#### Unconventional Oil Exploration in Wyoming Using Regional Chronostratigraphic Correlation\*

Ranie M. Lynds<sup>1</sup>, Joshua S. Slattery<sup>2</sup>, and Rachel N. Toner<sup>1</sup>

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#### **Abstract**

For more than a decade, the formal definition of an "unconventional" oil reservoir has proven elusive and variable, prompting adoption of a working definition throughout much of Wyoming: a reservoir in which production is improved through horizontal drilling and enhanced stimulation techniques. Practically speaking, Wyoming's unconventional oil reservoirs consist of horizontal wells with lengthy laterals and large multi-stage completions. Technically speaking, Wyoming's unconventional oil reservoirs are low permeability sandstones and siltstones that were deposited in marine to transitional marine settings of the Western Interior Foreland Basin (WIFB) during the Late Cretaceous and are now part of the Laramide Powder River and Denver basins. Seven of Wyoming's top ten oil-producing formations were deposited as part of the WIFB, and account for 59% of 2016 production. Reservoir facies are commonly highly bioturbated with pore space occlusion caused by clays and multi-phase porosity and permeability development. These reservoirs were produced historically with conventional vertical wells, yet recent unconventional exploration of these same reservoirs prompted a significant increase in production from each well drilled.

To assess potential correlative unconventional strata for equivalent depositional conditions, including time and environment of deposition, we correlated 25 Upper Cretaceous sections in Wyoming to U.S. Western Interior biostratigraphic zonation (molluscan, palynostratigraphic, and land vertebrate), radiometric age control, and polarity chrons. Results demonstrate that (1) second-order sea level cycle maximum flooding surfaces occur at approximately 10 to 18 Myr intervals, (2) the bulk of Wyoming's current unconventional oil production occurs as part of two different retrogradational transgressive sequence sets deposited in shallow marine environments during the upper Turonian and middle Campanian, which account for 29% and 9% of 2016 oil production, respectively, (3) the larger Niobrara play is part of the Coniacian to Santonian highstand sequence set, with 5% of 2016 oil production, and (4) exploration of unconventional plays in other basins may benefit from consideration of the regional chrono-stratigraphic setting. This correlation provides a statewide baseline for future assessment of Laramide basin-specific hydrocarbon systems.

#### **References Cited**

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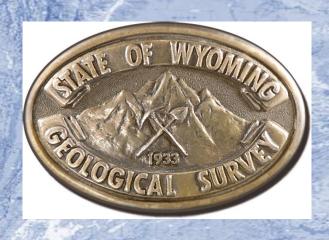
<sup>\*\*</sup>Datapages © 2018 Serial rights given by author. For all other rights contact author directly. DOI:10.1306/80655Lynds2018

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Slattery, J.S., W.A. Cobban, K.C. McKinney, P.J. Harries, and A.L. Sandness, 2015, Early Cretaceous to Paleocene Paleogeography of the Western Interior Seaway: The Interaction of Eustasy and Tectonism: Wyoming Geological Association Guidebook, p. 22-60.

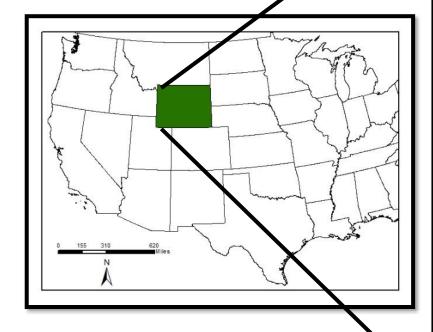
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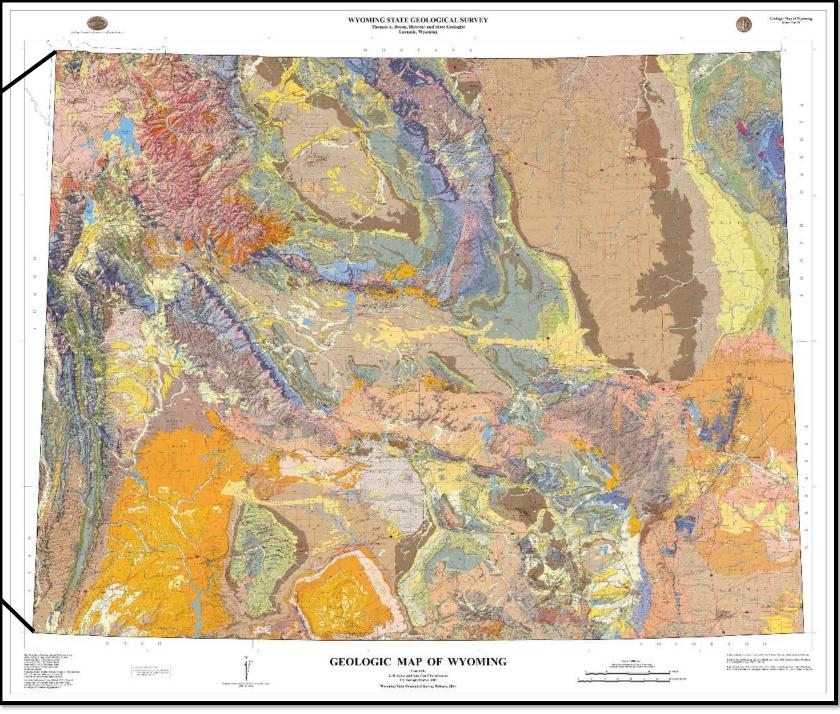
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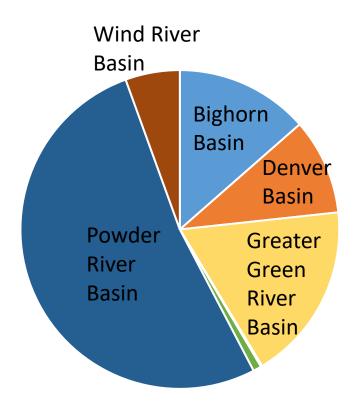




