Prepared for:

U.S. Department of Interior

Bureau of Reclamation

Contract Number 3-CS-40-0146A

# Geophysical Interpretation of Seismic Data

# Paradox Valley Unit

By

Lewis J. Katz
Richard Carroll

July 1984

UTAH GEOPHYSICAL, INC.
Salt Lake City, Utah

## ENCLOSURES

Site Selection Base Map

Top of Cutler Formation Structual Map

Top of Paradox Salt Structual Map

Top of Mississippian Formation Structual Map

Isopach - Paradox Salt to Mississippian

Isopach - Mississippian Formation

Cross-Section A - B

Cross-Section A - C

# INTRODUCTION

Utah Geophysical, Inc. (UGI), under contract to the U. S. Bureau of Reclamation (BOR) has interpreted seismic reflection data for the Paradox Valley Region (Figure 1), Montrose County, Colorado. Based on this interpretation recommendations have been made for the selection of the best available sites for brine injection wells.

The Bureau of Reclamation commissioned this study as part of an effort to reduce the inflow of brine springs to the Dolores River. This has been identified as one of the major sources of salinity in the Colorado River Basin. Brine water presently seeping in along the banks and bottom of the Dolores River would be collected by pumping it from existing wells along the river, and transported by pipeline to the injection well site. There it would be pumped into a natural reservoir provided by the Mississippian Leadville formation.

Using seismic and well log data provided by the BOR, and supplemented by well log data obtained directly by UGI, the necessary geophysical interpretations were made.

Two-way time maps were produced from the seismic data, and velocity maps for the region were generated from well log data. This information was then combined to produce structural maps showing the tops of the Paradox Salt and Mississippian Formations. In addition a structural map showing the top of the Cutler Formation, two cross-sections, and Isopach maps of the Parodox Salt to Mississippian and the Mississippian Formation, were made.

From this interpreted geophysical data appropriate well sites meeting the BOR's criteria were recommended. In addition to the above structural maps, a "Well Site Selection Base Map" summarizing results was produced. This map shows the locations of recommended well sites, the position of cross-sections, and other site related information.

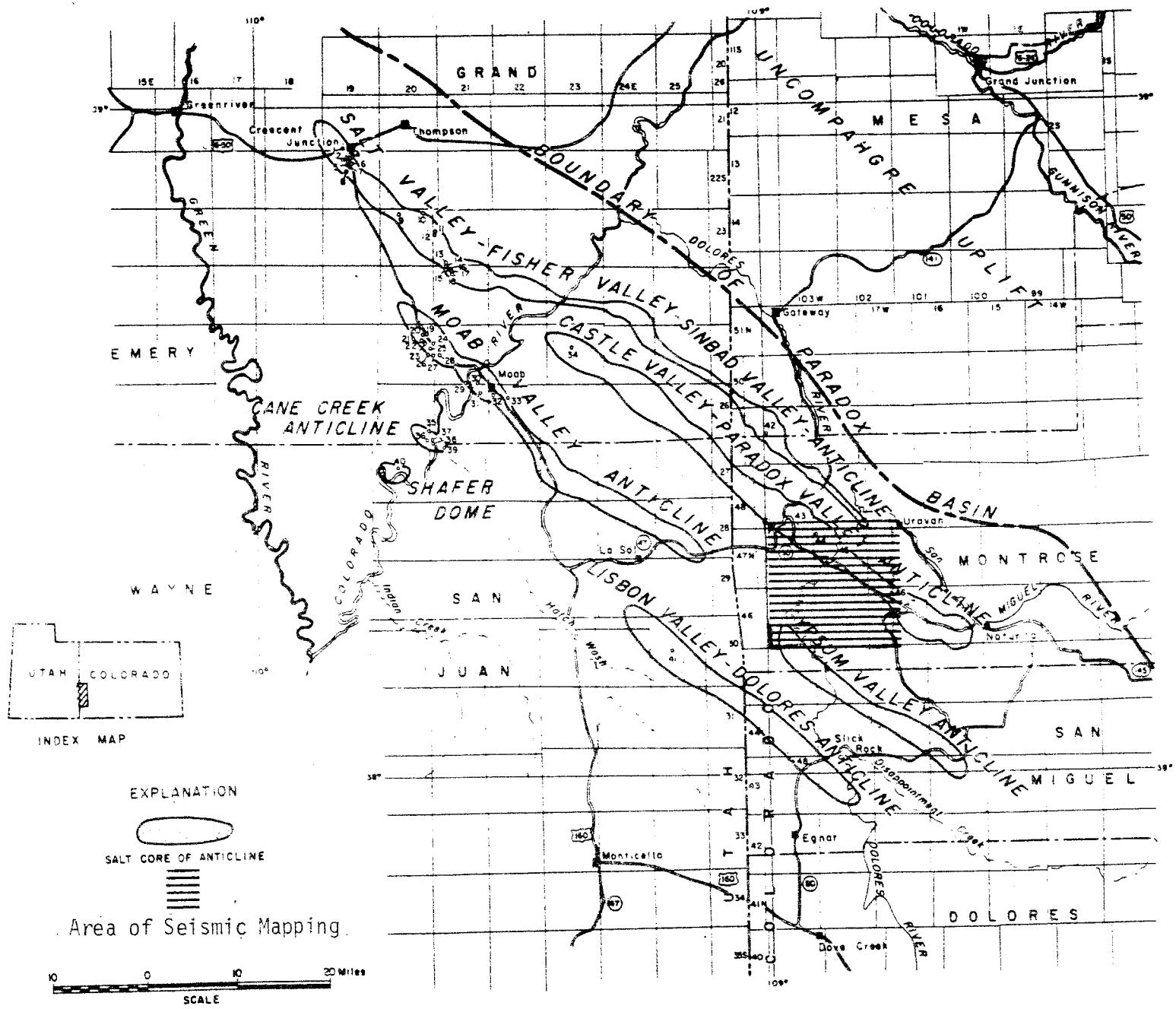



Figure 1, Location Map of reported area.

## LOCATION AND REGIONAL GEOLOGY

The Paradox Valley area of this report is located within the salt anticline region of the Paradox Basin of Southwestern Colorado. The Paradox Valley is underlain by a salt anticline with up to 20,000 ft. of interbedded salt and shales of the Paradox Formation (Penn.). Overlying beds have either not been deposited or eroded to form the present day valley.

The stratigraphy is summarized in Table I (Parker, 1981). Underlying the Hermosa Formation is the Mississippian Leadville Formation. It is composed of vuggy fractured limestone and dolomite. Although the effective porosity only averages 6%, widespread fracturing has significantly enhanced permeability to make it a reservoir of excellent deliverability. Late Mississippian faulting partially or completely eroded the Mississippian on the upthrown side of many fault blocks. The Mississippian thickness varies from 0 to 350 ft. It is likely that porosity and fracturing will increase with proximity to faulting on the upthrown side. A study of the prolific Lisbon oil field, 20 miles to the Southwest, could provide useful information about the Leadville Formation reservoir quality and anticipated injection rates.

The overlying Middle and Lower Hermosa of Pennsylvanian age is characterized primarily by the Paradox Salt Member. While this unit was deposited originally with a uniform thickness, subsequent overloading of Permian Cutler clastics caused the salt to flow and thus now have a thickness that varies from 0 to 12,000 ft. The Upper Hermosa Honaker Trail Formation roughly parallels the top of the Paradox Salt and marks the end of limestone deposition in a marine environment. The uplift of the ancient Uncompahgre of Permian times brought Cutler clastic wedges of sandstones, mudstone and conglomerates which vary in thickness from 500 to 5000 ft. thick. The Paradox Valley salt anticline formed at this time. Modern day surface structure dates from this time.

