WHY MODELERS NEED TO LOOK AT THE ROCKS!

Examples from Greater Aneth Field, Paradox Basin, Utah

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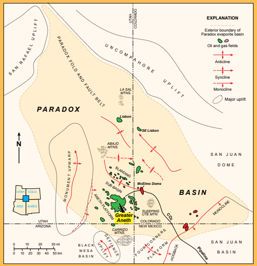

EXPLANATION
Exterior boundary of Paradox evaporite basin
Oil and gas fields
Anticline
Syncline
Monocline
Major uplift
SAN RAFAEL UPLIFT
PARADOX FOLD AND FAULT BELT
UNCOMPAHGRE UPLIFT
UTAH
COLORADO
LA SAL MTNS.
PARADOX
BASIN
Lisbon
SE Lisbon
ABAJO MTNS.
N
SAN JUAN DOME
MONUMENT UPWARP
BLANDING SUB-BASIN
McElmo Dome
ANETH PLATFORM
Greater Aneth
SLEEPING UTE MTN.
CO_2
Pipeline
MONOCLINE
UTAH
COLO.
ARIZ.
N.MEX.
UTAH
ARIZONA
COLORADO
NEW MEXICO
CARRIZO MTNS.
DEFIANCE UPLIFT
BLACK MESA BASIN
FOUR CORNERS PLATFORM
HOGBACK
SAN JUAN BASIN
0 10 20 30 mi
0 10 20 30 40 50 km

Location Map of the Paradox Basin and Major Oil and Gas fields

SUMMARY

Greater Aneth oil field, Utah's largest oil producer, was discovered in 1956 and has produced over 440 million barrels of oil. Because it represents an archetype oil field of the western U.S., Greater Aneth was selected to demonstrate combined enhanced oil recovery (EOR) and CO_2 sequestration under the auspices of the Southwest Regional Partnership on Carbon Sequestration, sponsored by the U.S. Department of Energy. Greater Aneth field is divided into four units. The Aneth Unit in the northwestern part of Greater Aneth field has not had significant CO_2 injection and therefore provides an opportunity to inject a relatively large volume of CO_2 from a nearby pipeline, and to extensively monitor the effects of injection from reservoir to surface. Thus, the Southwest Regional Partnership field demonstration is taking place in the 66-km^2 Aneth Unit, operated by Resolute Natural Resources and Navajo Nation Oil & Gas Co., Inc.

Located in the Paradox Basin of southeastern Utah, Greater Aneth is a stratigraphic trap, with fractures and minor faults. The primary reservoir is the Desert Creek zone sealed by the overlying Gothic shale, both within the Pennsylvanian Paradox Formation. Past geophysical well-log interpretations and published cross sections divide the Desert Creek into several correlatable reservoir subzones and units, as well as a few seals, across the field. However, caution is urged when using this type of information alone to generate reservoir models for CO_2 sequestration and movement over time at Aneth and other fields.

Examination of available slabbed conventional cores from Aneth unit wells reveals a complex reservoir consisting of limestone (oolitic, peloidal, and skeletal grainstone and packstone, and algal boundstone/bafflestone) and finely crystalline dolomite. These lithotypes represent a variety of depositional environments (open-marine shelf, shallow-marine beach and shoals, algal mounds, low-energy restricted shelf, etc.) that produce reservoir heterogeneity beyond what is determined from well logs. Fractures in cores are relatively common and there is evidence (hydrothermal dolomite, brecciation, etc.) of minor but important faults that may affect fluid flow. Cores reveal additional potential seals within the Desert Creek (mudstone and very fine grained sandstone units). Finally, several units containing the bryozoan Chaetetes have good porsity on well logs, but core observations show the porosity is ineffective.

