Stratigraphy and Petrophysical Characteristics of the Niobrara Formation in the Denver Basin, Colorado and Wyoming*

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Abstract

The ten major stratigraphic units of the Upper Cretaceous Niobrara Formation provide a framework for predicting both hydrocarbon source and reservoir potential of the formation throughout the Rocky Mountain region of the western United States. Water depth, climate, proximity to the thrust belt bordering the seaway on the west, paleobathymetry, current circulation patterns, and sea level fluctuations each played a role in shaping the nature and distribution of Niobrara lithologies within these units.

The Niobrara Formation contains a mix of chalk and marl lithologies. Coccolith-rich fecal pellets provide a distinctive feature of the formation. Black shaly marls, which are rich in coccoliths and chalk fecal pellets, are the major hydrocarbon source rocks. Similar shaly beds also provide sealing facies overlying more chalk-rich reservoirs intervals. Organic richness in the source interval is typically 2 to 4% but ranges up to more than 7% in less mature rocks. Thermal maturity of these source beds varies regionally on the basis of burial depth and local heat flow. The presence of multiple source beds of varying quality and maturity impact hydrocarbon-fluid quality across the play.

Recent developments in wireline logging technologies are allowing operators to better address some of the key criteria for exploiting heterogeneity in this play: pay recognition, lateral placement, and stress profile and orientation variation. The result is a more robust understanding of the complex mix of lithologic components and their effect on petro- physical models, drilling practices and completion optimization.

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2. QEP Resources

June 27, 2011

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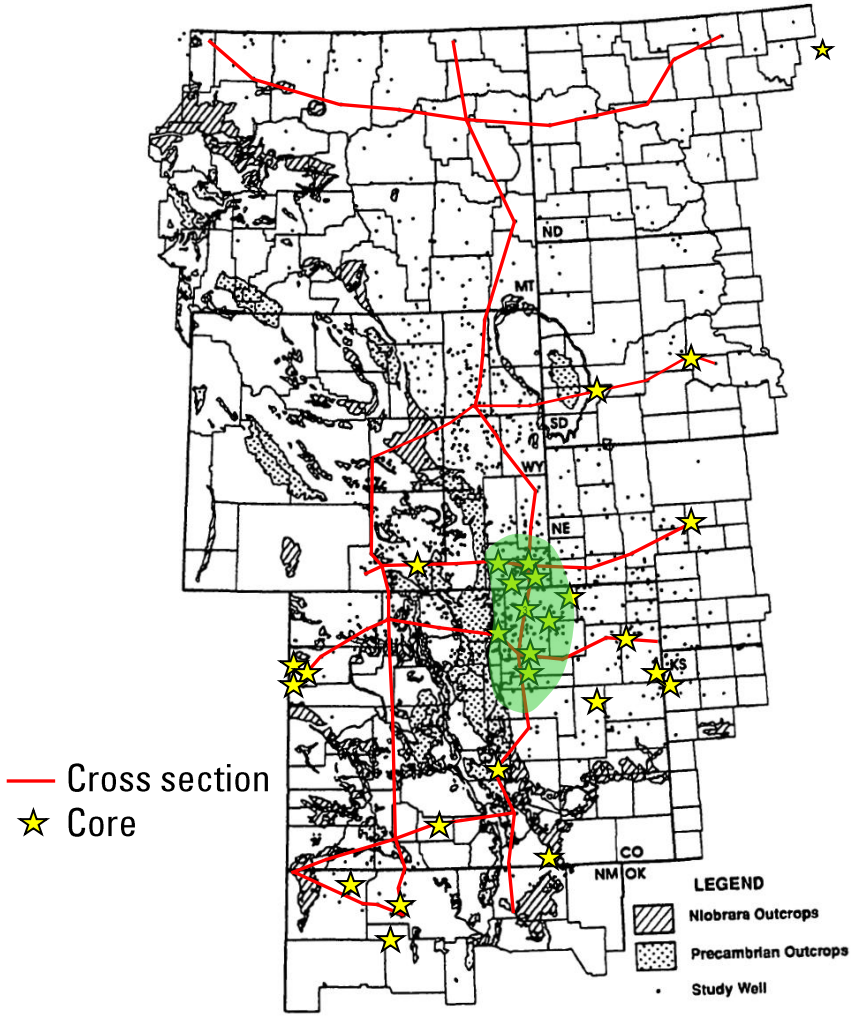
Outline

- Overview of 1991 regional Niobrara study
  - Longman et al., 1998
  - Landon et al., 2001
- Stratigraphic framework
- Source facies
- Storage facies
- Petrophysical characteristics

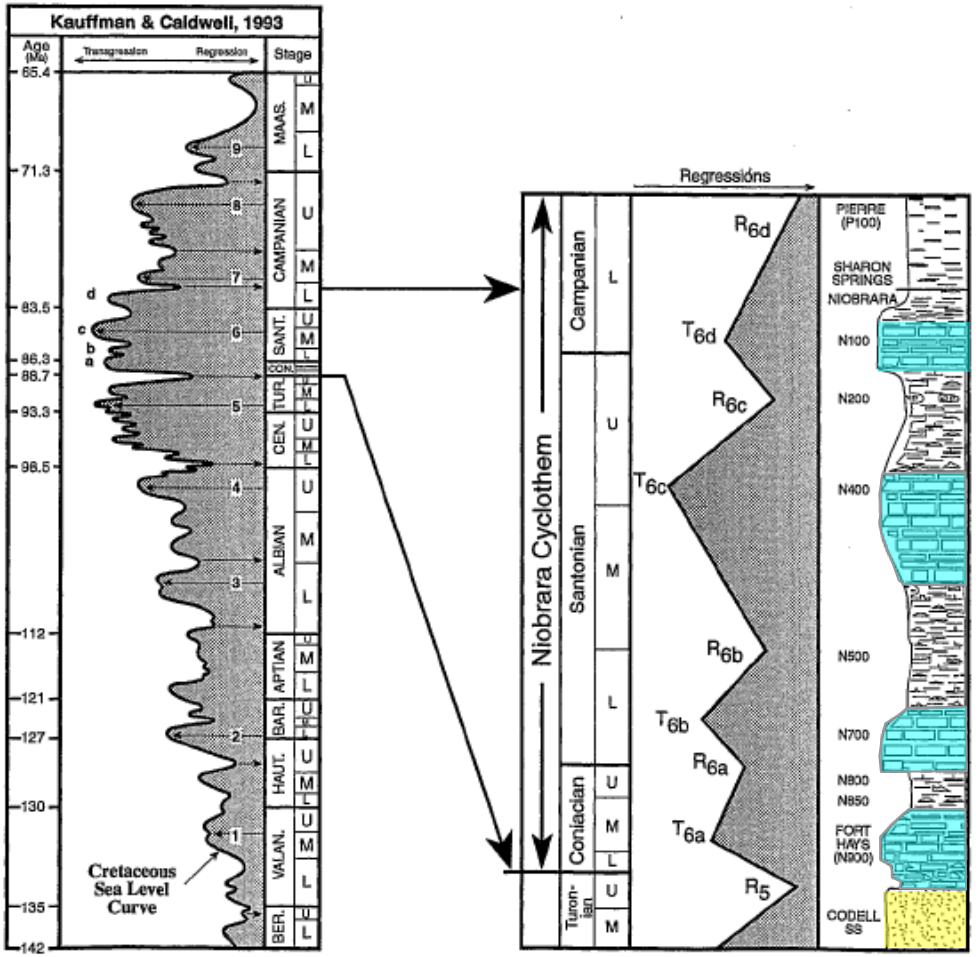
Regional Analysis of the Cretaceous Niobrara Formation of the Rocky Mountain Region



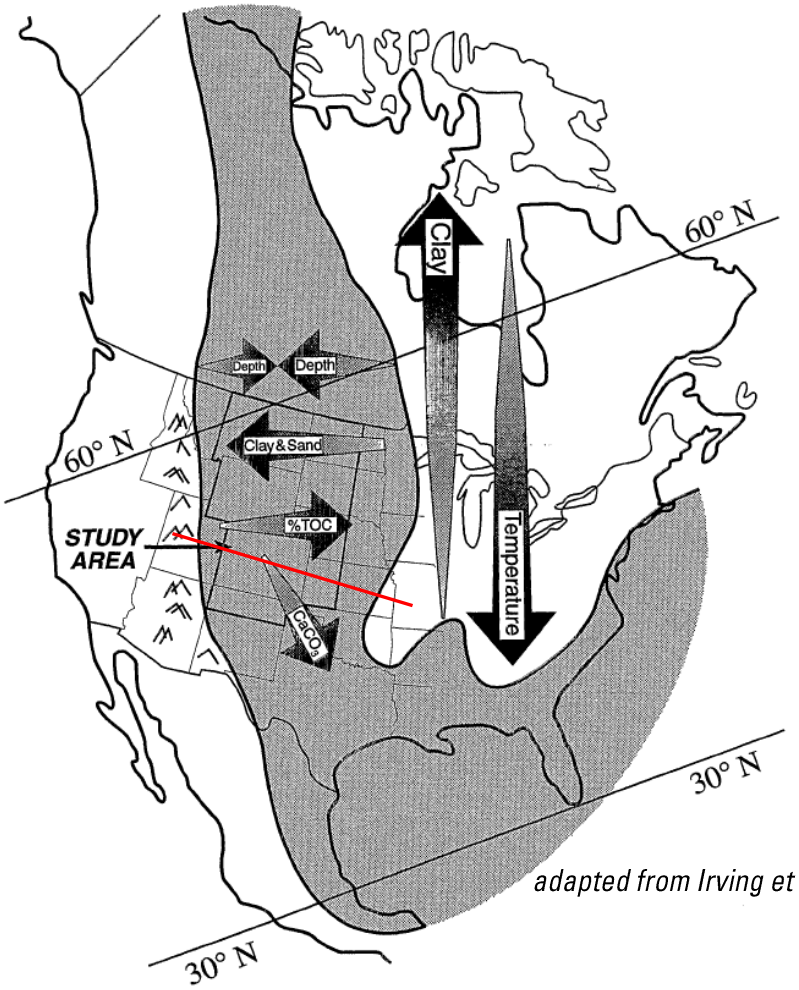
Scope

- 1000 wells
- 46 cores
  - Facies descriptions
  - Thin-section petrography
  - Rock Eval pyrolysis
- Lithostratigraphic well markers (12)
- Facies and log property mapping
- Depositional models & history
- Burial history and thermal maturity
- Lineament patterns and natural fracture occurrence
- Exploration concepts

