Complex Salts and Brines of the Paradox Basin

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INTRODUCTION

Wells drilled for oil and gas in the Paradox Basin of Utah have encountered several zones of supersaturated and complex 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 and gas, and one drilled for brine in southeastern Utah are used in formulating this report. The analyses were performed by chemists of the U. S. Geological Survey and by those of various company and commercial 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 which characterize southeastern Utah. In the subsurface, Pennsylvanian rocks are thick and well-developed and dominated by the great mass of cyclically deposited halite, anhydrite, and potash salts in the Paradox Formation. Because of the thick salt development, geologists refer to the region as the 'Paradox Basin.' There is no surface expression of such a large and prominent basin (Fig. 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. Depths to the top of the Paradox Formation range from surface outcrop on some of the piercement structures to several thousand feet in adjacent synclinal areas. 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 13,000 feet in thickness, and contains much of the potential mineral wealth of the region.

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 a possible reservoir for brine production, should such brines prove to be commercial. The lower part of the Paleozoic section, consisting of Devonian and Cambrian strata, has been penetrated by a number of wells. The McCracken Sandstone, or basal Devonian formation in the region, holds much promise 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.

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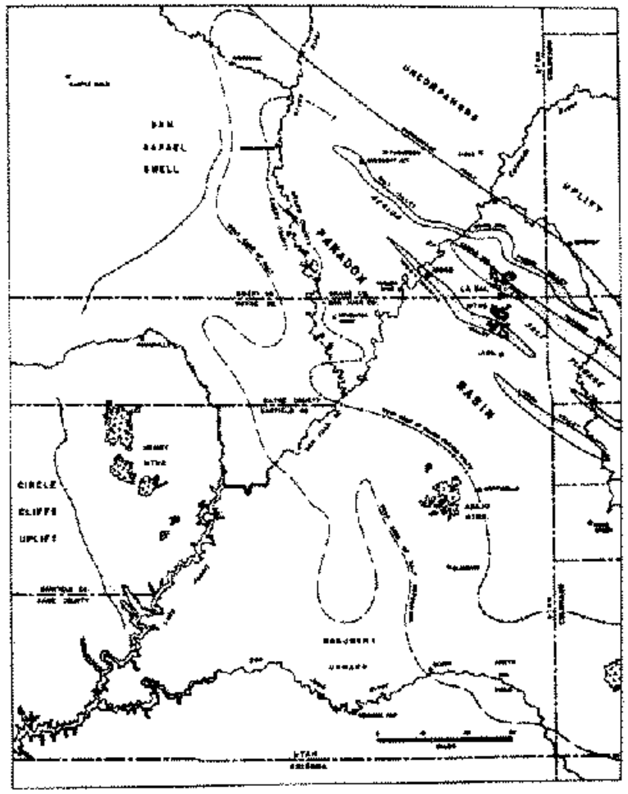

Figure 1. Regional Map of Paradox Basin.

One example of formation tops in the Big Flat area near Moab is as follows:

Jurassic	Kayenta Fm.	Surface
	Wingate Ss.	230 feet
Triassic	Chinle Fm.	560
	Moenkopi Fm.	890
Permian	Cutler Fm.	1,410
	Rico Fm.	2,175
Pennsylvanian	Honaker Trail Fm.	2,270
	Paradox Salt	4,280
	Pinkerton Trail Fm.	7,321
Mississippian	Leadville and Madison Fms.	7,465
Devonian	Ouray, Elbert, and McCracken Fms.	7,675
Cambrian	Unnamed Fms.	8,300

Permian and Pennsylvanian strata vary widely in both thickness and lithology, for example, in T. 26 S., R. 20 E., the Permian is 1290' thick and 26 miles to the east it is 11,000' thick. 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 (in preparation) have added considerably to the knowledge of the Pennsylvanian, and particularly the most important unit, the Paradox Formation. Interested readers are referred to the bibliography 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 nticlines. These features trend in a northwest direction and were caused by flowage of the rela-ively plastic salt beds in the Paradox Formation. The best known salt anticlines in the region are t Salt Valley, Castle Valley, Onion Creek-Fisher Valley, Moab-Spanish Valley, Lisbon Valley, nd Paradox Valley (Fig. 1). It is in the cores of the salt anticlines that Paradox salt beds come losest 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 he mother salt horizons of the Paradox Formation to cause salt flowage, thus initiating the for-nation of the salt anticline complex. Further, it is probably that the lineations of these anticlines ire closely related to the structural trends within the basement complex, assisted by the buttress ffect of the Uncompahgre Uplift on the east. West of the zone of salt flowage, the region assumes haracteristics typical of the Colorado Plateau Province, i. e., flat-lying or gently dipping rocks vith areas of gentle folds where faulting is insignificant except in limited areas.

