Potential Shale-Gas Resources in Utah

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Summary

Shale-gas reservoirs in Utah have tremendous untapped potential. These include the Mississippian Manning Canyon Shale, Pennsylvanian Paradox Formation (Gothic, Chimney Rock, Hovenweep, and Cane Creek shales for example), and Cretaceous Tropic and Mancos (Prairie Canyon, lower Blue Gate, and Tununk Members) Shales of north-central, southeastern, southern, and northeastern Utah, respectively. Shale beds within these formations are widespread, thick, buried deeply enough to generate dry gas, and contain sufficient organic material and fractures to hold significant recoverable gas reserves.

The Manning Canyon Shale is mainly claystone with interbeds of limestone, sandstone, siltstone, and mudstone, and has a maximum thickness of 2000 ft. Total organic carbon (TOC) varies from 1% to greater than 8% with type III (?) kerogen. In north-central Utah, the Manning Canyon was deeply buried by sediments in the Pennsylvanian-Permian-aged Oquirrh basin and is therefore likely very thermally mature.

Cyclic shale units in the Paradox Formation consist of thinly interbedded, black, organic-rich marine shale; dolomitic siltstone; dolomite; and anhydrite. They generally range in thickness between 10 and 70 ft. These units contain TOC as high as 15% with type III and mixed type II-III kerogen, are naturally fractured (usually on the crest of anticlinal closures), and are typically often overpressured.

The Tropic Shale consists of dark–gray claystone containing thin lenses of siltstone, very fine grained sandstone, and bentonite beds, and ranges in thickness from 500 to 825 ft. The Tropic can be divided into two units based on analysis of core from the Escalante No. 1 well in south-central Utah: an organic-poor, 460- to 690-ft-thick, finely laminated marlstone and calcareous claystone lower unit, and an organic-rich, 340- to 460-ft-thick, thinly interlaminated siltstone grading upward to claystone upper unit. The upper unit contains TOC as high as 3.9% with type II and mixed type II-III kerogen.

The Mancos Shale consists of interbedded claystone, siltstone, and very fine grained sandstone. The thickness of potential shale-gas members of the Mancos ranges up to 1500 ft. In the Uinta Basin, vitrinite reflectance at the top of the Mancos ranges from 0.65% to 1.50%; TOC is 1% to 2% with type II to mixed type II-III kerogen.

Acknowledgments

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Interpretations and several figures were selected from the following UGS open-file reports:

Shale-Gas Reservoirs of Utah: Survey of an Unexploited Potential Energy Resource, Open-File Report 461 (2005) by Steve Schamel.

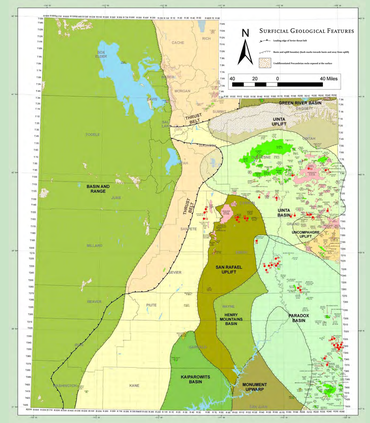
Shale-Gas Resources of Utah: Assessment of Previously Undeveloped Gas Discoveries, Open-File Report 499 (2006) by Steve Schamel.

Integrated Sequence Stratigraphic and Geochemical Resource Characterization of the Lower Mancos Shale, Uinta Basin, Utah, Open-File Report 483 (2006) by Donna S. Anderson and Nicholas B. Harris.

Hydrocarbon Potential of Pennsylvanian Black Shale Reservoirs, Paradox Basin, Southeastern Utah by S. Robert Bereskin (open-file report in preparation).

The poster design was by Stevie Emerson of the UGS. James Parker, Sharon Wakefield, Sonja Heuscher, and Cheryl Gustin of the UGS prepared the figures; Brad Wolverton of the UGS Core Research Center assisted with core photography.

