not commercial unless a method of continuously reliable production can be worked out. Many of the supersaturating constituents are pressure sensitive, some are temperature sensitive, and some, such as potash, are sensitive to both. Only one well has been produced continuously for more than two hours, and this without complete success. The Pure No. 1 Hobson-U.S.A. was produced long enough to recover several thousand barrels of brine, and to accomplish this, fresh water was pumped into the well in sufficient quantity to displace the tubing and casing when the flow rate dropped to five gallons per minute. This increased the flow rate to 1,000 gpm immediately, then the rate again started dropping off.

The brine industry has encountered and solved the supersaturation and plugging problem which occurs with NaCl, and this may indicate a solution is possible for the continuous production of this brine. Several methods of continuous production are suggested, such as;

1. Determining the critical pressures and temperatures at which crystallization begins, and producing at higher critical points.

2. Using plastic-coated equipment to minimize sticking.

3. Bleeding-in a sufficient amount of fresh water at the point of production to prevent crystallization.

4. Using high frequency vibration to minimize crystallization on casing and tubing walls.

5. Installing equipment at critical points to produce small crystals so they will be carried out with the brine flow.

These possible methods present unknown problems that can only be worked out in the laboratory and in field trials. Experience has shown that once the casing or tubing has filled with the supersaturated brine and is shut in, it bridges and plugs quickly from top to bottom.

BRINE ANALYSES

Partial analyses are available for over 200 brine samples taken from wells in southeastern Utah. In most instances, only routine analyses were made, determining the quantities of those radicals normally found in oil field waters. The total amount of dissolved solids reported, however, gives some indication of the potential mineral value of the brine. A few detailed analyses are available, performed by the U. S. Geological Survey laboratories and commercial laboratories, which give better insight on the true potential of the brines. Some of these analyses are given in the following lists.

Amerada Petroleum No. 2 Green River, section 2, T. 22 S., R. 16 E., Grand County. Paradox Formation, interval not known. Analysis by California Testing Laboratories.

Bicarbonate	919 ppm
Borate	2,362
Calcium	76,176
Carbonate	0
Chloride	249,600
Magnesium	9,484
Sodium	58,301
Sulfate	49
Silica	10
Total solids	397,061
pH	6.3

British-American No. 1 Gov't.-Norwood, section 15, T. 40 S., R. 22 E., San Juan County. Paradox Formation (Desert Creek zone, 5802-5812 feet). Analysis by Core Laboratories.

Barium	0 ppm
Bicarbonate	220
Calcium	25,600
Carbonate	0
Chloride	171,820
Magnesium	2,916
Sodium	78,513
Sulfate	4,185
Total solids	283,402
pH	5.0
Specific gravity (70°F)	1.17

California Oil No. 1 Navajo 177, section 3, T. 40 S., R. 24 E., San Juan County. Paradox Formation, 5612-1622 feet. Analysis by Chemical and Geological Laboratories.

Bicarbonate	255 ppm
Calcium	24,200
Carbonate	0
Chloride	182,000
Magnesium	5,073
Sodium	80,872
Sulfate	286
Total solids	304,500
pH	5.4
Specific Gravity (70°F)	1.18

Delhi-Taylor No. 2 Seven Mile, section 18, T. 25 S., R. 21 E., Grand County. Paradox Formation, interval not known. From Hite (1963).

Aluminum	66 ppm
Ammonia	849
Bicarbonate	1,010
Boron	660
Bromine	3,080
Calcium	52,700
Chloride	241,000
Copper	6
Fluorine	25
Iodine	42
Iron	750

Delhi-Taylor No. 2 Seven Mile (continued)

Lead	6 ppm
Lithium	66
Magnesium	39,200
Manganese	260
Potassium	18,800
Sodium	5,990
Sulfate	4
Zinc	60
Total solids	366,000

Humble No. 1 Rustler Dome, section 4, T. 29 S., R. 20 E., San Juan County. Mississippian 4905-5076. Analysis by Core Laboratories.

