FEASIBILITY STUDY OF BRINE DISPOSAL

BY DEEP WELL INJECTION

On

The Paradox Valley Unit, Colorado
River Basin Salinity Control Project

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FEASIBILITY STUDY OF BRINE DISPOSAL

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On

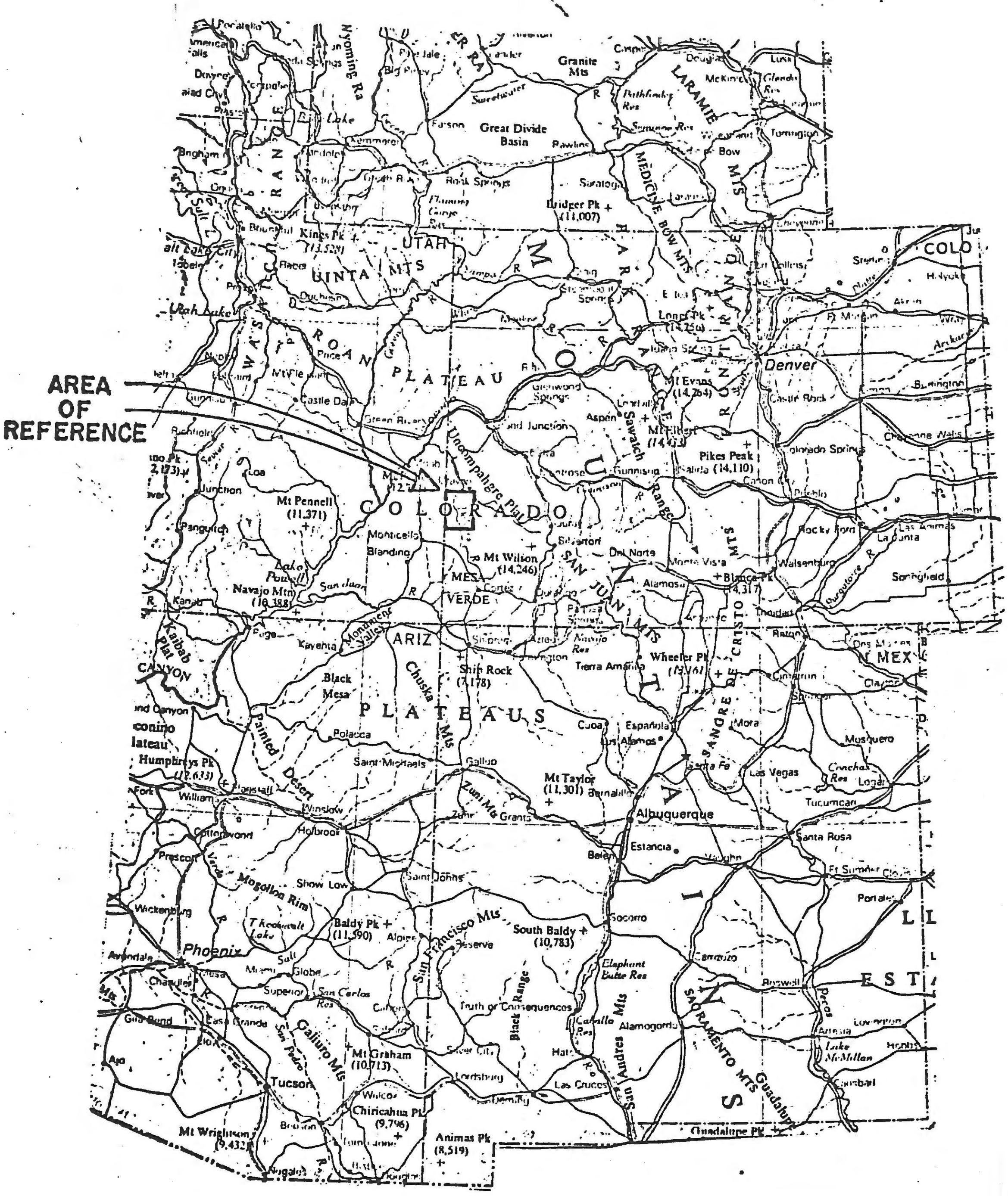
The Paradox Valley Unit, Colorado River Basin Salinity Control Project

PURPOSE

To investigate the feasibility of brine fluids disposal by deep well injection, in the Paradox Unit, to determine which scheme was at all possible, which is the best, and what physical and enviromental factors to be considered, and what methods are needed to implement the project.

SCOPE OF REPORT

This report includes a review of the various deep well injection schemes, interviews with individuals of Consultant Groups, Oil Companies, State and Federal Agencies for their input and recommendations. A general geologic study of the Paradox Valley area with description and reseroir properties of the rock formations and what structural influences might have on the injected fluid. A prime proposal and an alternate plan is made along with cost estimates and recommended procedures for testing, completion, and operations of a well disposal system. Finally, recommendation for what further studies necessary to more accurately assess this project.



LOCATION MAP

LOCATION

The source area for the brine waters and central point, of this report, is found in western Montrose County, Colorado in Township 47 North and Range 18 West. It falls within the Paradox Valley, a broad flat bottom valley, trending northwest-southeast to the Utah boarder. The valley has high rock walls of several hundred feet, rising on either side. The Dolores River cuts through these walls and flows to the northeast toward the Colorado River. Colorado State Highway No. 90, traverses the length of the valley, connecting to Utah State Highway No. 46 from Moab and La Sal, Utah. The Highway is paved and connects with Colorado State Highway at the town of Vancorum, Colorado, at the southeastern part of the valley. A small, slightly improved dirt road follows the south bank of the Dolores River from Bedrock, through the canyon wall and comes out at the community and mill site of Uravan, some 10 to 12 miles to the northeast.

BRINE PUMPING SCHEMES

General

The problem of dissolved salt entering the Dolores River within the Paradox Valley has been identified as a major contributcr of salinity to the upper basin drainage system of the Colorado River.

The Bureau of Reclamation's Colorado River Quality Improvement Program has considered many schemes for treating the salinity inflow at this point. The schemes that were considered for this report are restricted to the brine wellfield pumping schemes in which a series of barrier wells would be drilled along the Dolores River. These shallow wells would draw down the ground water containing dissolved salt that inflow into the existing channel of the river. Disposal of the brine from these pumping wells would then be the consideration.

The different brine wellfield pumping schemes by deep well injection disposal, are listed below:

1. Recycled to the salt dome.
2. Disposal into nuclear chambers, in the salt.
3. Disposal into nearby existing oil and gas fields.
4. By drilling new wells into porous formations.
5. Disposal into nearby abandened wildcat oil and gas tests.

Each of these schemes were investigated and evaluated on the bases of proximity to the project, overall costs, enviro-mental considerations, presence of geological formations, good reservoir conditions, physical factors, and many other considerations.

<u>Brine Recycled into the Salt Dome</u>

This scheme was looked on, at first, as the simplest approach to the problem, however, upon further study, it was rejected on the basis of lack of capacity and the complicated distribution system it would need.

Consultant Engineers, Earlougher and Amstutz, on their report to Union Carbide Nuclear Company, investigated this method as an alternative for waste material from the Uravan mill. Their study showed the capacity gained, as a result of dissolving the salt, is very little. An injection of fresh water into a 100 gallon salt cavity would dissolve 16 gallons of salt and the resulting brine would have a volume of 113 gallons, leaving a net gain of only 3 gallons. In the case where brine was injected into solid salt, the dissolving capacity would even be less.

The presence of clastic layers of shale, limestone, anhydrite form numerous breaks within the salt section. Shoemaker, et al, show the Paradox member of the Hermosa formation in Paradox Valley to be 65.1% salt, 28.1% shale and siltstone, 1.9% gypsum and anhydrite, 3.7% limestone and dolomite and 1.2% sandstone and conglomerate. Many of these clastic layers have "blown-out" with high pressure of gas and oil, during drilling operations. In most cases these zones have proven to be of low capacity and while showing signs of a reservoir, have very limited storage capacity.

Brine into Nuclear Chambers in the Salt

This scheme was placed low on the recommended list, primarily on the bases of cost and enviromental considerations. While the chambers would partly solve the capacity problem of the previous scheme, the cost of creating the chambers would be very expensive. This has been deminstrated where nuclear chambers were made to help in natural gas production in Colorado and Wyoming as part of the Plowshare Program. Other problems with making a large enough chamber to fully absorb the fluids over a long period of time. A growing concern about enviromental problems would also be a road-block to this scheme. These concerns, whether real or imagined, have been gaining momentum that would be certain in influencing regulatory agencies especially from citizen groups.

Brine Injected into Existing Oil and Gas Fields

This scheme has several advantages, the foremost being the using of an already existing disposal system, fully equipted and functioning into a proven reservoir. The closest fields to the Paradox Valley area are the two Lisbon Fields run by Union Oil Company. They are located in a northwest-southeast trend along a structural salt anticlinal trend simular to Paradox Valley. The Lisbon Field is located in T. 30 S. - R. 24 & 25 E., San Juan County, Utah, some 20-23 miles in a southwest direction. The other field is the Southeast Lisbon Field in T. 44 N. _ R. 19 W., San Miguel County, Colorado, which is 17 to 18 miles south and slightly west of Paradox Valley.

In contacting Union Oil Company's offices in Durango, Colorado, it was learned that the Lisbon Field was injecting gas into both the fields and what water was made in production, was returned to the Mississippian and Devonidn formations through injection wells. In December of 1974, 107,973 bbls of water was re-injected at the Lisbon Field. The Union Oil Company engineers indicated they would not be interested in additional water into their system. The other problem about this scheme is the long pipeline required and the high lifting costs to pump the fluid out of the deep canyons of the Paradox, across Gypsum Valley and into Lisbon Valley.