The broad Monument upwarp dominates the southern part of the region, while the Uncom-hagre uplift, San Rafael Swell, and Circle Cliffs uplift buttress the Paradox Basin on the north-ast and west. The Henry, Abajo (Blue), and La Sal Mountains, which are laccolithic igneous in-rusions, form unique and dramatic features either flanking or within the Paradox Basin. Upheaval Dome, 23 miles northwest of Moab, is a circular dome with a peripheral syncline, is about two niles in diameter and probably results from cryptovolcanic activity or a combination of this and alt flowage.

Figure 2 is a contour map of one Paradox brine zone in the Moab region also showing wells Irilled for oil, gas, and brine. The structural geology of southeastern Utah has been discussed at ength 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 excel-ent structure contour maps accompany their reports.

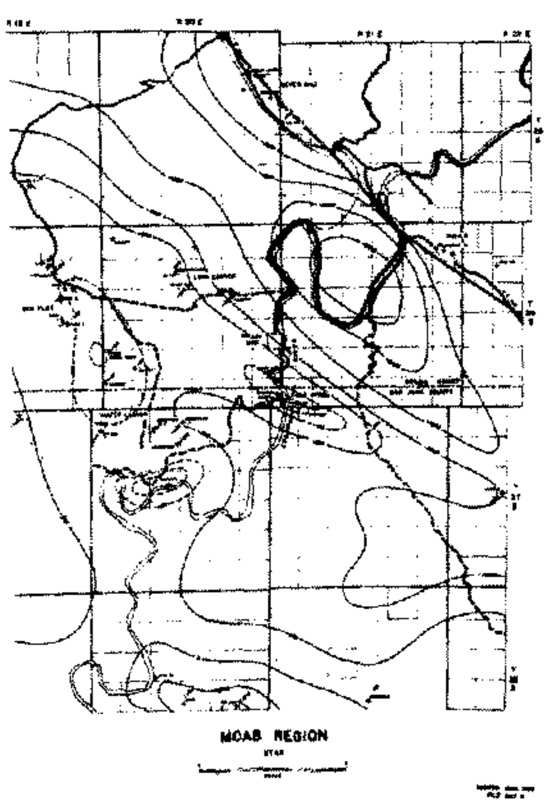

Figure 2. Well locations and contour map of main brine zone.

EVAPORITE MINERALS

Halite (NaCl), anhydrite ($CaSO_4$), carnallite ($KMgCl_3 \cdot 6H_2O$), and Sylvite (KCl) are the most common evaporite minerals in the Paradox Formation. Halite, of course, is the most common salt, totaling over ten thousand feet of thickness in some wells. Anhydrite is also common as well as 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 bed 6, contains carnallite over 140 feet in thickness in one area. Following are some analyses of typical carnallite cores;

	Low Insol.	Ave. Insol.	High Insol.
KCl	0.6%	2.4%	2.8
NaCl	15.1	4.1	46.0
$CaSO_4$	0.2	1.1	2.3
$CaCO_3$	0.3	0.7	1.2
Insoluble	0.3	1.4	3.1
$MgSO_4$		Nil	
Carnallite	83.1	88.0	45.0

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, Sec. 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. One interesting occurrence in the persistent carnallite beds is the presence of relatively large amounts of small hematite crystals. Another interesting occurrence is the presence of fluorspar (CaF_2) in some of the black shale zones. The fluorspar is in low concentration and crystals of 1 mm size.

Sylvite, the most important potash mineral, is also found throughout the central part of the Paradox Basin. The richest sylvite beds are found near the top of the various salt units. The mineral is known to have been deposited as an end phase in at least nine 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 have been identified in small quantities such as; polyhalite, syngenite, kieserite, and others.