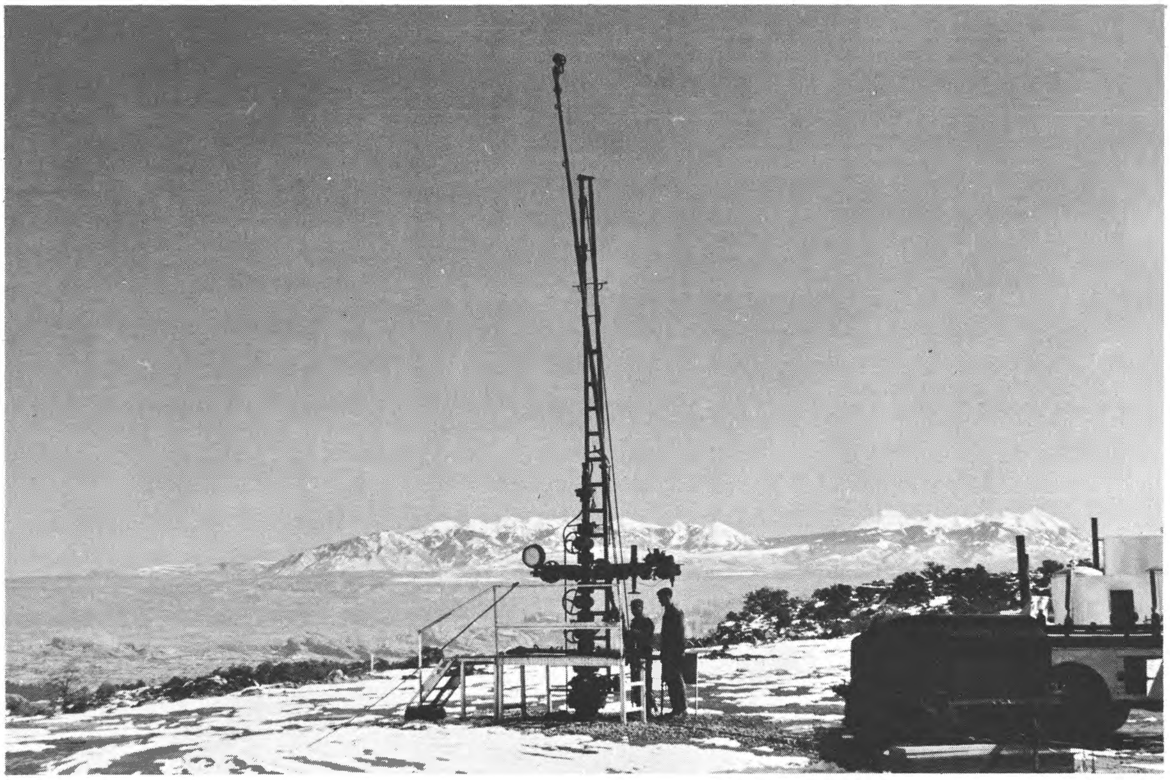
Calcium	12,000 ppm
Chloride	208,740
Magnesium	4,860
Sodium	115,335
Sulfate	6,770
Total solids	348,681
pH	5.0
Specific Gravity	1.2

King Oil No. 2 Big Flat, section 11, T. 26 S., R. 19 E., Grand County. Paradox Formation, 6196-6220 feet. Analysis by Chemical and Geological Laboratories.

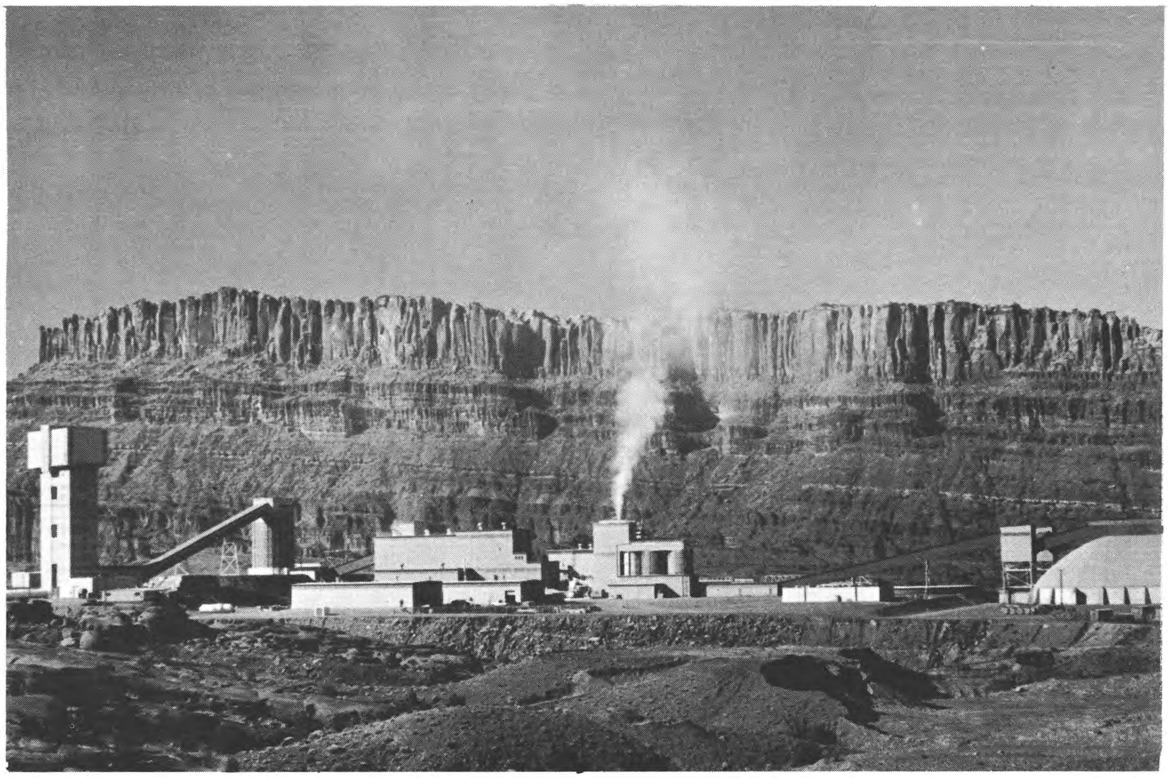
Ammonia	1,330 ppm
Borate (B_4O_7)	2,922
Bromine	1,150
Calcium	40,742
Chloride	259,106
Lithium	173
Magnesium	47,789
Potassium	41,957
Sodium	25,966
Sulfate	754
Total solids	421,889

Pure Oil No. 1 Hobson-U.S.A., section 30', T. 26 S., R. 20 E., Grand County. Paradox Formation, 5425-5435. Analysis by Ethyl Corporation.

