

Characterization of Fine Grained Lithofacies in Coeval Strata from a 1000 km Nearshore to Offshore Transect in the Upper Cretaceous of the North American Western Interior Seaway*

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Abstract

As the exploration of unconventional plays continues to expand into increasingly challenging geologic environments the ability to predict the distribution of high reservoir quality has become an area of active research. Strata deposited around the Cenomanian – Turonian (C-T) boundary have received particular attention globally. Widely regarded as one of the premier times of source rock accumulation this time period has been extensively studied regarding enhanced preservation of organic carbon. Given recent developments of C-T strata becoming world class unconventional reservoirs (i.e.: Eagle Ford) gaining a full understanding of regional variations in how these rocks both generate and store hydrocarbons requires knowledge of the detailed lithofacies variations both vertically and laterally. In this study we have logged and sampled strata spanning the C-T boundary super-regionally from the North American Cretaceous Western Interior Seaway (KWIS). Samples from both cores and exposures from central Utah to Kansas have been analyzed to 1. determine their biostratigraphic context; 2. facies attributes; and 3. environments of deposition. Lithofacies were observed from strata of the late transgressive to early highstand associated with the early Turonian maximum flooding. Strata from fluvial influenced environments are highly bioturbated argillaceous mudstones with abundant plant material. At the top of the interval coarsening upwards parasequences are more apparent with the tops of the parasequences becoming increasingly silt-rich with wave rippled laminae. Away from clastic input the coeval lithofacies are mixed calcareous - siliciclastic systems. The primary carbonate components are pelagic coccoliths and foraminifera. The early transgressive deposits consist of intervals of highly bioturbated bases that evolve upward to wave rippled thin (<1 cm) graded beds. Within the late transgressive to highstand a similar stacking is observed with the tops being 10 – 20 cm thick highly cemented carbonates. From these observations we believe that strata deposited in the transgressive interval of the mixed system environments make the optimal tight oil reservoirs in this part of the KWIS. The strata studied from the more terrestrially influenced environments were too influenced by fluvial processes. It is possible that other strata along strike where riverine input was less dominant could have high reservoir potential.

Website Cited

Middle Turonian paleogeographic map from Blakey (<http://cpgeosystems.com/wispaleogeography.html>).