BRINE ZONES

Brines supersaturated with complex salts have been encountered in Pennsylvanian, Mississippian, and Devonian rocks in almost every well that penetrated these formations in the Moab area of the Paradox Basin of Utah. Supersaturated brines have 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 but of the low Mg-K and high Na-Ca type. From the standpoint of reservoirs for brine accumulation, the Mississippian limestones and dolomites may hold as much promise as the overlying Pennsylvanian units since they range from 200 to 800 feet in thickness, and are usually vuggy with intercrystalline porosity, although locally they may be nonporous and tight. Devonian reservoir rocks are excellent within the potash deposition area, especially where they have been faulted against Paradox Salt beds. The top of the Mississippian ranges in depth from 3,500 feet 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 clastic breaks which separate the salt beds in the Paradox Formation (Fig. 3). The clastic breaks consist of black, fetid shale, siltstone, dolomite, anhydrite, and some fine-grained sandstone. The beds are frequently brecciated because of salt flowage. A space number has been responsible for brine flows but clastic break #31, between Hite's salt bed 15 and salt bed 16 has been

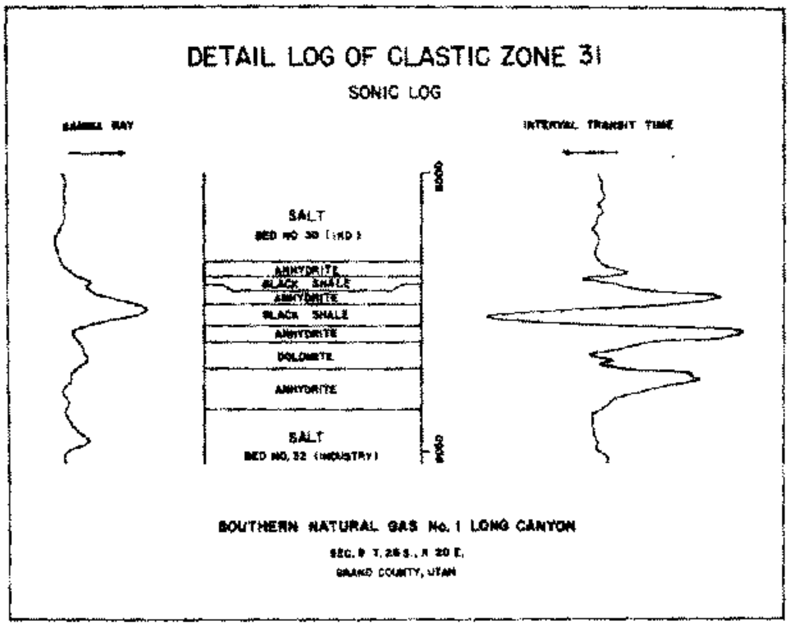

Figure 3. Detailed log of Main Brine Zone.

consistently responsible for flows of supersaturated brine in the Big Flat-Long Canyon area. 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., Sec. 30, T. 26 S., R. 20 E., Grand County. An analysis follows;

Boron	1, 260 ppm[3]	0. 19%[4]
Bromine	1, 612	3. 42
Calcium	55, 740	1. 23
Chloride	249, 300	70. 70
Lithium	134	0. 002
Copper		0. 001
Iron		0. 20
Magnesium	31, 350	1. 20
Potassium	25, 500	12. 25
Sodium	22, 000	10. 60
Strontium	1, 300	0. 50
Sulfate	23	0. 0

In the early drilling for oil on the Big Flat, the drilling fluid was not weighted enough, and upon striking the brine zones, blowouts occurred. Such blowouts were prevented in later wells in the area 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 one zone oil occurs along with the brine in the clastic break known as the 'Cane Creek Marker,' and two wells are currently producing sweet oil from this zone which is a thick and well-developed break between Hite's salt beds 21 and 22 near the base of the Paradox Formation. These brines were discovered unexpectedly while drilling into the underlying Mississippian and Devonian formations for oil and gas. Many have surface shut-in pressures of 3, 700 psi or more. To the oil people, these brines were nothing but an expensive nuisance which required a more expensive, 'weighted,' drilling mud for hydrostatic balance to prevent blowouts.

[3] Drip from tubing plugged with salts but under pressure.