The rocks exposed at the surface include the cliff forming sandstones of

**TABLE I STRATIGRAPHY OF LISBON FIELD AREA**

| *Age* | *Formation* | *Lithologic Description* | *Thickness (ft)* |
|---|---|---|---|
| Upper Cretaceous | Mancos | Gray marine shale. | 500 + (top not exposed in area) |
| | Dakota | Open-marine to shoreline and stream-channel sandstone, conglomerate, shale, mudstone, and coal. | 200 |
| | (unconformity) | | |
| Lower Cretaceous | Burro Canyon | Lagoonal, shoreline, stream-channel, and mud-flat sandstone, conglomerate, and variegated mudstone. | 200 |
| Upper Jurassic | Morrison | Variegated mudstone, sandstone, and thin limestone beds. Brushy Basin unit at top (225 ft ±) contains mostly mudstone and Salt Wash unit at base (325 ft ±) contains more sandstone. | 550 |
| | Summerville | Mudstone and sandstone. | 130 |
| | Entrada | Cross-bedded sandstone. | 130 |
| Upper and Middle Jurassic | Carmel | Siltstone and sandstone. | 75 |
| | (unconformity) | | |
| | Navajo | Cross-bedded sandstone. | 100–300 |
| | Kayenta | Fine-grained sandstone. | 75–250 |
| Upper Triassic | Wingate | Cross-bedded sandstone. | 300 |
| | Chinle | Sandstone, conglomerate, and mudstone. Shinarump sandstone and conglomerate unit at base. | 400–700 |
| | (unconformity) | | |
| Middle (?) and Lower Triassic | Moenkopi | Mudstone, siltstone, and fine-grained sandstone. | 0–550 |
| Permian | Upper Cutler | Conglomerate, siltstone, mudstone, arkosic sandstone, local chert and limestone. | 550–4,500 |
| | (unconformity) | | |
| | Lower Cutler | Mudstone and sandstone. | 500–800 |
| Pennsylvanian | Honaker Trail (Upper Hermosa) | Gray fossiliferous, marine limestone, interbedded with sandstone, siltstone, mudstone, and gray shale. Fewer red arkosic sandstone beds in basal part. | 1,600–1,900 |
| | Upper Paradox | (Ismay carbonate cycle of Four Corners area.) Dolomite, siltstone, gray to black shale, anhydrite. | 325–400 |
| | Middle Paradox | Salt with thin beds of black shale, anhydrite, siltstone, and a few earthy dolomite beds. | 500–8,000 |
| | Pinkerton Trail (Lower Hermosa) | Dolomite and limestone, gray-brown, dense, some gray dolomitic siltstone, thin anhydrite beds, some chert in the limestone. Thin gray-green and dark gray shales. | 15–170 |
| | Molas | Shale, red-brown, gray, green, purple, silty and sandy | 20–60 |
| | (unconformity) | | |
| Mississippian | Leadville | Dolomite and limestone. | 330–500 |
| Devonian | Ouray | Limestone. | 70–130 |
| | Elbert | Dolomite, gray-brown, interbedded with green shale. | 100–160 |
| | McCracken | Sandstone and sandy dolomite. | 70–140 |
| | Aneth | Dolomite, glauconitic with siltstone partings. | 200 ± |
| | (unconformity) | | |
| Upper Cambrian | Lynch | Dolomite. | 200 ± |
| Middle and Lower Cambrian | Ophir | Shale, gray, green; siltstone, tan. | 125 ± |
| | Tintic | Gray-green shale and siltstone at top, grading downward to red, pink, and buff coarse-grained sandstone. | 400 ± |
| | (unconformity) | | |
| Precambrian | | Granite, pink. 30% quartz, 60% feldspar, 10% biotite. | |

the Triasic-Jurassic Glen Canyon Group - Navajo, Entrada, Kayenta and Wingate. They are overlaid on the highest mesas by the Morrison (Jur.) and Dakota (Cret.) formations, the youngest rocks remaining after Larimide uplift (early tertiary) and erosion. All these formations are roughly parallel to the top of the Cutler Formation.

## DATA BASE

The structure maps included in this report were made based on the integration at seismic data and well control.

Two vintages of seismic lines were incorporated. Lines 136,131,103,340, 135,102,347,197,225,127,286,132,130,137 and 129 were acquired by Empire Geophysical for Union Oil in 1961. The data was recorded on analog tape. A single shot of 65 lbs. of dynamite at a denth of 65 ft. was recorded for each geophone spread. Twenty four geophone stations(traces) were laid over ½ mile with the shot in the center. This pre-modern method of recording resulted in 100% fold data. Western Geophysical reprocessed the data in 1984 for the BOR. The analog data was converted to digital and reprocessed to modern seismic industry standards. The data quality depended on both the medium the shot hole was drilled in and the subsurface geology. Areas of extreme salt expansion such as found in Twp 46 and 47 N. and Rge. 18 W. caused deterioration of data quality due to distortion of the seismic rays. Also, areas overlain by unconsolidated material such as in the valley bottoms deteriorated data quality. The lines shot on Wild Steer Mesa in Twp 46 N. and Rge. 17 W. are of excellent quality.

The second set of seismic data incorporated in this report were lines recorded by Seisport Exploration for Target Geophysical. They were recorded in a portable mode incorporating the use of helicopters. This is an expensive method of acquisition that is used to overcome extreme topographical relief. The data was recorded in 1982 using a portable dynamite source. Ninety-six geophone stations were laid out with a geophone station interval at 165 ft. Every 600 ft. a shot was recorded from the center of the spread in order to achieve 1200% fold. This means that each subsurface point is recorded from 12 different shot and station locations. The resultant 12 traces are averaged or "stacked" to enhance data quality. This compares with one shot for each subsur-

face point for the older Union data. The quality of the data varies from poor to good. The data quality worsens on Line 8 as it approaches the Shell #2 Unit well because of the distortion of the ray paths through the salt dome. The South two miles of line 204 is of poor quality because of unconsolidated sandstones and rough topography. Otherwise the data was good.

## DATA INTERPRETATION

Because two different sets of data were used in this study pre-interpretation preparations were needed. A base map was prepared on a scale of one inch to 2000 feet showing the shotpoint locations for both sets of data. Well locations were also plotted on this map.

The Target data was processed using a datum plane of 7500 ft. compared to 6500 ft. for the Western Geophysical data. The Target data was adjusted to a 6500 ft. datum using a 10,000 f.p.s. datum velocity. This provided a uniform 6500 ft. datum throughout the study. The seismic sections were marked to show locations of well ties and cross ties with other lines.

In order to properly identify reflectors on the seismic records with geologic units reported from wells synthetic seismograms were produced. Synthetic seismograms were generated for the Shell Unit #1 and #2, Union Oil and Jack Grynberg wells. Target Line 8 was tied to Shell Unit #1 and #2 wells using the synthetics. Sonic logs used to produce the Shell and Pure Oil well synthetics were obtained by UGI directly, and proved necessary for the interpretation. The other logs were supplied by BOR.

Using the synthetic seismograms the tops of the Hermosa (Honaker Trail), Paradox Salt, and Mississipian Formations were picked for Line 8. These were then traced for the entire line and cross tied to Line 208A. Using the Union Oil well for further control the respective reflectors were picked and tied on all lines. The reflection times at each shotpoint, for each reflector were hand digitized and entered into a computer. Computer generated two-way travel time maps were produced for the tops of the Paradox Salt and Mississippian Formations.

