

Characterizing Organic Rich Mudstone Facies and Stratal Architectures of the Upper Cretaceous Second White Specks Petroleum System: Implications for Reservoir Fairway Distribution across West-central Alberta, Canada*

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Abstract

The Upper Cretaceous Second White Specks petroleum system is actively being explored as an emerging shale oil resource play across western Alberta. Historically, several highly productive vertical oil wells (+1 million barrels) testify the prolific character of the Second White Specks petroleum system, although often dismissed as an unpredictable fracture controlled play based on poor production in offsetting wells. This study reveals complex stratal architectures comprised of 14 parasequences, each with mappable facies assemblages that characterize these heterolithic mudstone deposits. Sequence stratigraphic and sedimentological facies relationships highlight a series of stacked and intercalated mudstone units comprised of organic, siliciclastic, and calcareous sediments largely from locally sourced organic and pelagic fall-out as well as detrital sediments from western and eastern localities. Lateral distribution of sedimentary facies units therefore defines potential reservoir fairways, the foundation for subsequent play fairway characterization. Regional cross sections using 296 well logs across an area, T35–45, R3W5–9W5, established a sequence stratigraphic framework to evaluate parasequence stacking patterns. 10 cores and 27 petrographic samples help define facies assemblages within the succession. Identifying lateral and vertical variations in sedimentary facies is illustrated by facies isopach maps, complemented by facies distribution maps. These reflect petrophysical facies distributions that correlate to facies described in core and thin section samples. Depositionally, sedimentary bedforms (current ripples, graded beds, bioclastic debris layers) documents a depositional setting immediately below or above storm wave base, with deposition from a wide range of traction currents. This suggests deposition in a relatively high energy, shallow water

setting, supporting the interpretation of stacked shelf deposits comprising the Second White Specks petroleum system. In addition, analysis of pore size distribution data across the succession provides insights into pore throat morphologies that can be tied to facies distributions. Pore sizes occur as micro-, meso- and macropores (vol %), typically linked to interparticle and grain dissolution, providing insight into storage and flow characteristics for each facies. Collectively, this helps to identify various light oil fairways to be exploited by multistage hydraulically fractured horizontal wells.

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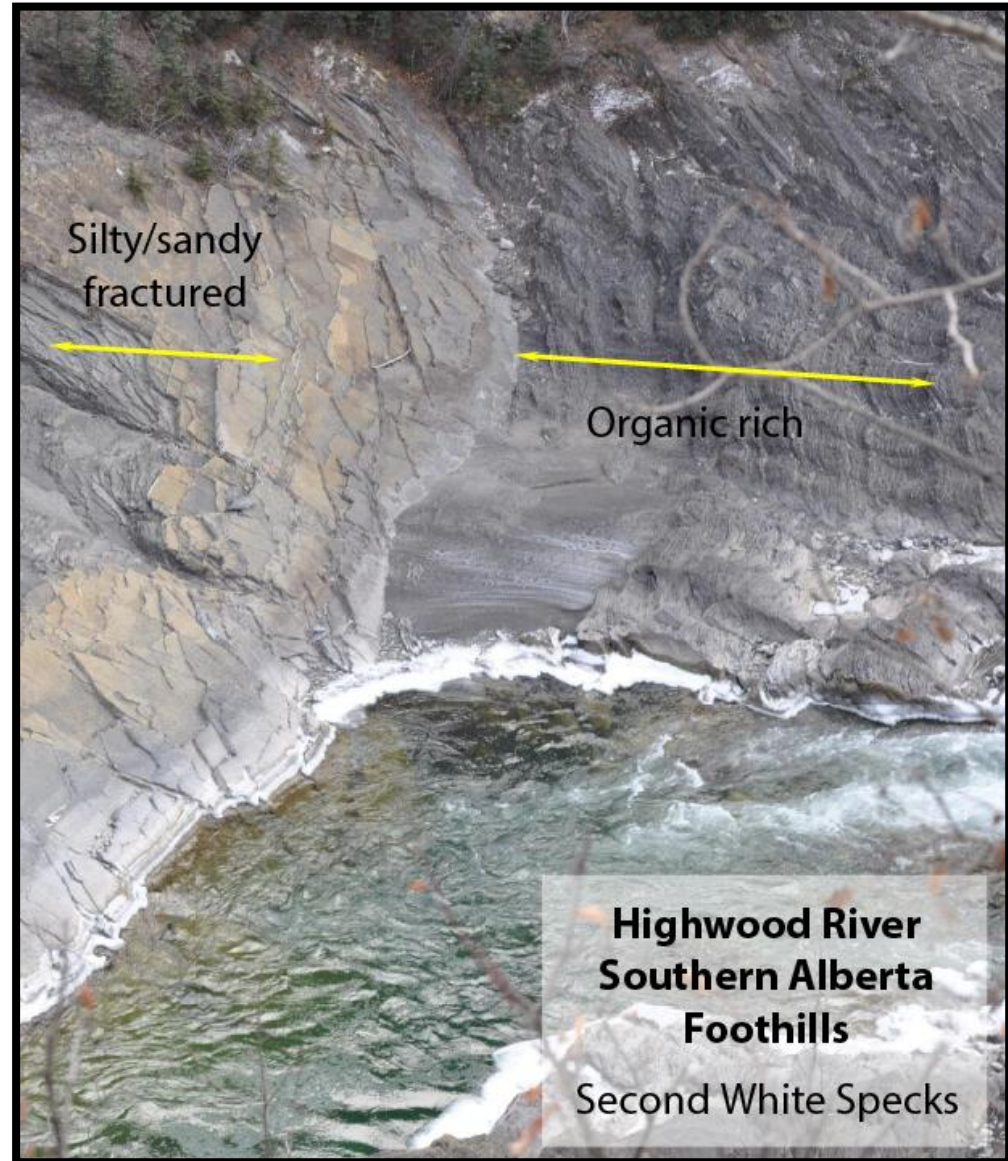
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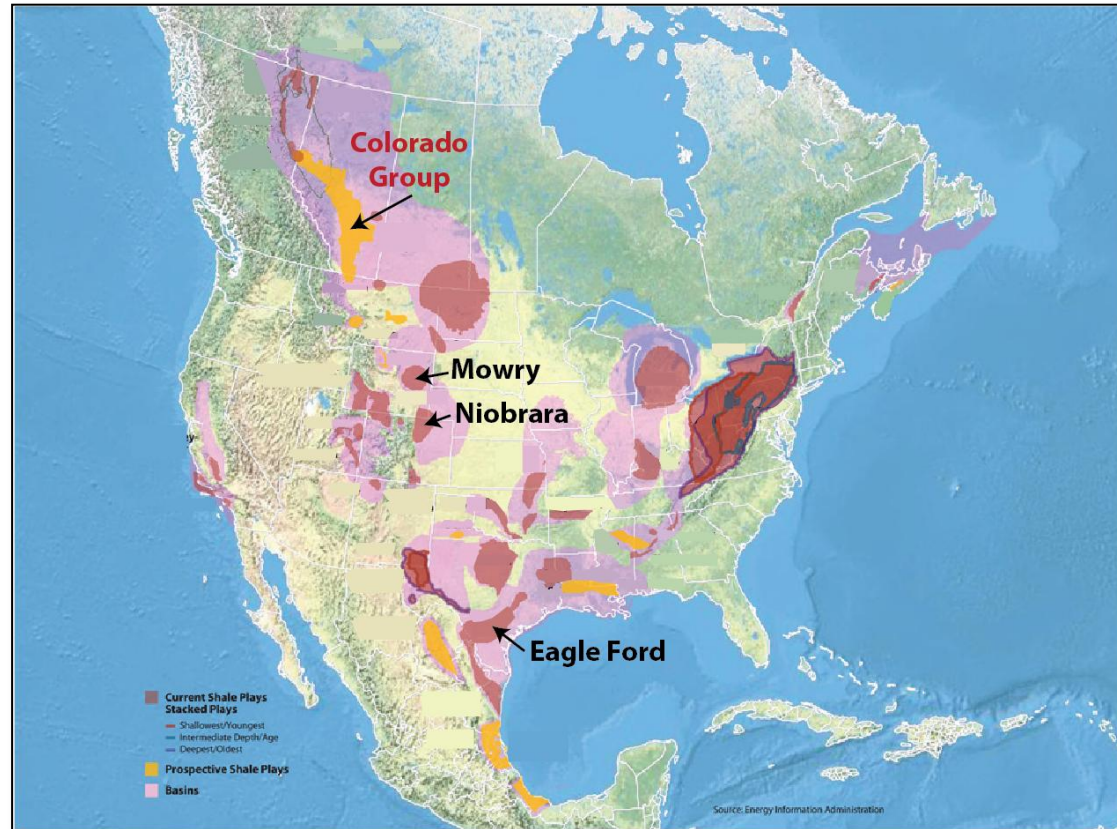
- Introduction
- Study Area & Dataset
- Geological Background
- Results
- Discussion
- Future Work



Project Importance & Objectives

■ The Second White Specks (2WS) Petroleum System:

- Middle-Upper Cretaceous Colorado Group mudstones
- Prospective shale oil resource play
- OOIP = **~460 Billion Barrels of oil**
- Inconsistent production across western Alberta. Why?



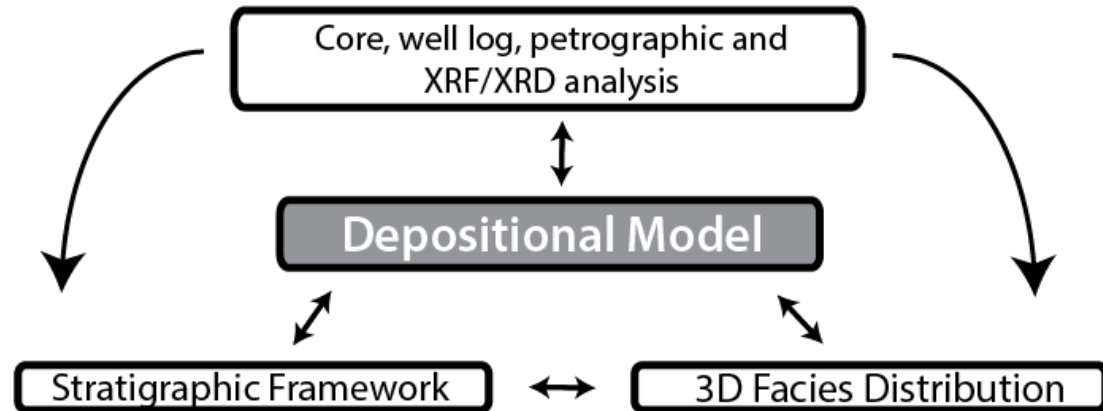
■ Critical to understand:

- Natural fracture systems
- Regional stratigraphy
- Facies distribution

1. How are facies fairway's distributed within stratal architectures of the 2WS?
2. How does this relate to potential reservoir 'Sweet spots'?

