Mudstone Aggregate Origins and Depositional Interpretations of the Second White Specks and Carlile Formations in Eastern Alberta*

Ben Montgomery[1], Dallin Laycock[1], Ron Spencer[1], and Per Pedersen[1]

Search and Discovery Article #51155 (2015)**
Posted September 28, 2015

*Adapted from oral presentation given at AAPG 2015 Annual Convention and Exhibition, Denver, Colorado, May 31 – June 3, 2015

[1]Department of Geoscience, University of Calgary, Calgary, Alberta, Canada (bencsmontgomery@gmail.com)

Abstract

Mudstone aggregates form the main detrital component of mudstone-dominated strata of the Upper Cretaceous Second White Specks and Carlile Formations. Although separated by a conformable boundary, these two formations were deposited in very different oceanic conditions within the Interior Cretaceous Seaway. The Second White Specks (2WS) Formation is comprised of organic rich mudstones with a large content of calcareous macro- and microfossils, and at several levels calcareous fine-grained sandstone beds. It varies from 5–7% TOC and is dominated by type II and III kerogens. The 2WS is an established target for biogenic oil and gas production but a thorough understanding of the complex stratal architecture remains challenging and ongoing. In contrast, the Carlile Formation is comprised of intensely bioturbated non-calcareous mudstones with a variable content of silt- and sand-sized silica grains, with the strata forming 20–30m tall mudstone clinoforms in contrast to the tabular stratal architecture of the 2WS strata. The mudstone aggregates are well preserved in the studied strata due to the relative shallow maximum burial of approximately 1500–2000m. The aggregates occur as silt- to sand-sized particles with different composition, with the oval shape indicating they are only slightly compacted and that they were semi-indurated at the time of deposition. Potential origin of the mudstone aggregates includes extrabasinal grains, and/or intrabasinal rip-up clasts, or crustacean micro-coprolite fragments. However, the presence of coccolith fragments within the aggregates clearly demonstrates that the majority of the mudstone aggregates are intraformational; however, their variable composition from the surrounding matrix mud suggests transport a significant distance from their site of origin. Furthermore, significant abrupt vertical changes in the grain size of the mudstone aggregates and their chemical composition shows that the area of origin changes between dominantly intra-formation rip-up clasts to micro-coprolites, relating to relative sea level changes. However, as individual

sequence stratigraphic units often have relative uniform composition of the mudstone aggregates, composition of the mudstone aggregates do not seem to be strongly related to water depth but rather changes in circulation within the Interior Seaway.

References Cited

Blakey, R., 2011, Library of Paleogeography: Web Accessed September 5, 2015, www.cpgeosystems.com/paleomaps.html.

Furmann, A., M. Mastalerz, A. Schimmelmann, K.P. Pedersen, and B. Bish, 2014, Relationships between porosity, organic matter and mineral matter in mature organic-rich marine mudstones of the Belle Fourche and Second White Specks formations in Alberta, Canada: Marine and Petroleum Geology, v. 54, p. 65-81.

Gray, D.A., J. Majorowicz, and M. Unsworth, 2012, Investigation of the geothermal state of sedimentary basins using oil industry thermal data: case study from Northern Alberta exhibiting the need to systematically remove biased data: Journal of Geophysics and Engineering, v. 9/5, p. 534-548, http://dx.doi.org/10.1088/1742-2132/9/5/534.

Laycock, D.P., 2014, Stratigraphy, sedimentology, and geochemistry of mudstone-dominated clinoforms and their depositional environments, Carlile Formation, Eastern Alberta, Canada: PhD Dissertation, University of Calgary, Calgary, Alberta, Canada, http://hdl.handle.net/11023/1525.

Schieber, J., and J.B. Southard, 2009, Bedload Transport of Mud by Floccule Ripples – Direct Observation of Ripple Migration Processes and their Implications: Geology, v. 37, p. 483-486, Web Accessed September 5, 2015, http://www.indiana.edu/~sepm04/PDF/JS-J45-Geology-2009.pdf.

MUDSTONE AGGREGATE ORIGINS AND DEPOSITIONAL INTERPRETATIONS OF THE SECOND WHITE SPECKS AND CARLILE FORMATIONS IN EASTERN ALBERTA

Ben Montgomery, Dallin Laycock, Ron Spencer, Per Pedersen

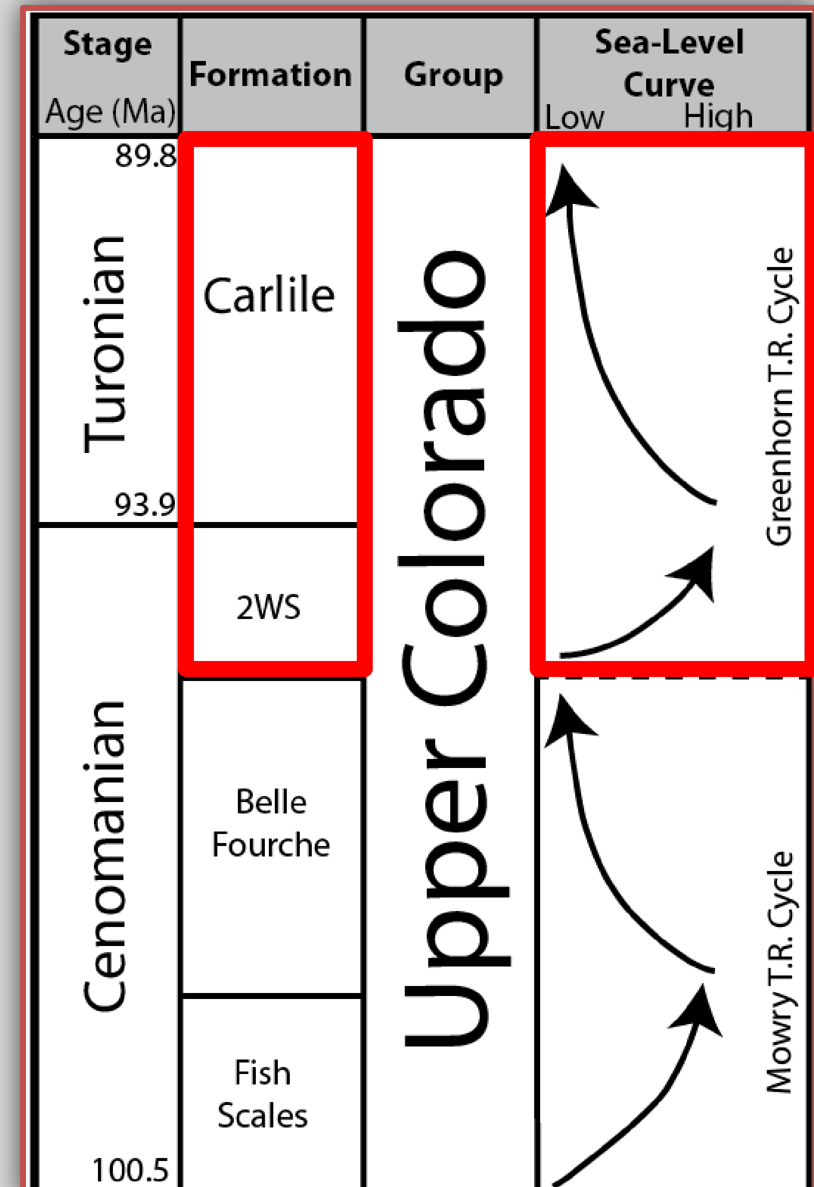
Centre for Applied Basin Studies
Department of Geoscience
University of Calgary
Calgary, AB

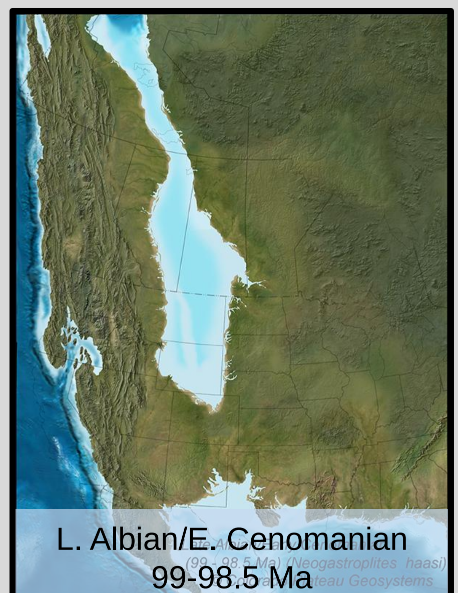
AAPG Annual Convention 2015

31 May – 3 June 2015

Denver, Colorado

Upper Colorado Group Paleogeography





Blakey, http://www.cpgeosystems.com/paleomaps.html

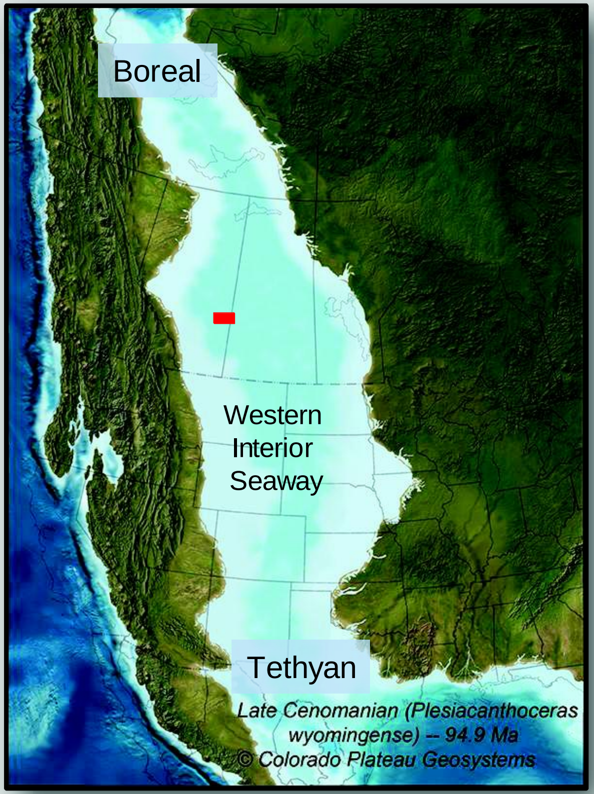
Second White Specks Formation

•Calcareous Mudstone Dominated

•Largely Storm-Influenced

•Deposited on:
Low-angle, Inner-Middle Shelf

•Deposition influenced by mixing of
Warm Water (Tethyan)
Cold Water (Boreal)



Blakey, http://www.cpgeosystems.com/paleomaps.html

Presenter's notes:
During the Middle Turonian, the Second White Specks Formation was deposited during msl transgression (Green horn):

- has been largely interpreted to be deposited on low angle, inner, middle shelf setting, largely storm influenced,
- bottom water circulation, full introduction of warm water biota, forams from Tethyran and cold water from boreal, forms counter clockwise oceanic gyre, significant influence of sediment transport mechanisms during this time
- Mixing of different water masses created a stratified water column with periods of anoxia and org preservation