To convert these time structure maps to depth structure, it was necessary to first make an average velocity map to the top of the salt. This was achieved by obtaining velocity information from well logs. These velocity values were

entered into the computer for each shotpoint. They were then applied to the previously entered time values of the top of salt reflector. This produced a depth above mean sea level map for the"Top of Paradox Salt".

Using the computer, the travel times to the "Top of Mississippian Formation" was substracted from the times for the "Top of Paradox Salt" to generate a time isochron of the Salt Formation. These values were then multiplied in the computer at each shotpoint by the appropriate salt velocites to produce a thickness of salt isopach. These isopach values were subtracted from the previously determined "Top of Paradox Salt" depth values to produce a "Top of Mississippian" structure map. The Paradox Salt Unit mapped in the isopach typically contains interbedded shales and should not be construed to be a massive salt bed. It also contains the Pinkerton Trail-Molas formations found at the base of the salt. These are thin beds usually less than 100' thick. Referring to the strategraphic column of Table 1, this unit would begin at the Middle Paradox and extend through the Molas. The unconformity found at the top of the Leadville Formation was used to map the "Top of Mississippian Formation".

The Cutler reflector was not discernable, therefore, the Cutler structure map is based primarily on surface structure and well control. In this case a surface map of the Entrada was produced. The depth of the Cutler below the Entrada was determined from well control. Using this depth difference, the Cutler structure was mapped.

It was not possible to resolve the thickness of the Mississippian Leadville from the seismic data. The Mississippian Leadville isopach was made from well control and structural elevation changes of the Leadville Formation. The Shell Unit #1 and #2 wells show the base of the salt to be above -4000 ft. and that the underlying Mississippian Leadville Formation to be eroded at this elevation. Whereas, the nearby Pure Oil Wray Mesa #3 shows the presence of Mississippian

Leadville at -4571 ft. Based on these observations, it has been assumed that whenever the Mississippian Leadville structural elevations exceeded approximately -4200 ft, the Mississippian was eroded as was noted in the Shell wells.

An approximate east-west striking fault crosses line 204 in Section 6, T.46N., R.18W. This fault occurs in a area of salt swelling. A thicker salt section of lower velocity material than the underlying Mississippian Formation could cause a time delay that would appear as a fault in the seismic sections. It is possible, but unlikely, that this fault is not present but was a result of salt swelling.

The fault north of the previous one and between proposed well sites 1 and 2 is shown on Cross-Section A-B truncated in the salt. A surface geology map (Withington, 1955) does not indicate surface faulting at this location. However, the change in course of the Dolores River and the presence of Wild Steer Canyon may be surface expressions of this fault. Preliminary observations of formation displacements in Wild Steer Canyon by UGI appeared to indicate offset. West of the Dolores River the fault may die out in the salt swell, whereas, east of the river it may be present in the absence of any significant salt deposits at depth. However, it is recommended that a qualified geologist visit the site and structurally map the area to determine if any surface expression of this fault exists.

Two cross-sections were produced. The location of these cross-sections are shown on the well site base map. These positions were chosen after consulting with BOR personnel. They were selected because they transverse previous and proposed well sites. Both cross-sections are truncated at the Conoco Well site. Cross-Section A-B transverses the Dolores River Gorge and encompasses proposed Well Sites 1, 2, 3, 6 and 7. Cross-section A-C crosses Wray Mesa and includes Well Sites 4, 5 and 6.

## WELL SITE SELECTION:

Selection Criteria:

The well sites were selected and ranked using the following criteria:

1. Reservoir properties. The injection reservoir should have significant porosity.

2. Salt Thickness: The thickness of salt being kept to a minimum but being at least 250 ft. thick to provide a confining barrier.

3. Depth to Mississippian Leadville: Locating a site with a minimum depth to the Mississippian Reservoir to reduce drilling costs.

4. Surface logistics: Elevation closest to 4950'.

5. Confidence in data interpretation.

6. Access: Locating a site that could be easily accessed.

7. Distance from withdrawal wells to injection site.

Ranking:

The following 7 well sites are listed in order of preference from first to last. The preferred region for siting a well lies within the Dolores River Gorge, north of Well Site #2, as shown on the Site Selection Base Map enclosed. West of Well #2 the salt thickens appreciably. Wells 1, 2 and 3 are located within this region. Well #1 was given the highest priority since it twins the Union Well and thus has known characteristics. Well #2 has a thicker salt section, but it occurs in a separate fault block from Wells 1 and 3. Thus, it may provide additional reservoir capacity if additional wells are needed. Well #3 was ranked third because it lies close to faulting which may cause drilling problems. Also, the salt section thins in this area and may not be present in the thicknesses required, although the Lower Hermosa shales should provide a reservoir seal. Well #4 should be quite similar to Well #3.

Well #5 differs from the other sites in that the targeted reservoir is the Honaker Trail-Upper Hermosa sands. This site is at a higher elevation and greater distance than the other wells, but is presented as an alternative to the deeper Mississippian reservoir. Wells #6 and 7 are considerably less desireable than the first four choices. Well #6 has a thick salt section that

makes drilling expensive. Well #7 is more distant and at a higher elevation making access more difficult.

An evaluation of each well site is stated in the following pages.

WELL #1 (First Choice):

Location: T.47 N., R.18W., SWSE Section 30 (Previous Union Oil Site)

Elevation: 5030'
Elevation Change to Withdrawal Site: +80'
Distance to Withdrawal Well: 19000'
Depth to top of Salt: 13,781'
Depth to top of Mississippian: 14,042'
Mississippian Thickness: 342'
Salt Thickness: 270'
Reservoir Quality: good
Top of Salt to Mississippian 864'

Comments:

This location twins the Union Oil Co. #1 Ayers. It is desireable because the geology is known from the previous drilling and, thus, it has been established that the above parameters are present. A drill stem test of the Mississippian recovered 6680' of salt water after a one hour flow period in which flowing pressures increased from 2558# to 5318#. In addition the distance and accessability to the withdrawal sites is excellent. It is recommended that a well twining this location be 600 ft. or closer to the present well site to stay within the same geologic section.

WELL #2

Location: T.47N., R.18W., NWSE Section 31

Elevation: 5050'
Elevation Change: +100'
Distance to Withdrawal Well: 24,000'
Depth to Salt: 10,250'
Depth to Mississippian: 12,450'
Salt Thickness: 1400'
Mississippian Thickness: 300'
Reservoir Quality: probably good
Top of Salt to Mississippian: 2200'

Comments:

This site has good accessibility to the withdrawal wells with minimum elevation change. The Mississippian is at least 1600' shallower than the #1 site. The salt section however is considerably thicker. Because of a deterioration of the salt reflector on the seismic sections, an alternative interpretation is possible. This interpretation would provide for a thicker salt section but would result in a shallower Mississippian depth by up to 1000'.

WELL #3

Location: T.47N., R.18W., NENE Section 30

Elevation: 5050
Elevation Change: +100
Distance to Withdrawal Well: 15000'
Depth to Top Salt: 13450'
Depth to Top of Mississippian: 13850'
Salt Thickness: 250'
Mississippian Thickness: 300'
Reservoir Quality: probably good
Top of Salt to Mississippian: 400'

Comments:

This site is attractive from the standpoint of its proximity to the withdrawal wells and minimum elevation change. There may be less salt section than the 270' of salt encountered by the Union Well (Well #1) located approximately 3/4 of a mile south. However, the lower Hermosa shale that should be present would likely form an adequate seal for the Leadville Formation. The reservoir quality should be similar to that found in the Union Well. In addition, faulting occurring approximately a ¼ mile to the northeast may enhance reservoir quality by fault associated fracturing. Shallow faulting at this site may cause loss circulation when drilling the first few thousand feet.