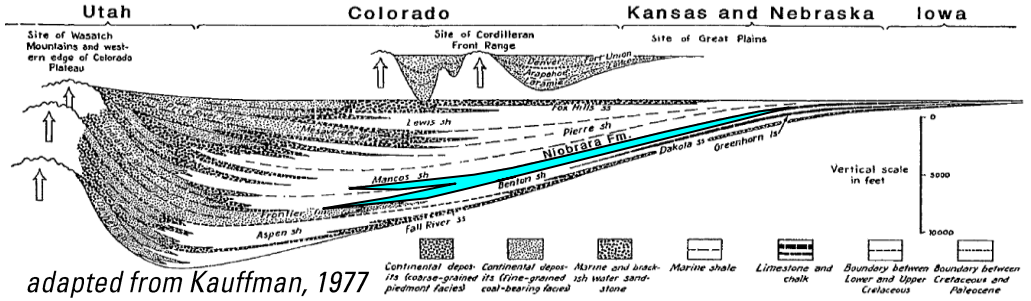
Upper Cretaceous Depositional Setting



adapted from Kauffman and Caldwell, 1993 and Obradovich, 1993



adapted from Irving et al., 1993



adapted from Kauffman, 1977

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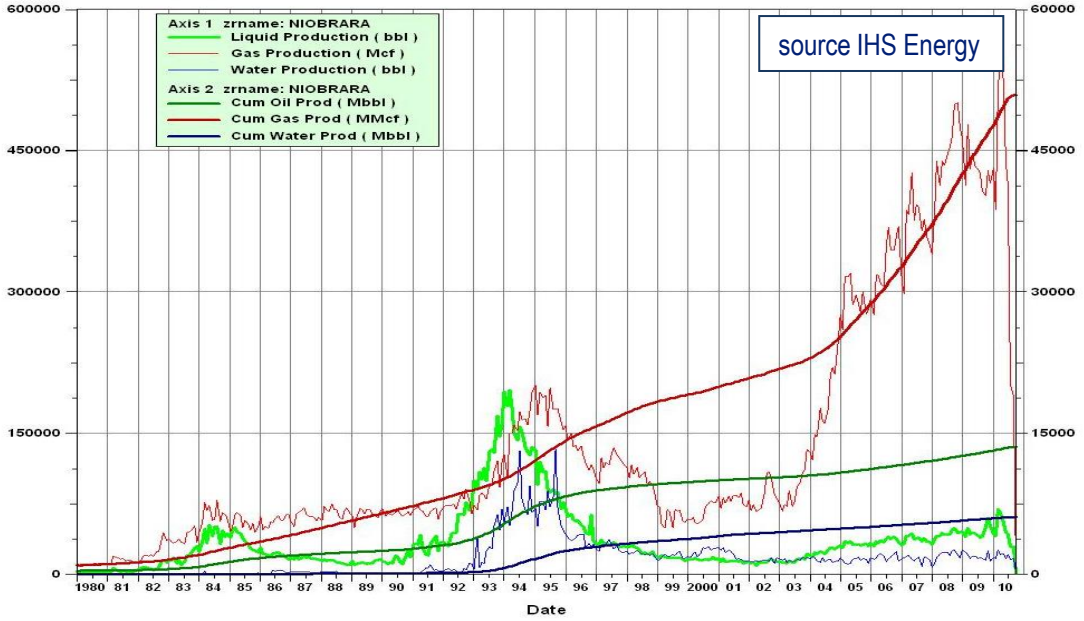
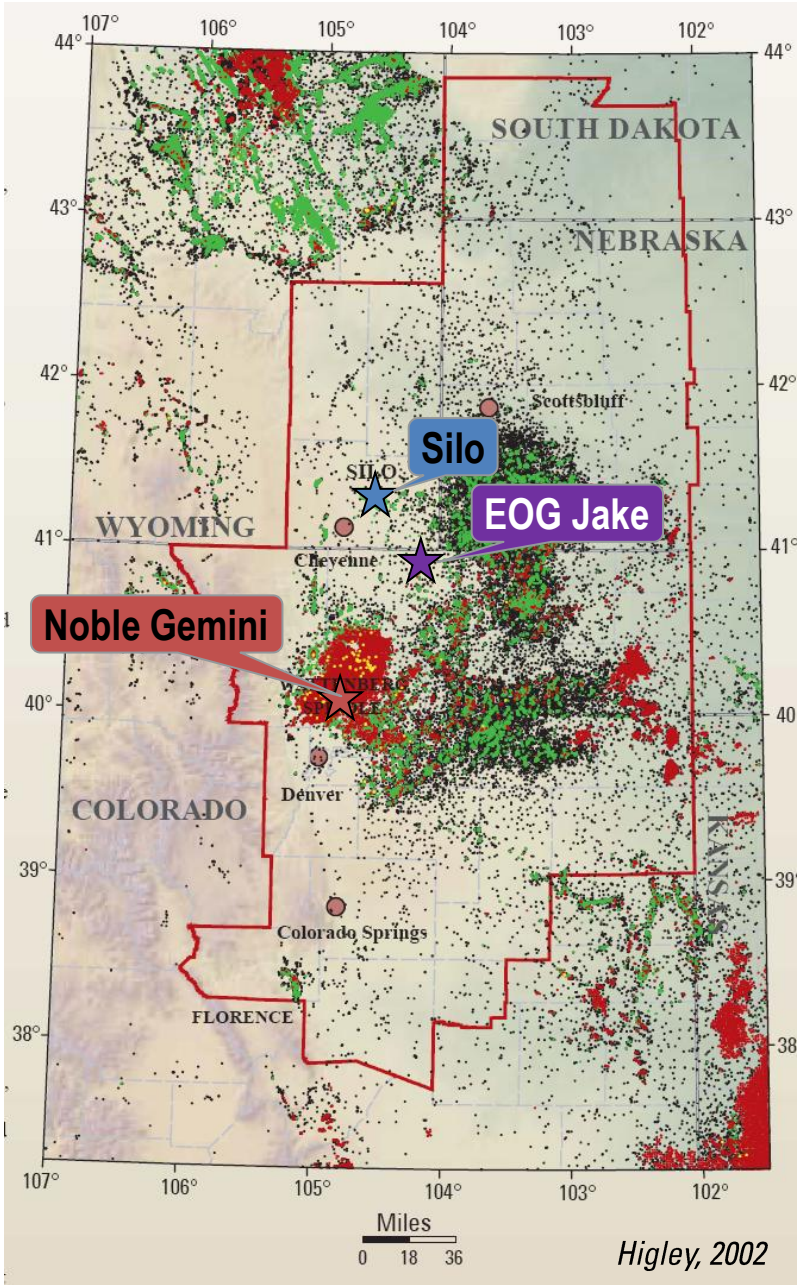
Post-1991 Niobrara Interest



Total Petroleum Systems (TPS) and Assessement Units (AU)	Field Type	Oil MMBO			
		F95	F50	F5	Mean
Niobrara TPS Denver Basin					
Niobrara-Codell (Wattenberg Area) AU 50390661	*Oil*	16.41	30.07	55.08	32.17
Fractured Niobrara (Silo Field Area) AU 50390261	*Oil*	4.32	7.29	12.27	7.66
Niobrara TPS Powder River Basin					
Niobrara Continuous Oil AU	*Oil*	135.53	217.49	349.03	226.67

2002 USGS Assessment of Oil and Gas Resource Potential of the Denver Basin
2008 USGS Assessment of the Mowry Shale and Niobrara Formation as Continuous Hydrocarbon Systems, Powder River Basin, Montana and Wyoming