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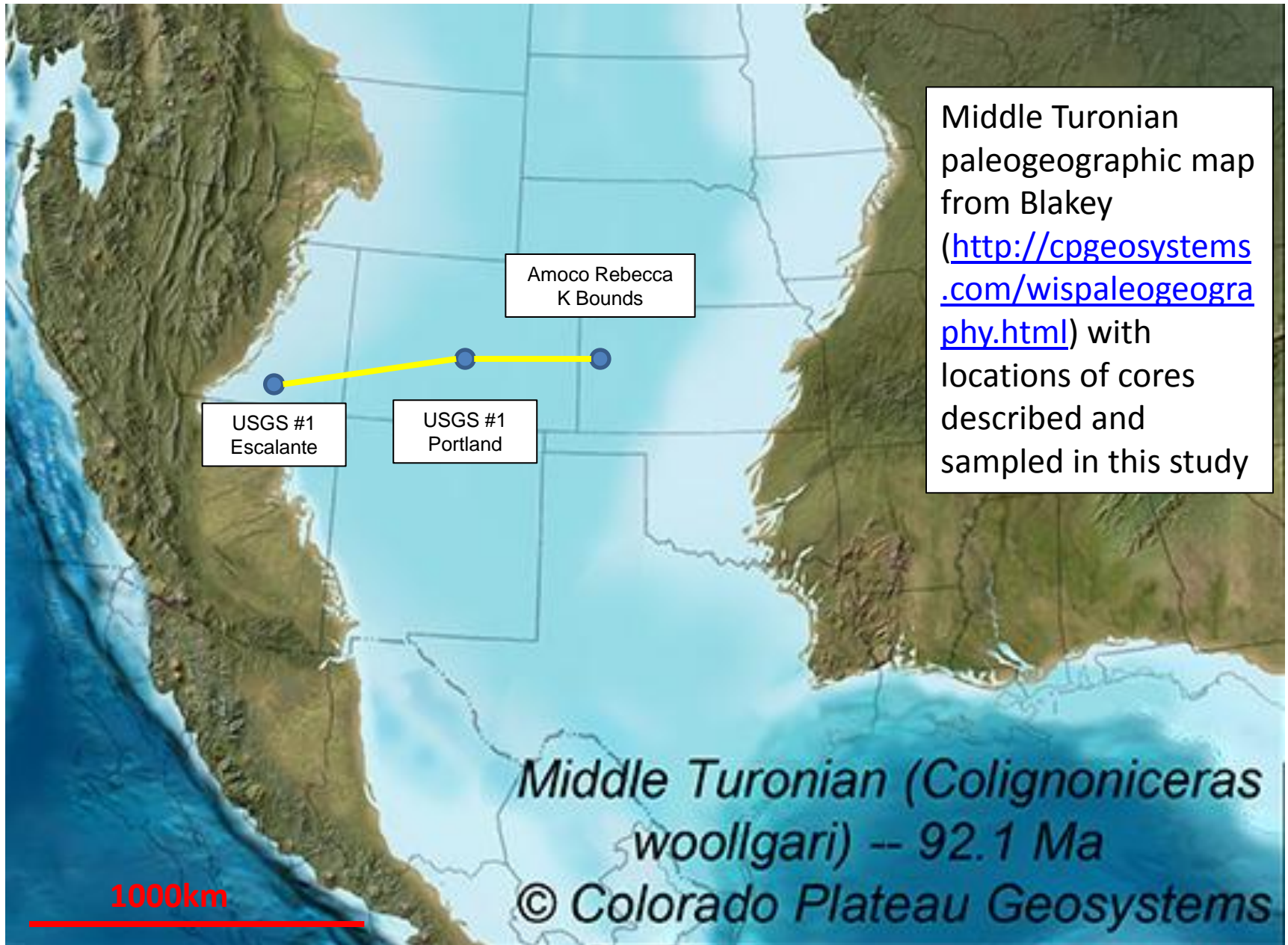
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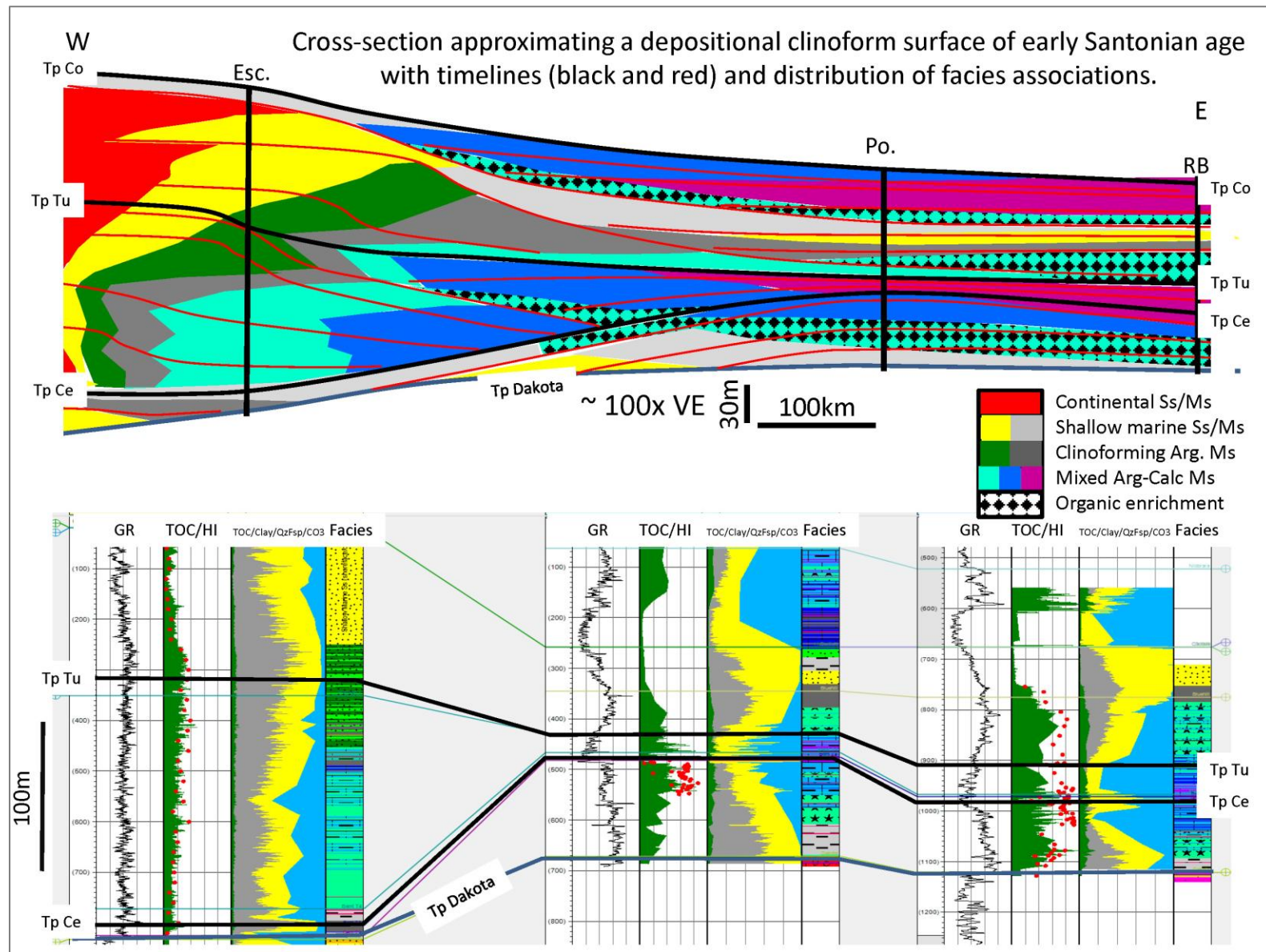
Introduction