Boron	1,260 ppm
Bromine	1,612
Calcium	55,740



Southern Natural No. 1 Long Canyon well. LaSal Mountains in distance.



Texas Gulf Sulphur potash mine at Cane Creek.

Pure Oil No. 1 Hobson-U.S.A. (continued)

Chlorine	249,300 ppm
Lithium	134
Magnesium	31,350
Potassium	25,500
Sodium	22,000
Strontium	1,300
Sulfate	23

Pure Oil No. 1 Hobson-U.S.A., section 30, T. 26 S., R. 20 E., Grand County. Paradox Formation. Analysis of solids collected from tubing. Analysis by Titanium Metals.

Boron	0.19%
Bromine	3.42
Calcium	1.23
Chloride	70.70
Copper	0.001
Iron	0.20
Lithium	0.002
Magnesium	1.20
Potassium	12.25
Sodium	10.60
Strontium	0.50
Sulfate	0.0

Pure Oil No. 2 Big Flat, section 14, T. 26 S., R. 19 E., Grand County. Mississippian, approximately 7,200 feet. Analysis by Ethyl Corporation.

Boron	780 ppm
Bromine	2,041
Calcium	41,800
Chlorine	210,500
Lithium	81
Magnesium	33,100
Potassium	21,000
Sodium	9,100
Sulfate	31

Roberts brine well, section 9, T. 26 S., R. 20 E., Grand County. Paradox Formation (sample collected from drippage at well head). Analysis by Ford Chemical Laboratories.

Bicarbonate	0 ppm
Boron	20,000

Roberts brine well (continued)

Bromine	2,500 ppm
Calcium	3,000
Carbonate	200
Chlorine	53,000
Iodine	450
Magnesium	34,000
Phosphate	15
Potassium	33,000
Sodium	43,000
Sulfate	500
Total solids	250,000
pH	6.1

Southern Natural No. 1 Long Canyon, section 9, T. 26 S., R. 20 E., Grand County. Paradox Formation, Cane Creek Marker, 7050-7075 feet. Brine produced with oil, collected from separator. Analysis by Ford Chemical Laboratory.

Bicarbonate	1,600 ppm
Boron	600
Bromine	3,000
Calcium	34,000
Carbonate	2,200
Chloride	45,000
Iodine	300
Magnesium	21,000
Phosphate	2,000
Potassium	20,000
Sodium	13,000
Sulfate	1,800
Total solids	388,000
pH	4.8

Southern Natural Gas No. 1 Long Canyon, section 9, T. 26 S., R. 20 E., Grand County. Paradox Formation, clastic zone 31. Analysis by U.S. Geological Survey.

Bicarbonate	1,400 ppm
Bromine	6,100
Calcium	65,800
Chloride	29,800
Lithium	500
Magnesium	45,500

Southern Natural Gas No. 1 Long Canyon (continued)

Nitrate	6 ppm
Potassium	23,400
Rubidium	700
Sodium	9,800
Sulfate	80
Total solids	439,000
pH	6.0
Specific Gravity (24°C)	1.37

Suburban Storage No. 1, section 26, T. 25 S., R. 21 E., Grand County. Paradox Formation. Sample taken from zone in which storage cavity was washed. This zone includes one bed of sylvite and one bed of carnallite.

Bicarbonate	110 ppm
Calcium	648
Carbonate	0
Chloride	182,730
Magnesium	1,388
Potassium	7,460
Sodium	116,923
Sulfate	12,800
Total solids	322,059
Specific Gravity (60°F)	1.21

Superior No. 22-34 Salt Wash, section 34, T. 22 S., R. 17 E., Grand County. Mississippian, 10,053-10,173 feet. Analysis by Superior Oil Company.

Bicarbonate	169 ppm
Calcium	5,563
Carbonate	0
Chloride	152,698
Magnesium	1,383
Sodium & Potassium	90,949
Sulfate	1,768
Total solids	251,719
pH	6.7
Specific Gravity (60°F)	1.18

Superior No. 14-5 Bowknot, section 5, T. 26 S., R. 17 E., Emery County. Mississippian, 6270-6350 feet. Analysis by Core Laboratories.

Barium	0 ppm
Bicarbonate	146

Superior No. 14-5 Bowknot (continued)

Calcium	240 ppm
Carbonate	0
Chloride	171,820
Iron	1,004
Magnesium	266
Sodium	110,004
Sulfate	240
Total solids	283,720
pH	5.0

Superior No. 14-24 Grand Fault, section 24, T. 21 S., R. 15 E., Emery County. Mississippian, 9555-9652 feet. Analysis by Core Laboratories.