Higley, 2002

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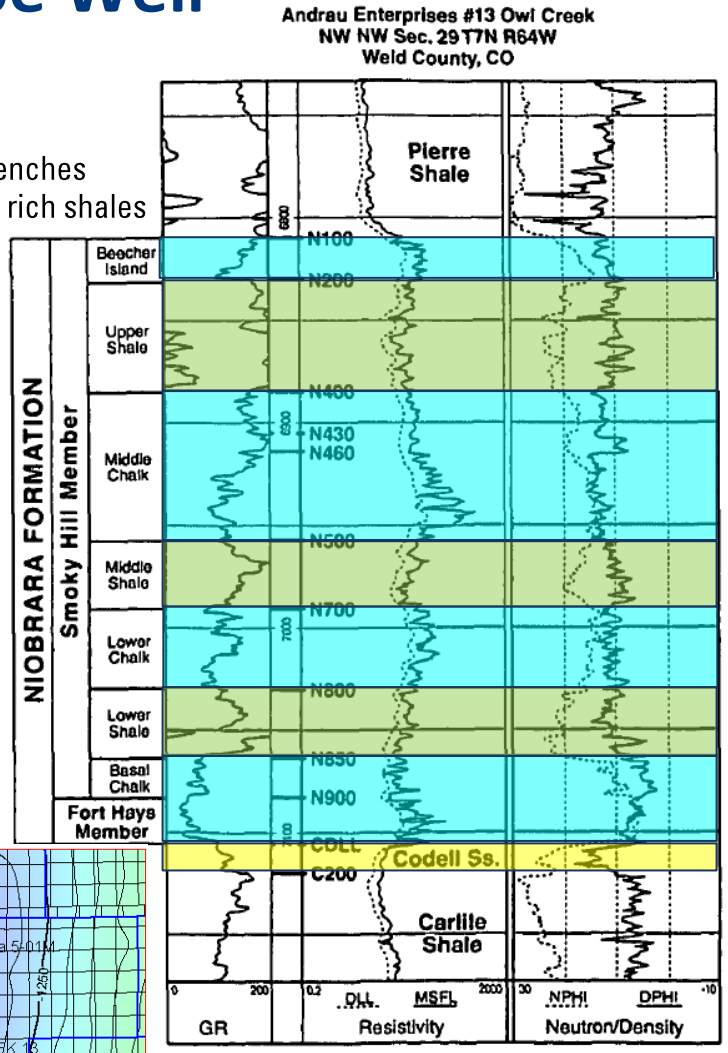
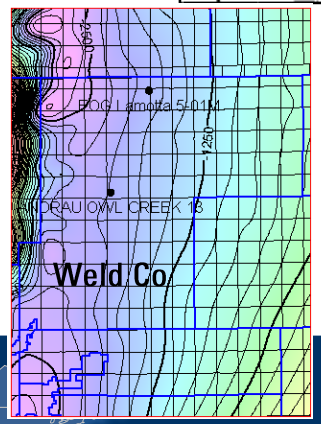
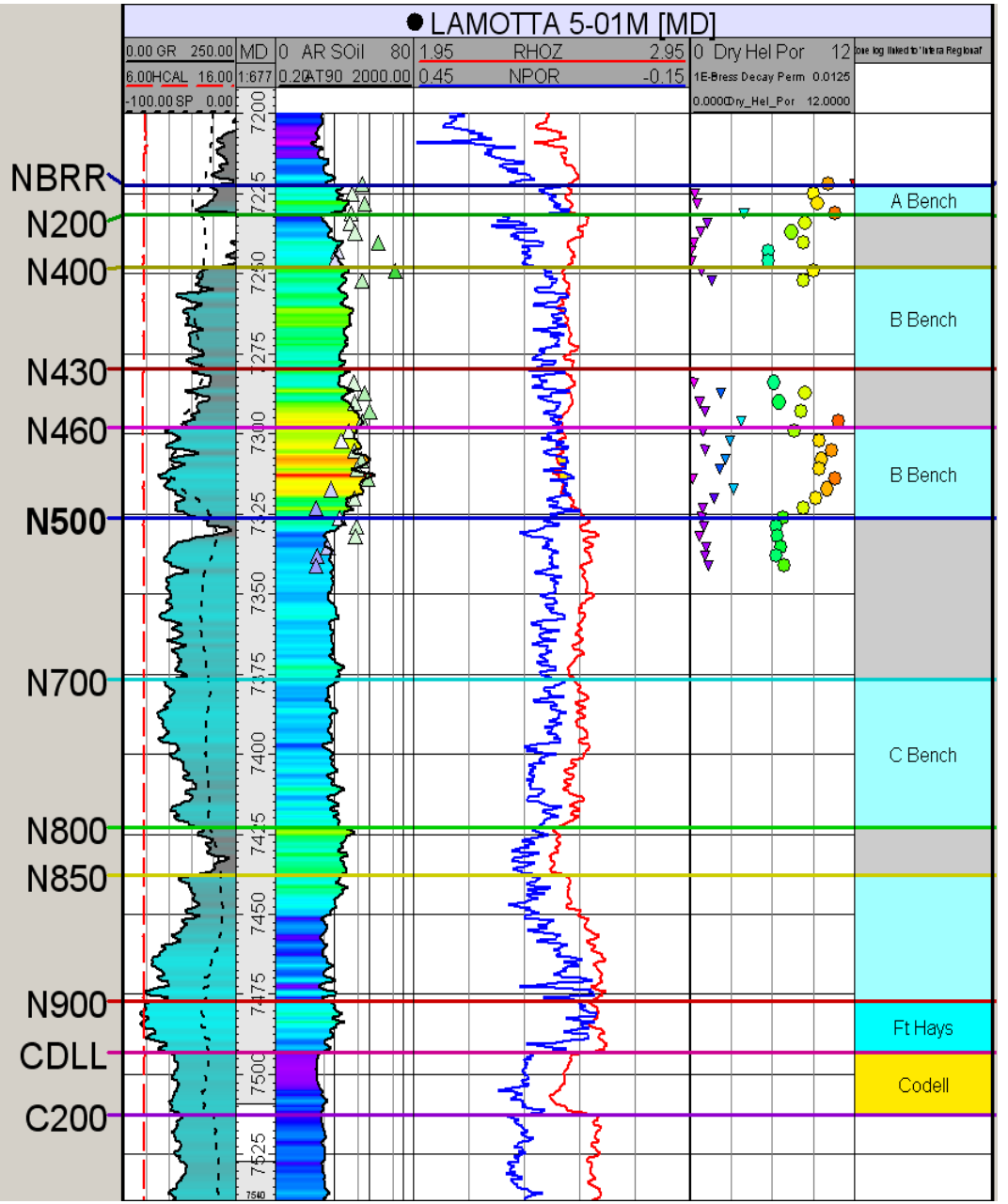
Type Well

Chalk benches
Organic rich shales







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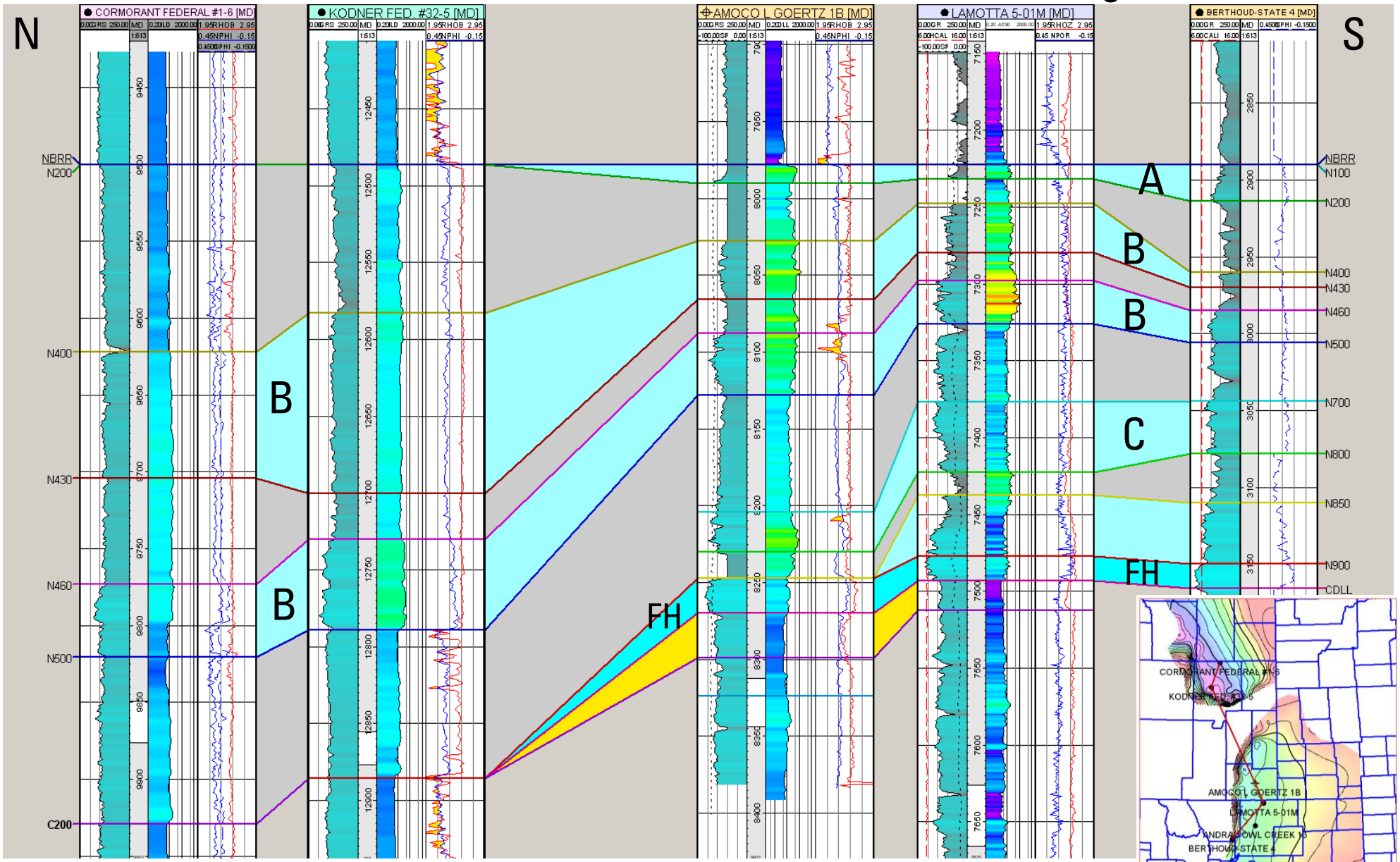
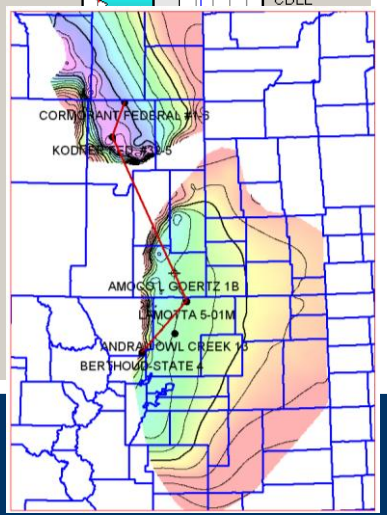
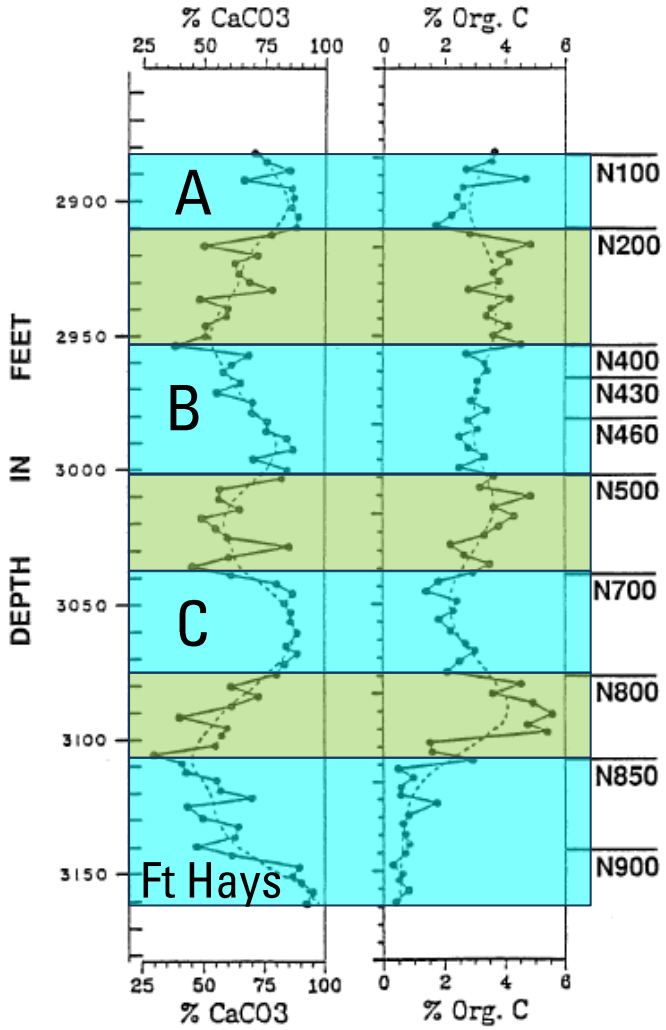
Powder River Basin

