Manning Canyon Shale: Depositional Setting of an Emerging Gas Resource Play in Utah*

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Abstract

At the north end of the San Rafael Swell 22 exploration wells that fully penetrate the Manning Canyon Shale (Upper Mississippian-lowermost Pennsylvanian) delineate a 600-square-mile area of an emerging gas resource play. In this region, the formation is 400-1200 feet thick. Approximately two-thirds of the section is dark gray, organic-rich silty limestone and mudstone. Organic matter content of the carbonaceous rocks is typically 1% to 10%, but it is even greater in thin coal beds. The rocks have measured vitrinite reflectance in the range 1.3% to 1.8%, putting them well within the gas generative window. Gas tests and shows are reported from many of the exploration wells. The stratigraphy and rock properties of the Manning Canyon Shale have been determined from well logs, cuttings and cores, including an 800-foot continuous core. The lithotypes within this heterogeneous formation are comprised of mixtures of four components: (1) calcite microbioclasts and shelly debris, largely thin-shelled brachiopods and thick-shelled pelecypods, (2) eolian coarse silt to fine-grained quartz sand, (3) an assemblage of mature clays (illite, smectite-illlite, kaolinite and chlorite) derived from an intensely leached regolith on adjacent Mississippian-age limestone, and (4) degraded fragments of terrestrial plants occurring as disseminated micron-size grains or as discrete plant parts. These four components combine to form a range of lithotypes: organic-rich or organic-poor, silty or non-silty packstones, wackestones, and dark gray or varicolored, calcareous or no calcareous mudstones. The several lithotypes are interbedded at a scale of feet to at most a few tens of feet. The continuous core exhibits a weak vertical cyclicity, indicating possible flooding surfaces and parasequences, but stratal cyclicity not detected in well logs. On the whole, the formation lacks lateral continuity of strata, even between close-spaced wells. In the gas-play area, the unit was deposited in a broad structural depression adjacent to the nascent Uncompaghre uplift. The fresh-water marshes of the Everglades, together with the shallow-water, brackish to marine carbonate factory of Florida Bay may serve as a conceptual model for the depositional setting of the Manning Canyon Shale. Hummocks and marshes formed on the carbonate mud mounds in the bay are an additional source of terrestrial and algal organic matter. A robust stratigraphic model is essential for effective future exploitation of this gas resource.

References

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Manning Canyon Shale

Depositional Setting of an Emerging Shale Gas Resource Play in Utah

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Manning Canyon Shale: Key Observations

1. The Manning Canyon Shale in north-central Utah has had good gas shows in the past and once again has attracted industry attention. Since 2008 two vertical wells and one horizontal well have been completed and have tested gas. The wells are still confidential, in part, pending further evaluation of the gas discoveries.

2. At the north end of the San Rafael Swell, 22 exploration wells fully penetrating the Manning Canyon Shale define the potential area for this gas play of 600 square miles. In this area the unit is 300-1,500 feet thick.

3. Organic matter of terrestrial origin and of good to excellent richness is distributed throughout the shales, limestones and even the siltstones that comprise the unit. Vitrinite reflectance measurements by the UGS indicate that the kerogen is in the dry gas thermal maturity window.

4. The Manning Canyon Shale lacks the cyclicity and lateral continuity associated with typical Carboniferous cyclothems. This organic carbon-rich unit may have been deposited in a shallow restricted carbonate- and organic-rich marine, brackish and fresh-water setting not unlike the modern Everglades and Florida Bay.

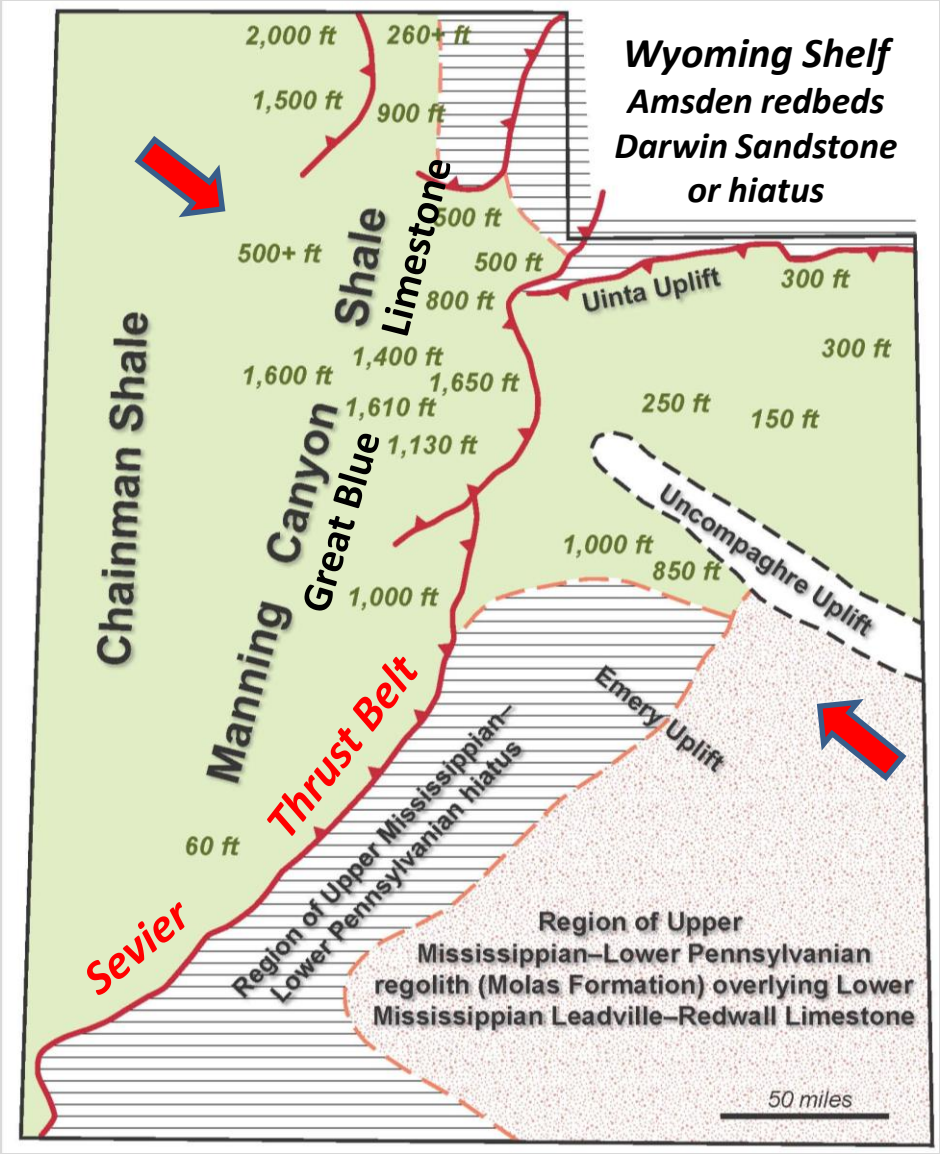
Regional Distribution of the Manning Canyon Shale

The Manning Canyon Shale is an organic-rich limestone-shale and sandstone unit of Late Mississippian-earliest Pennsylvanian age found in many of the ranges west of the Sevier Thrust Front and Hingeline, on the flanks of the Uinta Mountains, and in the subsurface in the Book Cliffs area near Price, Utah. In the west, the unit interfingers with the underlying Great Blue Limestone.

The unit is thickest in the Oquirrh Basin and in the Oquirrh Sag south of the Uncompaghre Uplift. The depositional thicks relate to the onset of Ancestral Rockies tectonism.

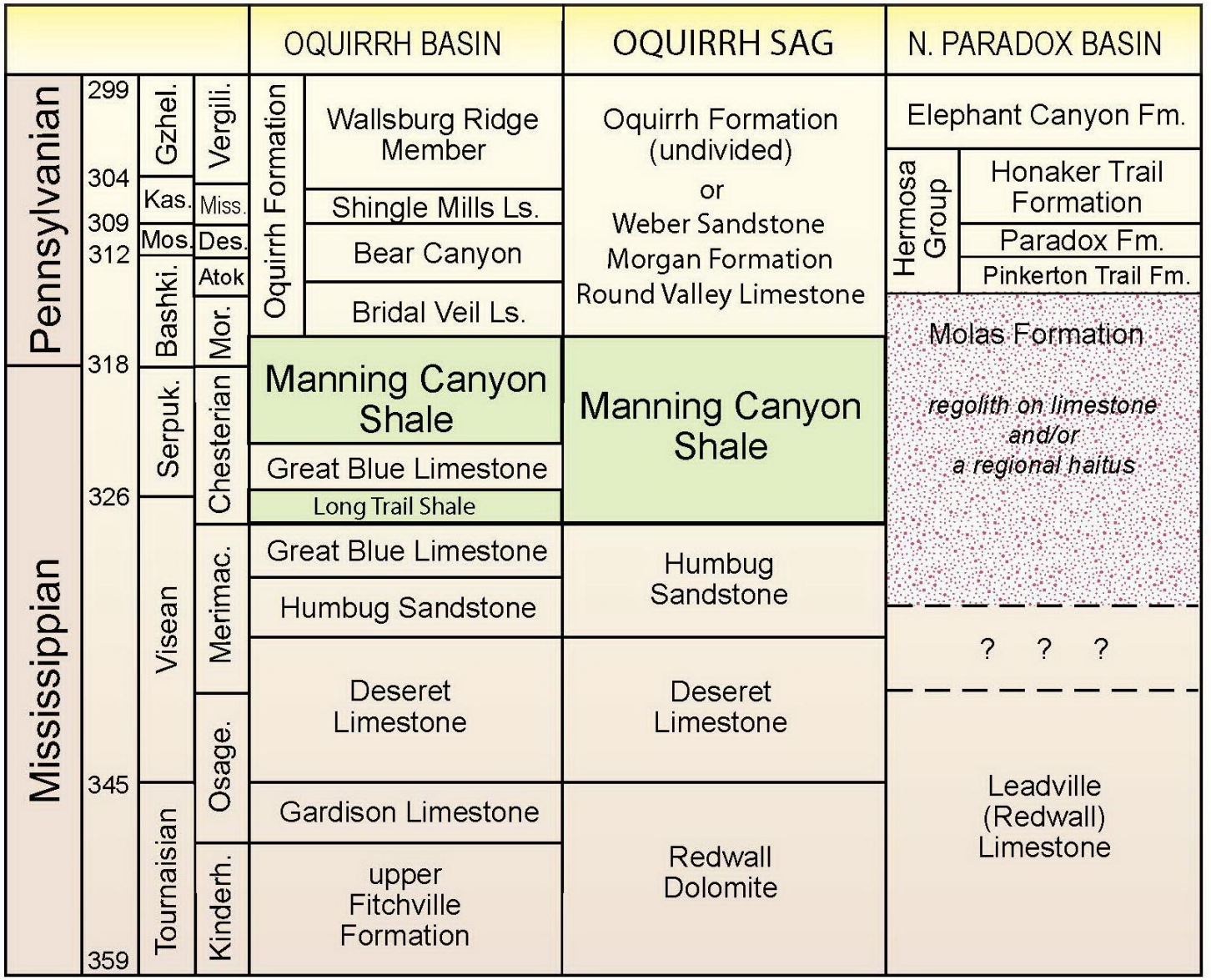
The Manning Canyon Shale is coeval with a lateritic regolith and red beds preserved in southeast Utah. The unit contains sediments eroded from this regolith by wind and water action.

