Utilizing the Delta Log R Method for Determining Total Organic Carbon of the Niobrara Formation, B Bench, Denver-Julesburg Basin, Colorado and Wyoming*

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Abstract

The Niobrara Formation was deposited in the Western Interior Seaway during the Late Cretaceous Coniacian-Santonian stages which coincided with high eustatic sea-level. In the Denver-Julesburg Basin study area, the Niobrara Formation occurs as a mixed shale/marl/carbonate sequence comprised of parasequences interbedded with organic-rich shale/marl units. These parasequences are developed as the three primary carbonate (chalk) benches. Total thickness of the Niobrara Formation ranges from two hundred feet to four hundred feet. Weight percent Total Organic Carbon (TOC) was calculated for the B Bench of the Niobrara Formation using the Delta Log R method of Passey et al. (1990) within third-party well interpretation software. The study includes 136 wells that had both deep resistivity and sonic logs available digitally. The B Bench of the Niobrara Formation was the focus of the study because recent drilling has indicated this zone to be a primary target for unconventional resource development.

The methodology for Delta Log R calculation of TOC involved overlay and base-lining of the resistivity and sonic logs and consideration of Niobrara thermal maturity patterns. Zonal statistics (maximum, minimum, mean) for Delta Log R predicted TOC were calculated for the B Bench and the results were gridded over the study area using the top and bottom of the B Bench as a zone. The resulting mean values range from <1% to 10% in the study area and reflect both thermal maturity and deposition controls. This work aligns with and extends the published source characteristics for the Niobrara Formation.

References Cited

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September 23, 2013

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Outline

- Overview
- Stratigraphic Framework of the Niobrara Formation
- Regional Paleo-Environment & Depositional Controls
- ∆ Log R Methodology
- Calculated TOC
- Closing Remarks

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Overview

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Overview

- Recent drilling has identified the B bench of the Niobrara as a primary target for unconventional resource development
- Organic richness is a key control on resource potential, but measured data are often scarce
- Weight percent Total Organic Carbon (TOC) was calculated for the B Bench of the Niobrara Fm using well logs and the Δ Log R method of Passey et al (1990)
- Organic richness trends reflect both thermal maturity and deposition controls

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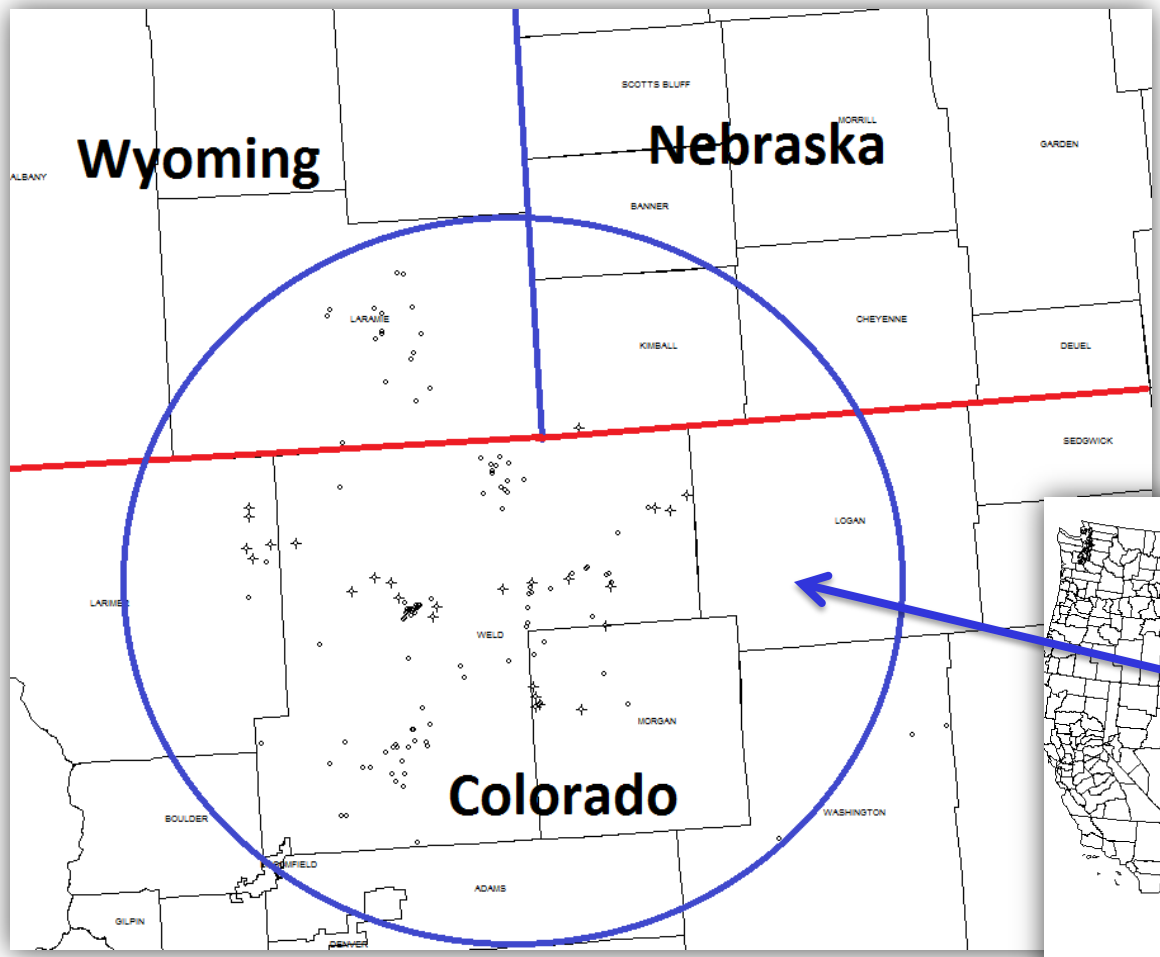
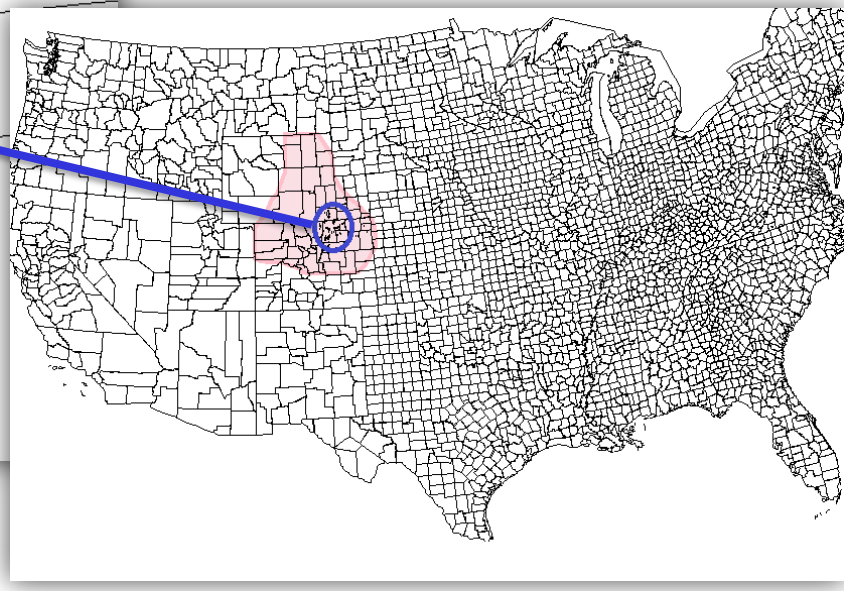
Study Area



The study includes 136 wells that had both deep resistivity and sonic logs available digitally.



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Stratigraphic Framework of the Niobrara Formation

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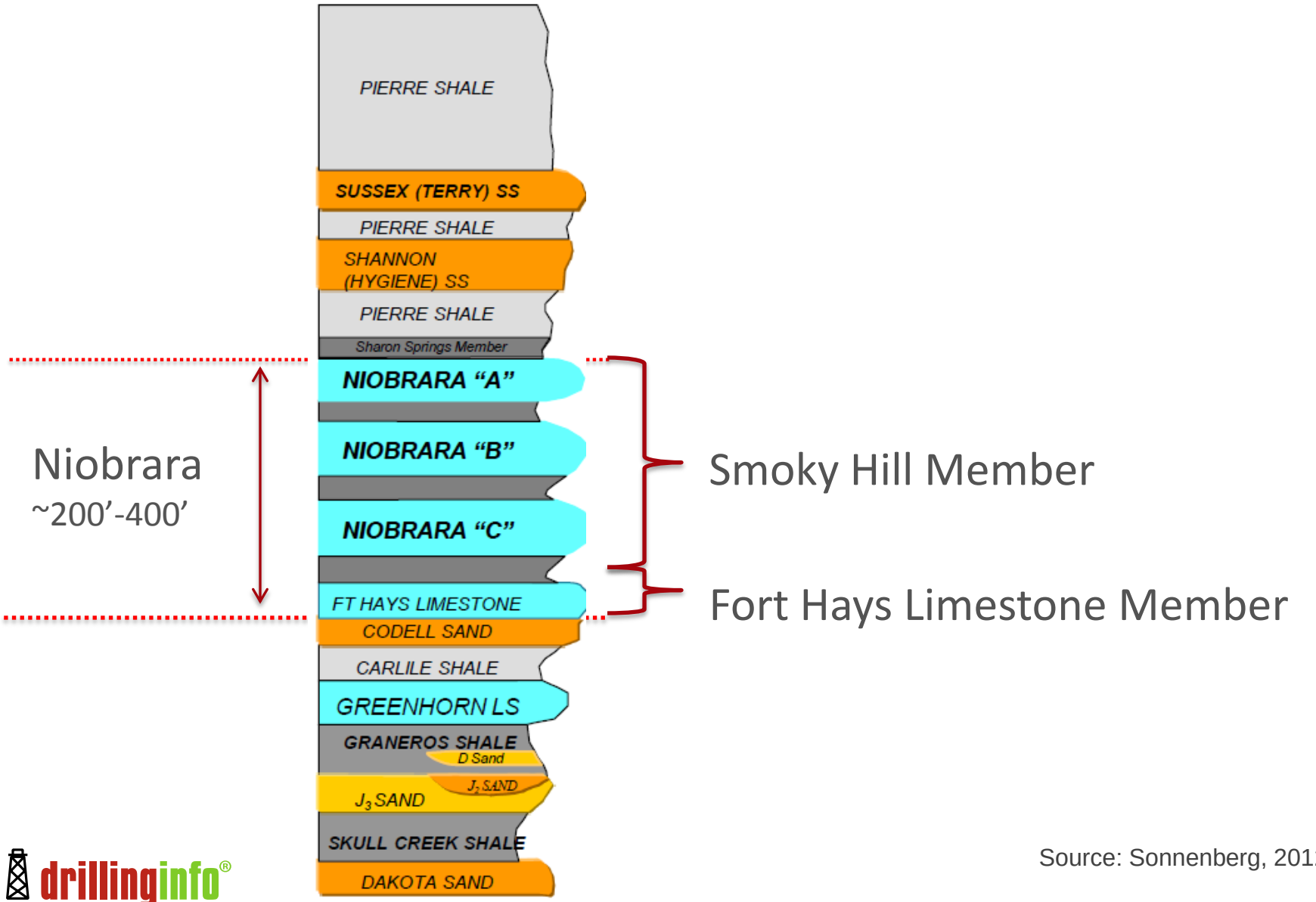
Stratigraphic Column of the Niobrara Petroleum System