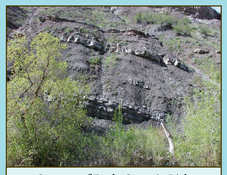
Shale-Gas Drilling Activity



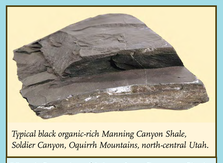
• Planned, Drilling, or Completed Shale-Gas Well

Cretaceous Mancos Shale		
Map No.	Operator	Depth (ft)
1	Questar	12,620
2	Wind River	10,500
3	Questar	11,539
4	Royale Energy	11,274
5	Royale Energy	11,322
6	Retamco	9,500
7	Petro-Canada	11,500
8	Gasco	15,941
9	Bill Barret Corp	19,000
10	XTO Energy	7,250
11	XTO Energy	8,730
12	XTO Energy	9,500
13	Questar	16,605
14	Questar	16,490
Pennsylvanian Paradox Formation		
15	Bill Barret Corp	6,483
16	Petro-Canada	7,388
17	Delta	
18	Delta	
19	Petro-Canada	7,331
20	Delta	9,472
21	Delta	8,950
22	Fidelity E & P	7,650
23	Babcock & Brown	7,925
24	CrownQuest	6,085
25	CrownQuest	6,085
26	CrownQuest	5,920
27	CrownQuest	5,875
28	CrownQuest	5,960
29	CrownQuest	5,883
30	CrownQuest	5,950
31	CrownQuest	5,880
32	CrownQuest	6,375
33	Baytex Energy	6,365
Mississippian Manning Canyon Shale		
34	Bill Barrett Corp	8,300
35	Chief O&G	7,300
36	Shell	9,400
37	Petro-Canada	37
38	Shell	38

Mississippian Manning Canyon Shale

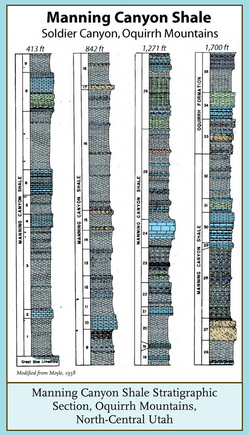


Outcrop of Dark, Organic-Rich Manning Canyon Shale Interbedded with Dark, Thin-Bedded Micritic Limestone, Western Provo Canyon, North-Central Utah

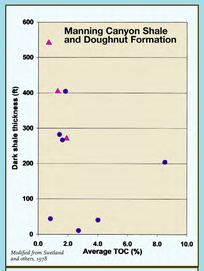


Typical black organic-rich Manning Canyon Shale, Soldier Canyon, Oquirrh Mountains, north-central Utah.

Hand Sample of Manning Canyon Shale



Manning Canyon Shale Stratigraphic Section, Oquirrh Mountains, North-Central Utah

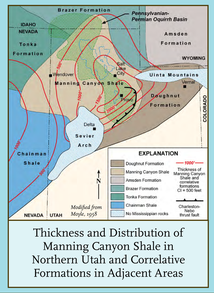


Average TOC Content Values vs. Thickness for Manning Canyon Shale & Doughnut Formation

Manning Canyon Shale

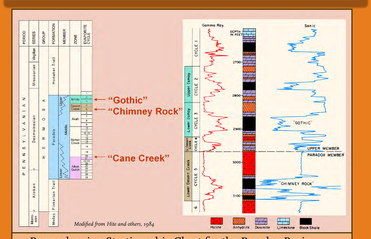
Relatively little is known about the gas potential of the Manning Canyon Shale. This unit is now being investigated by the Utah Geological Survey to:

- Identify and map the major trends for target shale intervals
- Identify areas with the greatest gas potential
- Characterize the geologic, geochemical, & petrophysical rock properties
- Reduce exploration costs & drilling risk
- Recommend the best practices to complete & stimulate targeted shale-gas zones to reduce development costs & maximize gas recovery

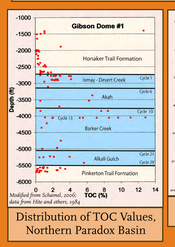


Thickness and Distribution of Manning Canyon Shale in Northern Utah and Correlative Formations in Adjacent Areas

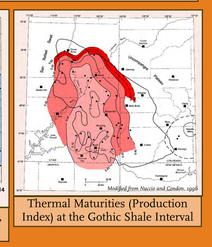
Pennsylvanian Paradox Formation



Pennsylvanian Stratigraphic Chart for the Paradox Basin



Distribution of TOC Values, Northern Paradox Basin

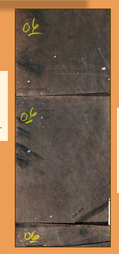


Thermal Maturities (Production Index) at the Gothic Shale Interval

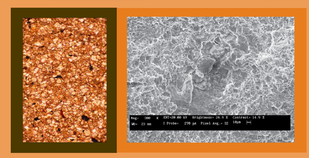
Chimney Rock Shale

Massive dark gray or brown dolomitic mudstone. Mule 31-K well, San Juan County; 6099 ft.