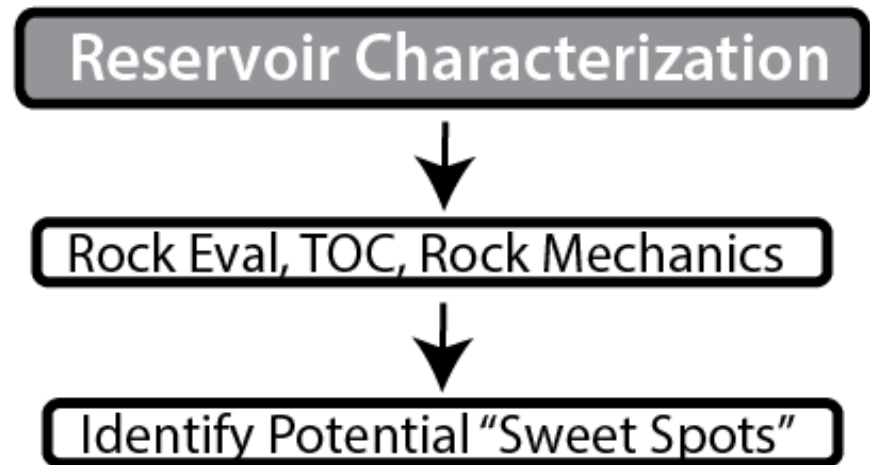
Depositional Model

- Stratigraphic framework
- Litho-facies identification
- Petrophysical well log facies
- Regional facies distribution

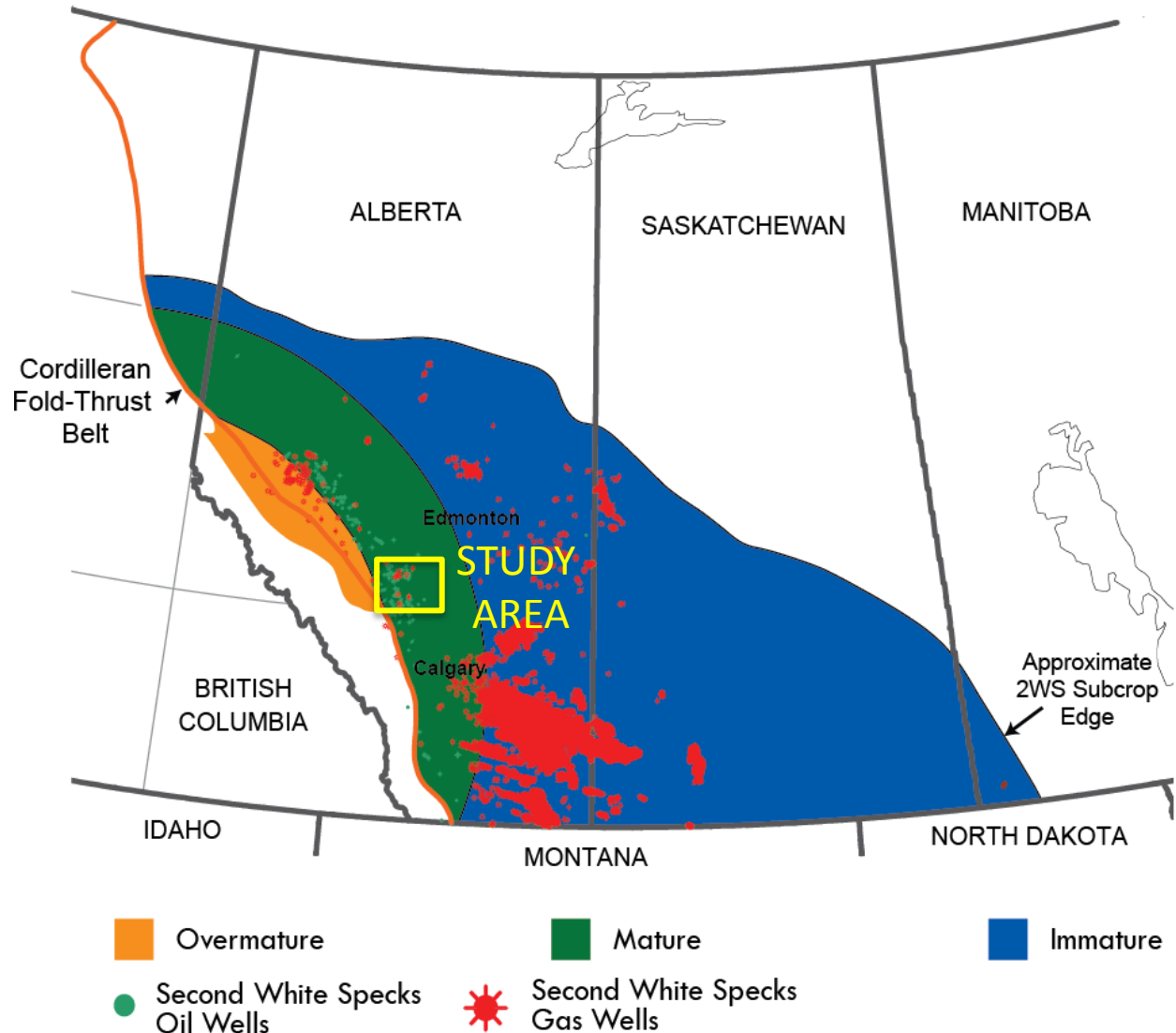


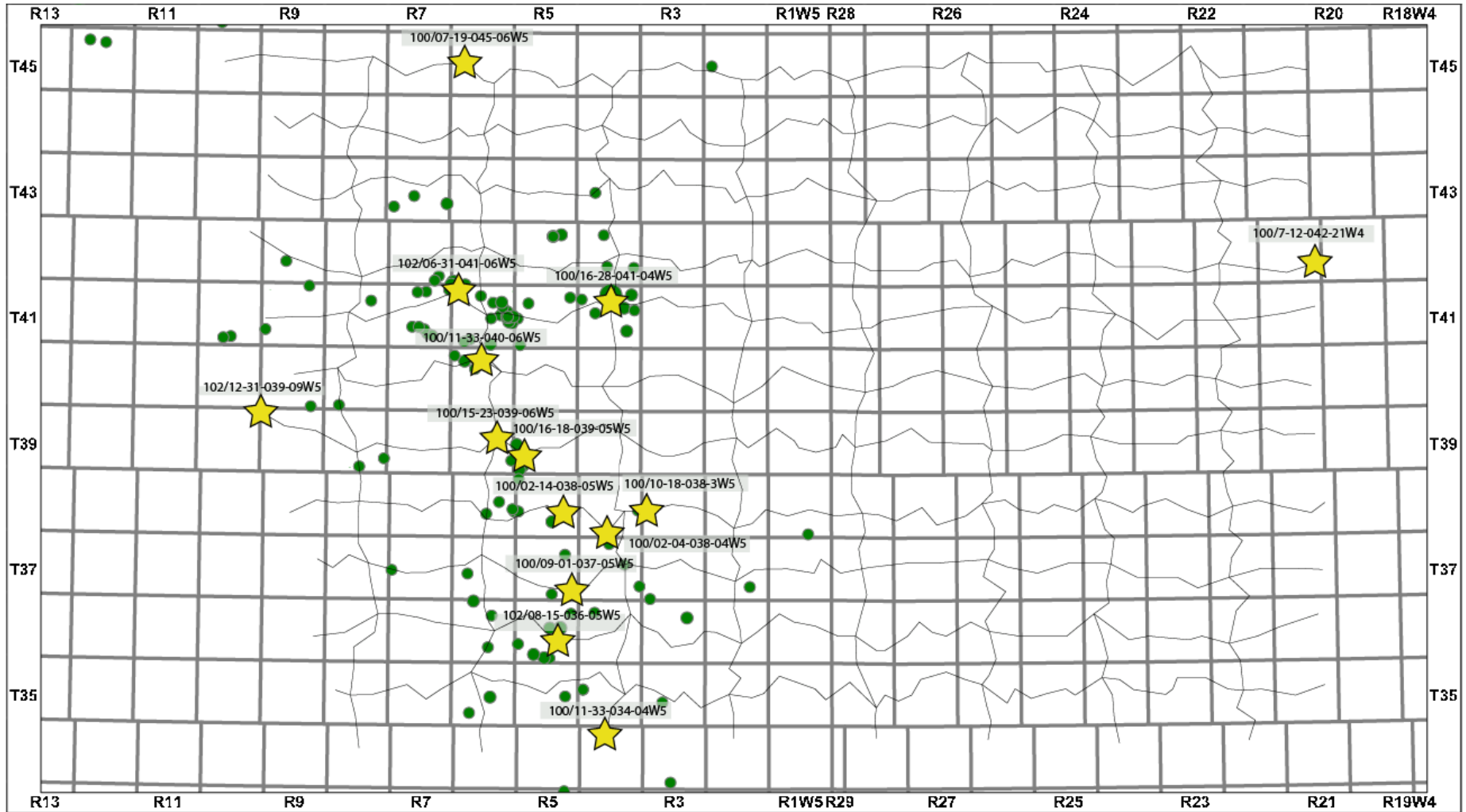
Reservoir Characterization

- TOC Rock-Eval data
- Potential reservoir fairway's
- "Sweet Spot" identification



- WCSB geothermal maturity gradient
- Conventional & unconventional 2WS
Biogenic gas, oil and dry gas producers
- Study area spans the mature oil window
- 4 main field areas, with abundant production, well log and core analysis data





