INTRODUCING THE LARGEST SINGLE OIL FIELD (GREATER ANETH, SOUTHEASTERN UTAH) COLLECTION OF CARBONATE CORES IN THE ROCKY MOUNTAINS—TOOLS FOR EDUCATION AND RESEARCH

by
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SUMMARY

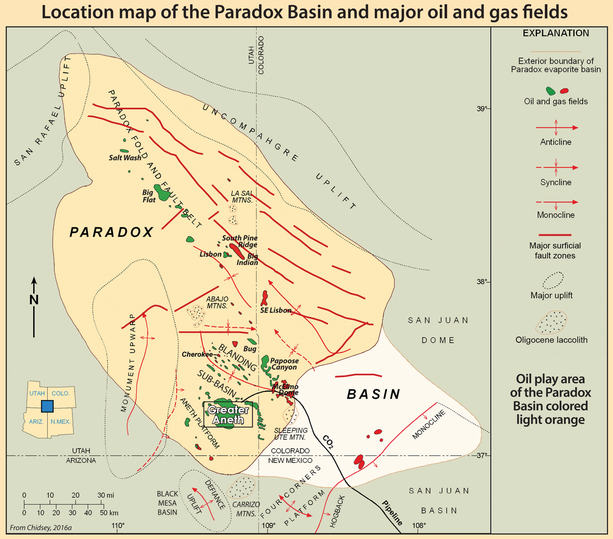
The Utah Core Research Center (UCRC) has added to its inventory a significant collection of carbonate cores (as well as thin sections and other formerly proprietary data) taken from wells in Utah's largest oil field, Greater Aneth, in the Paradox Basin. Greater Aneth has produced over 483 million barrels of oil and 441 billion cubic feet of gas from the shallow marine Pennsylvanian (Desmoinesian) Paradox Formation. Limestone and finely crystalline dolomite reservoir rocks are sealed by organic-rich, overlying and underlying shale beds, that are also the source of hydrocarbons in this enormous stratigraphic trap.

The new collection consists of cores from 127 wells totaling about 7.4 km (4.6 mi). These cores display a wide variety of characteristics that are critical for understanding carbonate rocks—lithofacies, diagenetic events, petrophysical properties, and sequence stratigraphy (flooding surfaces, stacking patterns, cyclicity, systems tracts). The Aneth cores reveal complex packages of carbonate rocks consisting of (1) oolitic, peloidal, and skeletal grainstone and packstone, (2) phylloid-algal bafflestone, (3) microbial boundstone, (4) thick anhydrites along the field margins, (5) dolomitized packages of chaotic carbonate rubble, and (6) deeper water, crinoid-bearing wackestone and mudstone. These lithotypes are the products of diverse depositional environments including shallow-marine beach and shoal, algal mound, low-energy restricted shelf, slope detrital aprons and fans, open-marine shelf, etc., that produce significant heterogeneity within the Aneth cores. Fractures are relatively common and there is evidence (i.e., hydrothermal dolomite, stylolite swarms, and local brecciation) of minor but important faults that may affect fluid flow. Porosity includes interparticle, shelter, intraparticle, vuggy, moldic, and intercrystalline pore networks, often enhanced by fractures. The original carbonate fabrics are commonly overprinted by dolomitization, early marine cementation, dissolution, and late, post-burial compaction and calcitic or anhydritic filling.

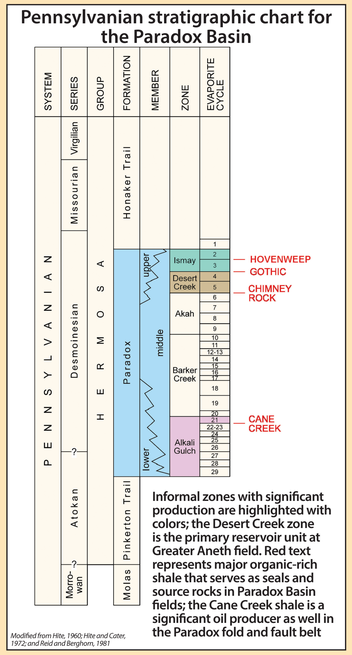
The Aneth core collection is now permanently preserved and publicly available at the UCRC for detailed studies by students, professors, and research organizations, as well as oil companies. The carbonate characteristics of the Paradox Formation observed in the Aneth cores provide outstanding teaching tools for geology students.