Several fields of the Greater Aneth Area in Utah are injecting formation water into wells at the present time. Continental Oil Company's White Mesa Unit in Sec. 34, T. 41 S. - R. 24 E., as an example, is injecting Desert Creek formation water into the Coconino formation at the rate of 7,800,000 bbls of salt water over the last 6½ years. Salinity is 75,000ppm, injection pressure is 1,500 psi. These fields are over 75 miles from Paradox Valley and over rough terrain which would make it very expensive, even if an agreement could be worked out with field operators.

Brine Disposal by Drilling New Wells into Porous Formations

The advantage to this scheme would be in placing the well close to the source area, providing porous reservoir rocks could be found at that location. In the center of the Paradox Valley, a well would have to be drilled to close to 15,000 feet to find possible porous rocks in the Lower Hermosa, Mississippian, or Devonian formations. To drill for shallower formations, the wells would have to be drilled on either flank of the valley, probabley into the Cutler formation. The risk, is the same as private Oil Companies encounter in oil and gas exploration, that of selecting a site and risking that rocks of sufficiant thickness and porosity could be found after the money was spent in drilling the well. It could mean that several wells may have to be drilled before the right reservoir could be found.

Brine Disposal by Using Existing Abandoned Wildcat Oil & Gas Wells

The final scheme should overcome the risk factors of the previous schemes where after examining the data and logs of the already drilled wells, one or more could be selected to fill the needs and be rehabilitated for disposal purposes.

There are several abandoned wells within one to four miles of the purposed brine wellfield location. Some of the wells went but a short distance into the alluvian or into the Paradox formation salt section. Two of these wells are currently being used for slat brine production by the Paradox Salt Company.

Possible Wells For Disposal Purposes

The Union Oil Company No. 1-0-30 Otho Ayers in the SW SE of Sec. 30, T. 47 N.-R. 18 W., is located 3½ miles southwest of the brine wellfield. It was drilled to 14,400 feet into the Devonion - Ouray formation in 1970-71. They encountered the Permian-- Cutler formation at 1,096 feet, the Pennsylvanian - Hermosa formation at 4,742 feet, the Mississippian - Leadville at 14,042 feet and the Devonian - Ouray at 14,042 feet. A drill-stem test in the Mississippian from 14,114 to 14,200 feet, was Shut-In 2 Hours, Open 1 Hour, Final Shut-In 4 Hours, Recovery of 4,150 feet of Water Cushion, and 6,680 feet of Salt Water. Formation Pressure 2558 - 5318 #, Shut-In Pressure 6220-6201 #, Hydrostatic Pressure 7674-7710 #. Casing set, at time of drilling was - 20" Conductor Pipe at 147 feet; 13 3/8" at 2,016 feet; and 9 5/8" at 10,188 feet.

The Continental Oil Company No. 1 Scorup-Somerville-Wilcox was drilled in late 1958, some 15,000 feet into the Mississippian-Madison formation. The well is located about 3/4 of a mile due west of the brine wellfield site, in the SW SW, Sec. 8, T. 47 N. - R. 18 W. They drilled into the Paradox Salt at 650 feet, after loosing circulation, base of salt was at 13,345 feet. The Mississippian-Leadville was topped at 14,726 feet and the Madison was at 14,968 feet. Several cores were taken with one in the Mississippian between 14,939 to 14,999 feet, showing limestone and dolomites with vuggy porosity and much fracturing. See Table A. for complete discription of this core. A drill-stem test from 14,780 to 15,000 feet was run. It was Open 2 Hours, Recovering 4,950 feet of Water Cushion, 8,500 feet of Salt Water, Formation Pressure 3440 - 6400 #, Shut-In Pressure for 1 Hour 6510, Hydrostatic Pressure 8760 #. Casing, 24" Conductor at 16 feet, 13 3/8" at 1,220 feet.

The Jack Grynberg and Associates, Federal 33-3 - was drilled the summer of 1975, located about $1\frac{1}{2}$ miles northeast of the brine wellfield, in the NW SE$\frac{1}{4}$ Sec. 3, T. 47 N.-R. 18 W. This well is so new, that at the time of this report, all of the information and logs had not been released. Total depth was reported as 7,289 feet in the Hermosa - Paradox formation. Top of the Paradox was at 6,515 feet. No cores or tests were reported. The hole was drilled mostly with air and at the time the author visited the site, on April 16, 1975, they were drilling in the Cutler formation with no sign of oil, gas, or water, at about 4,100 feet. Mr. C. H. Rovick, Geologist with the Bureau of Reclamation, visited on April 22 nd and reported they were at 5,100 feet with no shows.

Well Summary

In studying the above wells as to the possiblities of rehabilitating one for disposable purposes, it was determined that the Continental No. 1 Scorup would be the best for the following reasons:

1. This well is the closest to the source of the brine.

2. The presence of a porous, thick, continuous formation to serve as a storage reservoir. Mississippian rocks.

3. The formation is deep enough not to be effected by faults or other structure that could cause leakage to the surface.

4. A zone that is vertically well below fresh water circulation and confined by a thick salt layer above.

5. Already existing drill stem test data, log and core information as to the exsistance of a reservoir zone.

The Union well is $3\frac{1}{2}$ miles further from the source area, but it could be considered as an alternate well, as of the thick section of Cutler that could serve as a shallower reservoir. They also penitrated the Mississippian and went into the Devonion strata. The Mississippian rocks indicate good porosity from the drill stem information, although not quite as good as that found in the Continental well.

The Grynberg well has also drilled a good section of Cutler, but as of now, it is not known what the potential of the reservoir is. When information becomes available, it should be examined as a possible well for injection in the shallower zones. Near surface faulting along the flanks of the structural valley, should be considered in using the Cutler as a reservoir, in this area.

GEOLOGY

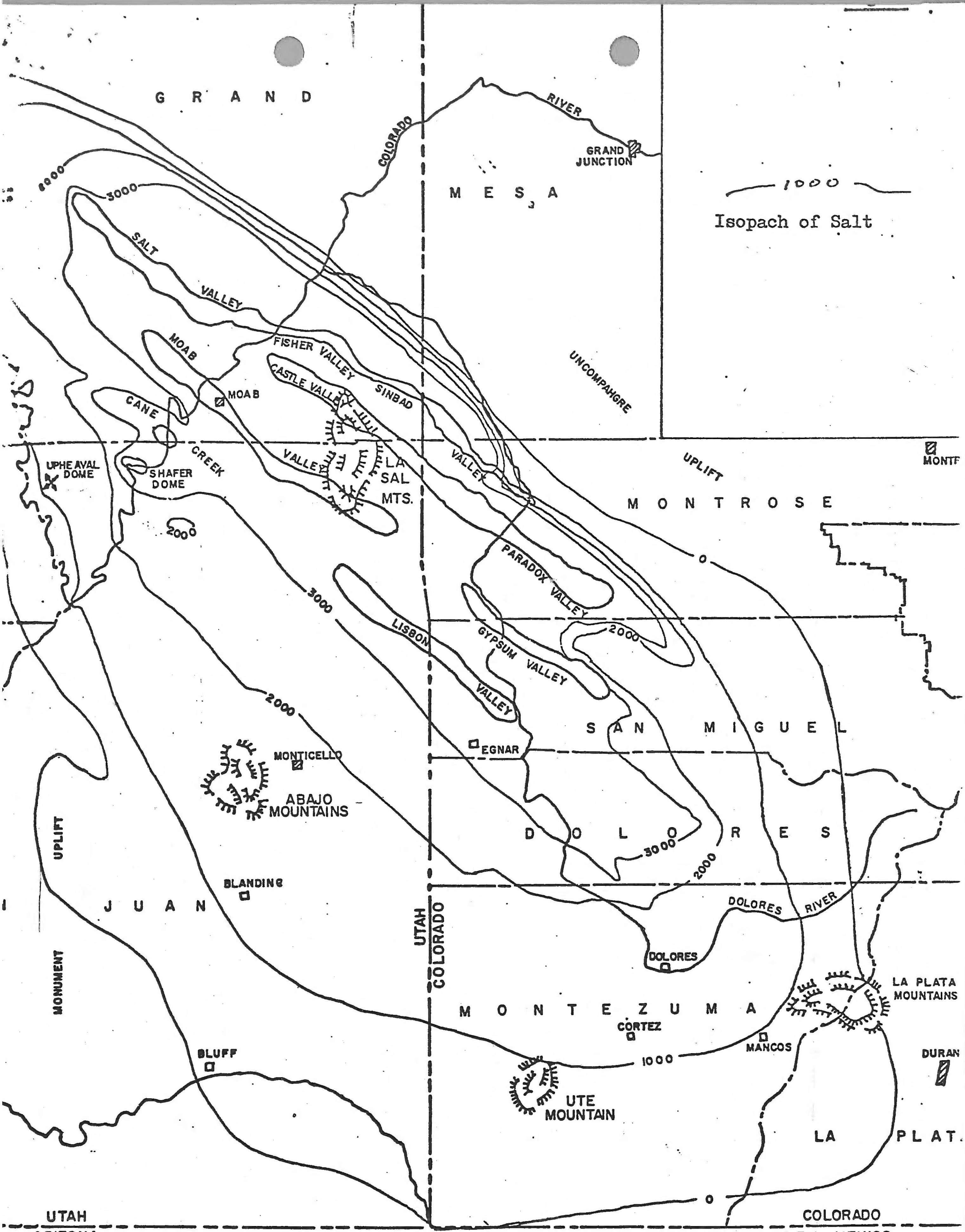
Introduction

The area of interest is located geologically within the Paradox Basin, of southeastern Utah and southwestern Colorado. This Basin is about 160 miles long and about 80 miles wide and covers close to 12,000 square miles. Tectonically, it is bounded on the northwest by the San Rafael Swell, on the west by the Circle Cliffs upwarp, and on the south by the Defiance uplift and on the northeast by the Uncompahgre uplift.