Denver-Julesburg Basin

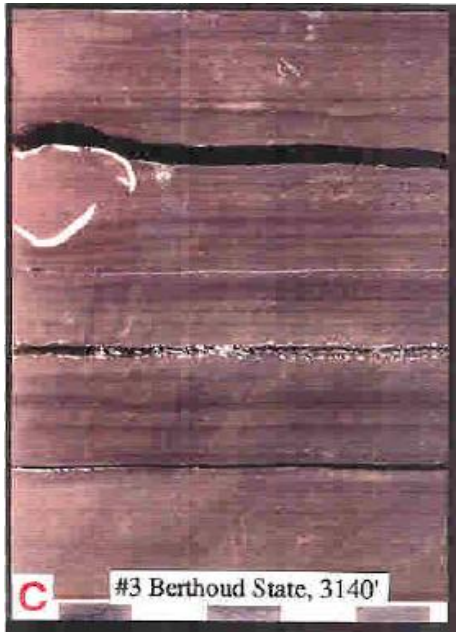


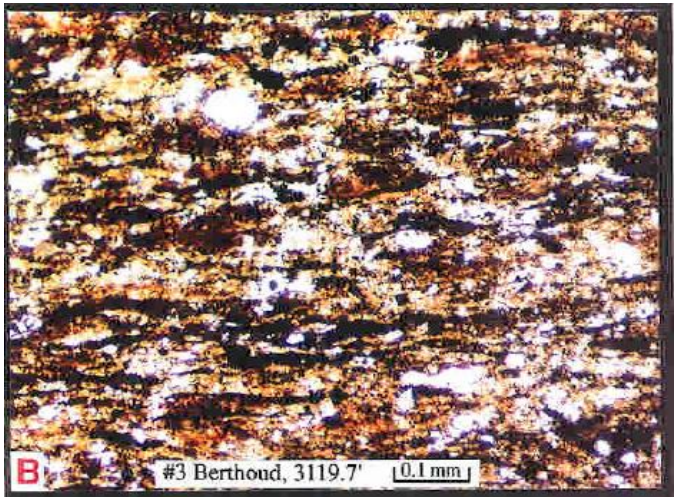


Source Facies



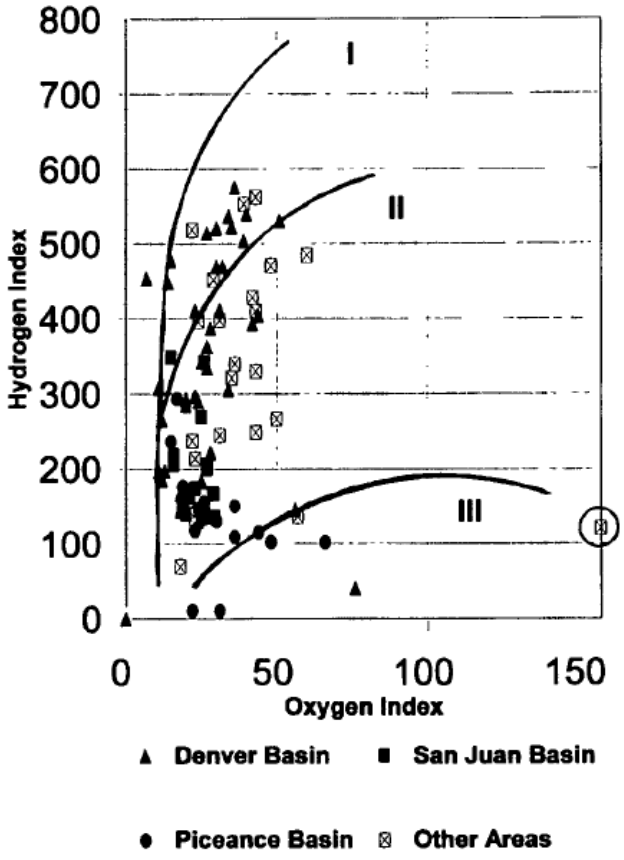
Berthoud State #4

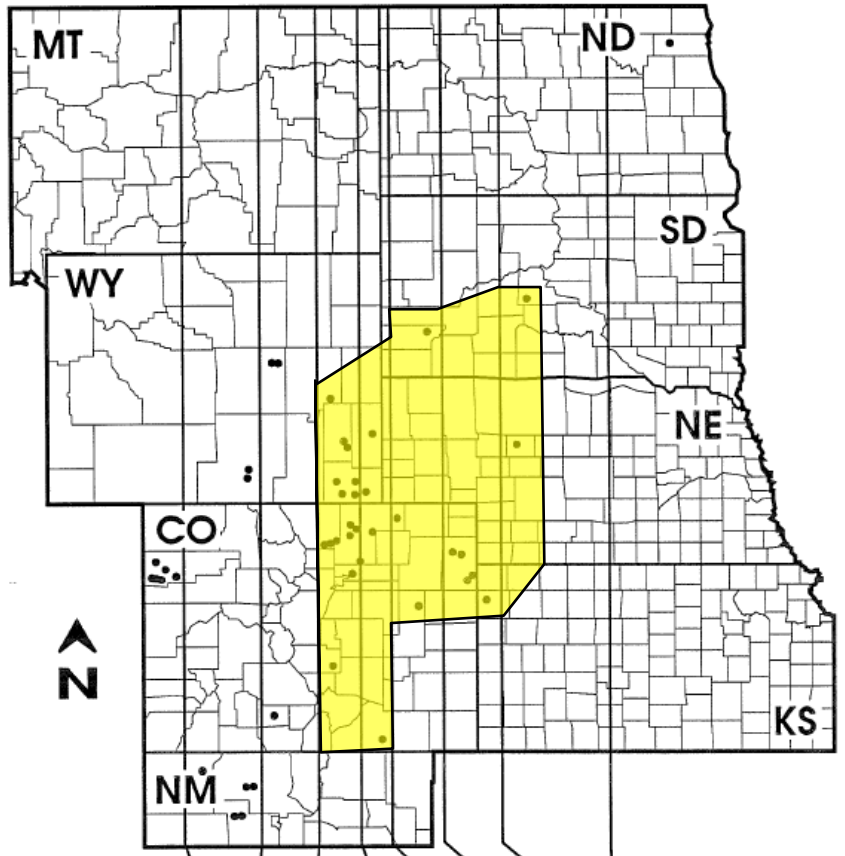




Source Richness & Type

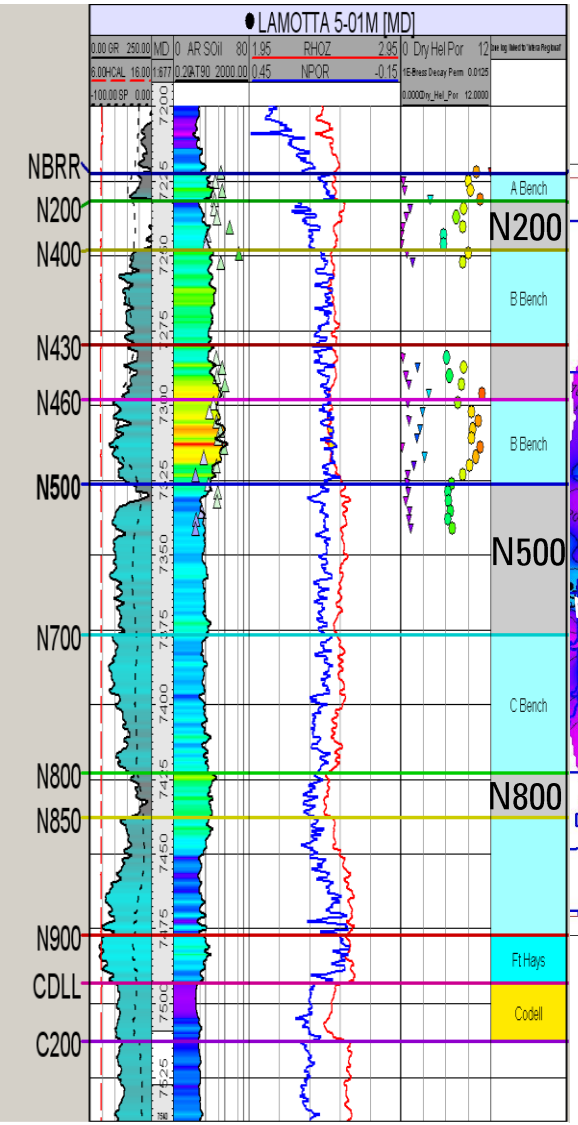
Modified Van Krevelen Diagram
Niobrara Formation



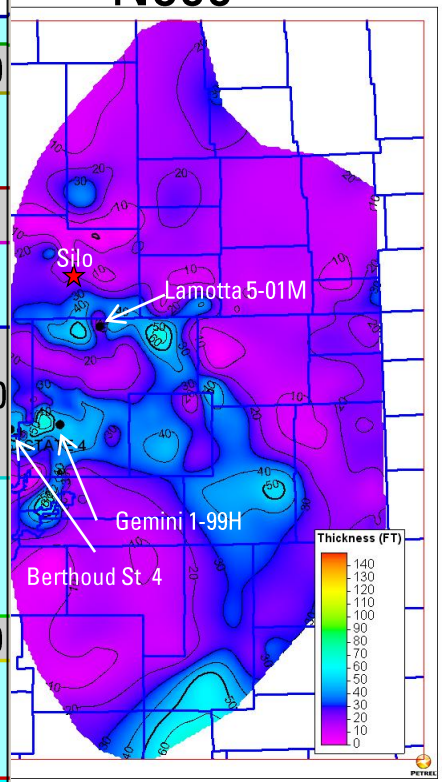


Avg. TOC	1.26	1.85	1.90	2.96	2.94	4.8	4.02	4.58	1.04
TOC Range	2.16-0.65	3.47-0.99	1.94-1.86	7.59-0.76	4.21-1.95	5.95-4.03	5.24-2.99	5.49-3.68	1.04
N	18	20	2	34	3	4	4	4	1
Type	III ?	II	?	II	II	II	II	II	III