WELL #4

Location: T.47N., R.19W., NWSE Section 14

Elevation: 5350'
Elevation Change: +400'
Distance to Withdrawal Well: 21,000'
Depth to Top of Salt: 12950'
Depth to Top of Mississippian: 13350'
Salt Thickness: 200'
Mississippian Thickness: 300'
Reservoir Quality: probably good
Top of Salt to Mississippian: 400'

Comments:

This location is on strike to Well #3 and shows similar characteristics. The surface elevation of this well is slightly higher than that of Well #3, but the depth to the Mississippian is likely a few hundred feet less. Both wells are estimated to have about 200 feet of salt but this interpretation is speculative since the wells are located in an area of salt evacuation (thinning). In the absence of any salt at these locations, the lower Hermosa shales should provide an adequate reservoir seal. Shallow faulting may cause loss circulation when drilling the first few thousand feet. The deeper faulting may enhance the Mississippian reservoir properties.

The interpretation at this site is more uncertain since it is located 3/4 of a mile from the nearest seismic control. However, the geologic characteristics are believed to be similar to that at Well #3.

WELL #5 (Honaker Trail Reservoir) Shell Oil #2 Wray Mesa Unit

Location: T.47N., R.19W., NENW Section 32

Elevation: 6982'
Elevation Change: +2032'
Distance to Withdrawal Well: 43,000'
Depth to top of Salt: 7033'
Depth to top of Mississippian: Eroded
Salt Thickness: 3026'
Mississippian Thickness: 0
Top of Cutler: 4042'
Reservoir Quality: good for Upper Hermosa lower Cutler sands-Top 4600'

Comments:

This location twins the Shell Oil #2 Wray Mesa Unit well. This location is recommended only because of well developed lower Cutler and Upper Hermosa sands beginning at a depth of 4600'. Logs indicate approximately 300' of clean sand development. Permeability is indicated by the fact that Shell apparently lost circulation while drilling through the zone. Other indications are the lack of resistivity differences between deep and shallow resistivity tools on the logs. These sands were not tested (DST).

Anomalously high porosity indicated by the sonic log at the top of the sands may be due in part to a gas effect. Therefore, there is a possibility of encountering gas in this reservoir.

The clean sand development should roughly follow the axis of the Salt Swell encountered by the Shell #2 Unit well. The extend of this reservoir is therefore estimated to follow the 2400' contour on the Salt Isopach map. It is likely that the salt began to influence structure as earlier as Honaker Trail time. Therefore, clean sands deposited in a shallow fluvial deltaic environment cleaned up on slightly positive features resulting from salt swelling.

The negative aspects of this site are its distance and elevation difference from the withdrawal wells. The attraction are its depth to the Honaker Trail reservoir and the porosity that is possibly there, although, the reservoir has not been tested.

WELL #6 (Conoco Well Site):

Location: T.47N., R.18W., SWSW Section 8

Elevation: 5062'
Elevation Change: +112'
Distance to Withdrawal Well: 8000'
Depth to Top of Salt: 3440'
Depth to Top of Mississippian: 14760'
Salt Thickness: 11231'
Mississippian Thickness: 250'
Reservoir Quality: excellent
Top of Salt to Mississippian: 11320'

Comments:

This location twins the Conoco Well. This well had excellent porosity. On a DST of the Leadville Formation 8500' of salt water was recovered after a two hour flow period. Flowing pressure increased from 3440# to 6400#. This site is the closest location to the withdrawal site with known reservoir and geologic properties. The disadvantage of this site is its thick salt section (11,231'). Salt tends to flow at depth which makes drilling very difficult and expensive. Also, the Mississippian at this site is deeper than any of the other recommended sites.

WELL #7

Location: T.47N., R.18W., NWNW Section 7

Elevation: 6500'
Elevation Change: +1550'
Distance to Withdrawal Well: 32,000'
Depth to Salt: 11,200'
Depth to Mississippian: 12,200
Salt Thickness: 1000'
Mississippian Thickness: 350'
Reservoir Quality: probably good
Top of Salt to Mississippian: 1000'

Comments:

This location is characterized by a reasonable Salt thickness and depth to Mississippian. The seismic data quality is good in this location which adds reliability to the interpretation. However, the distance and elevation difference from the withdrawal wells makes this our last choice.

