3-C3-40-0146B

GEOPHYSICAL INTERPRETATION

SEISMIC DATA

PARADOX VALLEY UNIT

Montrose County

Colorado

BY

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GEOPHYSICAL INTERPRETATION

PARADOX VALLEY UNIT

LOCATION:

The area of this survey is located in Townships 46 and 47 North, Ranges 18 and 19 West, Montrose County, Colorado. Geologically the area is within the Paradox Fold and Fault Belt, a structural lineament, lying wholly within the Paradox Basin Province of Southwestern Colorado and Southeastern Utah. The terrain is rough being typical canyonlands type and vehicular access is quite limited.

INTRODUCTION:

The purpose of this evaluation was to locate any and all feasible drill sites to be used for the injection of salt water into the Mississipian Leadville Formation or other formation.

The criteria considered for site selection included porosity, and reservoir capacity. It is felt that some porosity of 5% or greater must be available to start injection and to allow the fluid to reach fractures not directly connected to the borehole which, of course greatly enhances reservoir capacity. It was also considered that at least 250 feet of salt was necessary to seal the Leadville at faulted faces. The last consideration was to minimize the elevation difference between the existing brine field at 4950 and the site.

A number of oil and gas tests to and through the Leadville Formation exist in the area indicating widely varying structural and stratigraphic conditions. To properly evaluate sites, it became essential to know how and where these changes occur.

GEOPHYSICAL INTERPRETATION (Cont.)

The reflection seismograph is, at present, the best tool available to us for subsurface investigations. To this end, proprietary seismic data were purchased by the government from Target Geophysical and others and made available for this evaluation.

In tests drilled to date, no significant porous intervals were penetrated in the Permian Cutler Formation or the Pennsylvanian Honaker Trail Formation. It must be assumed that the Mississippian Leadville Formation is the best, and possibly the only, formation that can contain adequate reservoir capacity.

TECHNICAL:

Two types of dynamite source reflection data were furnished by the government. The Target Geophysical data is recent (1982) multiple coverage, digitally recorded and processed. The other data is older (1961) analog recorded single coverage. The older data were digitized from the analog tapes and processed to the same display scales as that of the Target data. The Target data used +7500 as the reference plane and the older data used +6500 as the plane. It was necessary therefore, to reduce the Target reflection times by 180 milliseconds to effect a time tie to the older data. This correction accommodates the shift of 1000 feet to datum plus the instrument lag inherent in the analog system.

The government furnished three synthetic seismograms constructed from sonic logs at the Pure No. 3 Wray Mesa Unit in Sec. 6, T46N, R19W, the Shell No. 2 Wray Mesa Unit in Sec. 32, T47N, R19W and at the Union No. 1 Ayres in Sec. 30, T47N, R18W. These synthetics were used to identify the reflections mapped and also to determine the velocity to the Leadville Formation used in converting the seismic times to depth.

Structure maps at the top of the Salt and at the Top of the Leadville were first constructed using only seismic times below a reference plane of +6500. Structural shape and fault patterns were determined from these maps. These maps were then converted to depth using the following velocities: from Fault "D" southward 14,400 feet per second based on the Pure No. 3 control point. 13,600 feet per second was used only at the Shell No. 2 test, it being anomolously slow due to the diapiric nature of the salt at this location. Between Faults "C" and "D", 15,200 feet per second was used. Between faults "B" and "C", 15,400 feet per second was used based on the Union No. 1 Ayres control point, then 15,000 feet per second between faults "A" and "B" where the section is all salt.

DISCUSSION OF DRAWINGS:

DRAWING NO. 1, Structure Map, Cutler Formation

The Cutler top is to shallow to map seismically in this area. This map is contoured using the formation tops from the existing oil and gas tests in the area. At this level, only regional southward dip is indicated off the flank of the Paradox Valley surface anticline. A slight flattening or possible closure is suggested over the deeper salt structures.

It should be noted that the Cutler formation is made up of conglomerate, arkose, silt and mud stones deposited as the Uncompahgre Uplift was eroded and dumped in this area to great thicknesses. There is no blanket porous zone in this formation, only local lenticular bodies. It is not considered a viable injection objective for this program.

