Correlation of Niobrara-Equivalent Strata in the Eastern Uinta Basin, Utah

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Revised Abstract

Examination of geophysical logs from about 200 oil and gas wells allowed us to correlate the Late Cretaceous Niobrara Formation in Colorado to time-equivalent strata within the Mancos Shale of the eastern Uinta Basin, Utah. A structure map shows the top of the Niobrara equivalent (NE) deepens from near sea level at the Utah-Colorado line to more than 10,000 feet below sea level at the Wonsits Valley field, about 35 miles to the northwest. Along the same path, the NE thickens from 1150 to more than 1450 feet. Most of the thickening occurs in the upper part of the NE, which we interpret as a highstand sequence set. The lower and middle parts of the NE, represented by lowstand and transgressive sequence sets, respectively, maintain relatively constant thicknesses.

Based on log character and limited core data from the NE, we suggest that the unit contains and is immediately adjacent to some of the more hydrocarbon-prospective parts of the Mancos Shale. Much of the upper NE consists of a sediment-starved shelf facies association (a primary target) and the base of the NE overlies a heterolithic organic-rich facies association (a secondary target). Given the thickness of the NE and variations in burial depth, organic maturation levels of the unit should also vary significantly. Applying our maturation model of the Uinta Basin, we predict vitrinite reflectance values for the top of the NE to range from 0.55 in westernmost Colorado to 1.55 northwest of the Natural Buttes oil field; predicted values at the base of the NE are 0.63 and 1.70 at the same locations. Further exploration should determine whether the NE in the Uinta Basin has petrophysical characteristics similar to those that make the typical Niobrara Formation so productive to the east.

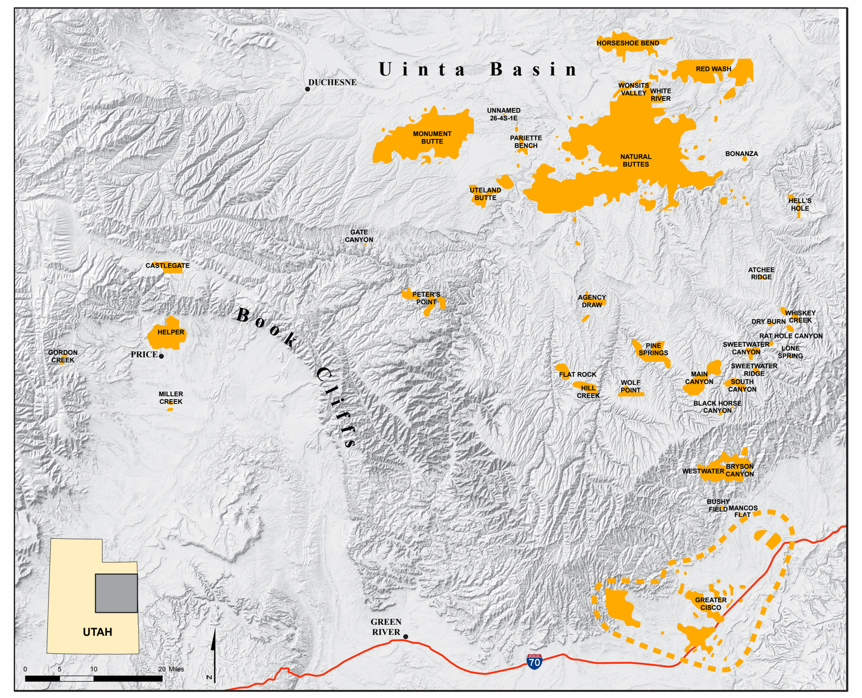
Introduction

The Utah Geological Survey (UGS) and the University of Utah are concluding a four-year, multidisciplinary study of the Upper Cretaceous Mancos Shale in the Uinta Basin of eastern Utah. The goals of this project are to provide the industry with an assessment of the oil and natural gas potential of the Mancos and to define the most prospective zones within this 4000-foot-thick stratigraphic unit.

In the Rocky Mountain region east of the Uinta Basin, the Coniacian-Santonian Niobrara Formation is a time-equivalent to much of Utah's lower Mancos Shale. In light of recent hydrocarbon exploration success in the Niobrara, we thought it might be informative to attempt correlating the Niobrara from western Colorado into the Uinta Basin, in order to identify potential exploration targets, in the event these strata have some of the lithologic characteristics of the Niobrara farther east. However, at present we cannot speculate on the extent of Niobrara (sensu stricto) lithofacies in the Uinta Basin. Consequently, we use the term "Niobrara equivalent" (or NE) to avoid implying that the strata in the Uinta Basin host the same lithofacies as, or have geomechanical properties similar to, the Niobrara Formation in Colorado.