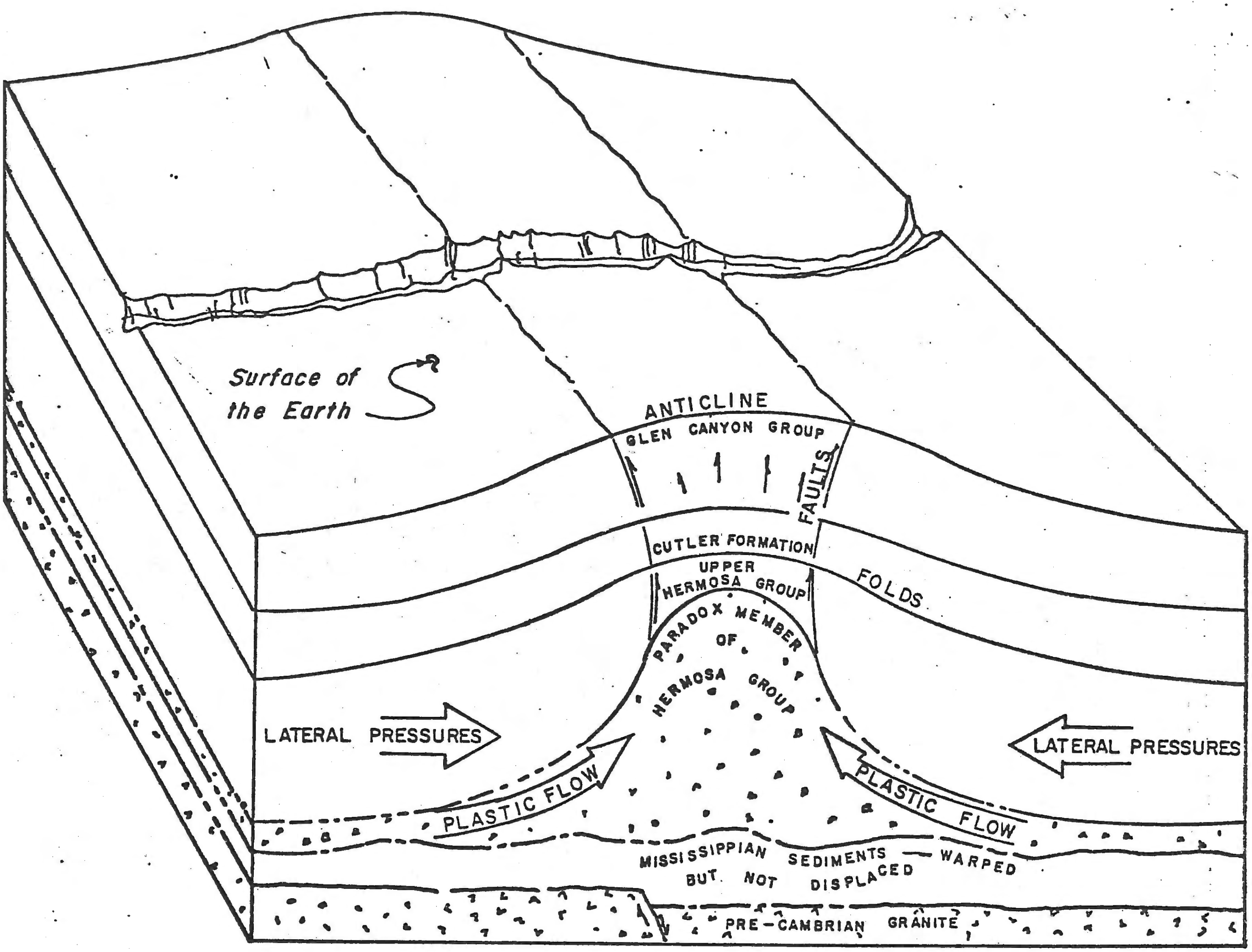
The Basin is asymmentrical in a northeast - southwest direction with the deepest part only a few tens of miles southwest of the Uncompahgre uplift. A series of broad folds trending northwestward, roughly parallel to the Uncompahgre uplift, have a central core of salt that has uplifted, later to collapse and faulted leaving elongated flat valleys throughout this region.

To the southwest of the Uncompahgre is the Salt Valley - Fisher Valley - Sinbad Valley trend. Next in sequence is the Castle Valley - Paradox Valley trend. The Moab or Spanish Valley - Gypsum Valley trend is the next in line. The final exposed trend is expressed by the Cane Creek - Lisbon Valley and then the un-eroided Dolores Anticline. (See Fig.2). More details of these trends will be covered under the structural part of this report.

It is the Paradox Valley, in western Montrose County, Colorado, that is the central interest of this report. Specifically at a point where the Dolores River cuts, at right angles, across the broad valley.



AREA REFERENCE MAP



PARADOX ANTICLINE
EARLY STAGE OF DEVELOPMENT

Cambrian

In the Paradox Valley area, there are no exposures of Cambrian rocks or has there been any penetrated by drilling, as of now. Near Silverton, Colorado, in the San Juan Mountains, the Ignacio quartzite is exposed, showing between 100 to 200 feet of Upper Cambrian overlying quartzites and shales of Algonkian age. It is probably that these beds extend beneath this portion of the Paradox Basin.

Mallory, and others, have suggested that the weathered Ignacio quartzites together with the granite of the Precambrian, eroding from the Uncompahgre uplift that is the source of the Cutler formation as well as arkosic beds found throughout the section.

Ordovician - Silurian

To date, there is no evidence that rocks of Ordovician or Silurian were ever deposited or were deposited and later eroded by pre-Devonian epeirogeny uplift. Several wells have reported possible Ordovician sediments, but it is believed, this has never been proven as to age.

Devonian

Rocks of Devonian age have been penetrated in wells several places in the eastern Paradox Basin.

Aneth Formation - are the earliest rocks deposited after the pre-Devonian epeirogenic uplift and have been dated from fish remains as Late Devonian. The Aneth consists of argillaceous, dark brown to black limestones and solomites which are often anhydritic and slightly glauconitic and calcareous shales, The shales are gray-green, brown, and some are carbonaceous. This formation is found, generall, in the Aneth-Bluff fields of

San Juan County, Utah, but it is unknown whether it is present in the Paradox Valley area.

Elbert Formation - has its type section in the San Juan Mountains where it overlies the Ignacio formation. It consists of red, buff, and gray shales, thin limestones, and interbedded quartzites of Upper Devonian age. In the Paradox Valley ares, the Elbert is composed of the lower McCracken Sandstone member and upper dolomite member which is sandy, thin-bedded and has streaks of gray-green and red sandy shales. Some 15 miles southwest of the Paradox Valley, the McCracken Sandstone produces natural gas at the Union Oil Company's Southeast Lisbon Field.

Ouray Limestone - is of Upper Devonian age with the type section at Ouray, Colorado where it consists of 100 to 300 feet of light gray to tan limestones, dense and oftenoolitic and occasional thin green shales interbedded. Fossils have indicated the very top may be a transitional zone between the Mississippian and Devonian.

Mississippian

It is difficult to settle on a name for the lower part of the Mississippian in the Paradox Basin. Fossils indicate Kinderhookian age which relates with the Madison of Central Utah. Some geologists use the Grand Canyon term of Redwall and others use Leadville for the entire section. For this paper, the terms that are most commonly used in the Paradox Basin, are Leadville for the upper limestone beds and Madison for the lower beds. In the subsurface, most Oil Company stratigraphers have been able to identify the entire Mississippian by 4 zones. In ascending order "A", "B", "C", and "D" Zones. The "D" Zone being basically limestone with some dolomites, cherts and is called Leadville. The "C" Zone is mostly dolomites, with some limestones, and identified by the abundance of crynoids. This zone is usually the more porous and where oil and gas production occurs in the Mississippian fields, it is usually in this "C" Zone. The "C" Zone and below would be called Madison.

Madison Limestone - consists of massive dolomites, tan, brown, gray and occasionly pink, in color. This section usually exhibits both granular and vuggy porosity and contains tripoltic cherts and in some areas thin beds of limestone occur, interbedded, near the top.

In the Paradox Valley area, the Mississippian was drilled in the Continental, et al, No. 1 Scorup well where were 274 feet logged. The "Leadville - Madison" lithology of an upper limestone and lower dolomite were not as easily defined as the "Zone" lithology. The upper "D" Zone samples were not recovered except for the lower portion where it was identified as mostly brown to tan limestone with tripolitic chert and some interbedded tan dolomites, grading into predominately tan and brown limestones, very dolomitic and with abundant crinoids, a few dolomites and black shales interbedded. The more porous section with the crinoids indicated the lower 32 feet to be "C" Zone. If they had continued to drill, probably much more of the massive dolomite would have been found.

Pennsylvanian

Molas Formation - This formation is predomoinantly a clastic red bed sequence comprising reddish-brown to variegated siltstone, red silty shale, calcareous sandstones, and some gray to reddish-buff limestone lentils. Sometime the basal part is composed of boulders to cobbles of the underlying Leadville. These rocks represent an old regolith or "terra rossa" remains of the erosional surface of the Mississippian rocks. The thickness varies from a few feet to over 150 feet on the Monument upwarp. In the Paradox Valley area, it is found to be 45 to 55 feet thick.