Source: Sonnenberg, 2012

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Methodology Behind Stratigraphic Picks

- To build high resolution subsurface models, Drillinginfo interprets well log data within a third party well interpretation software package
  - High-density interpretations are created using **allostratigraphic methodology**
  - This interpretation will soon be done using in-house software due to Drillinginfo's acquisition of Transform Software

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Methodology Behind Stratigraphic Picks

- **Allostratigraphy** is a methodology defined by the North American Stratigraphic Code that uses bounding discontinuities to subdivide the sedimentary section into mappable units.
- Bounding Discontinuities include unconformities, disconformities, discontinuities, and omission surfaces
- The bounding surfaces may relate back to sequence stratigraphic boundaries such as Marine Flooding Surfaces (Bhattacharya and Walker, 1991)

Source: Mark Robinson, Drillinginfo

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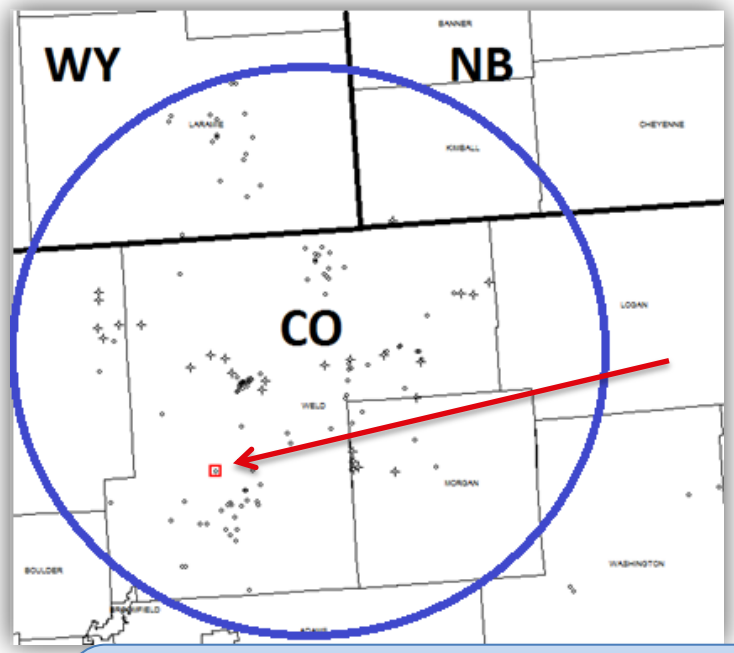
Stratigraphic Framework

Type Log

Atreyu F 34-23, Noble Energy



Niobrara A Bench

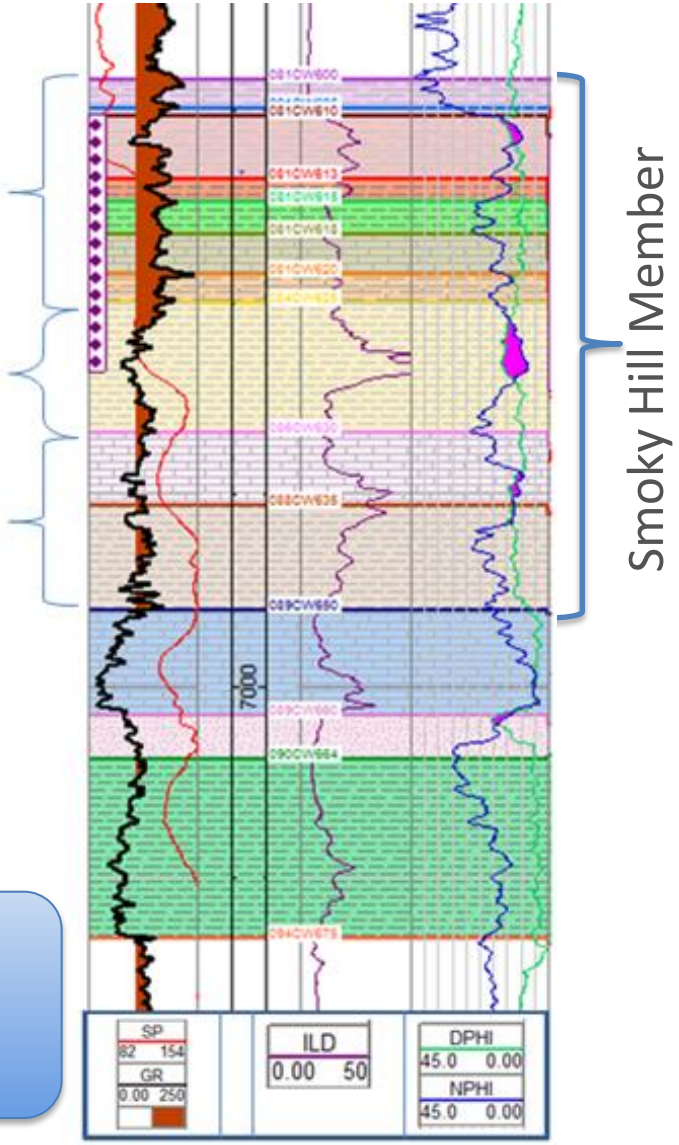
Niobrara B Bench

Niobrara C Bench

Fort Hays Limestone

Codell Sandstone

Carlile Shale



The B Bench is a naturally fractured, thick chalk/marl reservoir sandwiched between organic shale source rocks. With porosity ranging from 10% to 13%, it is a primary target for horizontal development.

Source: Drillinginfo

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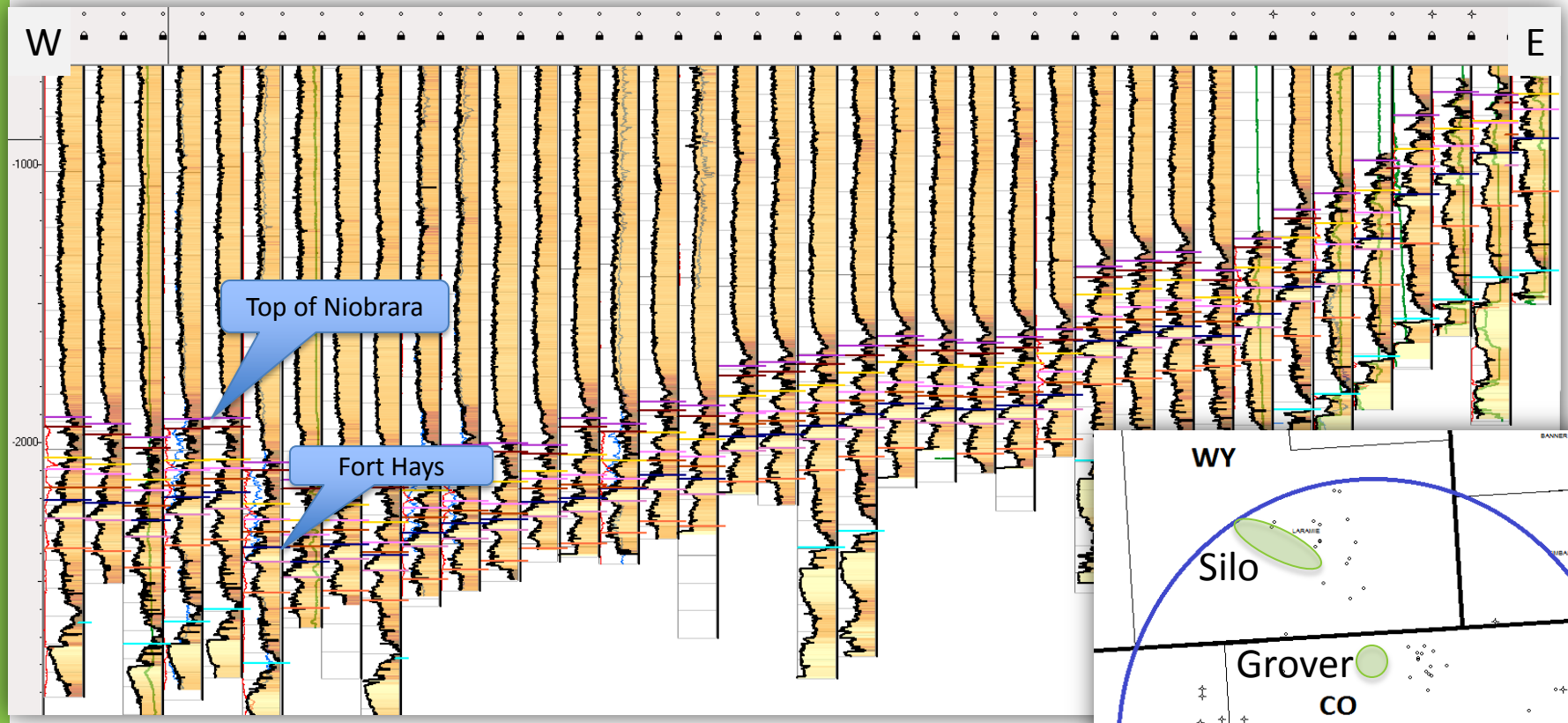
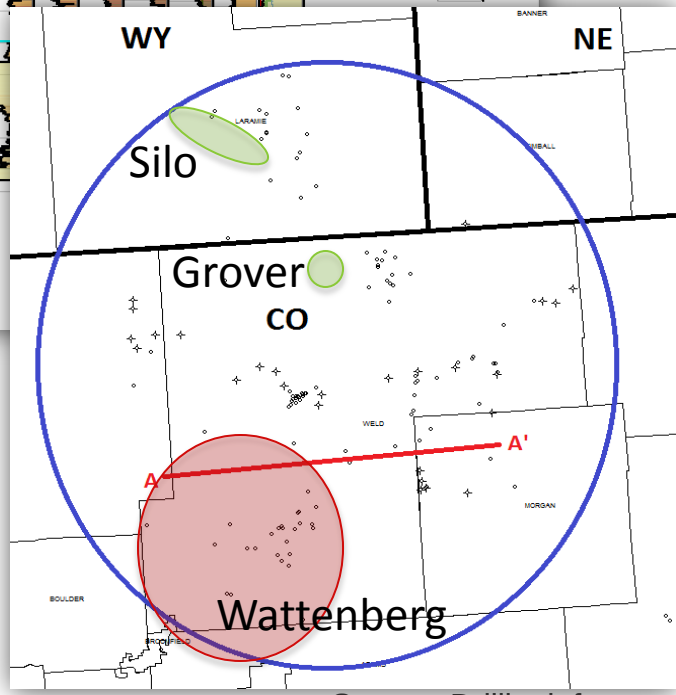
Regional Cross-Section





38 wells evenly spaced over 65 miles.