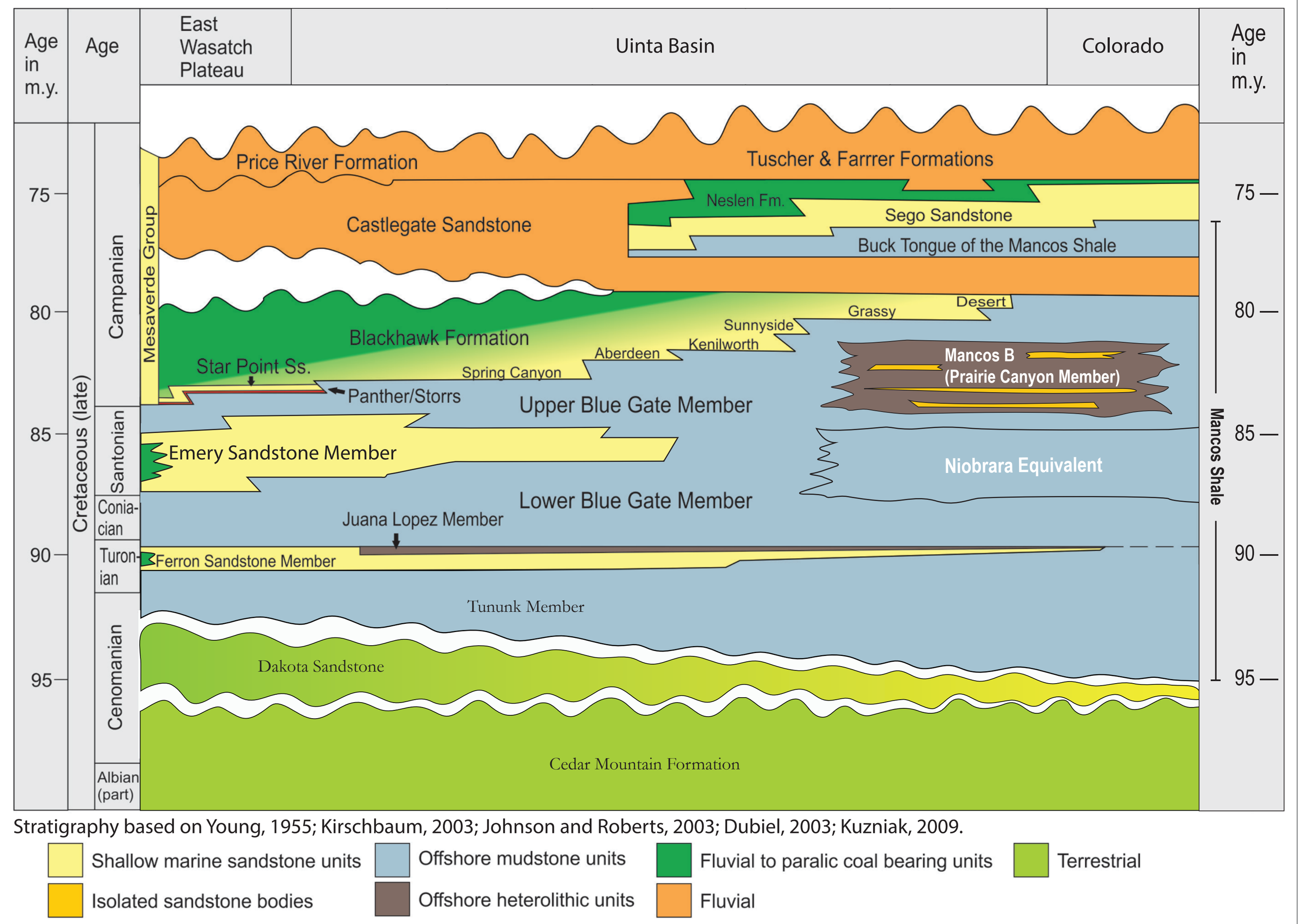
Location Map

Location of Uinta Basin Fields with Mancos Shale Production



The Uinta Basin is located in northeastern Utah, and is bounded by the Uinta Mountains to the north, which are a Late Cretaceous to early Tertiary Laramide uplift. The basin narrows and shallows to the west, and the basin fill gradually thins against the Wasatch Range where older Mesozoic and Paleozoic rocks crop out. The southern margin is the Book Cliffs where the Mancos crops out. The eastern margin is the Douglas Creek arch, which separates the Uinta from the Piceance Basin in Colorado.

The Utah Division of Oil, Gas, and Mining (DOGM) has identified about three dozen oil and gas fields with Mancos production or potential Mancos reservoirs. However, a number of these fields are inactive, and in the majority of the active fields Mancos production is comingled with production from lower reservoirs, commonly in the Dakota Sandstone, or overlying Cretaceous and Tertiary reservoirs, making it difficult to assess the Mancos productivity.