To the northeast are terrestrial redbeds (Amsden) and eolian sandstones (Darwin).

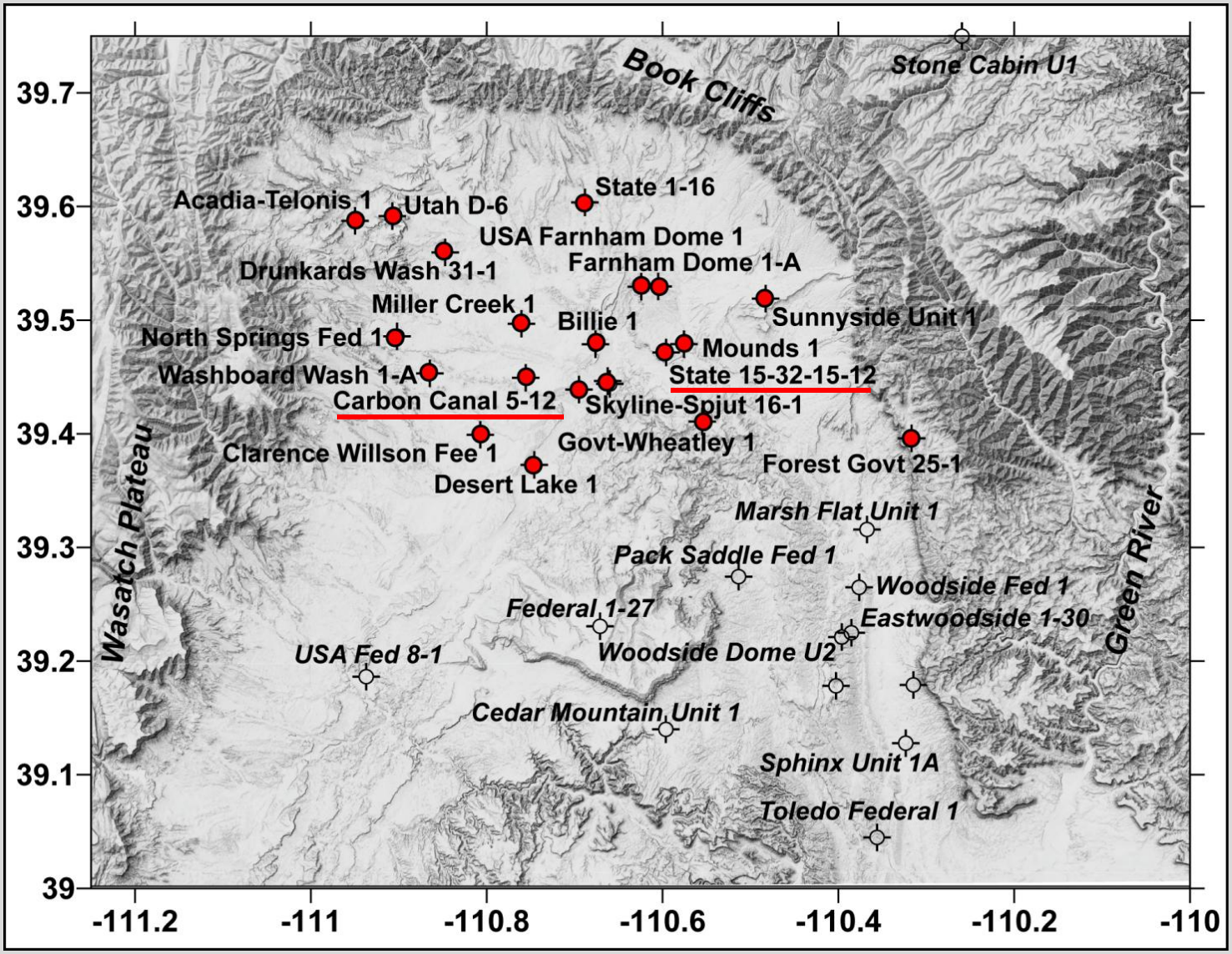


Sources: Hintze and Kowallis (2009), Long and Link (2007), this study.

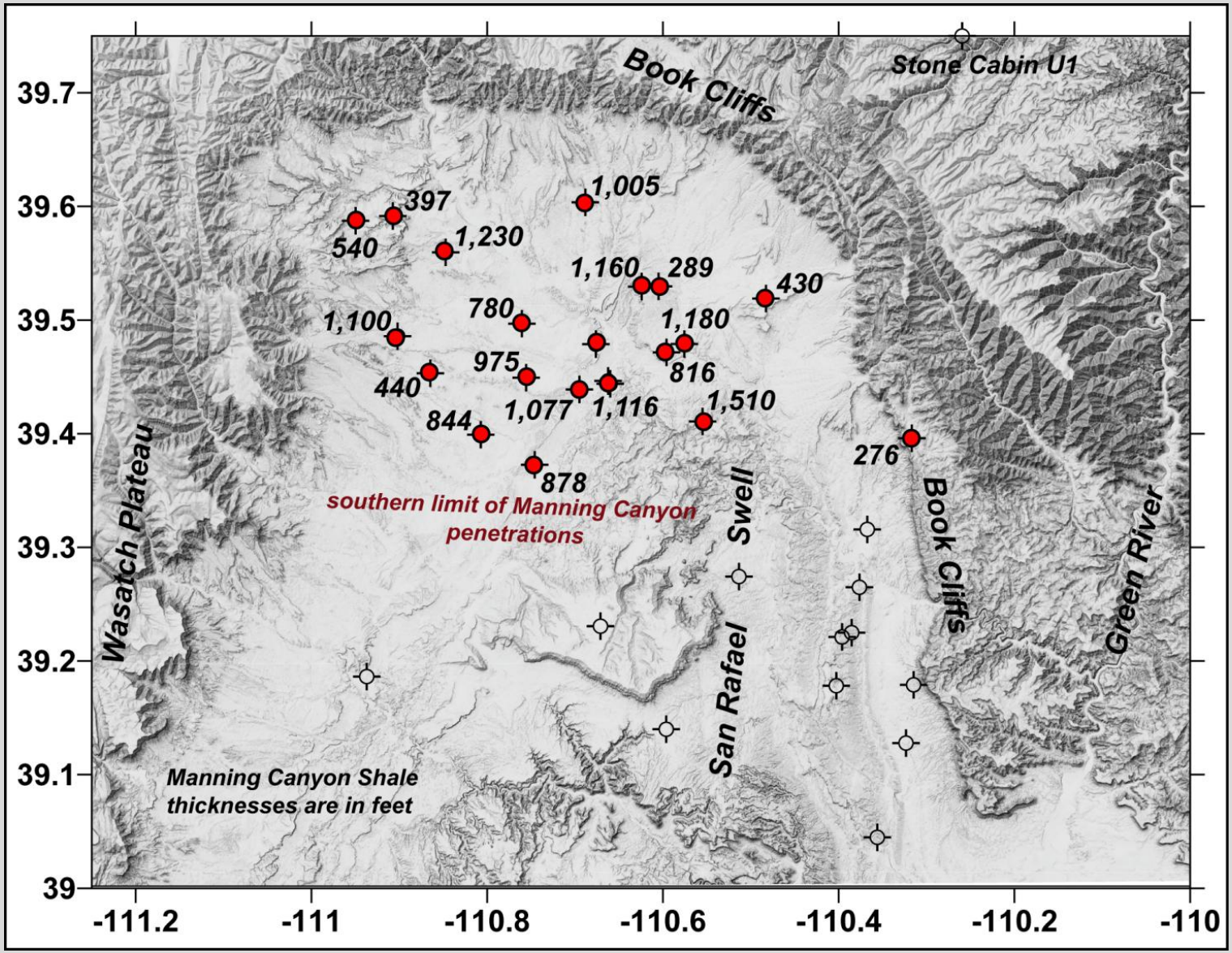
Late Mississippian-Early Pennsylvanian Age



Twenty-two Wells Penetrate the Manning Canyon Shale



Reported Well Thickness of Manning Canyon Shale



Manning Canyon Shale: Gas Shows and Tests

The Manning Canyon Shale was a specific exploration target for many wells drilled in the 1960-1980s. Operators were attracted by potential limestone and sandstone reservoirs embedded in a good source rock.

Federal Mounds 11-1 tested 759 Mcfgpd from "stray sands". Other wells, such as Skyline-Spjut 16-1, Mounds 1, and Washboard Wash USA 1-A, encountered gas in DSTs and in cuttings and core.

After a two-decade hiatus industry returned, drilling two vertical wells and one horizontal well near the nose of the San Rafael Swell.

Shell Western E&P (SWEPI) completed the Carbon Canal 5-12 well in April, 2008 with four frac stages. A 544-ft core was recovered for gas and reservoir analysis. The lower frac stage was plugged off due to heavy water flow. The other three had an IP of 178 Mcfgpd and 667 bwpd. 1,052 BTU gas. Currently shut-in.

Bill Barrett Corporation's Deep Hook project drilled State 15-32-15-12 in 2008 recovering 422 feet of core for gas and reservoir analysis. State 16H-32-15-12 was completed in late 2009, testing 225 Mcfgpd and 120 bwpd. Currently shut-in.