- Mudstones comprise the majority of the sedimentary fill of most shallow marine basins
- Mudstones influence all play elements of a petroleum system.
- Mudstone properties are a function of terrestrial inputs, production in the water column, and modification of these components by diagenesis.
- We know a great deal about mud origins, dispersal, and depositional processes from studying modern systems and ongoing experimental work
- This study characterizes the heterogeneity of fine grained rocks and the controls on their ultimate rock properties via lithologic observation, geochemical characterization, and petrographic analyses of strata spanning the Cenomanian – Turonian (C-T) time interval from the Cretaceous Western Interior Seaway
- Ample core and outcrop availability over a range of EODs
 - High quality age correlations
 - Large public datasets
 - Can we observe systematic temporal and spatial variability?

Introduction

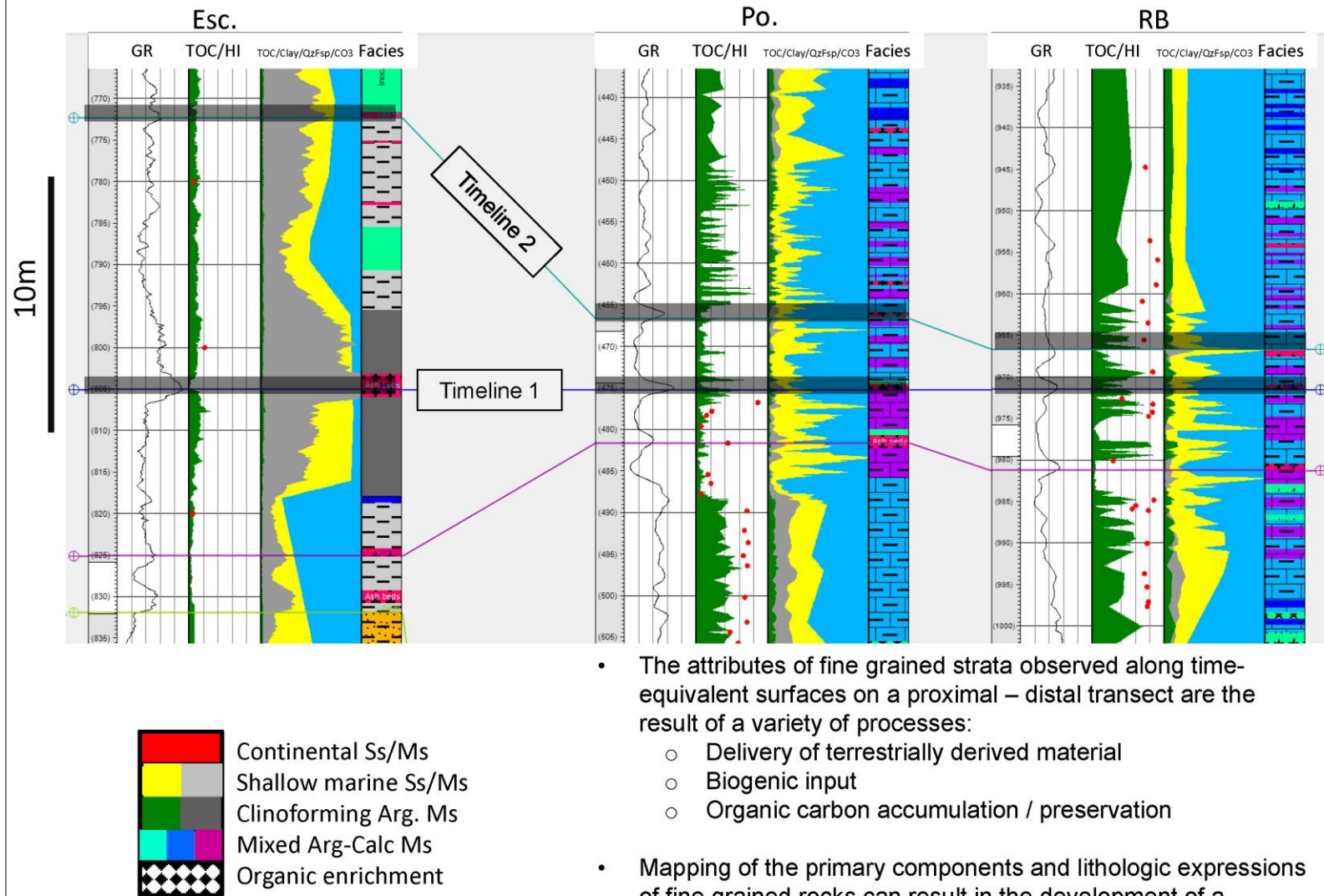




Presenter's notes:

1. Retrogradational to progradational stacking patterns.
2. Highly varied composition both stratigraphically and laterally.
3. From logs and geochemical analyses, get good broad characterization of facies over long distances and stratigraphic interval.