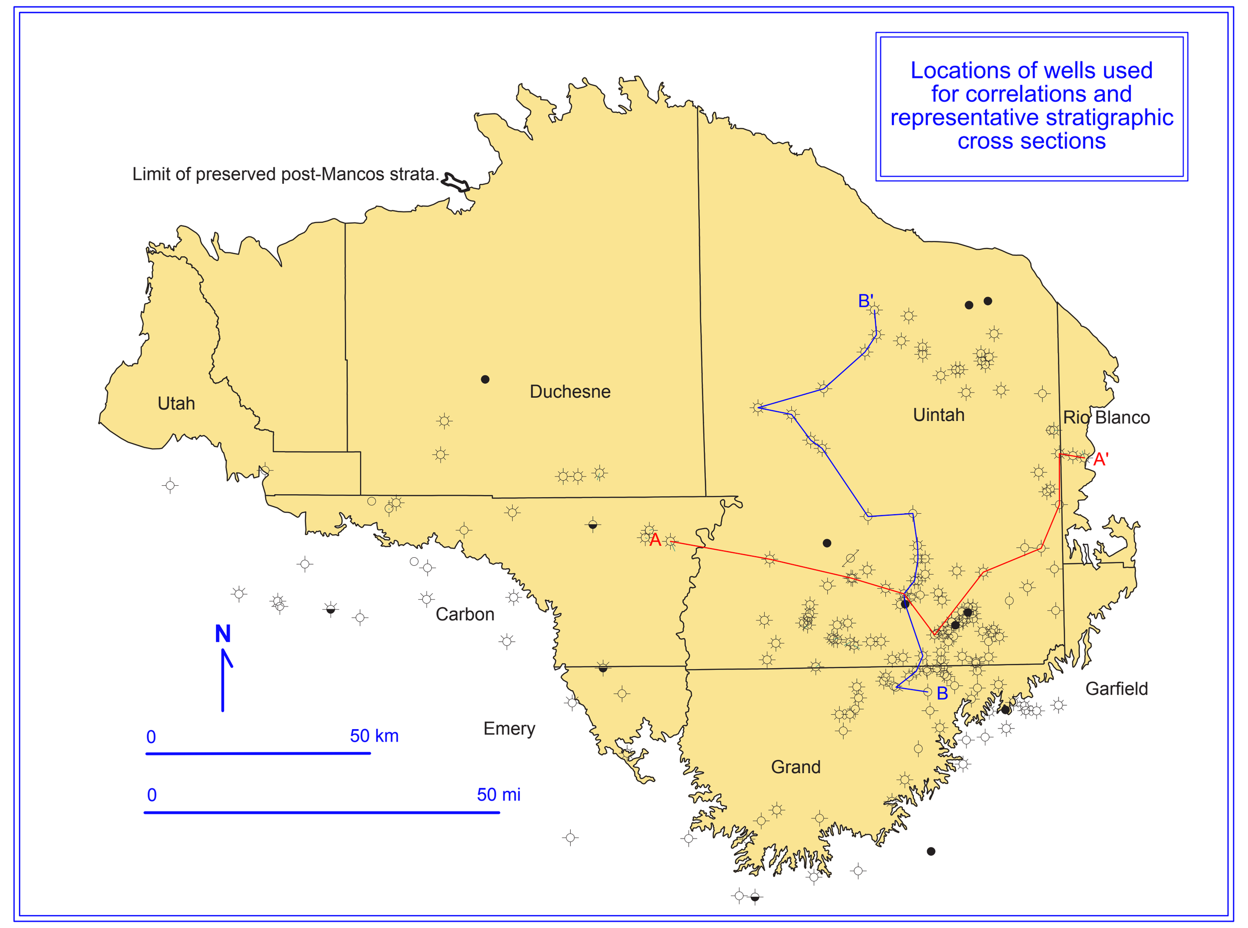


Stratigraphy based on Young, 1955; Kirschbaum, 2003; Johnson and Roberts, 2003; Dubiel, 2003; Kuzniak, 2009.

Stratigraphic Framework

An east-west chronostratigraphic section of the Mancos and adjacent units shows these relationships:

- The Mancos represents over 15 million years of deposition.
- The Late Cretaceous Sevier orogen to the west shed clastics to the foreland basin in the east.
- Clastics became progressively finer-grained to the east and interfingered with deltaic and marginal marine sands (Ferron and Emery Members, and Blackhawk Formation), which in turn graded into the units of the Mancos Shale.
- The Niobrara Formation is coeval with part of the lower Blue Gate Shale and Emery Sandstone Members of the Mancos.



Methods

The starting point for the correlations was the stratigraphic framework for the Niobrara developed at the Colorado School of Mines (Fisher, 2007; Kuzniak, 2009; D. Anderson, written communication, 2011). In addition, Anderson and Harris (2006) correlated the base of the Niobrara in several wells in the southeast part of the study area. The data for the subsurface correlations come from ~200 well records in UGS and DOGM files, supplemented with data donated by our industry partners. We used IHS Petra software for the correlations.

Stratigraphic Sections

Two representative stratigraphic sections show the interval between the base of the Mancos B (datum) and the top of the Dakota Formation. The logs are normalized gamma-ray curves at a scale of 60 to 130 API units. Well names and API numbers are above the logs, and project well sequence numbers are below. Red diagonal patterns in wells 181 and 208 show locations of cores.