OVERVIEW OF THE PARADOX BASIN, SOUTHEASTERN UTAH AND SOUTHWESTERN COLORADO

Location map of the Paradox Basin and major oil and gas fields



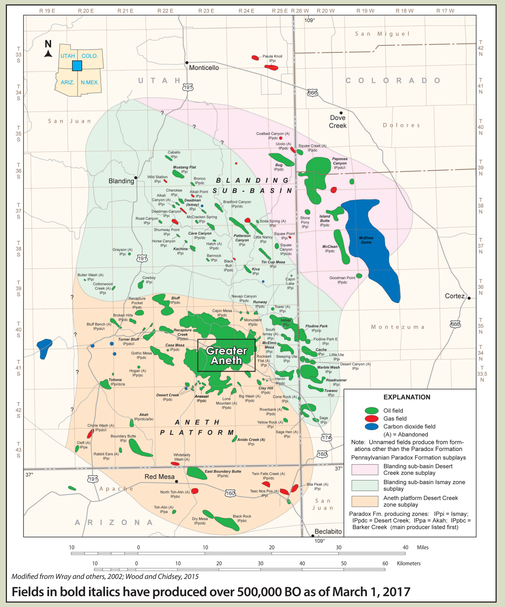
Pennsylvanian stratigraphic chart for the Paradox Basin



Informal zones with significant production are highlighted with colors; the Desert Creek zone is the primary reservoir unit at Greater Aneth field. Red text represents major organic-rich shale that serves as seals and source rocks in Paradox Basin fields; the Cane Creek shale is a significant oil producer as well in the Paradox fold and fault belt

PETROLEUM GEOLOGY OF GREATER ANETH FIELD

Location of the Paradox Formation Blanding sub-basin Desert Creek zone, Blanding sub-basin Ismay zone, and Aneth platform Desert Creek zone subplays, southeastern Utah, southwestern Colorado, and northeastern Arizona



Fields in bold italics have produced over 500,000 BO as of March 1, 2017

Discovery Well*

- Texaco #1 Navajo C
- Total Depth – 1805 m (5923 ft)
- Completed February 6, 1956
- Initial Potential Flow – 568 barrels of oil per day
- Initial Pressure – 14,960 kpa (2170 psia)
- Gas to Oil Ratio – 3448:1

** Utah Division of Oil, Gas & Mining well records*

Reservoir Data†

- Productive Area – 19,530 ha (48,260 ac)
- Trapping Mechanism – stratigraphic
- Net Pay – 15 m (50 ft)
- Porosity – 10.2%
- Permeability – 10 mD, range 3–30 mD
- Water Saturation – 24%
- Bottom-Hole Temperature – 52°C (125°F)
- Type of Drive – fluid expansion & solution gas
- Lithology – limestone (algal boundstone/bafflestone & oolitic-, peloidal-, & skeletal grainstone & packstone), as well as finely crystalline dolomitic limestone

† Babcock, 1978a, 1978b, 1978c, 1978d; Peterson, 1992; Moore and Hawks, 1993

Production Data and Reserves ‡

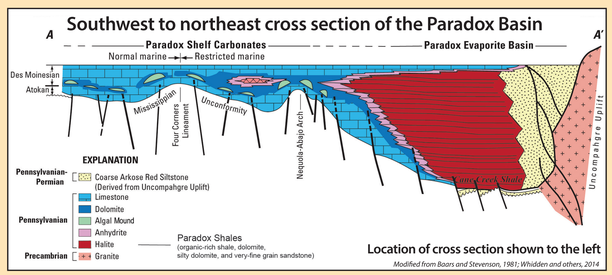
(as of March 1, 2017)