GENERAL FIELD OVERVIEW

Discovery Well

Texaco #1 Navajo C
T.D. – 5923 ft.
Completed February 6, 1956
IPF – 568 barrels of oil per day
Initial Pressure – 2170 psia
GOR Gas – 3448:1

Reservoir Data

Productive Area – 48,260 acres
Net Pay – 50 ft
Porosity – 10.2%
Permeability – 10 md, range 3-30 mD
Water Saturation – 24%
Bottom-hole Temperature – 125°F
Type of Drive – Fluid Expansion and Solution Gas
Lithology – Limestone (algal boundstone & oolitic-, peloidal-, & skeletal grainstone & packstone), as well as finely crystalline dolomitic limestone

Production Data (as of January 1, 2007) and Reserves

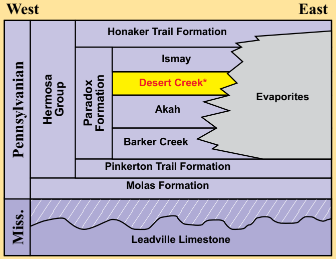
Cumulative Oil – 443,787,714 barrels
Cumulative Gas – 388,043,004 mcf
Cumulative Water – 1,447,923,351 barrels
Active Wells – 460
In Place Total Reserves – 1100 million barrels
Type of Secondary Recovery – Waterflood and CO_2 Flood, Horizontal Drilling

Oil Characteristics

Type – Paraffinic
Color – Dark Green
API Gravity – 40-42°
Viscosity, SUS – 0.53-0.54 cp
Pour Point – 10°F (-12°C)
Sulfur, wt% – 0.20%
Nitrogen – 0.04%

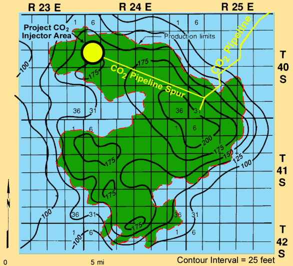
Aneth Unit

16,320 acres
421 Million Barrels of Oil in Place
Over 135 Million Barrels Recovered (33% Recovery)
Waterflood, 1962
Infill Drilling to 40 acres, 1982; Infilling to 20 acres, 1988
Horizontal Drilling Program, 1994


West
East
Pennsylvanian
Miss.
Hermosa Group
Paradox Formation
Honaker Trail Formation
Ismay
Desert Creek*
Akah
Barker Creek
Evaporites
Pinkerton Trail Formation
Molas Formation
Leadville Limestone

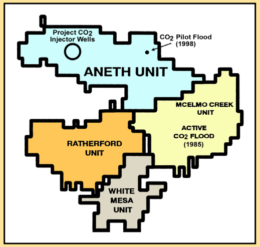
Pennsylvanian Stratigraphy of the Paradox Basin

*Reservoir Unit at Greater Aneth field

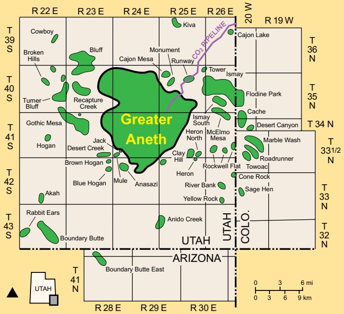

R 23 E
R 24 E
R 25 E
Project CO_2 Injector Area
Production limits
CO_2 Pipeline Spur
CO_2 Pipeline
T 40 S
T 41 S
T 42 S
100
125
150
175
200
0
5 mi
0
5 km
Contour Interval = 25 feet

Modified from Peterson and Ohlen (1963)

Generalized Thickness Map: Desert Creek Zone

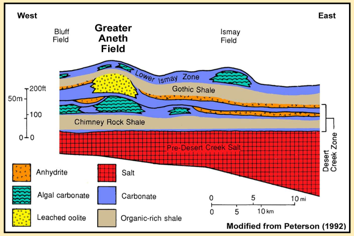

Project CO_2 Injector Wells
CO_2 Pilot Flood (1998)
ANETH UNIT
MCELMO CREEK UNIT
ACTIVE CO_2 FLOOD (1985)
RATHERFORD UNIT
WHITE MESA UNIT