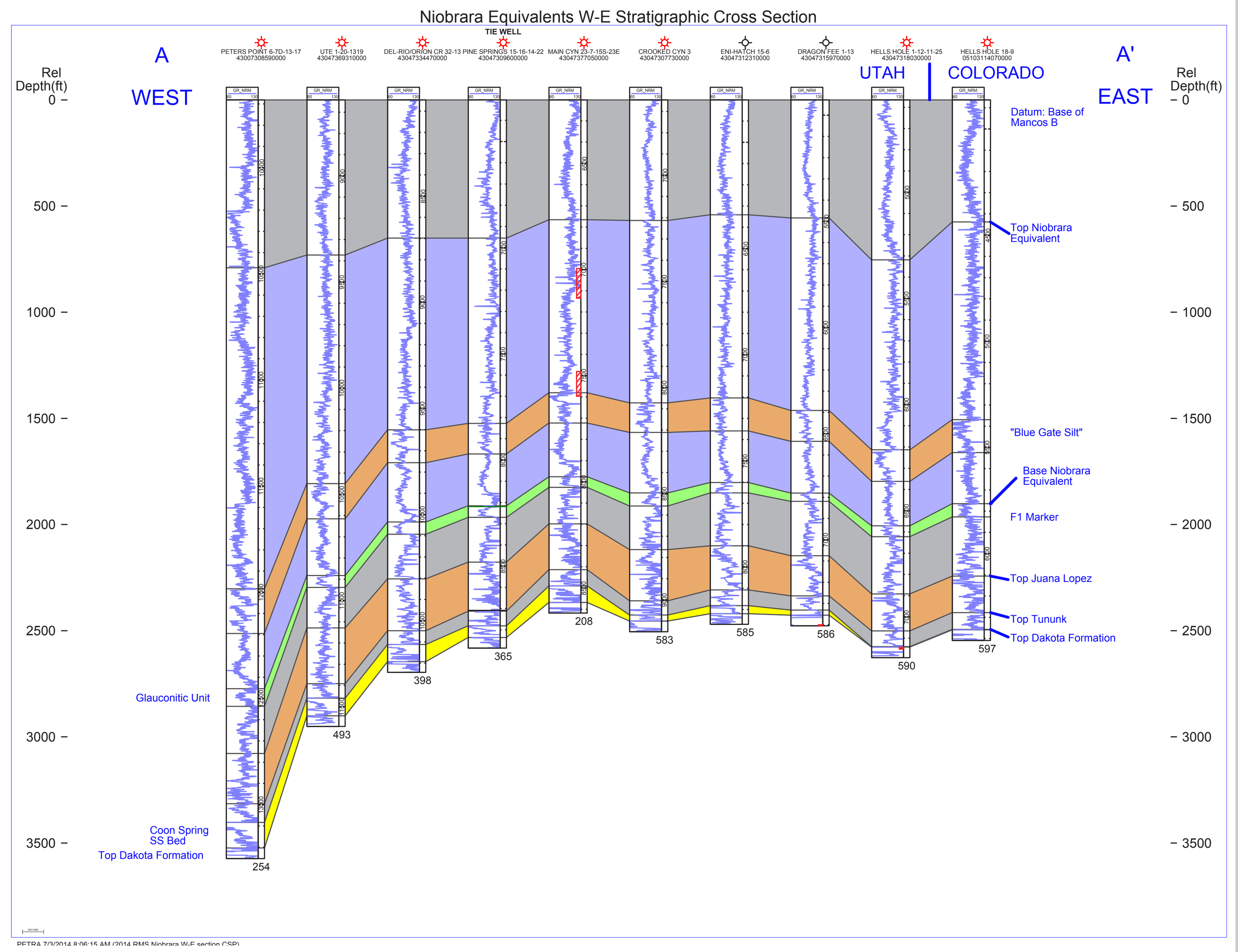
Below the base of the NE, the F1 marker is a high-gamma-ray zone interpreted as a condensed section by Anderson and Harris (2006), who also correlated the overlying glauconitic, sand-rich unit to cuttings in the Larsen State-1 well southeast of the study area. The top of the glauconitic unit is the base of the NE.

The informally named "Blue Gate silt" is a generally progradational unit, interpreted by Fisher (2007) as relatively sandy, distal deltaic sediments. In the central Uinta Basin, the Blue Gate silt has distinct, coarsening-upward intervals, consistent with Fisher's interpretation. Conceivably, it might represent early, distal lobes of the Emery Sandstone Member, but the reported age of the Blue Gate silt (middle Coniacian; Fisher, 2007) predates the Emery. Fisher also reported an elevated Young's modulus for the Blue Gate silt and concluded it is a candidate reservoir.

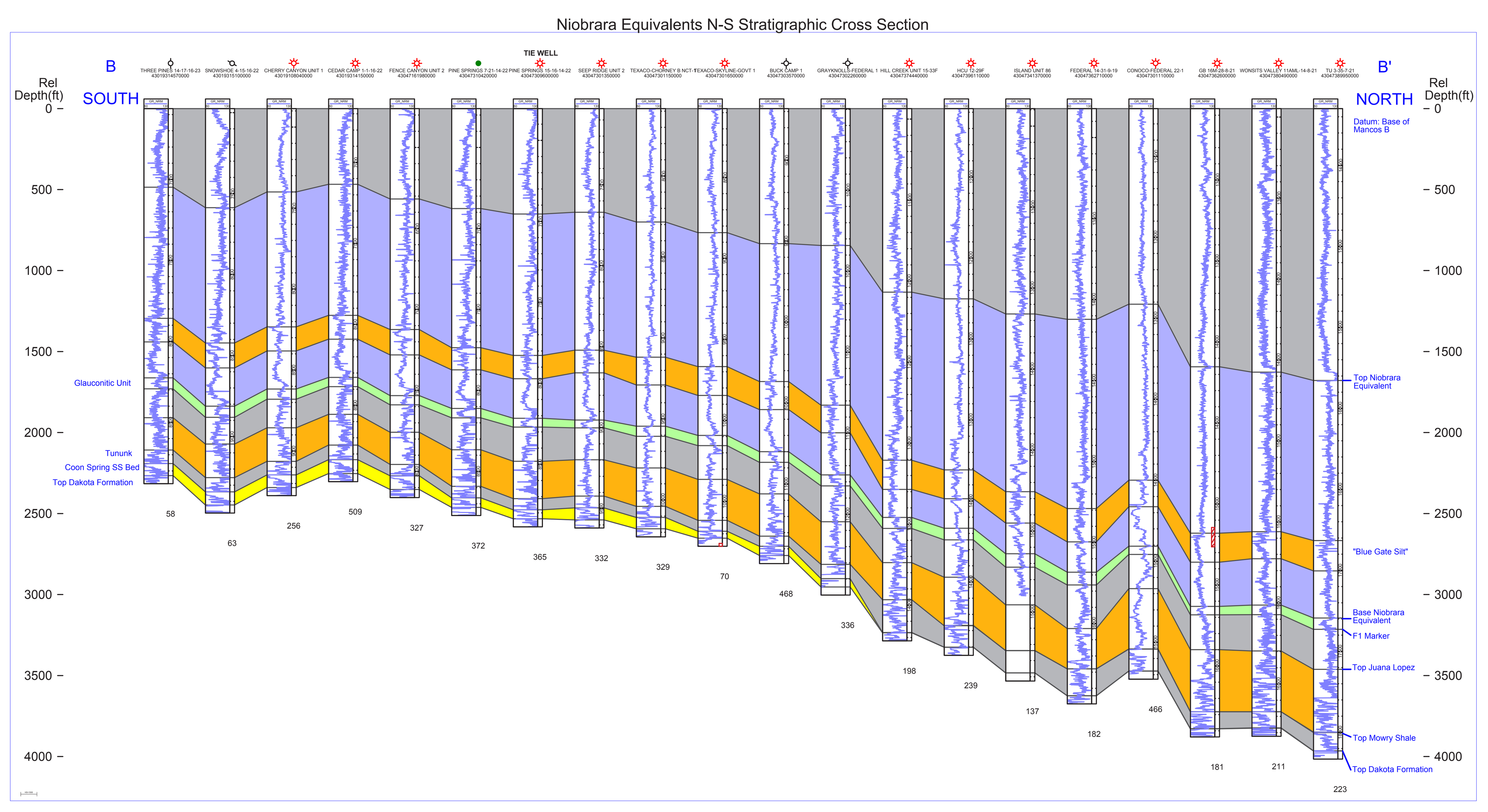
Cores in the Glen Bench 16 well (#181 on section B-B') and Main Canyon 23-7 (#208 on section A-A') penetrate the top of the Blue Gate silt. Horton and others (2012) interpreted the core in the Glen Bench well as containing a sequence boundary between middle mudbelt deposits (the Blue Gate silt portion of the core) and overlying sediment-starved shelf deposits in the transgressive interval above the Blue Gate silt. The Main Canyon core is similar in that the lower, Blue-Gate-silt part of the core consists of sandy, proximal mudbelt deposits transgressively overlain by intermediate mudbelt claystone and siltstone (Horton and others, 2012).