Carlile Formation

•Non-Calcareous Mudstone Dominated

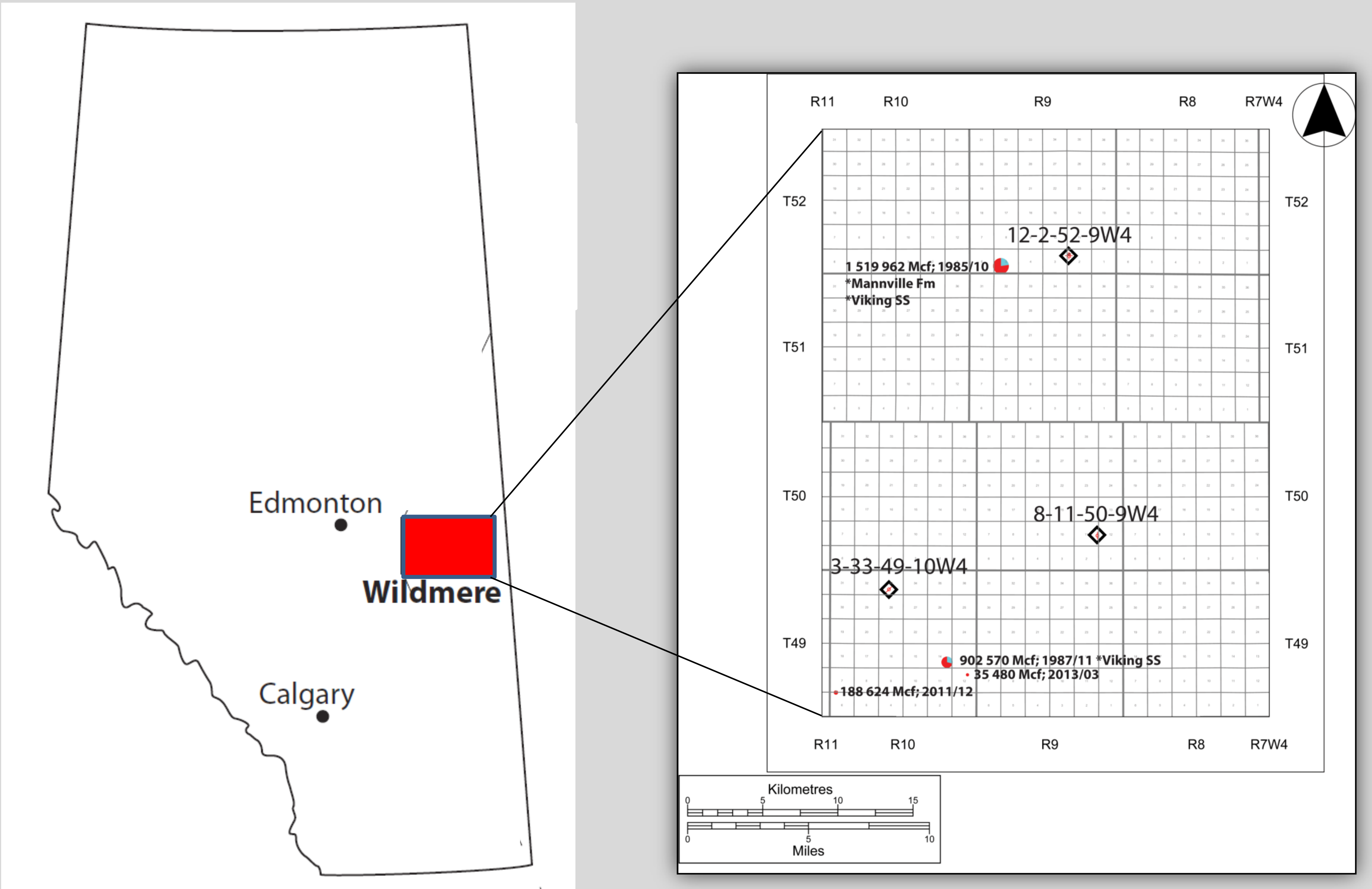
•Variable Amounts of Interbedded
Siltstone and Sandstone

•Deposited on:
Distal Shelf Environment

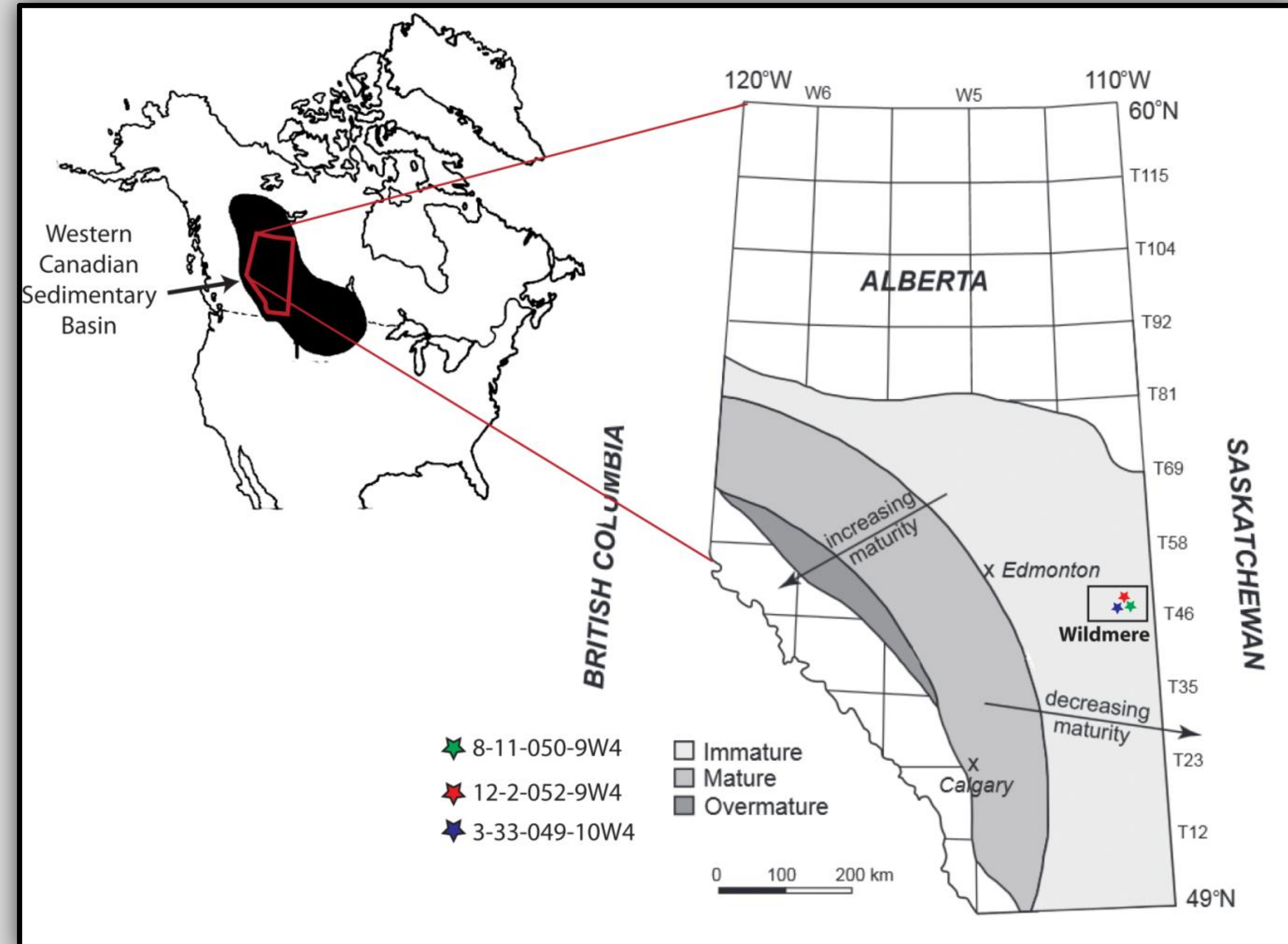
•In Study Area, Carlile Forms a Detached
Clastic wedge with Clinoform Geometry
(Laycock, 2014)

Blakey, http://www.cpgeosystems.com/paleomaps.html

Wildmere Study Site

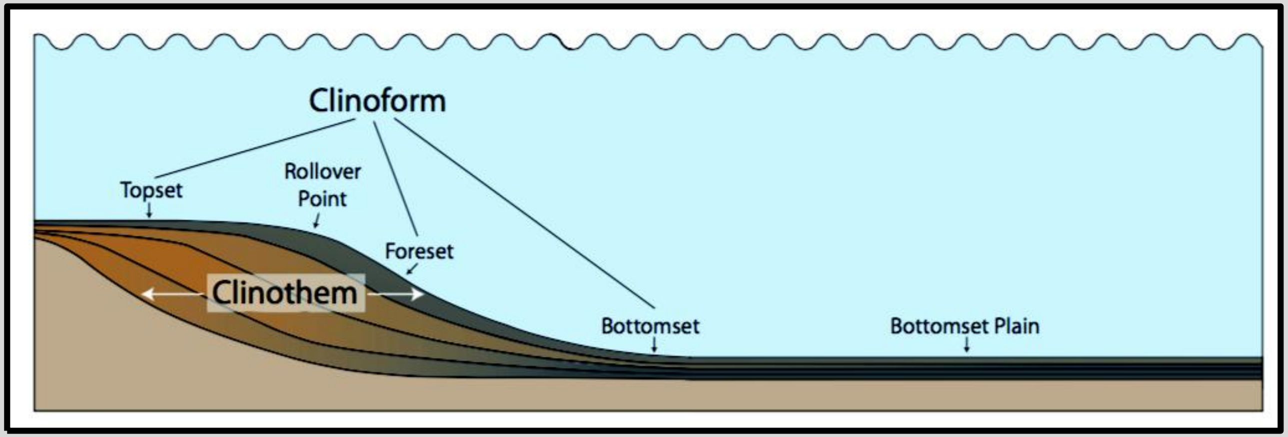


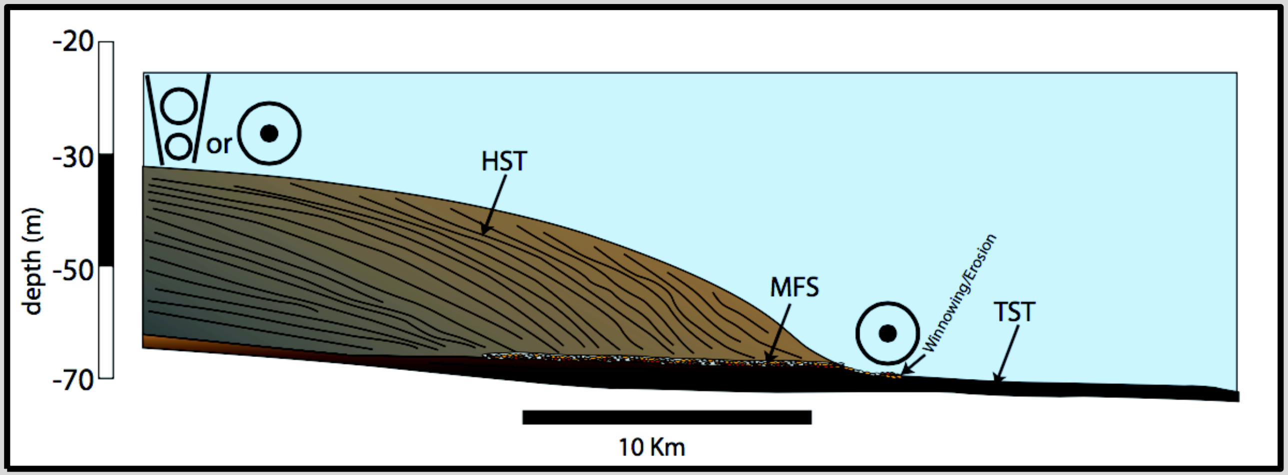
Thermal Maturity of Second White Specks Fm.