Barium	0 ppm
Calcium	3,120
Carbonate	0
Chloride	220,100
Bicarbonate	1,220
Iron	90
Magnesium	1,385
Sodium	140,484
Sulfate	7,400
Total solids	373,799
pH	6.0

Texaco No. 2 Navajo AC, section 34, T. 40 S., R. 26 E., San Juan County. Paradox Formation (Ismay zone). Analysis by Core Laboratories.

Barium	0 ppm
Bicarbonate	488
Calcium	3,600
Carbonate	0
Chloride	205,900
Iron	0
Magnesium	7,533
Sodium	115,455
Sulfate	200
Total solids	333,176
pH	4.5
Specific Gravity (66°F)	1.13

Texaco No. 1 Smoot (Salt Wash field), section 17, T. 23 S., R. 17 E., Grand County. Mississippian, 8785-8876 feet. Analysis by Rocky Mountain Engineering Company.

Bicarbonate	951 ppm
Calcium	2,865
Carbonate	0
Chloride	190,640
Magnesium	1,801
Sodium	119,418
Sulfate	4,320
Total solids	324,656
pH	6.0
Specific Gravity (70°F)	1.14

Tidewater No. 74-11 Big Flat, section 11, T. 26 S., R. 19 E., Grand County. Paradox Formation, interval 5920-5950. Analysis by Chemical and Geological Laboratories.

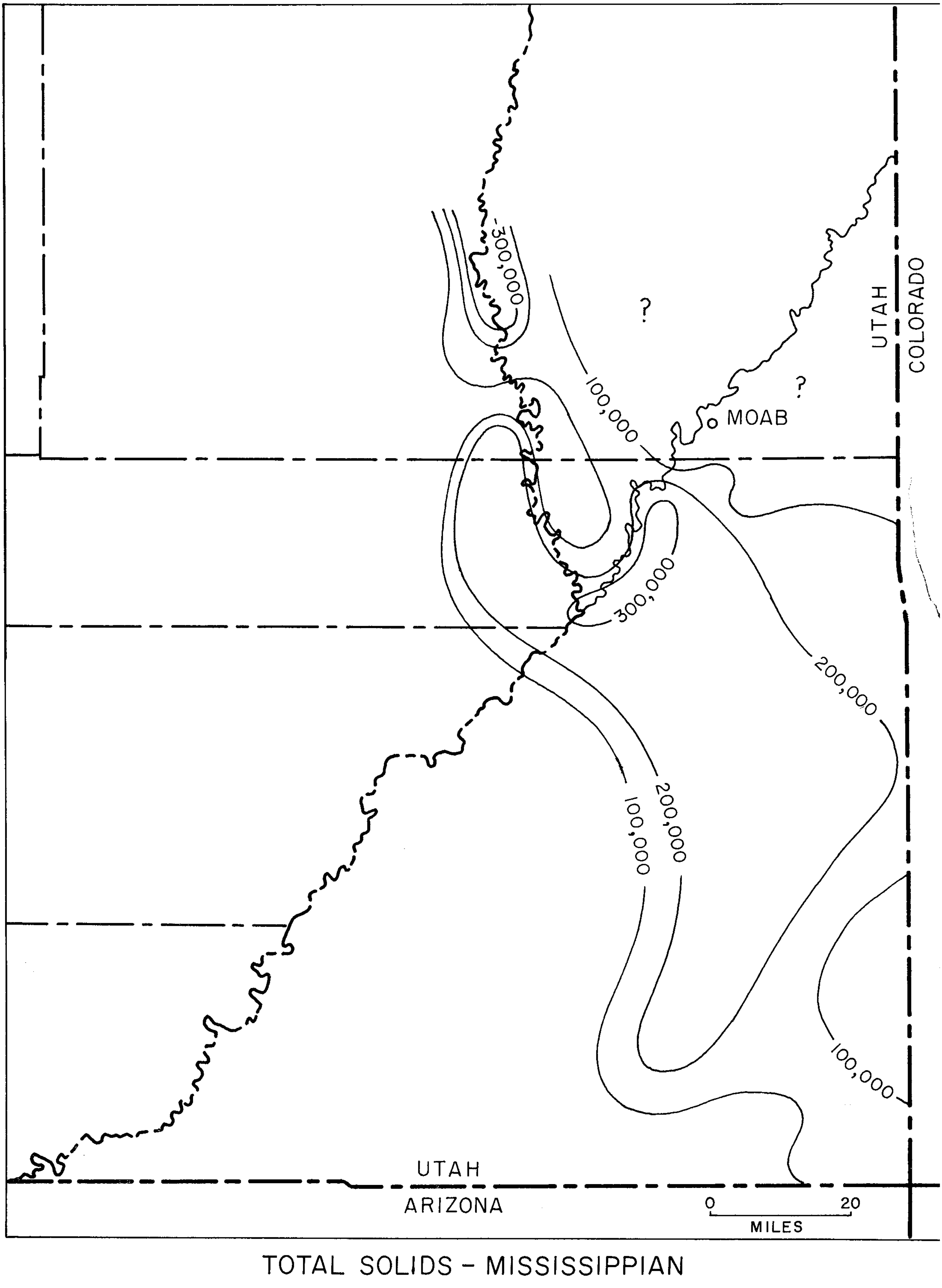
Bicarbonate	890 ppm
Calcium	32,900
Chloride	132,810
Magnesium	23,800
Sodium & Potassium	36,283
Sulfate	323
Total solids	338,952
pH	5.7