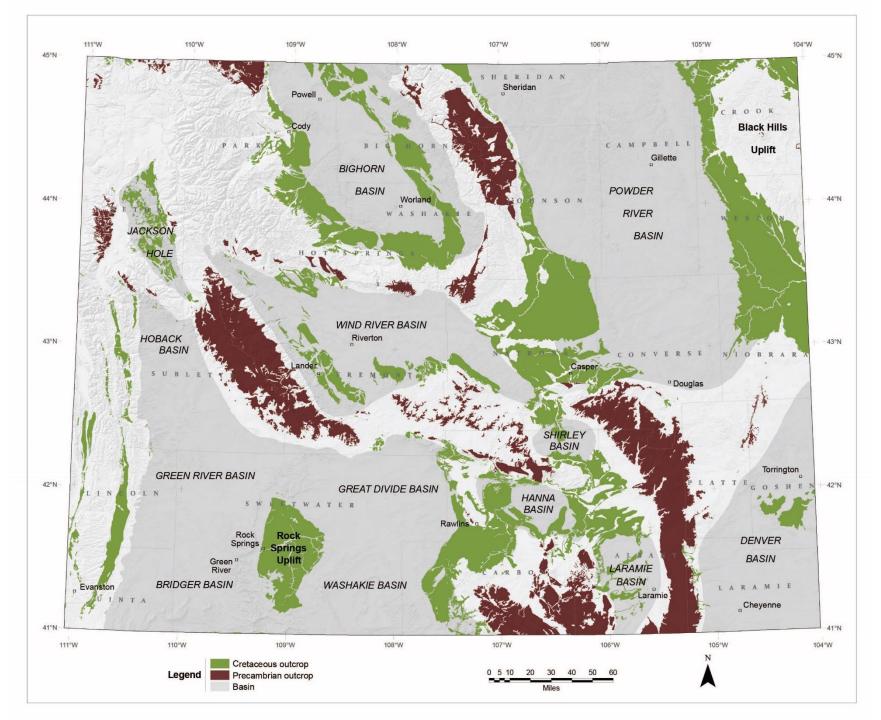
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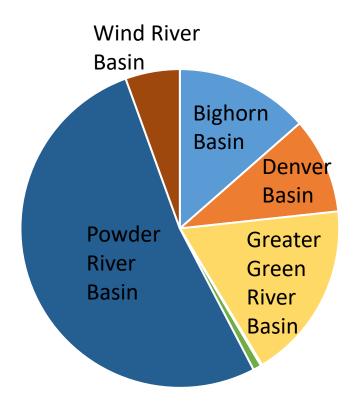




