Sequence-Stratigraphic and Depositional Framework of the Middle Bakken Formation, Williston Basin, North Dakota*

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Abstract

The Devonian-Mississippian Bakken Formation located in the Williston Basin, North Dakota is a significant oil reservoir with a complex depositional history. The Bakken Formation is composed of three members: (1) mudrock of the lower member; (2) dolomitic silty sandstone of the middle member; and (3) mudrock of the upper member. This study provides a high-resolution sequence-stratigraphic and depositional framework to explain the distribution of facies within the middle Bakken Formation. A total of 37 cores were evaluated in detail over an area of approximately 400 mi^2 (644 km^2). Core descriptions were paired with petrophysical logs to provide lateral correlations between core locations.

The middle Bakken Formation is composed of 11 facies indicative of a tidally-influenced-shallow-marine system. It is divided into three packages (lower, middle, and upper) based on facies and their stacking patterns. The lower package is composed of shallowing-upward offshore to transitional marine facies. The middle package is composed of subtidal ooid facies, and the upper package is composed of fining-upward tidally-influenced facies. Sequence-stratigraphic analysis is used to divide the entire Bakken Formation (lower, middle, and upper members) into five systems tracts: (1) a highstand systems tract of the lower member; (2) two lowstand systems tracts within the lower and middle packages; (3) a transgressive systems tract of the upper middle package; and (4) a highstand systems tract of the upper member. Two sequence boundaries are present: (1) between the lower and middle members; and (2) between the lower and middle packages of the middle Bakken Formation.

Facies-distribution maps within a sequence-stratigraphic context show a stratigraphic pinch-out to the east in the study area, and provides a link to reservoir productivity. The sequence-stratigraphic framework proposed provides a predictive component helpful in determining play elements within the hydrocarbon system, including reservoir size, location, and quality.

References

Hayes, M. D., 1985, Conodonts of the Bakken Formation (Devonian and Mississippian), Williston Basin, North Dakota: The Mountain Geologist, RMAG, v.22, p. 64-77.

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Sonnenberg, S.A., and A. Pramudito, 2009, Petroleum geology of the giant Elm Coulee Field, Williston Basin: AAPG Bulletin, v. 93/9, p. 1127-1153.

Website

Blakey, R., Colorado Plateau Geosystems, Inc. Reconstructing the Ancient EARTH: Web accessed 1 August 2012. http://cpgeosystems.com/index.html

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April 23, 2012

Marathon Oil Corporation

Outline

1. Introduction
2. Core Description
3. Sequence Stratigraphic Interpretation
4. Facies Distribution Maps
5. Application
6. Conclusions

Introduction

- Two Sequences which reflect a clastic/carbonate transition.
  1. Dolomite-dominated siltstone
  2. Calcite-dominated ooid grainstone

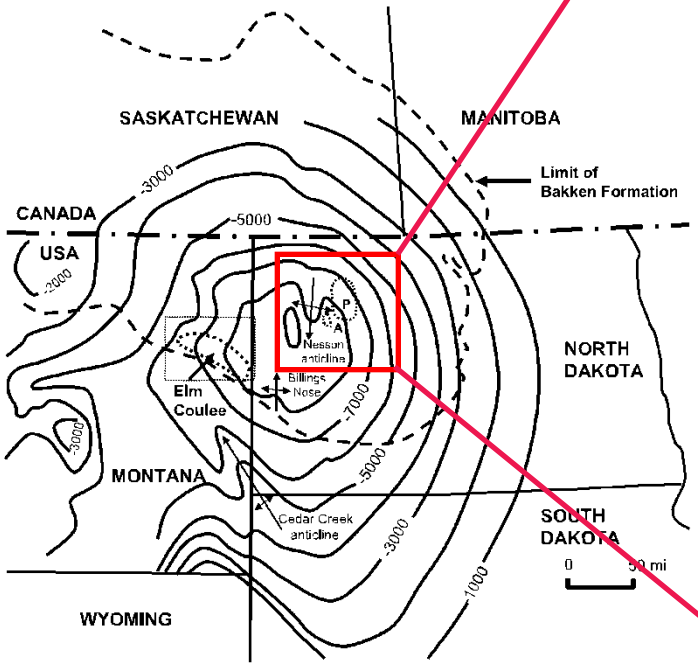
- The depositional and sequence stratigraphic framework is tied to reservoir characterization, production, and petroleum system play elements

- Database:
  1. 40 cores with full well log suites (13 described in detail ~2,700ft [823.2 m])

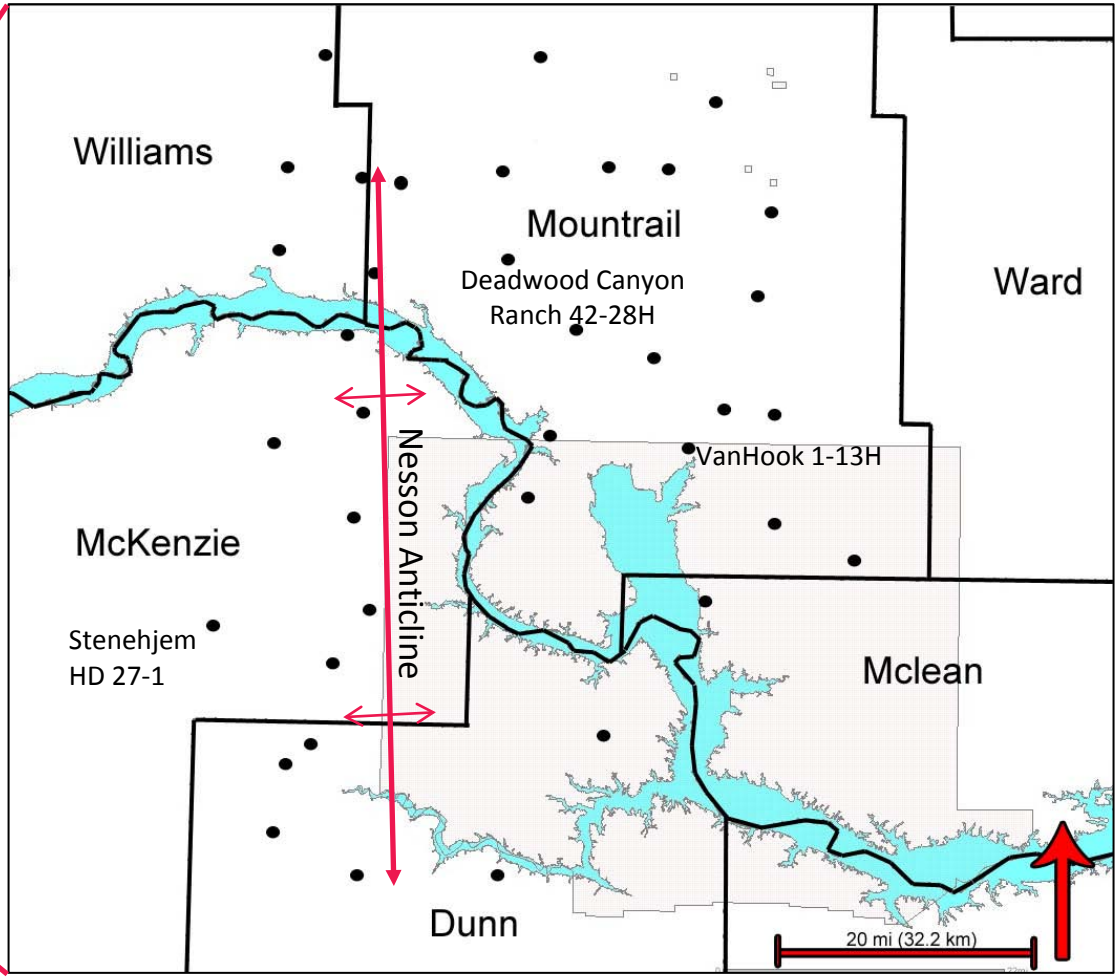
Questions

- Facies of the Middle Bakken?
- Facies distribution in the Middle Bakken?
- Sequence stratigraphy of the Middle Bakken?
- Application?