The NE can be identified in most of the wells, as shown in the two cross sections, but correlations become more tenuous towards the western Uinta Basin. This may in part be due to increased siliciclastic influx from the Sevier orogen to the west imparting its own log signature on that of the NE.

Niobrara Equivalents W-E Stratigraphic Cross Section



Niobrara Equivalents N-S Stratigraphic Cross Section



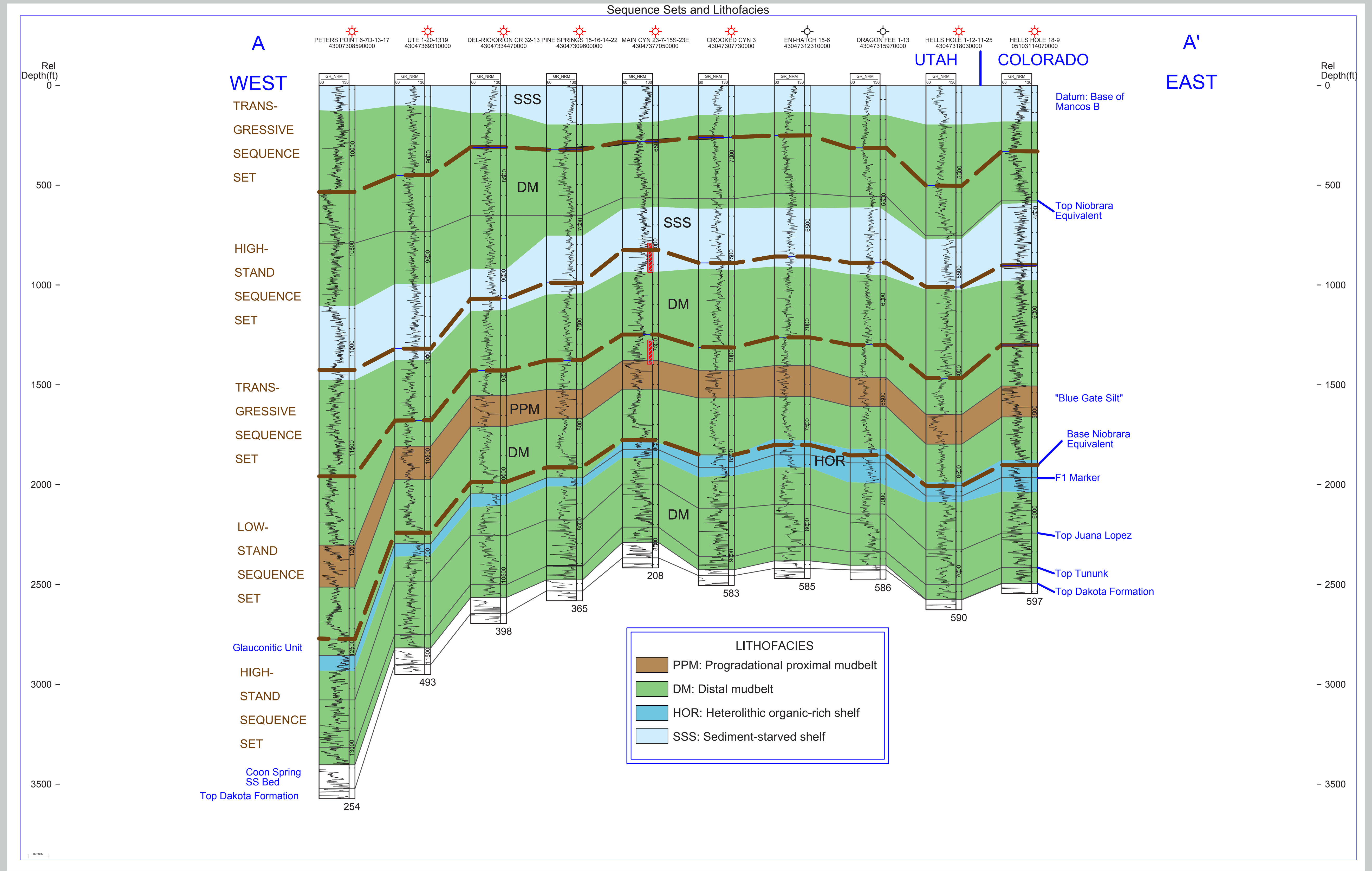
SEQUENCE SETS AND LITHOFACIES

The transgressive nature of the Niobrara Formation in the Rocky Mountain basins to the east has long been known (e.g., Weimer, 1960). The diagram at right superimposes our correlations of the NE in the Uinta Basin on the model of sequence sets and lithofacies in the Mancos Shale developed by McCauley (2013). The lithofacies, from shoreward to basinward are:

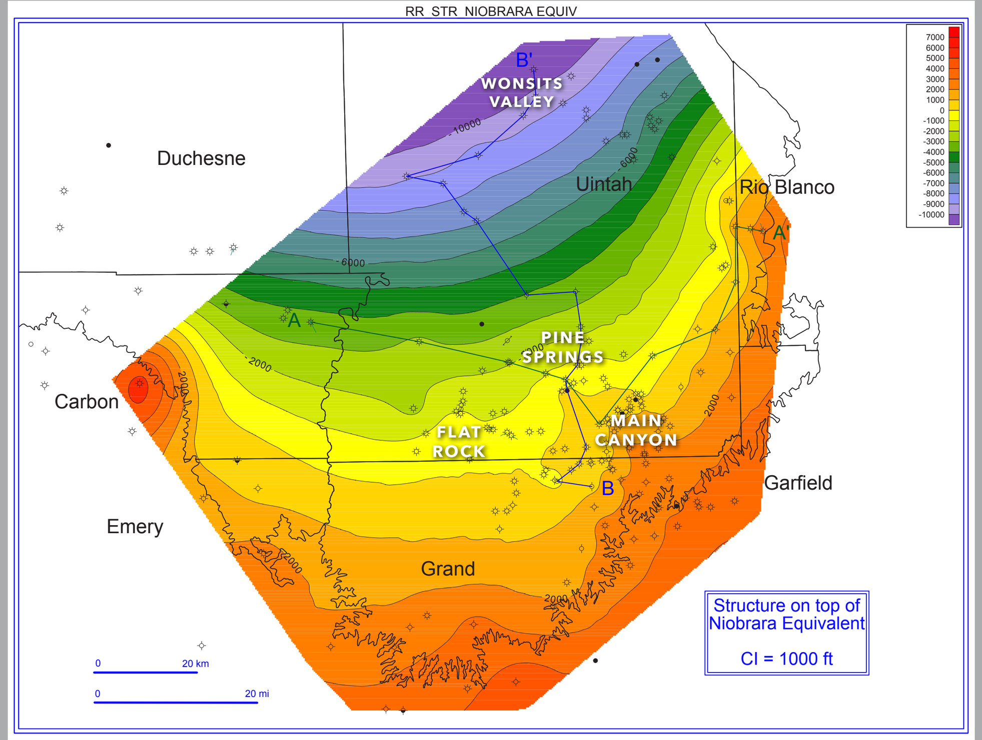
Progradational proximal mudbelt, confined to the Blue Gate silt;
Distal mudbelt;