Hermosa Formation - can be divided into three main units of Upper Hermosa member, Paradox member, Lower Hermosa member. The Upper Hermosa member is also known as the Honaker Trail formation and is composed of interbedded limestones, dolomites, anhydrite, back shales, and siltstones, ranging in thickness from 150 to 500 feet.

Paradox member or the "saline facies" is composed of interbedded black shales, dolomite, limestone, gypsum, anhydrite and predominately thin to thick beds of salt. On the southern and eastern margins of the salt basin, certain limestone and dolomite equivalents of the saline facies, have been given zone names derived from the oil and gas fields where they produce. Such names as Ismay, Desert Creek, Akah, and Barker Creek are commonly in usage.

True depositional thickness within the Paradox Basin of the salt ranges from zero to 7,000 feet, in the basin deep. Within the diapiric salt anticlines where large-scale transfer of salt by plastic flow from adjacent synclines, show the salt to be in excess of 13,000 feet.

The Lower Hermosa member is also know as the Pinkerton Trail, is simular to the Upper Hermosa and composed of thin intercolated beds of anhydrite or gypsum, dolomite, siltstone and black shales. Thickness varies between a few feet to 450 feet. In the Continental Scroup well there was only 41 feet of this member present.

Pennslvanian - Permian

Cutler Formation - is composed of maroon, purple, red and light - red - mottled arkosic sandstone, arkose, and arkosic conglomerate. The lower part of the Cutler, when recognizable, is called Rico where it is interbedded red and gray marine limestones. This represents the transitional beds between the Hermosa and true Cutler formation.

The arkosic material is poorly sorted, forms rudely cross-bedded layers and lenses, and consists of quartz, fresh feldspar, dark minerals, and pebbles to boulders of granite, gneiss, schist, and quartzite, the materials derived from the Precambrian crystalline rocks of the Uncompahgre highlands.

Thickness of these beds vary widely because of the nature of their deposition. It is estimated as much as 10,000 to 13,000 feet was orginally deposited before Late Permian and Early Triassic erosion. The Union Oil Company No. 1-0-30 Otho Ayers, in the Paradox Valley, drilled 3,646 feet of Cutler, but on the the side of the valley, the Grynberg well is reported to have drilled better than 5,000 feet. Carter and Craig, estimated some 9,000 feet of Cutler to be on the flanks of the Paradox Valley.

Triassic

Moenkopi Formation - crops out in Paradox Valley on either side at the base of the walls. There are three distinct units lithologically. The lower unit consists primarily of reddish brown to yellowish brown, distinctly bedded, poorly sorted, mudstone. In some places interbedded with the mudstones, are beds of reddish-buff, course-grained, dirty arkosic sandstone and thin bedded shale. The middle member is composed of a dark chocolate brown arkose and arkosic conglomerate interbedded with fine grained ripple-bedded chocolate shale. The upper member consists, largely, of fine-grained, ripple-bedded, chocolate colored shale with thin beds of arkosic sandstone. The thickness of all three units of the Moenkopi are between 800 to 1,000 feet.

Chinle Formation - is also found on either flank, low along the walls, of the cliffs with a thickness of 500 to 750 feet thick. The Chinle is composed of red to orange-red siltstone, with interbedded red fine-grained sandstone, shale, clay-pellet conglomerate containing limestone pebbles and at the base a conglomerate containing quartz pebbles. A few thin beds of gypsum occur in the base. The lithologic units are lenticular and discontinuous.

Triassic - Jurassic

Glen Canyon Group

Wingate Sandstone - is also widely exposed along the walls of the salt anticlinal valleys, forming sheer cliffs of about 300-350 feet of fine grained, reddish-brown sandstone stained and streaked, in places, with black desert varnish. The sandstone divided into horizontal layers, 2 to 50 feet thick, by bedding planes. Each layer is cross-bedded on a magnificent scale with great tangential crossbedds of eolian type cutting across the entire section of the horizontal layer.

Kayenta Formation - lies conformable over the Wingate and is composed of irregularly bedded red, buff, and gray and lavender fine to course-grained sandstone, siltstone, and shale with thin beds of conglomerate near the base. Some 106 feet is exposed in the Paradox Valley area.

Navajo Sandstone - is the uppermost formation of the Glen Canyon Group and conformably overlies the Kayenta. The Navajo is entirely a massive, fine-grained, very well sorted, clean, light buff, gray, or nearly white sandstone. A few thin lenes of limestone and shale splits are found throughout the cross-bedded sandstone. In the Paradox Valley area, the Navajo is found only on the southwestern flank and in an outlier on the north end of the valley. Only about 70 feet is exposed as this is near the "zero" line of deposition. Either from erosion or from non-deposition, the Navajo is not found northeast of this area.

Jurassic
San Rafael Group

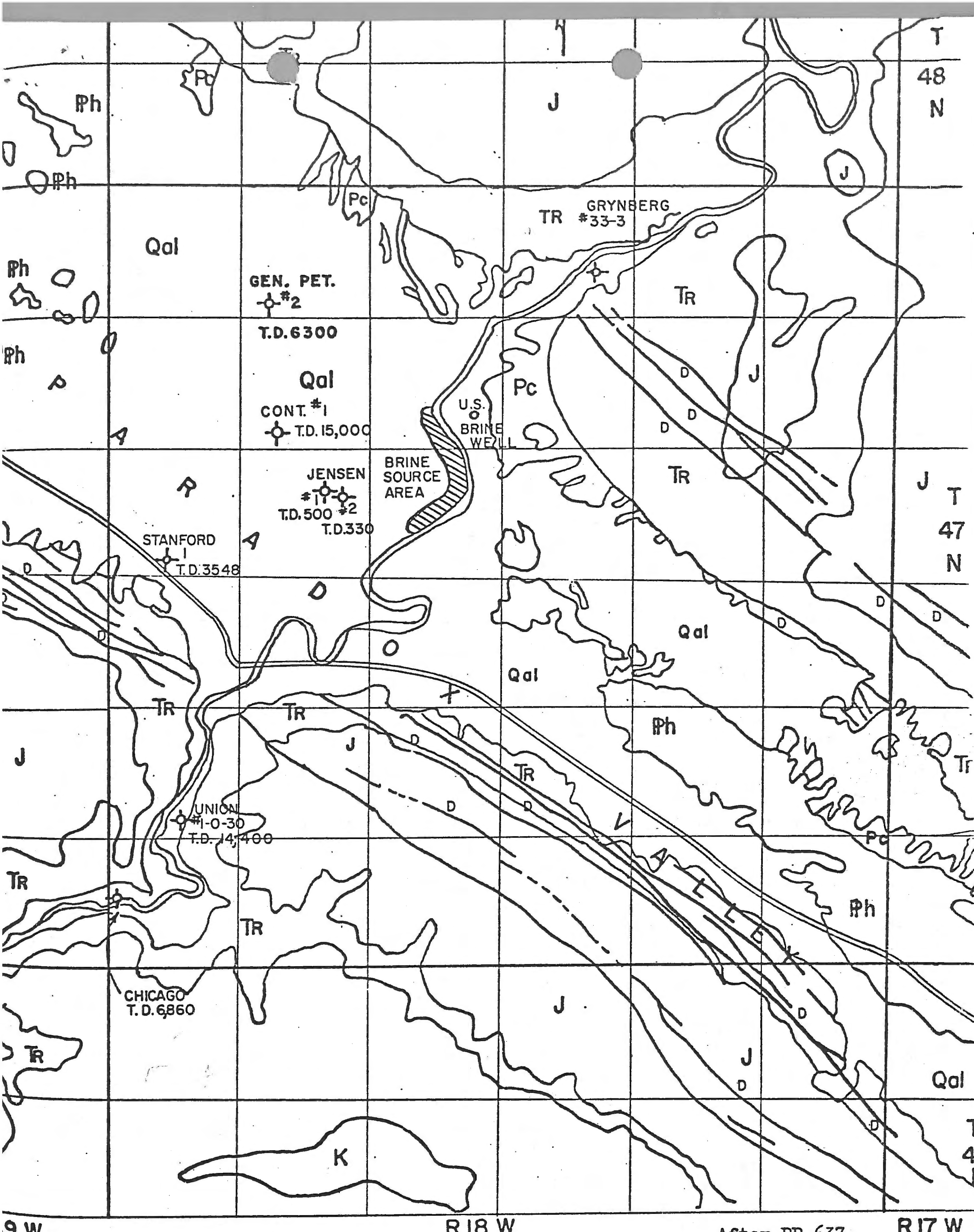
Entrada Sandstone - is divided into two units, the Dewey Bridge member and the Slick Rock member. The Dewey Bridge member is composed of red, buff, and orange, horizontally bedded mudstone, siltstone, and sandstone. Thickness of this unit varies, but in the Paradox Valley area, it is between 40 to 50 feet thick. It was probably not deposited across the tops of the salt cores in the salt anticlinal intrusives. The Slick Rock member is a orange, buff and white, fine-grained, massive and cross-bedded sandstone. It is usually 130 to 150 feet thick, thinning across the salt anticlines.

Summerville Formation - is a thin bedded, red gray, green, and brown sandstone, sandy shale, and mudstone. It is about 75 feet thick and pinches out in many places along the crests of the anticlines. This is probably due to depositional convergence against high ground produced by upward movement of salt or possibly was removed by erosion during early Morrison time.

Morrison Formation - is upper Jurassic in age and has two members of about equal thickness. The lower is called the Salt Wash and the upper is called the Brushy Basin member. The Salt Wash is composed of white, gray, buff, and rusty-red sandstone, red, reddish-brown, green, gray mudstone with scattered thin limestone beds. The Brushy Basin member is composed predominantly of variegated, bentonitic mudstone and shale; rusty-red and red sandstone and conglomerate. Sometimes thin light gray limestone can be mapped for short distances. Total thickness, in this area, of the Morrison formation is between 600 to 800 feet.