Modified from: Furmann et al., 2014

Mud-Dominated Clinoforms in Carlile Formation

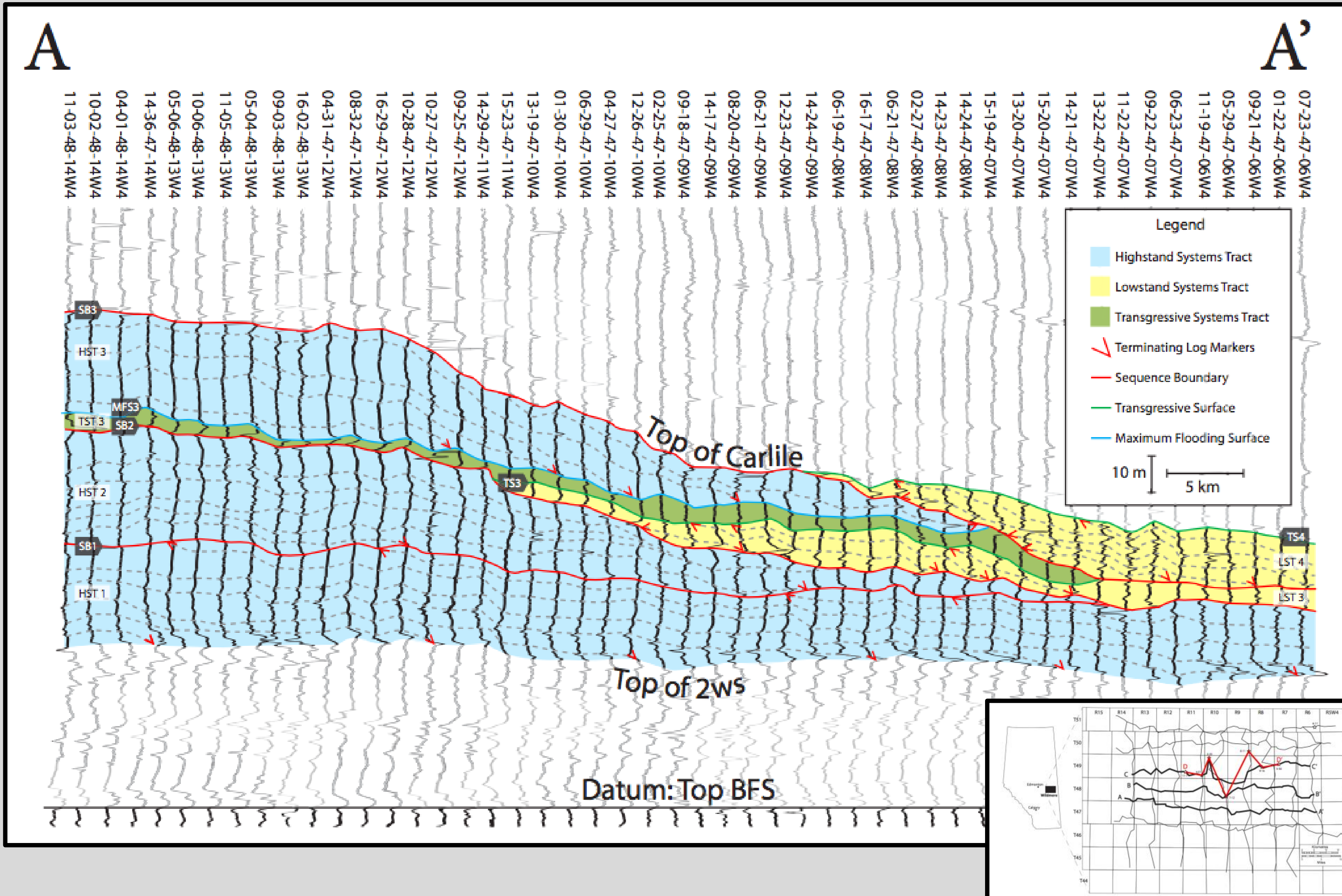




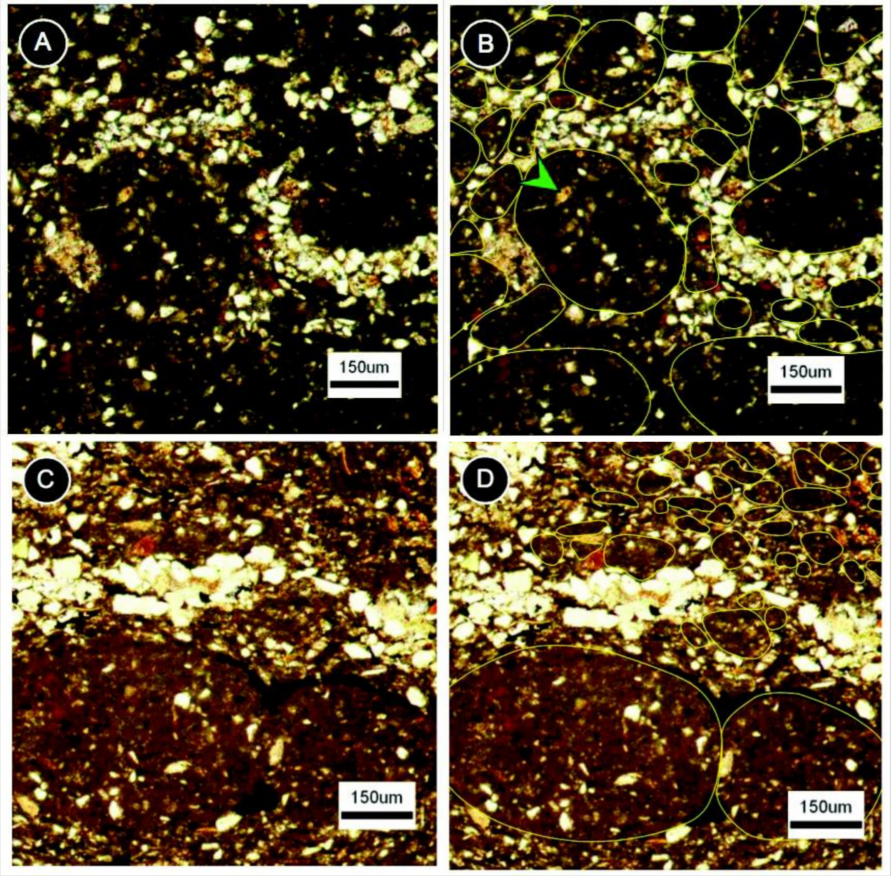
Laycock , 2014

Presenter's notes: The clinoform geometry observed within the Carlile Formation is likely the result of bottomset currents limiting deposition along the toe of the clinoforms, with either wave energy or other subaqueous currents limiting deposition along the topset of the clinoforms.

Mud-Dominated Clinoforms in Carlile Formation



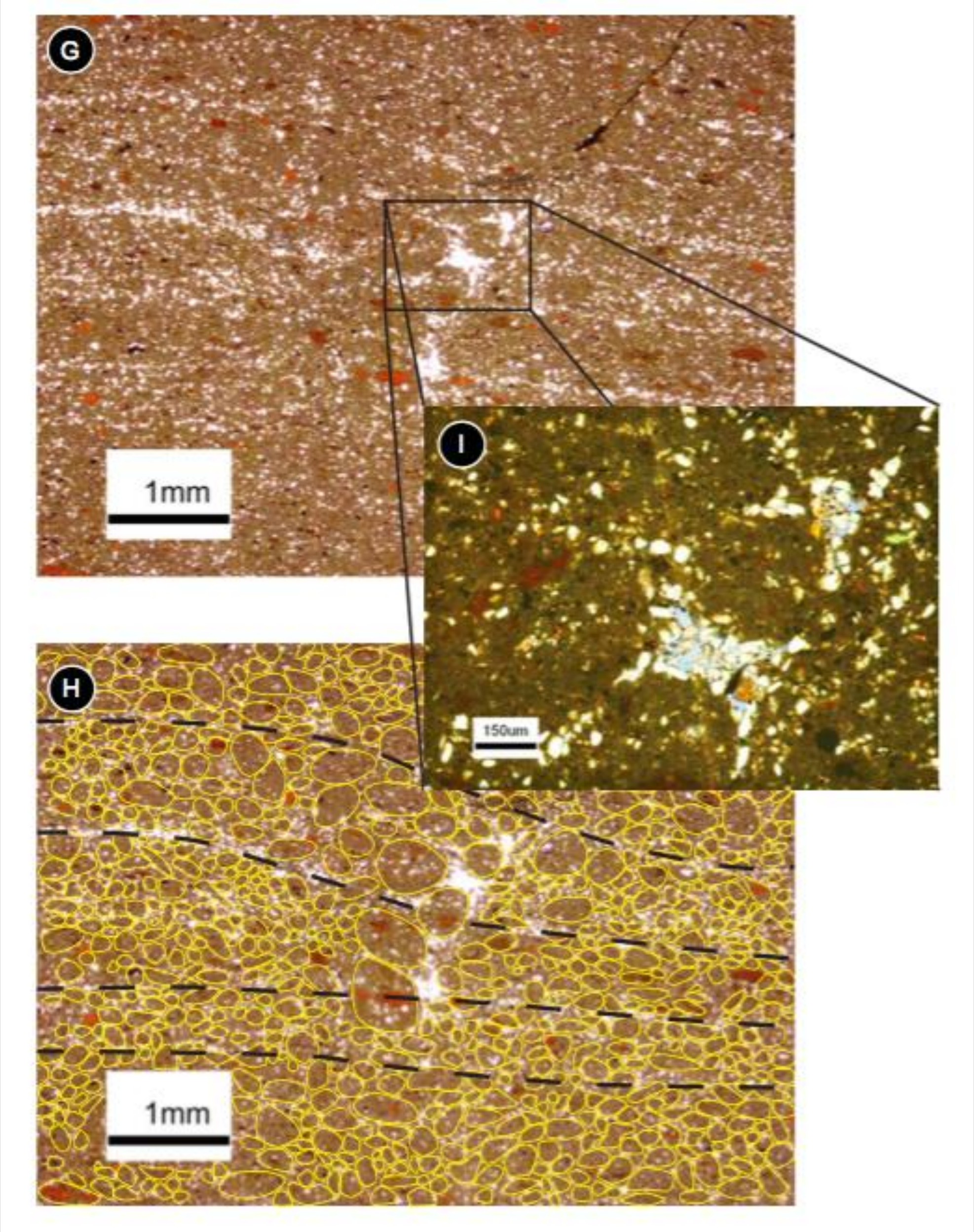
Mudstone Aggregates in the Carlile Fm.



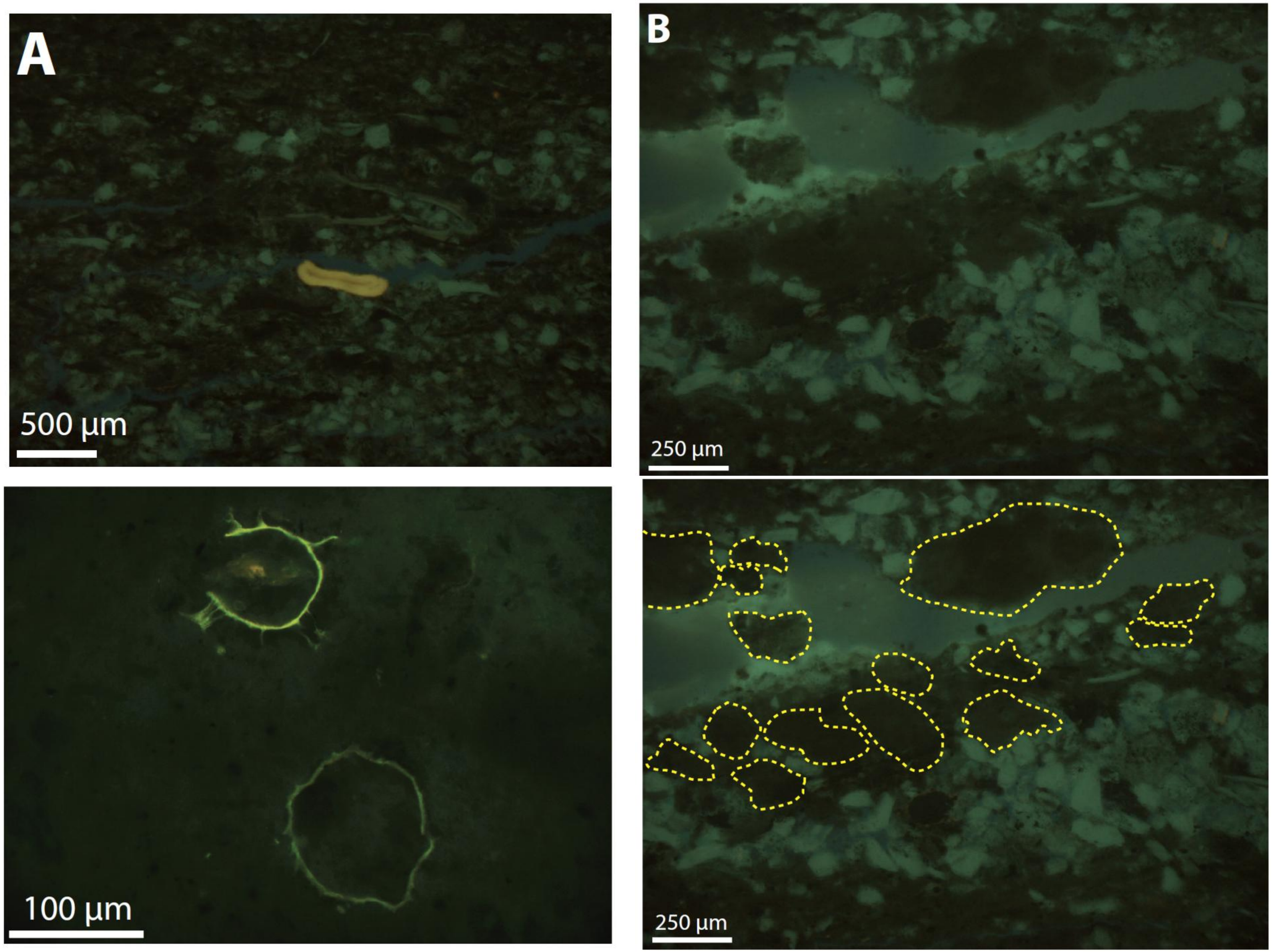
- Silt and Sand-sized
- Mainly composed of clay
- Various amounts of:
  - Quartz
  - Micritic Calcite
  - Shell Fragments
  - Siderite
  - Organic Matter