Units within Greater Aneth Field


R 22 E
R 23 E
R 24 E
R 25 E
R 26 E
20 W
R 19 W
T 39 S
T 40 S
T 41 S
T 42 S
T 43 S
T 36 N
T 35 N
T 34 N
T 33 1/2 N
T 33 N
T 32 N
T 41 N
R 28 E
R 29 E
R 30 E
Greater Aneth
CO_2 PIPELINE
Cowboy
Broken Hills
Bluff
Turner Bluff
Recapture Creek
Gothic Mesa
Hogan
Jack
Desert Creek
Brown Hogan
Blue Hogan
Mule
Anasazi
Akah
Rabbit Ears
Boundary Butte
Boundary Butte East
Kiva
Cajon Mesa
Monument
Runway
Tower
Ismay
Cajon Lake
Flodine Park
Cache
Desert Canyon
Ismay South
Heron North
McElmo Mesa
Clay Hill
Heron
Rockwell Flat
Marble Wash
Roadrunner
Towoac
Cone Rock
Sage Hen
River Bank
Yellow Rock
Anido Creek
UTAH
ARIZONA
COLO.
0 3 6 mi
0 3 6 9 km

Location of Greater Aneth and Surrounding Oil Fields, Paradox Basin

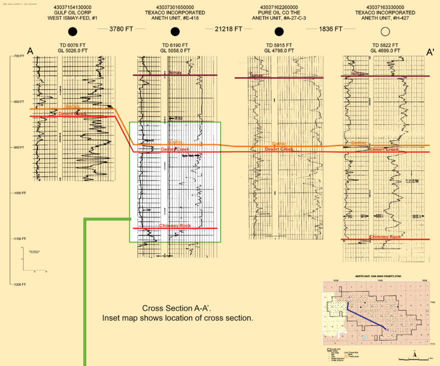
Published Schematic Interpretation


West
East
Bluff Field
Greater Aneth Field
Ismay Field
Lower Ismay Zone
Gothic Shale
Chimney Rock Shale
Pre-Desert Creek Salt
Desert Creek Zone
200ft
50m
100
0
0
Anhydrite
Salt
Algal carbonate
Carbonate
Leached oolite
Organic-rich shale
0 5 10 mi
0 5 10 km

Modified from Peterson (1992)

Simplified Diagrammatic Lithofacies Cross Section

Interpretation Based on Field Well-Log Correlation

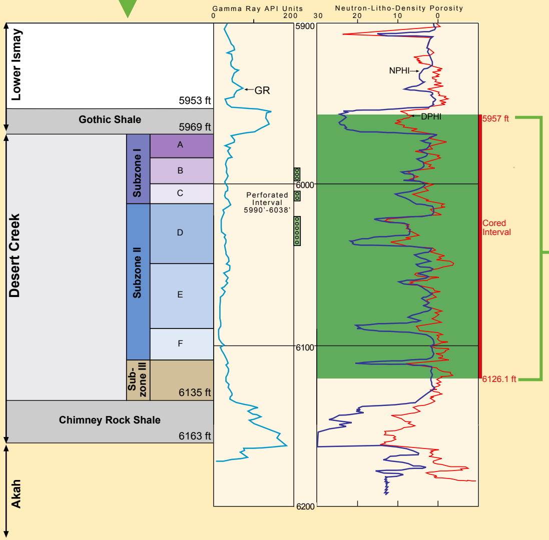


Cross Section A-A'.
Inset map shows location of cross section.