Scope/Area of Interest

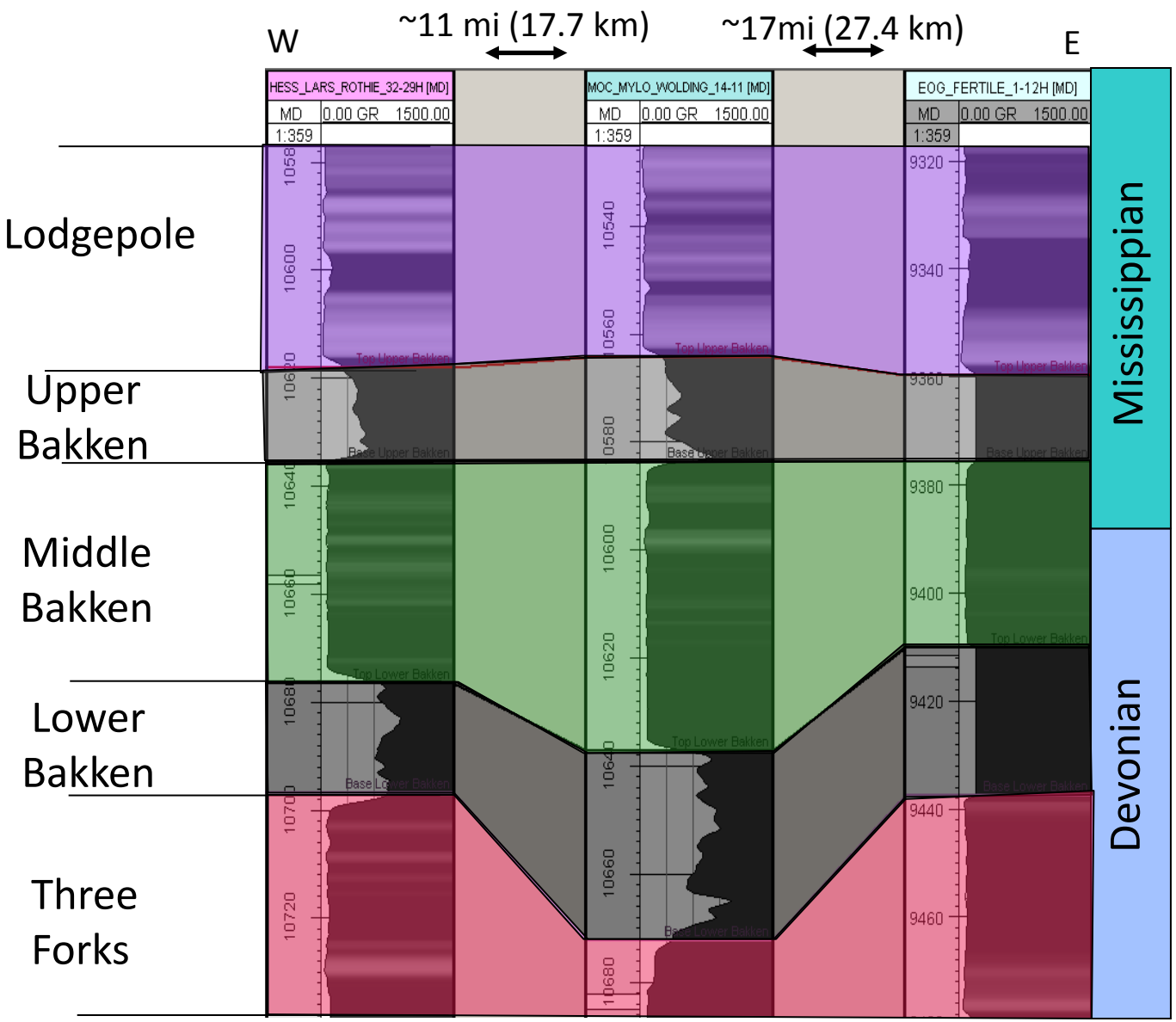


Structure contour map on base of Mississippian
Sonnenberg and Pramudito, 2009



- Wells

Stratigraphic Interval



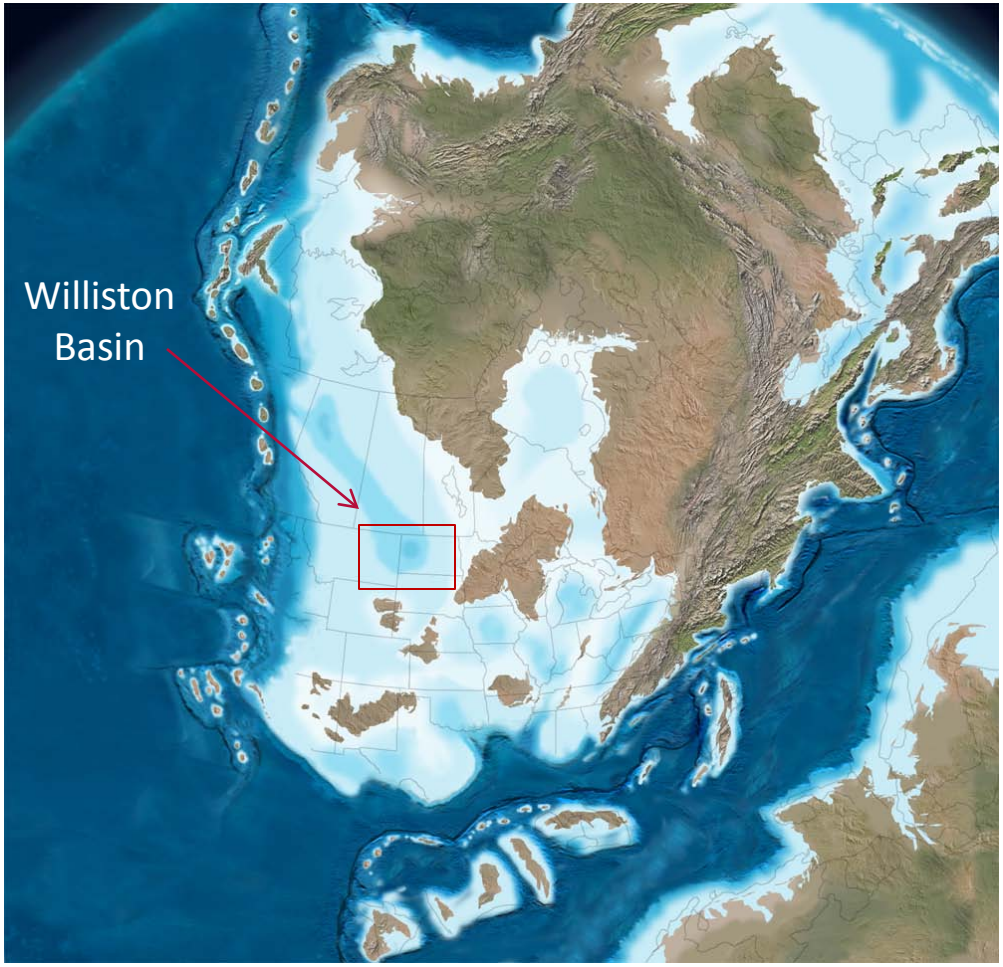
Datum: Base of Upper Bakken

~25-30 ft (7.6-9.1 m) avg. thickness

Ages based on Conodont biostratigraphy (Hayes, 1985)

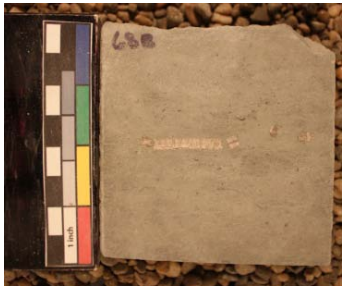
Paleogeography

- Marine depositional environment
- Devonian/Mississippian time frame
- Arid climate: within 5-10 degrees of the equator
- Carbonate/clastic mixed system
- Sediment starved –wind blown sand
- Stable tectonic setting
- Low gradient slope