Samples and data available in the public domain

Well completion reports, driller logs and e-logs available online from the Utah Division of Oil, Gas and Mining (www.ogm.utah.gov)

Internal files of the Utah Geological Survey and well cuttings in the Utah Core Research Center

Cores available from the U.S. Geological Survey Core Depository (Denver) and the Texas Bureau of Economic Geology

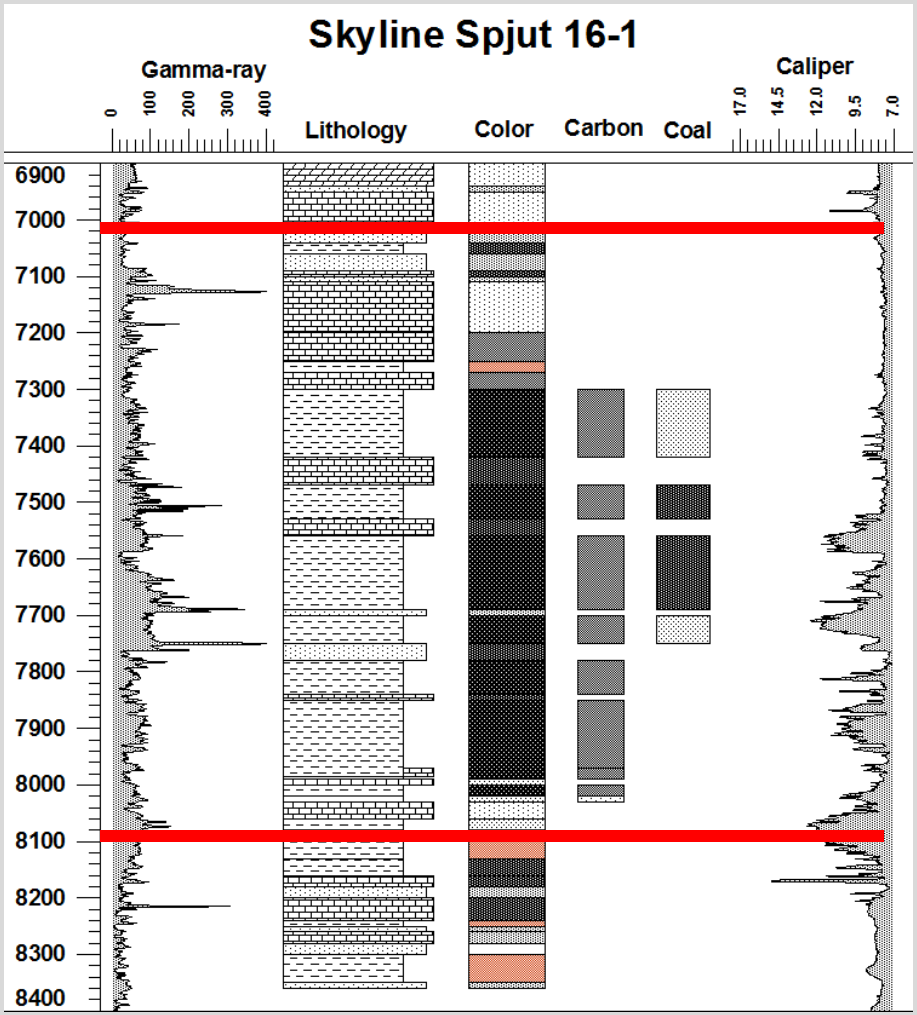
Published literature

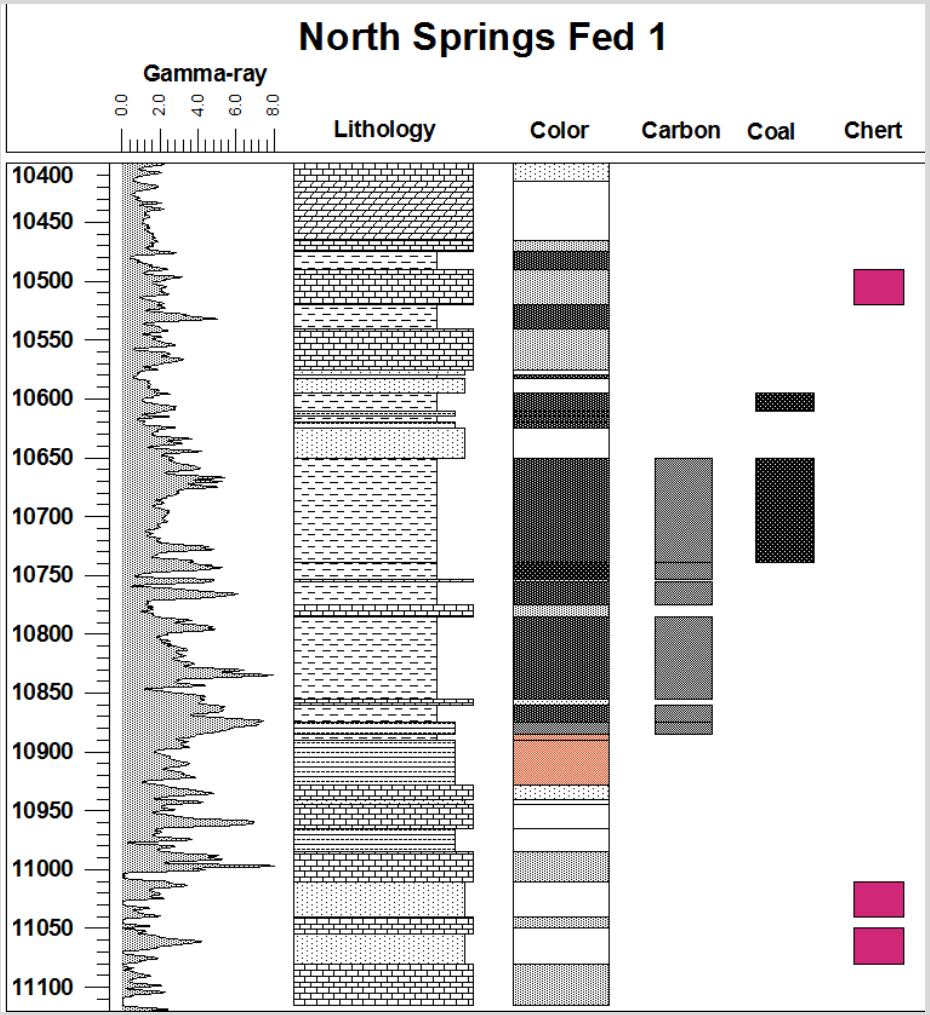
Shell Western E & P (SWEPI) donated the Carbon Canal 5-12 core and core analyses to the Utah Geological Survey for this study.

We gratefully acknowledge the assistance of many colleagues in the Utah Geological Survey: Thomas Chidsey, Jr., Jeff Quick, Craig Morgan, Michael Laine, Stephanie Carney, and Ammon McDonald

Technology transfer contribution to Paleozoic Shale Gas Resources of the Colorado Plateau and Eastern Great Basin, Utah: Multiple Frontier Exploration Opportunities, an Unconventional Onshore Program of the Research Partnership to Secure Energy for America (RPSEA) research project, 2008-2011

Interbedded dark silty carbonaceous limestone and shale



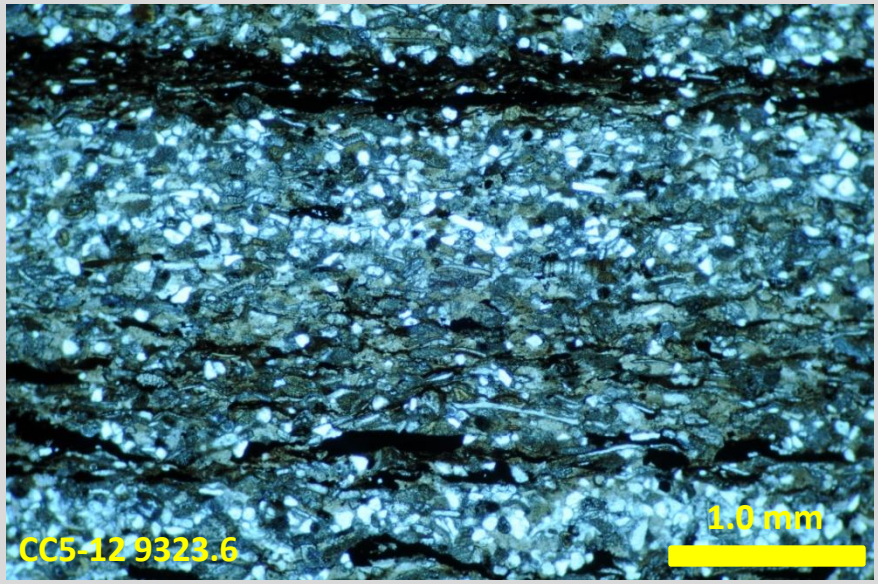


Only two wells permit comparison of a detailed drilling log with partial e-log suites.

Lithologies are mix of four major sedimentary components

Carbonate

Dominantly calcite microbioclasts and shelly debris organized into packstone, wackestone and limy mudstone. Fossils are mainly brachiopods and pelecypods with minor bryozoans, siliceous sponges and crinoids; absence of allochems and forams. A "heterozoan" faunal assemblage, normally typical of cool or turbid waters.



Silt and Sand

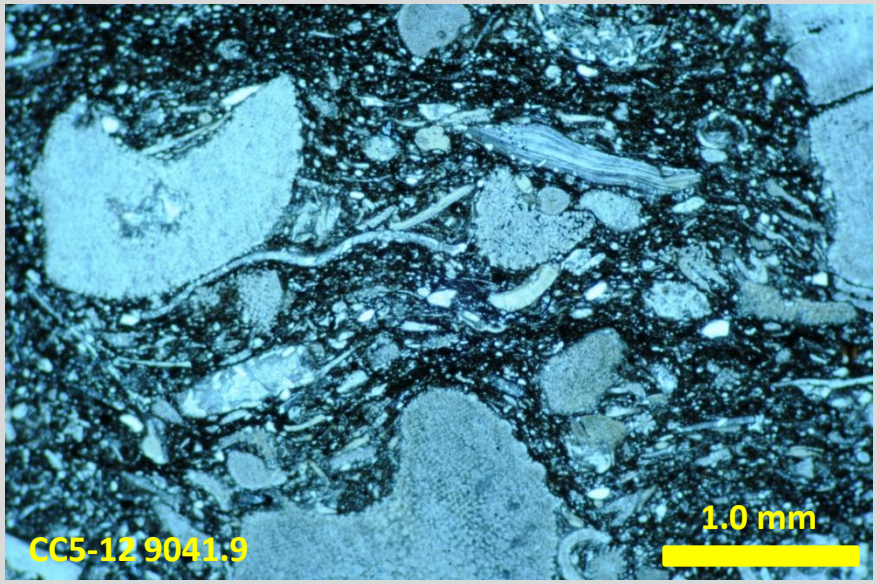
Fine to coarse silt and very fine-grained quartz sand, angular to subangular. Eolian.