Tidewater No. 74-11 Big Flat, section 11, T. 26 S., R. 19 E., Grand County. Paradox Formation, clastic zone 31. Analysis by U.S. Geological Survey.

Calcium chloride	11.36%
Magnesium chloride	15.31
Potassium chloride	4.32
Total chloride	22.40
Total sulfate	0.04

Figure 5 is an isoconcentration map showing total dissolved solids, in parts per million, in brines obtained from Mississippian rocks in southeastern Utah. A general increase in concentration toward the central part of the Paradox Basin is apparent, suggesting that concentrations in the Mississippian brines are, in fact, controlled by the amount and nature of salt development in the overlying Paradox Formation.

Figure 6 shows total dissolved solids in brines from the Paradox Formation. A remarkable similarity of outline with the known subsurface outline of the Paradox Basin can be observed. The 100,000 ppm line, for example, con-



TOTAL SOLIDS – MISSISSIPPIAN

Figure 5.

forms quite closely with the limit of evaporite deposition in the Paradox Formation, and the 300,000 ppm line roughly outlines the area where potash salts were deposited. There can be no question that the brine concentrations are directly related to the thickness and variety of salts present in the Paradox Formation

Sufficient information is not available to make accurate isoconcentration maps of economically important elements found in the brines. One such map, however, is attempted for magnesium (Figure 7). This map again outlines the Paradox Basin in a rough manner, with the greatest concentrations (over 40,000 ppm) being evident in the central part of the basin near Moab. It appears that the center of evaporite deposition in Pennsylvanian time was in the general Moab region, although analyses in the northeastern part of the basin, in the region of salt flowage, are lacking.

BRINE WELLS

Few wells have been drilled specifically for brine in southeastern Utah. Most wells were drilled for oil and gas, encountering saturated brines in the course of drilling operations. Records are not complete in regard to brine wells, but as nearly as can be ascertained, only four wells have been completed as brine wells, all in the Moab region and shown on Figure 2. These are as follows:

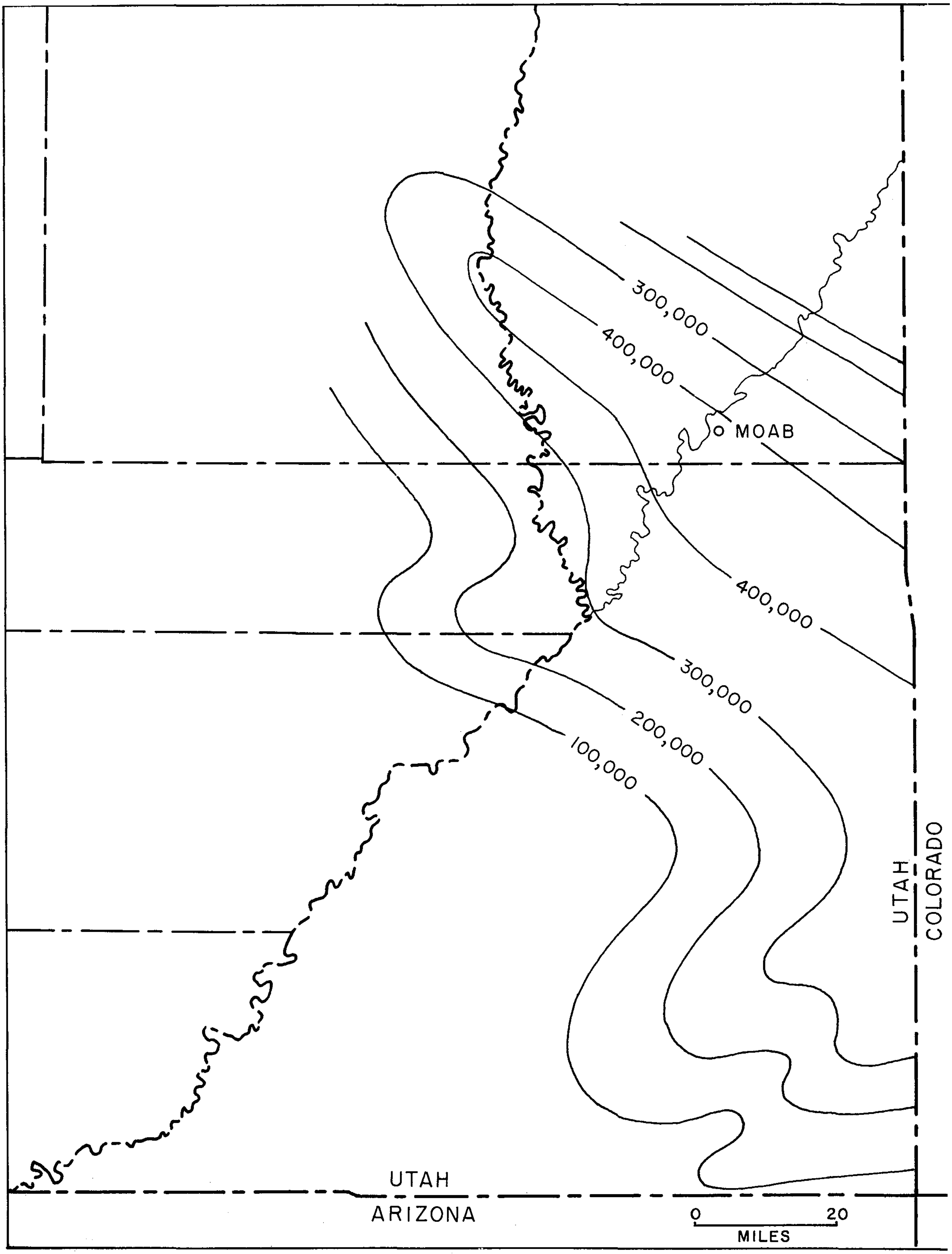
J. Roberts well (shut-in), SW$\frac{1}{4}$ NE$\frac{1}{4}$ section 9, T. 26 S., R. 20 E., Grand County. Producing zone at approximately 6,000 feet. Drilled 1963.