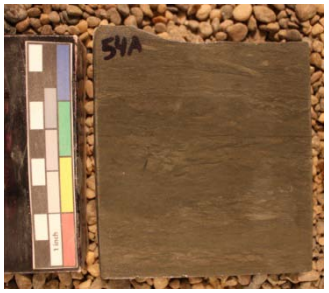


Blakey, 2012. Generalized Late Devonian Paleogeography

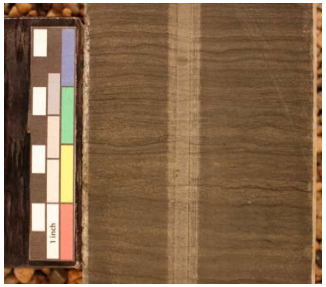
Clastic Facies

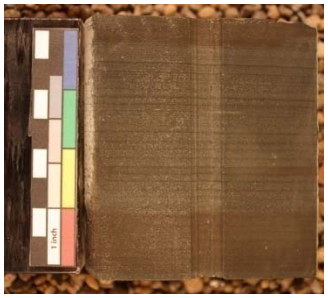


Heavily Bioturbated Structureless



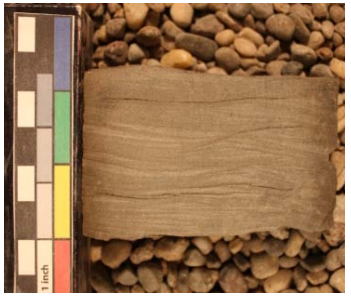
Moderately Bioturbated Structureless



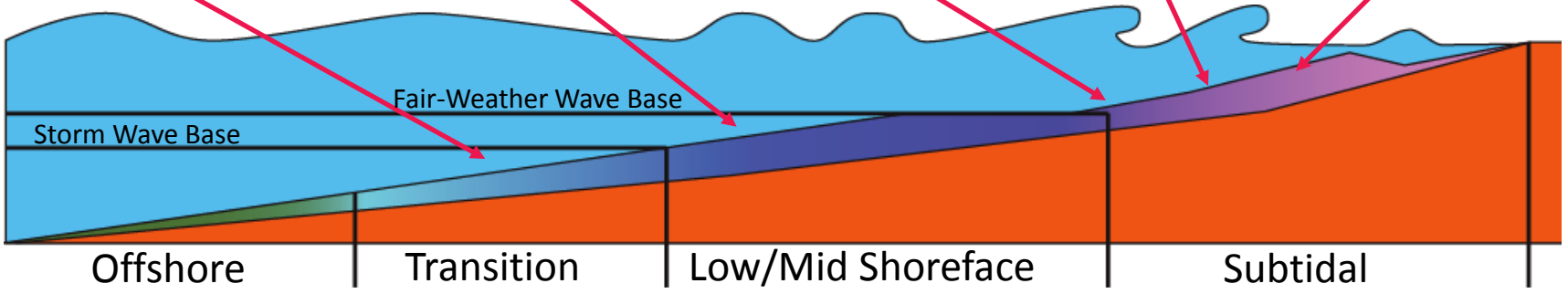


"Crinkle" Laminated

Parallel Laminated



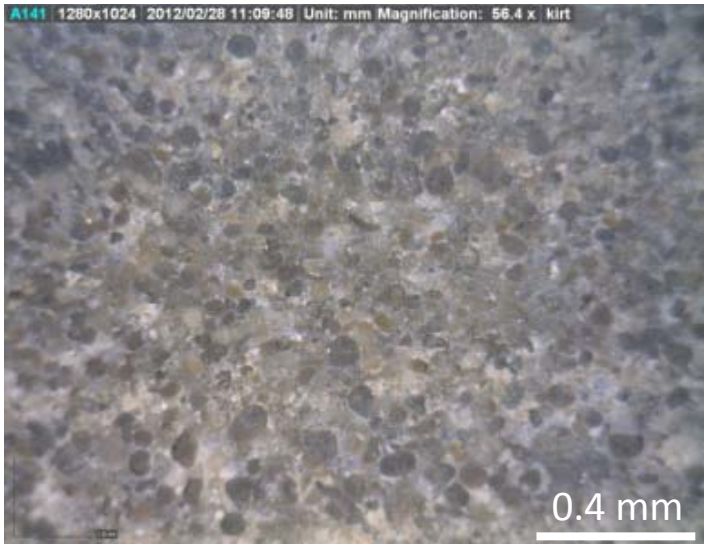
Combined-Flow Ripples



Bioturbation decrease

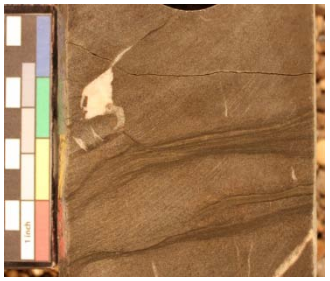
Energy Increase

Carbonate Facies

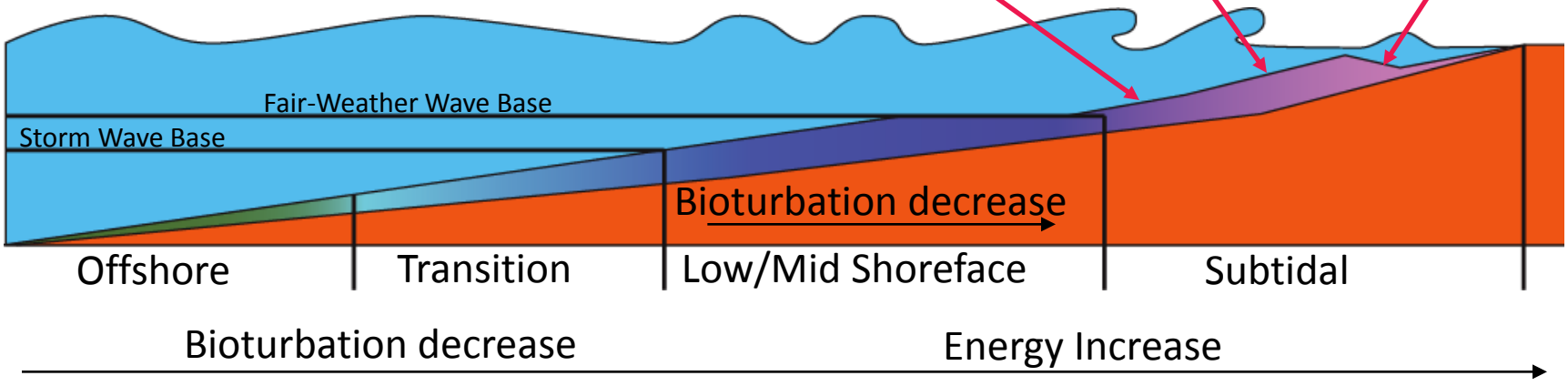


Int. Ripples and Bioclastic Debris

Cross-Laminated Ooid Grainstone



Convoluted Ooid Grainstone

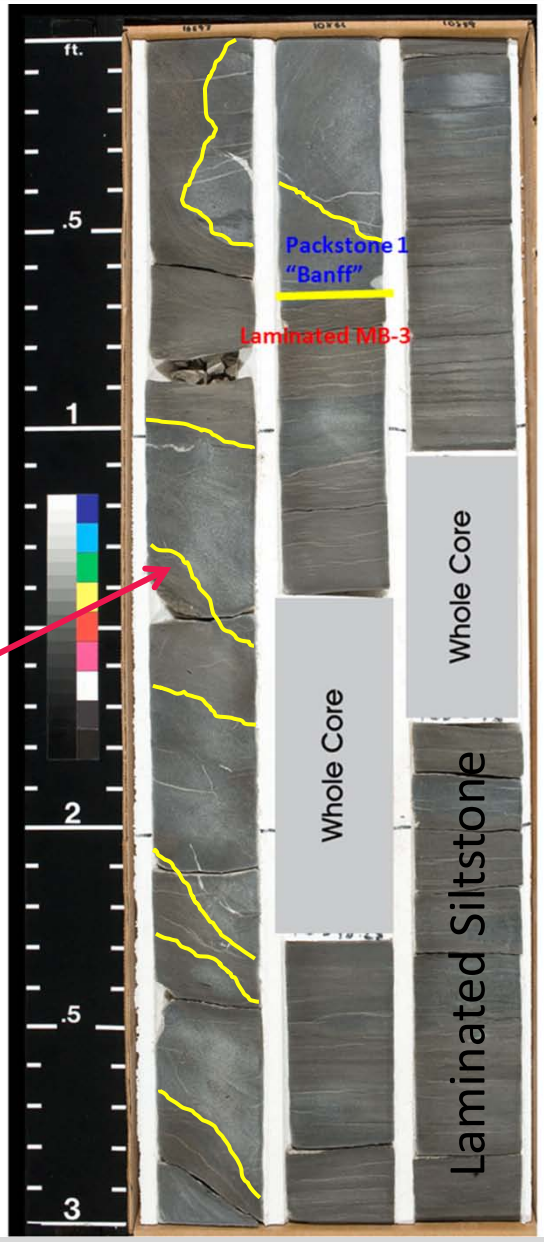


Depositional Contacts

Abrupt facies change
At base of Middle Bakken
Below: Lower Bakken
Pyritic Mudstone
Above: Poorly Sorted
Wackestone/Bioturbated
Dolomitic Siltstone

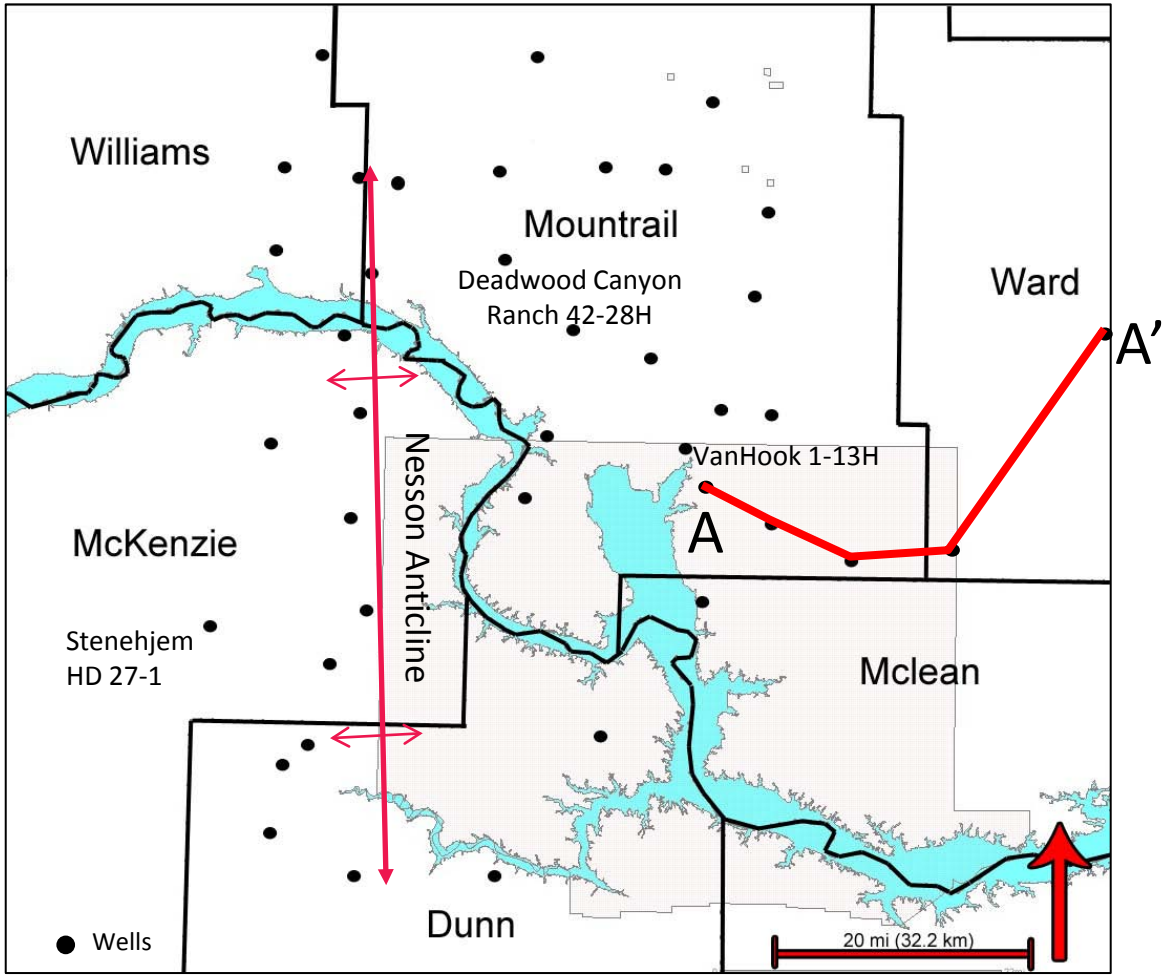
Irregular,
Convoluted Contact
Below: Laminated Dolomitic
Siltstone
Above: Convoluted Ooid
Grainstone