[4] Solids scraped from inside same tubing. Zone-5425-5435.

BRINE FLOWS

The first thought in developing a commercial Mg, K, Br, or other brine operation of this kind is; can a large enough brine flow be established and is there a reservoir of sufficient size?

The porous Mississippian dolomites and limestones appear to offer promise, especially where they have been faulted into contact with the Paradox Salt beds that contain carnallite and sylvite. Such faulting has probably occurred at Lisbon Valley, Moab Valley, Salt Wash, and elsewhere along the edge of the region of salt flowage. It appears that vertical communication has occurred at some time in the geologic past in the Big Flat area a few miles west of Moab, Utah. No gauges of brine flow are available from wells penetrating Mississippian beds although drill-stem tests were conducted at many wells in the region which recovered several thousand feet of brine in the drill pipe, indicating that brine is present but that pumping might be required for production. Most wells have been drilled on surface or subsurface anticlinal highs in search of oil and gas, and it would be pertinent to know what kind of brine flows could be obtained from wells drilled in synclinal areas where the hydrodynamic drive would be much greater. The richest brines have specific gravities between 1.13 and 1.4, and some of the heavier constituents 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, Sec. 29, T. 26 S., R. 20 E., Grand County (Fig. 2), a flow of 280 barrels (11,760 gallons) per hour of brine and some oil was obtained on a 3/4" choke test of clastic zone 39 at a depth of approximately 6,800 feet. The shut-in pressure in that interval was 3,370 psi. In the same well, a drill-stem test of clastic zone 31 at 6,025 feet produced a flow of 168 barrels per hour through a 2 5/8 inch tubing with a flow pressure of 175 psi.

The Pure Oil Co. No. 1 Big Flat well, Sec. 14, T. 26 S., R. 19 E., Grand County, tested brine in clastic zone 31 that was under a shut-in pressure of 4,000 psi. In the Pure 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, Sec. 11, T. 26 S., R. 19 E., Grand County, clastic zone 31 produced a flow to the surface which was guesstimated at 50 barrels per hour. This well also had supersaturated brine in the Mississippian, and following is the composition of this brine;

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

Concentrated brine flowed to the surface from the same clastic break (zone 31) at the Southern Natural Gas No. 1 Long Canyon well, Sec. 9, T. 26 S., R. 20 E., Grand County. The zone here is approximately 26 feet thick, the top lying at a depth of 6,016 feet. Brine is now being produced along with oil from clastic No. 43 in this well. The Pure No. 5 Big Flat had brine in the same zone, this well is some seven miles to the northwest. The main brine zone (clastic 31) has rarely been cored, but it has been adequately sampled and logged. Figure 3 shows a portion of the sonic log for the No. 1 Long Canyon above-mentioned. This log shows 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, while the anhydrite and black shale are crushed and broken. Usually the fractures in these zones are filled with salt, however, where the brine is present no salt filling occurs. In the Roberts brine well, which offsets the Southern Natural No. 1 Long Canyon, brine started flowing as soon as the top anhydrite was penetrated, and the increase in flow was so rapid that by the time the underlying black shale was penetrated no further drilling was attempted for control purposes.

Vertical porosity, permeability, and communication is indicated. Brine flows have been encountered in clastic zone 31 over a distance of 8 miles north-south and 8 miles east-west, and it remains to be proven whether or not the brine is present and the zone communicable over a much larger area.

Differential pressures on these wells are similar and could be exactly the same since the differences in pressure are within the limits of error of the gauges used for pressure testing. The authors believe that zone 31 is probably communicable between the same 20 wells that have penetrated it in the area.

A possible explanation for the presence of supersaturated brine in clastic zone 31, for example, is the presence of the porous and permeable dolomite. This bed probably acted as a reservoir for the brine during early salt flowage. Salt flowage caused fracturing of the clastic zones, establishing more porous zones for brine accumulation. Due to the plasticity of the salt beds at depth, it is also thought possible that a so-called 'salt drive' may exist and that as brine is removed from the clastic zones the salt will flow into the porous zones assisting in maintaining reservoir pressure and consequently effecting a high ultimate recovery of brine much the same as does a water drive in porous and permeable oil sand. Most of the clastic breaks are quite fractured and broken, and the fractures are filled with salt where brine is not present. Since the brine is the 'mother liquor' remaining after deposition of the less soluble salines, it contains the most soluble compounds extant in the saline series. It is probably that clastic zone 31 is continuous over a much larger area without regard to surface elevation, and the greatest flows as well as the highest concentrations of the heavier elements would then be found in the adjoining synclinal areas.