Second White Specks
Production



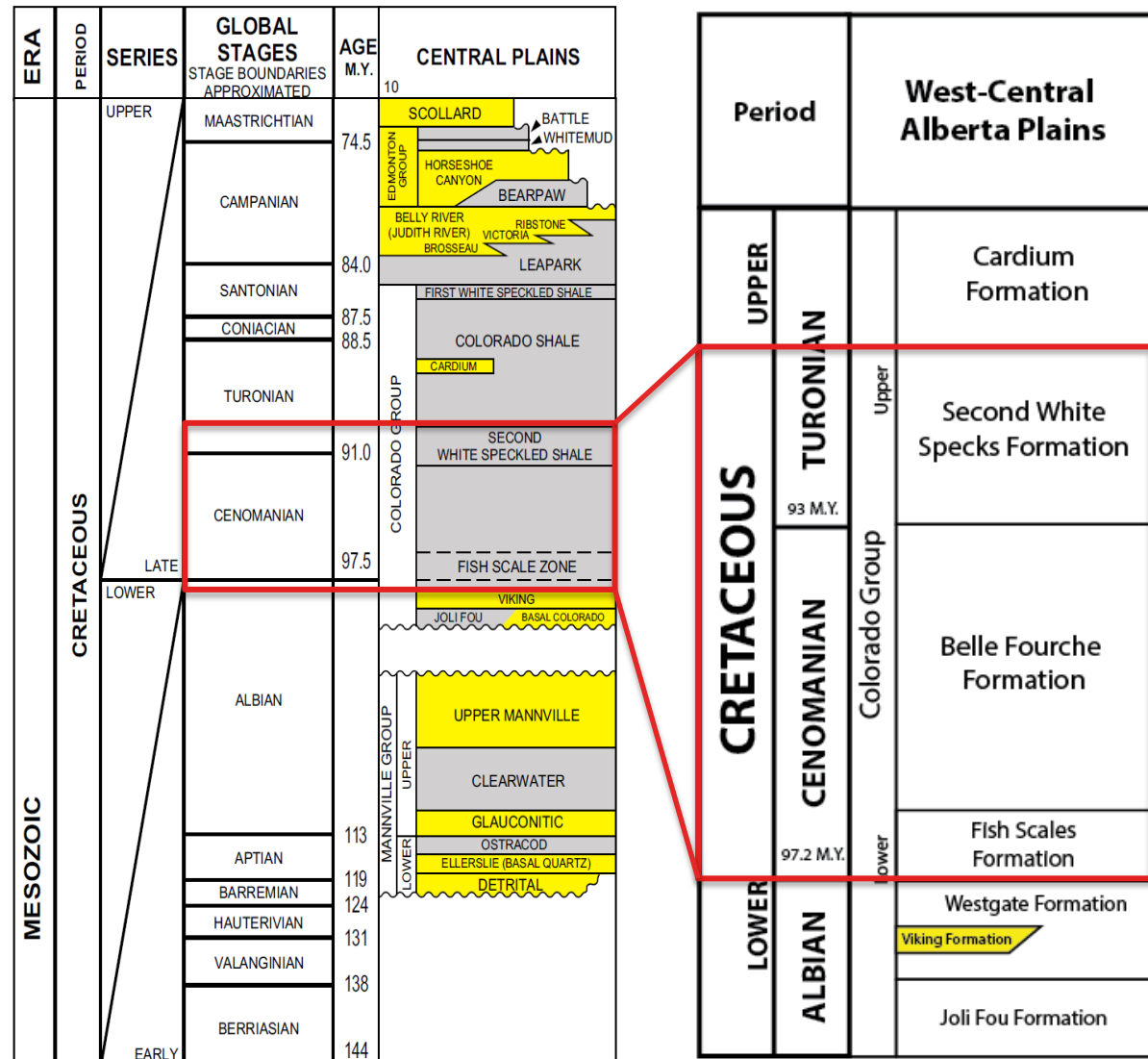
Analyzed Core



Cross Section Line

Stratigraphic Nomenclature

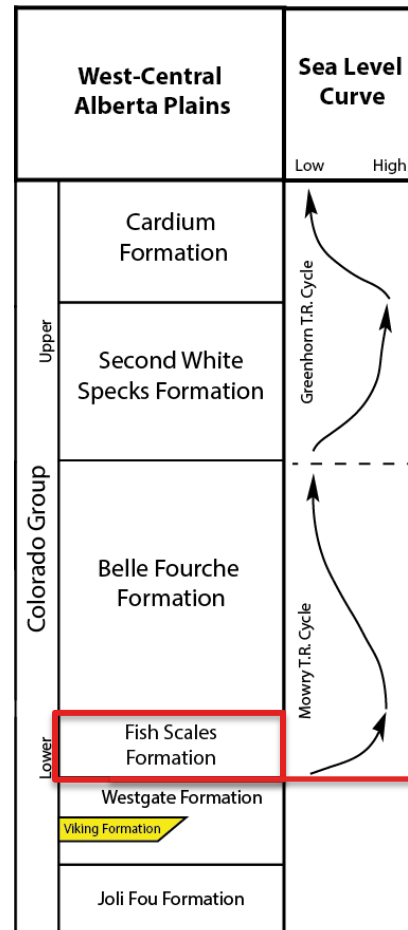
- Middle to Upper Cretaceous Second White Speckled Shales and Fish Scales Zone
- Comprised of 3 formations within west-central Alberta:
 - Fish Scales Fm
 - Belle Fourche Fm
 - Second White Specks Fm
- Deposited during ~8 my of variable:
 - Sea-level changes
 - Basin geometries
 - Oceanographic conditions
 - Sediment sources



Paleogeography- Late Albian/Early Cenomanian

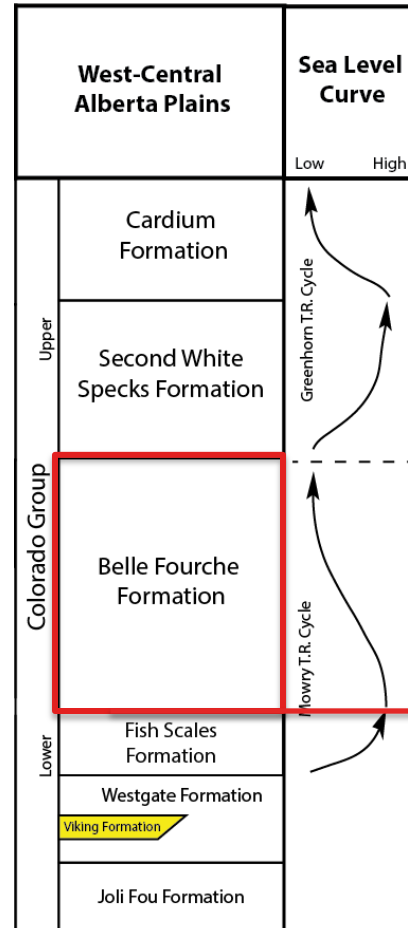
Fish Scales Formation

- Partial inundation of the North American Craton (Mowry Sea)
- Maximum Sea-level transgression
- Restricted bottom water circulation
 - Bottom water anoxia
 - Cold water biota
 - Siliceous input



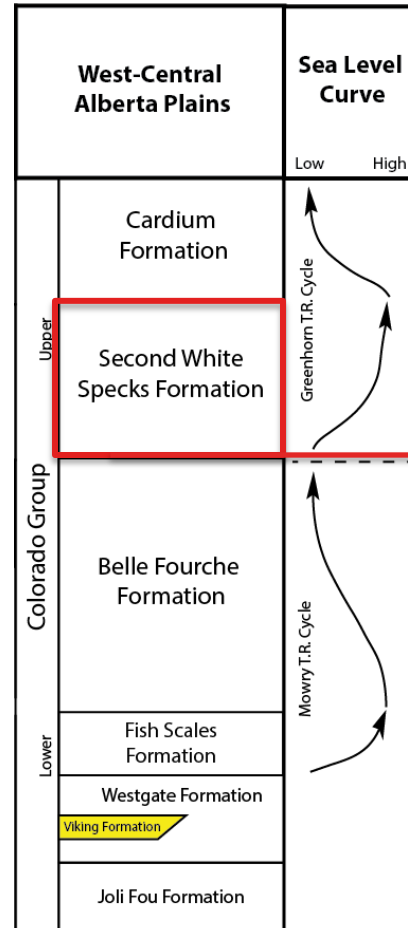
Belle Fourche Formation

- Boreal and Tethyan seas adjoin to form WIS
- Dunvegan Delta deposition
- Belle Fourche Fm forms lateral equivalent (Distal edge)
- Organic preservation potential? Reduced oceanic circulation?

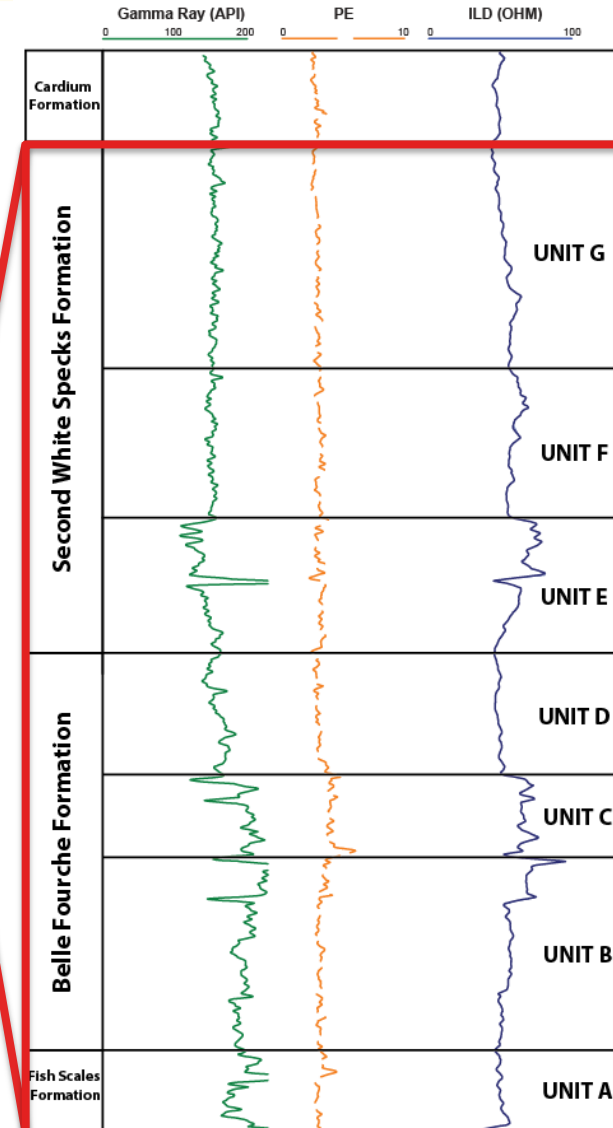
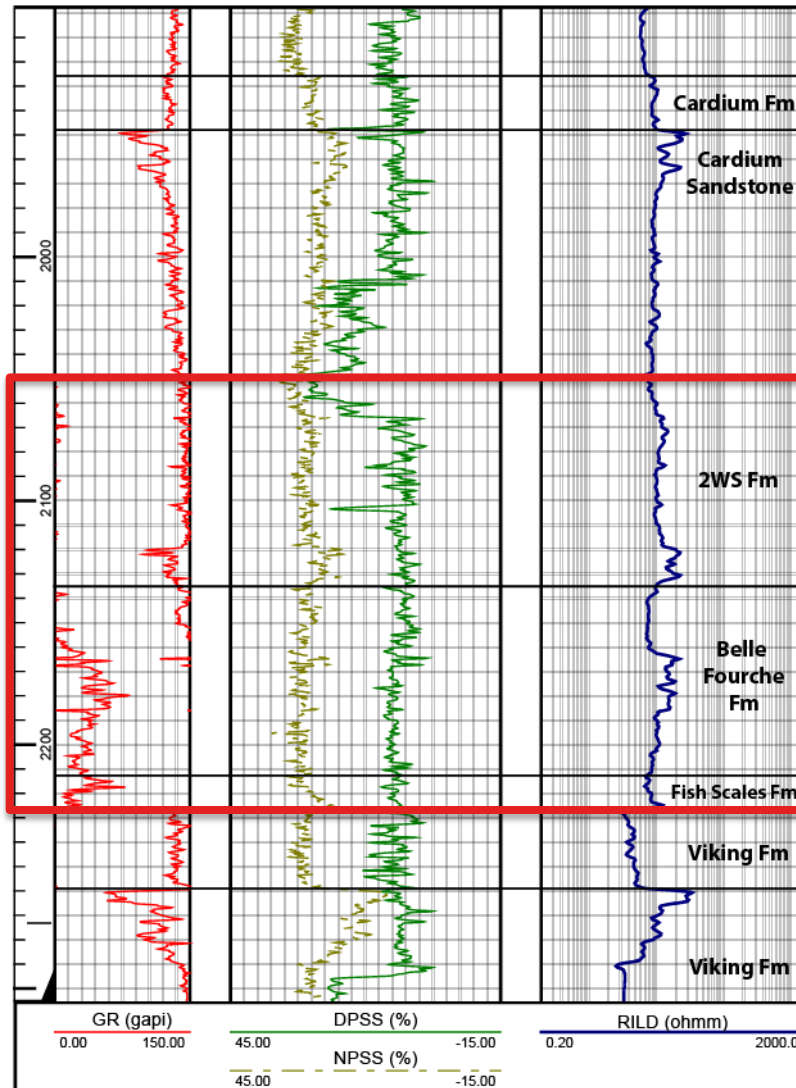