Heterolithic organic-rich shelf, deposited above storm wave base; and
Sediment-starve shelf, deposited below storm wave base.

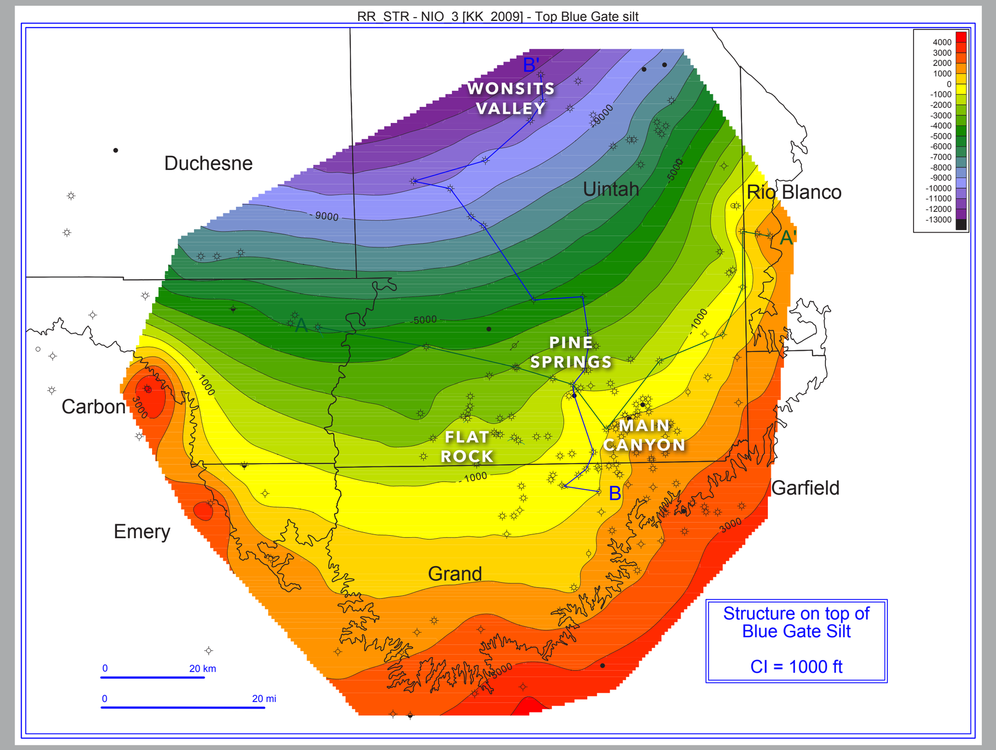
The Mancos Shale below the NE consists of a highstand sequence set that culminated in deposition of heterolithic, organic-rich-shelf and glauconitic sediments. The lower part of the NE, represented by a lowstand sequence set, appears from the gamma-ray-log patterns to be the most lithologically diverse part of the NE. This interval includes the Blue Gate silt. The middle of the NE generally displays less variable, overall transgressive log patterns characteristic of a transgressive sequence set. However, the wells to the west show progressively more distinct progradational packages within the transgressive backdrop. The upper NE forms the lower part of a highstand sequence set, which includes zones with the highest gamma-ray readings in the Mancos Shale, interpreted as sediment-starved shelf deposits.