Dark gray or brown dolomitic silty mudstone with wavy-laminated matrix. Mule 31-K well, San Juan County; 6102 ft.

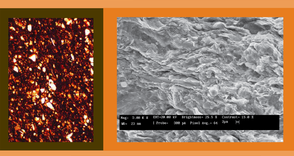


Massive dark gray or brown dolomitic mudstone. Mule 31-K well, San Juan County; 6107 ft.



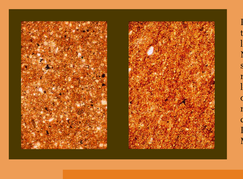
Photomicrograph of dolomite that appears almost bimodal because some of the crystals have replaced original quartz or feldspar grains. Some vestiges of white reflect what is left of these original terrigeneous clastics. Plane-polarized light (100x). Mule 31-K well, San Juan County; 6099 ft.

SEM image overview showing general texture of dolostone characterized by euhedral crystals of dolomite that are about 10 microns wide and sparse silt. Mule 31-K well, San Juan County; 6099 ft.

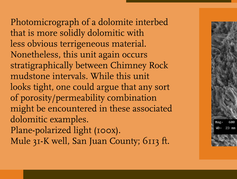


Photomicrograph of an organic Chimney Rock mudstone where terrigenous clastics are clearly entombed in the chloritic, illitic, and slightly smectitic matrix mud. Plane-polarized light (100x). Mule 31-K well, San Juan County; 6102 ft.

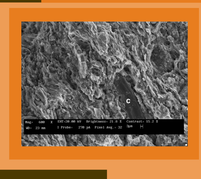
SEM image overview of dolomitic/calcareous mudstone that is characterized by a wavy-laminated matrix primarily composed of clay minerals. Closer examination reveals considerable amounts of calcareous and dolomitic cements admixed with laminated clay minerals. These cements reduce primary porosity that mainly includes flattened intercrystalline micropores between clay minerals. Mule 31-K well, San Juan County; 6102 ft.



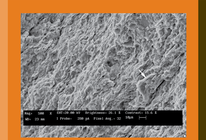
Photomicrograph of a silty dolomite bed situated between Chimney Rock shale sequences. These dolomite interbeds are reasonably common in core, and possess a low gamma ray signature on open-hole logs. Because these interbeds are microporous, petrophysical recognition of such interbeds is important for understanding the influence of lithologies, other than mudstones, on potential production results. Plane-polarized light (100x). Mule 31-K well, San Juan County; 6107 ft.



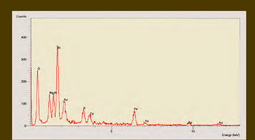
Photomicrograph of a dolomite interbed that is more solidly dolomitic with less obvious terrigeneous material. Nonetheless, this unit again occurs stratigraphically between Chimney Rock mudstone intervals. While this unit looks tight, one could argue that any sort of porosity/permeability combination might be encountered in these associated dolomitic examples. Plane-polarized light (100x). Mule 31-K well, San Juan County; 6113 ft.



SEM image of shale texture exhibiting weakly developed laminae composed of stacked and crenulated clay flakes. A matrix composition of mixed illite, illite/smectite, and chlorite is probable. Carbonaceous particles (c) aligned parallel to bedding in shale. Crenulated shapes of clay flakes, irregularities introduced by diagenetic cement crystals, and admixed organic particles all create open micropores in the heterogeneous shale matrix. Jefferson State 4-1 well, San Juan County; 6195 ft.

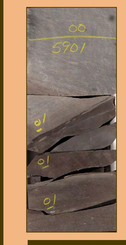


SEM image of shale highlighting a laminated fabric of crenulated clays. Little or no silt or sand-sized material is observed, identifying the sample as shale rather than mudstone. A mixture of detrital clays is most likely; the large flake (arrow) produces the spot elemental spectrum. Induced stress-release porosity is evident as elongate microfractures parallel to bedding. Jefferson State 4-1 well, San Juan County; 6193 ft.

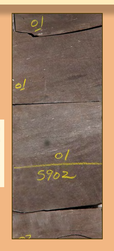


Elemental spectrum for the clay flake shown with arrow on image to the left. In addition to Si, O, and Al peaks indicative of clay, medium-sized peaks for Mg and Fe suggest a chlorite composition. The K peak likely denotes illite, whereas the Ca peak could indicate intermixed illite/smectite. Gold peaks reflect sample coating. Jefferson State 4-1 well, San Juan County; 6193 ft.