- Cumulative Production
  - Oil – 483,762,396 barrels
  - Gas – 441,344,687 thousand cubic feet (MCF)
  - Water – 1,886,116,338 barrels
- Daily Production
  - Oil – 10,981 barrels
  - Gas – 20,367 MCF
  - Water –110,474 barrels
- Active Wells – 444
- Estimated In-Place Total Reserves – 1100 million barrels of oil
- Type of Secondary Recovery – waterflood and CO_2 flood, horizontal drilling

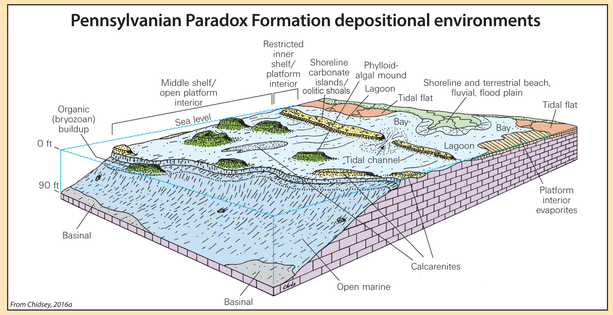
‡ Utah Division of Oil, Gas & Mining, 2017; Babcock, 1978a; Peterson, 1992

Generalized map of Paradox Formation facies with clastic wedge, evaporite salt basin, and carbonate shelf

Southwest to northeast cross section of the Paradox Basin



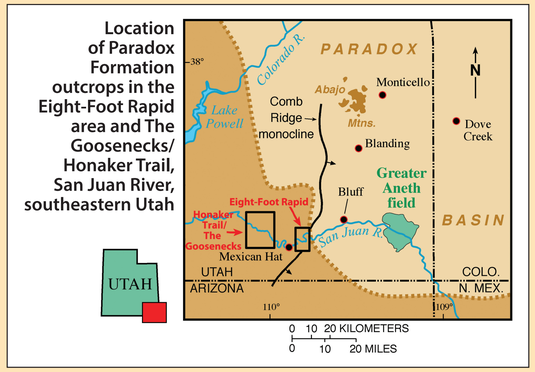
Pennsylvanian Paradox Formation depositional environments



Paleogeography of Utah during the Pennsylvanian

UTAH OUTCROP ANALOGS

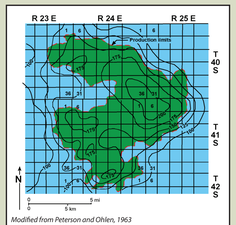
Location of Paradox Formation outcrops in the Eight-Foot Rapid area and The Goosenecks/ Honaker Trail, San Juan River, southeastern Utah



Large phylloid-algal mound complex in the lower Paradox Formation, Goosenecks area along the San Juan River

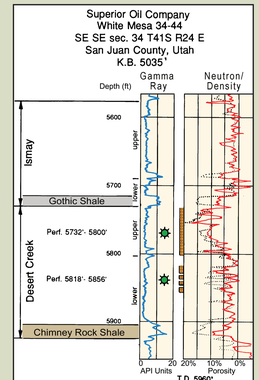
Cross-bedding in a grainstone representing a bioclastic shoal in the lower Paradox Formation, Goosenecks area along the San Juan River

Organic-rich Gothic shale at the base on the Ismay zone of the Paradox Formation along the Honaker Trail



Generalized thickness map of the Desert Creek zone, Greater Aneth field

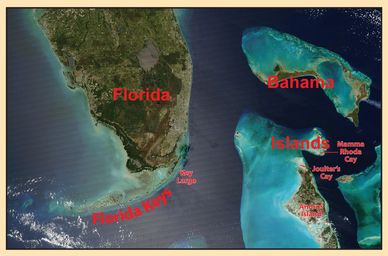
Contour interval = 25 ft



Typical gamma ray-compensated neutron/density log for the Desert Creek zone, Greater Aneth field