Second White Specks Formation

- Deposited during maximum sea-level transgression (Greenhorn T.R cycle)
- Low-angle, shelf setting influenced by:
 - Increased bottom water circulation (Warm water biota)
 - Periods of bottom water anoxia (preservation)

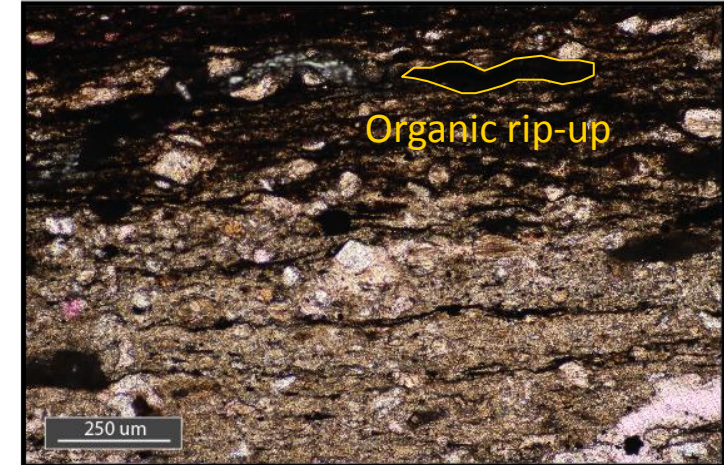
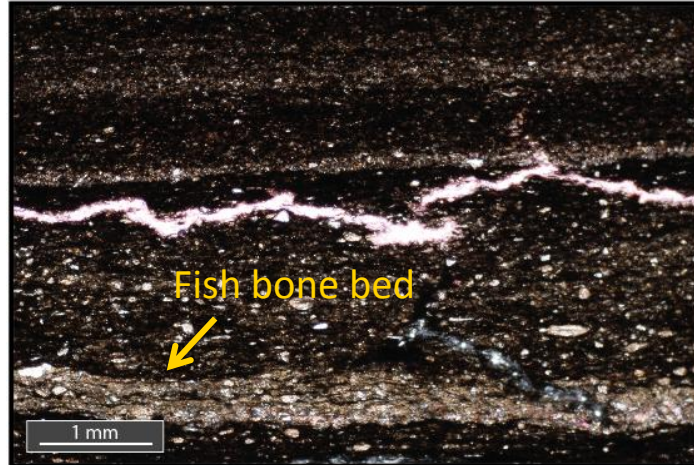
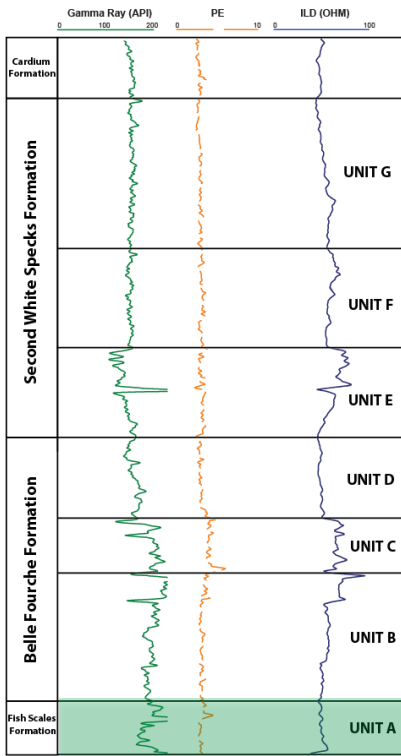


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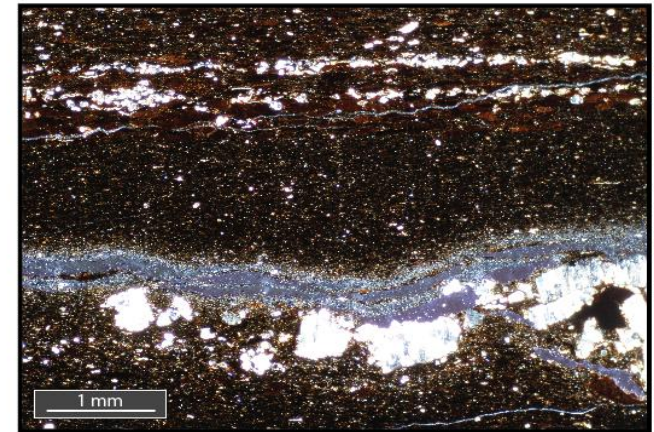
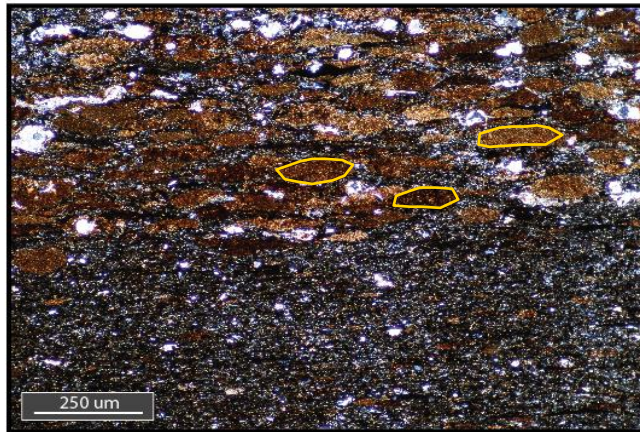
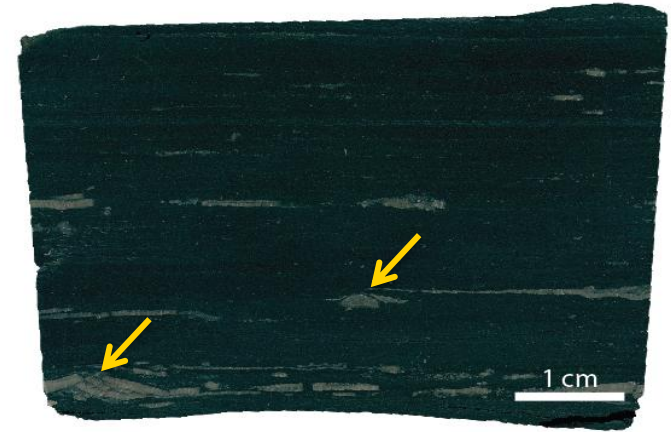
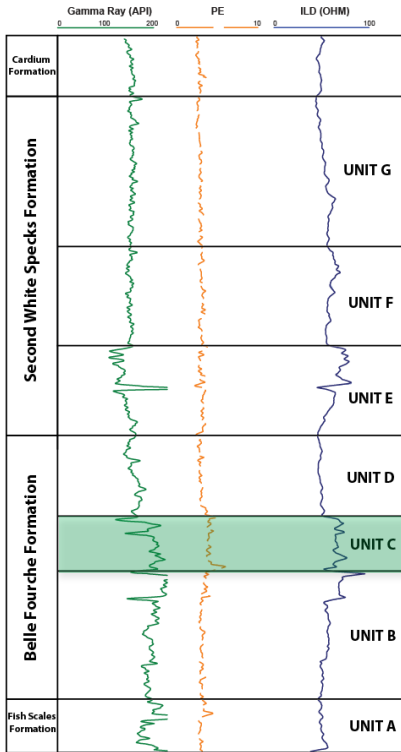
- Type log representative of the 2WS petroleum system
- Highly variable well log responses
- Succession broken up into 7 units each with characteristic lithofacies assemblages
- Multiple parasequences characterize each unit