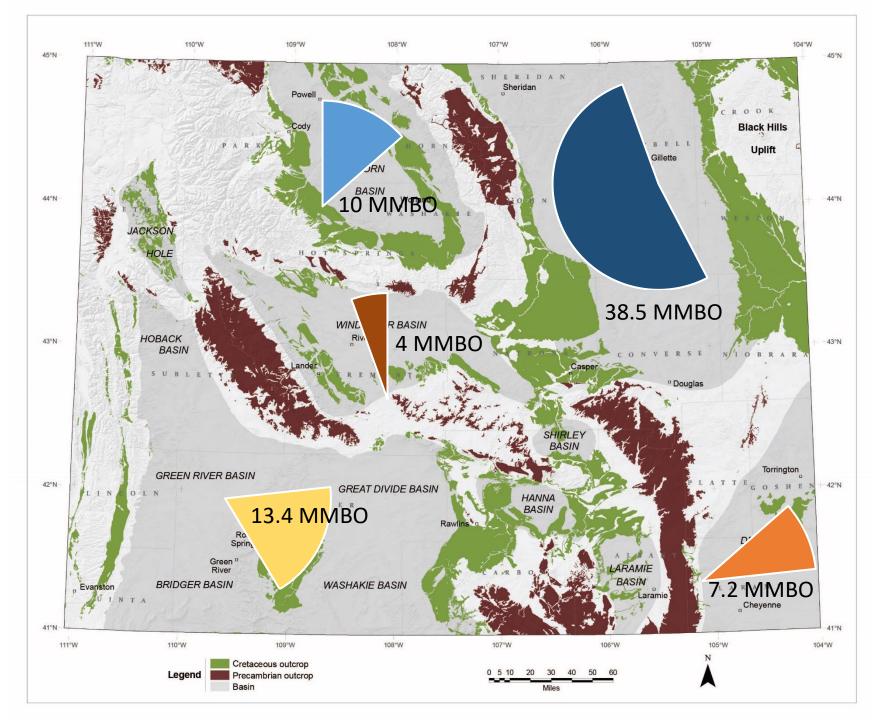


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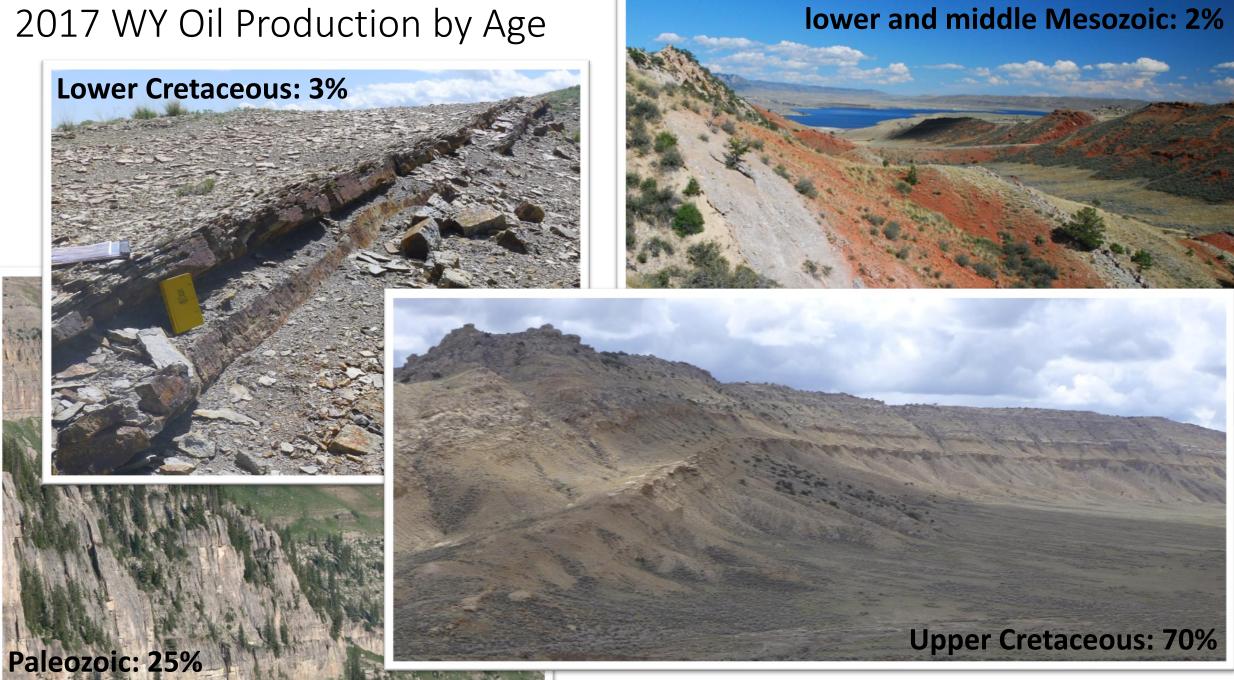












# Wyoming Unconventionals

a.k.a. tight sand and siltstones



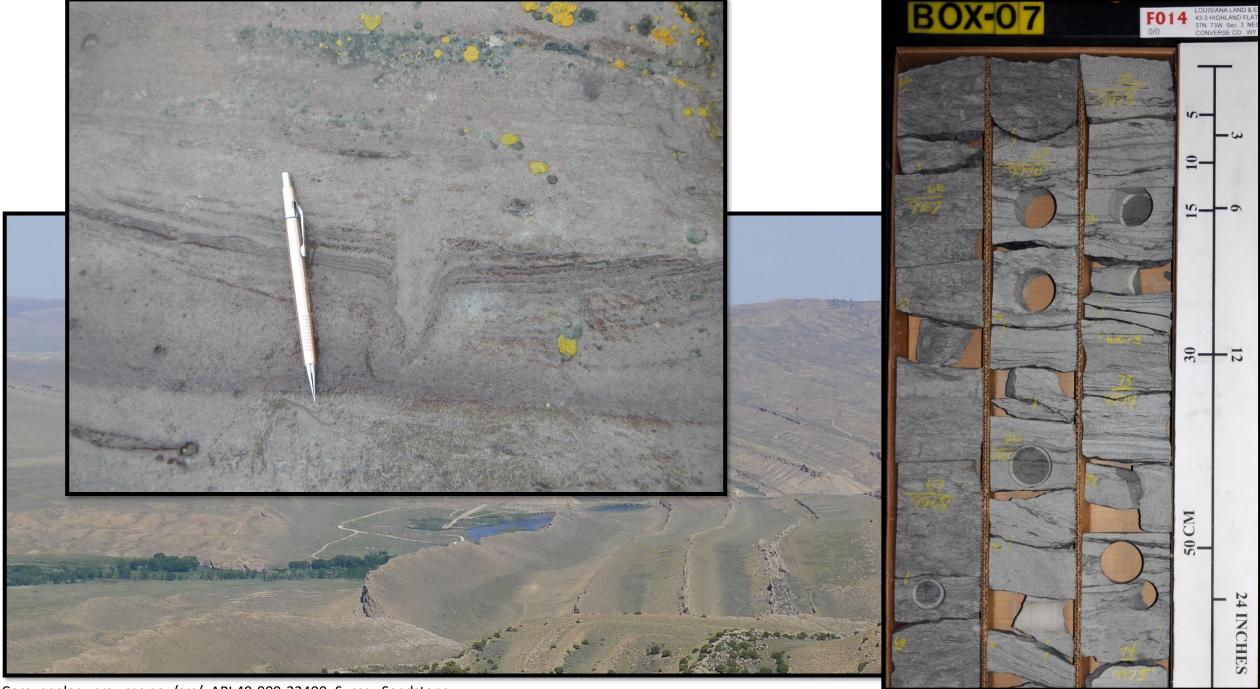
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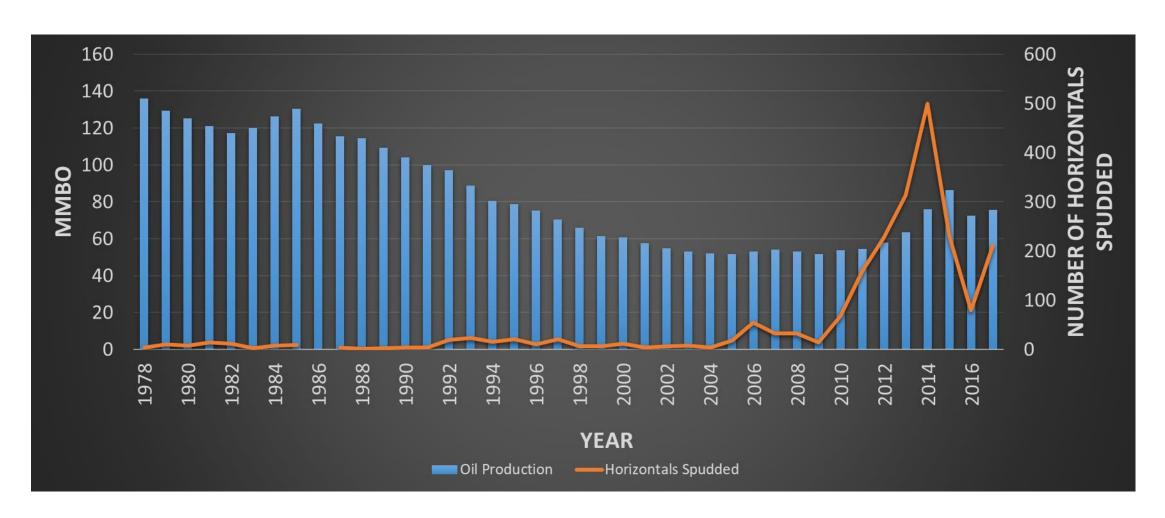