Detailed North-Northwest to Southeast Stratigraphic Cross Section

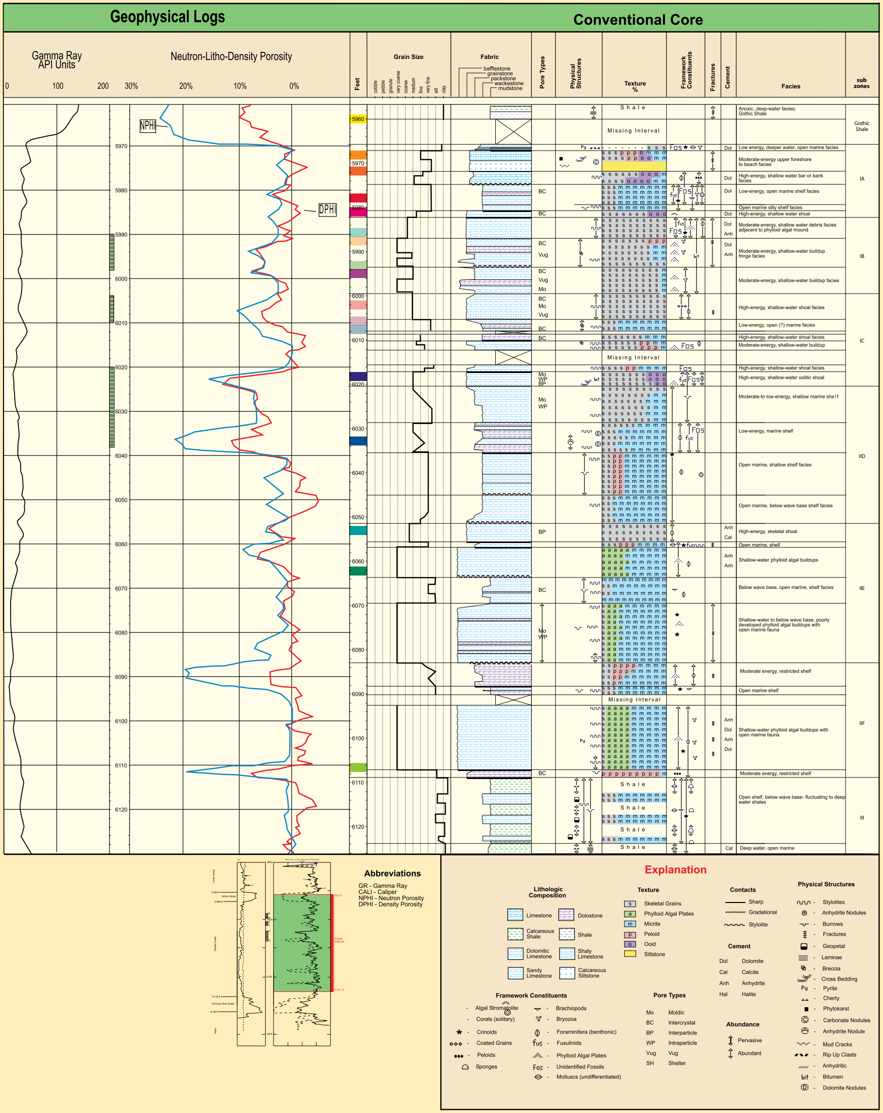
Greater Aneth Field

Texaco Inc.
Aneth Unit E-418
SW SWSec. 18 T. 40S R. 24E
San Juan County, Utah
KB 5070'
Cumulative Oil Production = 233,000 BO



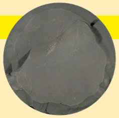
Interpretation of Typical Aneth Unit Geophysical Well Log

Reality! Based on Interpretation of Conventional Core



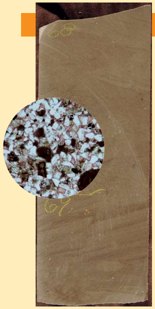
Core Description from Aneth Unit E-418

Reservoir



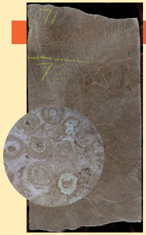
5960 ft.

- Gothic Shale - Black Siliceous, Calcareous Shale
- Anaerobic Deep Water Marine
- No Porosity, No Permeability
- Major Reservoir Seal



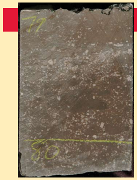
5969 ft.

- Quartz Sandstone with Cross-Bedding and Desiccation Cracks
- Upper Foreshore to Beach
- Low Porosity and Low Permeability
- Potential Seal/Barrier



5972 ft.

- Oolitic/Skeletal Grainstone,
- Shallow Marine Shoal,
- Low Porosity and Low Permeability,
- Baffle

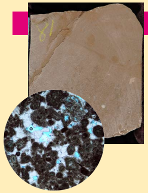


5979 ft.

- Skeletal Crinoidal Wackestone
- Deeper Water Open Marine
- Low Porosity , Low Permeability
- Potential Seal/Baffle

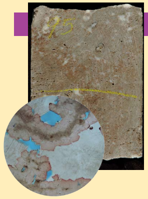
ANETH RESERVOIR SUBZONES AND UNITS

Heterogeneity: Seals, Baffles, and Flow Units



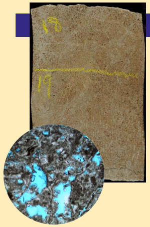
5981 ft.