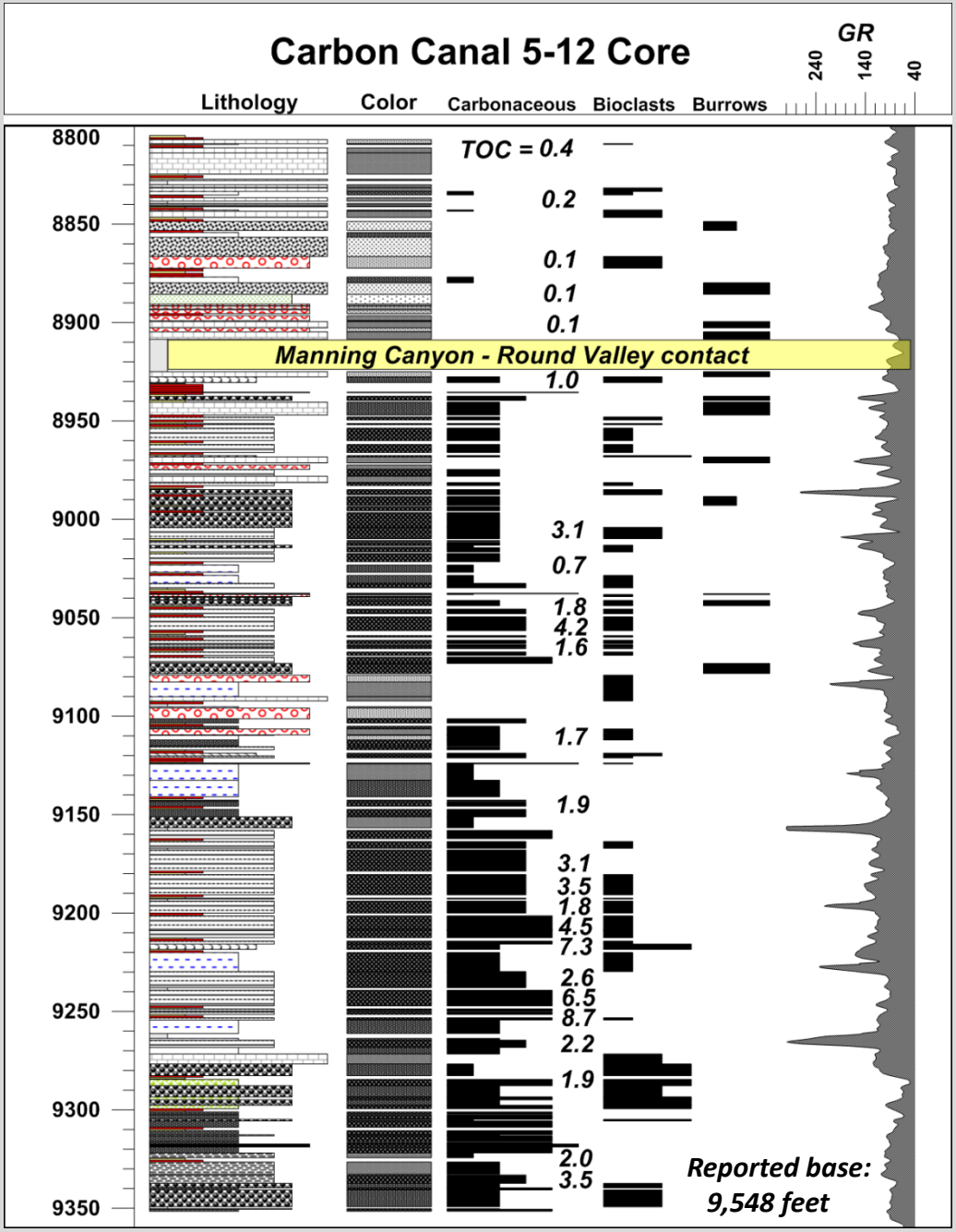
Clays

An assemblage of smectite-illite, illite, kaolinite and chlorite. Rock chemistry indicates enrichment in Al, K, Fe and Ti compared to NA Composite Shale.

Organic Matter

Dominantly degraded fragments of terrestrial plants found as disseminated micron-size grains or as discrete plant parts.



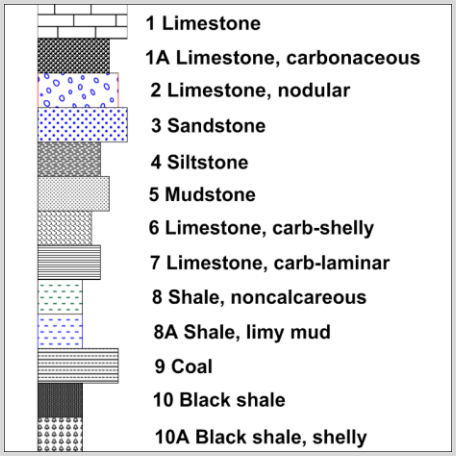


Manning Canyon Shale lithotypes

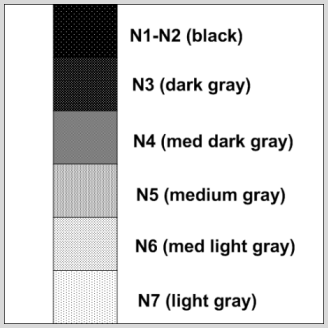
The rocks are dominantly carbonaceous with high TOCs and black to medium gray color. Whole fossils and fragments are distributed throughout; burrows are rare in the lower, more organic-rich, part of the cored interval.

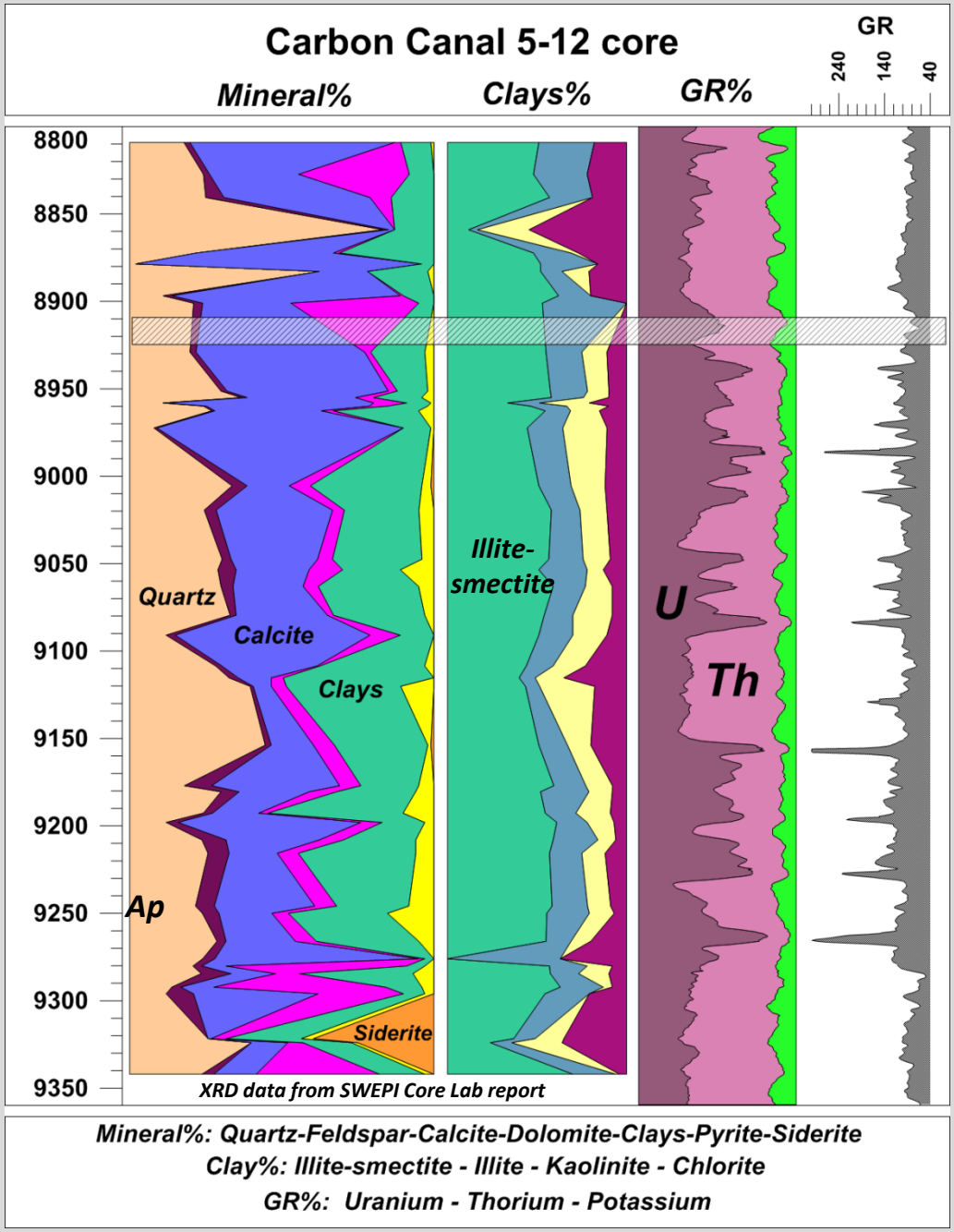
The most prevalent lithology is carbonaceous, silty,laminated packstone to wackestone , with and without thin-shelled brachiopods. Quartz silt is present in most lithotypes, and less commonly is the dominant component. There are gray and black shales, silty and silt-free.