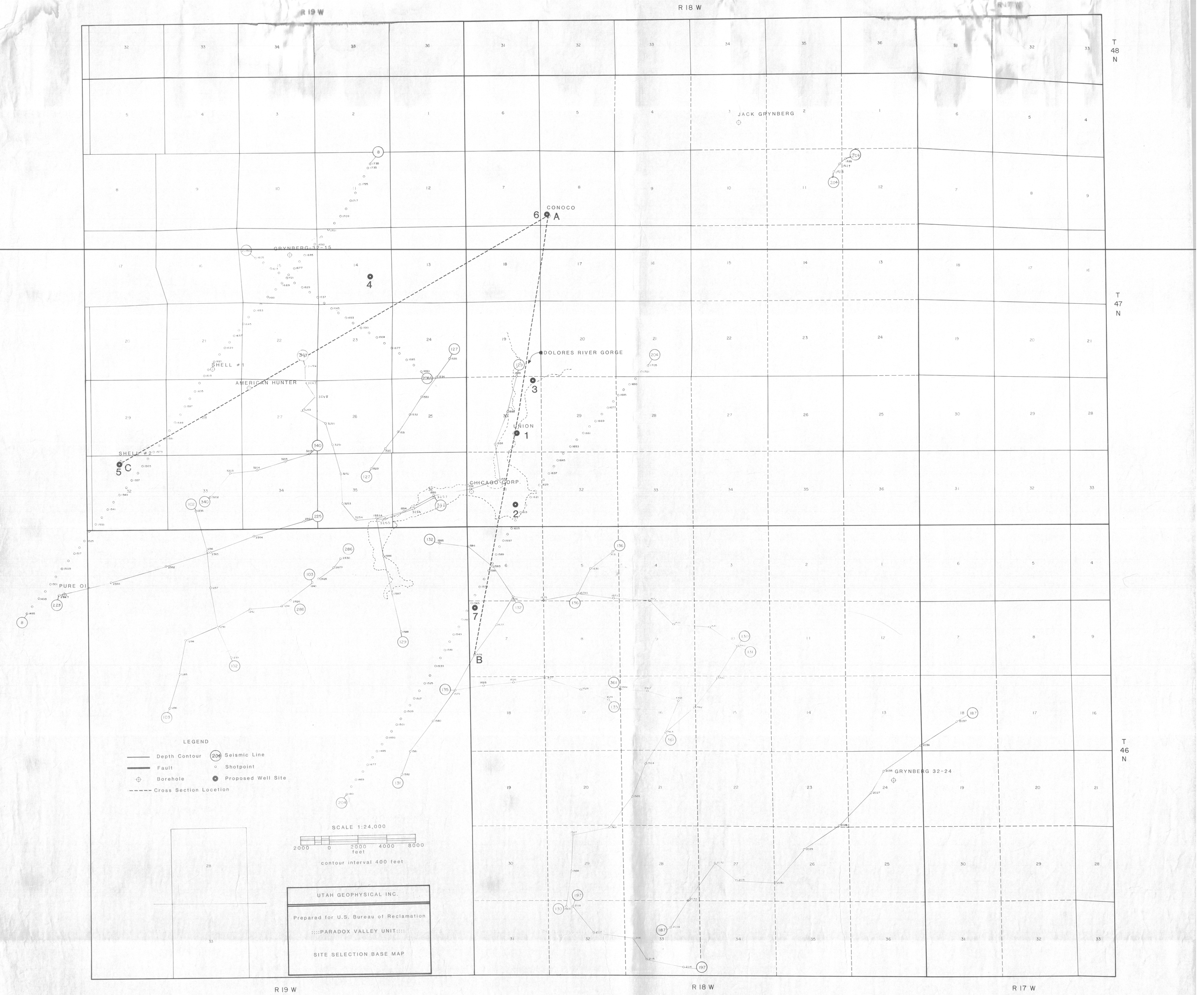
## CONCLUSIONS

Seismic data has been used by the oil industry to select well sites for years. It makes good sense for BOR to use this same technology to site their wells. This is especially true when the data is readily available on a shared cost basis as was the case here. Although, this was not the best data quality area, the information extracted should prove worthwhile in siting and reducing drilling costs of the injection wells. The data also provided insight into the location of faulting that may either enhance or limit reservoir quality. This information is also useful in informing the engineers of possible drilling problems.

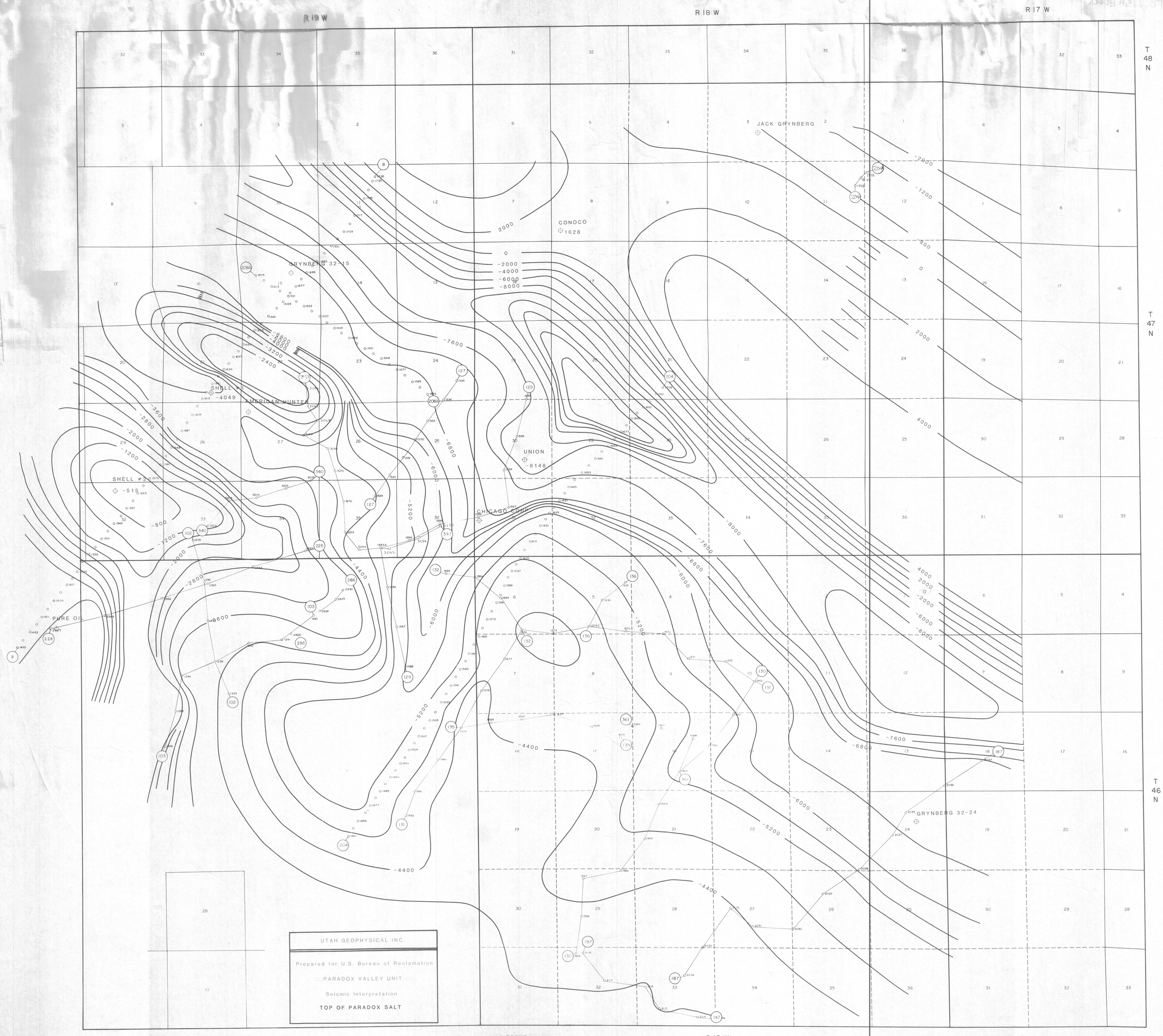
## REFERENCES

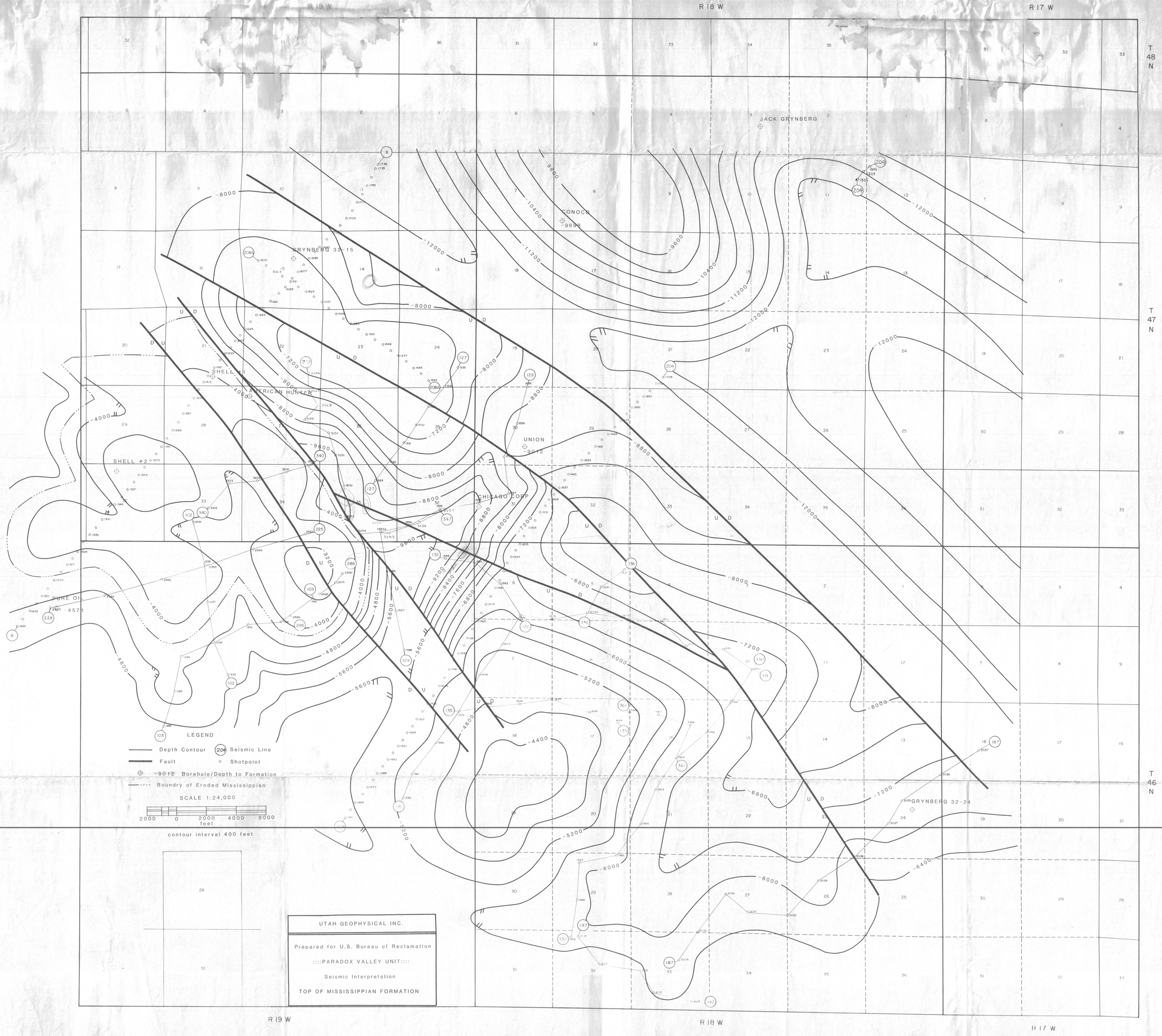
Parker, J. M. (1981). Lisbon Field area, San Juan County, Utah, Guidebook Geology of the Parodox Basin, published by Rocky Mountain Association of Geologists, Denver, Colorado