BRINE PRODUCTION

The only deliberate brine production in the area is the Moab Brine Company which operates a brine well 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 for removal of the lime. The latter compound would be a contaminant in the uranium milling process used at the Atlas Minerals mill in Moab, where the brine is used.

One of the problems in sustaining a brine flow or any kind of production of the supersaturated complex brines is the fact of supersaturation (as high as 448,000 ppm dissolved solids), 160°F bottom hole temperatures and pressures of 4,000 psi to 6,000 psi. A drop in temperature, and/or pressure causes immediate precipitation to occur. The precipitated solids soon clog tubing and other production equipment.

The presence of this brine is interesting but not commercial unless there is enough of it and a method of continuous 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 a few hours and of the three that have been tried, all plugged up rather quickly. The Pure No. 1 Hobson U. S. A. was produced long enough to recover a few 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 brining industry has encountered and solved the supersaturation and similar problems which occur with NaCl, and its experience and methods may indicate solutions possible for the continuous production of this brine. Several methods of continuous production are suggested, such as;

1. Determing the critical pressures and temperatures at which crystallization begins, and produce 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. Use high frequency vibration to minimize crystallization on casing and tubing walls.
5. Install equipment at critical points in the tubing to produce small crystals that will be carried out with the brine.

These possible methods or combinations of methods present problems that can only be worked out in the laboratory and in actual field trials. Experience has shown that once the casing or tubing has filled with the supersaturated brine and 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 probable minerals in the brine. A few detailed analyses were performed by the U. S. Geological Survey laboratories and commercial laboratories, which give better insight on the true mineral content of the brines.

Figure 4 is an attempt at an isoconcentration map showing total dissolved solids in parts per million in brines obtained from Mississippian wells 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 5 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, conforms 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

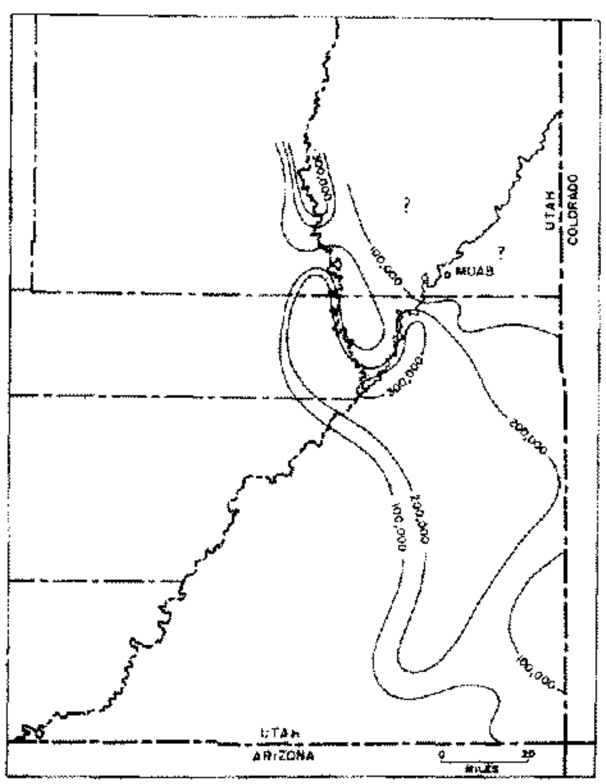

Figure 4. Isoconcentration Contours of Total Dissolved Solids in Mississippian Brines.