Producing (perforated) interval between depths of 5732 and 5856 ft

MODERN ANALOGS: SOUTHERN FLORIDA AND THE BAHAMA ISLANDS



Landsat image of southern Florida and the Bahama Islands that have world-class modern carbonate environments that are seen in cores from Greater Aneth and other Paradox Basin oil fields

Joulter's Cay ooid shoal complex, Andros Island, Bahamas. Inset is close-up of typical Joulter's Cay ooids

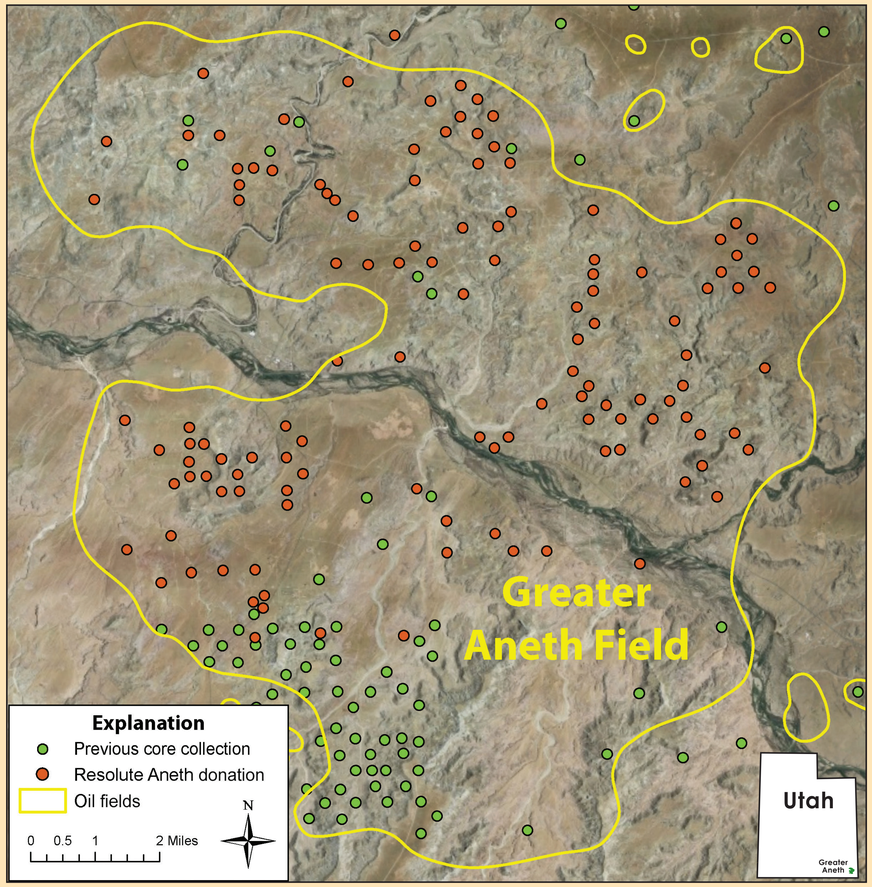
Carbonate tidal flats, northwest side of Andros Island, Bahama Islands, consisting of algal mats and laminated, soft peloidal mud in the intertidal to supratidal zone

Underwater photograph of "clean," rippled, calcareous sands of the White Bank sand shoal off Key Largo, Florida. Inset is close-up of coarse-grained, clean skeletal (primarily coral) sand grains from the White Bank sand shoal