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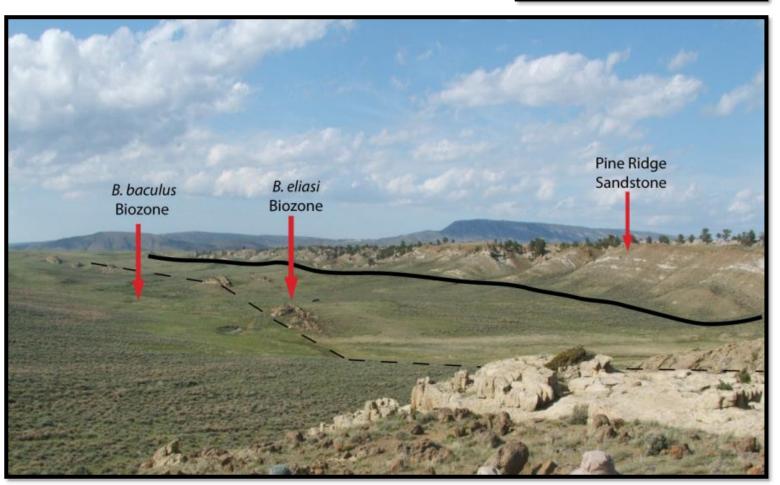


# Western Interior Seaway (WIS) Paleogeography

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# WIS Chronostratigraphy

- Lithostratigraphy
- Biostratigraphy
- Radiometric dates
- Magnetostratigraphy



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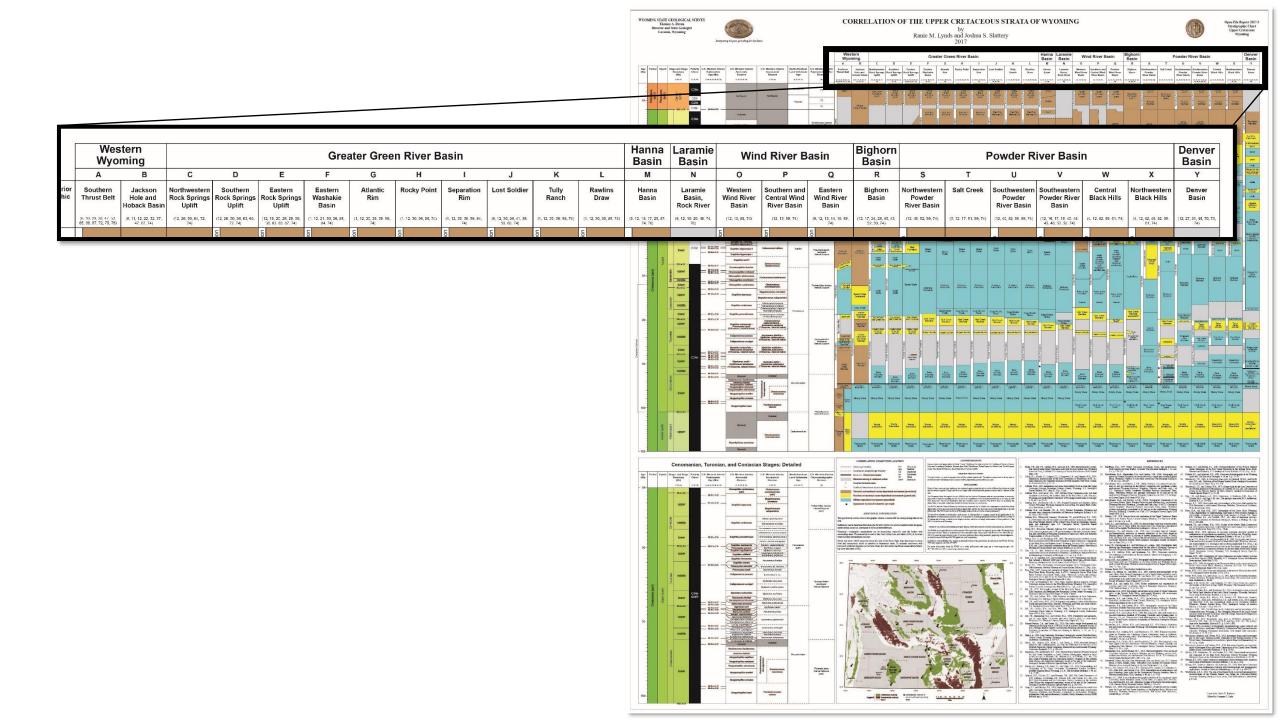
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by
Ranie M. Lynds and Joshua S. Slattery



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WYOMING STATE GEOLOGICAL SURVEY Thomas A. Dream Director and State Golegist Lavante, Wyoming