Presenter's notes: These are mostly composed of clay particles, but also include varying amounts of smaller grains of quartz, micritic calcite, shell fragments, siderite, and organic matter.

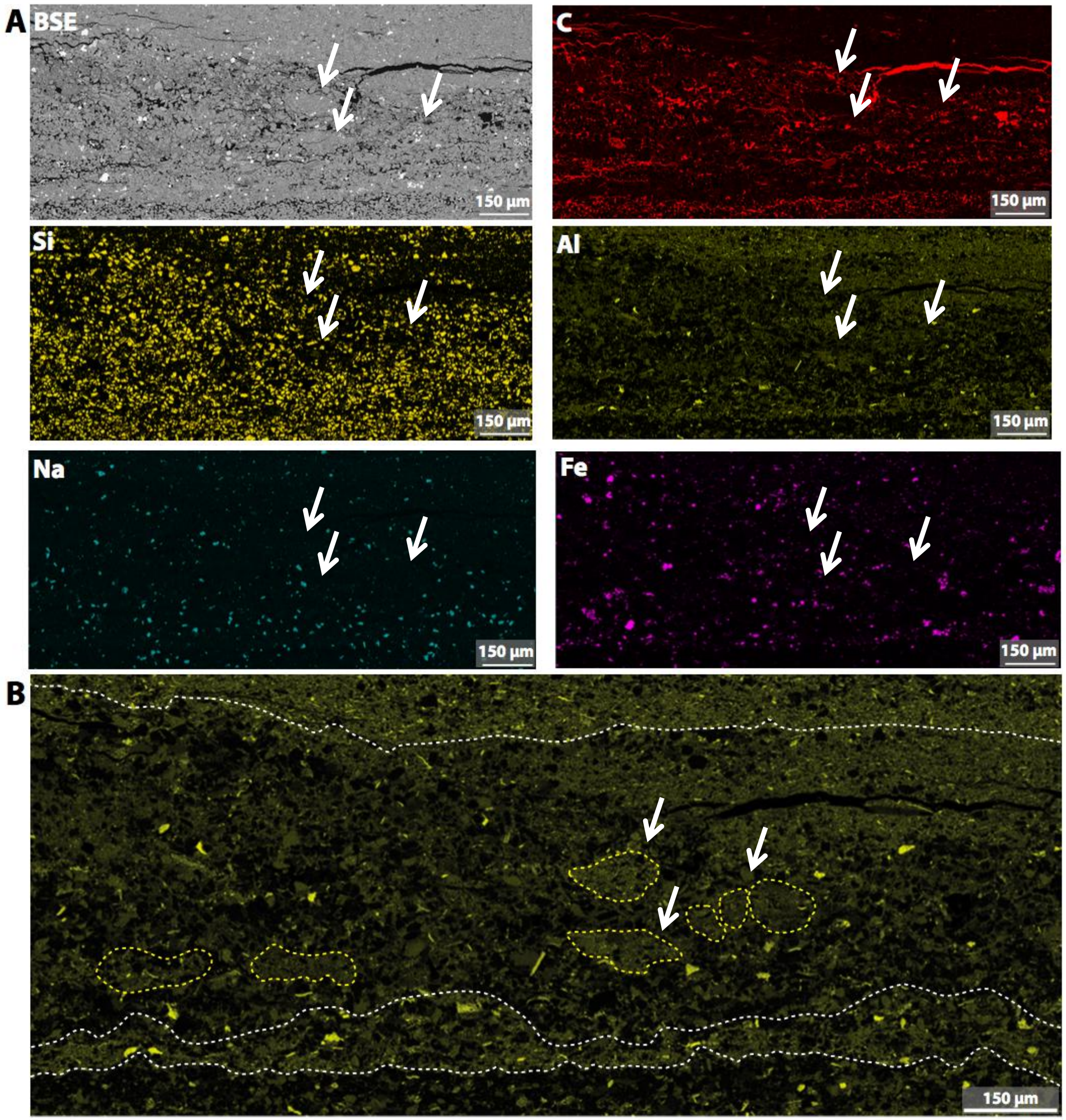
Mudstone Aggregates in the Carlile Fm.



Fluorescent Microscopy of Mudstone Aggregates



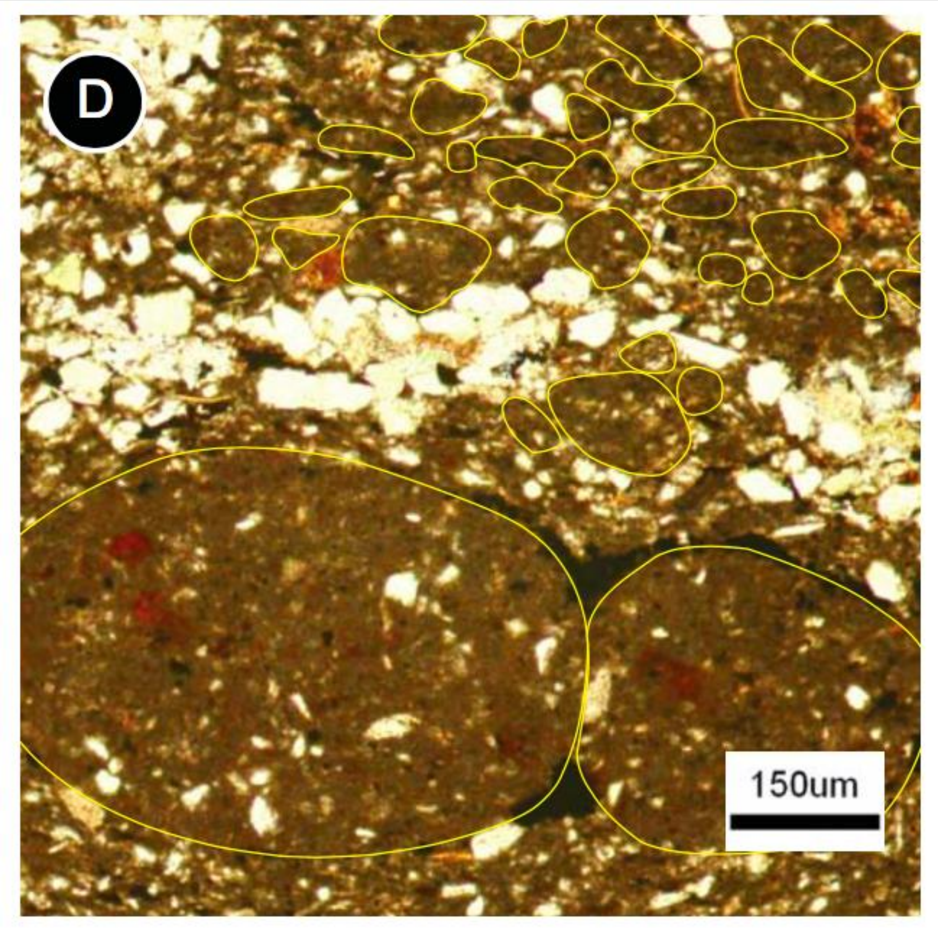
SEM-EDX of Mudstone Aggregate



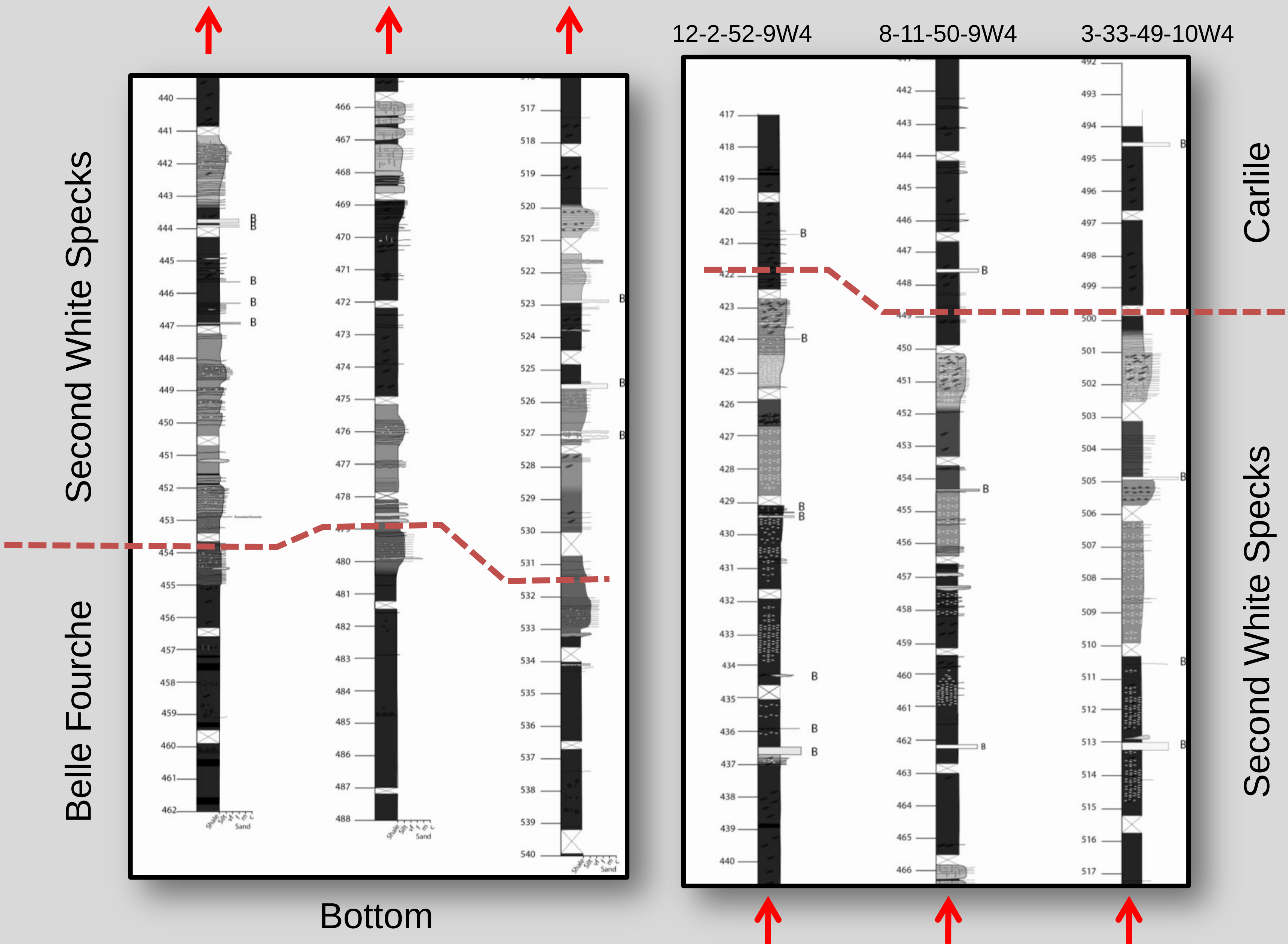
Carlile Mudstone Aggregates Conclusions

Source of Mudstone Aggregates:

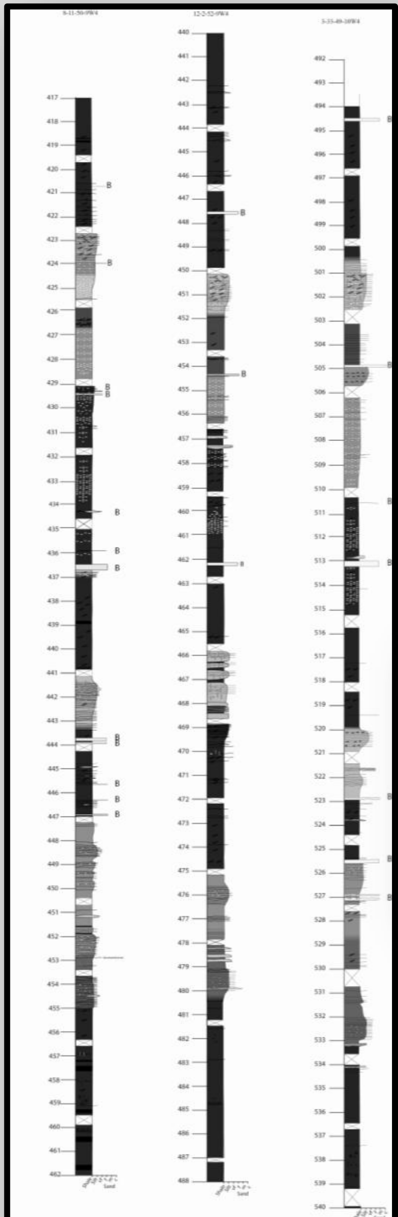
- Intra-basinal rip-up clasts?
- Extra-basinal rip-up clasts?

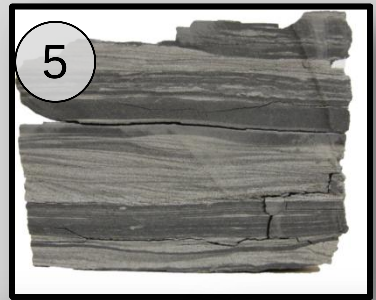


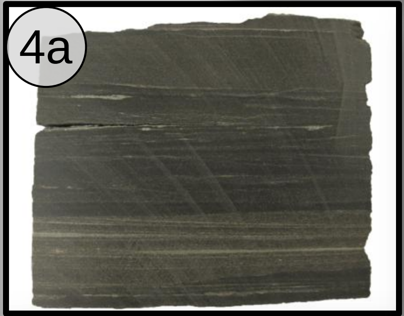
Second White Specks Core

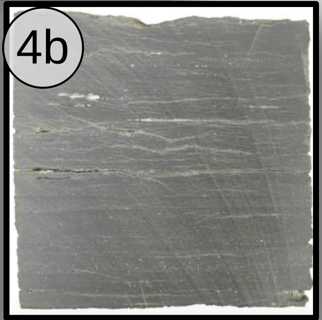


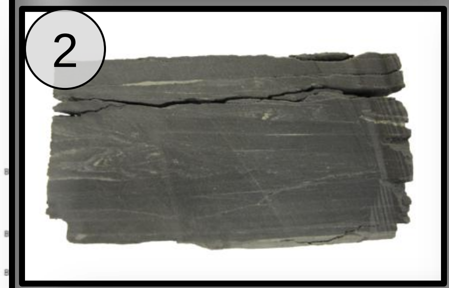
2WS Lithofacies

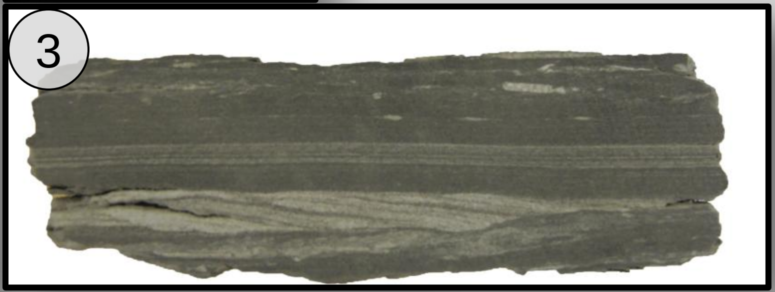


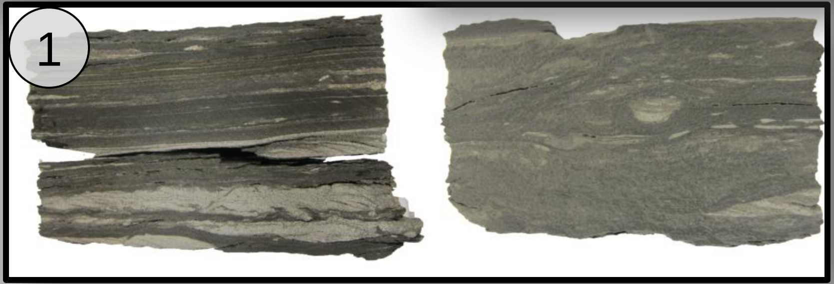








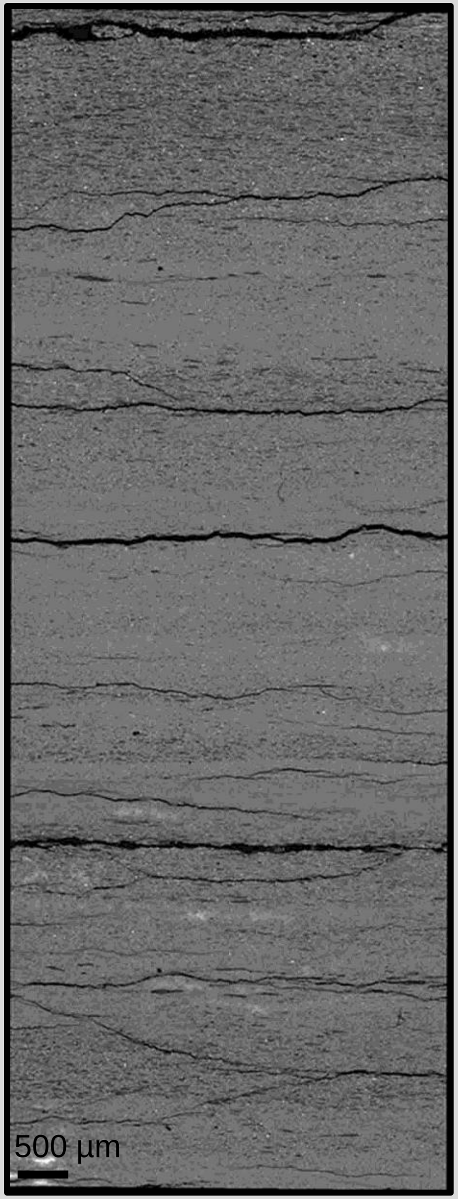




Lithofacies 4a and 4b

- Calcareous
- Abundant “White Specks”
- Rare silt laminae
- Rare bioturbation
- *Inoceramus* and foram fragments
- High TOC (6-11%)

Second White Specks Organic-Rich Mudstone Lithofacies

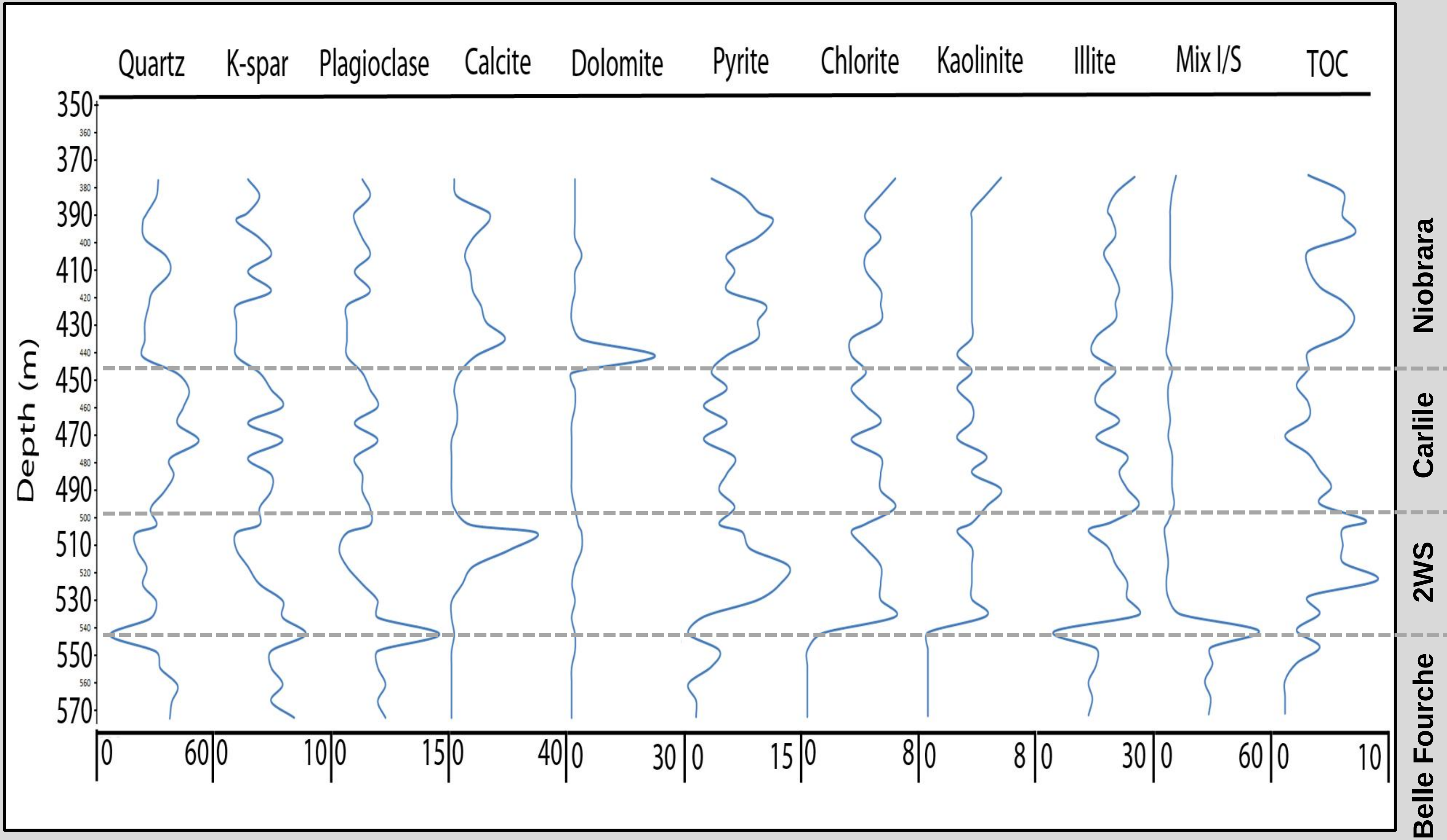


- Mudstone composition is highly variable
- Pellets are predominantly carbon-rich with varying calcium composition
- Organic-rich strata are interspersed with clay-rich strata