CT Scan

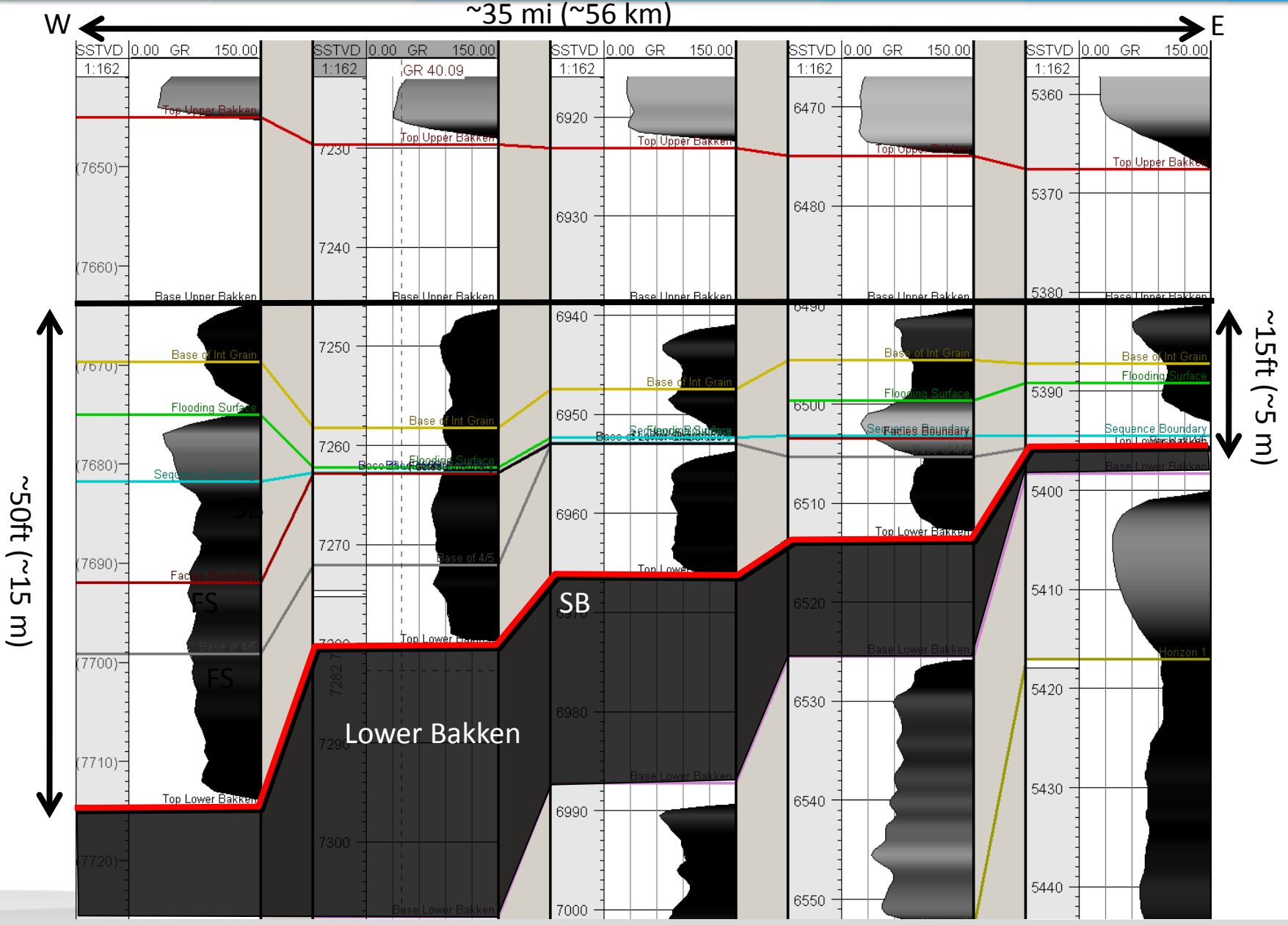


Core Photo

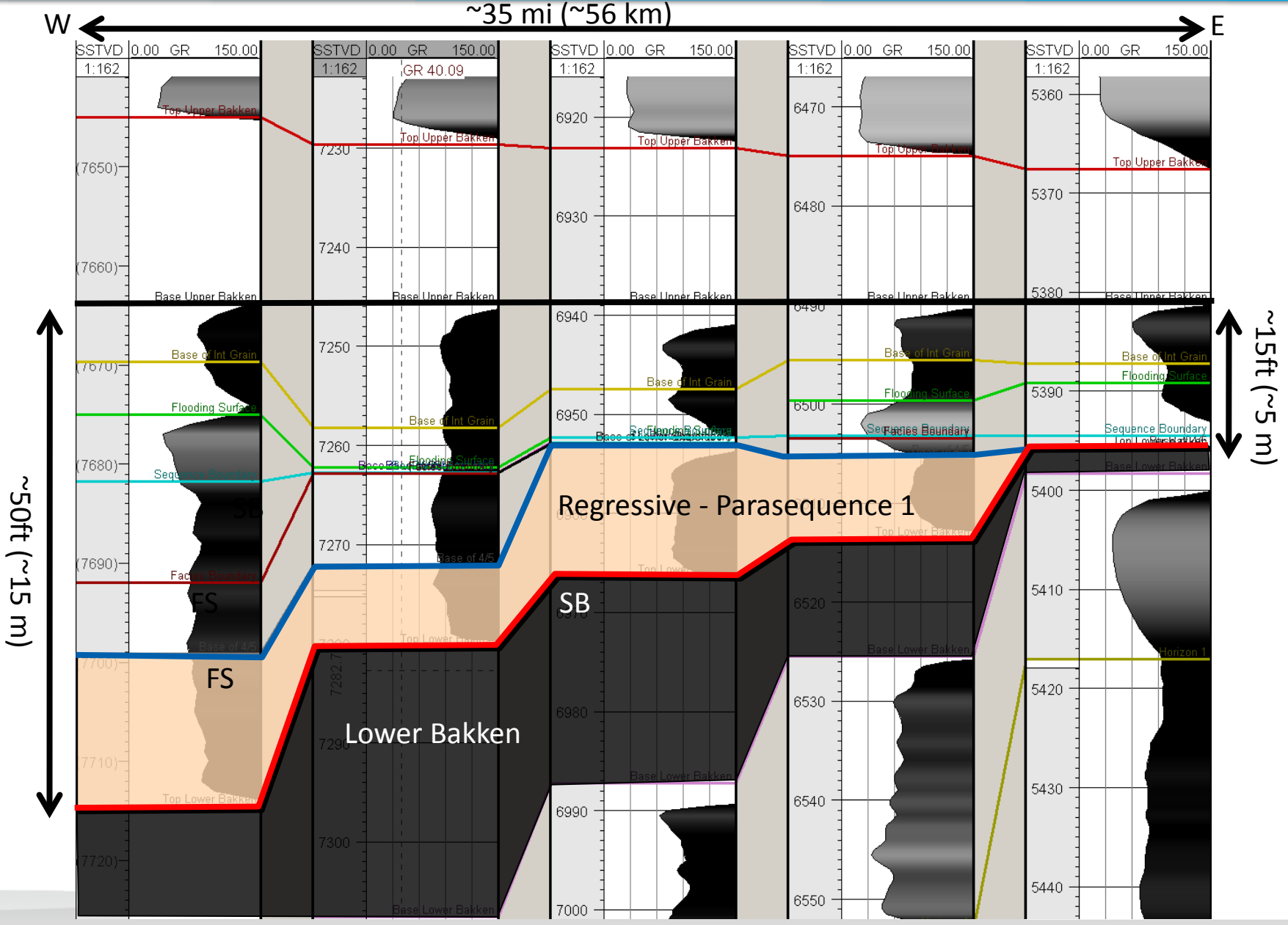
Sequence Stratigraphy



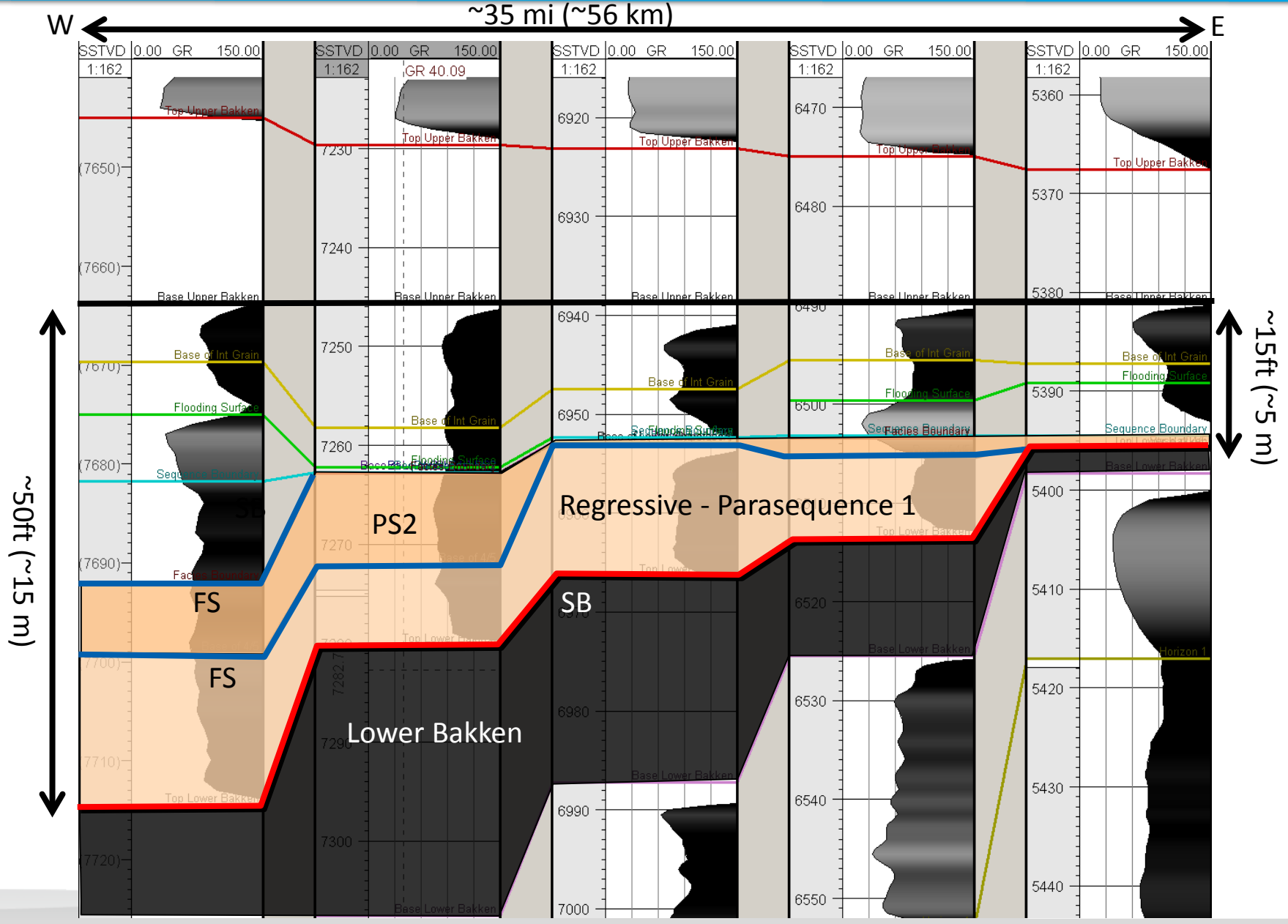
Sequence Stratigraphy



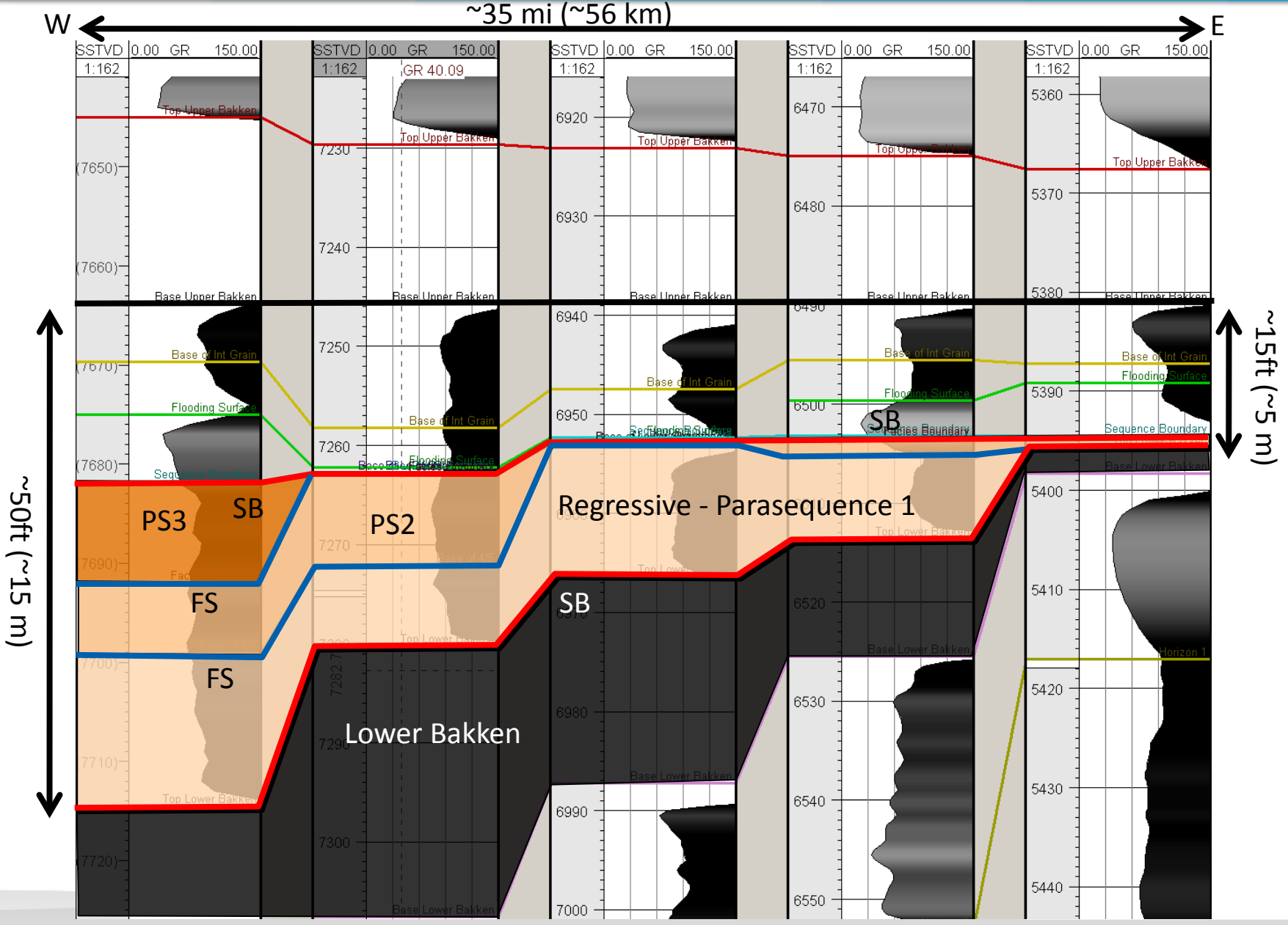