#### CORRELATION OF THE UPPER CRETACEOUS STRATA OF WYOMING

by Ranie M. Lynds and Joshua S. Slattery



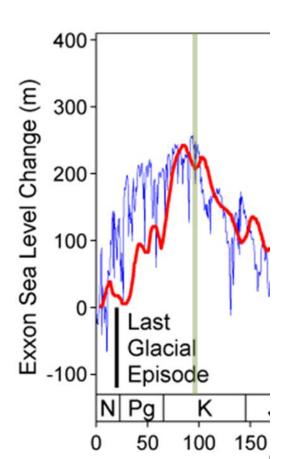
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9:	-			upper		94.10 ± 0.27 ————————————————————————————————————	Nigericeras scotti Neocardicoeras juddii Burroceras cydense Eumph. septemseriatum Vascoceras dieritanum Dunveganoceras albertense	Mytiloides hattini Inoceramus pictus Inoceramus ginterensis			Cence	omanian. Tur	Pastylina rasins (hand		1.00   1.00
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#### **Early Cenomanian**

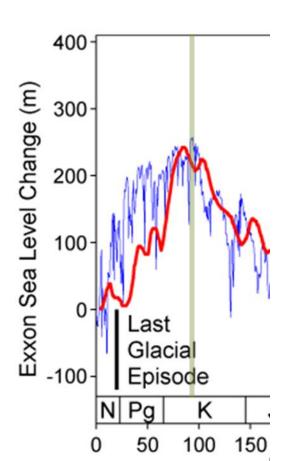
- Loss of connection between Gulf of Mexico and Arctic ocean
- Mowry Seaway





#### **Late Cenomanian**

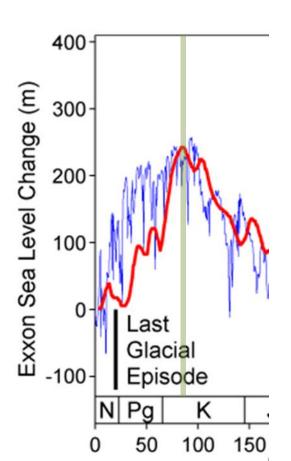
- Full connection between Gulf of Mexico and Arctic Ocean
- Greenhorn Seaway





#### **Middle Coniacian**

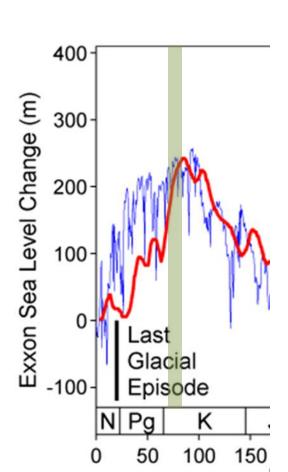
- Continued connection between Gulf of Mexico and Arctic Ocean
- Niobrara high stand





#### **Middle Campanian**

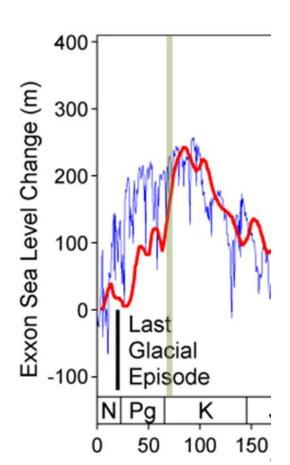
- Narrowing of WIS
- Mesaverde progradational regression





#### **Early Maastrichtian**

- Major eastward shift of shoreline
- Drop in eustatic sea level and onset of Laramide Orogeny
- Late Pierre (Lewis) Seaway