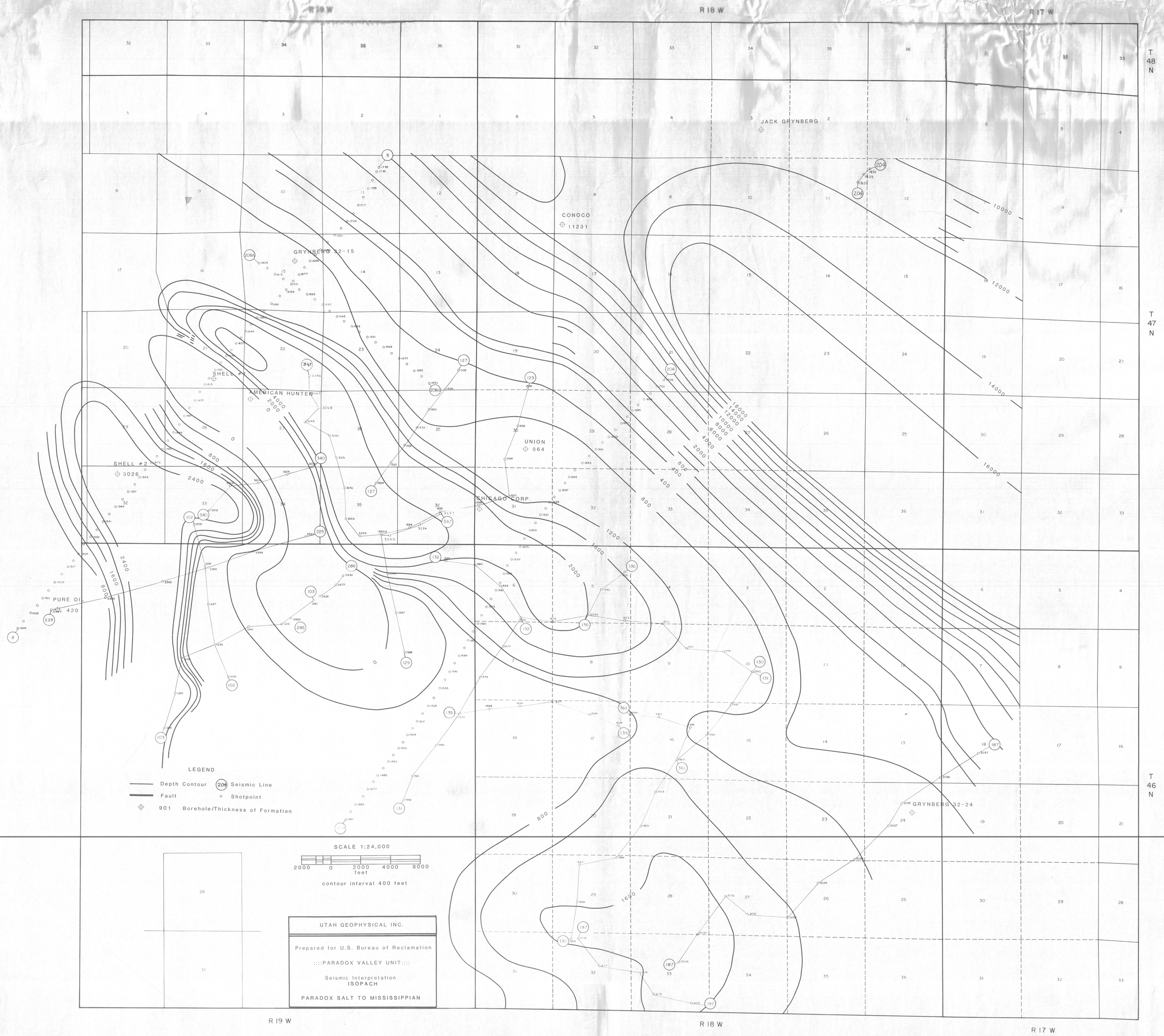
Withington, C. F. (1955). Geologic Map of the Paradox Quadrangle, Colorado, U.S.G.S. Publication