Sequence Stratigraphy



Sequence Stratigraphy



Sequence Stratigraphy



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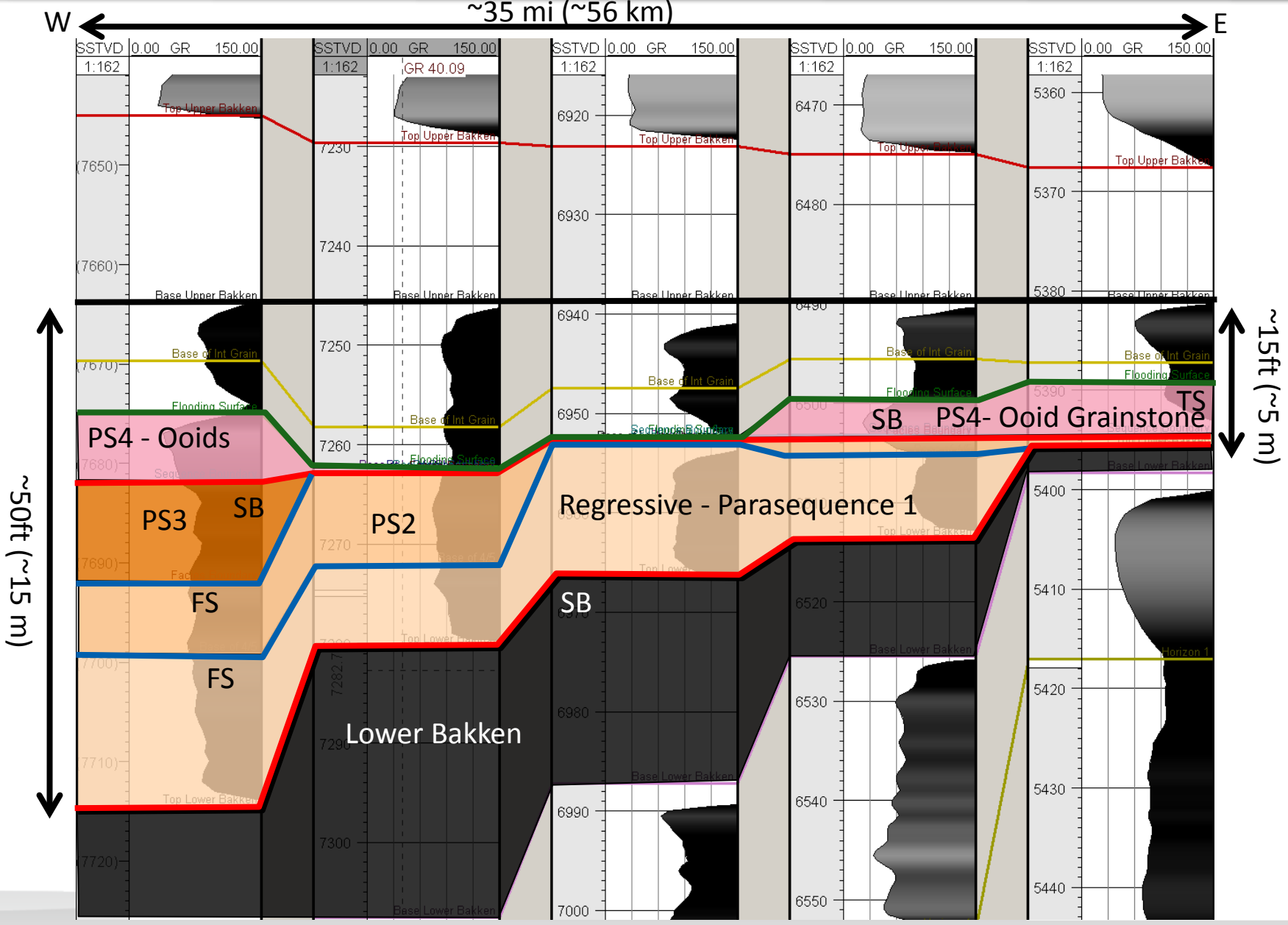
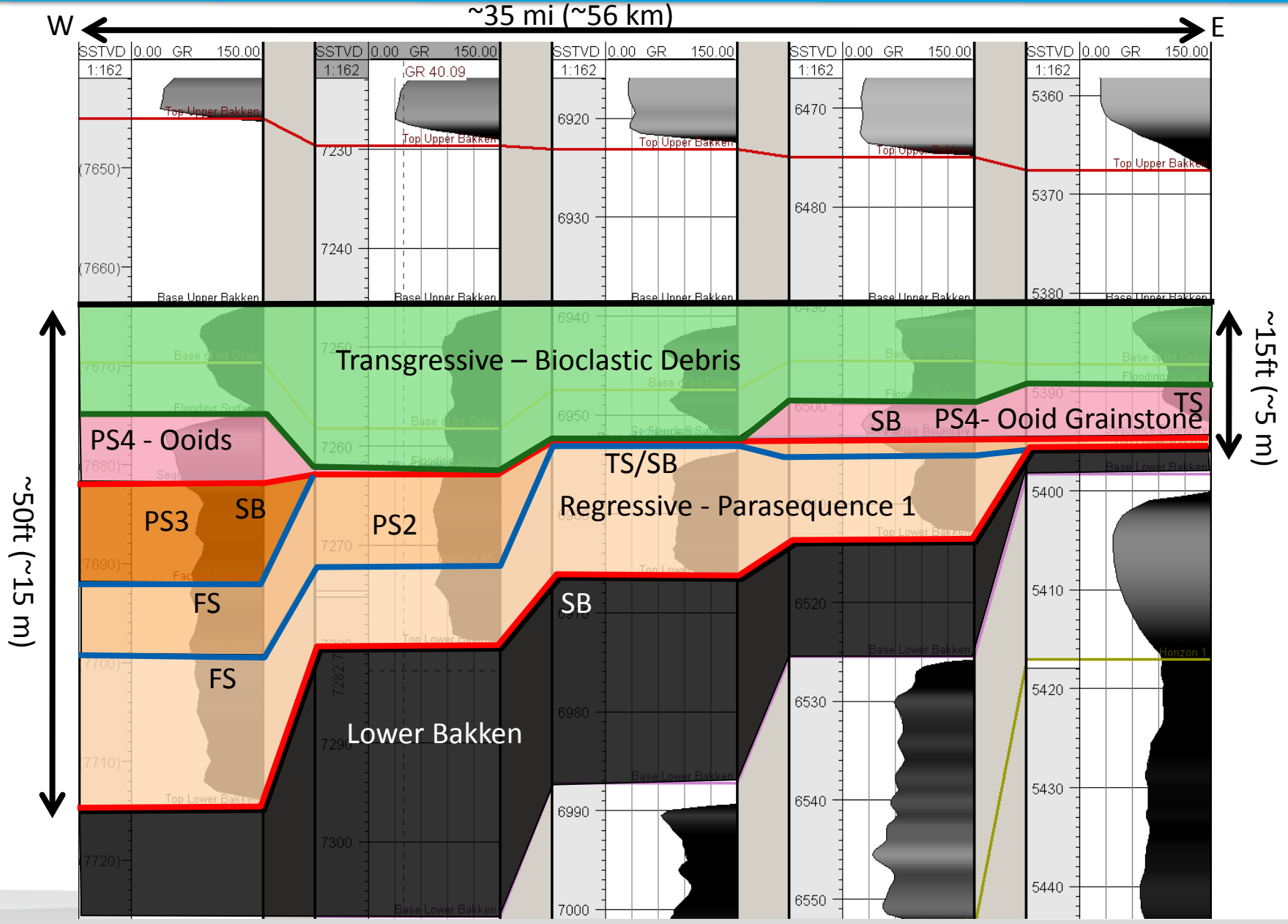
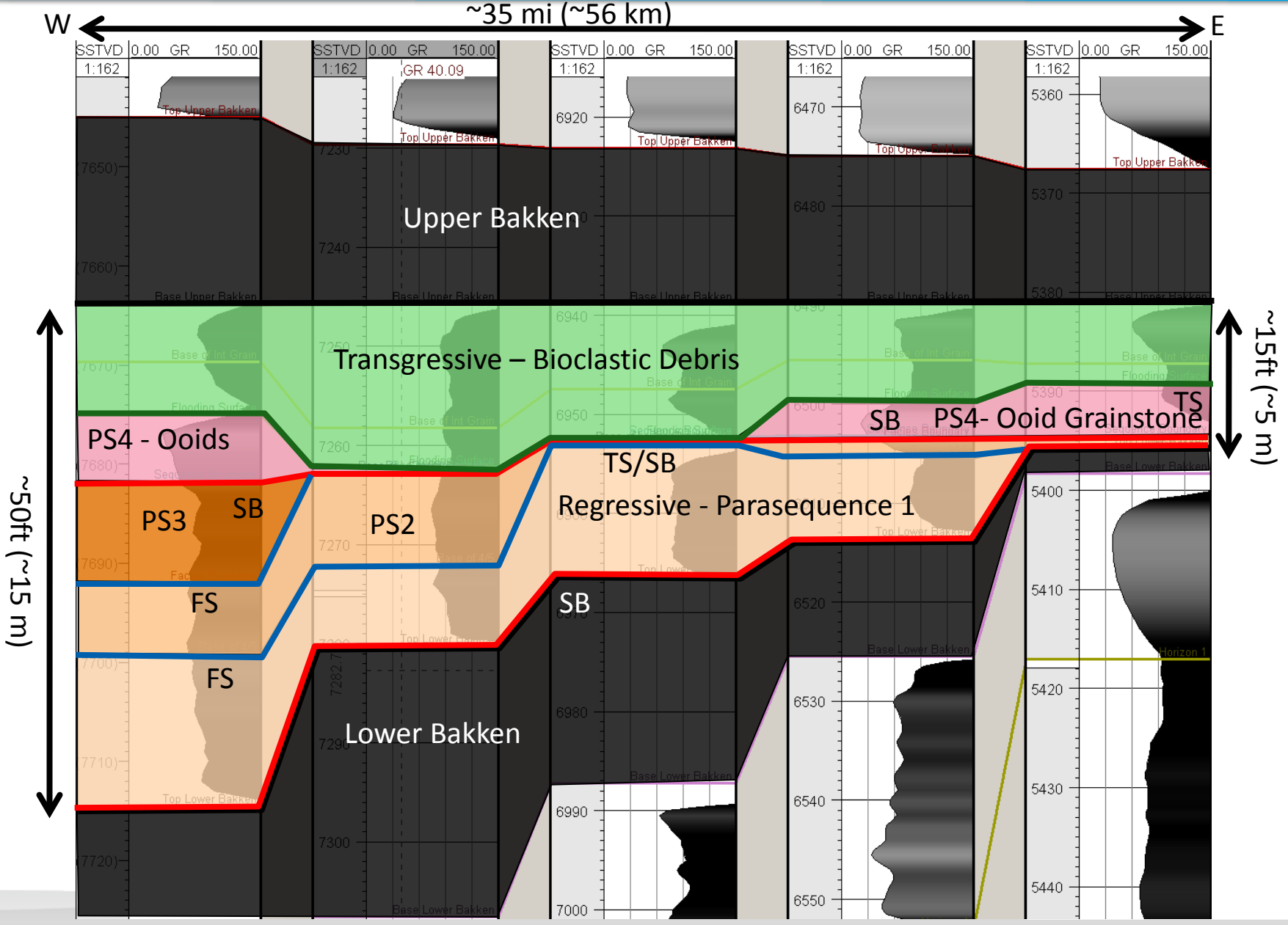