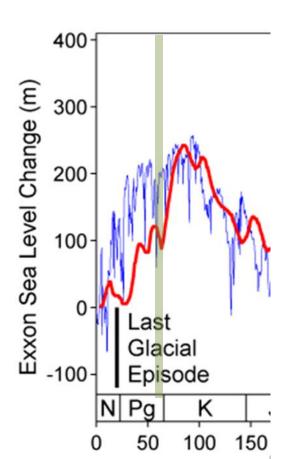


Retreat of the WIS

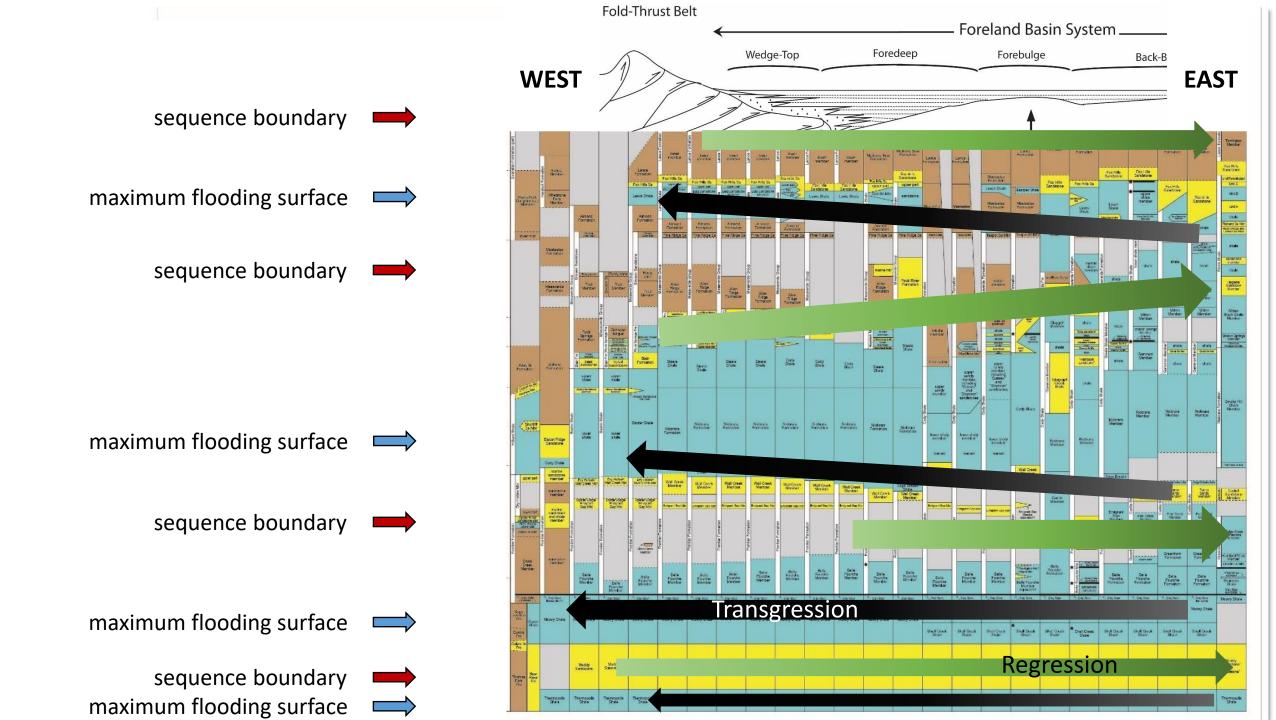
• Cannonball Formation in Dakotas

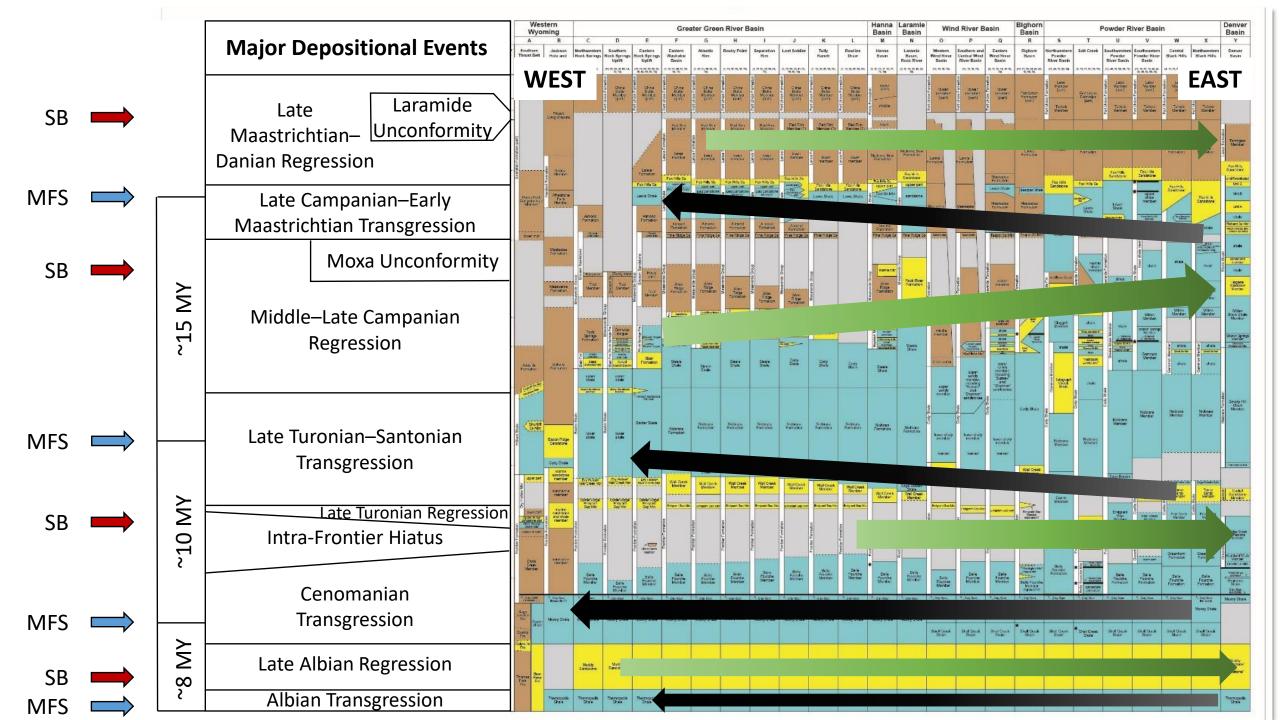
 Ferris and Fort Union formations in Wyoming