Unit A- Fish Scales Formation



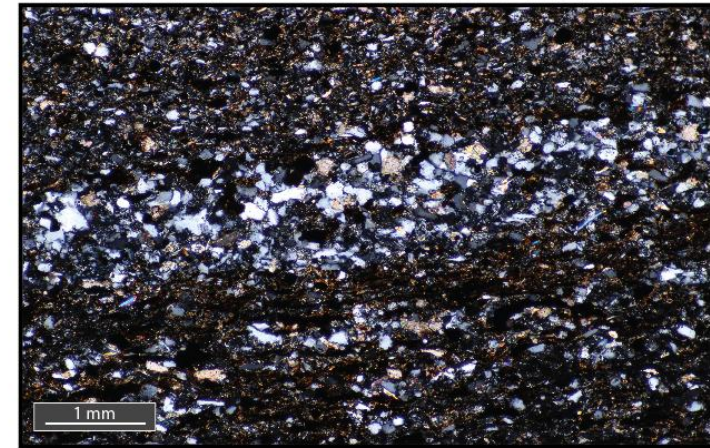
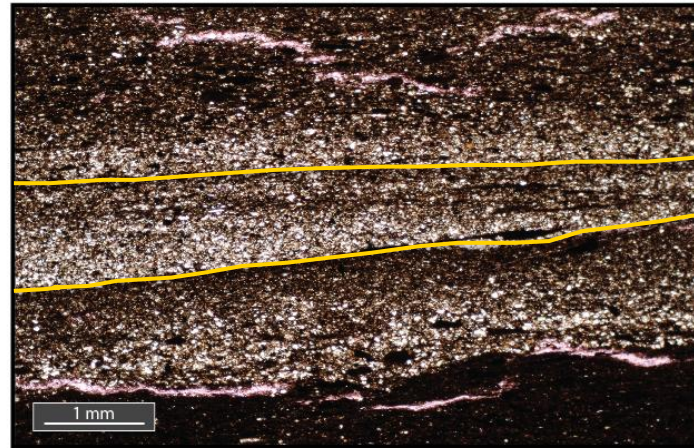
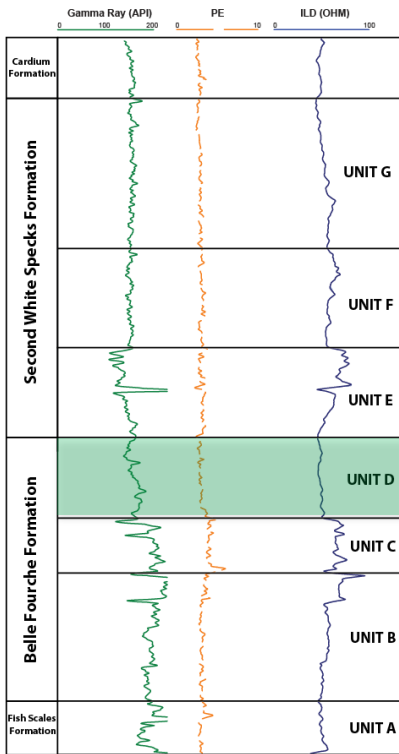
- Silty to very fine-grained organic rich mudstones
- Combined current structures, mottled silts, organic rip-ups
- Dispersed fish bone beds, graded beds
- Bioclastic debris, organic rip-up aggregate grains

Unit C- Middle Belle Fourche



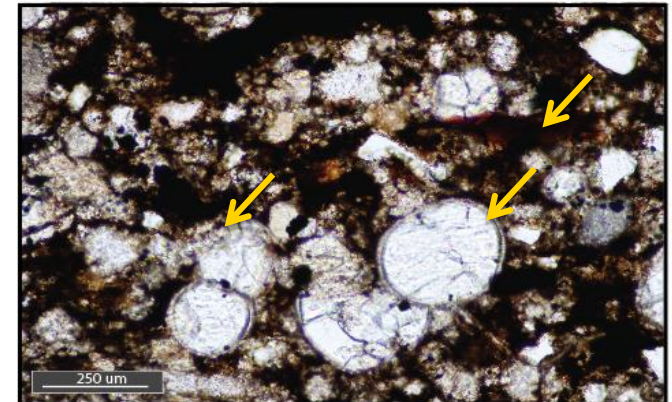
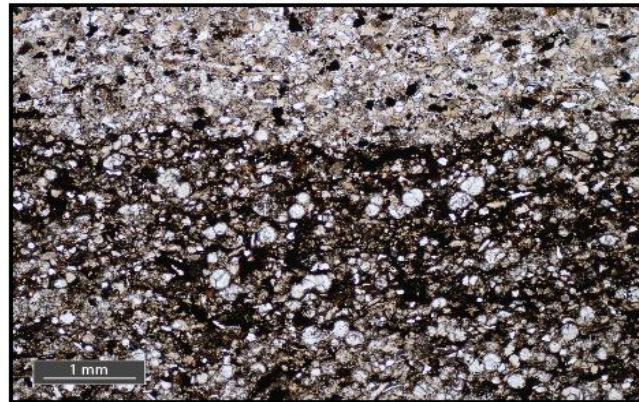
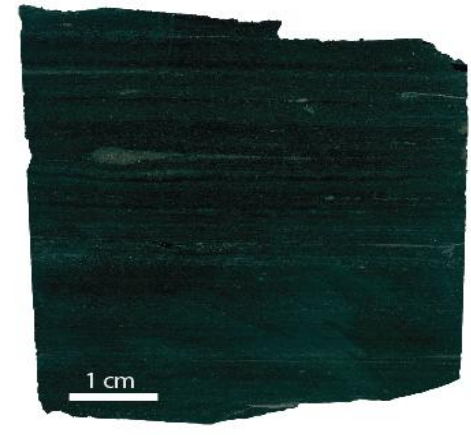
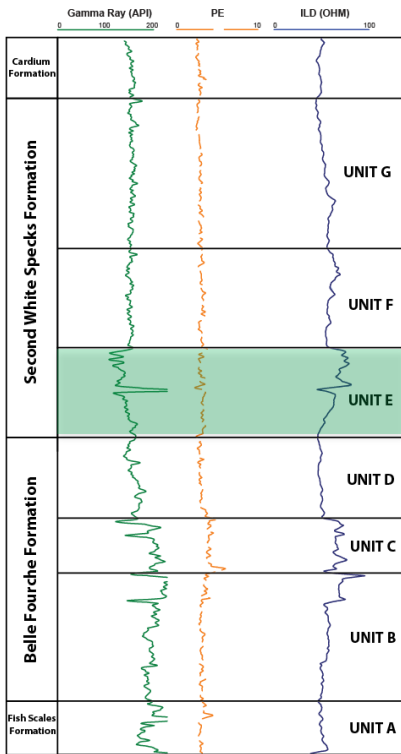
- Organic-rich, black calcareous mudstone
- Faint silt laminations and shell beds
- Calcified fecal pellet aggregates, siliceous bioclastics
- Laminated organic rip-up aggregates

Unit D- Upper Belle Fourche



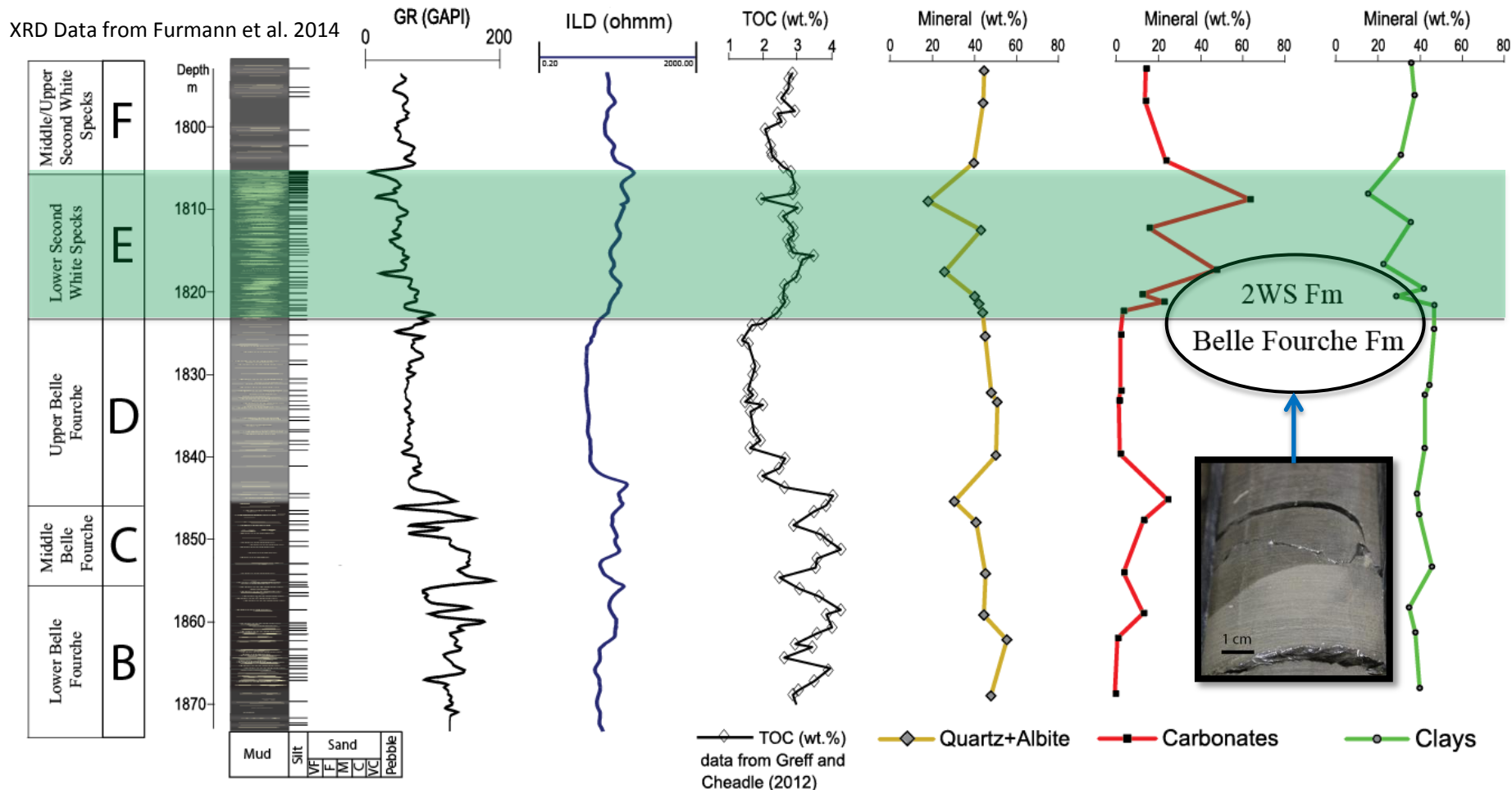
- Non to slightly calcareous grey silty mudstone
- Graded & erosive beds, scattered shell debris
- Abundant detrital quartz content, limited detrital calcite content
- Dispersed organic rip-up aggregates