Pure Oil No. 1 Hobson-U.S.A. (shut-in), NW$\frac{1}{4}$ NW$\frac{1}{4}$ section 30, T. 26 S., R. 20 E., Grand County. Producing zone 5,425-5,435 feet. Drilled 1955-58.

Moab Brine Company (two wells, producing), SW$\frac{1}{4}$ SW$\frac{1}{4}$ section 1, T. 26 S., R. 21 E., Grand County. Producing zone in Paradox salt at approximately 2,000 feet. First well drilled for oil in 1943, recompleted as a brine well in 1960.

The Moab Brine Company is producing brine used at the uranium reduction mill in Moab. Fresh water is injected into the well, dissolving massive salt beds at depth, thus forcing out an artificial brine. A large cavern is being formed in the Paradox Formation. From 400 to 3,000 barrels of brine are produced daily. This is the only brine production in the region.

A number of wells and core holes have been drilled in southeastern Utah in search of commercial salts, but none has been completed as a brine well. Information from the core holes is confidential and not available for publication. Several wells were drilled on the north end of the Salt Valley anticline near



TOTAL SOLIDS – PENNSYLVANIAN

Figure 6.

Crescent Junction in 1942 and 1943, for the purpose of testing the oil, potash, and magnesium potential of the area. In the Defense Plant Corporation No. 1 Reeder, section 4, T. 22 S., R. 19 E., thick carnallite and sylvite beds, along with concentrated brines, were encountered between 2,091 feet and 4,207 feet. Sylvite beds containing as much as 32.8% K_2O, and carnallite beds containing as much as 27.45% $MgCl_2$, were cored (Severy, et al., 1949). This well was later drilled to a depth of 10,350 feet, remaining in the Paradox Formation to total depth. In a well in the Seven Mile area, the following analyses were made on carnallite beds:

Typical High-Grade Carnallite, Low Insol.

KCl	0.6%
NaCl	15.1
$CaSO_4$	0.2
$CaCO_3$	0.3
Insoluble	0.3
Carnallite	83.1
	99.6

Typical Medium-Grade Carnallite, High Insol.