Backgound GR is slightly elevated with sharp peaks perhaps marking phosphatic layers, but not distinct "hot shale" layers.



Cored interval: 544 ft
Core available: 422 ft





Manning Canyon mineral composition

Most of the 35 samples examined by XRD contain subequal amounts of quartz, calcite and clays.

The samples analyzed are representative of all lithotypes. Feldspar is found throughout and may be an anchimetamorphic phase.

Illite-smectite (±20% smectite layers) is the dominant clay mineral. Illite and kaolinite are relatively uniform, but chlorite is variable in a pattern suggesting interaction with pyrite.

Unusually high siderite in nodules is observed at 9322-9324 ft in association with very low pyrite.

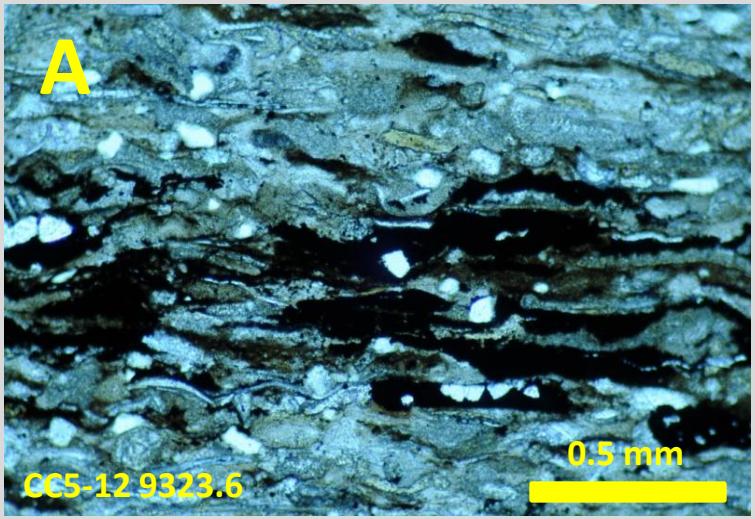
This may indicate a fresh-water depositional setting. High content of pyrite through the overlying section may imply a dominantly brackish to marine setting.

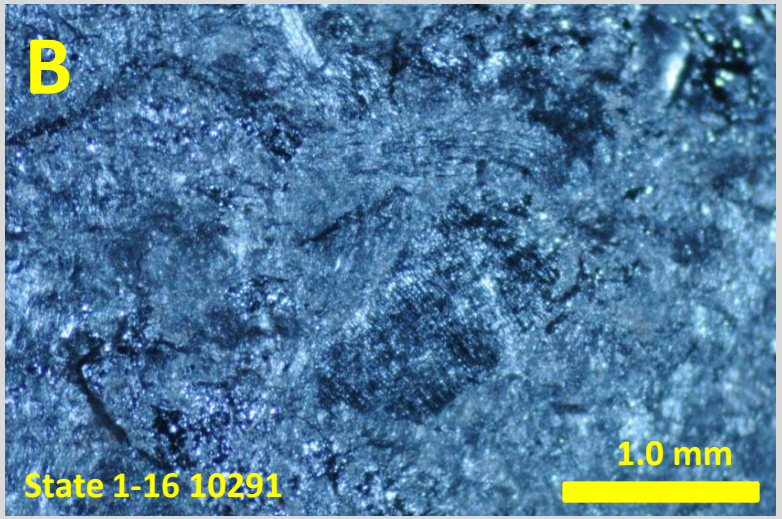
Unusually high apatite is observed at 9246-9250 ft.

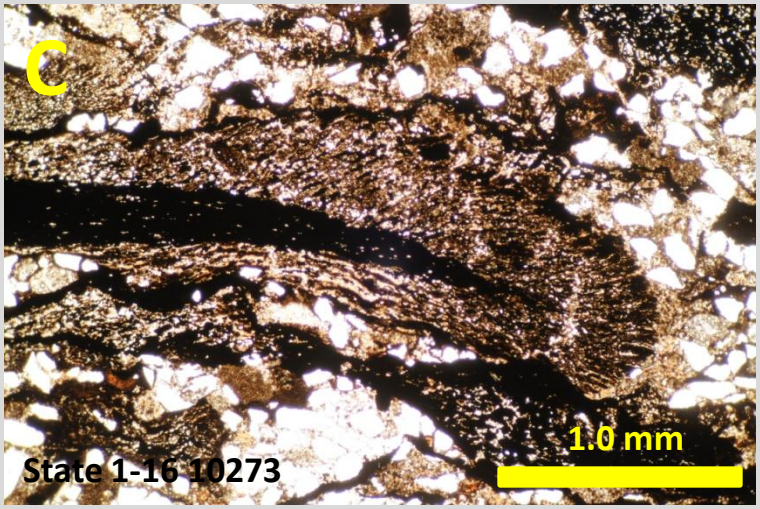
Uranium and thorium have approximately equal contribution to the total gamma-ray signal, except in the GR spikes in which U is the major radioactive source. The contribution of potassium is relatively small.

Organic Matter

Dominantly structured macerals: inertinite and minor vitrinite, semi-fusinite, and sporite. Amorphous kerogen may be present but appears rare in the untreated samples examined. Organic matter occurs in finely disseminated grains (A), discrete plant tissue fragments (B, C), and in thin coal beds(D).







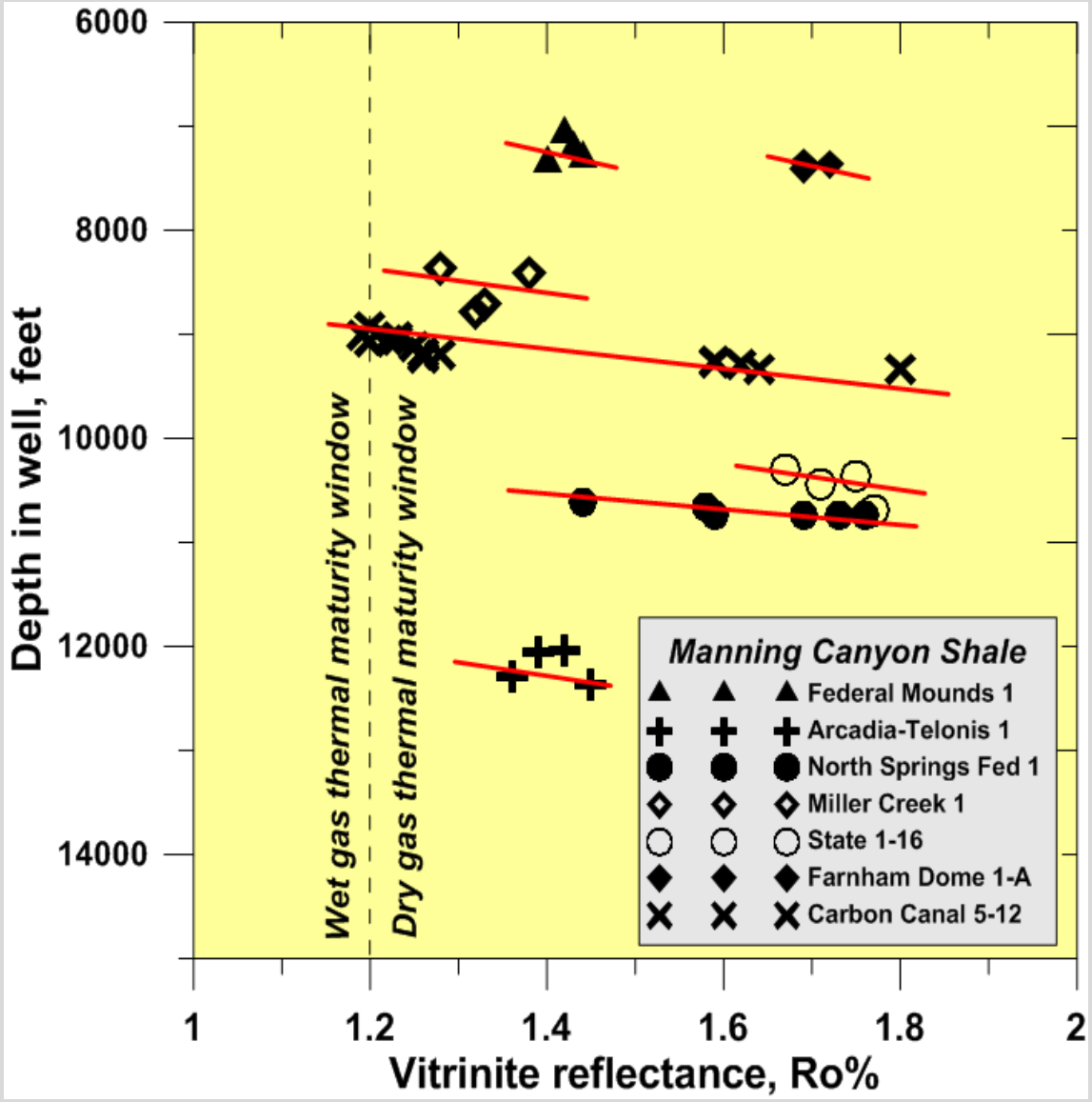
Thermal Maturity of Kerogen

Samples are cuttings and core from both flanks of the north-plunging San Rafael Swell representing a range of present depths of burial.