Unit E- Lower Second White Specks



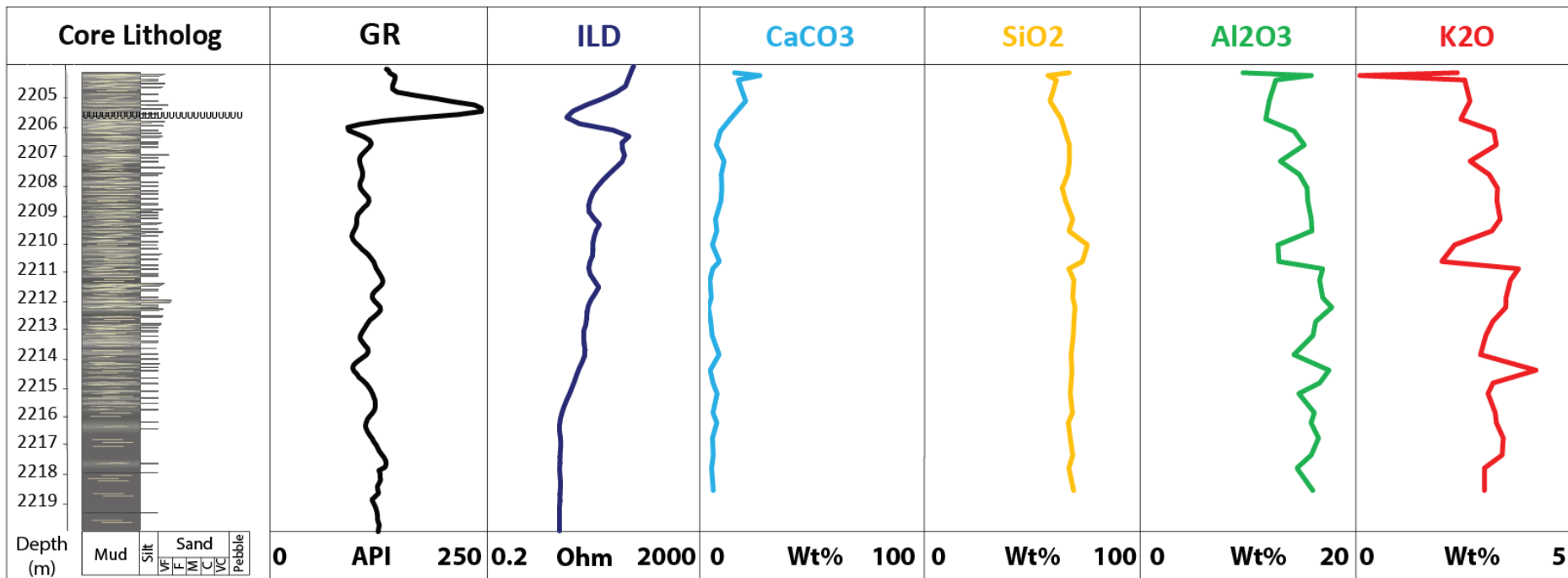
- Organic rich, silt to very-fine grained calcareous mudstone
- Moderately to heavily bioturbated silt laminations and beds
- Intermixed quartz and calcified forams
- Dolomite and ferroan calcite cementation
- Intermixed organic material

7-19-045-6W5 XRD & Rock-Eval Data



- Distinct well log responses associated with each unit
- Correlates to mineralogical and Rock-Eval data
- 2WS/Belle Fourche Contact

8-15-036-5W5 XRF Analysis-Unit E

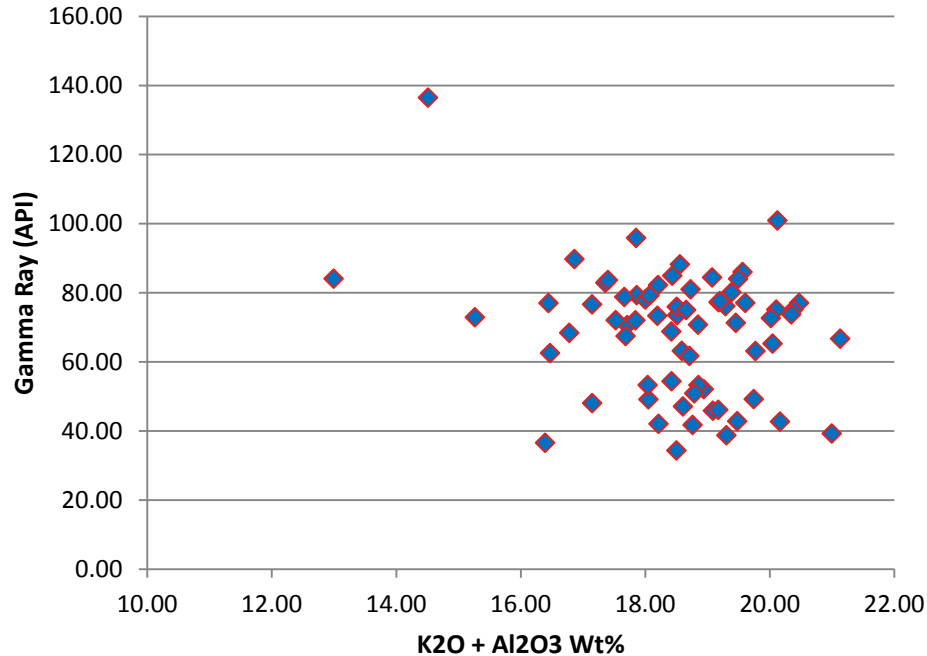


XRF Data collected by Shale Petroleum Ltd

- XRF data collected over unit E used to compare well log responses to lithological changes
- Used to compare GR and resistivity (ILD) responses to framework and matrix mineralogy's
- Al₂O₃ + K₂O Wt%'s correlate well with ILD, poor with GR
- Resistivity logs better reflect changes in lithology

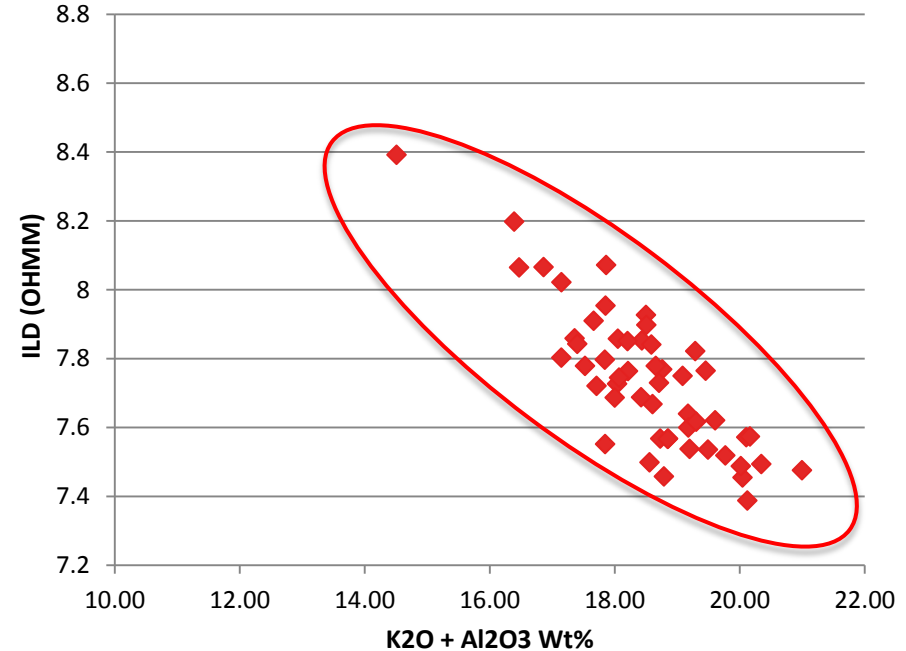
8-15-036-5W5 XRF Analysis-Unit E

K2O + Al₂O₃ vs Gamma Ray



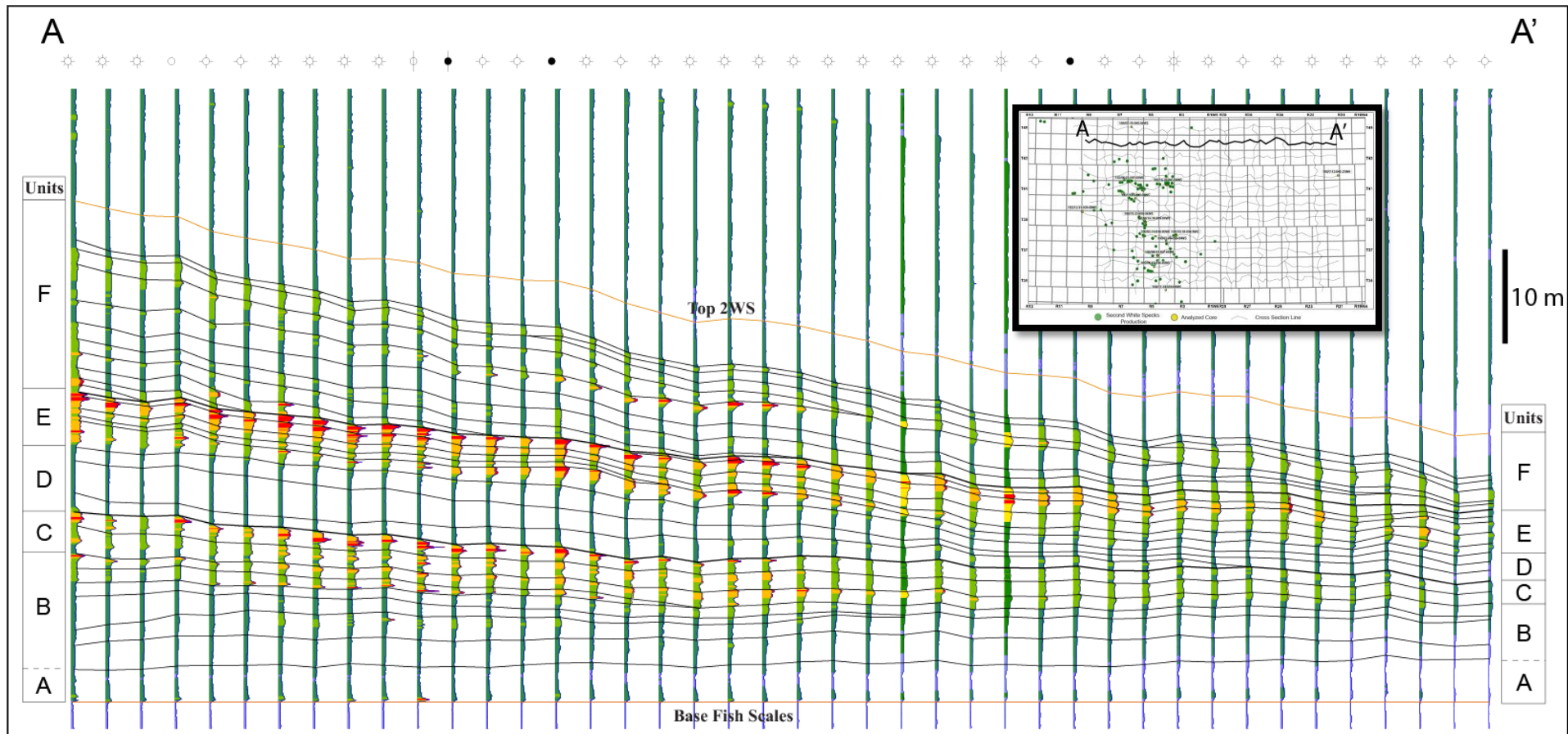
- K2O + Al₂O₃ Wt% vs GR
- Poor correlation between oxides and GR readings
- Suggests GR is a poor indicator of lithology