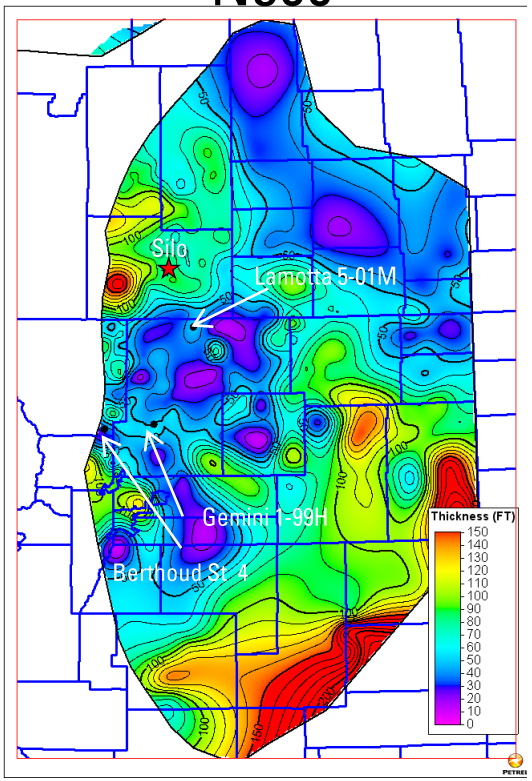
Source Facies Thickness



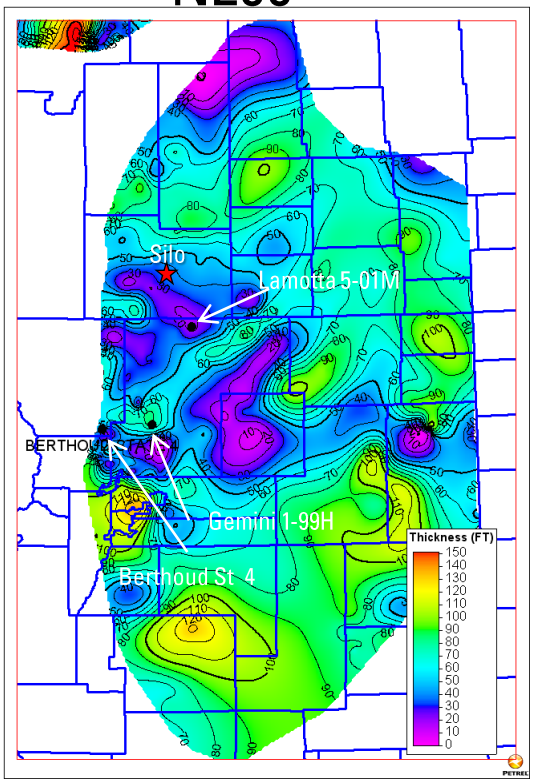
N800



N500



N200



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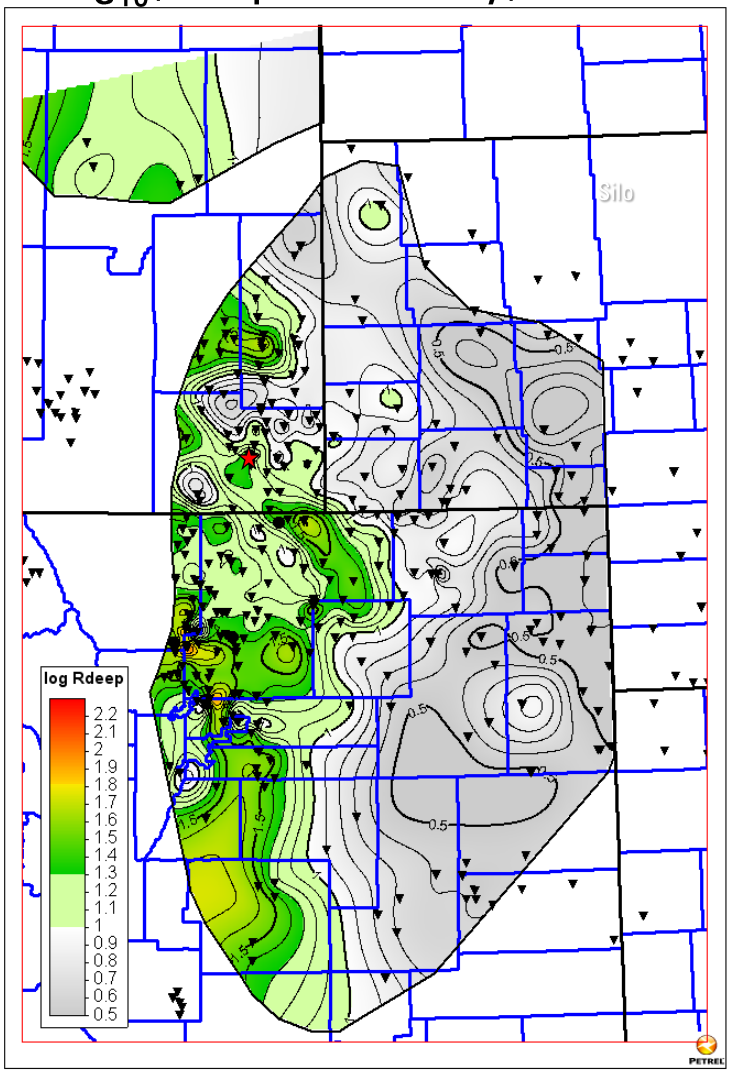
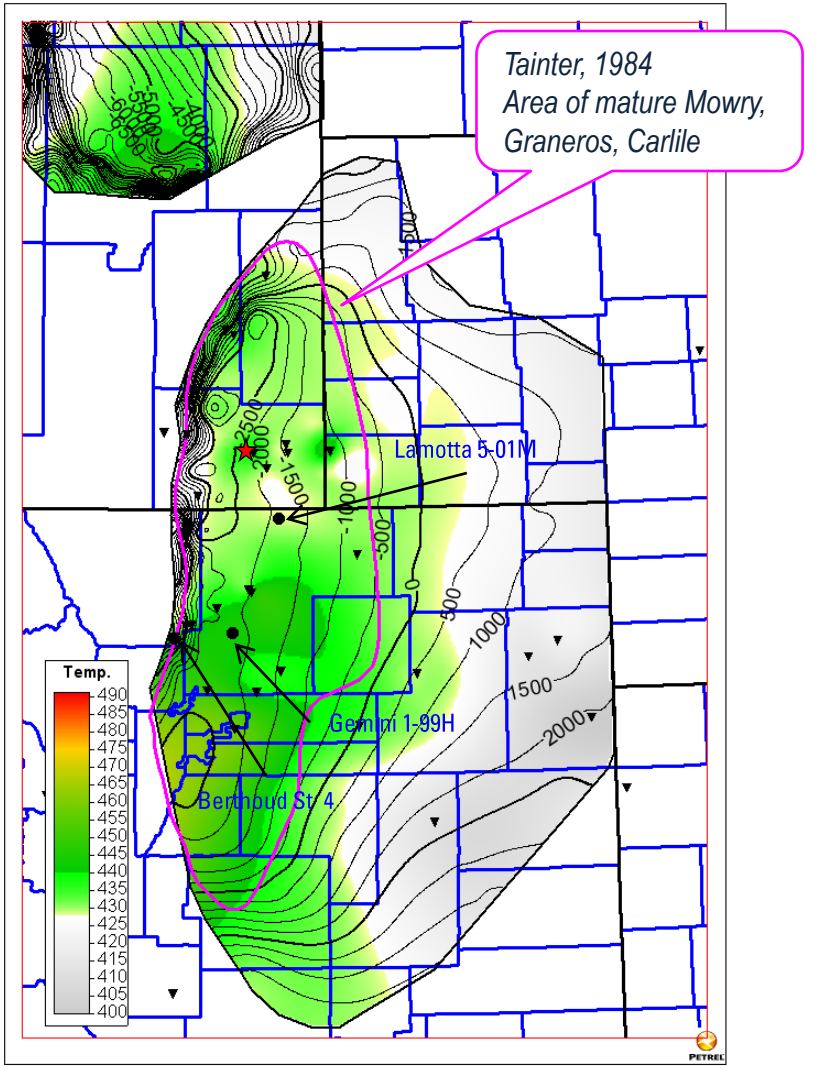
Maturation Trends