BSE Composite of Second White Specks Thin Section

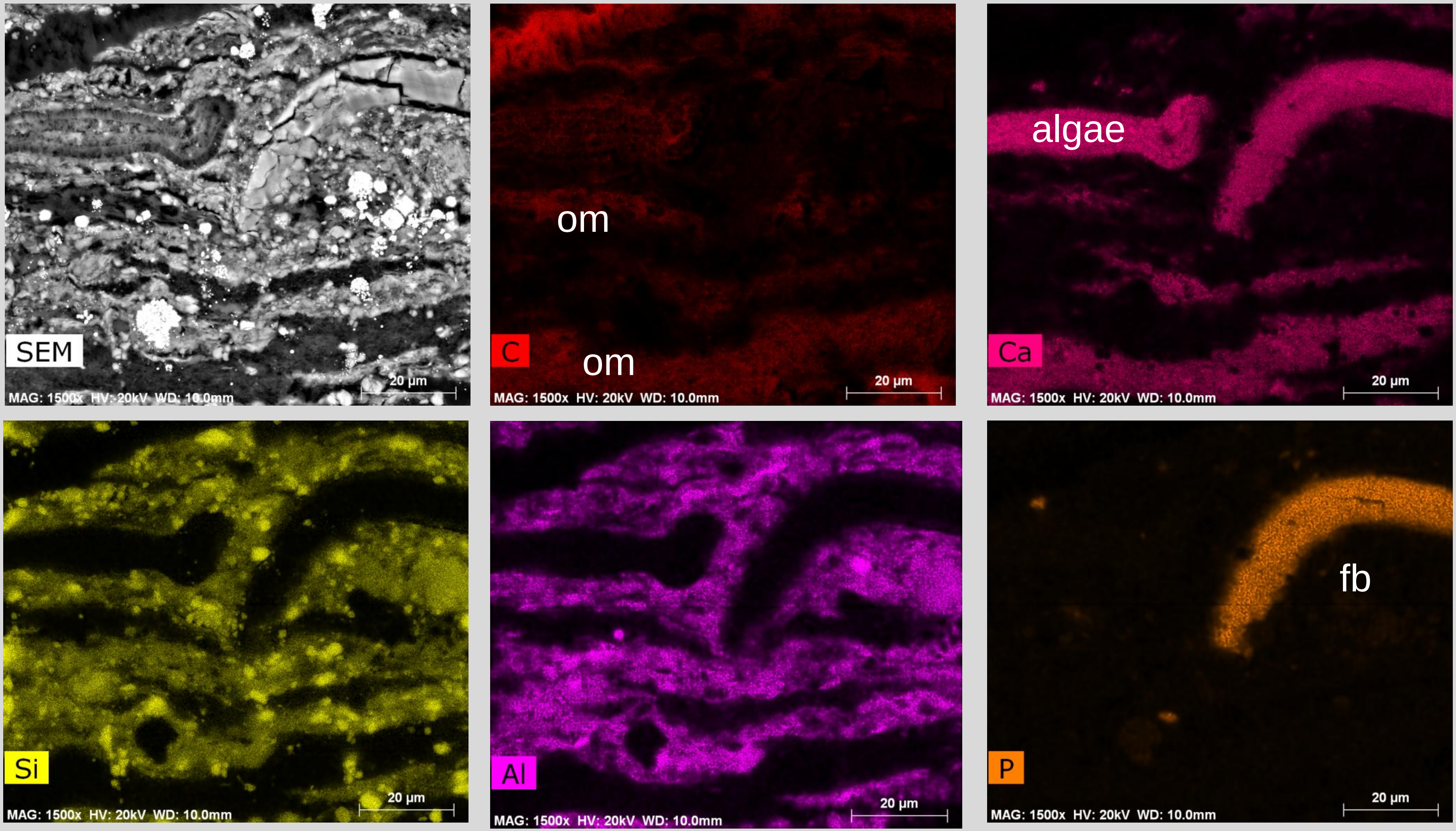
12-2-52-9W4

XRD Analysis of 2WS and Carlile



3-33-49-10W4

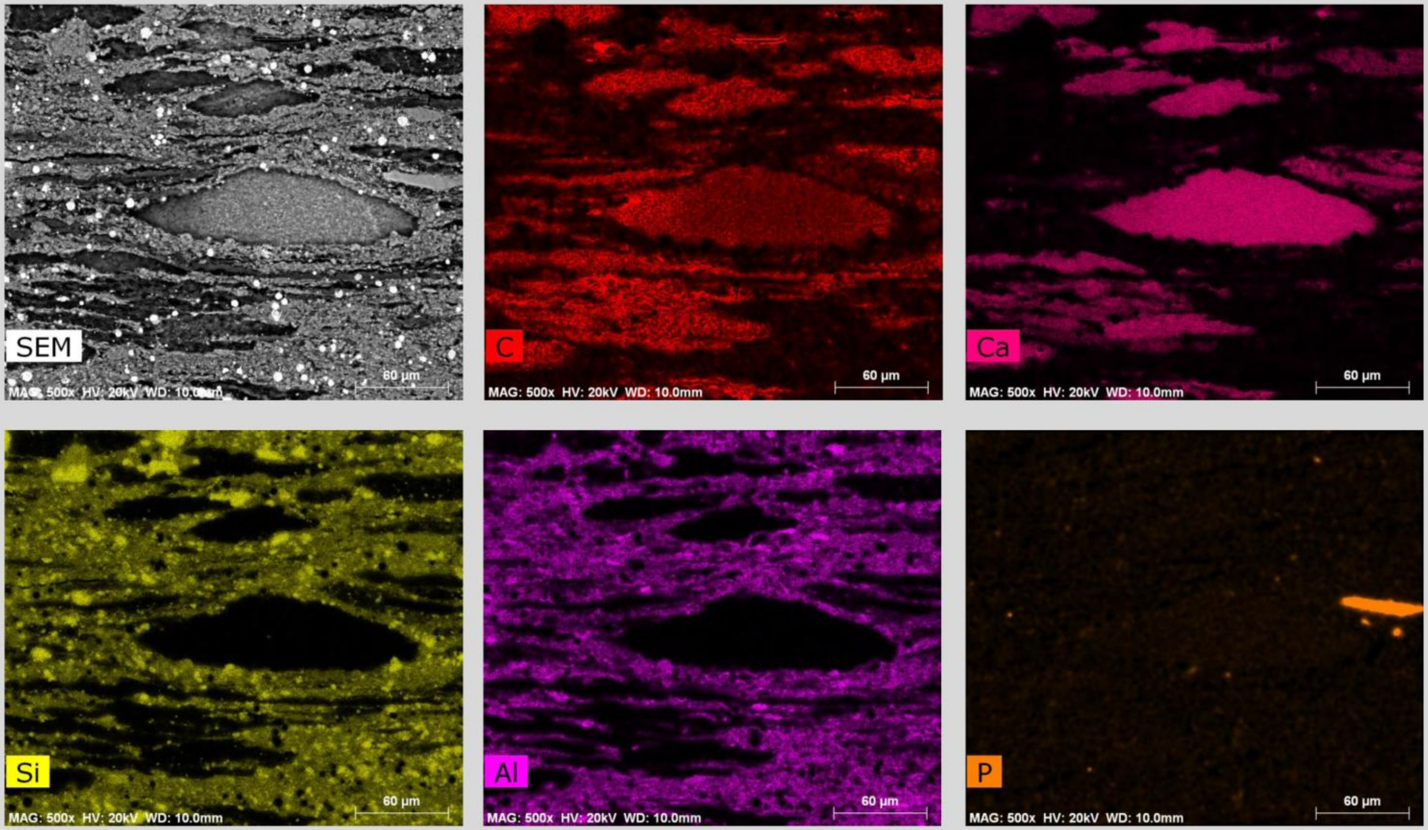
Second White Specks Mudstone Variability



om=Organic Matter
fb=Fish bone

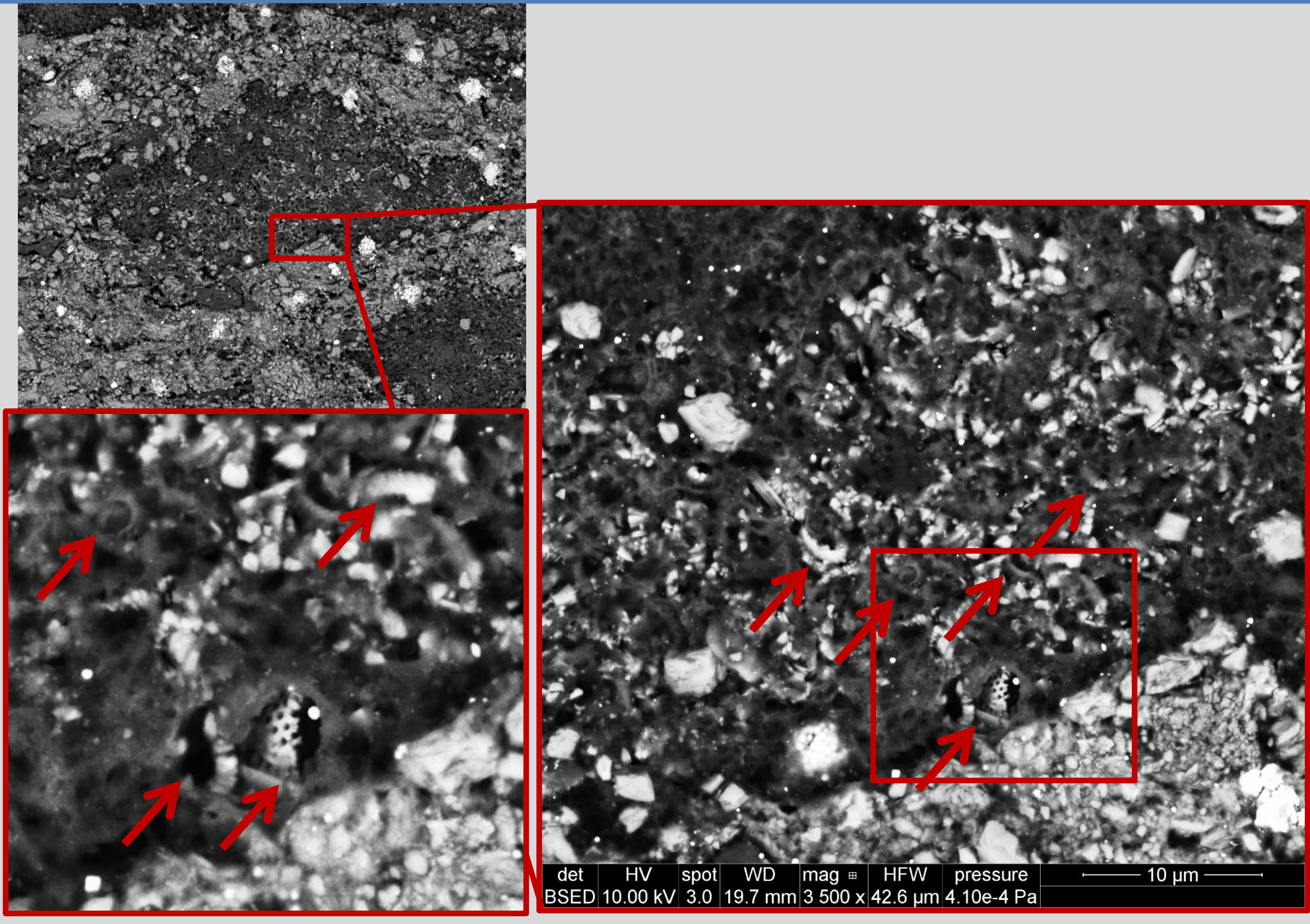
Second White Specks Pellet Variability

- Pellets vary in both carbon content as well as size and compressibility
- Pellets are Ca- and C-rich and Al- and Si-poor