HERMOSA (HONAKER TRAIL FORMATION)

The top of this formation was not mapped in this survey but is shown on the cross sections. It is approximately 3000 feet thick in this area and is structurally conformable to the top of the Salt Formation. It represents the transition zone from the marine evaporite zone (Salt) to the continental Cutler Formation above.

The formation consists of limes, shales and sandstones. Pore spaces in the sandstones usually contain highly water-sensitive clay particles which swell when wet and effectively seal off permeability making an unlikely target for injection.

The lower part of the formation is devoid of sands being mostly limestones and silty shales. In the event some good porosity is encountered in this section, it might be advisable to test injection.

DRAWING NO. 2, Structure Map, Salt Member

This map is constructed on top of the "Massive" salt member. It should be noted that there are thin salt stringers both above and below this member formed when salt deposition began and later as it ended but the top of the "Massive" members is usually called the top of the salt due to its easy identification.

Two rather prominent anticlines or domes are noted at this level. The one centering at the Shell No. 2 Wray Mesa test appears to be diapiric, that is, it was pierced completely through the overlying Hermosa Honaker Trail section and into the Cutler. The other, centering in the Northwest quarter of T46N, R18W, is much less dramatic being more of the pillow type not rupturing the overlying formations. Off the north flank of these structures

DRAWING NO. 2 (Cont.)

the sale is essentially conformable to the Leadville up to its contact with the giant salt wall on the south side of the Paradox feature. Off the south flank a similar condition exists. Structure at this level may also be a clue as to why the river took the course it did.

DRAWING NO. 3, Structure Map, Leadville Formation

Structure at this level suggests an anticlinal trend through and southeasterly from the prominent Wray Mesa structure. There is a fairly prominent saddle across the trend in the vicinity of the river. The north flank of this trend appears to be a series of faults stepping down toward the center of the basin. It is probable that this fault zone is a significant, if not major, system that extends for miles in both directions from this area. It is more than likely that this system triggered and located the massive Paradox Salt Valley feature of today.

There is no seismic control for the positioning of fault "A" immediately south of the Conoco Scorup Test. Its presence is based on the inability to tie the test from the low control points on the northeast ends of Lines #8 and #204 with dip.

It should also be noted that the Leadville Formation has been completely eroded from the top of the Wray Mesa Structure. This phenomena cannot be foreseen with seismic data since the Devonian Formation becomes the basal reflector in the absence of Leadville rocks.

Control points on the north flank of Paradox Valley (Sec. 11, 47N, 18W) indicate the Leadville is at -12,500 sub-sea and still plunging northward.

DRAWING NO. 4, Isopach Map, Salt Member

In addition to the "Massive" salt member, this interval also spans the Lower Penn. Pinkerton Trail and Molas members immediately overlying the Leadville Formation. These formations consist of dense limes, dolomites, anhydrites and shales and act as an effective seal at the top of the Leadville Formation. At the Union #1 Ayres test, this interval is approximately 400 feet thick. This suggests that where this interval stabilizes at approximately 800 feet in thickness in the area between the two salt features and the salt wall on the south side of the Paradox feature, no more than 400 feet of "Massive" salt can be expected. (Refer to Drawing No. 2) Similarily, south of the salt features where this interval seems to stabilize at approximately 400 feet in thickness, no more than 275 feet of "Massive" salt is to be expected as indicated at the Pure #3 Wray Mesa test.

DRAWING NO. 5, Isopach Leadville Formation (C.L. Harr)

This is an isopach map of the gross thickness of the Mississippian Leadville formation. The data was derived from gamma ray-sonic and gamma ray neutron logs of Leadville wells drilled in the immediate area of the salt-brine disposal project. There is a total of nine data wells, six of which were drilled into the underlying Devonian, allowing an exact determination of Leadville thickness. The trending of contours is baled on personal Knowledge of regional thickness patterns of the Leadville throughout the Paradox Basin.

The Leadville isopach exhibits local pre-Des Moines thinning by truncation over a post-Leadville regional horst trend. In the immediate area of the Shell Wray Mesa No. 1 (21-47N19W) and No. 2 (32-47N-19W) wells, the

DRAWING NO. 5 (Cont.)

entire Leadville and a portion of the Devonian has been removed. The southeast trend of thinning off of the denuded area is not substantiated by well control, nor can it be supported by seismic; however, it fits logically with the "ancient" Sneffels Horst trend.