Interval around the C-T boundary (flattened on the approximate boundary)



- The attributes of fine grained strata observed along time-equivalent surfaces on a proximal – distal transect are the result of a variety of processes:
 - Delivery of terrestrially derived material
 - Biogenic input
 - Organic carbon accumulation / preservation
- Mapping of the primary components and lithologic expressions of fine grained rocks can result in the development of a predictive framework for petroleum system analysis

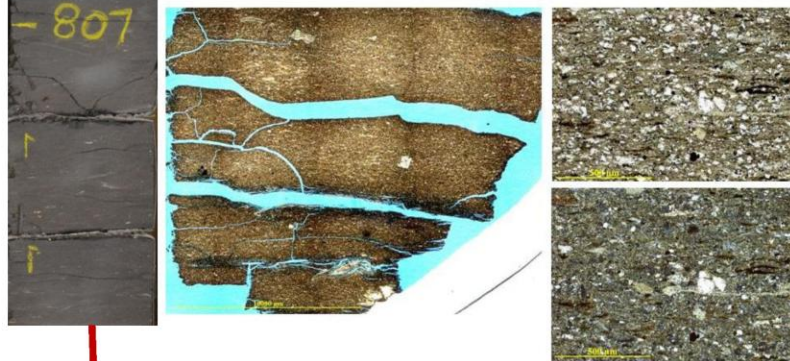
Presenter's notes:

1. Two timelines based upon well studied ash beds.
2. Significant variation in composition; as expected.
3. Is variation in composition reflected in observable lithologic expressions?

Timeline 1 Facies

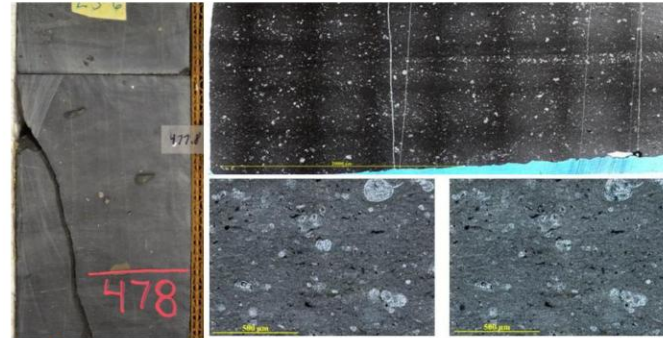
Escalante 807.5

Highly reworked; Grains (Qz/Fsp) and matrix (Clay mineral aggregates) detrital sourced; Minor carbonate from shells, minor (terrestrial) organic matter



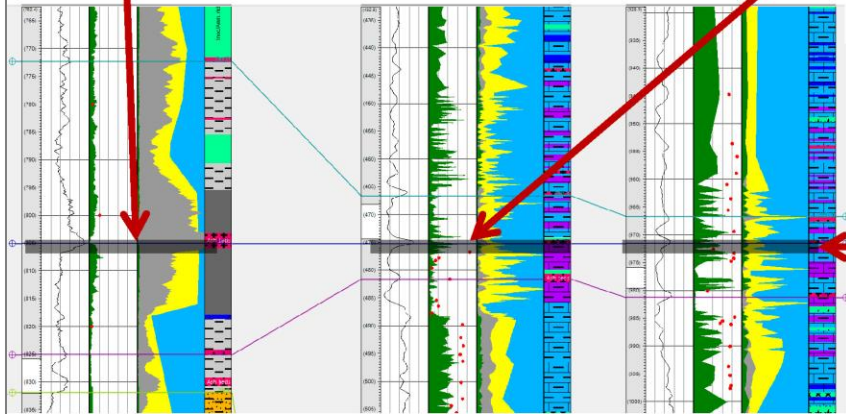
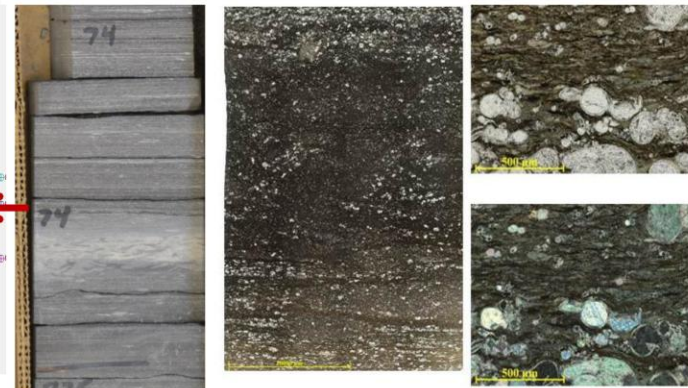
Portland 477.8

Highly reworked w/ some remnant bedding; Carbonate in both "grains" (forams) and pervasive early diagenetic cement



Bounds 974.5

Thin (1 – 2 cm) bedded calcareous mudstones; Component grains forams; Matrix mix of coccolith-rich pellets and marine organic matter



Presenter's notes:

1. Escalante: Fine-medium churned siliciclastic mudstone w/ broken and highly reworked shell fragments. Matrix consists primarily of clay minerals w/ some minor carbonate (cement / coccoliths?). Grains mostly terrestrially derived siliciclastics w/ minor amounts of shell fragments. Seal? (Presenter's notes continued on next slide.)