Cretaceous

Burrow Canyon Formation - consists of alternating conglomeritic sandstone and mudstone with a few beds of limestone and chert.



After PP 637

GEOLOGIC MAP

LTS

QAL QUATERNARY ALLUVIUM	J JURRASIC ROCKS	PC PERMIAN CUTLER
K CRETACEOUS ROCKS	TR TRIASSIC ROCKS	Ph PERMO-PENN-HERMOSA

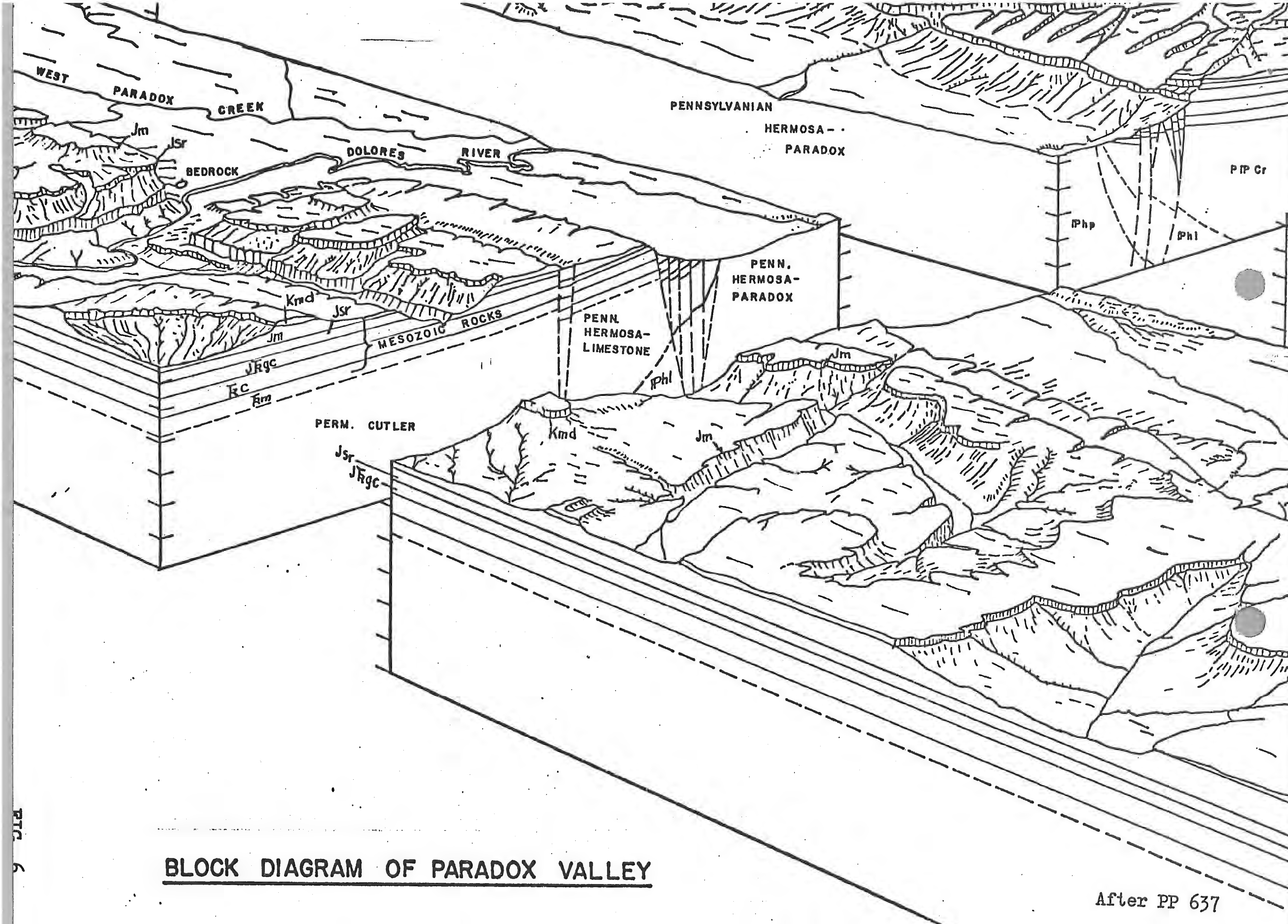


FIG. 6

BLOCK DIAGRAM OF PARADOX VALLEY

After PP 637

RESERVOIR CHARACTERISTICS

General

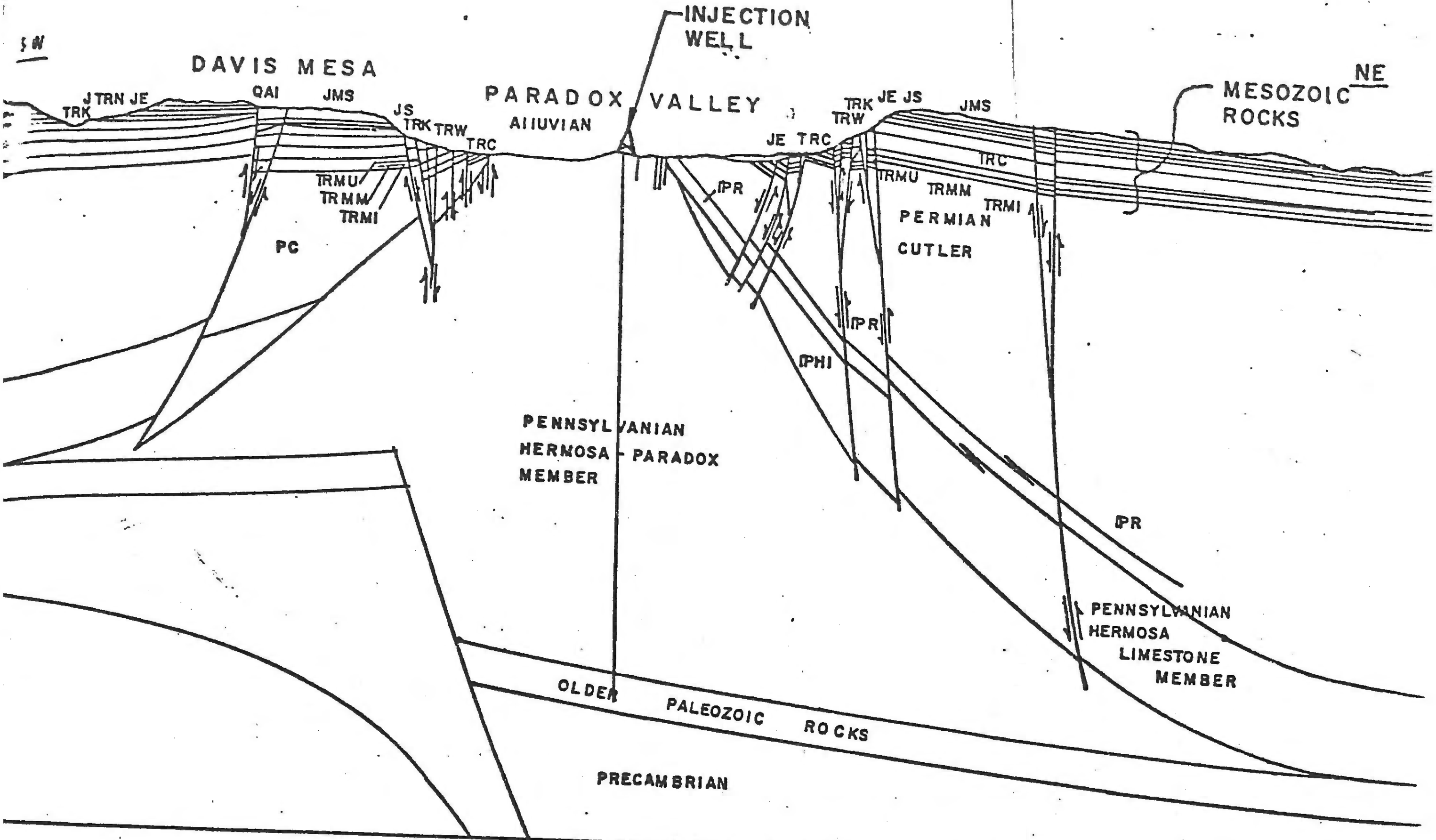
The stratigraphy of the Paradox Valley area was covered under the Geology Section, of this report, and included a discription of all the rocks exposed on the surface as well as those expected in the subsurface, between the Precambrian to the Quaternary. Only part of these rocks will be considered for reservoir disposal purposes, in this report. Rocks younger than the Permo-Pennsylvanian - Cutler formation have been eliminated as they lie above the valley floor where the well would be located. Other formations, in the Paleozoics, either do not have reservoirs or not enough is known about them, in this area.

Reservoirs in the Devonion

Elbert - Probabley the best reservoir, of the Elbert would be the McCracken sandstone member, that produces oil and gas in the Lisbon fields. The sandstone is somewhat quartzitic and tightly cemented, but porosity of 15 to 20%, pereabilities of 500 to 800 mds. have been found. The McCracken is known to be present in the Aneth area, as well as in the Lisbon fields, but it is unknown as to how far it extends to the north and east. Samples of water, from the McCracken, show concentrated brines to contain 31,583 to 71,948 ppm of dissolved solids to be present.

Ouray- like the Elbert is mostly limestone and dolomite, and show porosity of less than 1% to 20% in localized zones with waters being very saline to concentrated brines of 29,869 to 83,940 ppm of dissolved solids.