Not only was the Leadville reservoir thickness reduced by the exposure and erosion along the "old" structural high, but the quality of the reservoir was also affected. "Karst-type" weathering occurred during exposure with subsequent infill of Molas red shale and clay. There was no effective porosity developed within the "Karsted" chalky limestone portion of the upper part of the Leadville carbonate. Regionally, this karsted interval varies between 100 and 300 feet in thickness. If the Leadville is sufficiently thin, the Karsting negates any chance for quality reservoir.

For one of several reasons, the prime reservoir beds of the Leadville are the dolomitized zones immediately underlying the "karst" interval. Effective porosity improves with the degree of diagenetic dolomitization. Dolomitization conincided with the flooding of the Des Moines seas: however, the quality and quantity of porosity was dependent primarily on the relative position of the Leadville carbonate to the water table at the time of "karsting" prior to Pennsylvanian inundation. Therefore, porosity development in the Leadville is eratic and difficult to predict in areas of "old" structural highs which influenced the water table, such as the Wray Mesa trend. Map No. 8, Isopach Map of Leadville Porosity Greater Than Five Per Cent was prepared and submitted as a visual interpretation of the Leadville reservoir trends.

DRAWING NO. 6, Structural Cross Section X-X'

This cross section was selected to pass through and show the relationships between recommended wellsite Locations No. 1, No. 2 and No. 3.

DRAWING NO. 7, Structural Cross Section Y-Y'

This cross section was selected to pass through and show the relationships between recommended wellsite Locations No. 1 and No. 4.

DRAWING NO. 8, Isopach Map of Leadville Porosity (C.L. Harr)

Greater Than Five Per Cent

Porosity data used in the construction of the Leadville porosity isopach was obtained from eight sonic logs and one neutron log from nine separate wells in the near vicinity of the salt-brine disposal project.

Sonic porosities are based on a dolomite matrix travel time of 43.5 micro sec./ft. The porosity calculations from the neutron log of the Continental No. 1 Scorup (8-7N-18W) were based on a sonic derived shale porosity of 19% and a salt/anhydrite porosity of zero. A five per cent cut-off was utilized to show the leadville reservoir trends. Porosity values less than five per cent cannot realistically be considered as effective porosity except in local areas with sufficient reservoir control data.

The best reservoir quality and thickness in the mapped area was exhibited by the No. 1 Scorup logs (8-47N-18W). The well penetrated 267 feet of Leadville of which 86 feet contained porosity greater than five per cent. Fluid recoveries on drill stem test were sufficient to indicate quality reservoir conditions. The lateral extent of the reservoir is unknown, however the southwest limit is probably controlled by the 1000 foot fault southwest of the well. The location of the fault is not defined.

DRAWING NO. 8 (Cont.)

The Union Oil Company No. 1 Ayres (30-47N-18W), drilled three miles to the south, penetrated the entire Leadville, but encountered only seven feet of porosity greater than five per cent. A drill stem test of eight six feet of the leadville recovered 6680 feet of salt water, plus the 4150 fee of water cushion. Flow essentially stabilized in one hour. The fluid recovery and pressures indicate the reservoir is highly fractured. One must assume such fracturing is associated to the major fault system between the No. 1 Ayres and the Sell No. 1 Wray Mesa (21-47N-19W) and would be present throughout the immediate area.

It is contended that porosity development along the "old" structural high is minimal.

CONCLUSIONS:

It is believed that a reasonably good evaluation of the structure and stratigraphy exist within the area of control. The finite depth to any given point is, as with all seismic, subject to the vagaries of velocity. Conversion velocities represent the interpreter's best guess based on measured velocities and historical experience in the area.

The absence of a consistent predictable porous zone within the Leadville make it impossible to calculate reservoir capacities. In order to accomplish the desired results of this program, reservoir capacities will have to be enhanced by fracturing of the Leadville. The most likely place for fracturing to occur is within a fault zone or system such as the one mapped in the northern half of the area. The Union No. 1 Ayres test is known to be in contact with a fracture system and is therefore, considered to be the least expensive and quickest place to test a fracture reservoir.