K2O + Al₂O₃ vs ILD

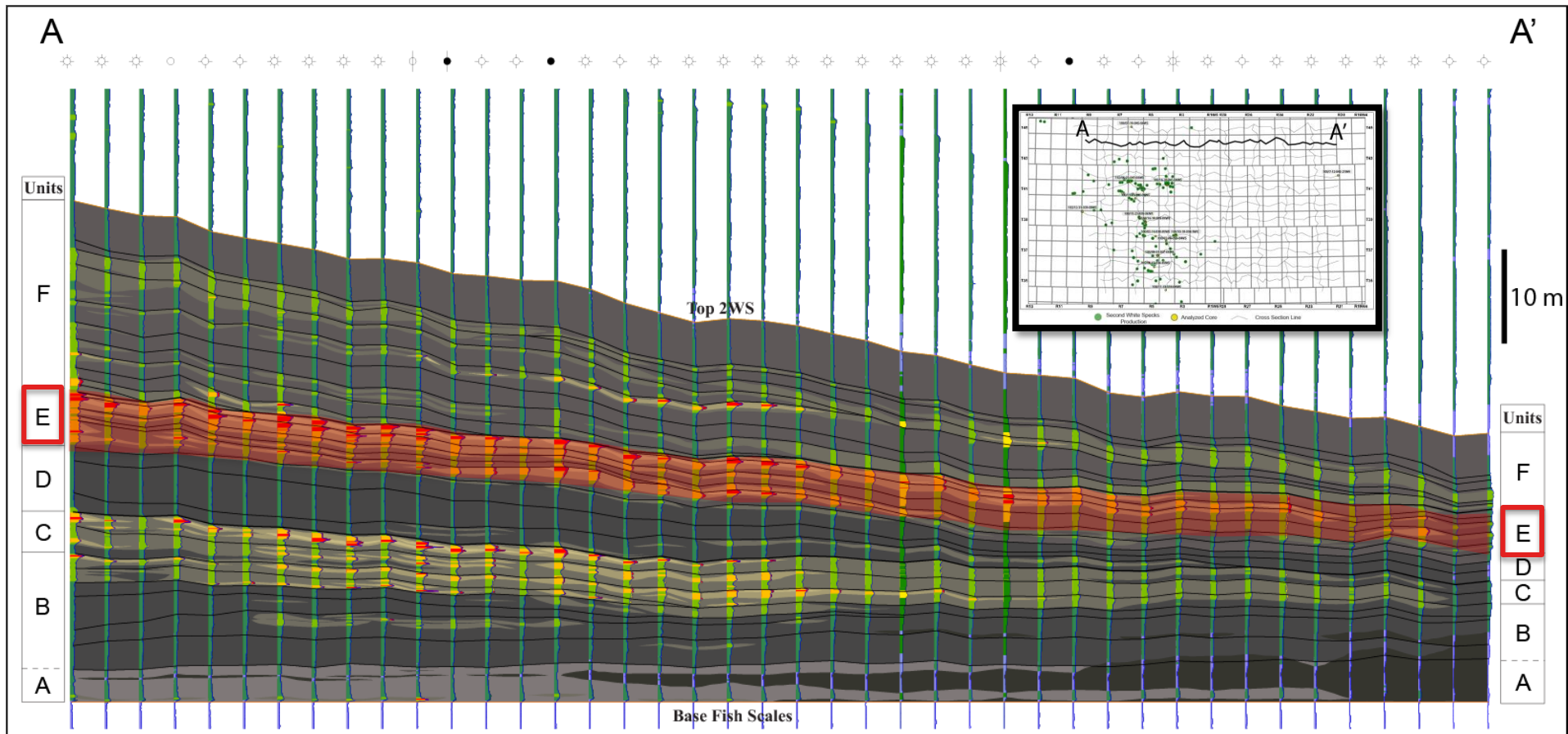


- K2O + Al₂O₃ Wt% vs ILD
- Linear relationship between oxides and ILD
- Suggests ILD responds well to changes in lithology
- “Petro-facies” identification?

Stratigraphic Architecture



- Major stratigraphic surfaces correlated regionally across the study area
- Surfaces reveal complex stratal architectures (basin-tapering wedges)
- Well log facies visualized using average resistivity intervals
- Enables interpretation of lateral and vertical facies changes



- Lateral facies changes within each unit and along stratigraphic surfaces

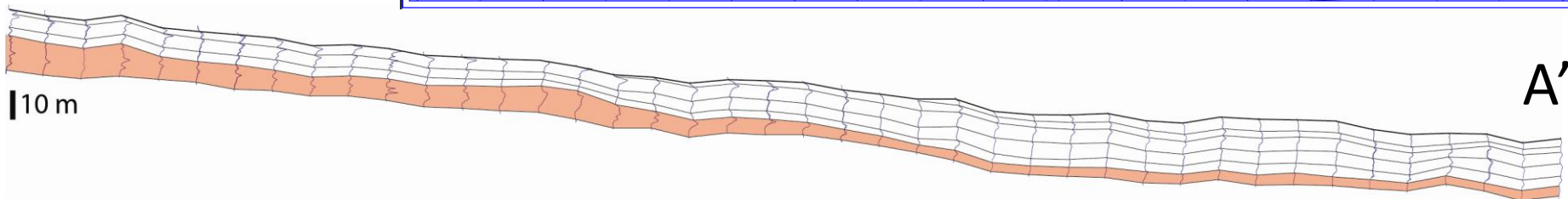
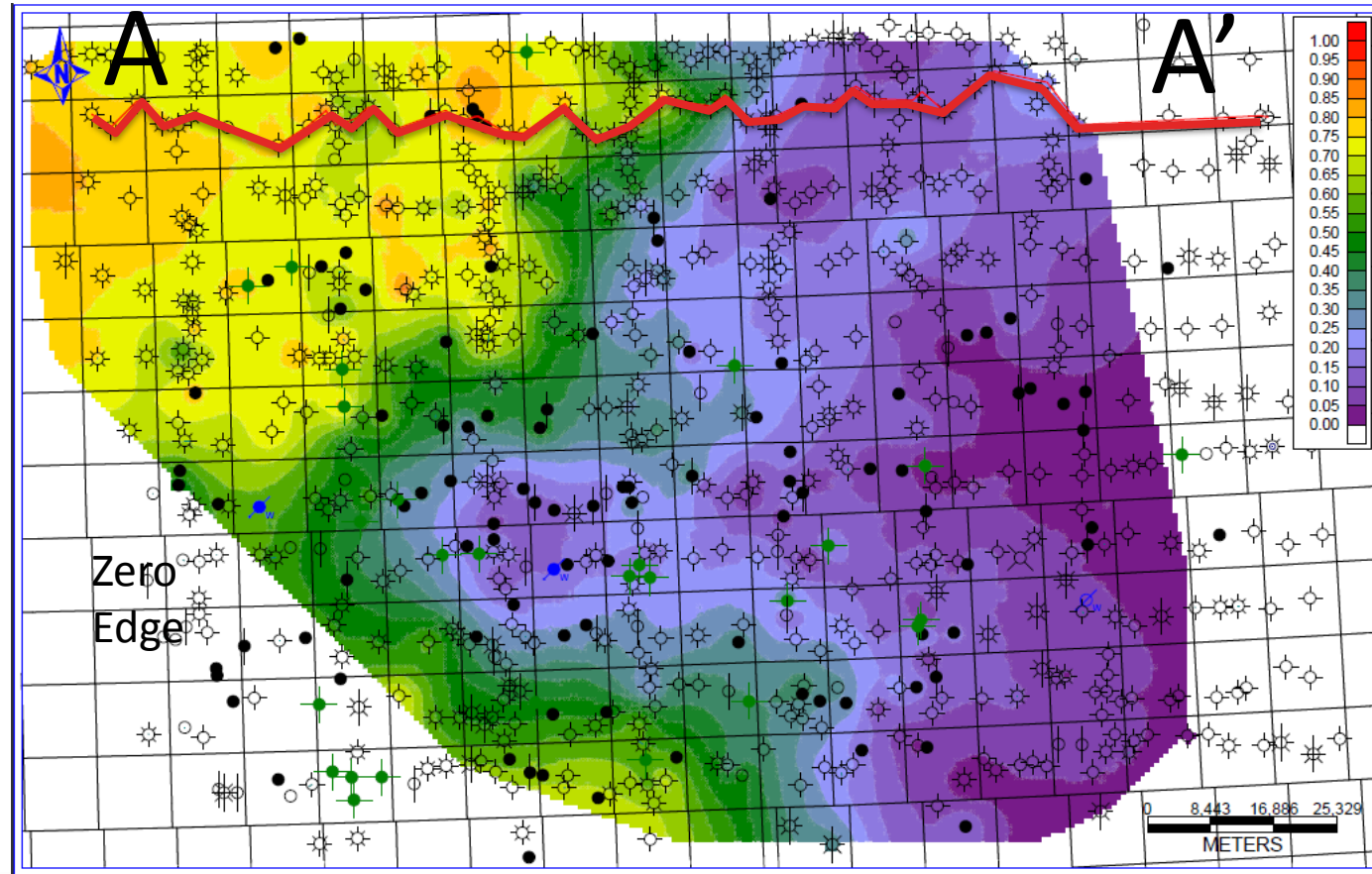
- Changing water depth? accommodation space? Source areas?