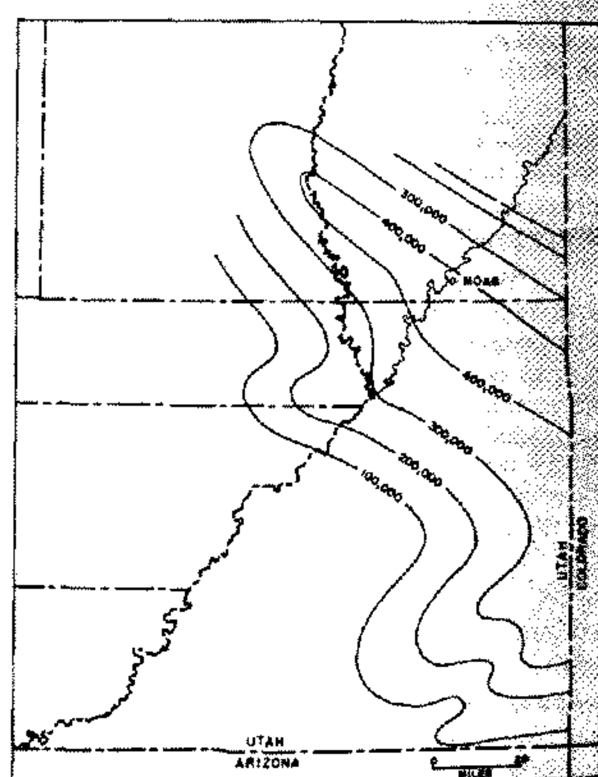

Figure 5. Isoconcentration Contours of Total Dissolved Solids in Pennsylvanian Brines.

sited. There can be no question that the brine concentrations are directly related to the and variety of salts present in the Paradox Formation.

icient information is not available to make accurate isoconcentration maps of economi- ortant elements found in the brines. One such map, however, is attempted for magne- ;. 6). This map again outlines the Paradox Basin in a rough manner, with the greatest ations (over 400, 000 ppm) being evident in the central part of the basin near Moab. It ap- it the center of evaporite deposition in Pennsylvanian time was in the general Moab region, analyses in the northeastern part of the basin are lacking.

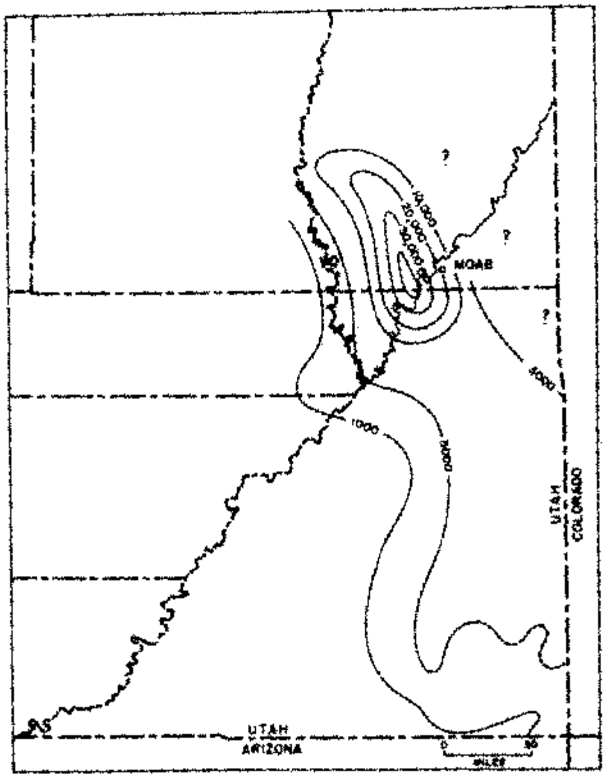

Figure 6. Isoconcentration Contours of Magnesium Concentration in Pennsylvanian Brines.

The following are analyses of brines from selected wells in southeastern Utah:

ıerada Petroleum No. 2 Green River, Sec. 2, T. 22 S., R. 16 E., Grand County. Paradox ırmation, interval not known. Analysis by Cal. 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, Sec. 15, T. 40 S., R. 22 E., San Juan County. Paradox Formation (Desert Creek, 5802-5812). 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, Sec. 3, T. 40 S., R. 24 E., San Juan County. Prasox Formation, 5612-5622 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, Sec. 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	
Lead	6	
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, Sec. 4, T. 29 S., R. 20 E., San Juan County. Mississippian 4905-5076. Analysis from Core Laboratories.