RECOMMENDATIONS:

Four locations are recommended in their order of preference which satisfy the specifications. These locations are not to be considered pin point and can be moved 400 feet in any direction without effecting the objective. This will allow the drilling engineer latitude for his preferred rig orientation.

LOCATION NO. 1	SW,SE, SEC. 30, T47N, R18W
	Re-enter and wash down
	Union No. 1 Ayers
ELEV:	5010 GL
ACCESS:	Excellent
LOC. COST:	Minimum
DEPTH:	14,384 (thru Leadville)
SALT:	13,178,-13600 (422 feet)
POROSITY:	7 Feet greater than 5%
SIZE:	3600+ Acres
DST:	14,114-14,200 Rec: 4130' wtr cusion 6680' salt water
	HP; 7710 psi

This well is designed to test the injection rates at position where all of the geologic perameters are known. It will be the quickest and least expensive of any of the proposed tests. The drill stem test at this location indicates the borehole is in contact with a fracture system.

LOCATION NO. 2 SE,NW,SE, SEC. 31, T47N, R18W

New Hole

ELEV: 5020 GL

ACCESS: Requires approximately 6000 feet of road southward from Loc. No. 1 along the east bank of the Dolores River. 2000 feet of road to be cut into base of steep face. Moderate Cost.

LOC. COST: Normal

DEPTH: Normal

SALT: 11,020-12.520 (1500 feet)

POROSITY: 7+ feet greater than 5%

SIZE: 3600+ Acres

This well is designed to test a reservoir separated from the No. 1 Location by faulting and approximately 1000 feet higher structurally. The geologic conditions are expected to be quite similar to the No. 1 test. This well may also test for transmission across the fault between 1 and 2 although it is considered highly unlikely to occur.

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GEOPHYSICAL INTERPRETATION

LOCATION NO. 3	SW,SE, SEC. 8, T47N, R18W
	Offset and Redrill
	Conoco No. 1 Scorup
ELEV:	5040 GL
ACCESS:	Excellent
LOC. COST:	Minimum
DEPTH:	15,100 (Thru Leadville)
SALT:	625-14,330 (13,705 feet)
POROSITY:	86 feet greater than 5%
SIZE:	Unknown but expected to be similar to the others.
DST:	14,780-15,000 Rec; 4950' wtr. cushion 8500' salt water
	HP: 8760 psi

This well is designed to test injection rates into the best matrix porosity known within the area. The area available to this test is unknown due to lack of control but it is expected to be similar to the others. The most serious problem with this location is drilling and maintaining a hole through 14,000 feet of plastic salt section. If it were not for the drilling and casing problems, this location would be considered No. 1 in preference.

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GEOPHYSICAL INTERPRETATION

LOCATION NO. 4 SE,SE,NE, SEC. 2, T46N, R19W

New Hole

ELEV: 5060 GL

ACCESS: Requires 13,000 of road building west and south from Loc. No. 2. The road would be along the south and east bank of the Dolores River and including a river crossing immediately north of the location. Moderate cost.

LOC. COST: Moderate

DEPTH: 11,100 (Thru Leadville)

SALT: 10,460-10,810 (250 feet)

POROSITY: 10 feet greater than 5% (Estimated)

SIZE: Unknown but extensive to the south and southeast.

This well is designed to test the structurally highest block at a reasonable elevation above the brine field. this location is considered the least desirable for the initial stage of the program but should be kept in mind as a position where additional reservoir capacity might be developed.

The isopach of the Leadville Formation indicates that only 100 feet of Leadville rock is present at this location but this is considered conservative. If the Leadville were to thicken as fast down the southeast plunge of the Wray Mesa structure as it does on the southwest flank, it could be significantly thicker at this location.