- Pisolitic/Oolitic/Skeletal Grainstone with Anhydrite Plugging, Dolomitic
- Peritidal Evaporite
- Low Porosity and Low Permeability
- Seal/Baffle



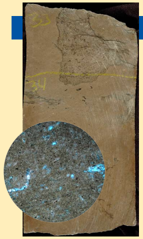
5996 ft.

- Chaetetes Skeletal Framestone with Replacement Saddle Dolomite and Anhydrite
- Deep Water, Agitated Marine
- High "Heartbreak" Porosity, Low Permeability
- Baffle to Very Poor Flow Unit



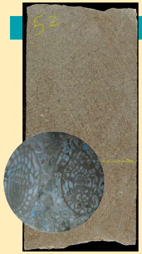
6019 ft.

- Skeletal/Coated-Grain, Grainstone
- Storm-Dominated Shallow Marine
- High Porosity, High Permeability
- Best Reservoir Flow Unit within the Section (Perforated)



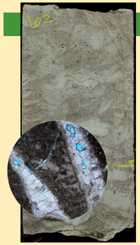
6033 ft.

- Dolomitized Skeletal Hard Peloidal Packstone to Wackestone
- Low-Energy Open Marine
- High Porosity, Low Permeability
- Baffle to Poor Quality Flow Unit (Perforated)



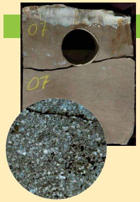
6053 ft.

- Foram (Fusulinid)/ Skeletal Grainstone
- Shallow Water Foram Bank
- High Porosity, Low Permeability
- Baffle to Poor Flow Unit



6062 ft.

- Phylloid-Algal Bafflestone with Kansasphyllum
- Shallow Water Algal Buildup
- Low Porosity, Low Permeability
- Baffle



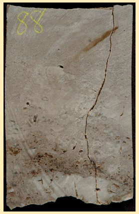
6107 ft.

- Dolomitized Peloidal Mudstone/Wackestone with Anhydrite Plugging
- Restricted Shallow Marine
- High Porosity, Low Permeability
- Baffle to Poor Flow Unit

Evidence of Faulting

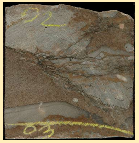
5988 ft.

Vertical Fractures



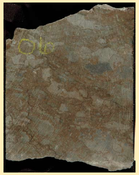
6002 ft.

Dolomite Replacement Bounded by Stylolites and Fracture Swarms



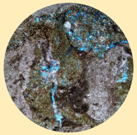
6006 ft.

Breccia with Limestone Clasts Surrounded by Stylolites and Dolomite



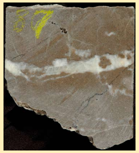
6007 ft.

Thin Section Photomicrograph, Breccia with Limestone Clasts and Dolomite



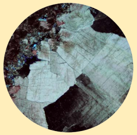
5987 ft.

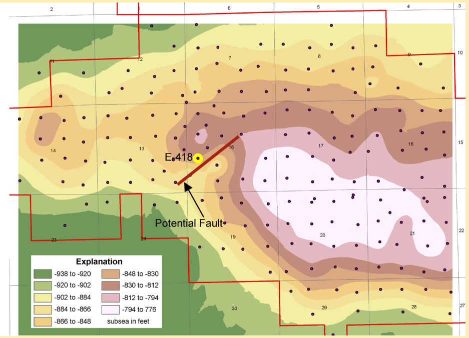
Saddle Dolomite Replacement (Hydrothermal Alteration) and Vugs Lined with Saddle Dolomite, Well-Terminated Quartz, and Bitumen



5995 ft.

Saddle Dolomite (Hydrothermal Alteration) and Small Vugs (Upper Perforated Zone)




E-418
Potential Fault
Explanation
-938 to -920
-920 to -902
-902 to -884
-884 to -866
-866 to -848
-848 to -830
-830 to -812
-812 to -794
-794 to 776
subsea in feet

Structure Contour Map of the Top of the Desert Creek Zone, Aneth Unit