Fig. 7



CROSS SECTION — PARADOX VALLEY

After PP 637

Jurassic	Jm	Morrison
	Js	Summerville
	Je	Entrada
Triassic	JTrn	Navajo
	Trk	Kayenta
	Trw	Wingate
	Trc	Chinle
	Trm	Moenkopi
Permian	Pc	Cutler
Permo-Penn	IPr	Rico

Areal extent, of the carbonate members, of the Devonion, are widespread throughout the Paradox Basin, with little lithological change expected.

<u>Reservoirs in the Mississippian</u>

<u>Madison</u> - Limestones and dolomites of the widespread and homogeneous Mississippian - Madison, are noted for their local porosity development, almost everywhere drilled in the Paradox Basin. It is usually composed of courely crystalline to finely sucrosic dolomite which exhibits both granular and vugular porosity. This porosity is found widespread and generally scattered throughout the section. In several wells, where the entire section has been drilled, 300 to 400 feet of excellent porosity has been developed. In the Lisbon fields, as well as other areas, this intercrystalline porosity is further enhanced with the presence of vertical and horizonal fracturing. Porosity of 30 to 40% and permeability of 1000 mds. have been recorded.

<u>Leadville</u> - Is usually more of a dense formation, but local dolomintation can occur within this zone to show porosity. In the Paradox Valley wells, this upper zone show considerable interbedding of limes and dolomites and signs of the limestones having vuggy porosity.

It is the authors opinion that the Mississippian affords the best reservoir and has the best aquifer characteristics of any of the formations considered.

A chemical analyses of 52 water samples from the undifferentiated rocks of Mississippian age, showed a range of from 7,172 to 327,283 ppm. of dissolved solids. Six of the water samples were moderately saline, 16 samples were very saline, and 30 samples were brines. Table B. lists several

Partial analyses of waters from the Mississippian formations, in the Utah section of the Paradox basin.

Reservoirs in the Pennsylvanian

Molas - This formation would not be considered a good reservoir because of its composition of shale and what sands are present, are ususally very tight. Water sample from an oil well showed 6,035 ppm of dissolved solids.

Hermosa

Paradox Member - This sequence of thin to thick salt beds with numerous clastic penesaline interbeds, have shown signs of being reservoirs, but it is considered that permeabilities are very low and within the salt, tests have shown very little volume can be created by injection of water into the halite. For these reasons, this section is not considered an attractive zone for injection purposes.

Upper and Lower Members - These rocks are considered poor reservoirs, because of the limited amounts of porous sands and tight limestones. These formations show erratic changes in thickness and in lithology.

An analyses of 34 water samples from the Hermosa, mostly the Paradox, show a range of 5,342 to 397,061 ppm of dissolved solids.

Reservoirs in the Permo-Pennsylvanian

Cutler Formation - This formation is quite thick with between 3,500 to 9,000 feet expected to be present in the Paradox Valley area. As was explained earlier, these rocks are clastic materials washed and weathered off the Uncompahgre uplift and dumped into the deep troughs of the Paradox Basin.

As the sands were carried, washed, and cleaned basinward, several identifiable tonques and members can be mapped toward the southwest. The Cedar Mesa tonque, Organ Rock member, DeChelly member, and the White Rim member, are examples of this reworking of the "granite wash" material. In the Paradox Valley area, the Cutler is relatively close to the source of the material, so little opportunity for the cleaning of the sands has taken place. Thick, clean sands would not be expected, in this part of the basin. The great thickness, of the total formation is the advantage, where numerous thin zones, where porosity may develop, may be found throughout the entire section. It could be considered a possible reservoir if the entire Cutler and basal Rico were drilled and opened to perferations.

Earlougher Engineering, in making a study for Union Carbide Nuclear Company, in 1962, cored 300 feet into the Cutler in the Paradox Valley. They reported 13% of the core contained sandstone (40 ft.), in which porosity and pereability determinations were taken for each foot of sandstone recovered. Porosities range from a high of 18.6% to 6.6%, an average of 13.82% for the entire sampled section. Pereabilities range from 40 md to 0.02 md or an average of 5.01 md. It was determined that pereability capacity for the 300 feet is 200 milidarcy feet. If this were a representative of the entire formation, a 6,000 foot section would provide a capacity of only 4,000 milidarcy feet, considerable less than needed for the 575 GPM injection requirement of Union Carbide.

In their report, they made a study of the surrounding well logs which included the Continental No. 1 Scorup in Sec. 8, T. 47 N.-R. 18 W., that a gross thickness of 3,900 feet, only 500 feet of net sand was logged (13%). They made an error in calling these sands Cutler, as there is no Cutler present in this well. They must have logged the sands of the Upper Hermosa. In the Chicago Oil Corporation well in Sec. 13, T. 47 N.-R. 18 W., they logged 870 feet of net sand thickness from a total of 3,600 feet (24%) in the Cutler. One 200 foot sand section appeared to be developed. The Union Oil Company 1-0-30 Otho Ayers in Sec. 30, T. 47 N.-R. 18 W. drilled a total of 3,646 feet of Cutler and found several well developed sands, most of which were thin. These sands do not seem to be continous over a large area and correlation is difficult. The lenticular deposition of the sands may or may not, be interconnected, so that interjection of fluids into them may have a limited areal reservoir.

Waters, in the Cutler, indicate 4,957 to 16,331 ppm of dissolved solids while closer to the La Sal Mountains, the water is influenced by the fresh water run-off, the tests show only slight salinity of 770 ppm of dissolved solids.

Summary

Of the reservoirs considered, the Mississippian - Madison, is by far the best, but the Devonian - McCracken, and the Permo-Pennsylvanian - Cutler also show possiblities as injection zones. The full areal extent of the McCracken in not fully known, in this area and the lenticular nature of the Cutler makes these two formations not as attractive as the Mississippian. Salinity of the waters is not as great in the Cutler which would make treatment more difficult.

Reservoir Storage Area

To calculate the storage area that will be influenced by the injected fluid, the porosity, permeability, and the thickness of the formation, must be determined. Using the standard formula of 1 % porosity is equivalent to a total pore volume of 77.58 barrels of void space per acre-foot of bulk volume. The bulk volume of a rock, one acre in area and one foot thick is 43,560 cubic feet.

In the case of the Continental No. 1 Scorup well, assuming there is 100 feet of 20 % porosity, about 13,000,000,000 gallons or 295,227,272 bbls, of fluid could be stored within one mile radius of the bore hole. The presence of fractures would greatly increase the available storage space. This would be true if all the space was "available" to be filled, but these pore spaces will be filled naturally with formation water. The area of influence of an injection well, under these conditions, the volume of waste that can be injected is limited to that achieved by compression of the native fluid and of the injected waste, by compression of the rock matrix of the injection zone.

From drill stem data and experience in oil field production, petroleum company geologists and engineers, have been able to predict the hydrodynamic gradient and movement of water through aquifers in enclosed basins. Injection modifies the hydrodynamic gradient and accelerates movement of interstitial liquid away from the point of injection. This movement then makes the pore space "available" to the injection water.

In the case of the Mississippian formation, to be used as a injection aquifer, with porosities of 10 to 20 % and zones of 100 to 250 feet thickness, the injected fluid will have traveled no more than 2 to 3 miles in 50 years away from the bore hole. The interstitial liquid acting in a hydralic brake for the injected fluid. The life of the reservoir will depend on how much liquid is to be injected, as well as varieables in the formation such as changes in porosity, faults, fracture systems and other local structural conditions that may channel the fluid in different directions.

WELL COMPLETION METHODS

CASE "A"

Method of Completion to 15,000 feet Into The Mississippian

The procedures to rehabilitate the Continental No. 1 Scorup - Summerville - Wilcox well in the SW SW Sec. 8, T. 47 N.-R. 18 W. into the Mississippian for brine injection are as follows:

1. Prepare location and improve road.

2. Move in drilling rig, (National 100), to set up over old hole, cut off pipe.

3. Drill out surface plug, the 24" Conductor pipe should still be in place to 16 ft. The 13-3/8" surface pipe should also be in place to 1,220 feet.

4. Drill, wash and ream hole to bottom, 15,000 ft. with 10-1/2" bit.

5. Get large scale copies of Gamma Ray-Neutron and Latrolog from old well run. Clean out hole and run Micro-Calaper, Latrolog, Density and Sonic in lower 1,600 feet of hole.

6. From log, run drill stem tests, probabley two tests, leave open long enough to get stable flow test to evaluate the reservoir charateristics of porous zones.

7. Results of test may be that deeper drilling may open up more porous zones, money allowed under contengencies would permit some additional, limited, drilling.

8. Run casing to bottom, 9-5/8" OD K-55 H-40 .352 wall. Lower 275 ft. should be slotted and gravel packed at bottom.

9. Cement casing in place with special salt treated cement, so that all of casing is cemented, except for bottom section.

10. Move off drilling rig and move on compeletion rig.

11. Hang string of tubing from well head to bottom. Tubing 3-1/2" OD N-80 .254 wall.

12. Add diesel oil to annulus to protect steel from acid water.

13. Acid treatment pumped under pressure, estimate 40,000 gals. of 28% Hydrocloric Acid.

14. Swab out acid treatment flush hole with water.

15. Pressure test hole for leaks.

16. Conduct pump-out or injectivity tests to determine capacity of well to take water.

17. Install surface pump and treatment equipment.

Well Cost - An estimated $437,170 would be needed to get the well to this point. An additional $180,000 would be needed for the surface. Table C gives a break down of these costs. A contengency factor is added in, because of so many variables as for additional testing, delays, type of acid frac job., ect. The surface equipment and treatment facilities would very as to the salinity and other chemicals needed to treat the water for injection.