R 19 W

R 18 W

T 47 N

T 46 N

SALT

+4500

+4000

+3500

+3000

X Y

X'

Y'

CONOCO

STANFORD 1

SHELL 1 +4302

SHELL 2 +4273

UNION +3934

+3916

GRY +4789

PURE 3 +3674

GRY +3880

+2711

LEGEND

- Dry hole with depth on mapped horizon
- (130) Seismic line with identifier
- 5360 Shot point with depth on mapped horizon
- X-X' Cross section

DRAWING NO. 1

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GEOPHYSICAL INTERPRETATION

PARADOX VALLEY UNIT
SEISMIC

STRUCTURE CONTOUR MAP
CUTLER FORMATION

CONTOUR INTERVAL: 100ft
SEISMIC DATUM +6500'

by: Bremkamp, Harr, Prather

R 19 W

R 18 W

T 47 N

T 46 N

LEGEND

- Dry hole with depth on mapped horizon
- Seismic line with identifier
- Shot point with depth on mapped horizon
- X-X' Cross section

DRAWING NO. 2

3-CS-40-0146B

GEOPHYSICAL INTERPRETATION

PARADOX VALLEY UNIT SEISMIC

STRUCTURE CONTOUR MAP
PARADOX SALT MEMBER

CONTOUR INTERVAL: 100ft
SEISMIC DATUM +6500'

by: Bremkamp, Harr, Prather

R 19 W

R 18 W

T 47 N

T 46 N

X Y

CONOCO

STANFORD 1

GRY

SHELL 1

SHELL 2

PURE 3

UNION

No data for exact location of fault

A

B

C

D

D'

X'

Y'

LEGEND

- Dry hole with depth on mapped horizon
- (130)—o-o-o Seismic line with identifier
- Shot point with depth on mapped horizon
- X–X' Cross section

DRAWING NO. 3

3-CS-40-0146B

GEOPHYSICAL INTERPRETATION

PARADOX VALLEY UNIT SEISMIC

STRUCTURAL CONTOUR MAP

LEADVILLE FORMATION

CONTOUR INTERVAL: 100ft
SEISMIC DATUM +6500'

by: Bremkamp, Harr, Prather

R 19 W

R 18 W

T 47 N

T 46 N

X Y

X' Y'

CONOCO
14,362

STANFORD 1

UNION

SHELL 1

SHELL 2

PURE 3

GRY

-14,300

-15,000

THICKNESS CONSTANT @ 800'±

THICKNESS CONSTANT @ 400'±

THICKNESS CONSTANT @ 800'±

SALT THICKENS TO 15,000'± ACROSS THIS AREA

U D

LEGEND

- Dry hole with depth on mapped horizon
- (130) Seismic line with identifier
- 5360 Shot point with depth on mapped horizon
- X-X' Cross section

DRAWING NO. 4

3-CS-40-0146B

GEOPHYSICAL INTERPRETATION

PARADOX VALLEY UNIT SEISMIC

ISOPACH MAP
PARADOX SALT MEMBER

CONTOUR INTERVAL: 100ft
SEISMIC DATUM +6500'

by: Bremkamp, Harr, Prather

R 19 W

R 18 W

T 47 N

T 46 N

MISSISSIPPIAN

ABSENT

BY PREPENNSYLVANIAN

TRUNCATION

X Y

X'

Y'

CONOCO 2674'

STANFORD 1

SHELL 1

SHELL 2

UNION 3401'

PURE 3 2901'

GRY

GRY

LEGEND

- Dry hole with depth on mapped horizon
- Seismic line with identifier
- Shot point with depth on mapped horizon
- X-X' Cross section