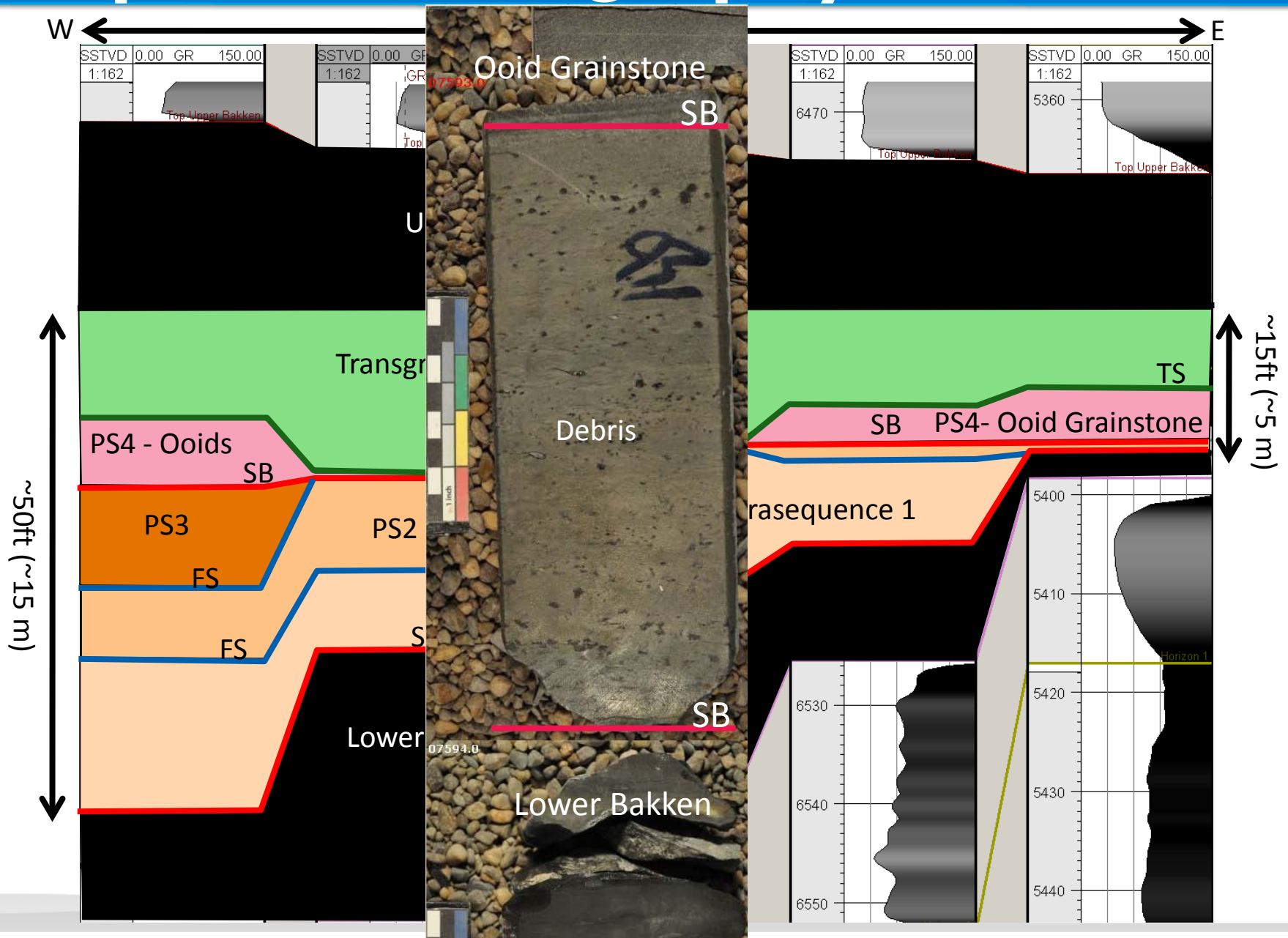
Sequence Stratigraphy



Sequence Stratigraphy



Sequence Stratigraphy



Facies Distribution

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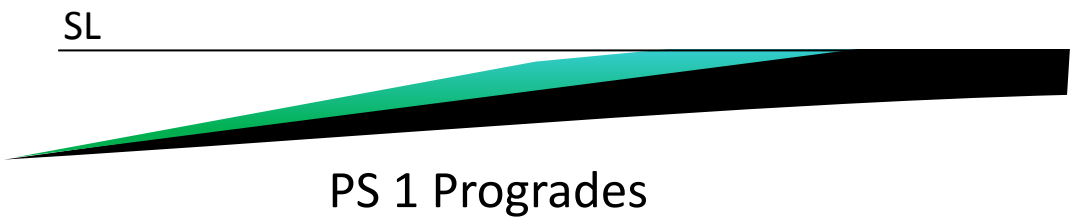
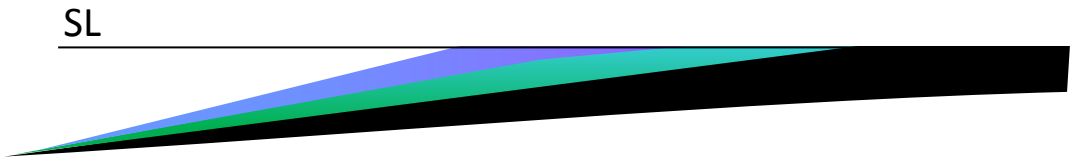
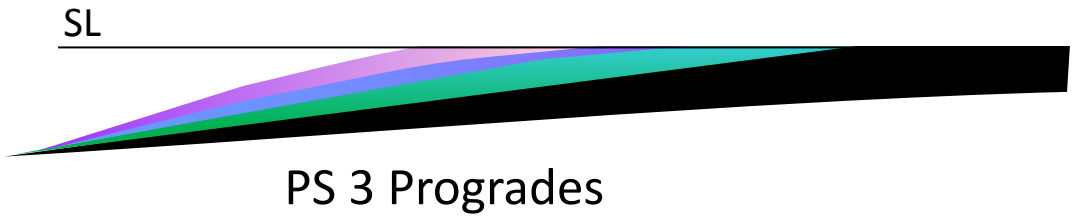


Facies Distribution



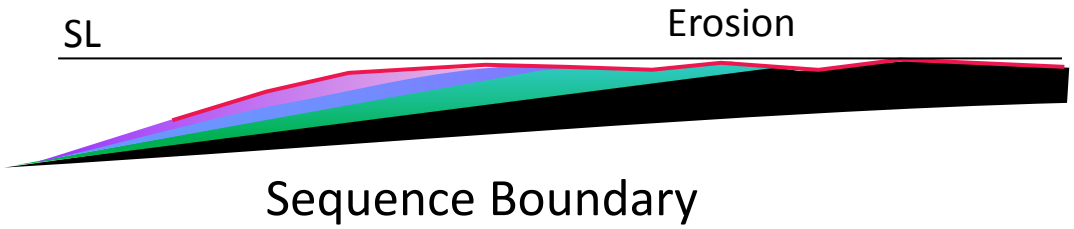
PS 2 Progrades

Facies Distribution



PS 3 Progrades

Facies Distribution



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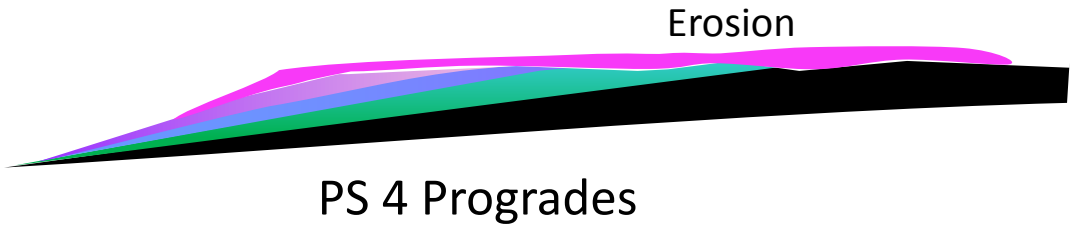

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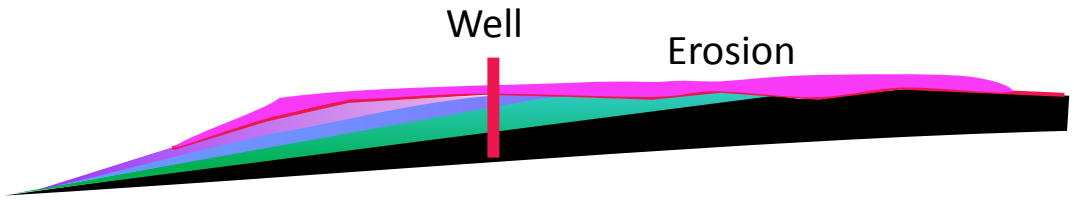
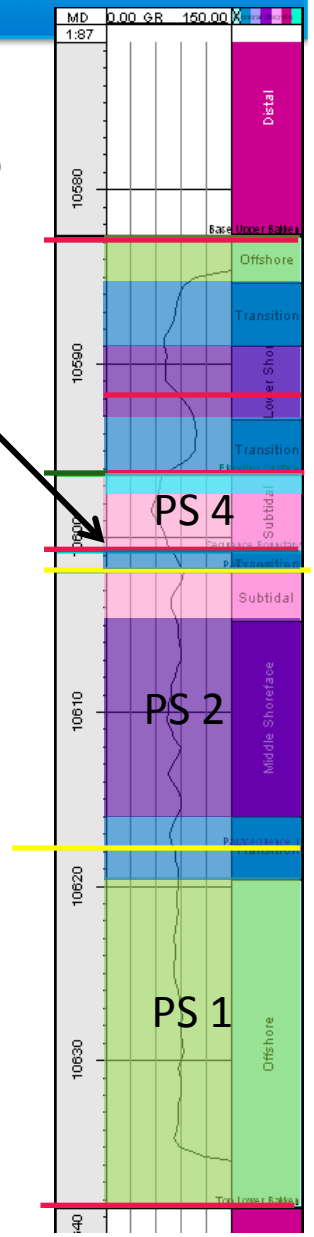
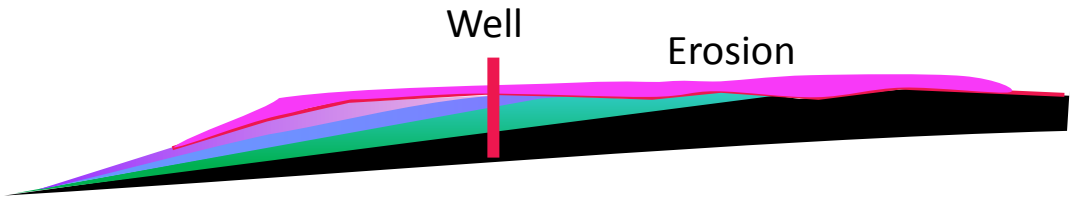