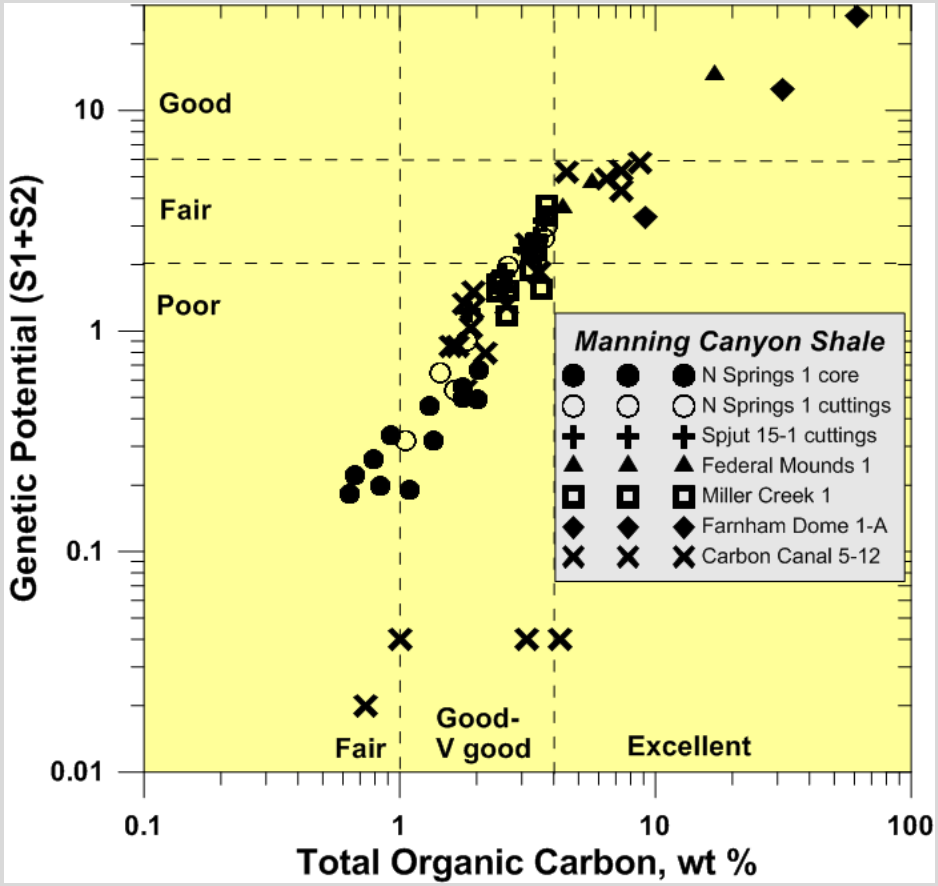
All vitrinite reflectance values are well within the dry gas thermal maturity window. The absence of a depth-Ro relationship indicates that peak of maturity was reached prior to uplift of the San Rafael Swell in latest Cretaceous-Paleocene time.

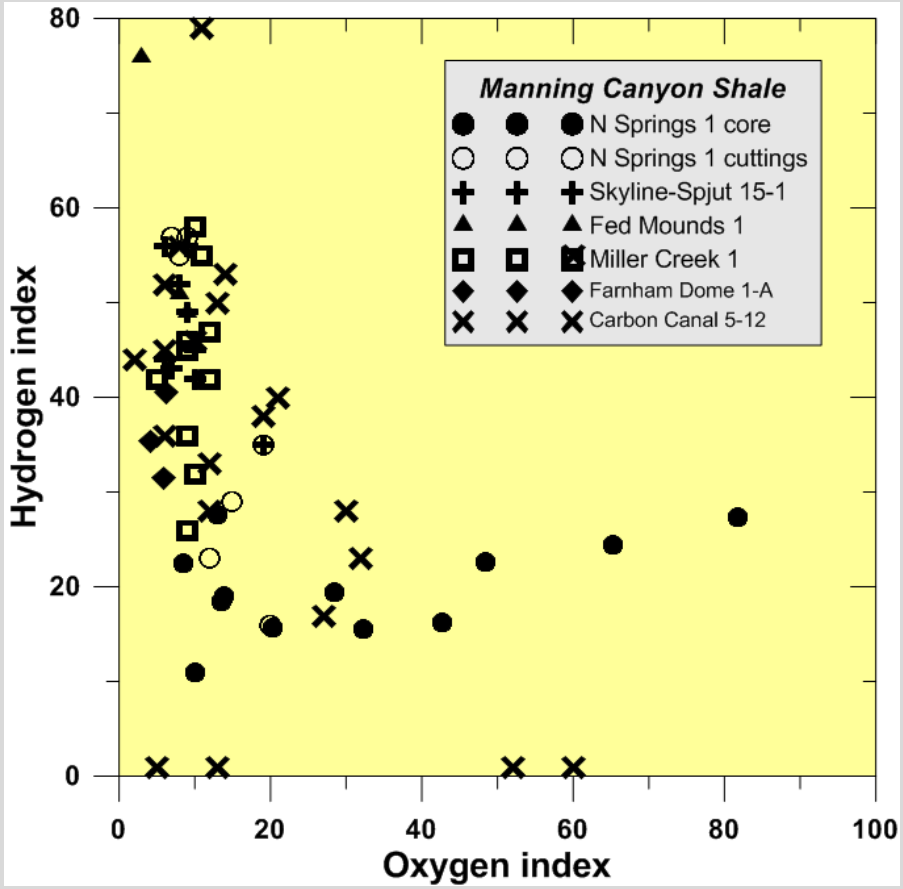
Inertinite is the dominant organic maceral type. Result of incomplete aerobic macrobial degradation of terrestrial plant matter and partial combustion by wildfires.