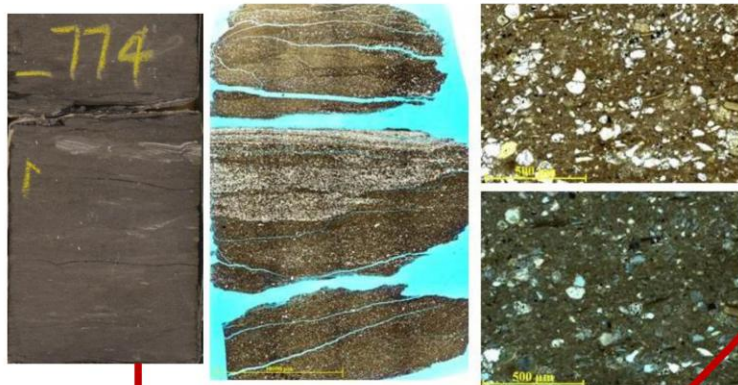
(Presenter's notes continued from previous slide.)

2. Portland: Fine-medium churned calcareous mudstone w/ some remnant wavy discontinuous bedding. Matrix predominantly carbonate cement w/ minor amounts of organics. Grains predominantly forams and highly broken and reworked shell fragments. Possible low quality source. Question of ability to preserve OM w/ such prevalent reworking.
3. Bounds: Medium – coarse calcareous thin bedded mudstone. Beds are normally graded w/ wavy erosive bases filled w/ forams grading up to bioturbated fine calcareous mudstones. Matrix a mix of coccolith-rich pellets and organic mascerals. Grains primarily forams. Potential high quality source and reservoir.

Timeline 2 Facies

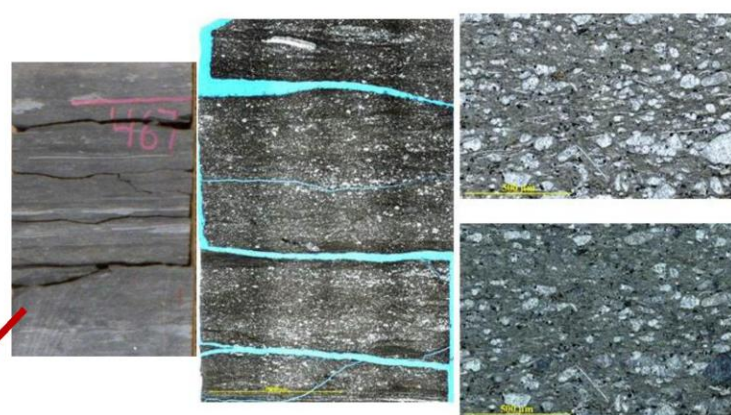
Escalante 774.15

Highly reworked w/ some remnant bedding; Grains (Qz/Fsp) and matrix (clay mineral aggregates) detrital sourced; Minor carbonate from shells/forams



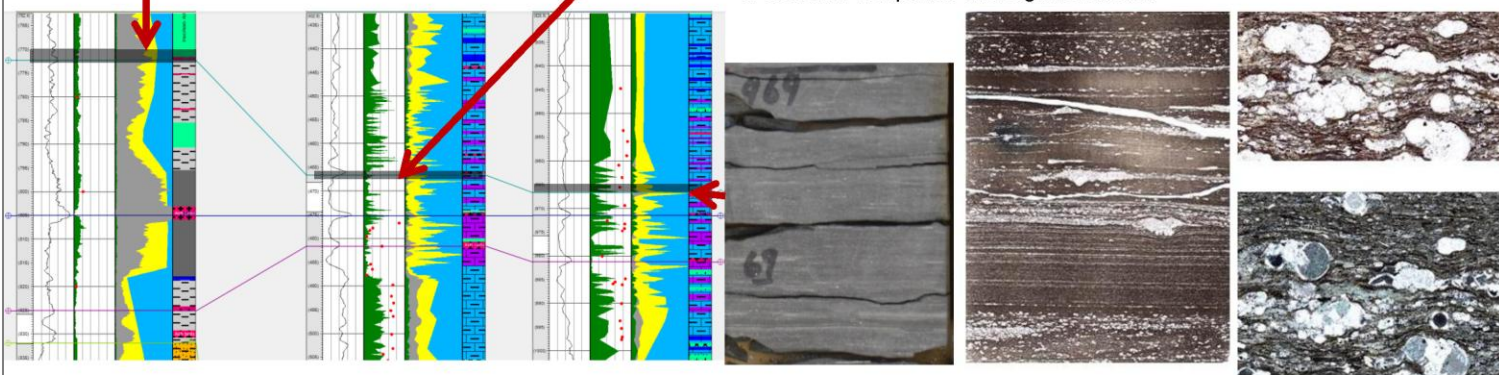
Portland 467

Reworked w/ moderate remnant bedding; Carbonate in abundant forams and cement.