Source: Drillinginfo

Regional Paleo-Environment & Depositional Setting

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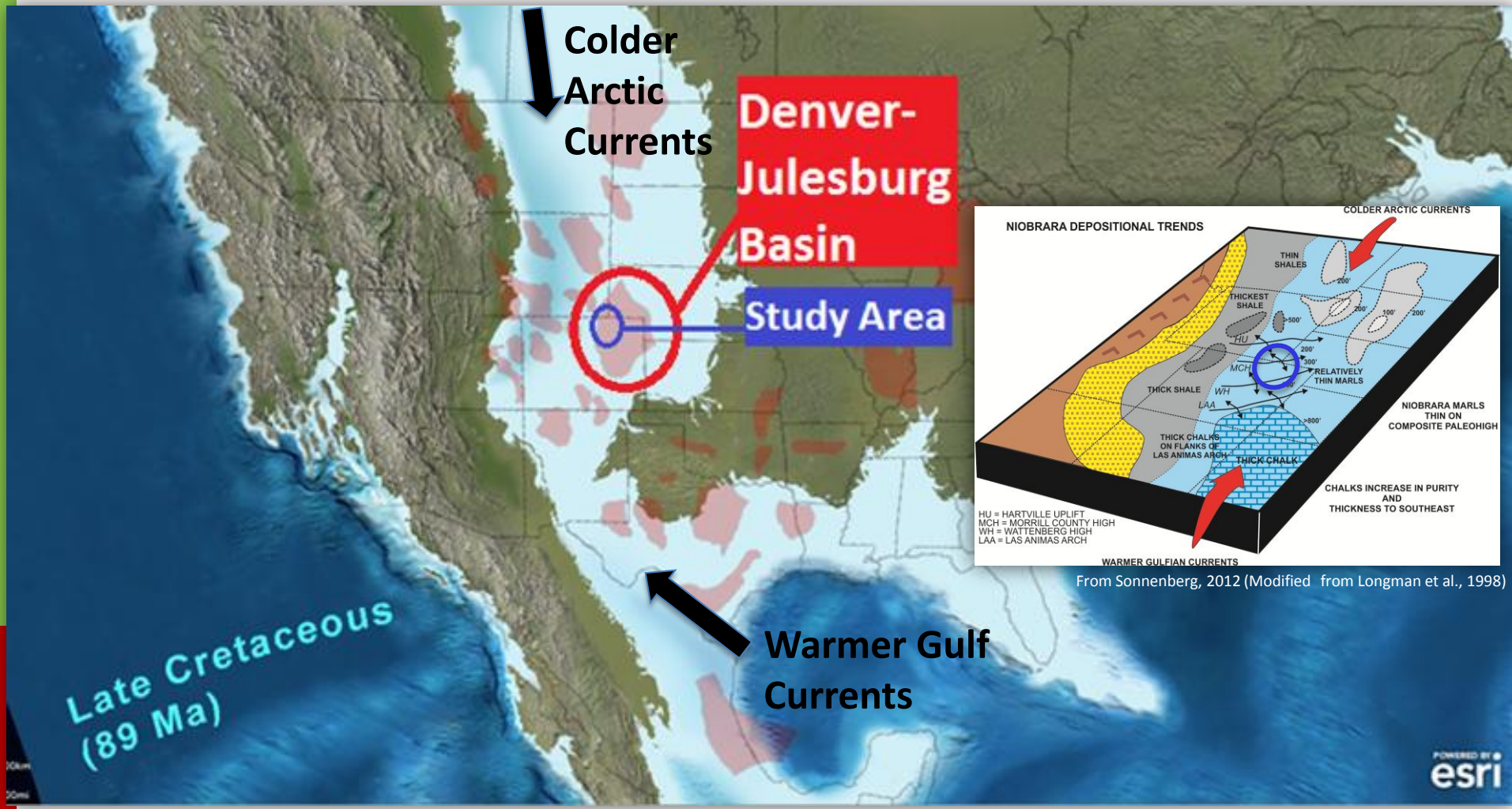
Late Cretaceous Paleogeography and Western Interior Seaway



From Sonnenberg, 2012 (Modified from Longman et al., 1998)

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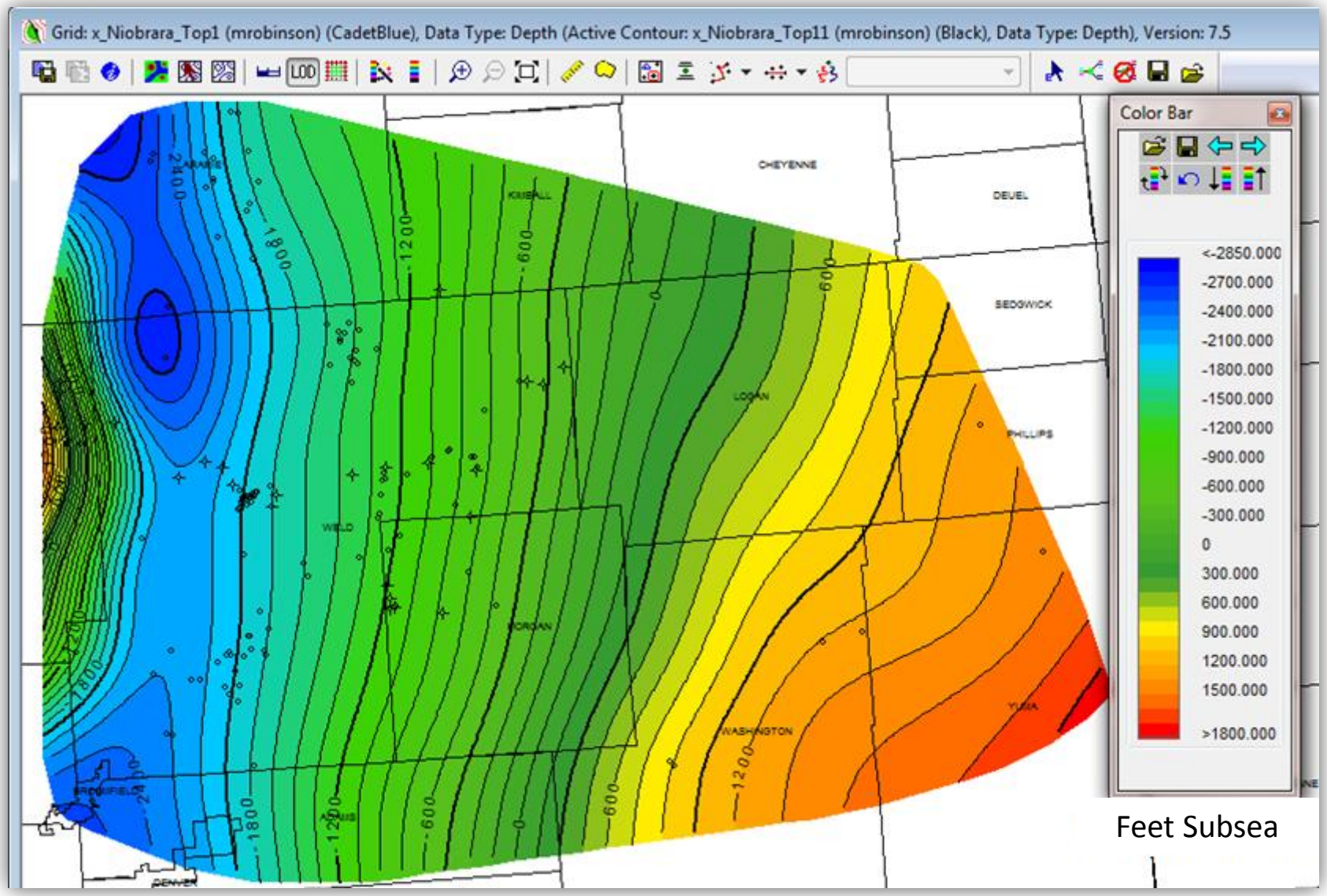
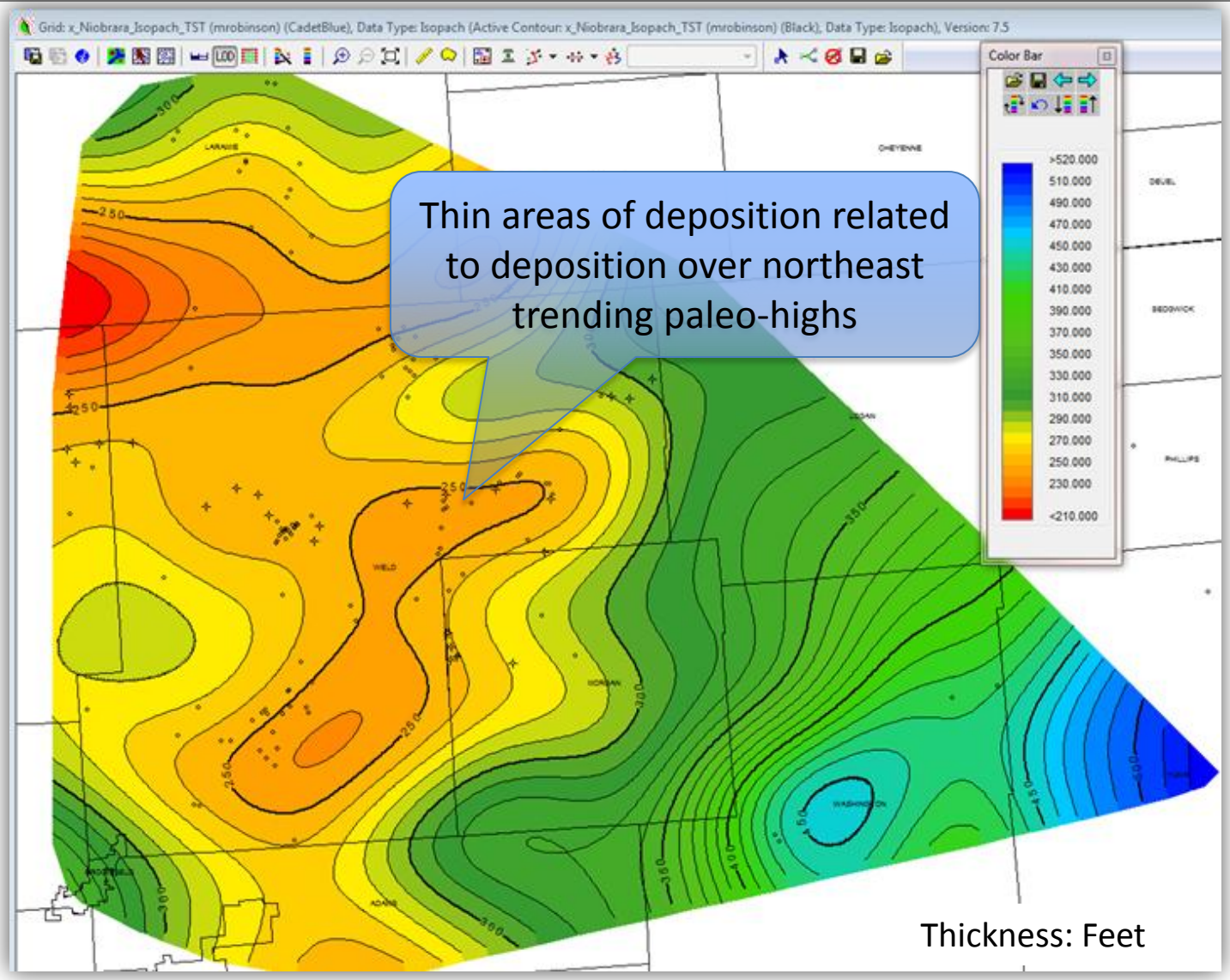
Structure Map – Niobrara