THE GREATER ANETH CORE COLLECTION

- Cores from 64 wells prior to 2016
- Cores from 127 wells donated by Resolute Energy Corporation, Denver, Colorado
- Core collection now consists of 43% of all wells in the field
- Cuttings from 584 wells
- Additional Aneth materials available for study:
  - thin sections
  - core analyses (porosity & permeability)
  - core descriptions
  - company reports
- Recent M.S. theses from the Department of Geological Sciences, Brigham Young University
  - "Lithofacies and Sequence Architecture of the Upper Desert Creek Sequence (Middle Pennsylvanian, Paradox Formation) in the Greater Aneth Field, Southern Paradox Basin, Utah", by Evan Gunnell
  - "Lithofacies and Sequence Architecture of the Lower Desert Creek Sequence (Middle Pennsylvanian, Paradox Formation) in the Greater Aneth Field, Southern Paradox Basin, Utah", by Chanse Rinderknecht

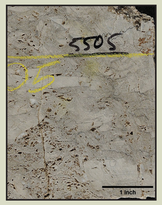
Graduate students and Dr. Scott M. Ritter from Brigham Young University examining newly donated Greater Aneth cores as part of their thesis research

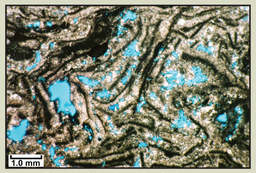


Location of cores in Greater Aneth field now available at the Utah Core Research Center

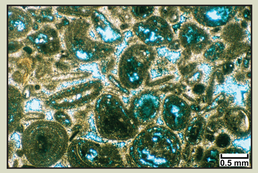
OPPORTUNITIES FOR RESEARCH AND TEACHING WITH CARBONATE ROCKS IN GREATER ANETH CORES— AND WE'VE ONLY SCRATCHED THE ~~SURFACE~~ SUBSURFACE!

Facies*

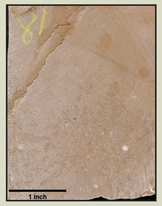


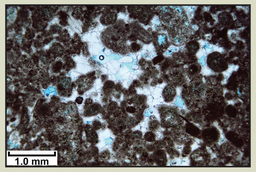


Phylloid-algal buildups (algal bafflestone)

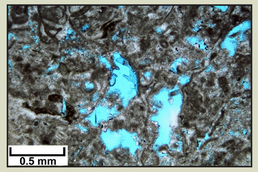


Oolitic shoals (grainstone)



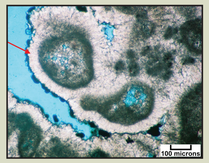


Peloids (grainstone) from the intertidal to supratidal zone

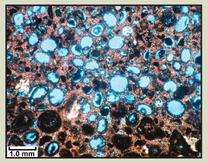


Bioclastic debris from a carbonate sand shoal (skeletal grainstone)

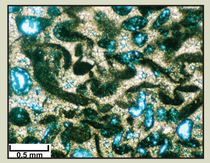
Diagenesis*



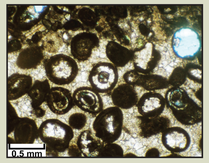
Rinds of early marine isopachous cement (red arrow) on ooids and skeletal grains



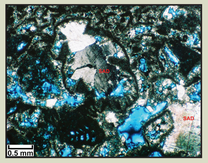
Early dissolution resulting in oomoldic porosity (blue) in an oolitic grainstone



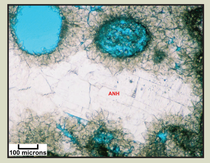
"Elephant trunks and tails" texture formed by the late compaction of ooid molds.



Late calcite cement completely filling the original interparticle pores between ooids and oomoldic pores

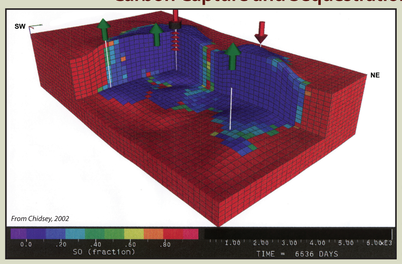


Late saddle dolomite (SAD) within skeletal molds



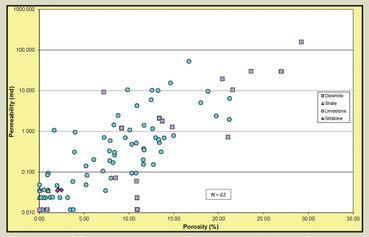
Large, late, anhydrite replacement crystals (ANH) within an oolitic grainstone