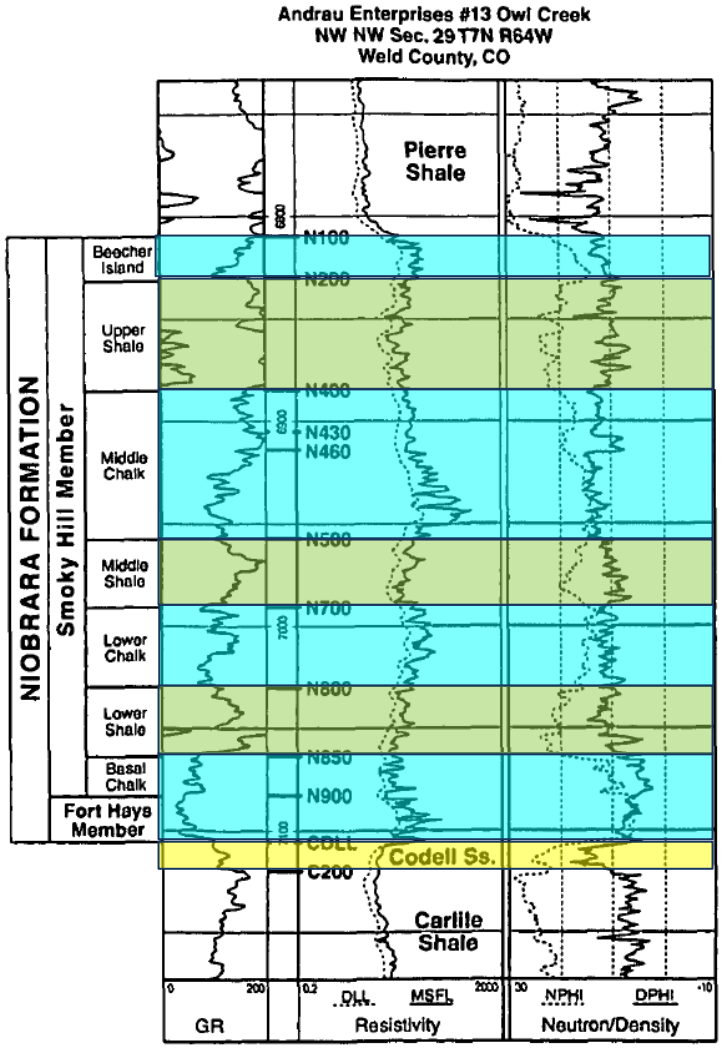
Log_{10}(Deep Resistivity) N800

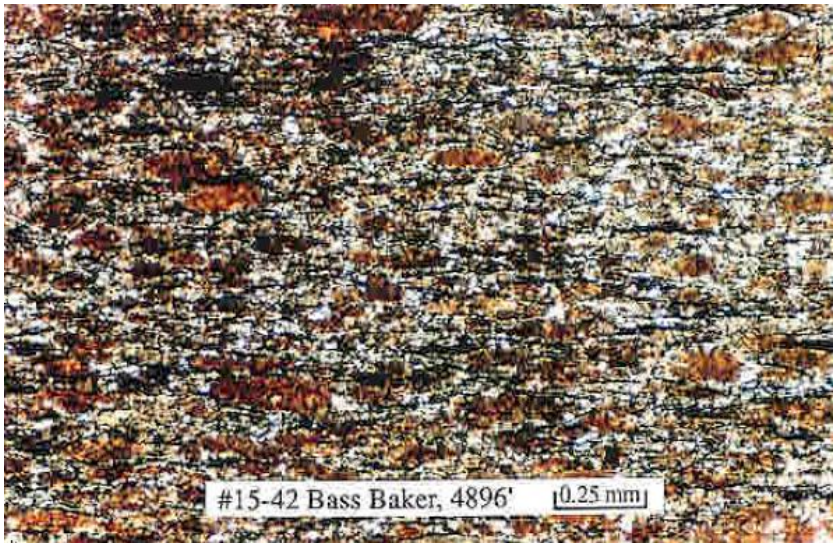


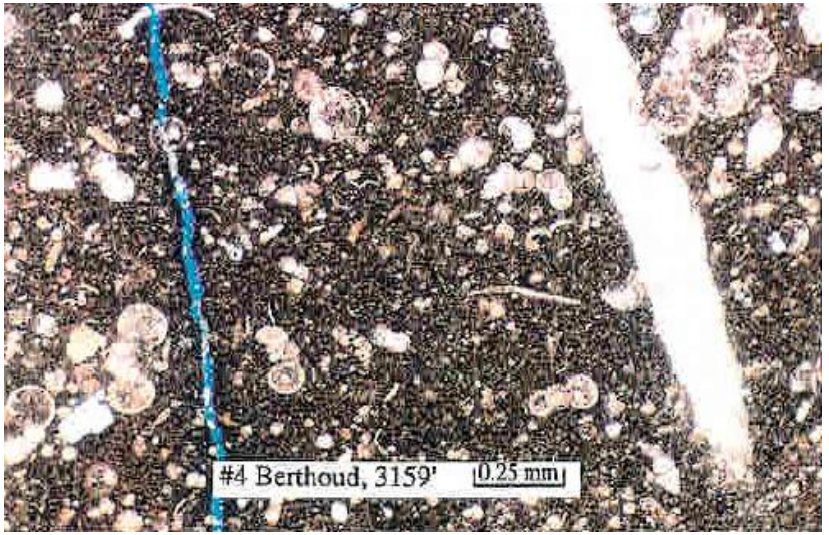
Tmax (Study and USGS)



Storage Facies

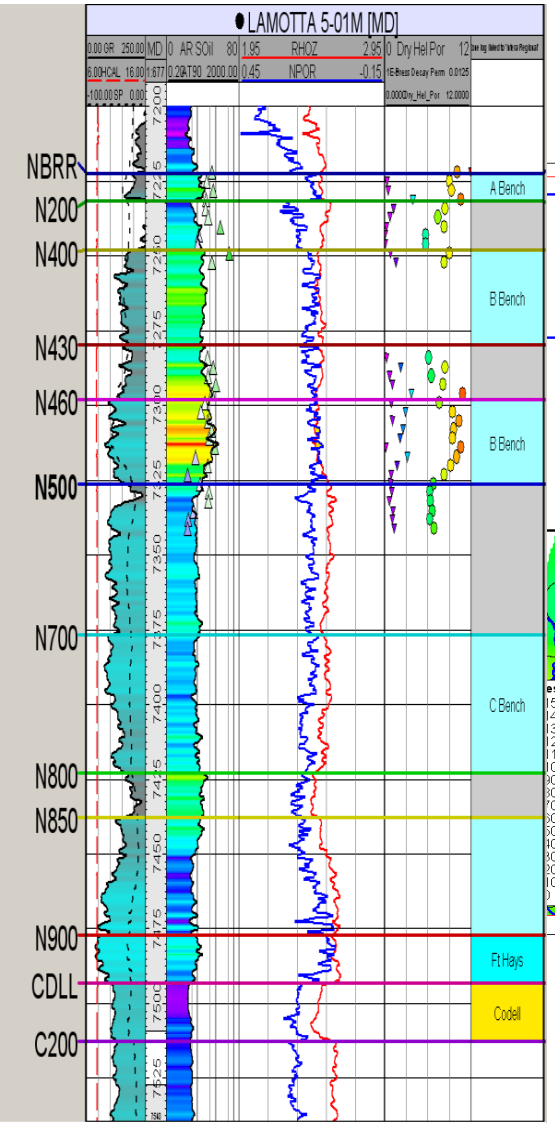




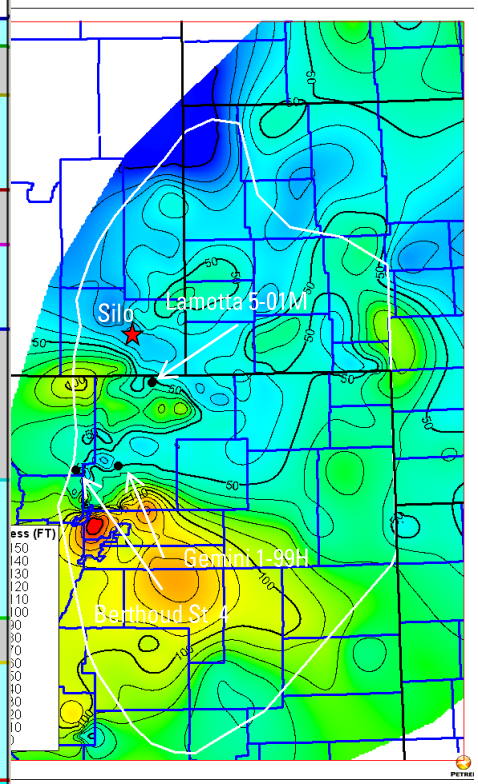


Chalk benches
Organic rich shales

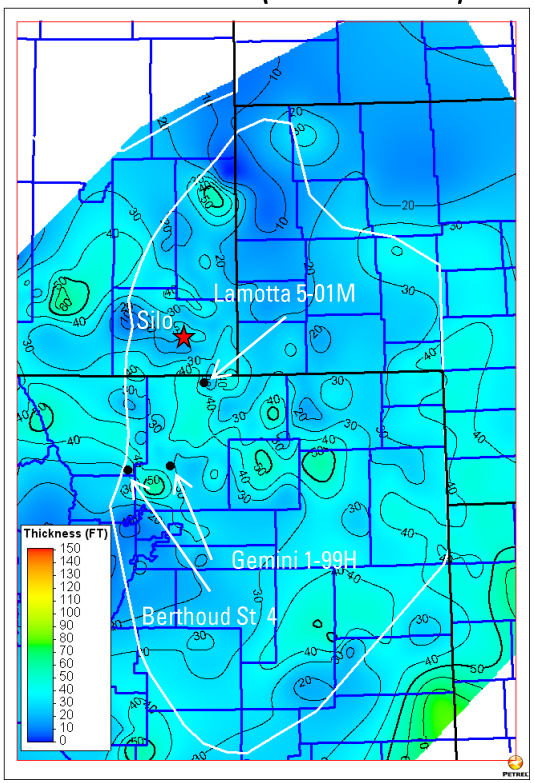
Storage Facies Distribution & Thickness



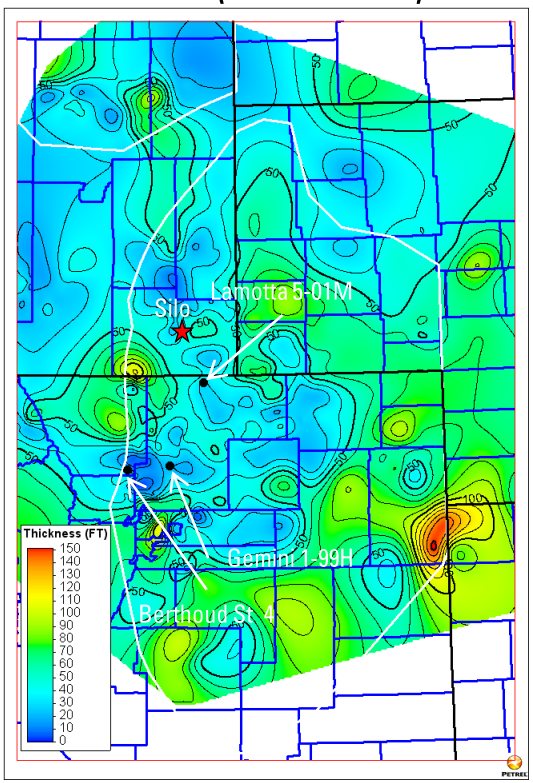
Basal Chalk N850-CDLL



N700 (C Bench)



N460 (B Bench)