PS 4 Progrades

PS3 not present due to erosion at the Sequence Boundary



Facies Distribution



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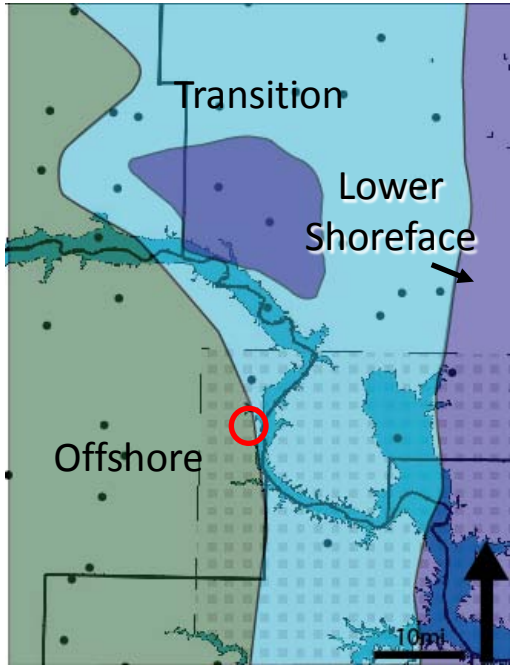
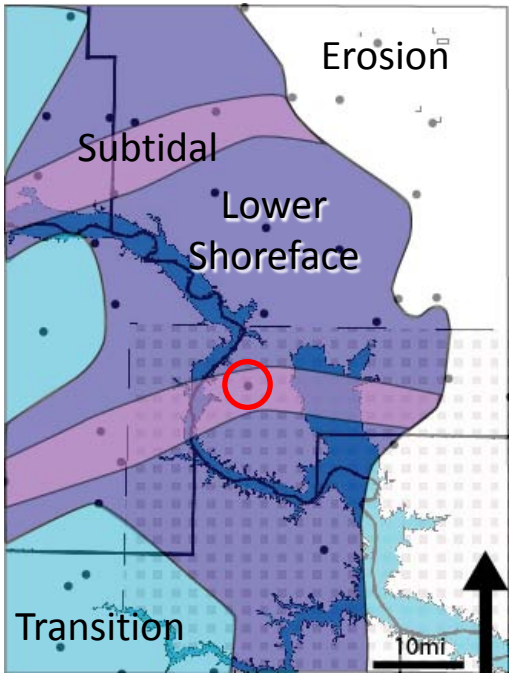
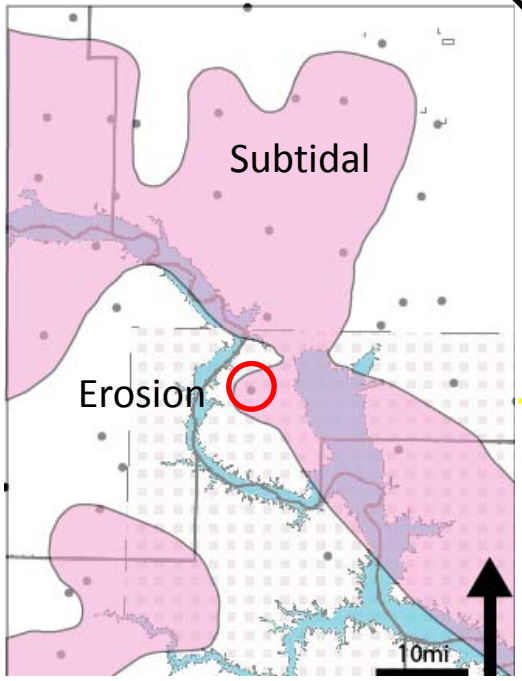