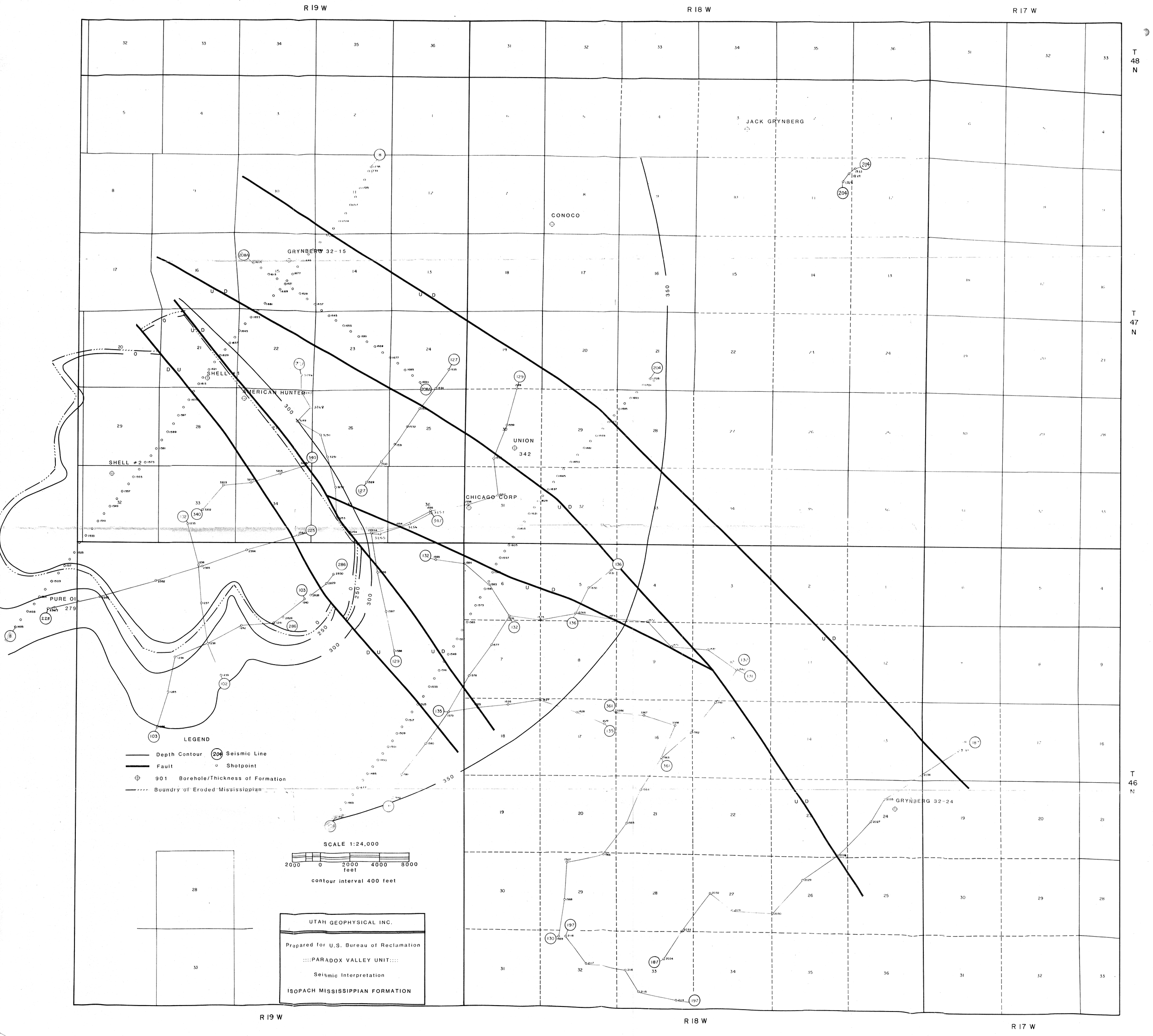

R 19 W
R 18 W
R 17 W
T 48 N
T 47 N
T 46 N
JACK GRYNBERG
CONOCO
6 A
GRYNBERG 32-15
4
DOLORES RIVER GORGE
3
SHELL #1
AMERICAN HUNTER
UNION
1
SHELL #2
5 C
CHICAGO CORP.
2
PURE OI
7
B
GRYNBERG 32-24
LEGEND
Depth Contour
Fault
Borehole
Cross Section Location
Seismic Line
Shotpoint
Proposed Well Site
SCALE 1:24,000
2000 0 2000 4000 8000
feet
contour interval 400 feet
UTAH GEOPHYSICAL INC.
Prepared for U.S. Bureau of Reclamation
::::PARADOX VALLEY UNIT::::
SITE SELECTION BASE MAP

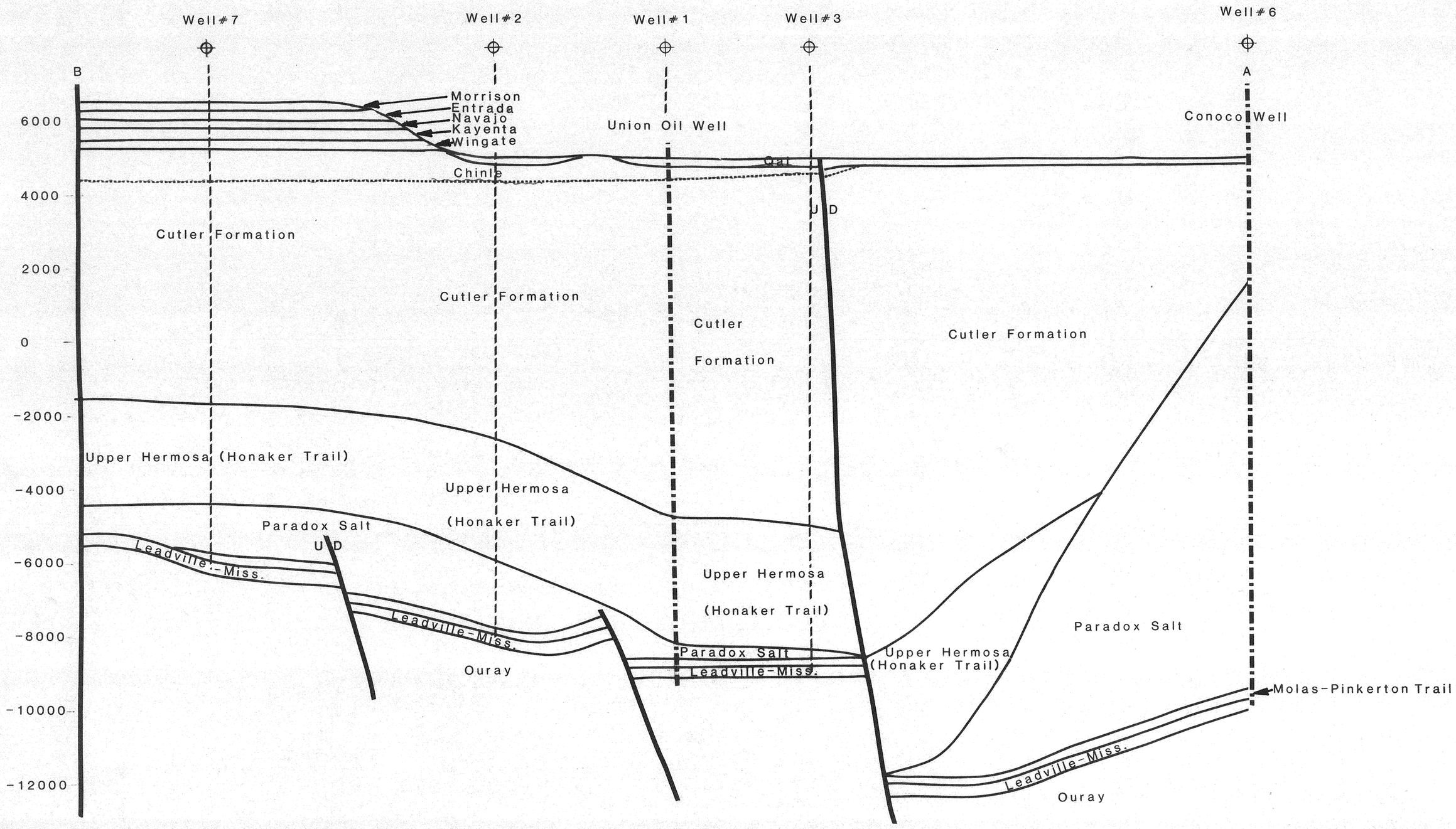
R 19 W
R 18 W
R 17 W
T 48 N
T 47 N
T 46 N
JACK GRUNBERG
4848
CONOCO
GRYNBERG 32-15
4780
SHELL #1
4366
AMERICAN HUNTER
SHELL #2
4042
UNION
CHICAGO CORP.
4350
PURE OIL
GRYNBERG 32-24
4221
5000
4800
4600
4400
4200
4000
3800
6000
6200
6400
UTAH GEOPHYSICAL INC.
Prepared for U.S. Bureau of Reclamation
::::PARADOX VALLEY UNIT::::
Seismic Interpretation
TOP OF CUTLER FORMATION
LEGEND
Depth Contour
Fault
Seismic Line
Shotpoint
-9012 Borehole/Depth to Formation
SCALE 1:24,000
2000 0 2000 4000 8000
feet
contour interval 400 feet