Gothic Shale



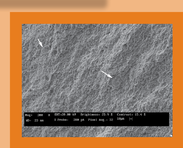
Dark gray dolomitic mudstone showing contact with overlying Ismay zone. Mule 31-K well, San Juan County; 5901 ft.



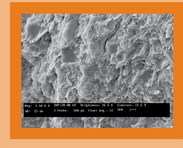
Dark gray dolomitic silty mudstone with wavy to planar lamination. Mule 31-K well, San Juan County; 5902 ft.

Photomicrograph of the Gothic Shale composed of terrigeneous material, fossils, and clays. Mottled appearance may be related to some bioturbation. In this well, the Gothic is fractured, and in this view a subvertical fracture is composed of red-stained calcite. However, not all fractures in this interval are completely occluded by diagenetic minerals. Plane-polarized light (40x). Jefferson State 4-1 well, San Juan County; 6037 ft.

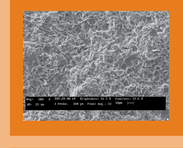
Photomicrograph of the Gothic Shale at higher magnification illustrating the mixed mineralogy/grain content, the ribbonlike nature of the calcitic (red) fracture filling, and the dark material representing both carbonaceous material and pyrite. The mud matrix is modestly microporous. Plane-polarized light (100x). Jefferson State 4-1 well, San Juan County; 6037 ft.



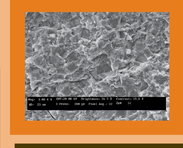
SEM image of poorly laminated mudstone at low magnification. Likely minerals include clays (illite and possibly chlorite), dolomite, and quartz. Several pyrite framboids (arrows) are visible in this image. Jefferson State 4-1 well, San Juan County; 6051 ft.



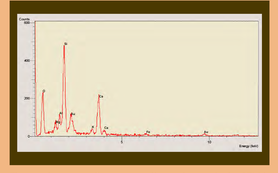
SEM image at higher magnification, silt-sized calcite and non-ferroan dolomite grain replacements populate a matrix of wavy and crenulated clay flakes. The most common pores are intercrystalline micropores between clay flakes. Jefferson State 4-1 well, San Juan County; 6051 ft.



SEM image of mudstone texture dominated by interlocking, subhedral dolomite crystals. Porosity is likely minimal. Jefferson State 4-1 well, San Juan County; 6070 ft.



SEM image of at higher magnification of dolomitic mudstone highlighting packets of clays (preferred alignment lower left to upper right) sandwiched between dolomite crystals. The tightly crystalline fabric leaves little visible microporosity. Jefferson State 4-1 well, San Juan County; 6070 ft.

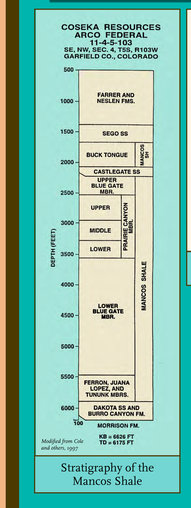


Elemental spectrum for corresponding to the area in the SEM image above. Peaks for Si, O, Al and K likely indicate illite, whereas Ca, Mg and O peaks denote dolomite. A likely interpretation is a diagenetic dolomite overprint on an illitic mudstone matrix. The small Fe peaks are more likely associated with clays than dolomite because the analysis on individual dolomite crystals shows no Fe component. Jefferson State 4-1 well, San Juan County; 6070 ft.

Paradox Formation

- Pennsylvanian "black shale" Gothic and Chimney Rock (as well as the Cane Creek and Hovenweep shales) are likely gas productive in certain zones.
- The porosity of all reservoirs is modest – estimated between 2 and 5% based on testing to date.
- The interbedded dolomite within and bounding the mudstone sections may be the most permeable conduit for sustained hydrocarbon production. Permeability is likely modest but appears best represented by intercrystalline porosity from euhedral to subhedral dolomite crystal aggregates.
- The larger, partially filled natural fractures (filled mainly by calcite) could assist in providing a respectable initial potential flow especially when the hydraulic fracturing protocol is able to access natural fracture occurrence. Much of this fracturing occurs in the associated dolomites, although not exclusively.
- The calcareous mudstones are likely productive as well, although matrix permeability is still in the nanodarcy range. Production from the mudstones is possibly related to both interstitial and desorbed gas.