On the basis of relatively high gamma-ray logs and organic carbon contents, McCauley (2013) suggested that the heterolithic and sediment-starved shelf deposits represent the most promising hydrocarbon reservoirs in the Mancos Shale of the Uinta Basin.

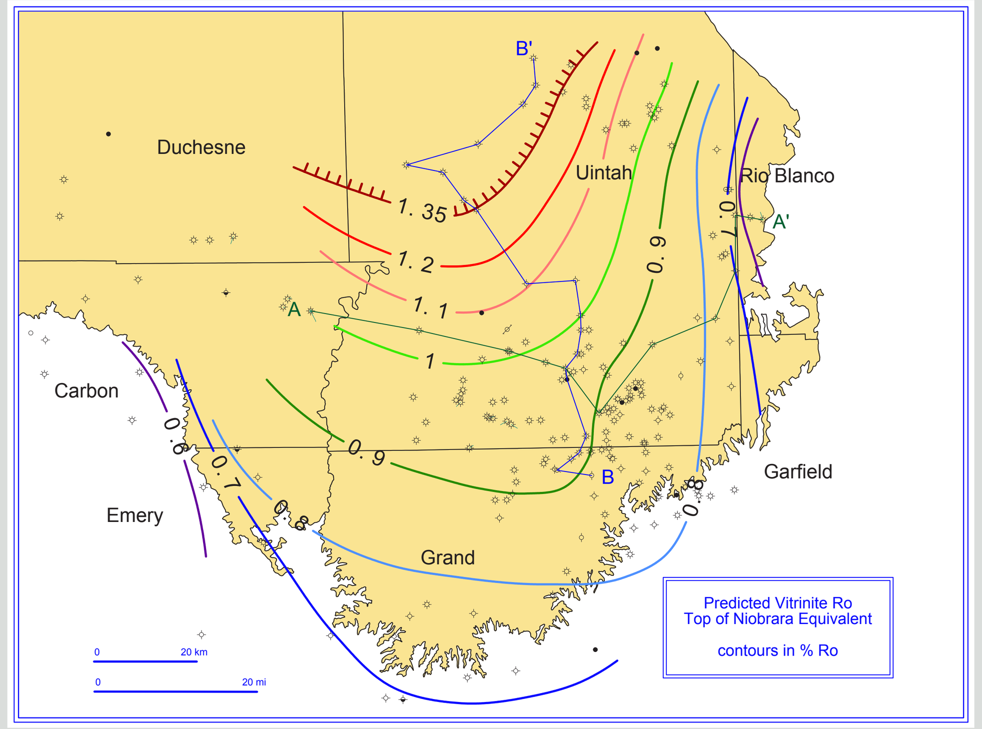


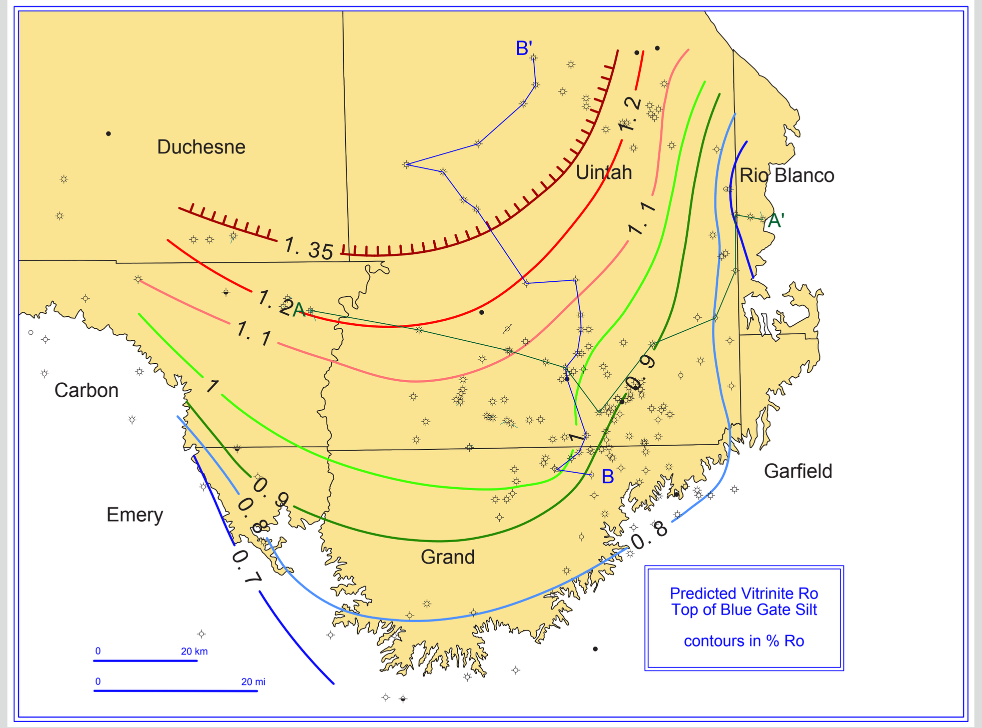
STRUCTURE CONTOUR MAPS

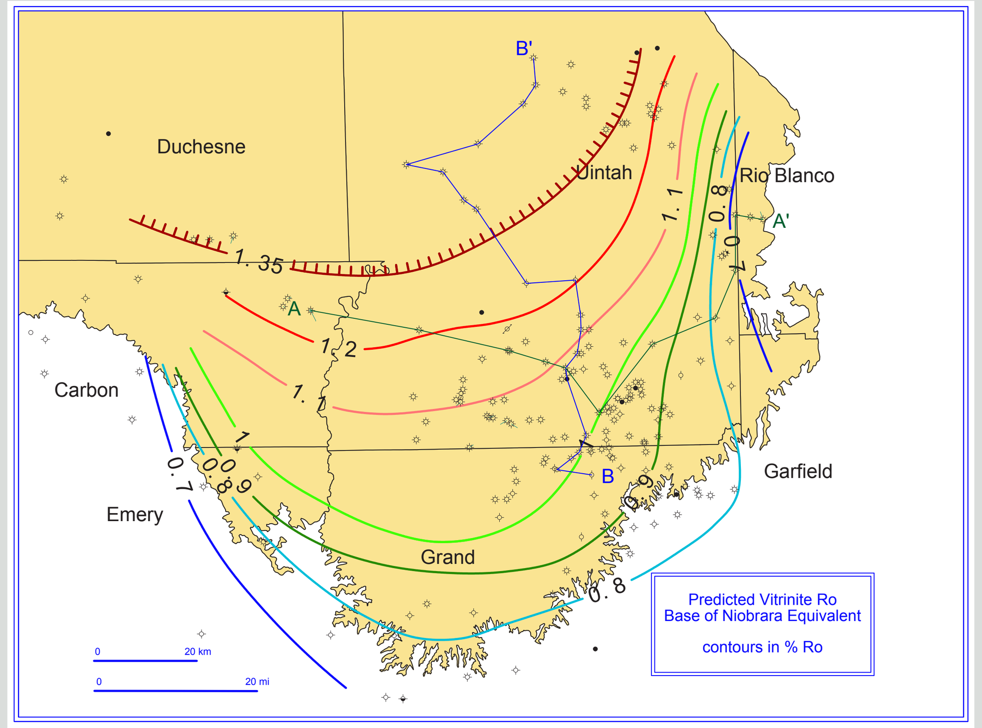




Structure contours on the tops of the NE and the Blue Gate silt show relatively uniform gradients, deepening northwestward toward the Uinta Basin interior. Structure elevations range from about 3000 feet above sea level along the basin's southern margin to more than 10,000 feet below sea level at the Wonsits Valley field. Northwestward-trending structural highs are apparent near Main Canyon, Pine Springs, and Flat Rock fields.







THERMAL MATURATION

Earlier in this project, Quick and others (2013) collected vitrinite reflectance (%Ro) data for the Mancos and other Uinta Basin strata, and by regression analysis obtained a formula to predict %Ro based on location and structural depth (elevation):

$$\%Ro = 14.9X + 33.2Y - 80.1Z + 0.0847X^2 - 0.264Y^2 + 29.3Z^2 - 0.364XY - 2.48YZ - 642.3$$

where:

X = UTM easting/100,000
Y = UTM northing/100,000
Z = 1,000,000/(300,000 + elevation [ft])