Logging, Coring, Tests - Continental's Denver, Colorado Office should make available the large scale logs, detailed core analyses, drill stem test information. Samples of the water should be kept from tests.

Acid Treatment - Engineers from Service Companys can better design the correct amount of acid, pressures, and what retardents will be needed, after seeing results of logs, and tests.

Pump-Out or Injectivity Test - This test must be made to get a final determination of the capacity of the well to take water. Either type of test will provide the desired information needed. Pump-out tests require the installation of a submergeble pump and tanks or open reservoir for the pumped-out water. An injective test requires an outside pump and an adequate supply of water. This equipment can be rented. With either type of water test, the static water level should be determined when the pumping is started and any changes of the fluid level recorded.

CASE "B"

Method of Completion to 4,742 feet Into the Cutler

The procedures to rehabilitate the Union Oil Company's No. 1-0-30 Otho Ayers, in the NE SW SE of Sec. 30, T. 47 N.-R. 18 W., Montrose, County, Colorado, into the Cutler formation for brine injection, are as follows:

1. Prepare location and improve road.

2. Move in drilling rig, (National 50) to set over old hole, cut off pipe.

3. Drill out surface plug, 20" conductor pipe should be set at 147 ft. The 13-3/8" surface pipe should still be set at 2,016 ft.

4. Drill, wash, and ream to 4,742 ft. with 10-1/2" bit. Old Total depth is 14,400 feet. Set bridge plug at 4,742.

5. Clean out hole, run porosity logs from 4,742 to 1,000 ft.

6. From log, run drill stem tests estimate 5 tests to evaluate entire section.

7. If tests are positive, run steel casing to 4,742, 9-5/8" OD H-40 K-55, .352 wall, from 2160-4742.

8. Cement casing inplace.

9. Hang string of tubing from well head to bottom. Tubing, 3-1/2" OD N-80 .254 wall.

10. Perferate casing at selected porous zones.

11. Run fracture treatment, sand/water fracture.

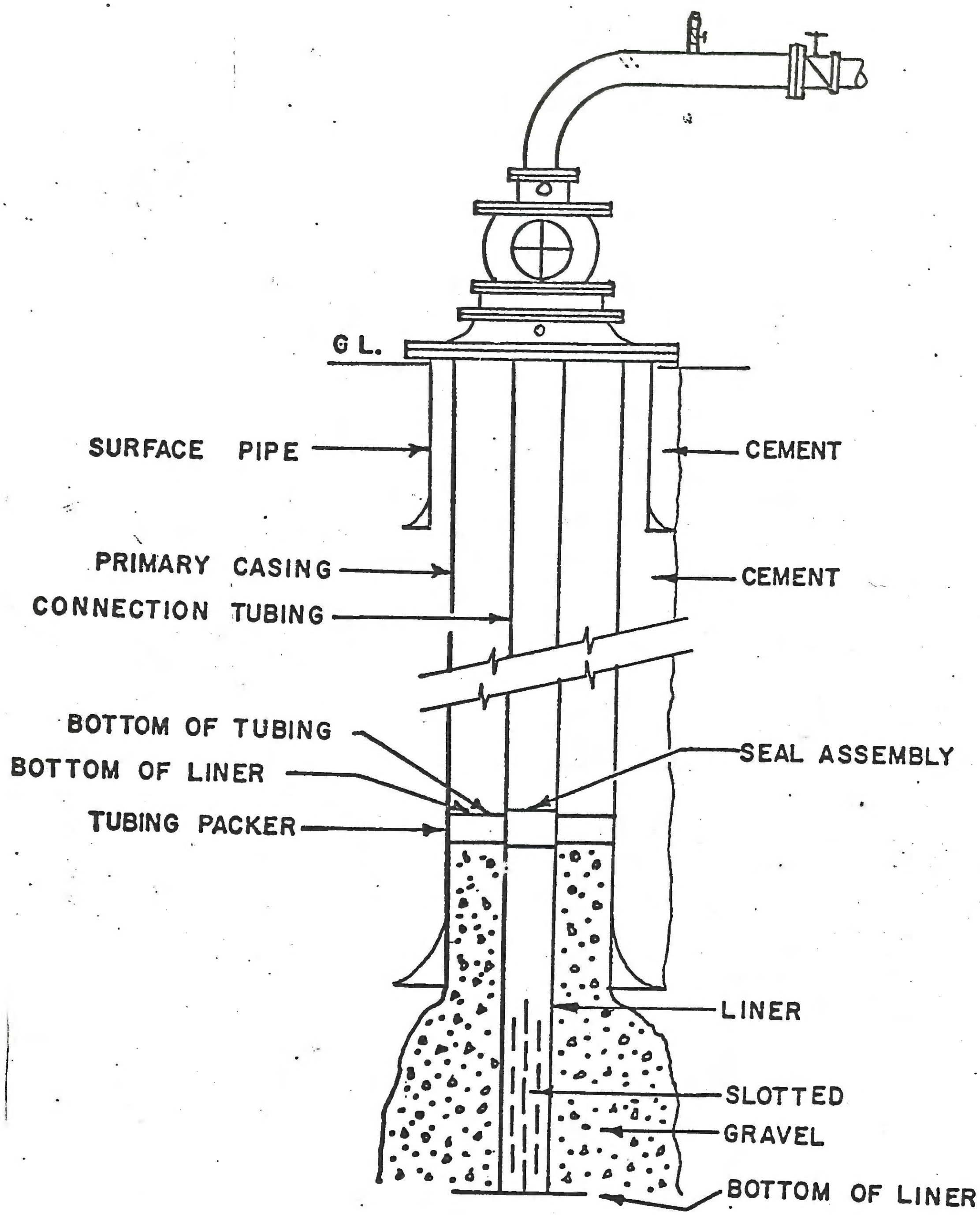
12. Swab out hole, pressure test hole.

13. Conduct pump-out or injectivity tests to determine capacity of well to take water.

14. Install surface pump and treatment equipment.

Well Costs - An estimated $172,933 would be needed to get this well to this point. An additional $180,000 would be needed for the surface equipment. Table D.

Fig. 8



SCHEMATIC DRAWING OF TYPICAL WASTE-DISPOSAL WELL gives a break down of these costs. Other recommendations as mentioned in previous case will also apply to this well.

Cost Projection

Cost of materials and services, estimated for this project were made from the best information obtained at the time of this report. In contacting drilling contractors, service companies, and suppliers, on projecting costs on a two year extension, the consensus were that a 10 per cent increase would be realistic. The sharp rise in goods and services experienced over the past two years, is felt to be leveling out and becomeing more stable.

Shared Costs

Union Carbide Nuclear Company has been concerned with the disposal of 400,000 gallons daily of acidic mill effluent containing dissolved and suspended solids and minor radioactivity materials, from their Uravan mill.

In 1962, they engaged the services of Earlougher Engineering, from Tulsa, Oklahoma, to make a study of the feasibility of using a disposal well for these waste materials. Part of this study included a test project of coring a 300 foot hole into the Cutler formation in which porosity and permebility analysis were made. This test hole was drilled in Sec. 10, T. 47 N.-R. 18 W., in Paradox Valley, about one half mile southeast of the Dolores River.

The final recommendation, of this report, was to drill a 7,500 foot well into the Cutler formation, possibly into the top of the Upper Hermosa formation, hoping to find sufficent porosity zones. Cost estimates, at that time, were $331,000 which included the surface treatment equipment.

The percent succes ratio of finding a sufficient disposal zone for; 600 GPM is 65 % to 70 %, and for 300 GPM is 80 % - 85 %.

Union Carbide's local personnel, were kind enough to make this report available, to the author, for this study. They also expressed an interest in this project of salt water disposal by deep well injection, possibly as a shared project. A combined effort of a private company and a Government Agency to jointly solve a common goal, of cleaning up the waters of the Dolores River, could be worth pursuing. The sharing of the initial costs and operations would also cut the risk factor for both parties.

The mill waste materials would take a different pre-injection treatment than the brine water, but this could be designed into the system, at some additional cost.

CONCLUSIONS AND RECOMMENDATIONS

1. In making a study of the feasibility of brine disposal by deep well injection, several schemes were investigated. It was concluded that the rehabilitation of an already exsisting, abandoned oil and gas exploration well would be the most practical.

2. Investigation of the geologic formations best suited for reservoir purposes, indicated the Mississippian formation to be the best. Secondary reservoirs could be found in the McCracken sandstone and the Cutler formation.

3. Examining the nearby wells, showed three wells within 4 miles from the source area. It was determined the Continental No. 1 Scorup, et al, SW SW Sec. 8, T. 47 N.-R. 18 W., to be the prime recommendation to be rehabilitated in the Mississippian at 15,000 feet. Estimated costs to be $437,170.

4 An alternate recommendation would be to rehabilitate the Union Oil Company No. 1-0-30 Ortho Ayers, to 4,742 feet in the Cutler formation. Estimated costs would be $172, 933.

5. Surface Treatment installations for both projects is estimated at $180,000.

Recommendations for Supplementary Studies

1. A detailed analyses of the biological and chemical properties of the injected fluid and the formation water, when it becomes available. Effects of injection fluid on the rocks of the reservoir what long range impact it may have, should also be studied.

2. Research on rates of injection and injection pressures, lithostatic pressures, and other engineering data should be investigated, to design pumping equipment.