DRAWING NO. 5

3-CS-40-0146B

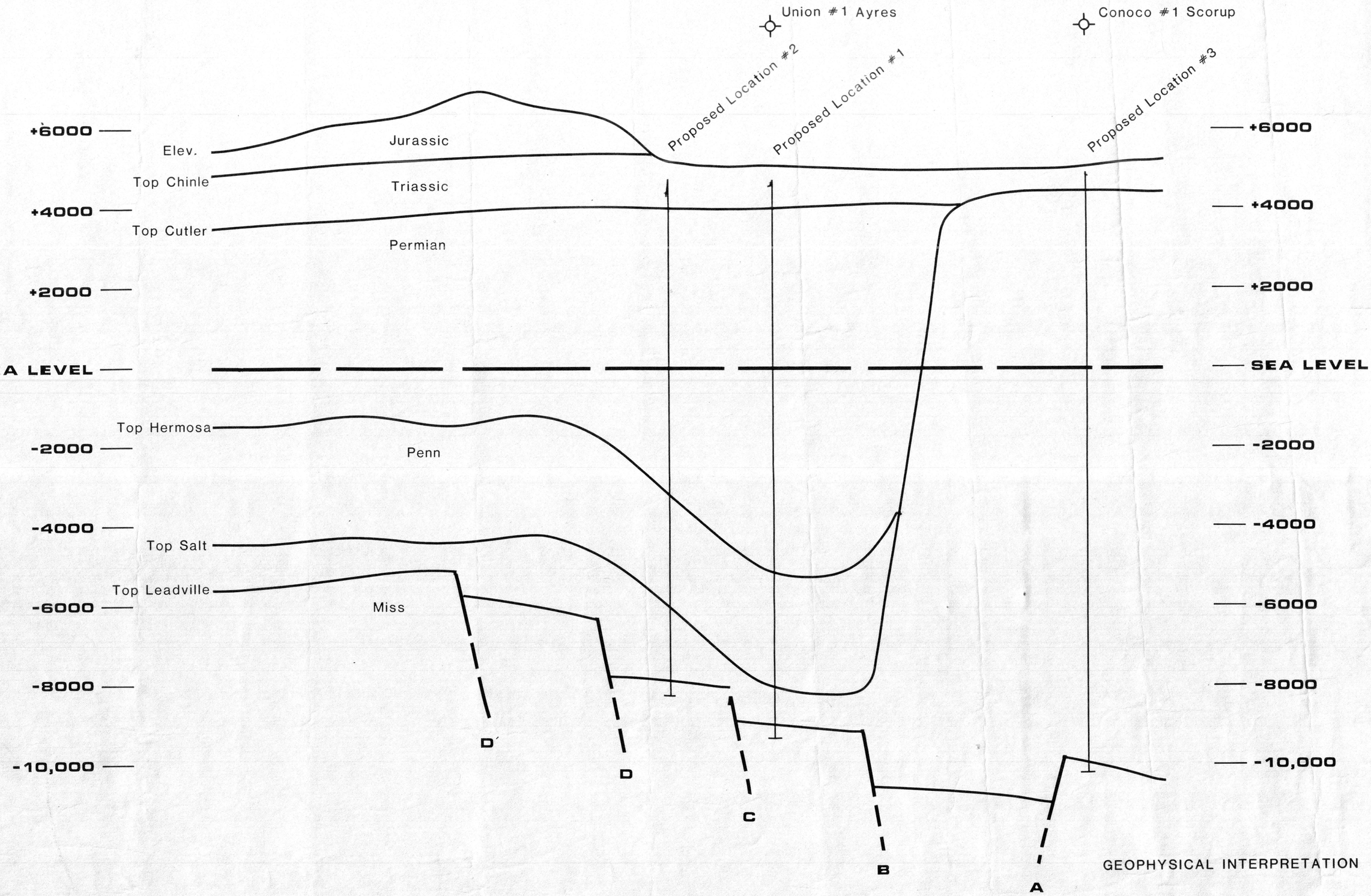
GEOPHYSICAL INTERPRETATION

PARADOX VALLEY UNIT SEISMIC

ISOPACH MAP
LEADVILLE FORMATION

CONTOUR INTERVAL: 100ft
SEISMIC DATUM +6500'