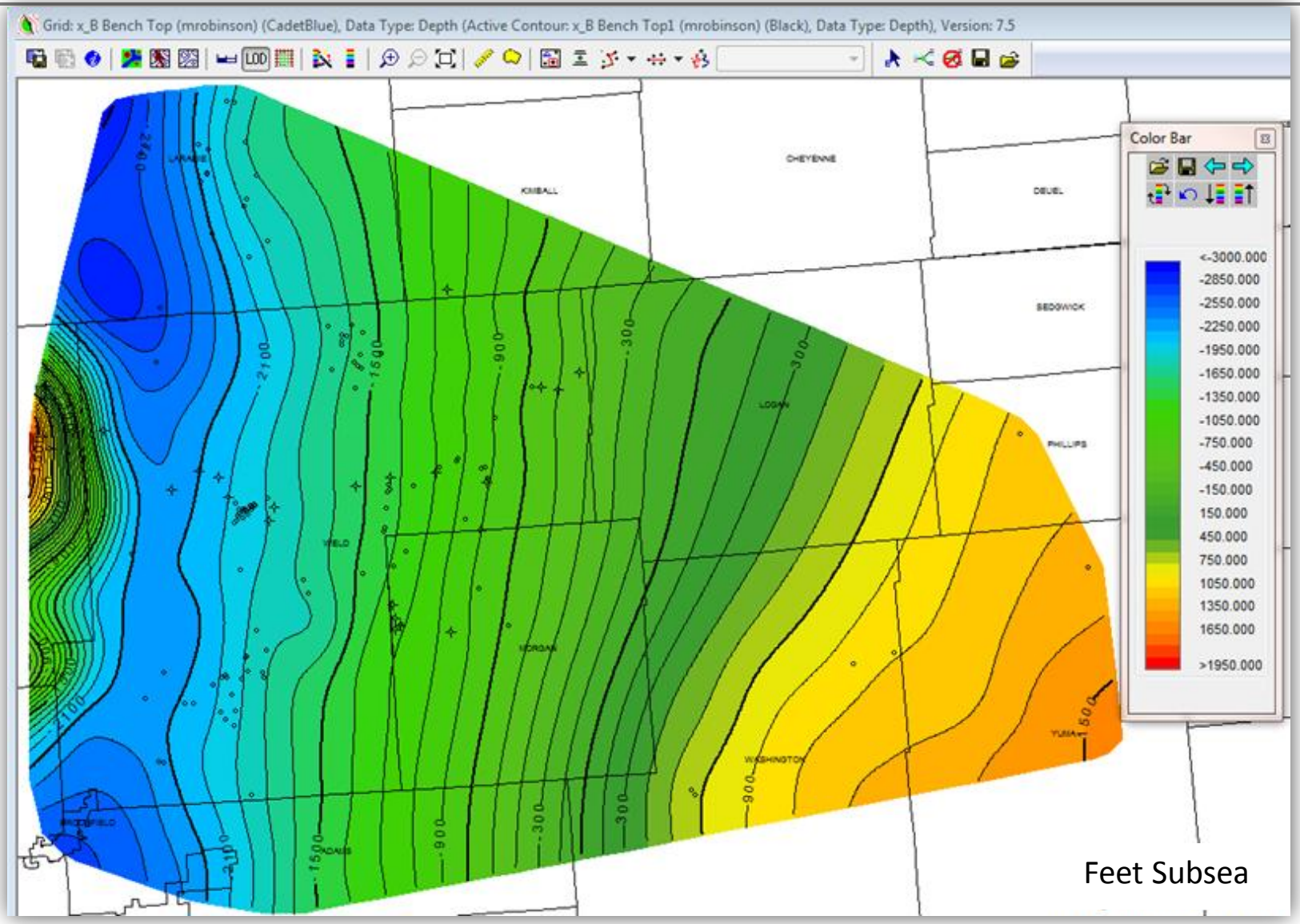
Source: Drillinginfo

Isopach Map – Smoky Hill Member of the Niobrara



Source: Drillinginfo

Structure Map - B Bench



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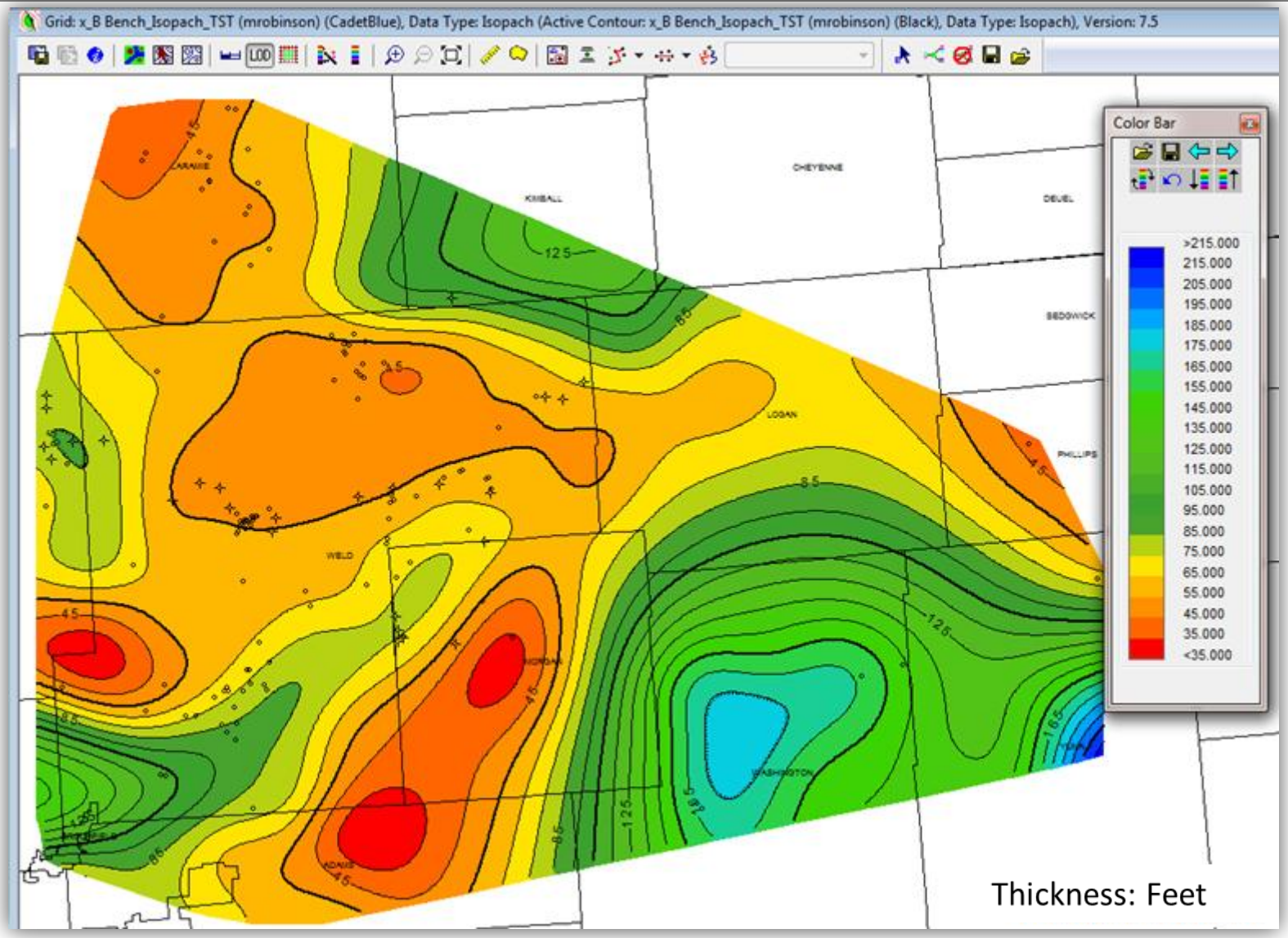
Isopach Map - B Bench