Respectfully submitted

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CORE DESCRIPTION

OPERATOR: Continental, et al.
No. 1 Scorup - Summerville - Wilcox
Section 8, T. 47 N.-R. 18 W.
Montrose County, Colorado

TOP OF MISSISSIPPIAN FORMATION 14,726

Core #4, 14,929 - 89 Cut 60', Recovered 60'

14,929-30	1'	Dolomite, dark gray, fine grained, vertical fractures, coated with anhdrite.
14,930-39	9'	Limestone, dolomitic in streaks, gray crinodial, fine to medium grained, pellitoid in part (10%), vuggy porosity, appears wet, very scattered hairline fractures throughout.
14,939-42	3'	Dolomite, (limey streaks), dark gray, fine grained, vuggy porosity, scattered brachiopods, scattered vertical fractures.
14,942-45	3'	Limestone, light gray to gray, fine to medium crystalline, crinodial, pellitoid in part (5%), with white anhydrite inclusions, scattered vertical fractures, styolites.
14,945-48	3'	Dolomite with gray limey streads, (dark gray), fine crystalline, crinoidal, vuggy porosity, limey streaks to coarse. 1/8" to ½" band of white chert @ 46½'.
14,948-56	8'	Limestone, gray, medium to coarse crystalline, crinodial, pellitoid (30 to 60%), well developed vertical fracture 49'-51', and 54'-55' coated with anhydrite.
14,956-65	9'	Dolomite, dark gray, fine crystalline, (with light gray limey streaks), fine to medium crystalline, vuggy porosity, fossiliferous (brozoan, crinoids), scattered vertical fractures throughout.
14,965-68	3'	Limestone, gray, fine to medium crystalline, crinoidal, finely pellitoid (25%, more or less) scattered irregular fractures - 45° to vertical.

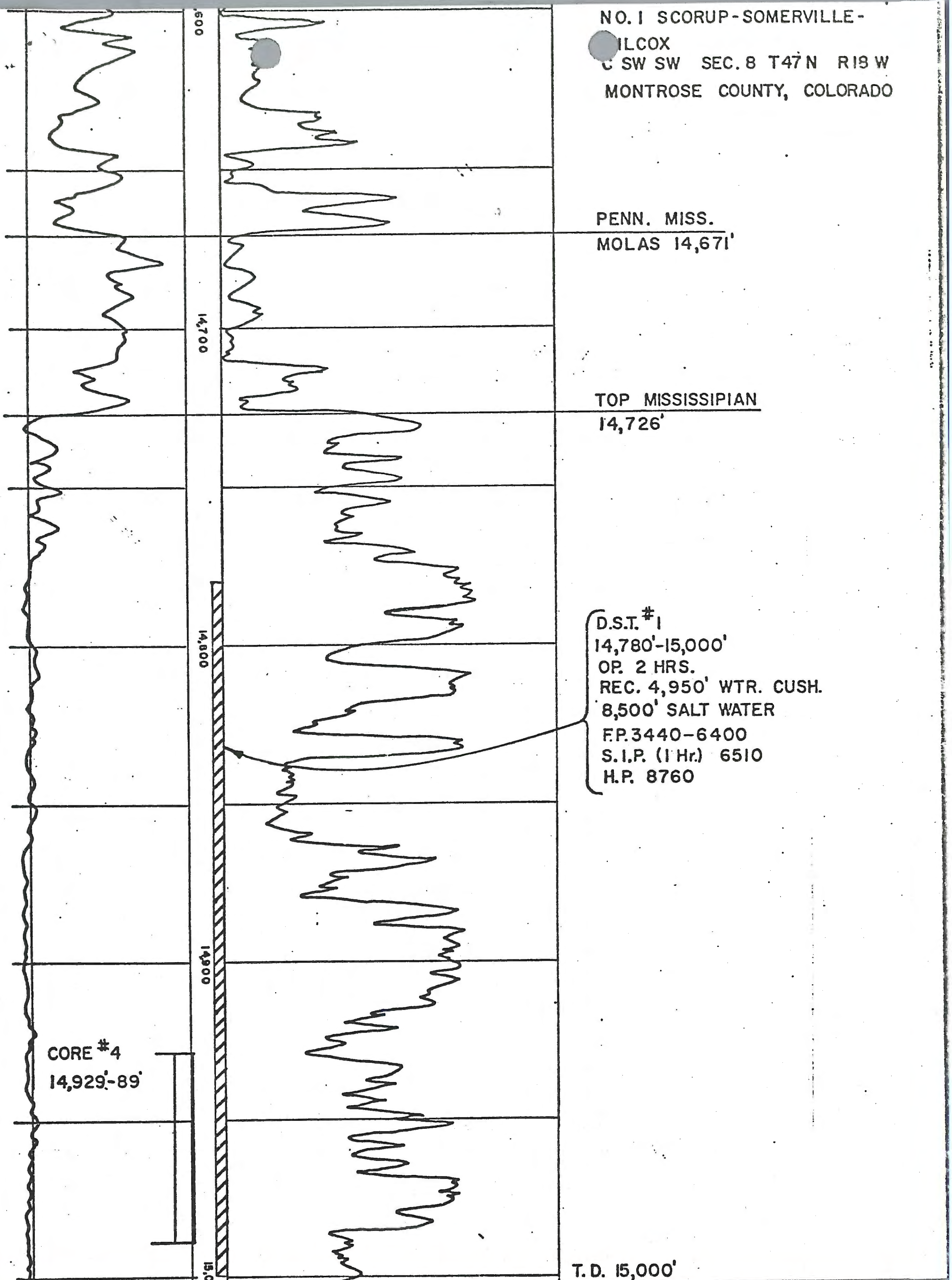
NO. 1 SCORUP-SOMERVILLE-
WILCOX
C SW SW SEC. 8 T47 N R18 W
MONTROSE COUNTY, COLORADO
600
PENN. MISS.
MOLAS 14,671'
14,700
TOP MISSISSIPIAN
14,726'
14,800
D.S.T. #1
14,780'-15,000'
OP. 2 HRS.
REC. 4,950' WTR. CUSH.
8,500' SALT WATER
F.P. 3440-6400
S.I.P. (1 Hr.) 6510
H.P. 8760
14,900
CORE #4
14,929'-89'
15,0
T.D. 15,000'

TABLE B

EXAMPLES OF BRINE ANALYSES

MISSISSIPPIAN WATER SAMPLES

Humble No. 1 Rustler Dome, Sec. 4, T. 29 S.-R. 20 E.
San Juan County, Utah, Miss. 4905 - 5076

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

Superior No. 22-34 Salt Wash, Sec. 34, T. 22 S.-R. 17 E.
Grand County, Utah, Miss. 10,053 - 10,173

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	1.18

Superior No. 14-5 Bowknot, Sec. 5, T. 26 S.-R. 17 E.
Emery County, Utah, Miss. 6270 - 6350

Barium	0 ppm
Bicarbonate	146
Calcium	240
Chloride	171,820
Iron	1,004
Sodium	110,004
Sulfate	240
Total Solids	283,720
pH	5.0

MISSISSIPPIAN WATER ANALYSES
Cont.

Superior No. 14 - 24 Grand Fault, Sec. 24, T. 21 S.-R. 15 E.
Emery County, Utah, Miss. 9555 - 9652

Barium	0 ppm
Calcium	3,120
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. 1, Smoot, Sec. 17, T. 23 S.-R. 17 E.
Grand County, Utah Miss. 8785 - 8876

Bicarbonate	951 ppm
Calcium	2,865
Chloride	190,640
Magnesium	1,801
Sodium	119,418
Sulfate	4,320
Total Solids	324,656
pH	6.0
Specific Gravity	1.14

Pure Oil Company, No. 2 Big Flat, Sec. 14, T. 26 S.-R. 19 E.
Grand County, Utah Miss. appox. 7,200 feet.

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

ESTIMATED TOTAL COSTS TO REHABILITATE THE CONTINENTAL NO. 1 SCORUP WELL

Total Depth - 15,000 feet to Mississippian, Cased Hole

Entering Old Hole, Testing and Completing

Drilling Rig, 10 days	$ 30,000	
Workover Rig, 10 days	10,000	
Prepare Location, road work	2,000	
Steel Casing, 13,780 ft. 9-5/8" OD H-40	101,420	
Tubing, 15,000 ft., 3-1/2" OD H-40	194,250	
Run and Cement Casing	50,000	
Logging and Drill Stem Tests (2)	3,000	
Acid Treatment - Fracturing	40,000	
Engineering Supervision	3,500	
Pump Out Testing	3,000	
Sub Total		$437,170

Surface Equipment and Installation

Pump, Separator, Sump, Filters, Tanks, Piping, ect.	$125,000	
Site Preparation, Buildings, Distribution Pipe	53,000	
Sub Total		$180,000
Contengencies 15 per cent		92,575
Grand Total		$709,745

TABLE D

ESTIMATED TOTAL COSTS TO REHABILITATE

THE

UNION OIL COMPANY NO. 1-0-30 ORTHO AYERS

Total Depth - 14,400 feet to the Devonion,
To Set Bridge Plug at 4,742 feet to Complete in the Cutler.

Entering Old Hole, Testing and Completing

Drilling Rig, 15 days	$ 37,500	
Prepare Location, road work	2,000	
Steel Casing, 2,585 ft. 9-5/8" OD H-40	19,025	
Tubing, 4,742 ft. 3-1/2" OD H-40	61,408	
Run and Cement Casing	9,000	
Logging and Drill Stem Tests (5)	8,000	
Perferating, Fracturing (sand/water)	30,000	
Engineer Supervision	3,000	
Pump Out Testing	3,000	
Sub Total		$172,933

Surface Equipment and Installation

Pump, Separator, Sump, Filters, Tanks, Piping, ect.	$125,000	
Site Preparation, Buildings, Distribution Pipe	53,000	
Sub Total		$180,000
Contengencies 15 per cent		52,940
Grand Total		$405,873

TABLE E

PERSONAL CONTACTS

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