by: Bremkamp, Harr, Prather



GEOPHYSICAL INTERPRETATION

DRAWING NO. 6

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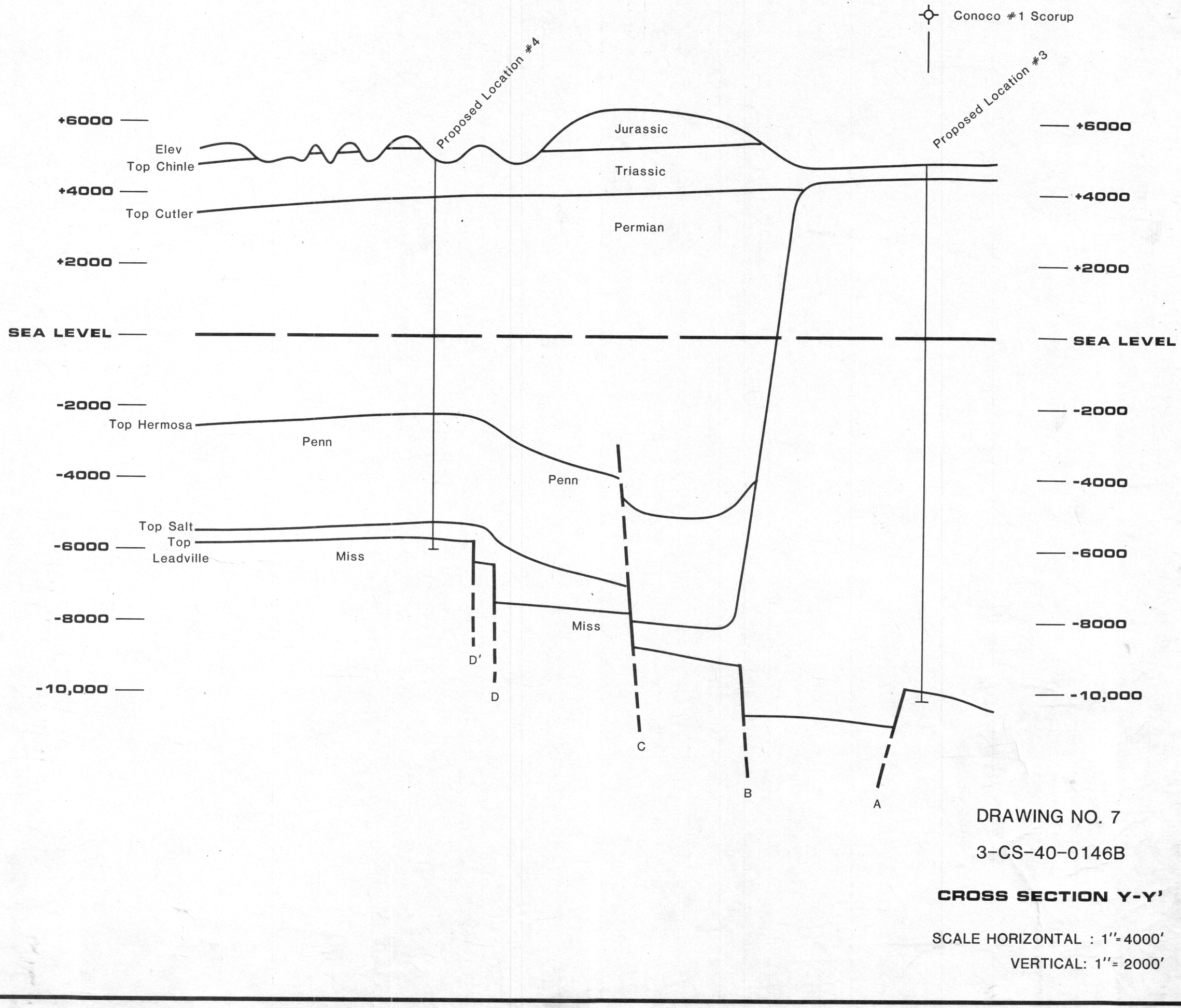
CROSS SECTION X-X´

SCALE: HORIZONTAL: 1''= 4000'

VERTICAL : 1''= 2000'



DRAWING NO. 7

3-CS-40-0146B

CROSS SECTION Y-Y'

SCALE HORIZONTAL : 1"= 4000'

VERTICAL: 1"= 2000'

R 19 W

R 18 W

T 47 N

T 46 N

MISSISSIPPIAN ABSENT BY PREPENNSYLVANIAN TRUNCATION

SHELL 1

SHELL 2

PURE 3

GRY

STANFORD 1

CONOCO

UNION

X Y

X' Y'

U D

0 10 20 30 40 60 80

LEGEND

- Dry hole with depth on mapped horizon
- (130) Seismic line with identifier
- 5360 Shot point with depth on mapped horizon
- X–X' Cross section

DRAWING NO. 8

3-CS-40-0146B

GEOPHYSICAL INTERPRETATION

PARADOX VALLEY UNIT SEISMIC

ISOPACH LEADVILLE POROSITY GREATER THAN 5%

CONTOUR INTERVAL: 100ft
SEISMIC DATUM +6500'

by: Bremkamp, Harr, Prather