Source: Drillinginfo

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∆ Log R and Calculated TOC

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Δ Log R Methodology

- The methodology of Passey et al (1990) was used for Δ Log R calculation of TOC and involved overlay and base-lining of the resistivity and sonic logs and consideration of Niobrara thermal maturity patterns

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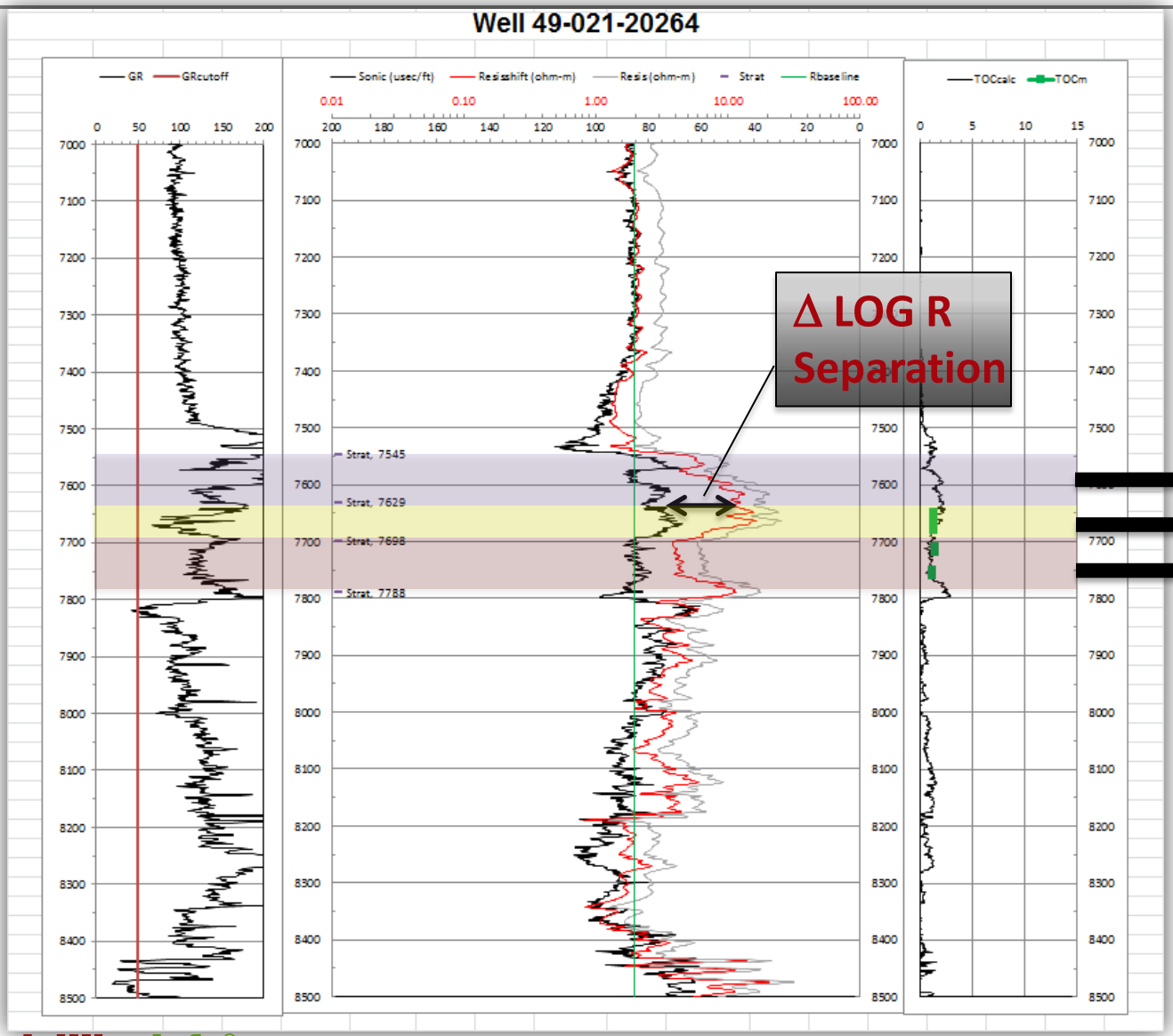
Δ Log R Methodology



Source: Drillinginfo

Δ Log R Methodology

- Zonal statistics (min., max., mean, etc.) for Δ Log R were calculated for the B Bench and the results were gridded over the study area.

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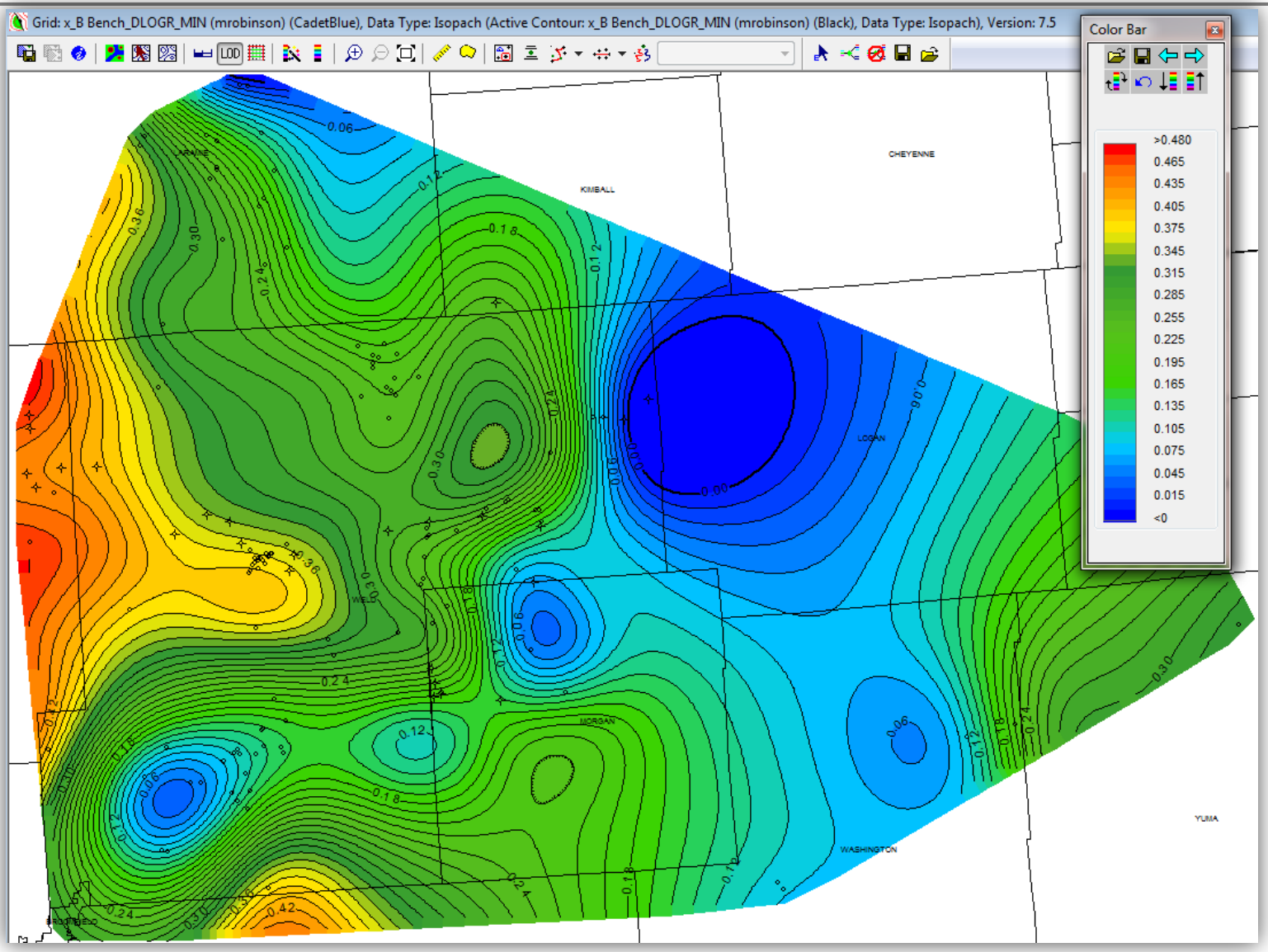
Minimum Δ Log R - B Bench