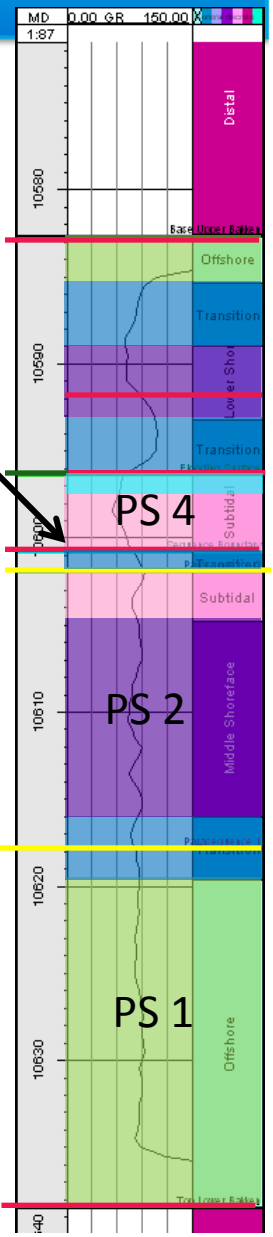
Parasequence 1



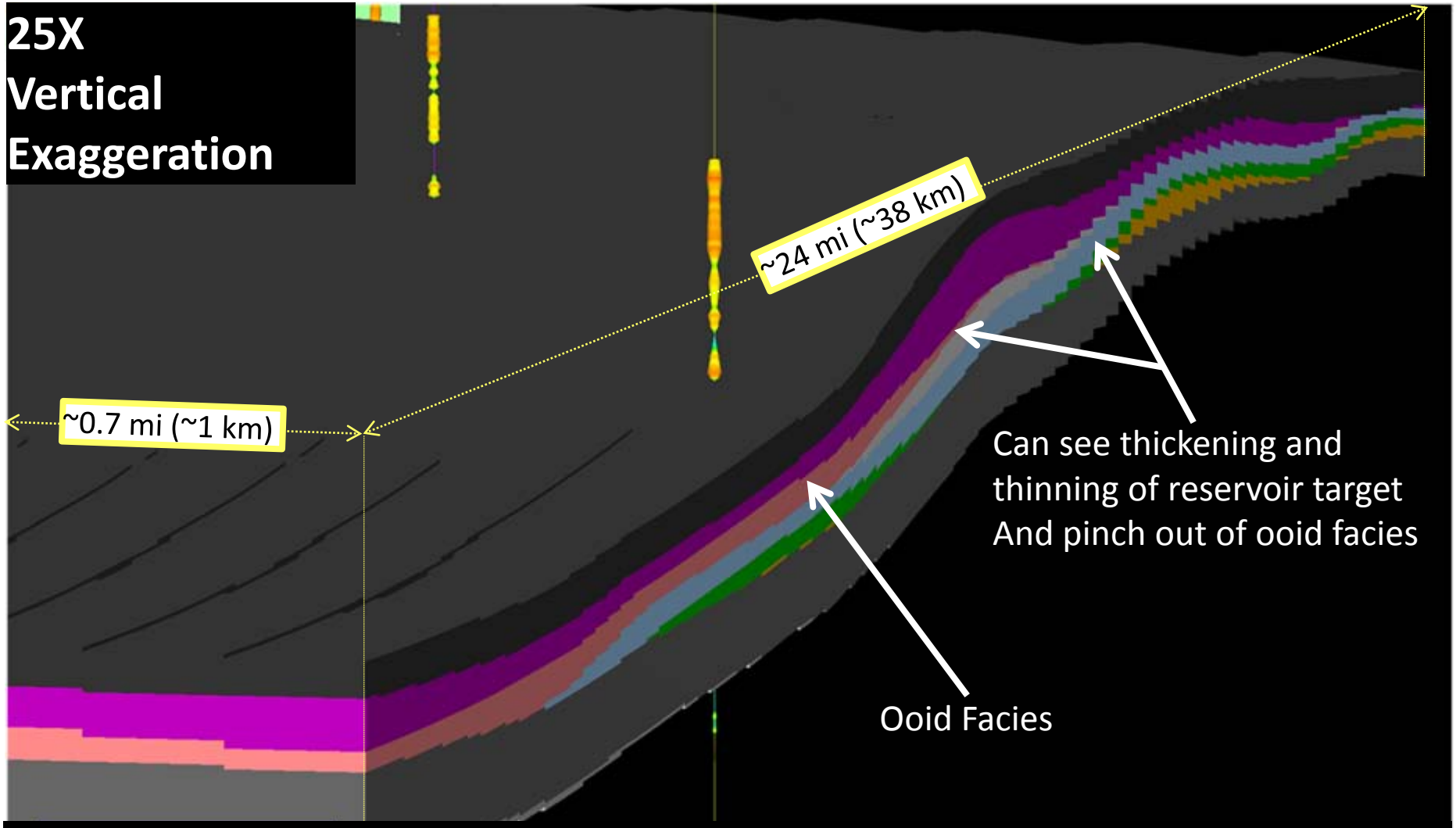
Parasequence 2



Parasequence 4

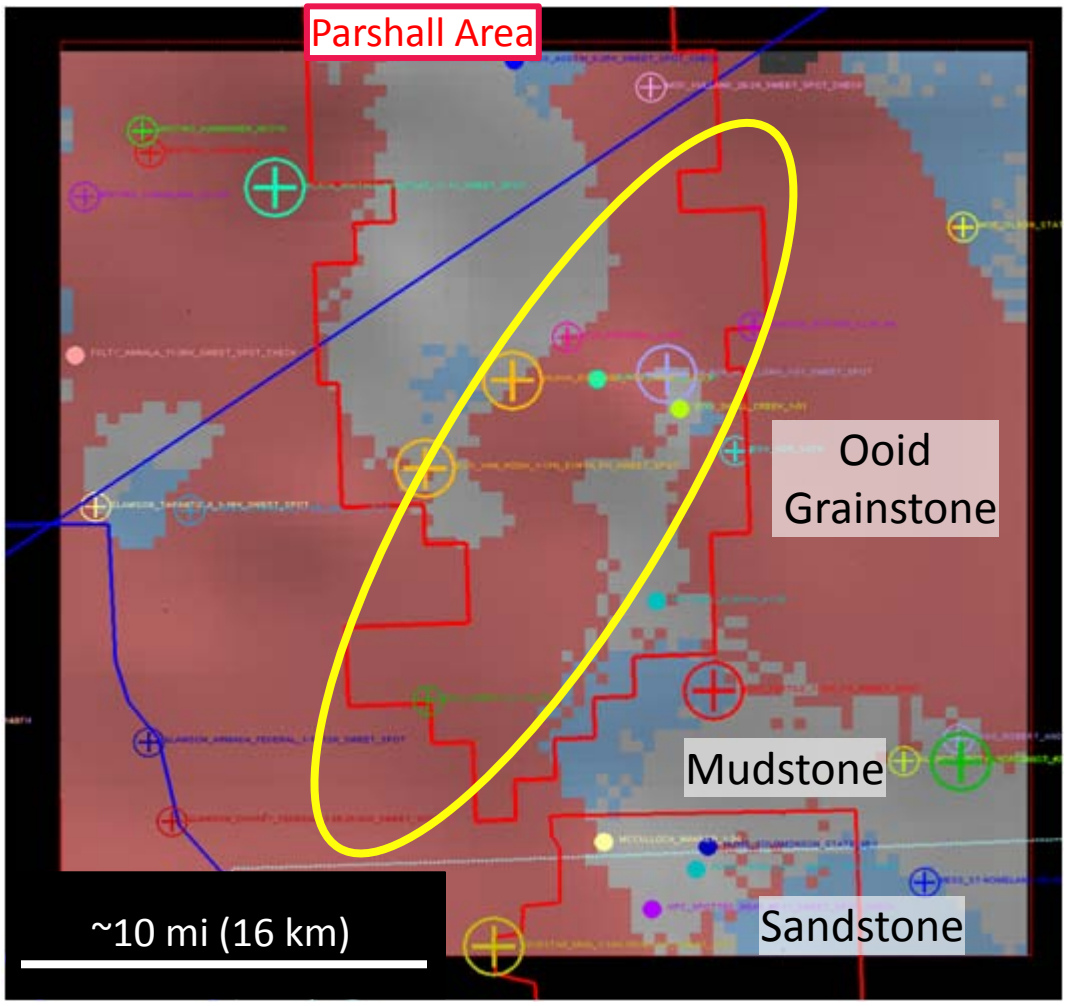


Reservoir Modeling

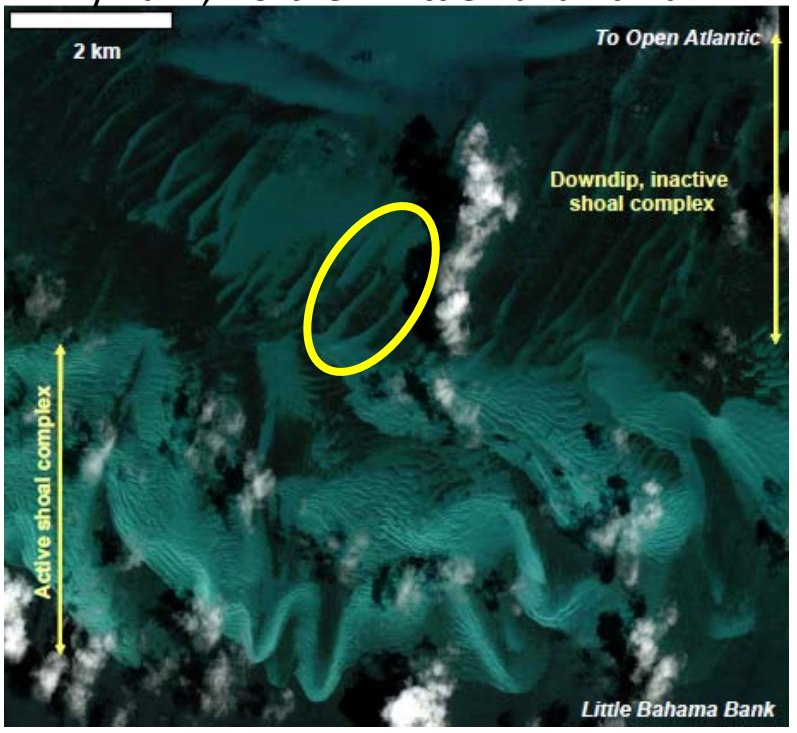


1. Facies Broken out by geomechanical properties
2. Facies Mapped and Modeled using Petrel

Facies Mapping



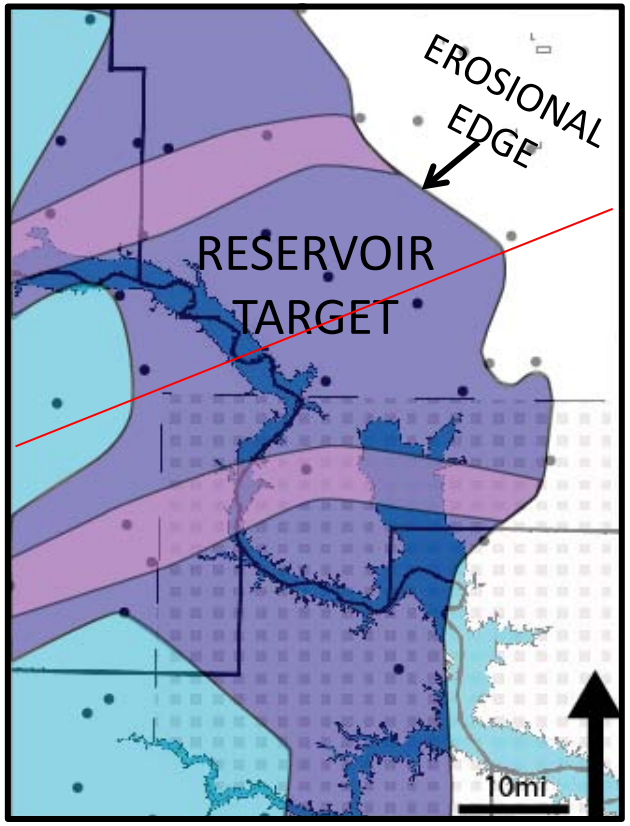
Lily Bank, Northern Little Bahama Bank



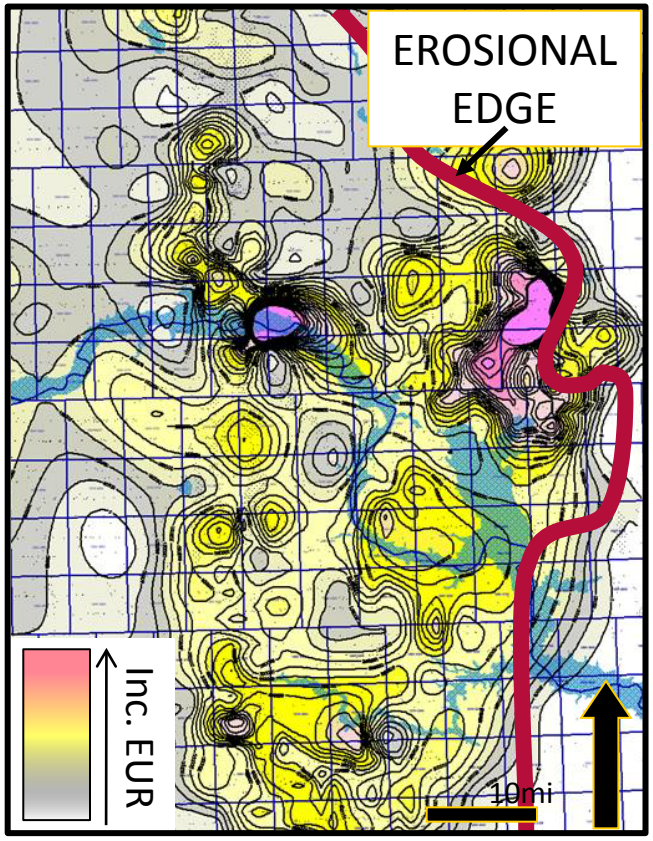
Rankey and Reeder, 2011

Applications - Production

Facies Map

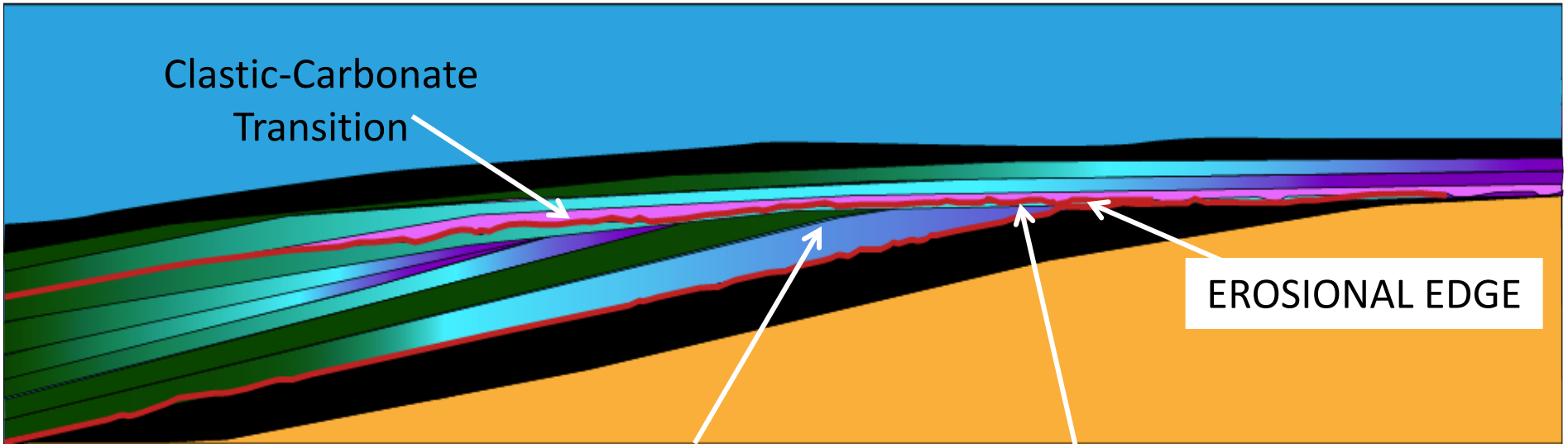


Relative EUR



Application – Play Elements

Idealized Cross Section



VE: ~50

Reservoir
Target
(mid/lower
Shoreface)

Lateral Pinch-outs
Potential stratigraphic traps

Conclusions

- Developing a sequence-stratigraphic framework is key to determining lithofacies distribution
- Building a sequence-stratigraphic framework within the Middle Bakken offers a predictive capability that lithostratigraphy does not
- Careful core description and calibration with well control allows you to map “petrofacies” and calibrate wells in the absence of core data.