

Unconventional Reservoir Facies Characteristics of the Montney Formation Resource Play in the Western Canada Sedimentary Basin*

Thomas F. Moslow¹, Matthew G. Adams¹, Alessandro Terzuoli^{1,2}, and Beth Haverslew³

Search and Discovery Article #11029 (2021)**

Posted January 25, 2021

*Adapted from extended abstract based on oral presentation given at AAPG/SEG International Conference and Exhibition, London, England, October 15-18, 2017

**Datapages © 2017 Serial rights given by author. For all other rights contact author directly.

¹Progress Energy Canada, Calgary, AB, Canada (moslow@telus.net)

²AT Geoscience Consulting, Calgary, AB, Canada

³Altimin Resources Ltd., Duncan, BC, Canada

Abstract

Analysis of 2500 m of full-diameter core from wells in the Lower Triassic Montney Formation, northeastern British Columbia have identified three principal unconventional reservoir facies associations. Their excellent hydrocarbon deliverability makes the origin, lateral variability and heterogeneity of these reservoir units an issue of economic significance within a leading North American resource play. Montney facies are observed to be of siliciclastic, bioclastic and phosphatic origin and interpreted to have been deposited primarily in shallow marine (shoreface through offshore) depositional environments on a broad westerly dipping ramp of a semi-enclosed seaway with restricted circulation (Davies et al., 1997).

Geologic Setting

The Montney Formation is a Lower Triassic (Griesbachian through Anisian) (Golding et al., 2014) stratigraphic unit deposited within the Western Canada Sedimentary Basin (WCSB) and preserved in the subsurface of west-central Alberta and northeastern British Columbia ([Figure 1](#)). The study area is bounded immediately to the west by the eastern edge of the Rocky Mountain fold and thrust belt, informally referred to as the “Disturbed Belt”, and is situated in the northwestern part of the informally named Montney Depositional Basin, immediately east of the Rocky Mountain fold and thrust belt and north of the Fort St. John Graben Complex and Peace River.

Stratigraphic Framework

The Montney Formation unconformably rests on Permo-Carboniferous beds or sub-cropping Mississippian limestone where the Permo-Carboniferous has been eroded, and overlain by the basal phosphatic beds of the Middle Triassic Doig Formation ([Figure 2](#)). This upper contact is diachronous and unconformable in places (Golding et al., 2014).

Internally there are five sequence boundaries or their correlative conformities, and hence four sequences, roughly coincident with the Griesbachian-Dienerian, Smithian, Spathian and Anisian Lower Triassic sub-stages (Davies and Hume, 2016). In northeastern British Columbia, the contact of the Middle and Lower Montney is a sequence boundary informally referred to as the “Mid-Montney Sequence Boundary”. This surface varies in expression in core but is commonly a brecciated interval with a distinctive well log signature (Moslow et al., in press). A sequence boundary at the top of the Spathian interval marks the lower bounding surface of a relatively thin, unconformity bounded, siliciclastic wedge of bioturbated siltstone to sandstone referred to as the Anisian Wedge (Furlong et al., in press). The latter is the fourth of the four Montney sequences in the study area of northeastern British Columbia. Internally, the Spathian stratigraphic sequence is dominantly siliciclastic and characterized by a prograding and off-lapping set of shoreface parasequences (Euzen et al., in press), each of which grades in the study area from silty very-fine grained sandstone in the east to bituminous rich siltstone in the west. This lateral variability in lithofacies is a product of proximal through distal shoreface sedimentation. The Griesbachian-Dienerian and Smithian sequences in the study area consist of bioclastic, dolomitic and bituminous siltstone facies.

A stratigraphic framework for the Montney specific to the study area is provided in the schematic cross-section shown in [Figure 3](#). Oriented from southeast to northwest, the section extends from Blueberry to Green/Caribou North, and displays a westerly dip to internal stratigraphic units that mimics a clinoforming surface and infers progradation (or off-lap) to the west. The section displays four erosional surfaces coincident with the sequence boundaries described previously at the base, middle and top of the Montney making the stratigraphy in this cross-section readily comparable to the sequence stratigraphic framework observed regionally.