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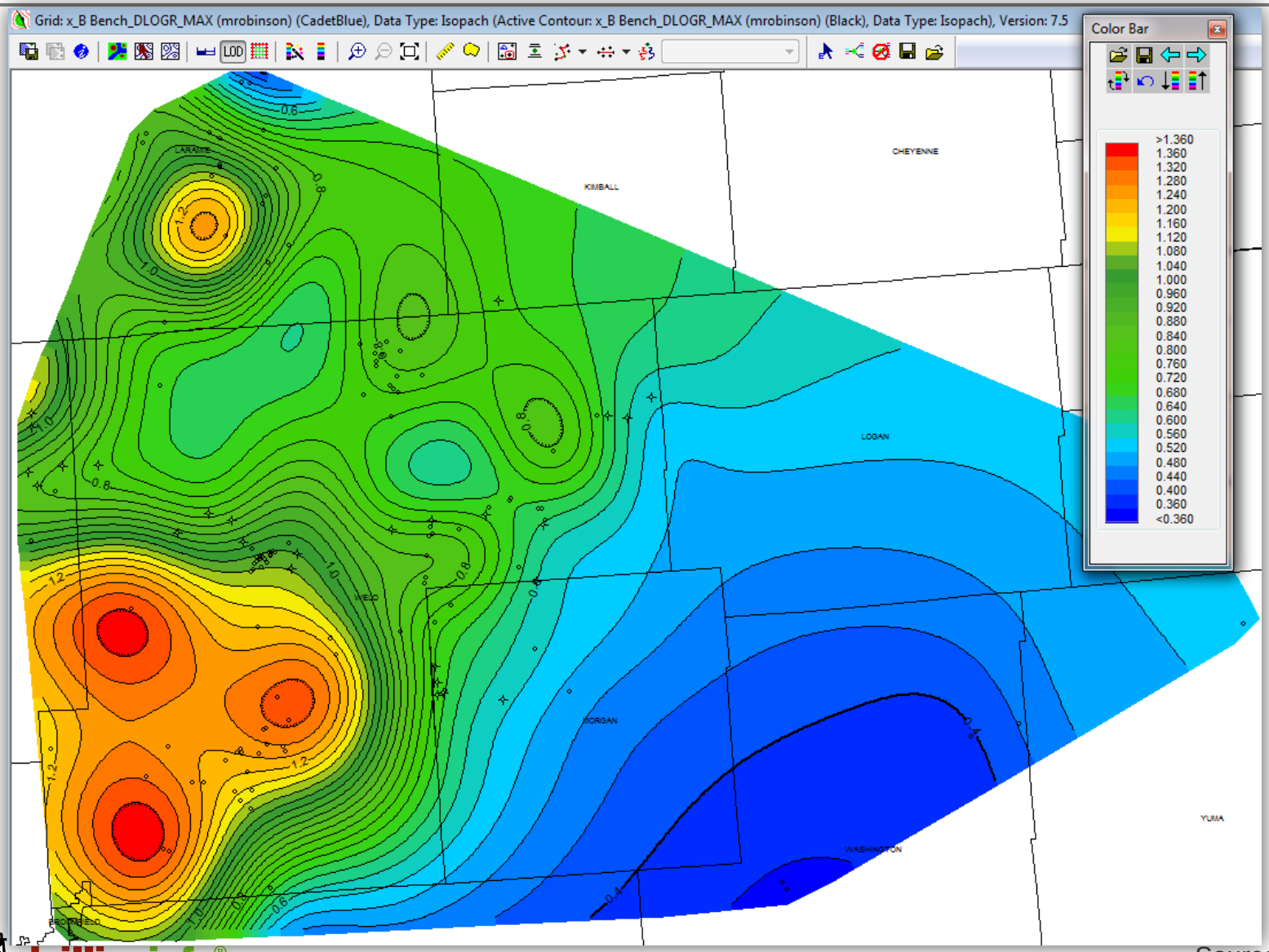
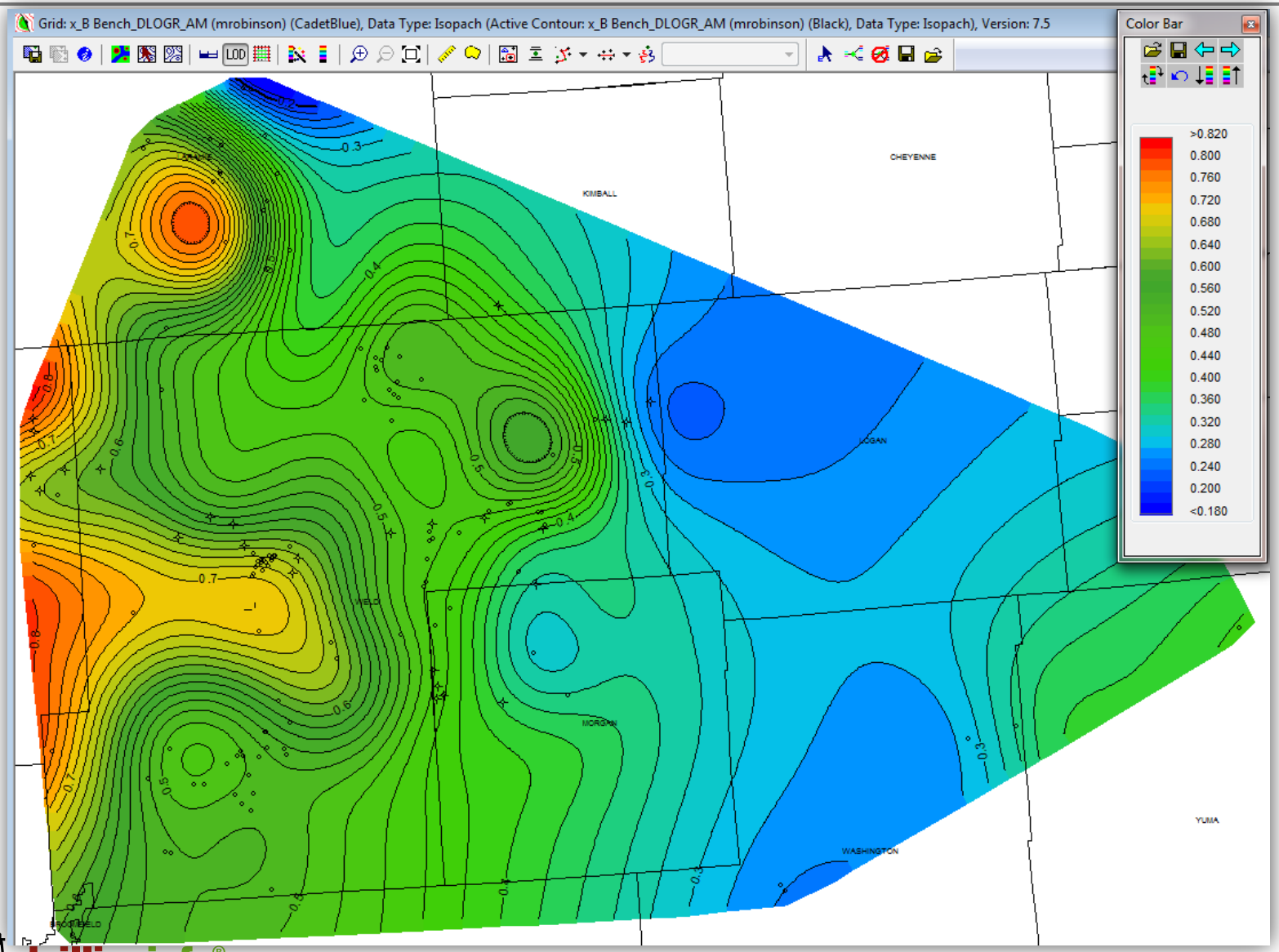
Maximum Δ Log R - B Bench



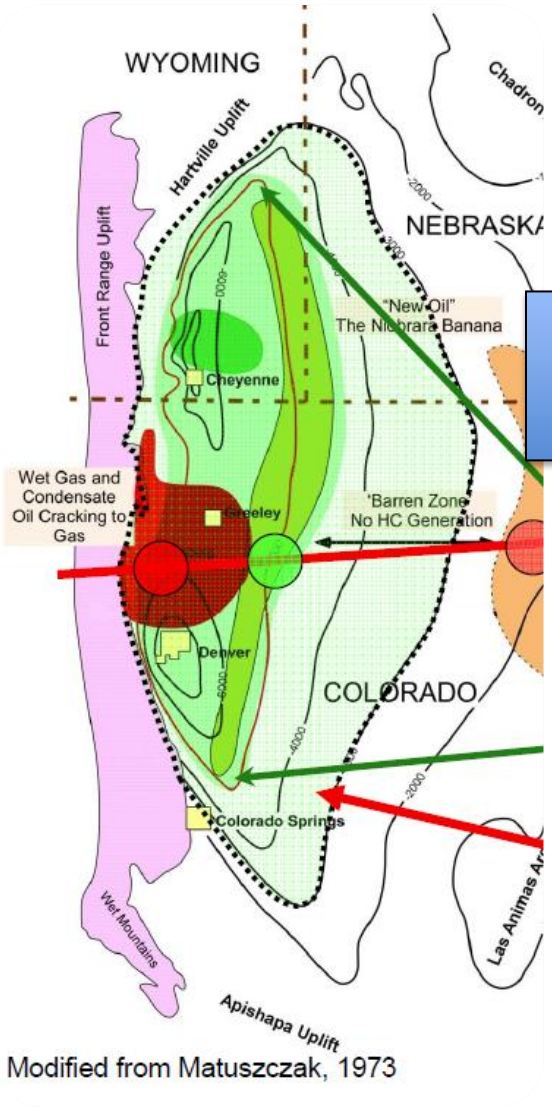
Source: Drillinginfo

Mean Δ Log R - B Bench



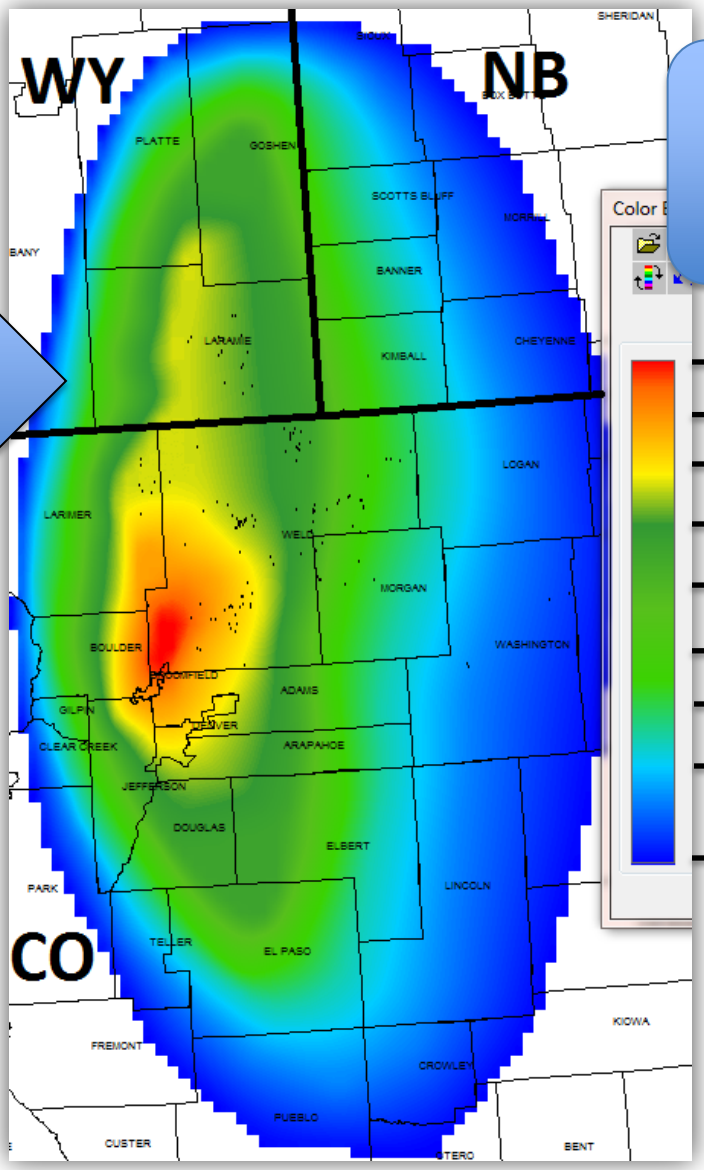
Source: Drillinginfo

Level of Organic Metamorphism (LOM)