Reservoir Modeling for Enhanced Oil Recovery/ Carbon Capture and Sequestration

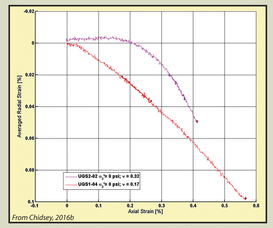


Reservoir oil saturation after 10 years of CO_2 injection in a satellite algal mound, southwestern Greater Aneth field

Petrophysical Properties/Rock Mechanics*

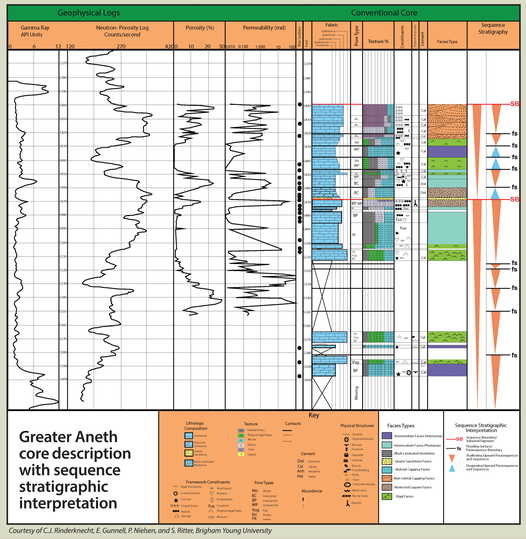


Permeability versus porosity cross plot by lithology



Averaged radial strain versus axial strain, Gothic shale

Sequence Stratigraphy



Greater Aneth core description with sequence stratigraphic interpretation

Courtesy of C.J. Rinderknecht, E. Gunnell, P. Nielsen, and S. Ritter, Brigham Young University

*see Chidsey and Eby (2014) for additional examples, detailed core descriptions, etc., from the northwest part (Aneth Unit) of Greater Aneth field

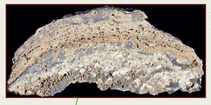
UTAH CORE RESEARCH CENTER

Educational Cores and Workshops

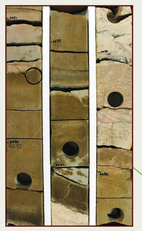
The Utah Geological Survey has the expertise to teach or host several workshops, for both industry and academia, using core available at the UCRC. Many of these core workshops can be paired with field trips to observe the same rocks in spectacular outcrops throughout Utah.

- ***Ferron Sandstone*** – Cretaceous fluvial-deltaic depositional environments – Muddy Creek and Ivie Creek cores from the western San Rafael Swell
- ***Navajo Sandstone*** – Jurassic eolian systems – Covenant oil field, Central Utah Thrust Belt
- ***Leadville Limestone*** – Depositional environments, diagenesis, and hydrothermal alteration of the Mississippian Leadville Limestone, Paradox Basin
- ***Ismay and Desert Creek Zones, Paradox Formation*** – Pennsylvanian heterogeneous shallow-shelf carbonate buildups of the Paradox Basin, including the giant Greater Aneth field and nearby satellite fields
- ***Green River Formation*** – Eocene lacustrine systems, carbonate reservoirs – Skyline 16 research core, Uinta Basin
- ***Microbialites*** – Modern and ancient microbialite formation – modern Great Salt Lake, Eocene Green River Formation, Jurassic Twin Creek Limestone, Triassic Moenkopi Formation, Permian Kaibab Formation
- ***"Shale" plays*** – Uteland Butte and Mahogany zone (Eocene Green River Fm.); Cane Creek, Gothic, Hovenweep, and Chimney Rock shales (Pennsylvanian Paradox Fm.); Mancos Shale (Cretaceous); Manning Canyon Shale (Mississippian)
- ***"Tight" sands*** – Cretaceous Mesaverde Group, Uinta Basin
- ***Karst features in petroleum reservoirs*** – Emphasis on Mississippian carbonate cores