Calcium	12,000	ppm
Chloride	208,740	

Magnesium	4,860	ppm
Sodium	115,335	
Sulfate	6,870	
Total solids	348,681	
pH	5.0	
Specific Gravity	1.2	

King Oil No. 2 Big Flat, Sec. 11, T. 26 S., R. 19 E., Grand County. Paradox Formation, 6196-6220 feet. (Clastic 31) Analysis by Chemical and Geological Laboratories.

Ammonia	1,330	ppm
Borate	2,922	
Bromine	1,150	
Calcium	40,742	
Chloride	259,106	
Lithium	173	
Magnesium	47,789	
Potassium	41,958	
Sulfate	754	
Total Solids	421,889	

Roberts brine well, Sec. 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	2,000	
Bromine	2,500	
Calcium	3,000	
Carbonate	200	
Chloride	153,000	
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, Sec. 9, T. 26 S., R. 20 E., Grand County. Paradox Formation, Cane Creek Marker-Clastic 43' 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	
Cesium	16	
Rubidium	95	
Lithium	98	
Bromine	1,200	
Potassium	20,000	
Sodium	13,000	

Sulfate	1,800	ppm
Total solids	388,000	
pH	4.8	

Superior No. 22-34 Salt Wash, Sec. 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 and Potassium	90,949	
Sulfate	1,768	
Total solids	251,719	
pH	6.7	
Specific Gravity (60°F)	1.18	

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

Barium	0	ppm
Bicarbonate	146	
Calcium	240	
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, Sec. 24, T. 21 S., R. 15 E., Emery County. Mississippian, 9555-9652 feet. Analysis by Core Lab.

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, Sec. 34, T. 40 S., R. 26 E., San Juan County. Paradox Formation (Ismay zone). Analysis by Core Lab.

Barium	0	ppm
Bicarbonate	488	
Calcium	3,600	
Carbonate	0	
Chloride	205,900	
Iron	0	
Magnesium	7,533	

Sodium	115,455	ppm
Sulfate	200	
Total solids	333,176	
pH	4.5	
Specific Gravity (66°F)	1.13	

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

Bicarbonate	951
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, Sec. 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 and Potassium	36,283	
Sulfate	323	
Total solids	338,952	
pH	5.7	

Tidewater No. 74-11 Big Flat, Sec. 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

NOTE: Obviously very few brine samples have been assayed completely and it must be remembered that these brines were inadvertently discovered and because of existing conditions at the time of the brine flows very few if any were accurately sampled.

BRINE WELLS

Few wells have been drilled specifically for brine production in southeastern Utah. Most wells were drilled for oil and gas, encountering saturated brines in the course of drilling operations.

Only four wells have been completed or used as brine wells, all in the Moab region and shown on Fig. 2. These are as follows:

J. Roberts well (plugged with salts), SW 1/4 NE 1/4 Sec. 9, T. 26 S., R. 20 E., Grand County, Producing zone at 6000 feet (1963).

Pure Oil No. 1 Hobson-U. S. A. (plugged with salts), NW 1/4 NW 1/4 Sec. 30, T. 26 S., R. 20 E., Grand County. Producing zone 5,425-5,435 feet. Drilled 1955-58 for oil and gas.

Moab Brine Company (two wells, producing), SW 1/4 SW 1/4 Sec. 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 for brine in 1960.

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

No wells have been successfully completed in the high-pressure supersaturated brine zones of the Paradox Formation.

CONCLUSIONS

Supersaturated brines under high pressures are common in the Paradox Basin of southeastern Utah. Brines occurring in the areas of known potash and magnesium salts are unusually high in those elements as well as in lithium, boron, ammonia, bromine, strontium, rhodium, and caesium. At least five of the clastic breaks between various salt beds provide reservoirs for brine and one, (clastic break 31), is known to be productive in some 20 wells in the Big Flat area of Grand County west of Moab, Utah.

One well gauged flows totaling over 600 barrels per hour of the high Mg-K brine from three zones.

In addition to the clastic breaks in the Paradox Formation, porous dolomites and limestones of Mississippian age are potential producers of this brine but must be pumped.

Brine concentrations of the following 'highs' are known; Total solids, 450,000 ppm; Mg-50,000 ppm; K-48,000 ppm; Ca-75,000 ppm; Li-3,000 ppm; Br-6,100 ppm; Ammonia 1,300 ppm; Sr-1,300 ppm.

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

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