R 19 W
R 18 W
R 17 W
T 48 N
T 47 N
T 46 N
JACK GRYNBERG
CONOCO
1628
GRYNBERG 32-15
SHELL #1
-4049
AMERICAN HUNTER
SHELL #2
-515
PURE OIL
UNION
-8148
CHICAGO CORP
GRYNBERG 32-24
2000
0
-2000
-4000
-6000
-8000
-7600
-6800
-5200
-4400
-3600
-3200
-2800
-2400
-1200
-800
4000
UTAH GEOPHYSICAL INC.
Prepared for U.S. Bureau of Reclamation
::::PARADOX VALLEY UNIT::::
Seismic Interpretation
TOP OF PARADOX SALT
LEGEND
Depth Contour
Fault
-9012 Borehole/Depth to Formation
Seismic Line
Shotpoint
SCALE 1:24,000
2000 0 2000 4000 8000
feet
contour interval 400 feet


R 19 W
R 18 W
R 17 W
T 48 N
T 47 N
T 46 N
JACK GRYNBERG
CONOCO
GRYNBERG 32-15
SHELL #1
AMERICAN HUNTER
SHELL #2
UNION
CHICAGO CORP
PURE OIL
GRYNBERG 32-24
LEGEND
Depth Contour
Seismic Line
Fault
Shotpoint
-9012 Borehole/Depth to Formation
Boundry of Eroded Mississippian
SCALE 1:24,000
2000 0 2000 4000 8000
feet
contour interval 400 feet
UTAH GEOPHYSICAL INC.
Prepared for U.S. Bureau of Reclamation
::::PARADOX VALLEY UNIT::::
Seismic Interpretation
TOP OF MISSISSIPPIAN FORMATION


R 19 W
R 18 W
R 17 W
T 48 N
T 47 N
T 46 N
JACK GRYNBERG
CONOCO
11231
GRYNBERG 32-15
SHELL #1
AMERICAN HUNTER
SHELL #2
3026
UNION
864
CHICAGO CORP.
PURE OI
420
GRYNBERG 32-24
10000
12000
14000
16000
18000
LEGEND
Depth Contour
Fault
901 Borehole/Thickness of Formation
Seismic Line
Shotpoint
SCALE 1:24,000
2000 0 2000 4000 8000
feet
contour interval 400 feet
UTAH GEOPHYSICAL INC.
Prepared for U.S. Bureau of Reclamation
::::PARADOX VALLEY UNIT::::
Seismic Interpretation
ISOPACH
PARADOX SALT TO MISSISSIPPIAN


R 19 W
R 18 W
R 17 W
T 48 N
T 47 N
T 46 N
JACK GRYNBERG
CONOCO
GRYNBERG 32-15
SHELL #1
AMERICAN HUNTER
UNION
342
SHELL #2
CHICAGO CORP
PURE OIL
279
GRYNBERG 32-24
350
300
250
LEGEND
Depth Contour
Fault
901 Borehole/Thickness of Formation
Boundry of Eroded Mississippian
Seismic Line
Shotpoint
SCALE 1:24,000
2000 0 2000 4000 8000
feet
contour interval 400 feet
UTAH GEOPHYSICAL INC.
Prepared for U.S. Bureau of Reclamation
::::PARADOX VALLEY UNIT::::
Seismic Interpretation
ISOPACH MISSISSIPPIAN FORMATION



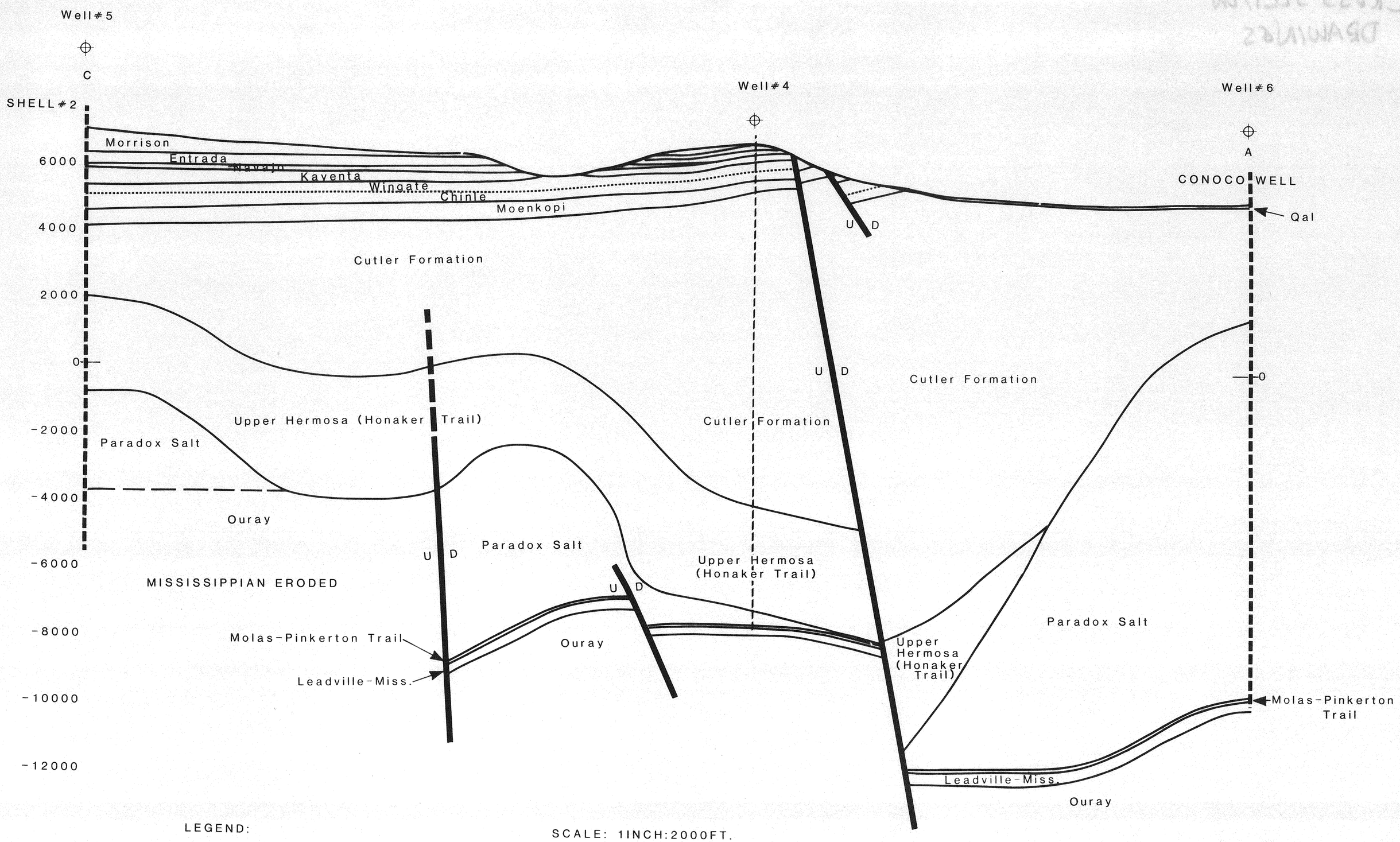

LEGEND:

Proposed Well Site

Fault

SCALE: 1inch:2000ft.

# CROSS-SECTION : A-B




LEGEND:

Proposed Well Site

Fault

SCALE: 1INCH:2000FT.

# CROSS-SECTION:A-C