Bounds 969.4

Reworked w/ abundant remnant bedding; Some intervals of well preserved thin (5 – 10 mm) normally graded beds; Grains predominantly forams; Matrix mix of coccolith-rich pellets and organic material



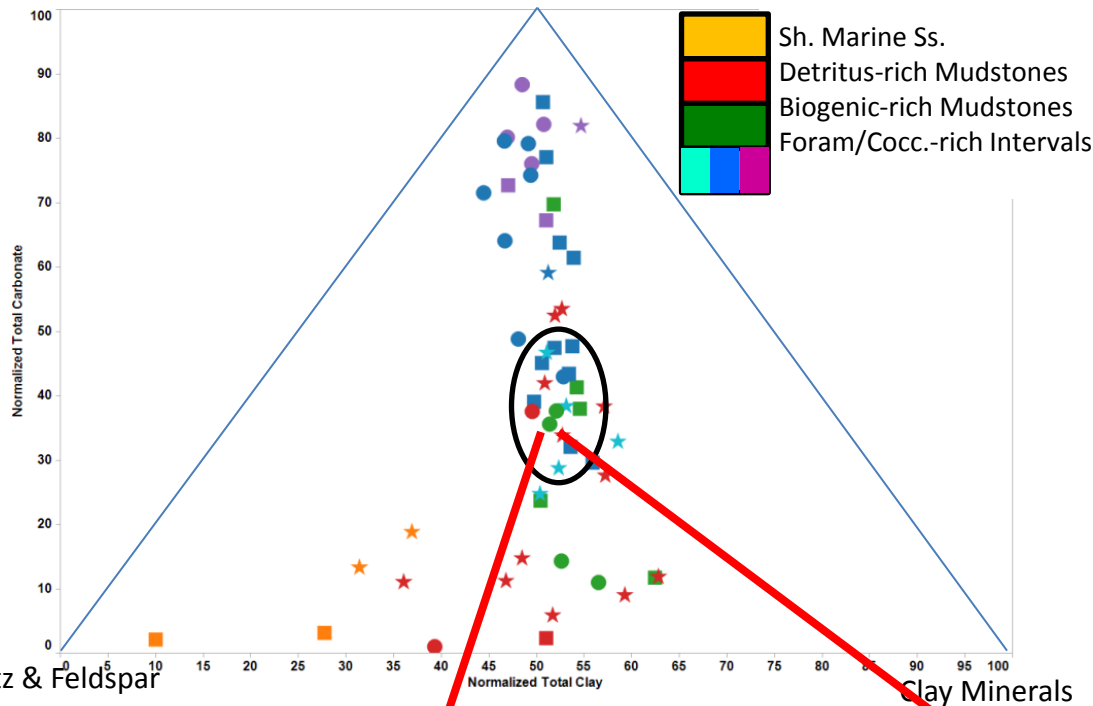
Presenter's notes:

1. Escalante: Highly reworked siliciclastic mudstone w/ intervals of remnant bedding that have highly erosive bases, are coarse grained above with a sharp top contact back to reworked fine grained mudstone. Matrix material composed primarily of clay mineral aggregates with some minor amounts of carbonate cement. Component grains mix of terrestrially derived quartz and feldspar with some carbonate from foram tests and broken, reworked shell material. (Presenter's notes continued on next slide.)

(Presenter's notes continued from previous slide.)

2. Portland: Reworked fine – medium calcareous mudstone w/ intervals of thin remnant bedding. Where preserved, beds are normally graded w/ wavy discontinuous erosive laminae at base composed of forams that grade up to bioturbated calcareous fine mudstones. Matrix predominantly carbonate cement. Component grains mostly forams w/ some broken, reworked bivalve fragments.
3. Bounds: Medium – coarse calcareous mudstones w/ mix of thin normally graded bedded intervals w/ reworked intervals. Graded beds are erosive at base w/ mix of parallel to slightly wavy continuous laminae composed of foram tests that grade up to bioturbated fine calcareous mudstones. Component grains foram tests w/ matrix composed of a mix of coccolith-rich pellets, organic macerals, and carbonate cement. High quality reservoir and source.