Facies Distribution

10 Ohm N/G Isopach Map

- N/G mapping associated with each parasequence within unit E
- Highlights potential shoreline orientations, depocenters and facies changes

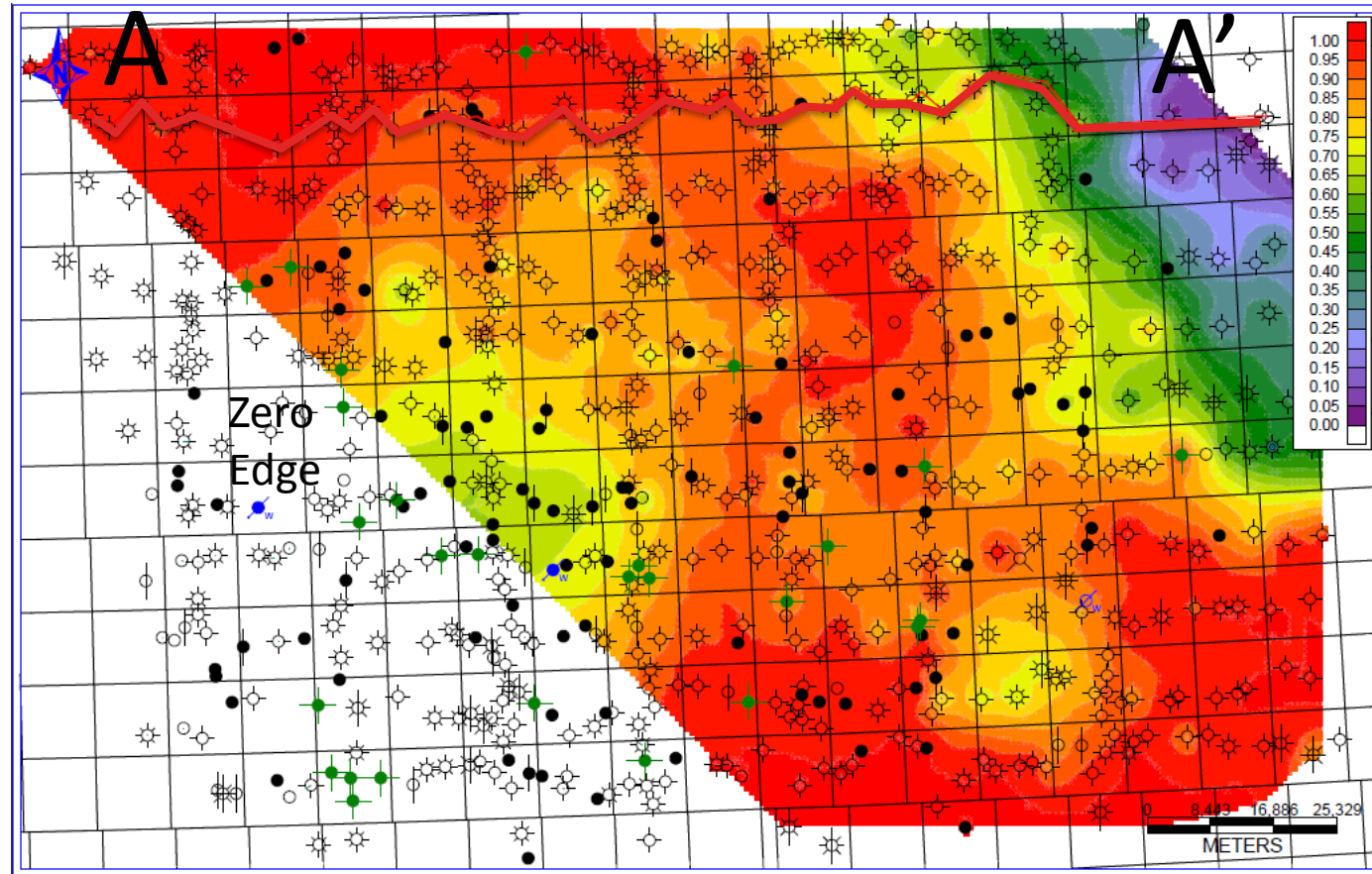
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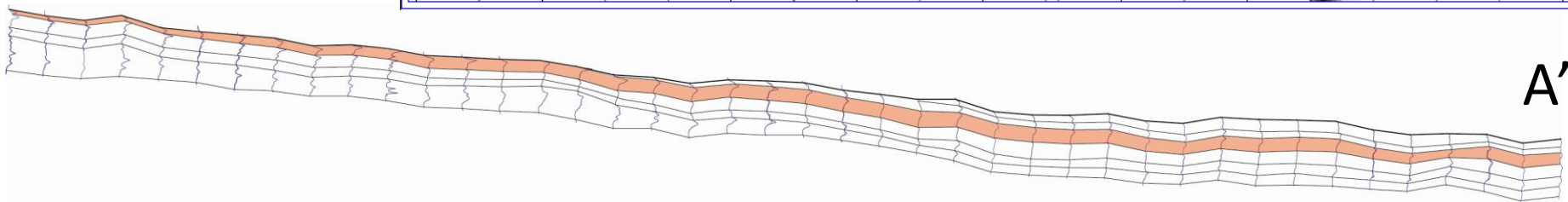
Facies Distribution-Unit E

10 Ohm N/G Isopach Map

- NW-SE fairway trend
- Progradation towards the northeast, subsequent filling of accommodation space
- Southwestern sediment source?



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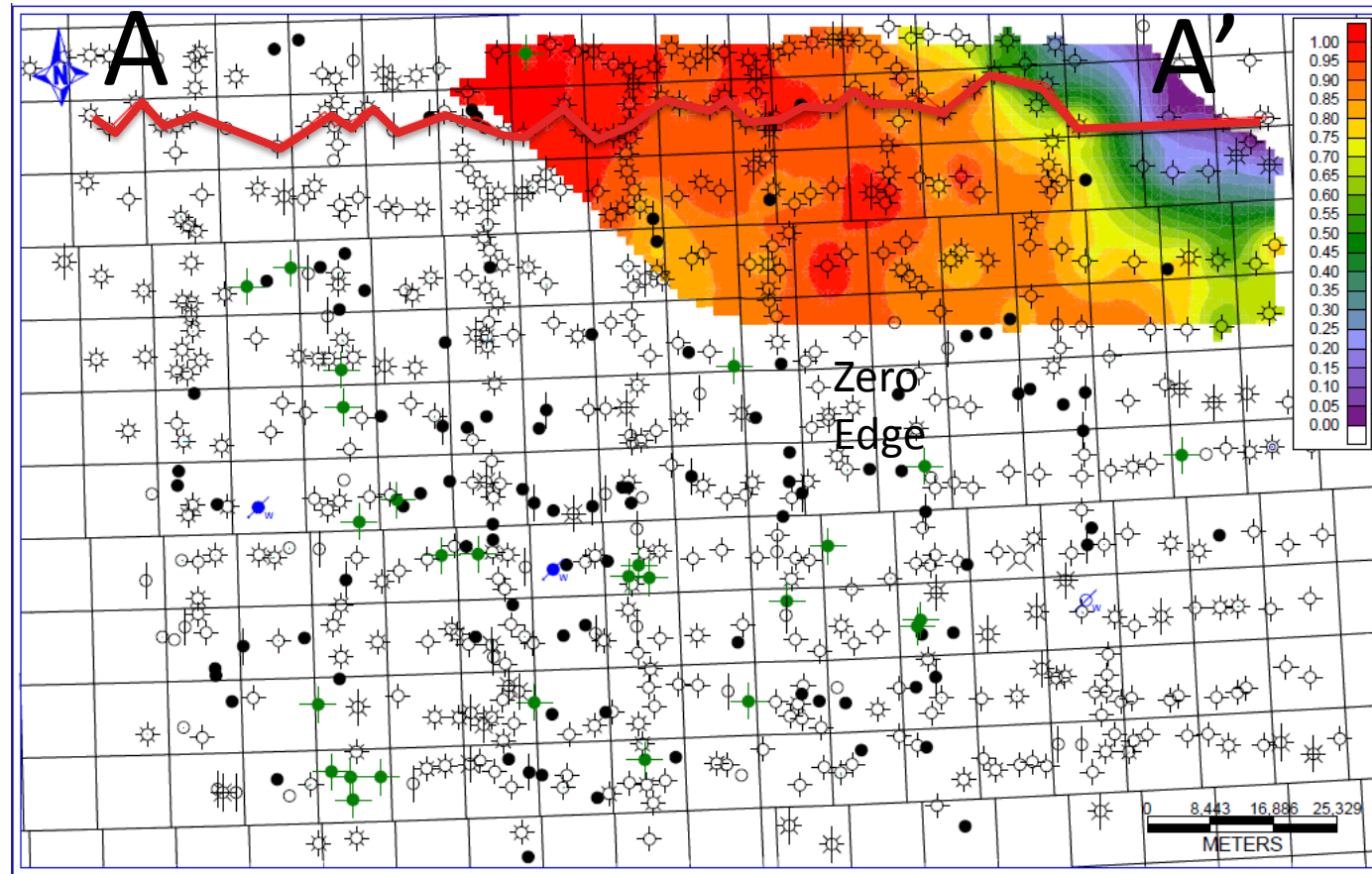


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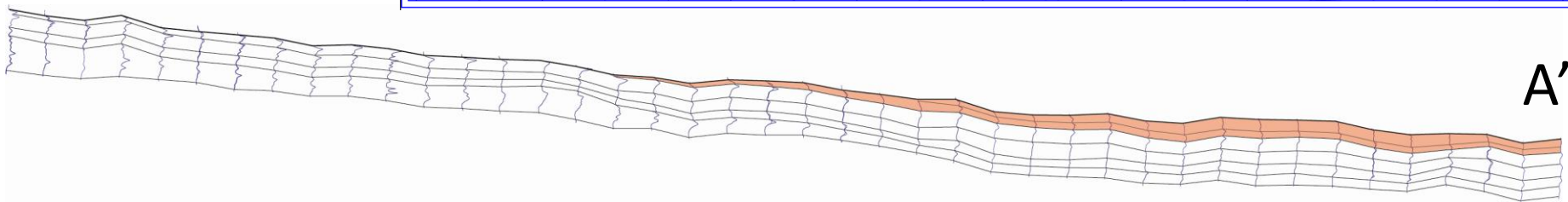
Facies Distribution-Unit E

10 Ohm N/G Isopach Map

- ~ E-W fairway trend
- Final progradational cycle within unit E
- Infilling of northeastern accommodation space



A



A'

1. Litho-facies heterogeneity

- Litho-facies assemblages unique to each unit
- Compositional variability:
 - Carbonate, siliciclastic detrital grains, mudstone aggregates.
- Sediment sources:
 - Western derived siliciclastics, bioclastics and aggregate grains.

2. Stratigraphic framework & lateral facies variability

- Low-angle, basin tapering wedge “clinoforms”
- Lateral facies changes along stratigraphic surfaces

3. Facies fairway trends

- High grading potential reservoir “sweet spots”
- Reflect complex depositional and basin histories



**Thank you to all
the sponsors of the
Tight Oil Consortium (TOC)**



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QUESTIONS?