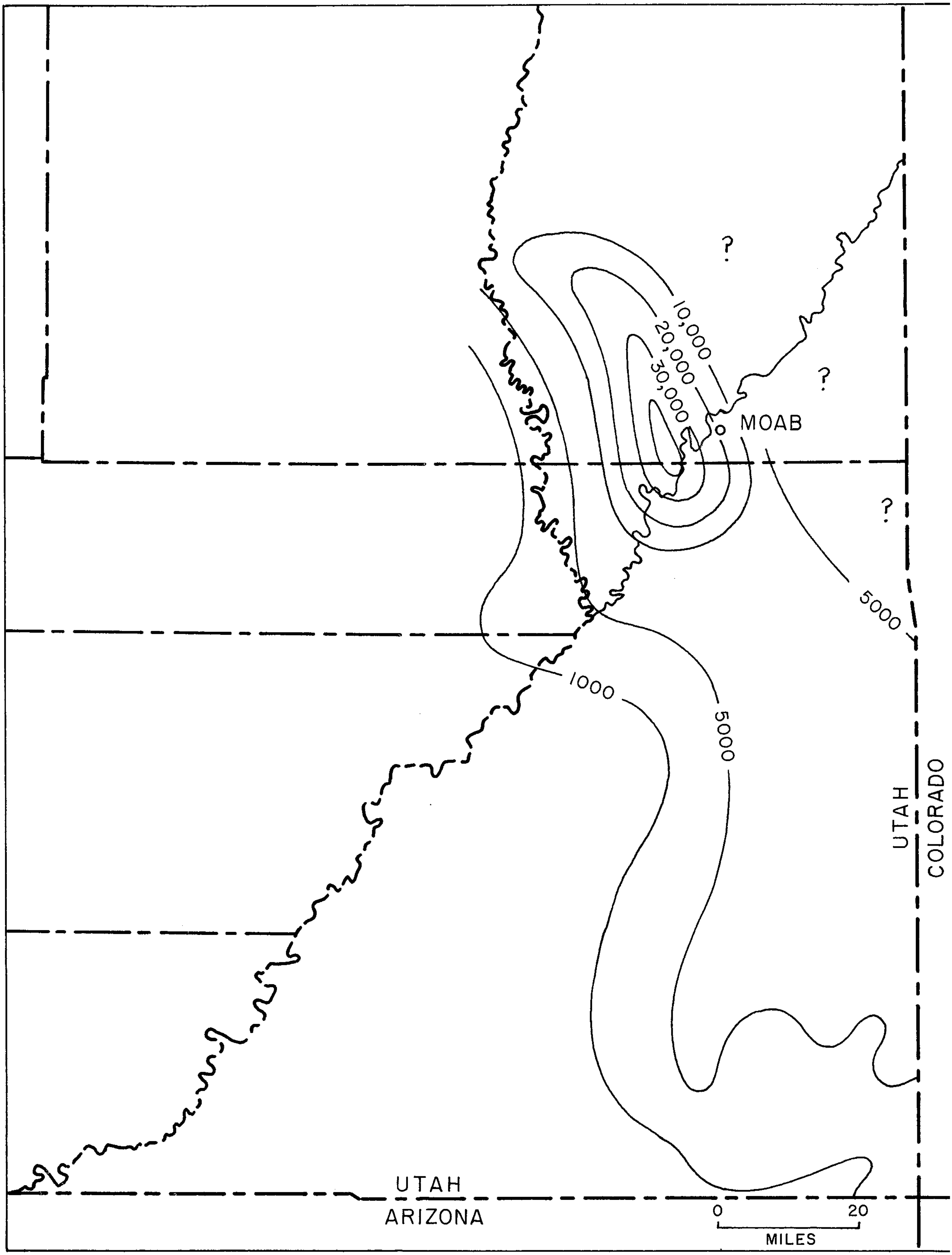
KCl	2.8
NaCl	46.0
$CaSO_4$	2.3
$CaCO_3$	1.2
Insoluble	3.1
Carnallite	45.0
	100.4

Very High-Grade Carnallite, Average Insol.

KCl	2.4
NaCl	4.1
$CaSO_4$	1.1
$MgSO_4$	nil
Insoluble	1.4
Carnallite	88.0
	97.7

CONCLUSIONS

Supersaturated brines, containing substantial quantities of many elements, are present in the subsurface of southeastern Utah, particularly in the Moab region. The town of Moab is in the central part of the Paradox Basin where the salts are well developed and the brines are supersaturated. Clastic breaks between various salt beds provide potential reservoirs for brine ac-



MAGNESIUM - PENNSYLVANIAN

Figure 7.

cumulation. Clastic break 31, a 5 to 30 foot zone separating Hite's salt beds 15 and 16, is brine productive throughout the Big Flat-Long Canyon area, with some flows gauged in excess of 150 barrels (6,300 gallons) per hour. In addition to the clastic breaks in the Paradox Formation, porous dolomites and limestones of Mississippian age are within reach of the drill under much of southeastern Utah.

With proper development of production techniques, concentrated brines could be commercially extracted in southeastern Utah.

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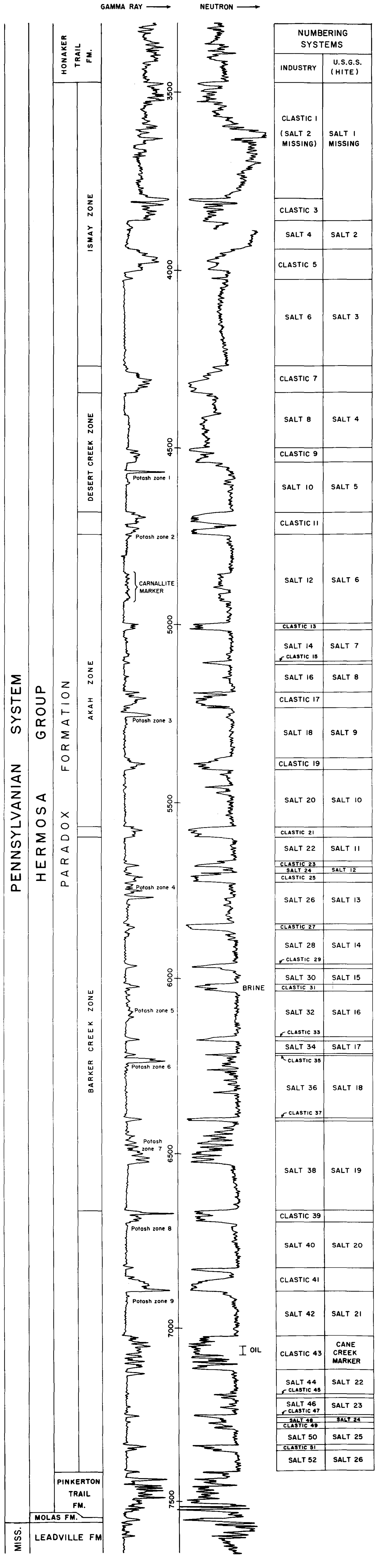
GAMMA RAY - NEUTRON LOG