Hand-contoured and Gridded

Area of effective oil generation



LOM scale is used by Passey (1990) in his methodology

Source: Stark and Coskey, 2011

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Calculated TOC

- TOC was calculated using a map calculator in third party interpretation software
- The min., max., and mean Δ Log R grids were each used along with the LOM grid to calculate min., max., and mean TOC for the B Bench
- The resulting equation is from the TOC equation of Passey et al (1990) substituting grids required for mapping TOC variation at current LOM (i.e. not original TOC)

TOC=(Δ Log R)*10^(2.297-01688*LOM)

Grid Grid

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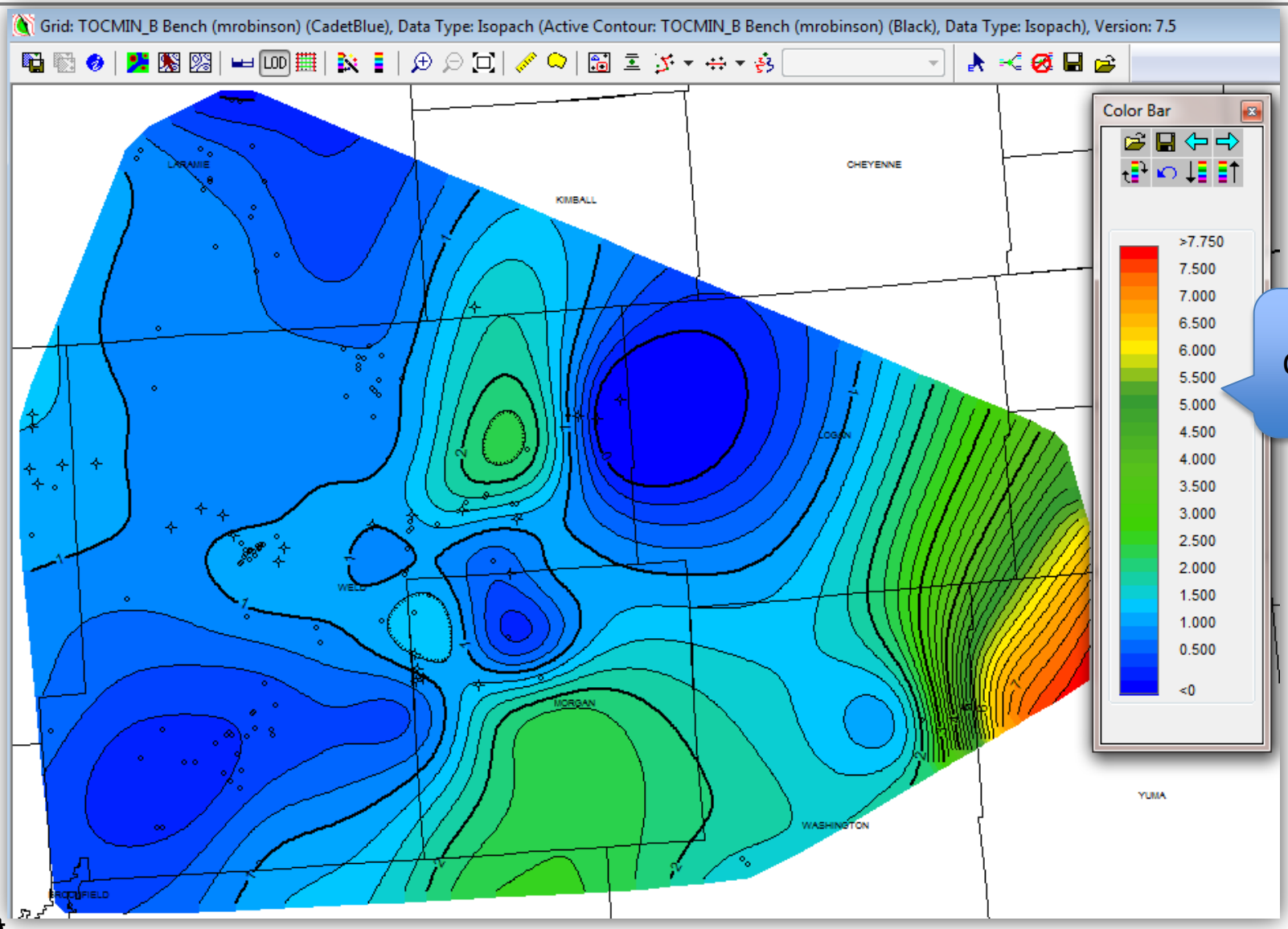
Minimum Calculated TOC - B Bench



% Calculated TOC

Source: Drillinginfo

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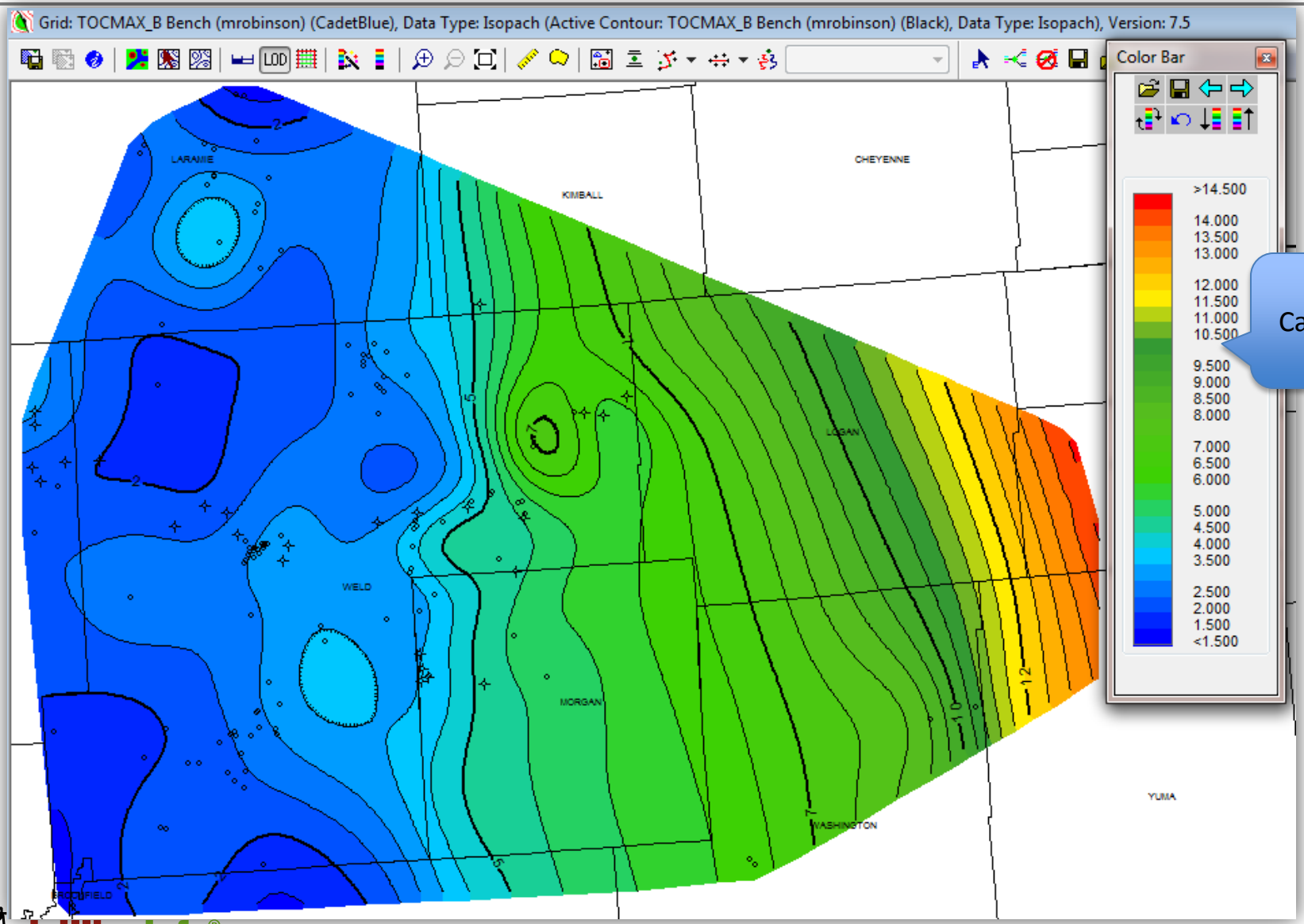
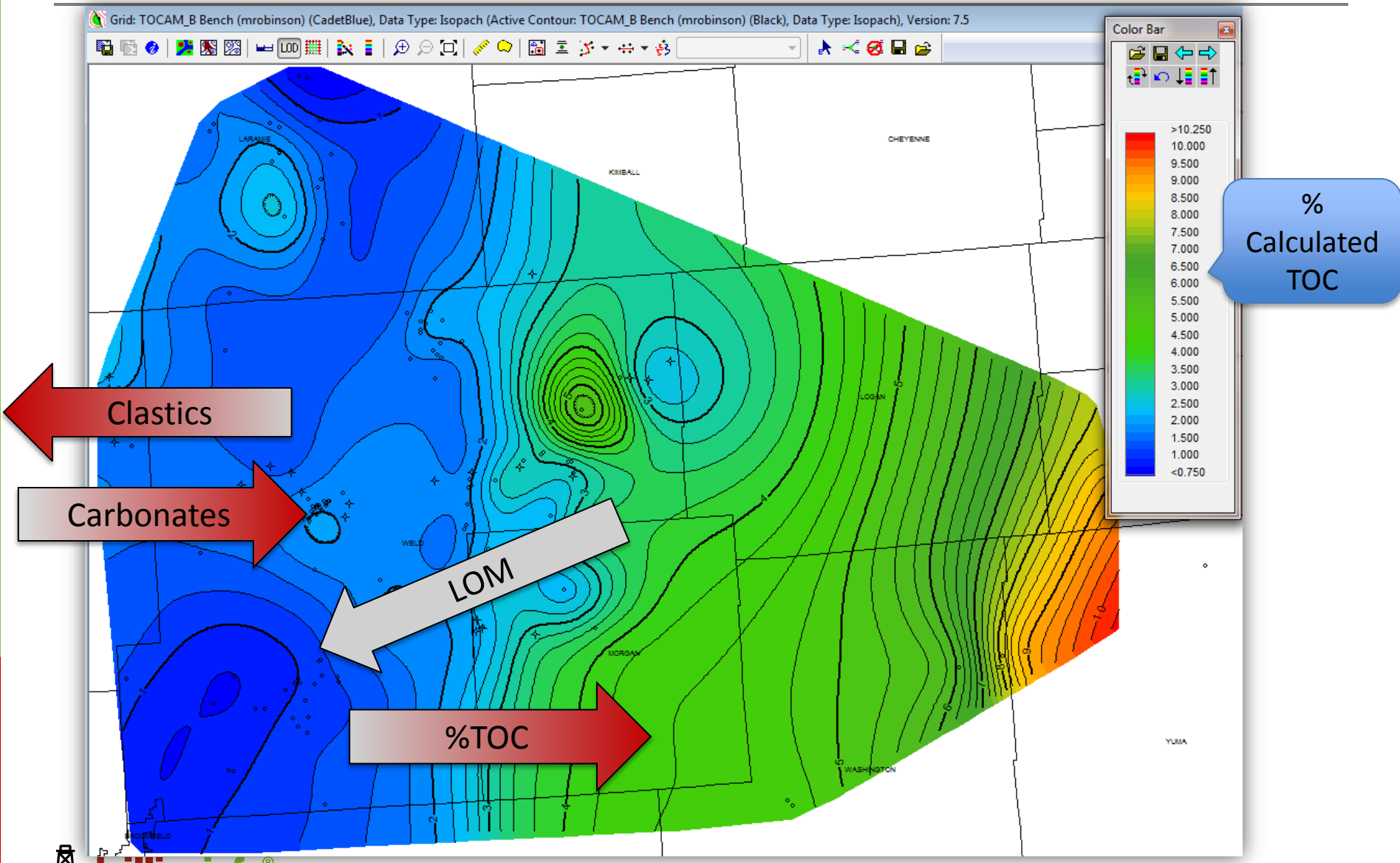
Maximum Calculated TOC - B Bench