Carbonate



Bulk Mineralogical Composition deceiving:

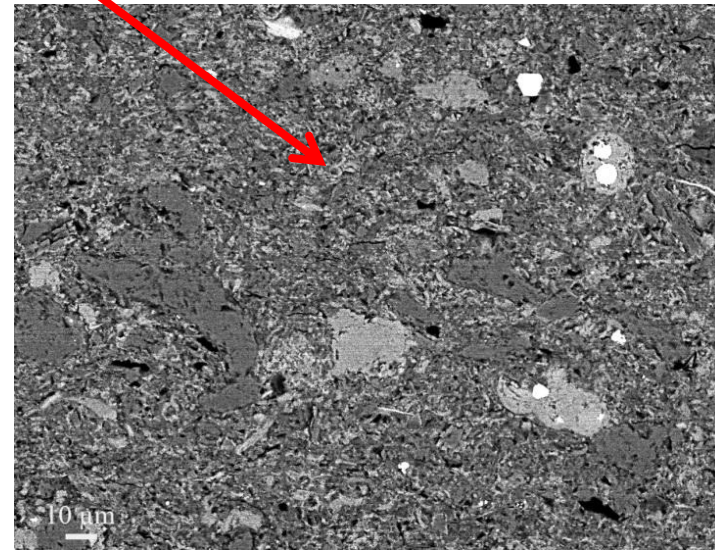
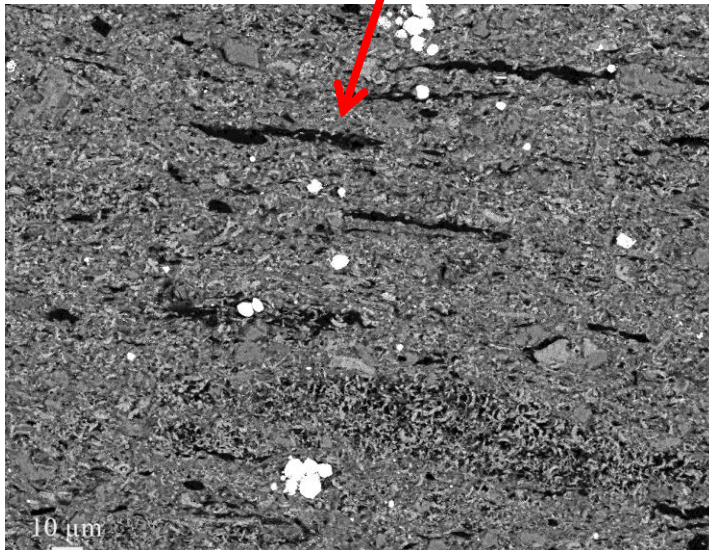
Rocks of similar bulk composition have very different origins of the mineralogical components.