SOUTHERN NATURAL GAS

NO. 1 LONG CANYON

NW¼ Sec. 9, T. 26 S., R. 20 E.

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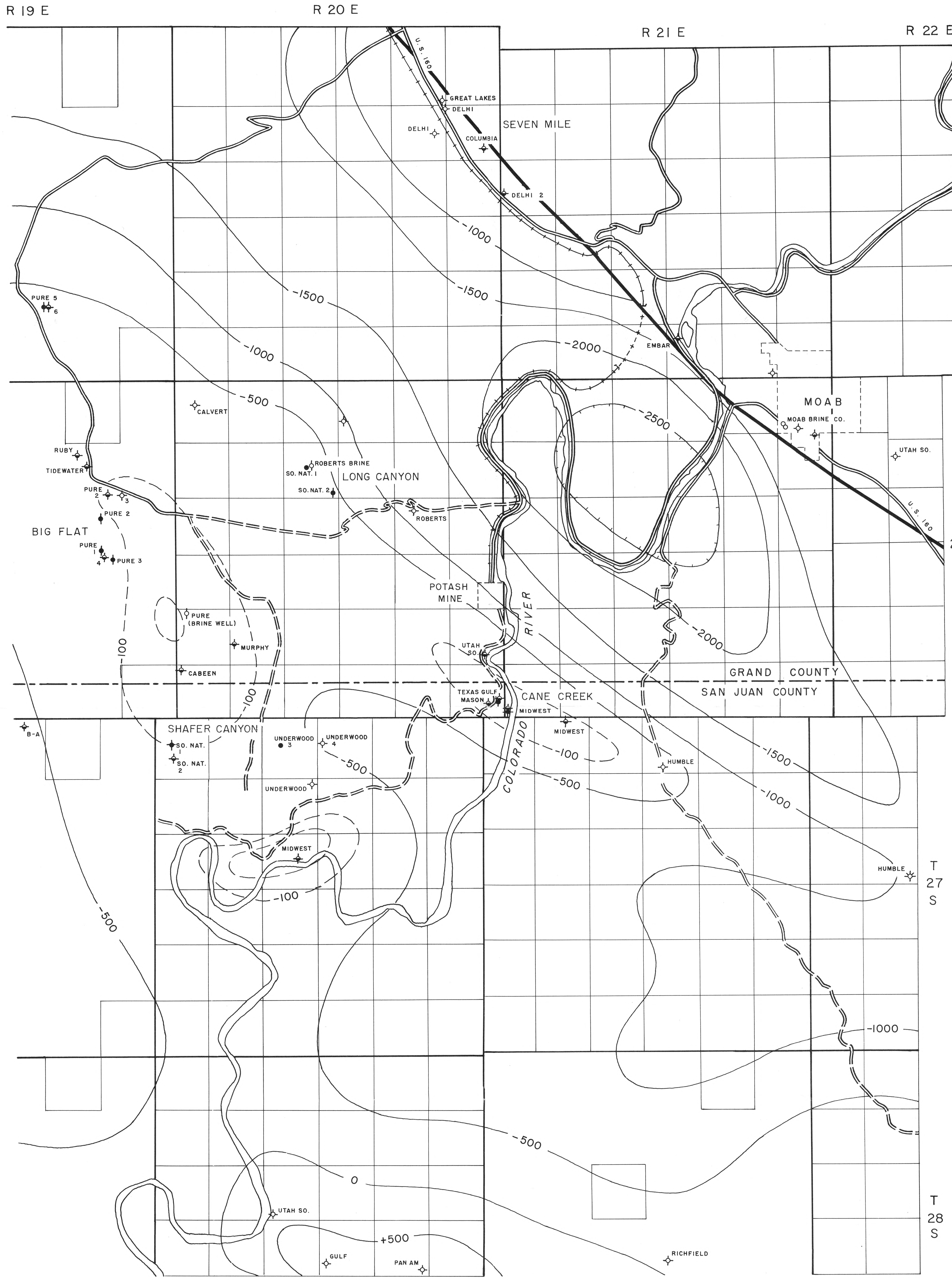
Figure 2



MOAB REGION

UTAH

0 — 5

SCALE

STRUCTURE CONTOURS ON TOP OF CLASTIC ZONE 31

Figure 3

EBH