Source: Drillinginfo

Mean Calculated TOC - B Bench



Source: Drillinginfo

Results and Remarks

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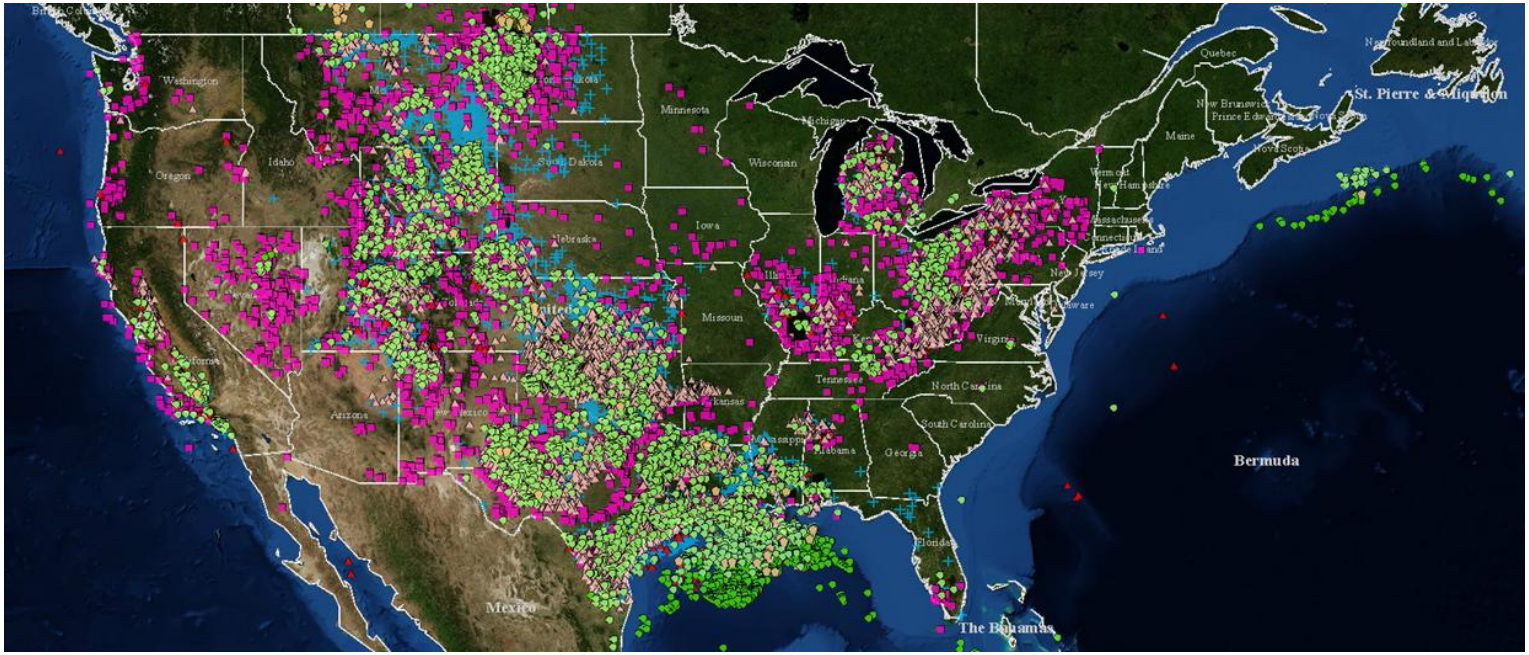
Checking our Results

- GeoMark Research
  - We used measured TOC values from core and cuttings to calibrate our calculated TOC values
  - TOC data was contributed by GeoMark Research which granted us access to the Denver-Julesburg portion of their Rock and Fluid Database (RFDbase.com)



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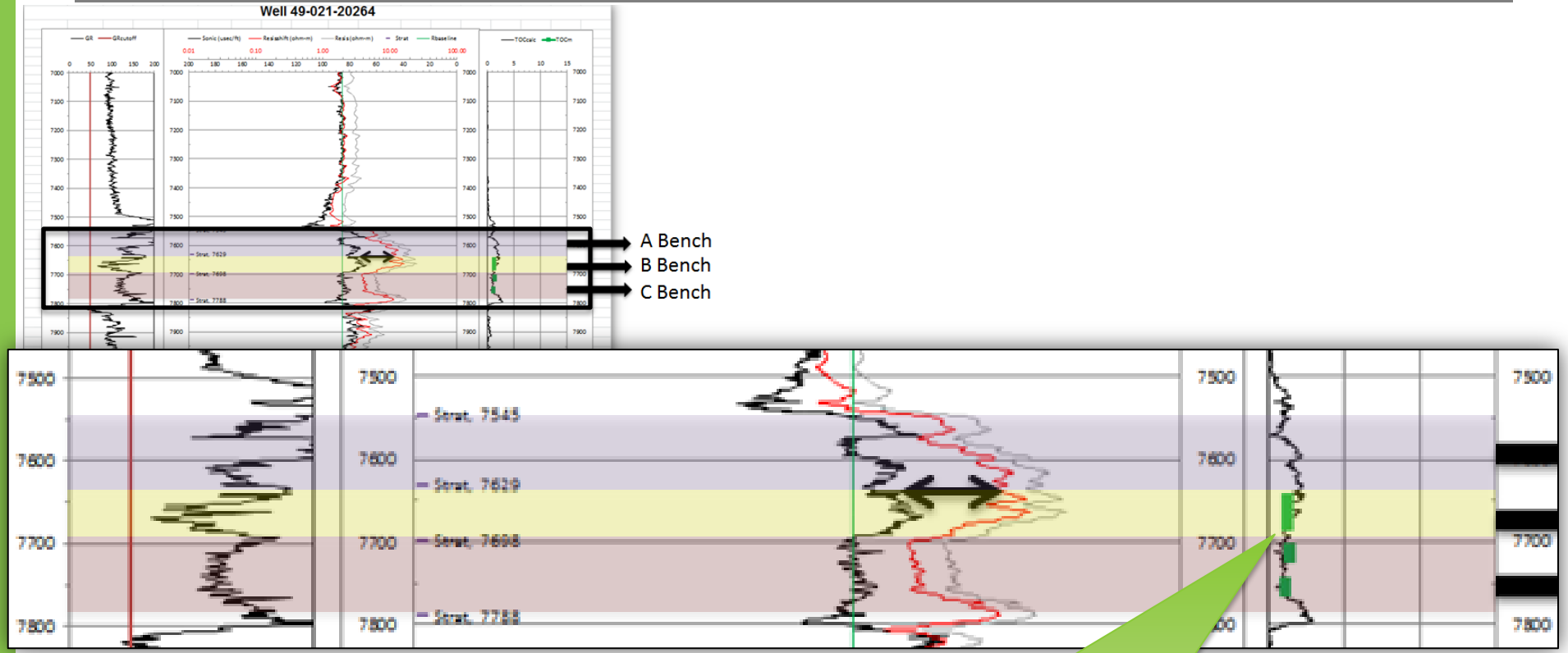
Checking our Results



The Green points on the Calculated TOC curve represent Measured TOC data points from the GeoMark Rock and Fluid Database.

Source: Drillinginfo

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Remarks

- Two controlling phases contributed to the present B Bench TOC patterns discovered in this study:
  - Deposition → Original TOC – a function of productivity, preservation, and dilution
    - Higher TOC to the east is consistent with decreasing seafloor O2 and lower clastic dilution with more distal depositional conditions
  - Burial → Original TOC reduction due to thermal maturity
    - Higher TOC to the east is consistent with decreasing thermal maturity and generative loss of TOC moving out of the foreland basin depocenter

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Remarks

- This was a preliminary study for Drillinginfo to develop tools and workflows for calculating TOC over conventional and unconventional play areas using digitized well logs
- Resistivity and Sonic Baseline maps along with better maturity mapping will be used for future studies.

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Acknowledgements

- Robert Cunningham – working as a consultant with Drillinginfo to assist with expanding our analytical data offerings
- GeoMark Research
  - http://www.geomarkresearch.com

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