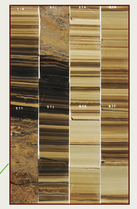
Wells with Available Core and Cuttings



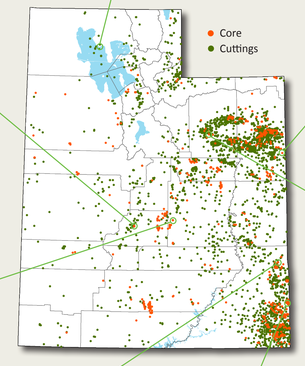
Great Salt Lake modern microbialite hand sample

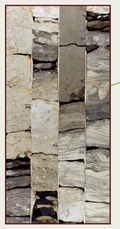


Navajo Sandstone, Covenant oil field



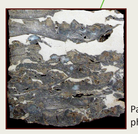
Green River Formation, Skyline 16 lacustrine core





Ferron Sandstone, Muddy Creek Canyon

Leadville Limestone brecciation



Paradox Formation phylloid-algal buildups

Green River Formation, Uteland Butte "tight" oil play

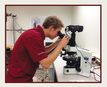
UCRC Collection

- Cores and cuttings from wells drilled for petroleum, coal, metals, potash, oil sands, oil shale, and water
- Core from about 2100 wells totaling 550,000 feet
- Cuttings from about 4900 wells totaling 24,000,000 feet
- 2300 thin sections
- 8400 core photographs
- Large collection of analytical data and geophysical logs

THE UCRC IS ALWAYS ACCEPTING CORE AND CUTTINGS DONATIONS

UCRC Facility and Services

- Large classroom (75+ people) for meetings or lectures, with projection equipment
- Large, well-lighted, core viewing area
- Binocular petrographic and stereoscopic microscopes
- High resolution core photography capabilities
- Slabbing, core plugging, and other sampling capabilities
- X-ray diffraction and x-ray fluorescence analyses



UCRC Fees

- Nominal fees apply for viewing core and general use of the facility
- Discounts offered to academia
- Contact the curator for more details

Curator: Peter Nielsen, P.G.
peternielsen@utah.gov

Assistant Curator: Thomas Dempster
thomasdempster@utah.gov

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Salt Lake City, UT 84116

geology.utah.gov
(801) 537-3359
Open Monday–Friday
8:00 am to 5:00 pm

ACKNOWLEDGMENTS

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Surface and Subsurface Geological Characterization of the Aneth Unit, Greater Aneth Field, Paradox Basin, Utah, as part of the Southwest Regional Partnership on Carbon Sequestration – Phase II: Field Demonstrations Project, contract no. DE-FC26-05NT42591.

Major Oil Plays in Utah and Vicinity, as part of the Preferred Upstream Management Program (PUMPII), contract no. DE-FC26-02NT15133.

Additional support for these projects was provided by the UGS and Eby Petrography & Consulting, Inc.

Cheryl Gustin, Jim Parker, Mike Laine, and Brad Wolverton of the Utah Geological Survey (UGS), drafted figures and photographed core. The poster was designed by Jen Miller and John Good of the UGS.

The following organizations contributed funds to ship the new collection of cores from Texas to the UCRC:

- Resolute Energy Corporation
- Utah Geological Association
- Rocky Mountain Section of the American Association of Petroleum Geologists
- Rocky Mountain Section Foundation of the American Association of Petroleum Geologists

DISCLAIMER

REFERENCES

Baars, D.L., and Stevenson, G.M., 1981, Tectonic evolution of the Paradox Basin, Utah and Colorado, *in* Wiegand, D.L., editor, Geology of the Paradox Basin: Rocky Mountain Association of Geologists Guidebook, p. 23–31.

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