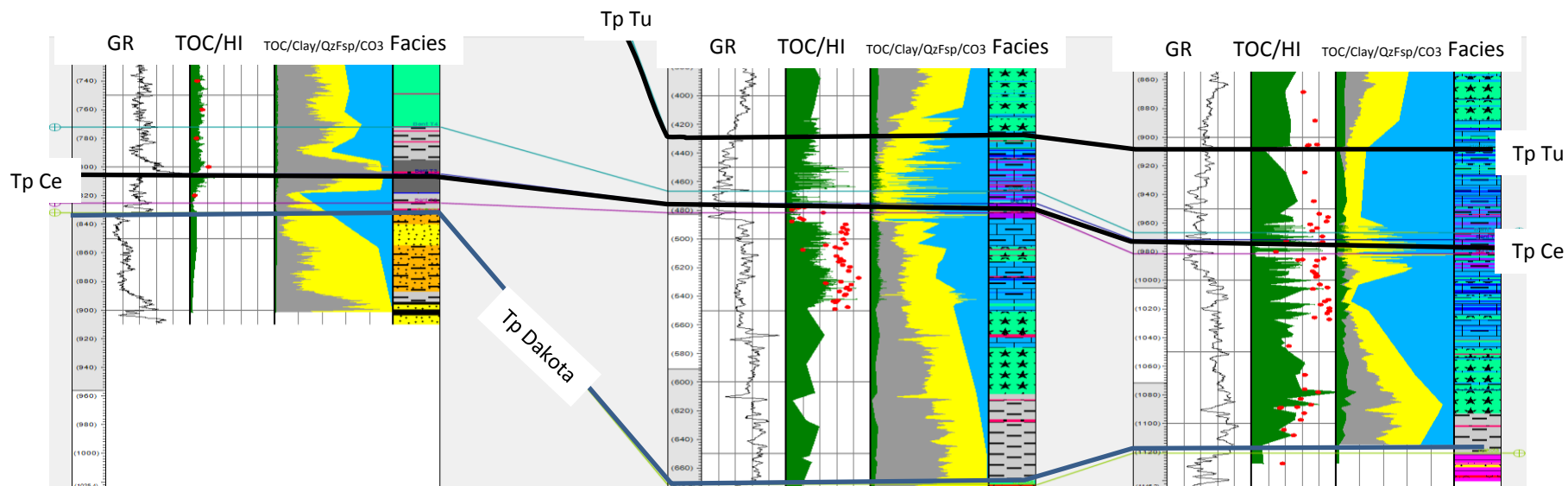
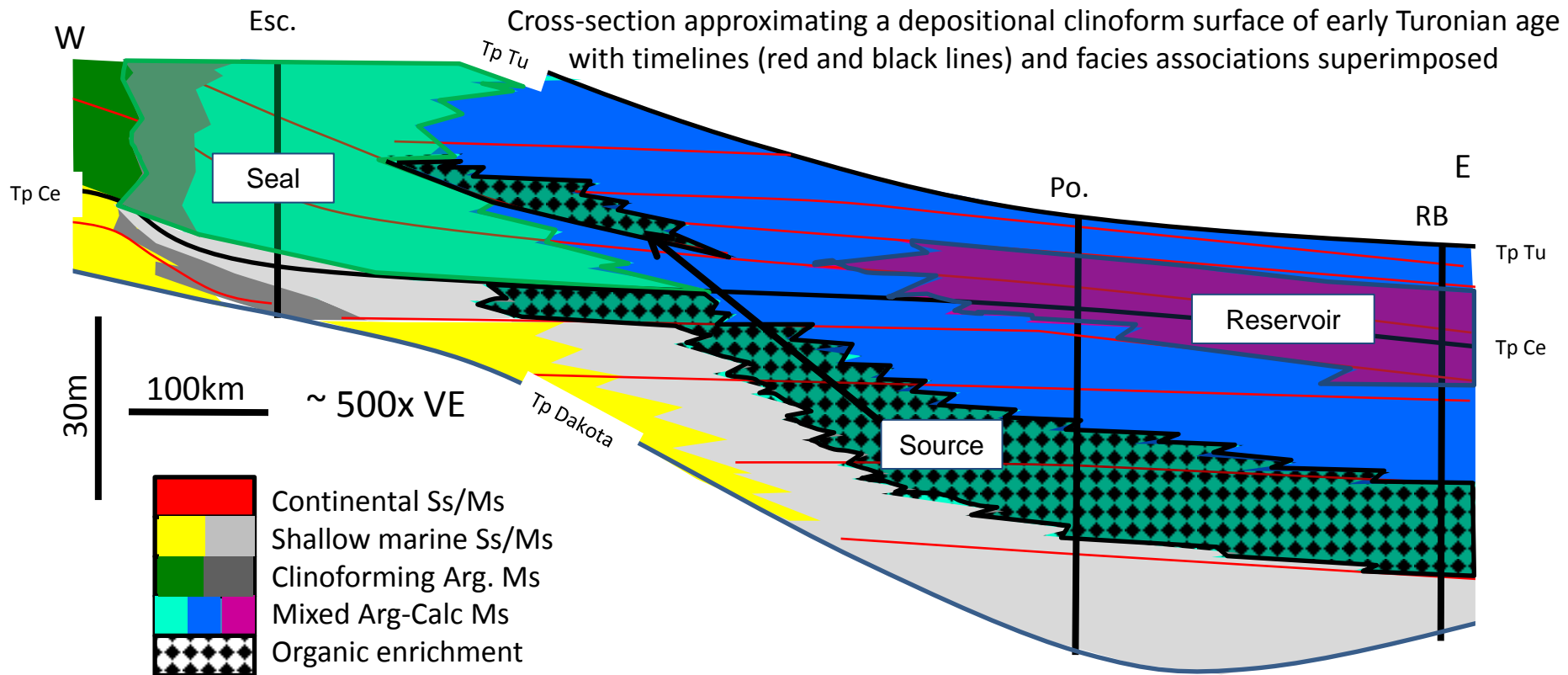
As a result, one facies of that bulk composition is:

An excellent oil-prone source rock, moderate unconventional reservoir and poor capillary seal.

Another facies of that bulk composition is:

A poor gas-prone source rock, poor unconventional reservoir and good capillary seal.





Summary

- Mudstones are highly heterogeneous, both in their lithofacies and composition
- Heterogeneity is a product of variable composition driven by variable primary inputs
- Observed lithofacies (hand samples) can be highly misleading on their own
 - Highly churned facies of fine grained rocks from EODs ranging from terrestrially influenced argillaceous mudstones to pelagic calcareous mudstones can be indistinguishable in hand specimen
 - Thin (5 – 20 mm) bedded, normally graded mudstones composed primarily of terrestrially sourced material can appear very similar to thin bedded (5 – 10 mm), normally graded mudstones whose composition is predominantly derived from biogenic input
- Geochemical characterization may also be very misleading
 - Time equivalent strata from highly variable EODs have similar bulk mineralogy
- Such comparisons on their own can provide false information with regards to a given intervals potential as a source, reservoir, or seal in a petroleum system analysis
- Lithofacies and lithofacies associations, petrographic observations, and geochemical characterization all need to be mapped within a sequence stratigraphic framework in order to truly understand the 3D interaction between the fine grained play elements of a petroleum system