G. Waanders reports the presence of only terrestrial palynomorphs in these rocks.

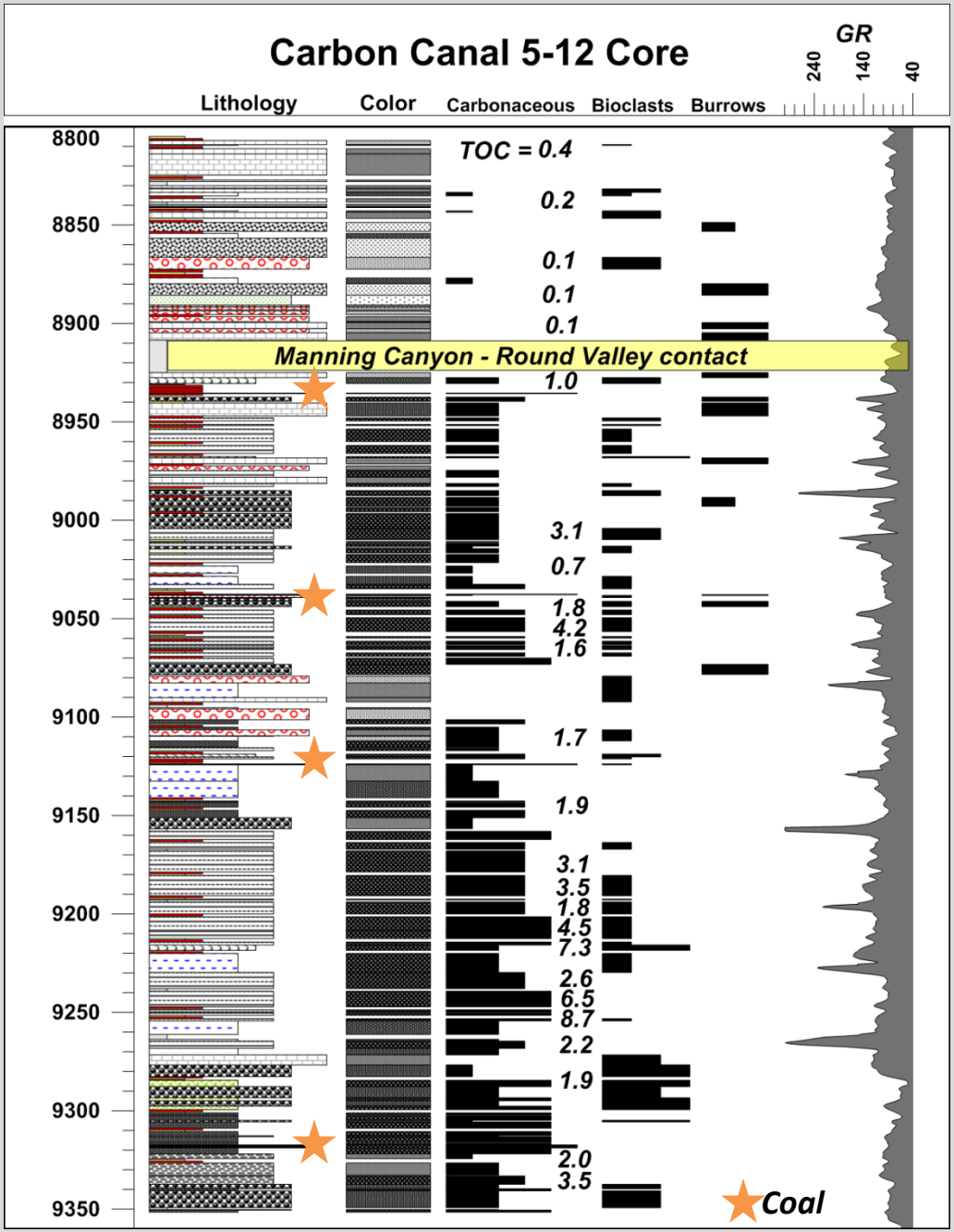


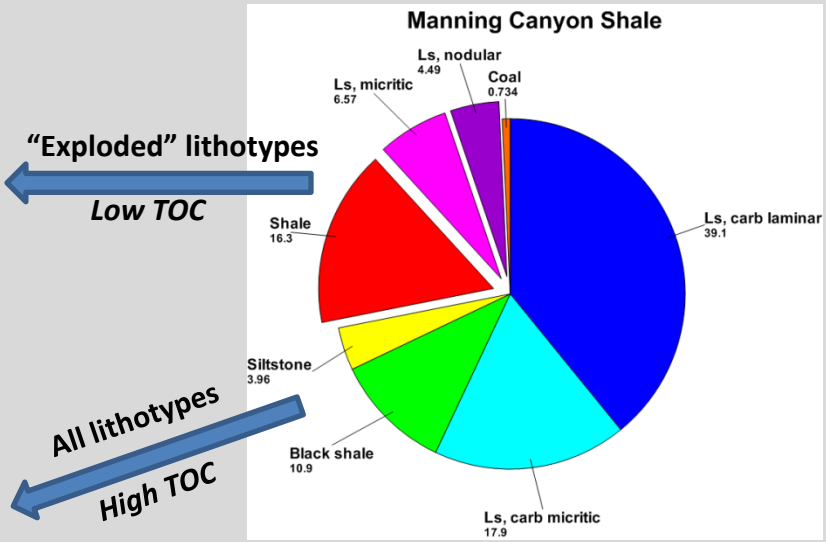
Programmed pyrolysis geochemistry

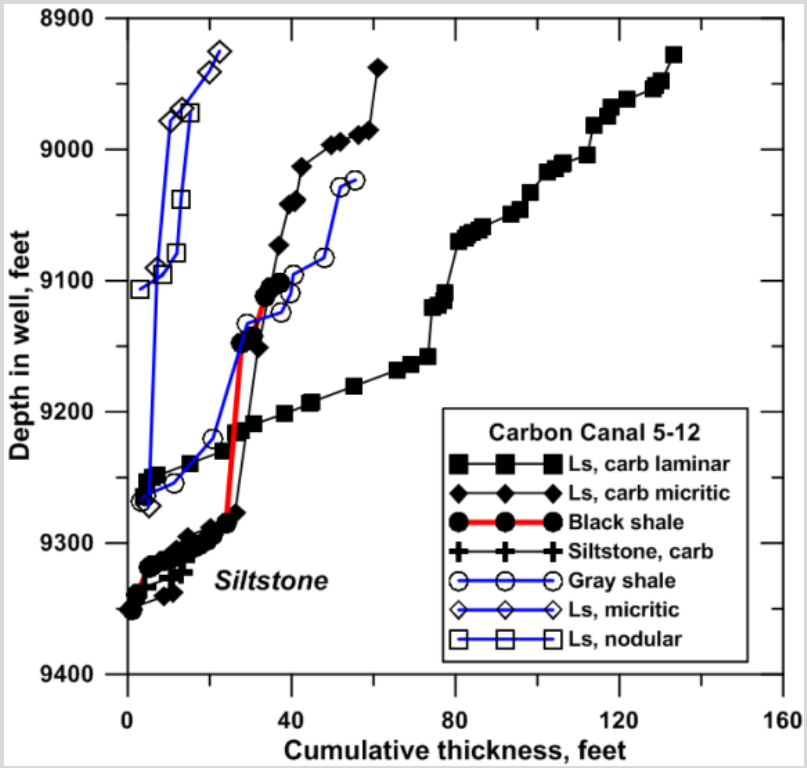


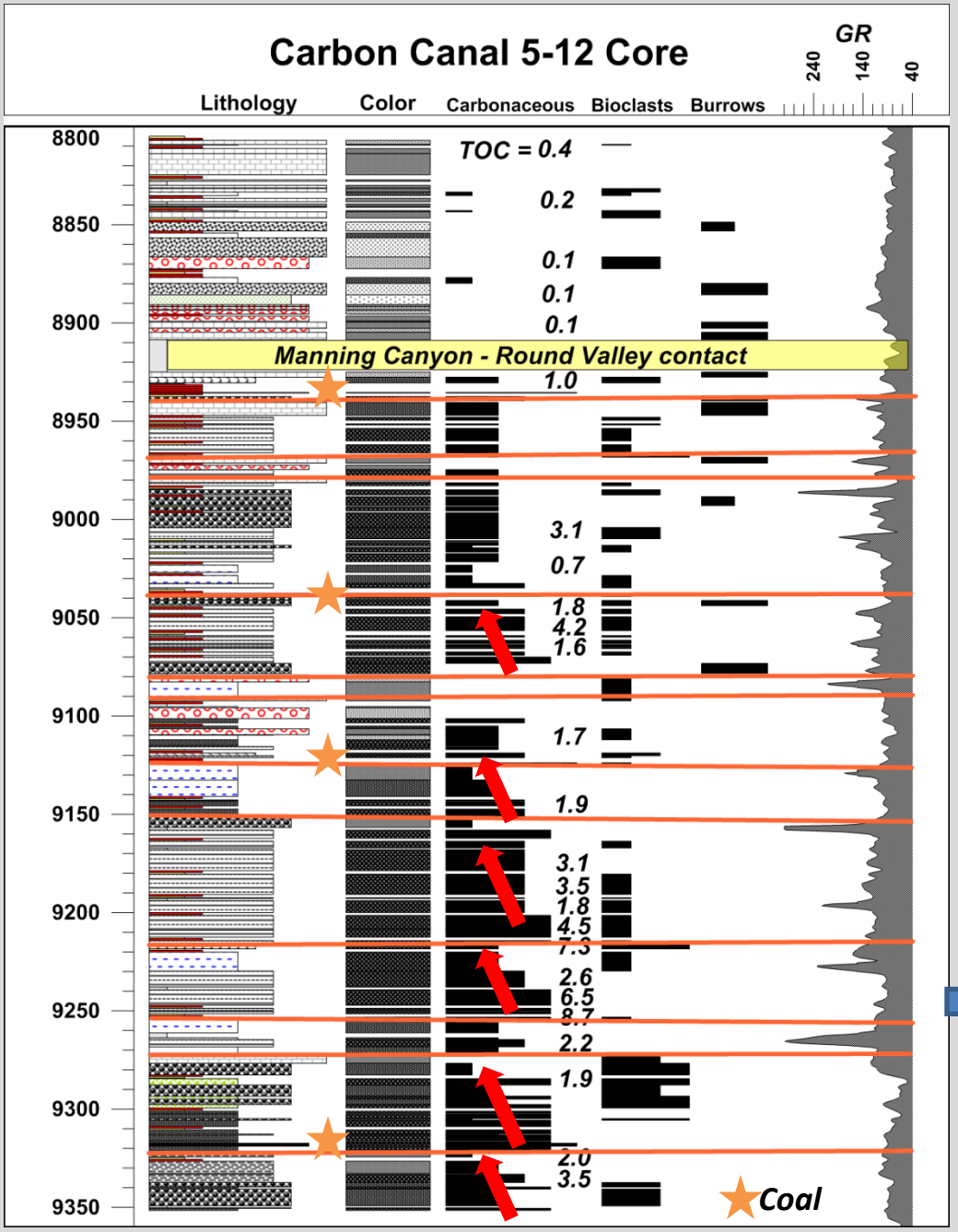


The low values of hydrogen index and genetic potential are consistent with the high thermal maturity of the kerogen and large inertinite content. If corrected for maturity, the TOC values would increase considerably. Also the coaly rocks may be under-represented in the samples.


Carbon Canal 5-12 Core
GR
240
140
40
Lithology
Color
Carbonaceous
Bioclasts
Burrows
8800
8850
8900
8950
9000
9050
9100
9150
9200
9250
9300
9350
TOC = 0.4
0.2
0.1
0.1
0.1
Manning Canyon - Round Valley contact
1.0
3.1
0.7
1.8
4.2
1.6
1.7
1.9
3.1
3.5
1.8
4.5
7.3
2.6
6.5
8.7
2.2
1.9
2.0
3.5
Coal


"Exploded" lithotypes
Low TOC
All lithotypes
High TOC
Manning Canyon Shale
Ls, nodular
4.49
Coal
0.734
Ls, micritic
6.57
Shale
16.3
Ls, carb laminar
39.1
Siltstone
3.96
Black shale
10.9
Ls, carb micritic
17.9

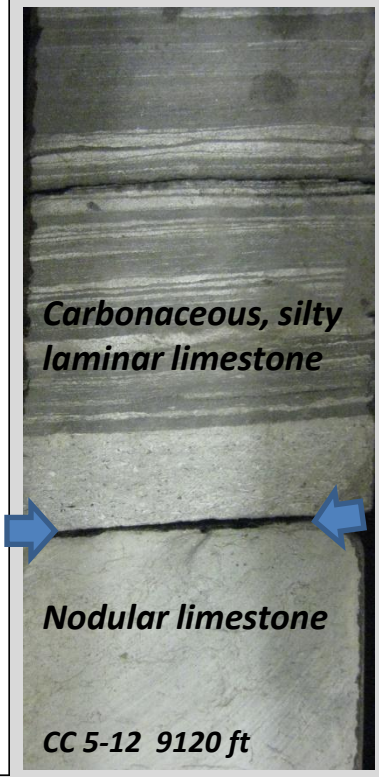

Depth in well, feet
8900
9000
9100
9200
9300
9400
0
40
80
120
160
Cumulative thickness, feet
Siltstone
Carbon Canal 5-12
Ls, carb laminar
Ls, carb micritic
Black shale
Siltstone, carb
Gray shale
Ls, micritic
Ls, nodular



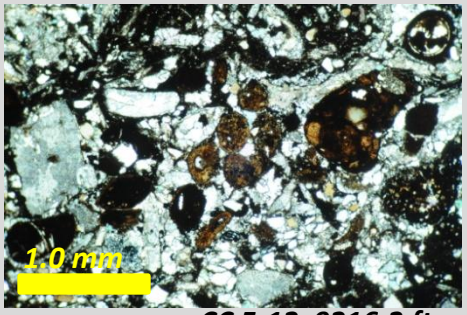
Parasequences and cyclicity

Stratigraphic cyclicity is subtle and parasequence boundaries are not easily delineated.

Cycles are expressed by the upward gradation in lithotype and reduction of organic-carbon content. Commonly organic-rich laminar limestone or shale passes upward into organic-poor micritic limestone. The coals are associated with parasequence boundaries, and in some instances phosphate and glauconite.