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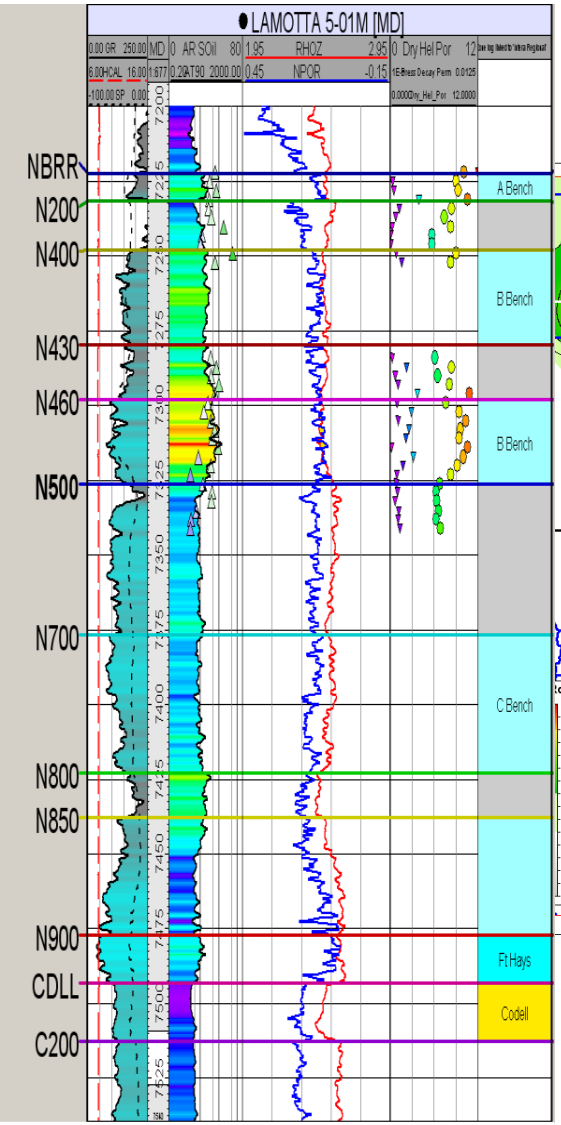
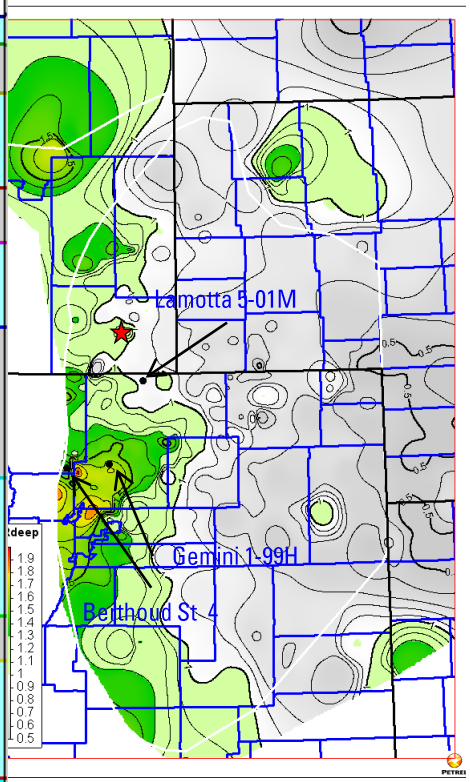
Saturation Proxy -- Log10(deep resistivity)



Basal Chalk N850-CDLL



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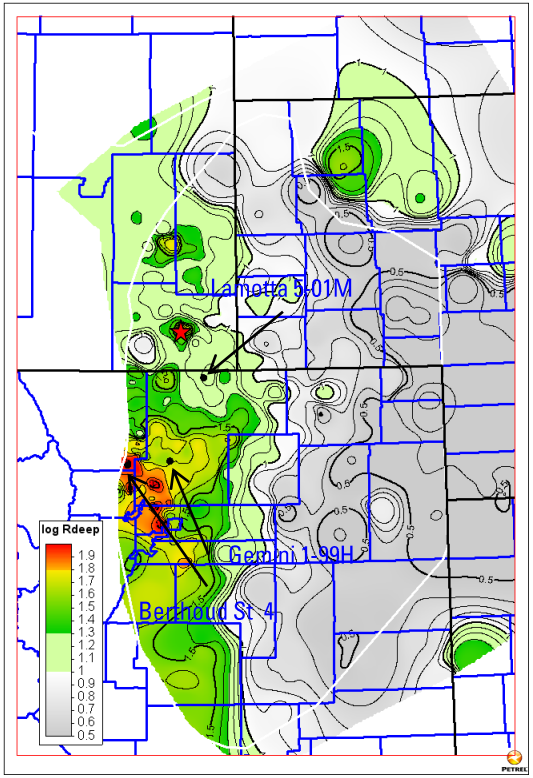

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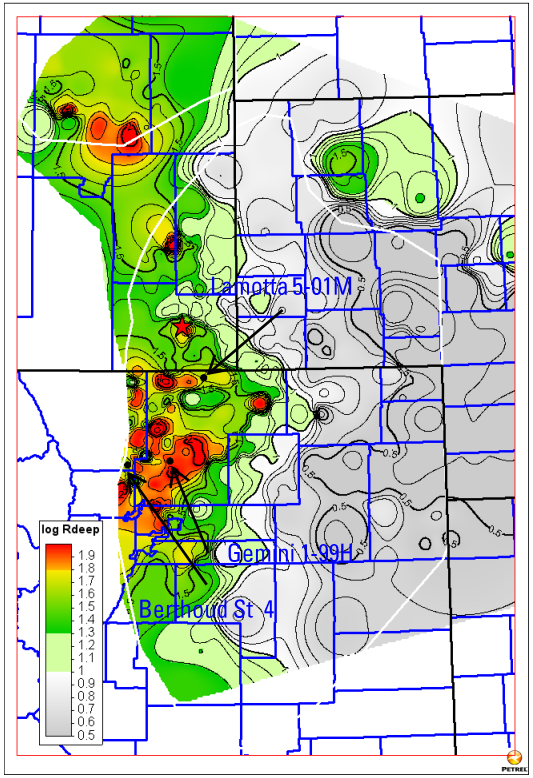

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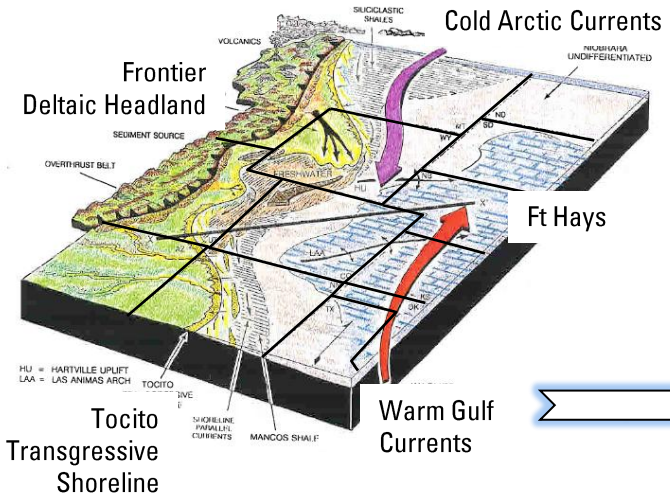
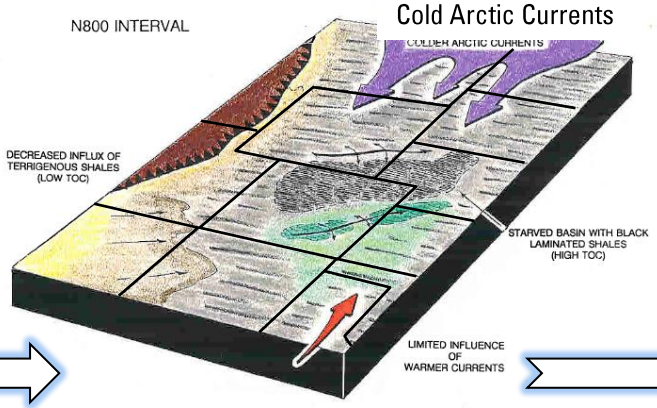
Depositional History

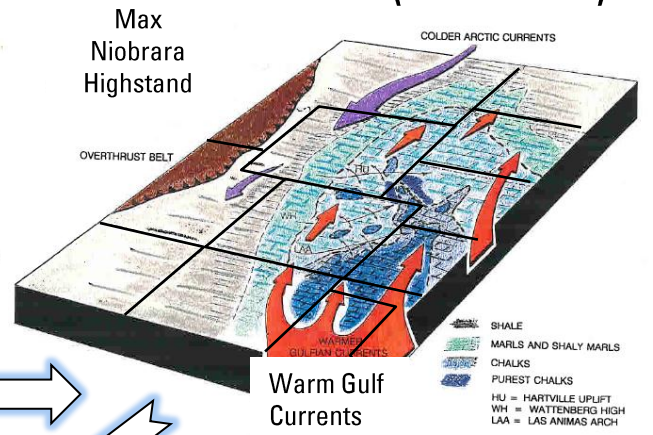
Juana Lopez-Ft Hays



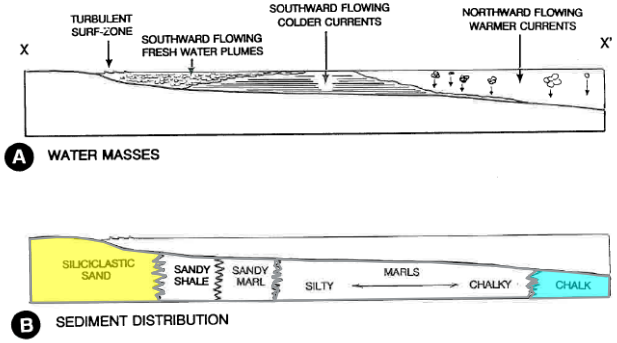
N800 (C Marl)



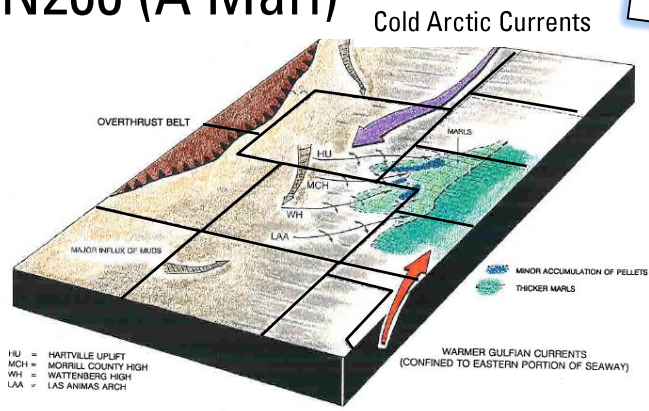
N400 (B Chalk)