Applying the formula to depths to the Niobrara equivalent in the database wells indicates that thermal maturation in the NE ranges from 0.6 %Ro on the basin's southern margin to 1.78% in the north of the study area. Because of different kerogen types in the NE lithofacies, we have not determined depths to oil and gas "windows." It is apparent, however, that the NE is in the oil and gas generating zones in most of the eastern Uinta Basin.

SUMMARY

- Strata equivalent to the Niobrara Formation of Colorado are about 1200 feet thick in the eastern Uinta Basin of Utah, and occur within the lower Blue Gate Shale Member of the Mancos Shale.
- The depositional environment for most of the NE was a distal marine shelf mudbelt. The most shoreward environment was a prograding proximal mudbelt (represented by the "Blue Gate silt"). The deepest-water environments were just above storm wave base (heterolithic, organic-rich-shelf) and below it (sediment-starved shelf).
- The predicted vitrinite %Ro of the NE ranges from 0.6 to 1.35% in most of the eastern Uinta Basin, indicating the NE is presently in the oil- and gas-generating zone.
- On the basis of mechanical, geochemical, and mineralogic properties, we suggest that prospective hydrocarbon reservoirs in the NE are:
  - the heterolithic, organic-rich-shelf facies just below or at the base of the NE,
  - the relatively sand-rich Blue Gate silt in the lower NE, and
  - the sediment-starved shelf facies in the upper NE.

For additional information about the UGS/University of Utah Mancos Shale project, please visit the UGS exhibit booth or the project website at: http://geology.utah.gov/emp/shalegas/cret_shalegas/index.htm.

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