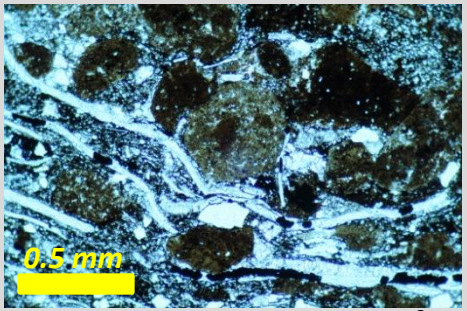


Phosphate nodules

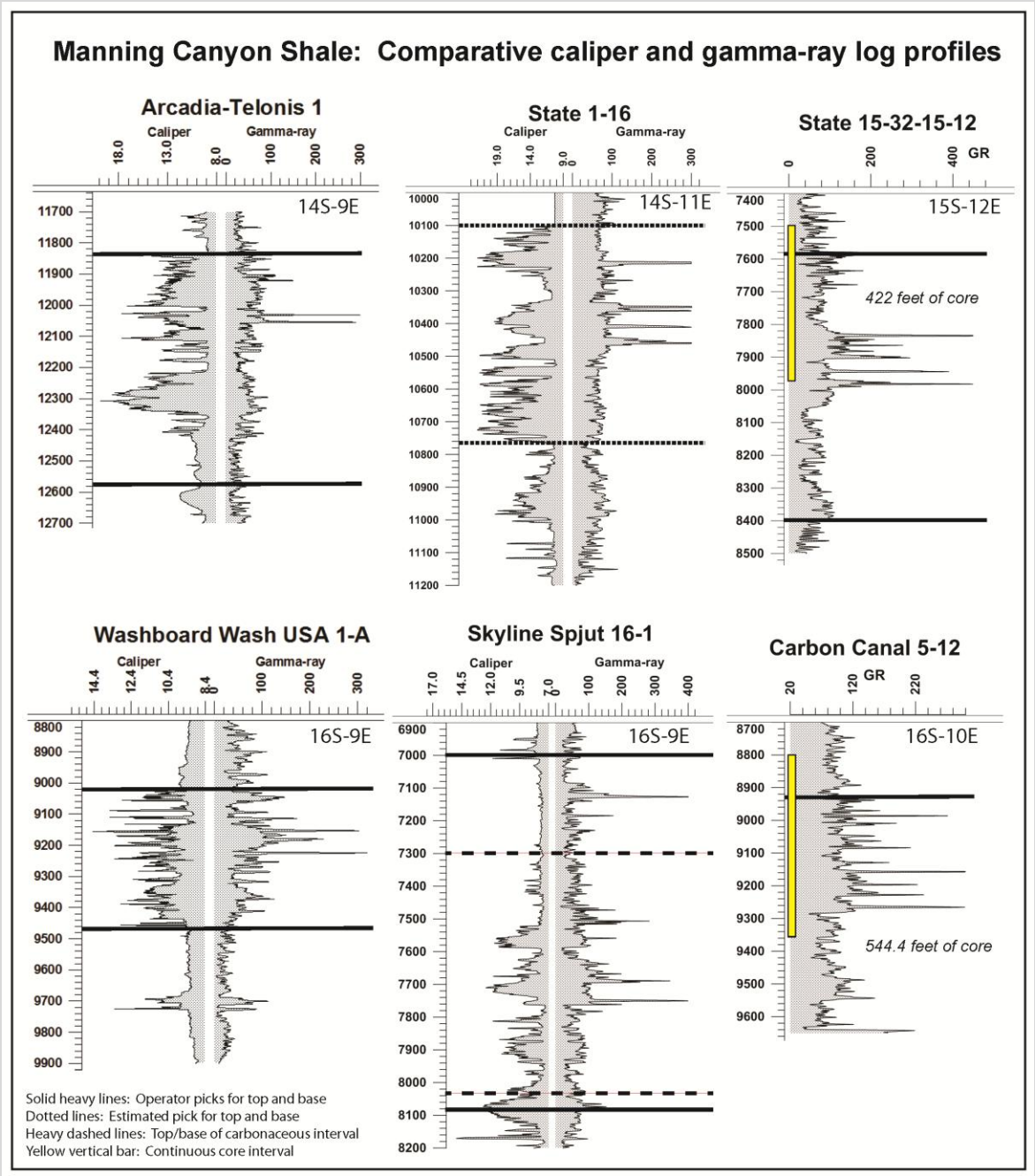


CC 5-12 9216.2 ft

Glauconite



CC 5-12 9184.1 ft



Stratigraphic correlations

Reliability of e-logs for well-to-well correlation is limited by:

1. **Diverse age and quality of the logs and restricted size of the log suites.**

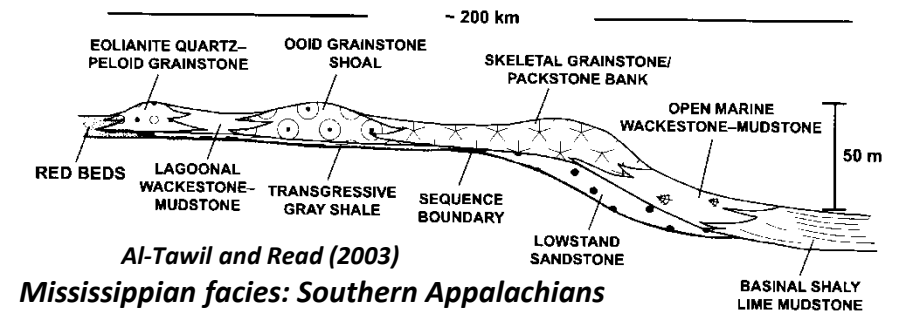
2. **Massive wash-out zones in the Manning Canyon Shale as evidenced by the caliper logs. The wash-outs are so large as to make corrections of other logs, where available, unreliable.**

The caliper-GR log pairs are avaliable for only a few of the 22 wells in the Price area.

If there was a correlative vertical cyclicity between nearby wells in the Manning Canyon Shale, it should be detected in the log pairs, but it is not.

Depositional Setting: Alternative Models

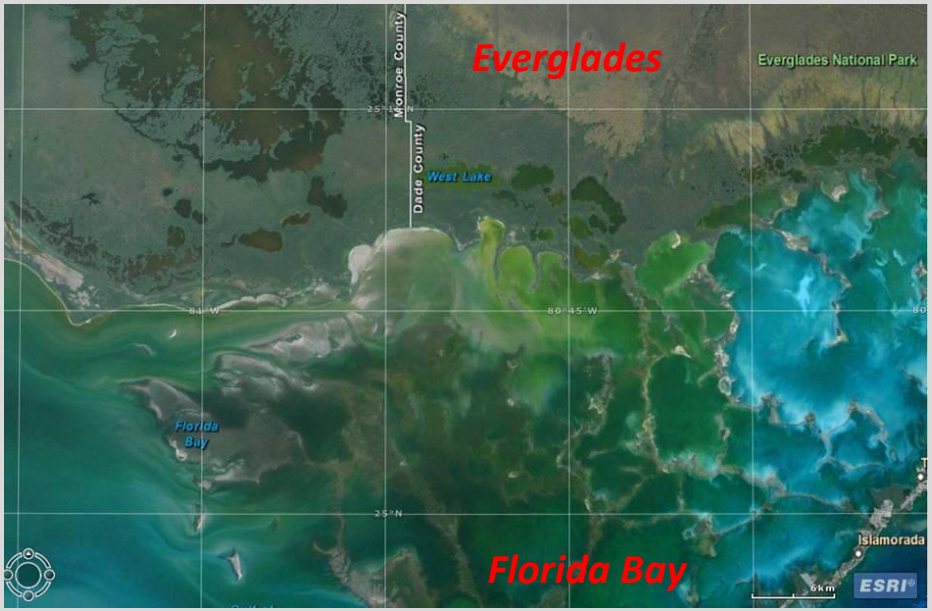
Marine Shelf and Slope



Carboniferous cyclothems on a marine shelf and slope setting is the model proposed for the cyclic limestone-shale of the Bridal Falls Limestone overlying the Manning Canyon Shale in the Provo Canyon (Shoore and Ritter (2007). This is the anoxic basinal black shale model.

However, the Manning Canyon Shale appears to lack either a consistent shoaling-upward cyclicity or a lateral continuity of stratigraphic units. Evidence points to a restricted, shallow-water nonmarine to marine, paludal to lagoonal depositional setting with brief intervals of marine flooding . Organic matter is terrestrial.

Shallow Marine-Nonmarine Embayment



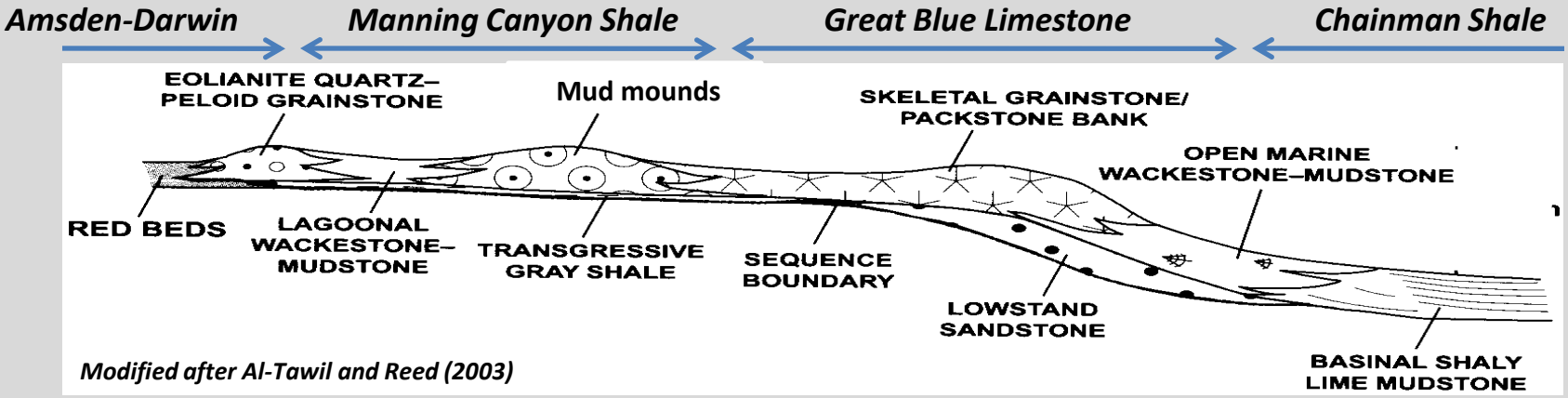
The fresh-water marshes of the Everglades and shallow brackish to marine carbonate factory of the Florida Bay might serve as a conceptual model for the depositional setting of the Manning Canyon Shale. The hummocks and marshes formed on the carbonate mud mounds (keys) in the bay are an additional source of terrestrial organic matter.

Manning Canyon Shale in the regional perspective

Late Mississippian-Early Pennsylvanian stratigraphy in central Utah is influenced by:

- **Onset of Ancestral Rockies basin subsidence.**
- **World entering Late Paleozoic "icehouse" conditions.**
- **Climate, even in equatorial belt, entering a perodicity between warm-wet and cool-dry.**

The consequence of these factors appears to have been the development of a broad, shallow embayment along the Oquirrh Basin-Oquirrh Sag trend that filled with many thousands of feet of largely cool-water carbonates and eolian loess blown off the surrounding lateritic land surfaces. The lateritic soils formed during the warm-wet periods and was transported during the cool-dry periods. Glacio-eustatic cyclicity is apparent in the outer shelf Great Blue Limestone, but less so in the inner shelf-paludal Manning Canyon Shale.



Modified after Al-Tawil and Reed (2003)