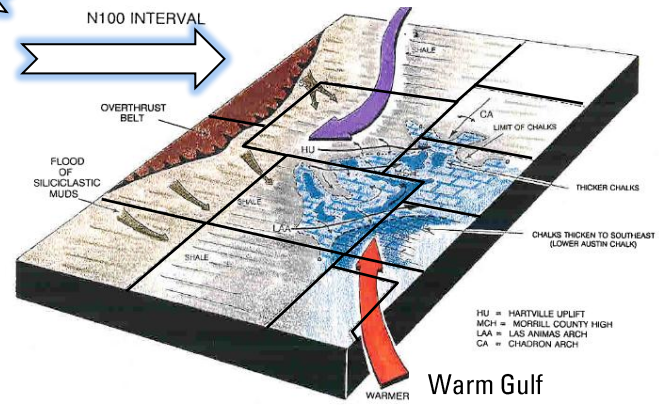
Warm Gulf Currents



N200 (A Marl)



N100 (A Chalk)



Warm Gulf Currents

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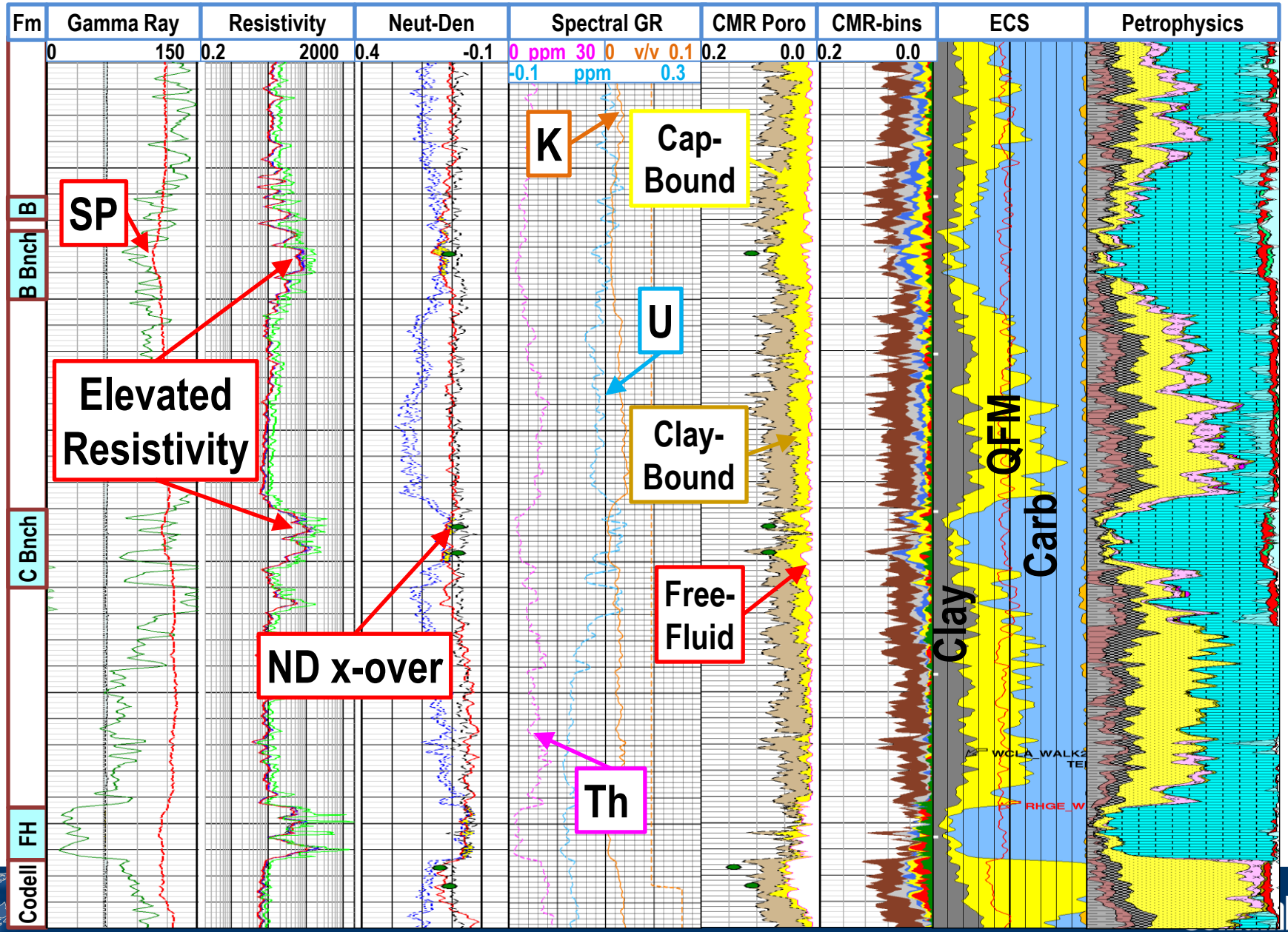
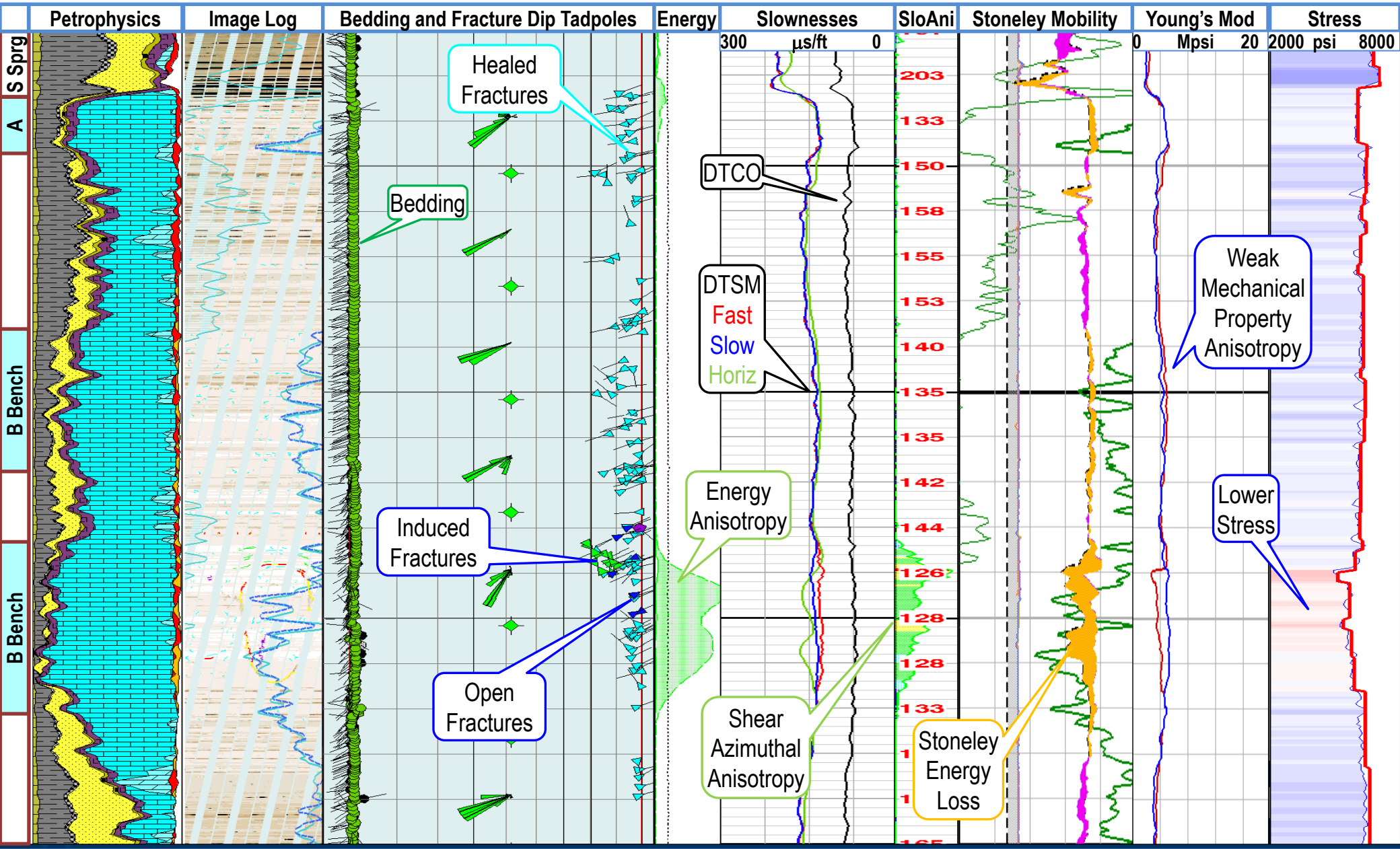
Petrophysical Evaluation—Porosity, Saturation, Lithology



Fracture and Stress Evaluation



	Niobrara (DJ Basin)	Bakken	Eagle Ford	3rd Bone Spring/Wolfcamp
Age	Upper Cretaceous	Mississippian-Devonian	Early Cretaceous	Permian (Leonardian – Wolfcampian)
Depth	5500' – 8500'	8500' – 11500'	5000'-11500'	4,000' - 11,100'
Thickness (net)[1]	~300' (~40')	75'-130' (40'-70')	140'-450' (250')	450' - 550' (250' - 300')
Prospective area[2]	14,000 sq miles	14,000 sq miles	56,000 sq miles	9,000 sq miles
Natural fractures	Locally abundant May be critical for success	Very localized Not essential for success	Present Not essential for success	Very localized Not essential for success
TOC weight %	2-4% Disseminated through Niobrara	10-12%+ in Upper/Lower Bakken	3-7%	2 - 9%
Total Porosity (FF)	8-10% (~2-3%)	5-10% (3-5%)	6-9%	4 - 16% (~3-8%)
Hydrocarbon Type	Oil to Condensate (32°-62°)	Oil (42°)	Oil (30-50°) to Dry Gas	Oil to Condensate
Pressure Gradient	0.41 – 0.67	0.50 – 0.70	0.40 – 0.70	0.43 - 0.60+
Well Cost[3]	$3.5 MM	$5-7 MM	$5.5-8.5 MM	Vertical: $3.7 - 4.3MM Horizontal: $8MM

[1]Gross thickness of Bakken and Niobrara intervals compared to net thickness of Middle Bakken and Niobrara "C" chalk
[2]Approximate area of mature source rock
[3]As reported in investor and market analyst reports

Acknowledgments

- Contributors to the original Niobrara Study
  - Susan Landon, Mark Longman, Steve Sturm, John Horne, Rory Wellings
  - Alan J. Scott
- The operators that supported the study
- Schlumberger Data & Consulting Services