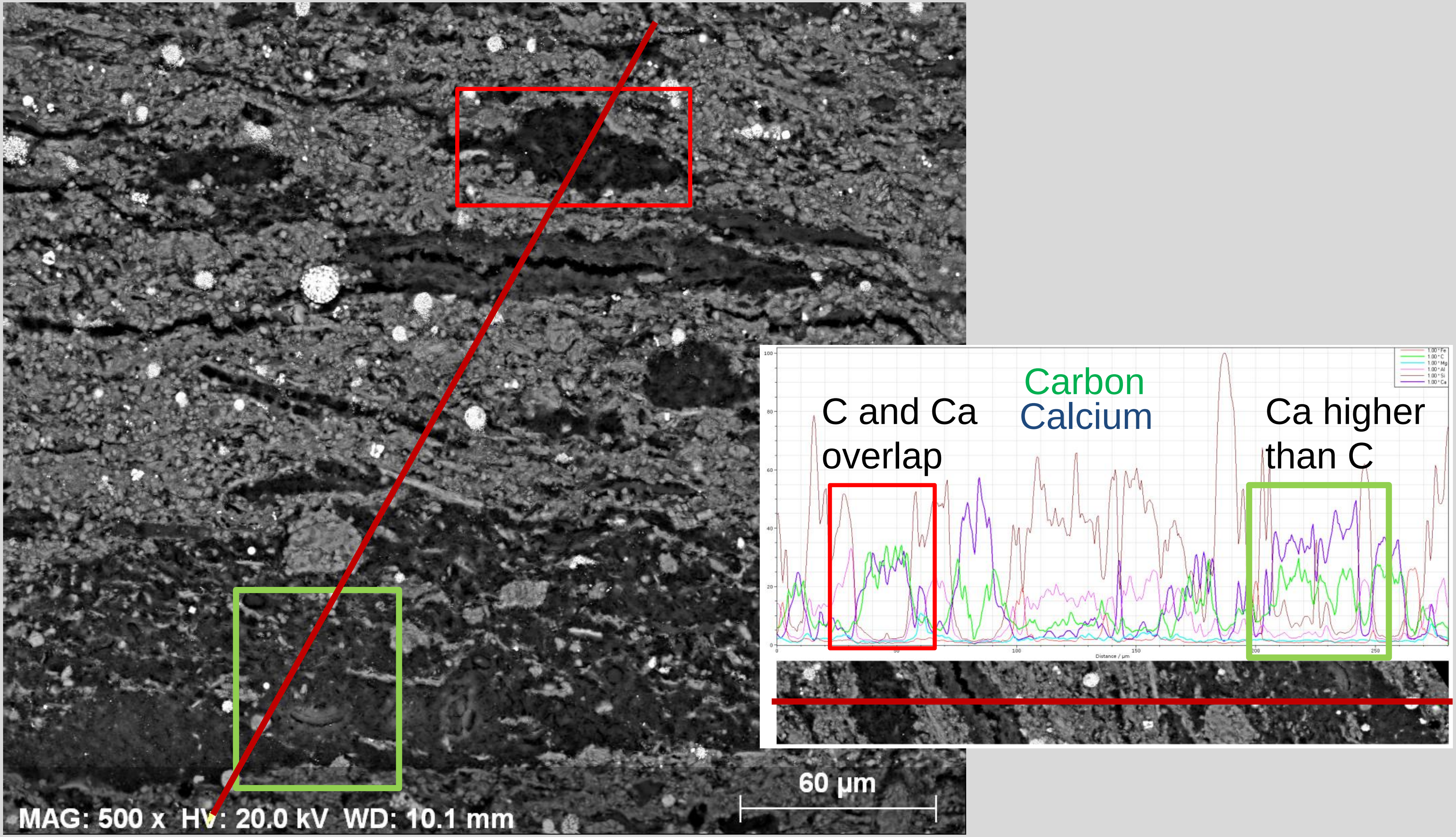


Presenter's notes: Two types of C-rich pellets, one is more Ca-rich, these are the coccolith fragment fecal pellets.

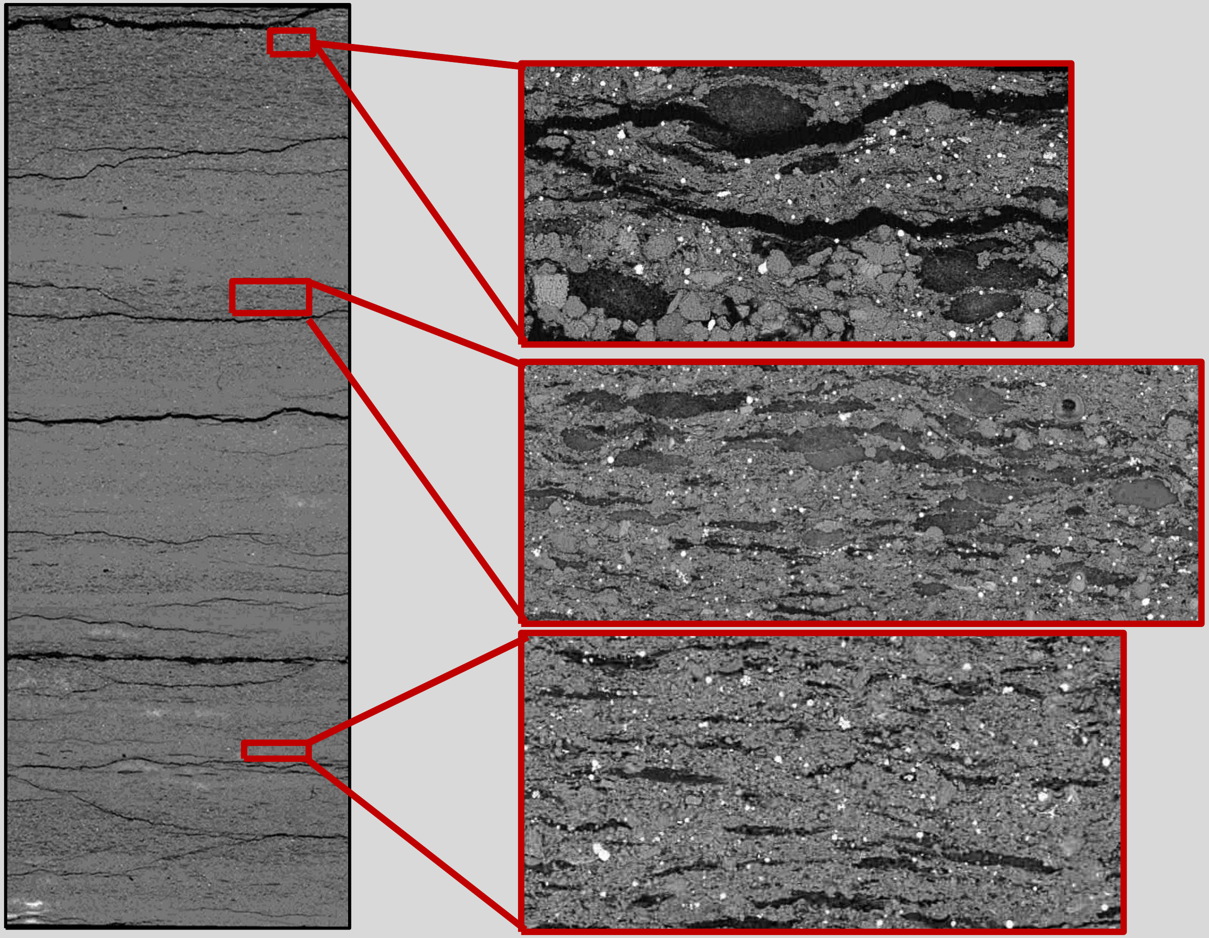
Bioclastic Pellets Contain Abundant Coccolith Fragments with Potential Porosity



Carbon and Calcium Compositional Variations



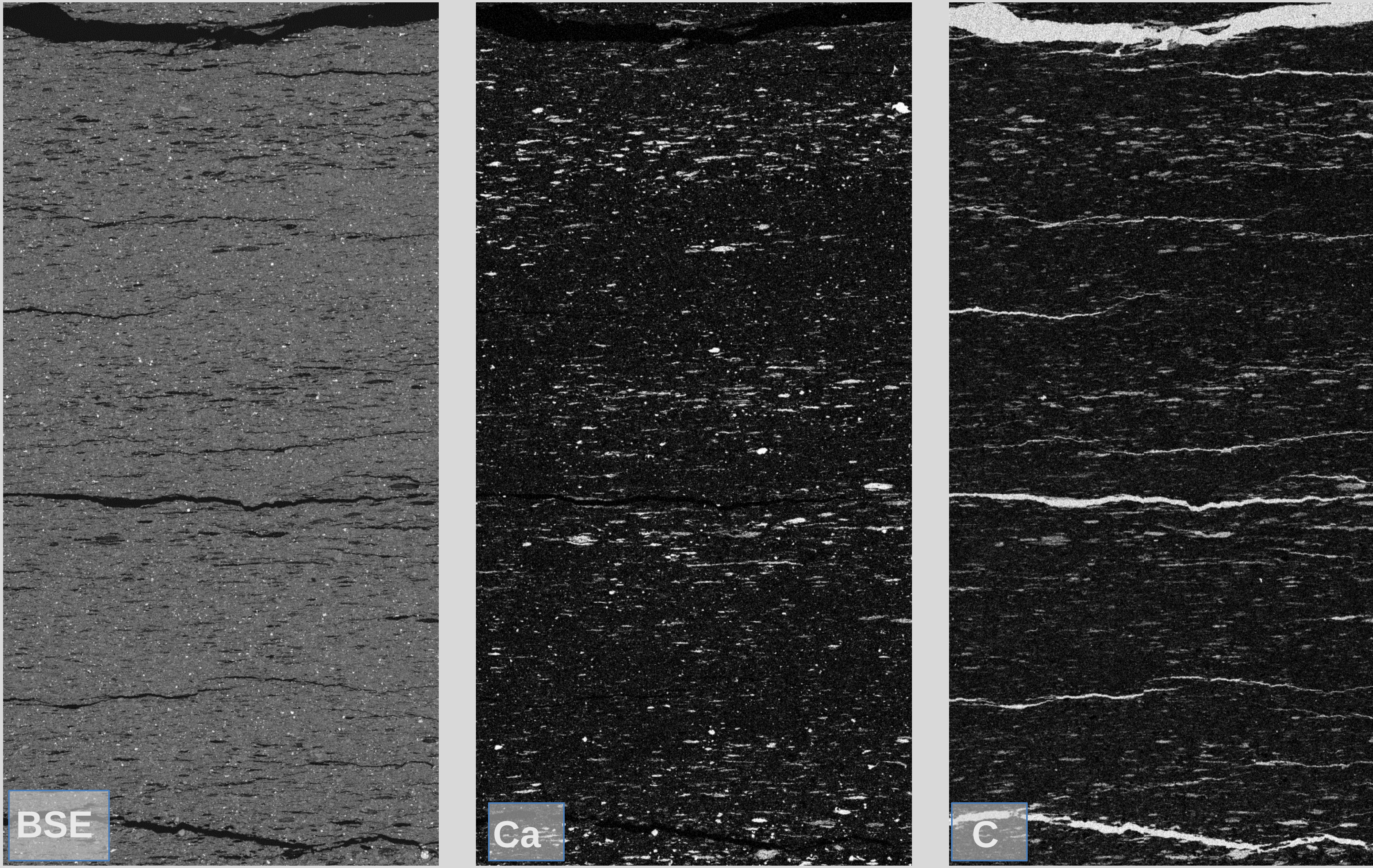
Heterogeneity of 2WS Organic -Rich Facies