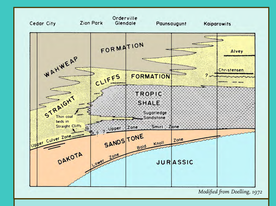
Cretaceous Tropic and Mancos Shales



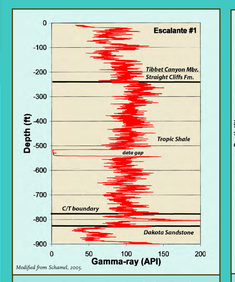
Stratigraphy of the Mancos Shale

Late Cretaceous Paleogeography

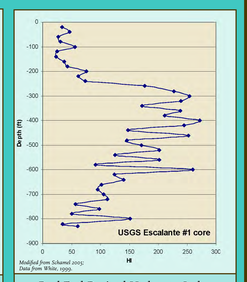
Tropic Shale



Stratigraphic Position of the Tropic Shale, South Central Utah



Gamma Ray Log, Tropic Shale, Escalante No. 1 Well, Northern Kaiparowits Plateau, South Central Utah



RockEval-Derived Hydrogen Index (HI) Escalante No. 1 Well, Northern Kaiparowits Plateau, South Central Utah

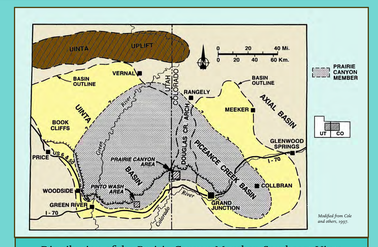
Tropic-Tununk and Lower Blue Gate Shale

- Zones with organic richness in excess of 2.0%
- Wide distribution of these units
- Thin-bedded sandstone intervals could be gas-charged where in close juxtaposition to organic-rich shales
- Potential "sweet spots" for shale gas where the rocks are sufficiently buried
- Oil-prone shale intervals that are in the uppermost oil window may yield gas in deep-burial conditions in the Uinta Basin

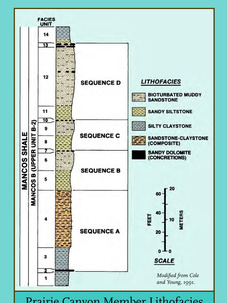
Interbedded thinly laminated, graded siltstone with loadcasts and dark gray claystone. Escalante 1 well, Garfield County; 434 ft.

Graded laminated siltstone lenses within very dark gray laminated calcareous claystone. Escalante 1 well, Garfield County; 436 ft.

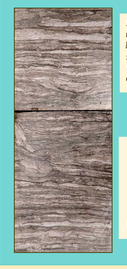
Prairie Canyon Member



Distribution of the Prairie Canyon Member, Southeast Uinta Basin, Douglas Creek Arch, Piceance Creek Basin



Prairie Canyon Member Lithofacies



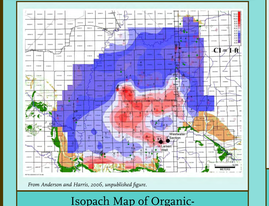
Bioturbated muddy sandstone lithofacies. 8-2-15-22 State of Utah well, Uintah County; 5425 ft.

Sandstone-claystone lithofacies with lenticular lamination and wave-ripple and current-ripple lamination. 8-2-15-22 State of Utah well, Uintah County; 5435 ft.

Sandstone-claystone lithofacies with wave-ripple and current-ripple lamination. 8-2-15-22 State of Utah well, Uintah County; 5433 ft.

Sandstone-claystone lithofacies with lenticular lamination. 8-2-15-22 State of Utah well, Uintah County; 5436 ft.

Blue Gate Shale



Isopach Map of Organic-Rich Mancos Shale

Thermal Maturities (Vitrinite Reflectance) at the Top of the Mancos Shale

Upper high-TOC interval with dense, non-fissle, dark gray claystone and scattered, light gray silt laminae and bivalve fragments. River Gas of Utah 1 well, Carbon County; 797 ft.

Lower high-TOC interval with dense, non-fissle very dark gray claystone. River Gas of Utah 1 well, Carbon County; 1175 ft.

Total Organic Carbon, Lower Blue Gate Shale, River Gas of Utah No. 1

Tununk Shale

Dark gray calcareous mudstone with silt to very fine sand laminae and interbeds, and silt-filled burrows. River Gas of Utah 1 well, Carbon County; 1885 ft.

Prairie Canyon Member

- Lean, dominantly humic, kerogen is contained in the shale interlaminated with the siltstone-sandstone
- High quartz content is likely to result in a higher degree of natural fracturing than the enclosing claystone-mudstone rocks
- May respond well to hydraulic fracturing
- Porosity of the sandstone interbeds averaging 5.4% can enhance gas storage
- Extends beneath the southeast Uinta Basin reaching depths sufficient for gas generation and retention from the gas-prone kerogen

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