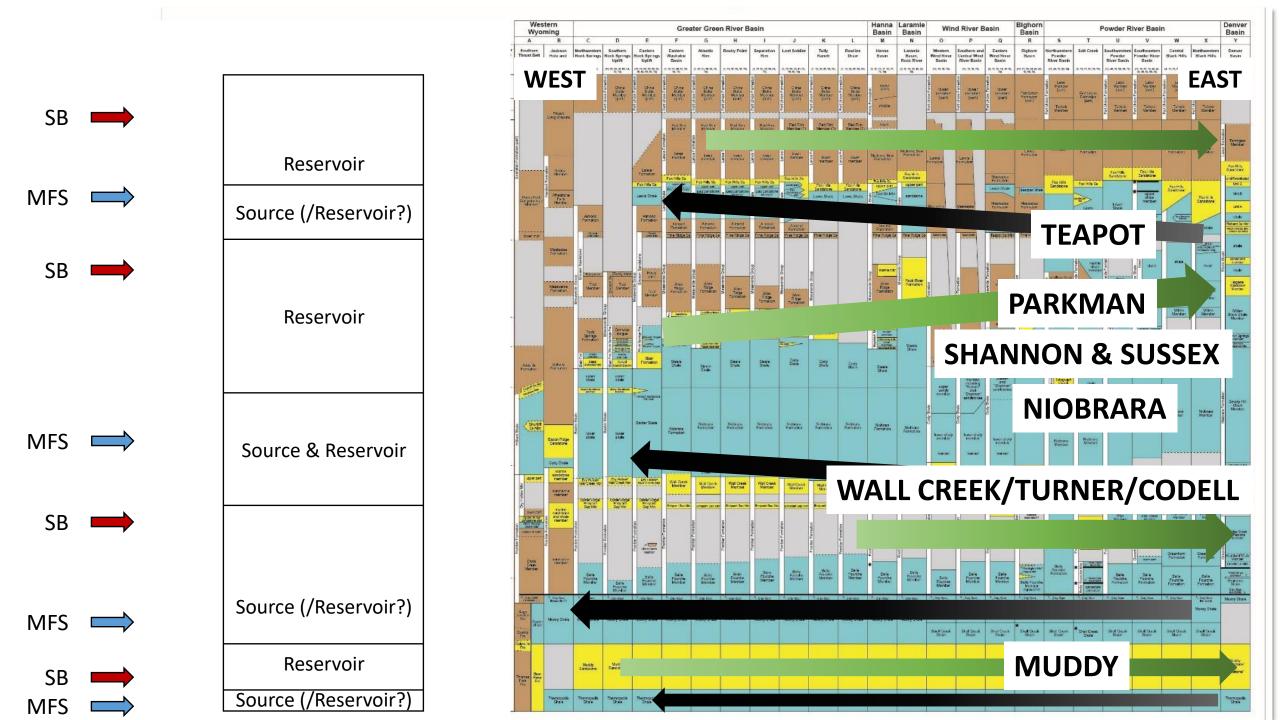
Peace Garden Member in Alberta

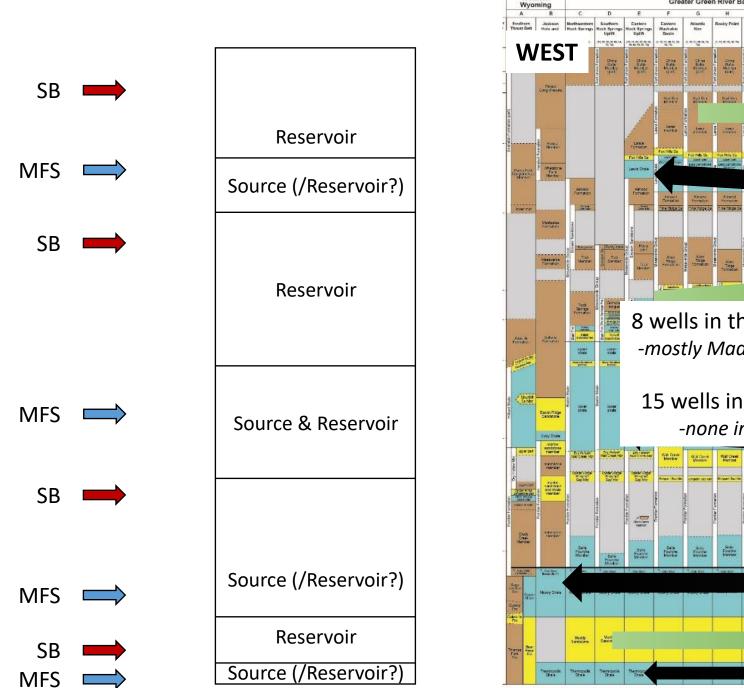


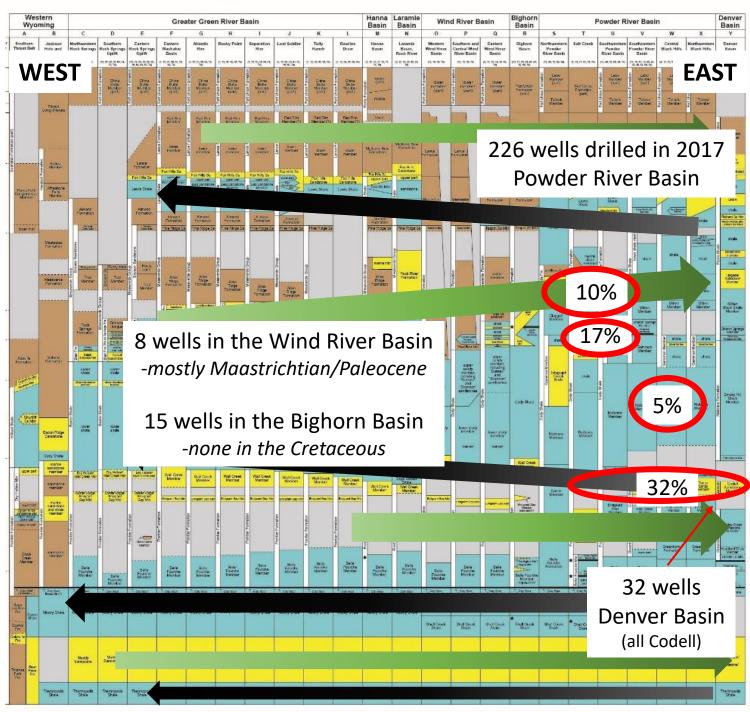


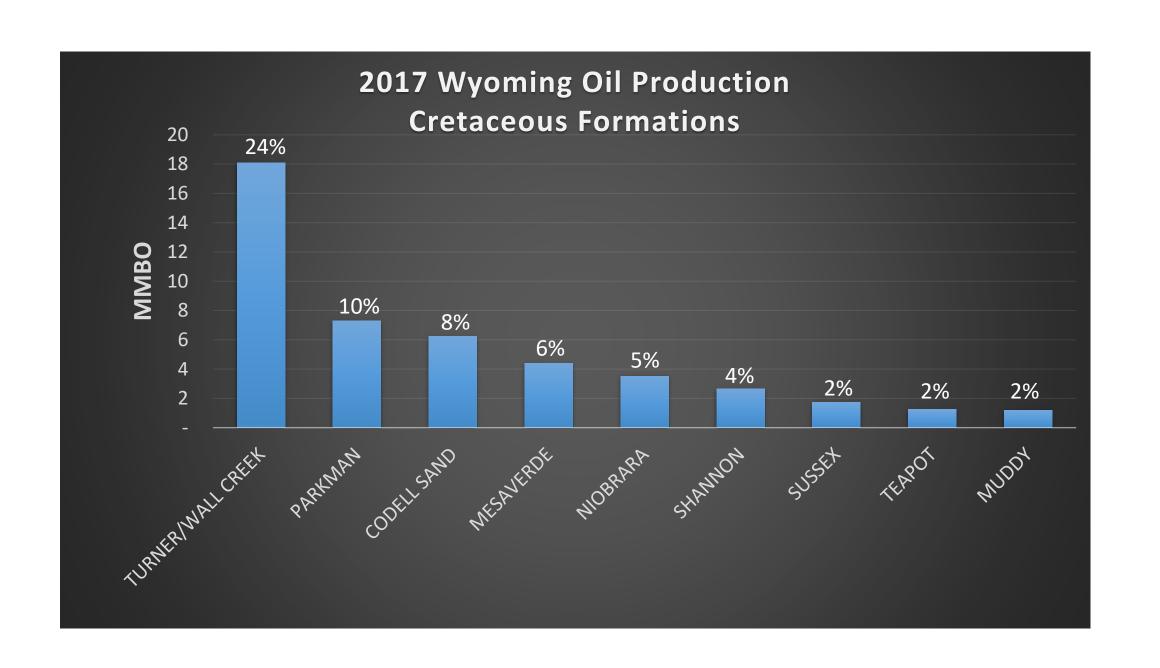










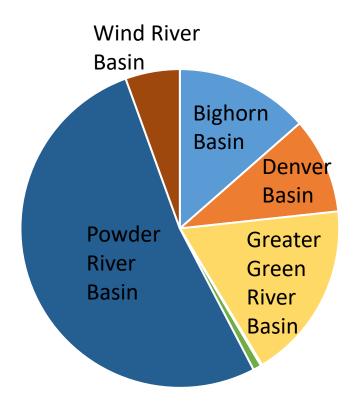


### Conclusions

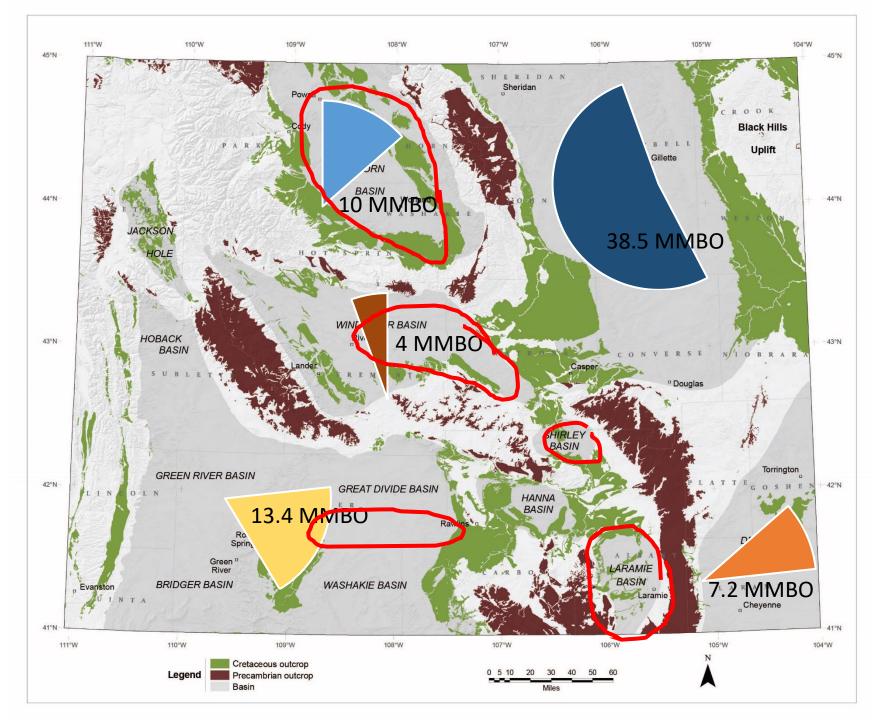
- During the Late Cretaceous in Wyoming, 2<sup>nd</sup>-order sea level fluctuations occurred on 8 to 15 MY intervals.
- Organic-rich source rocks were deposited during all high stands of the WIS.
  - The Niobrara Formation is part of the Coniacian—Santonian high stand and is both a source and reservoir, with 5% of Wyoming's 2017 oil production.
- Transgression during the late Turonian resulted in a retrogradational reservoir package of the Wall Creek/Turner/Codell, with 32% of Wyoming oil production in 2017.
- The middle Campanian narrowing of the WIS left the progradational/aggradational Mesaverde (Parkman) reservoir, with 10% of Wyoming's 2017 oil production.

# Conclusions, cont.

- The eight Upper Cretaceous formations with the most production were responsible for approximately 60% of oil recovered in Wyoming in 2017, or 45 MMBO.
- Exploration of unconventional plays in other basins may benefit from consideration of the regional chrono-stratigraphic setting.



2017 WY Oil Production 73.9 MMBO



# Many Thanks

- Biostratigraphy: W. Cobban, J. Gill, and E. Merewether
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   H. Roehler
- Radiometric Ages: J. Ogg, L. Hinnov, M. Schmitz, and B. Sageman et al.
- USGS Mesozoic Invertebrate Database
- Chart reviews by M. Kirschbaum, R. Raynolds, R. Scott, D. Sawyer, J. Fox, A. Wroblewski, and D. Boyd
- And many, many others...