BSE Composite (width of image: 7mm)

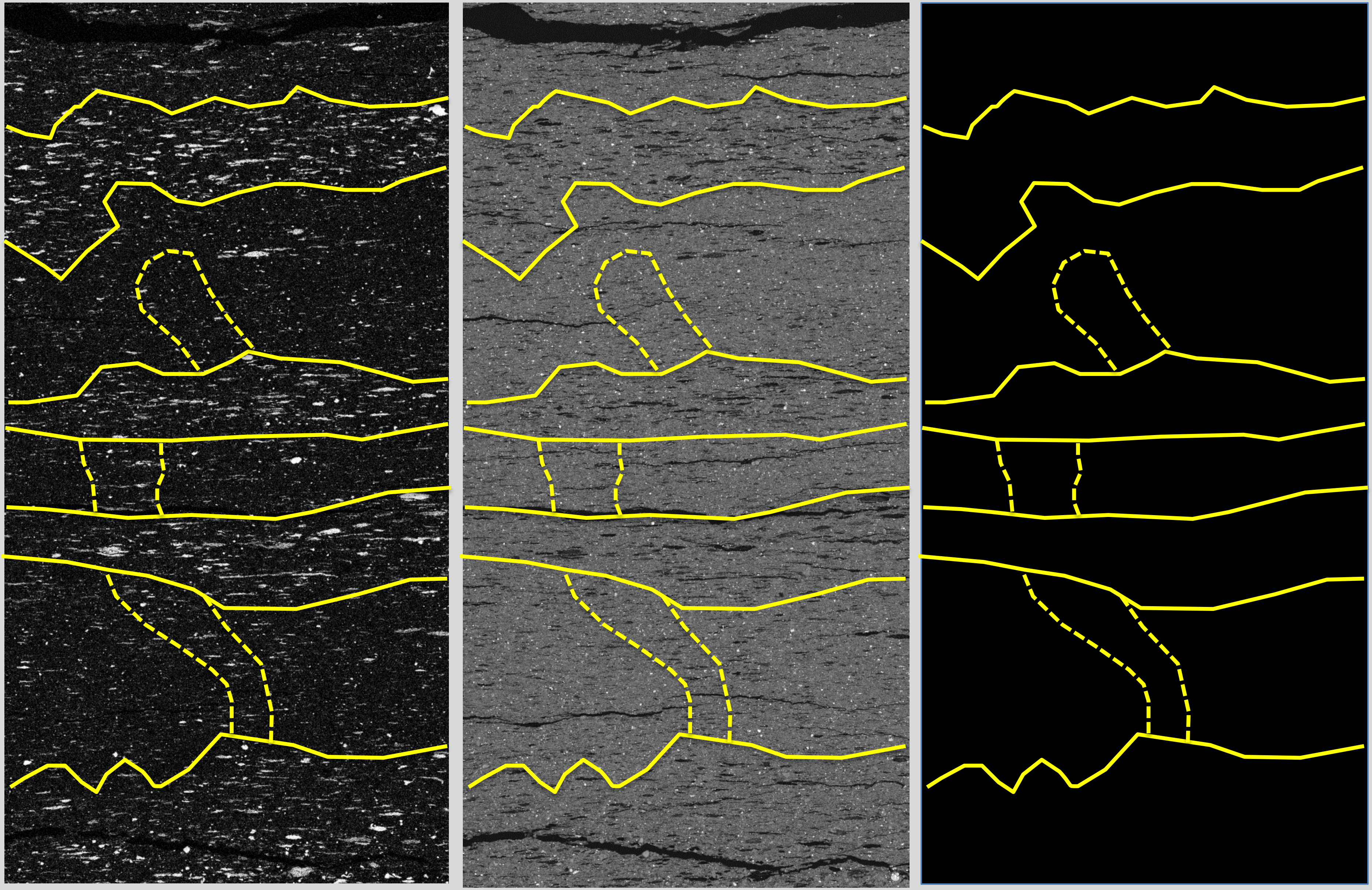
Presenter's notes: Did it erode nearshore or just the shelf? Multiple sources with simultaneous deposition.

Element Mapping-SEM

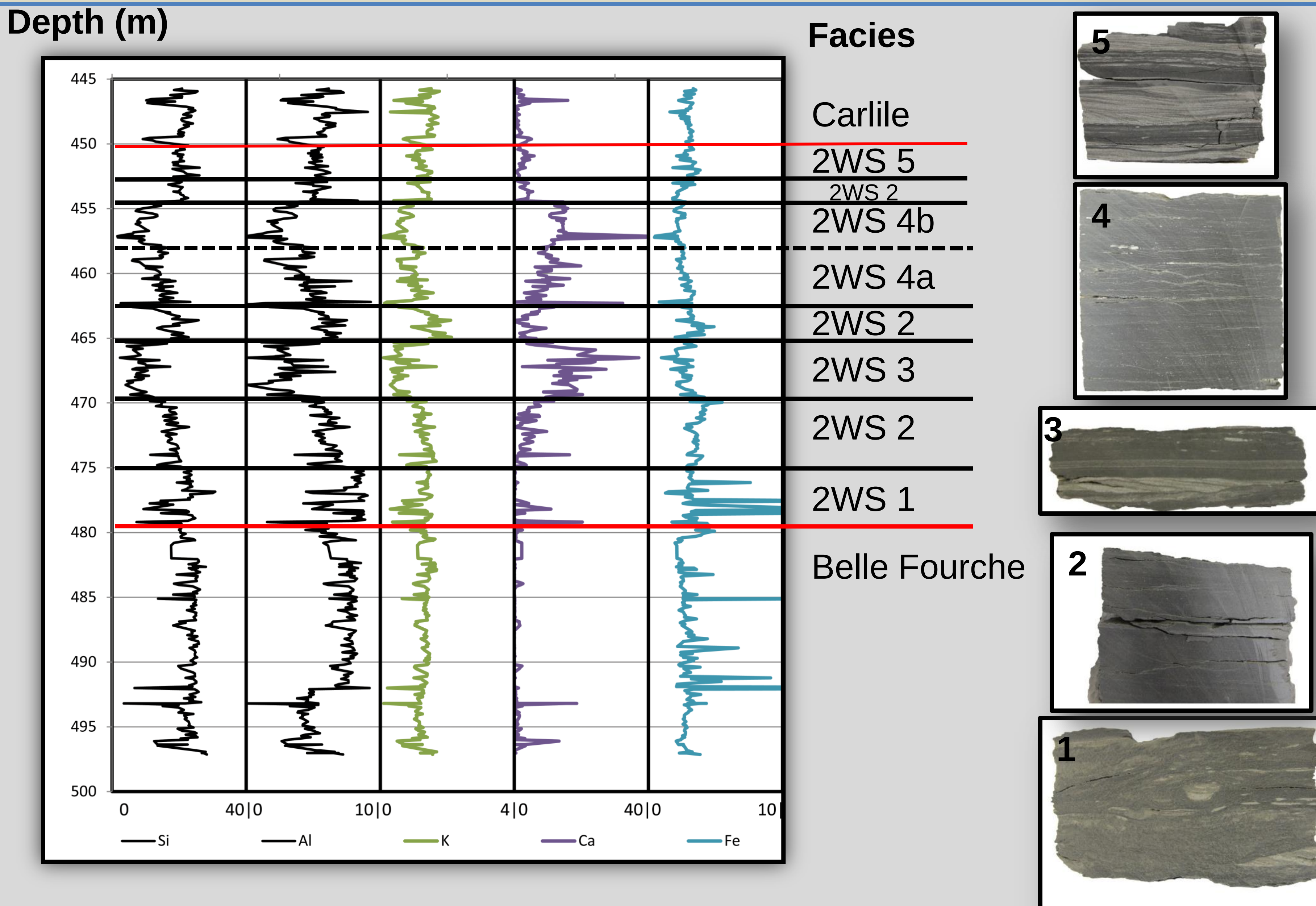


7mm

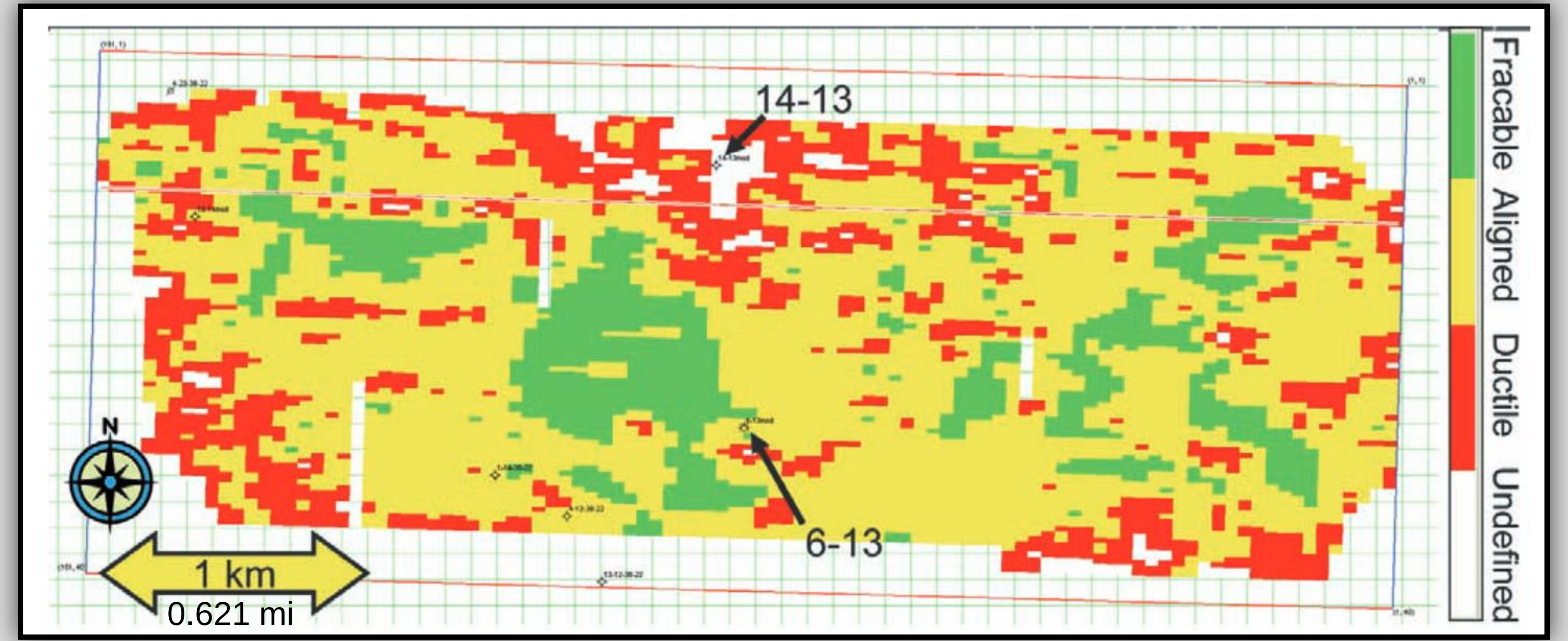
Element Mapping-SEM



Future Directions: XRF Analysis



Implications for Reservoir Quality



- **What is causing this variability in reservoir quality**
  (i.e. Why are some areas fracable and others not?)
  – Silt and coarser-grained components?
  – Pre-existing fractures?
  – Mudstone composition (Diagenesis)

Gray et al., 2012

Acknowledgements

- Dr. Per Pedersen
- Dr. Chris de Burgh; SEM
- Dr. Hamid Sanei, Dr. Omid Hadakani; Geological Survey of Canada
- Dr. Ron Spencer; XRF
- Dallin Laycock, CABS Group

CABS
CENTRE FOR APPLIED BASIN STUDIES