Facies Associations, Reservoir Characteristics and Depositional Models

In the study area, there are three principal facies associations targeted for horizontal drilling and multi -staged hydraulic fracturing, details of which are provided below. From oldest to youngest, these three reservoir facies associations are:

(1) Dienerian *Claraia* sp. Biostrome

An in-situ, monospecific, life assemblage of *Claraia* sp. “flat clams” interbedded with bituminous (avg. 2% TOC), parallel laminated siltstones deposited out of suspension at or near storm-weather wave base. Individual bioclastic beds are inversely graded and flat bedded to parallel laminated. *Claraia* sp. valves are observed both macroscopically and microscopically to be mostly aligned parallel to bedding. The unit is a parasequence bounded by a marine flooding surface below, and maximum flooding surface above ([Figure 4](#)). Regionally, this reservoir interval has been colloquially referred to for years as “the turbidite zone,” based presumably on its down-hole log signature and stratigraphic position in the subsurface. This facies association is interpreted as a biostrome and is observed in numerous cores sub-regionally in northeastern British Columbia ([Figure 5](#)). A depositional model is provided in [Figure 6](#) which displays the linear geometry and lateral continuity along depositional strike of the *Claraia* biostrome facies association.

(2) Mid-Late Smithian Mixed Clastic/Carbonate Ramp

Sharp- to erosionally-based, normally graded, bioclastic beds, interpreted as tempestites, consisting of a monotypic assemblage or low diversity mixture of calcite overgrown or recrystallized calcareous bivalve fragments. Both concave and convex valve orientations are observed. Phosphate replaced bioclast fragments, including the skeletal remains of fish (Davies et al., 1997) and/or marine reptiles are locally concentrated at the base of individual beds. High-relief basal contacts, indicating incision or scour from high velocity currents, as observed in a limited number of bioclastic beds are interpreted as gutter casts. Plane bedding and wavy bedding are observed in the upper, more siliciclastic half of individual beds ([Figure 7](#)). Bed thickness varies from 5 cm to 25 cm and amalgamation of bioclastic beds is common. Based on observed bedding and sedimentary structures, the bioclastic deposits are interpreted as the product of episodic current- generated tractive flows at the sediment water interface. The normal grading infers a waning of flow in the latter stages of deposition. The bioclastic event beds are interpreted as tempestites deposited by storm transport processes between mean storm- and mean fair-weather-wave base. The observed increase in the thickness and frequency of bioclastic beds within this facies association in the paleo-landward (east) direction is consistent with a lateral gradation from distal through proximal positioning on the mixed clastic-carbonate ramp depositional profile ([Figure 8](#)). Stratigraphically, two or three parasequences occur within this reservoir interval, each of which is observed regionally to grade basinward into interbedded bituminous siltstone and hemipelagic dolosiltstone. Paleolandward (east-northeast) this stratigraphic interval thins through erosion at the overlying regional unconformity coincident with the Smithian–Spathian sequence boundary as schematically depicted in [Figure 3](#).

(3) Late Spathian Siliciclastic Shoreface

This almost exclusively siliciclastic facies association is a shoaling or shallowing upwards succession of offshore, offshore transition, and lower shoreface facies ([Figure 9](#)). This association is characterized by an upwards increase in bed thickness, coincident with an increase in net: gross ratio of sandstone to siltstone, inferring deposition through a basinward shift of shallow through deeper water deposits during shoreface progradation. The lateral distribution of these sedimentary facies is shown in [Figure 10](#). Medial and distal shoreface facies associations occur within a progradational set of parasequences in the Spathian interval. Individual parasequences are bounded by marine flooding surfaces demarcated by an inferred rapid deepening in sedimentary environments of deposition.

The greatest abundance and diversity of macroscopic burrow traces is associated with the lower shoreface and offshore transition facies. Sediment reworking from bioturbation can develop a bimodal distribution of pore throat size apertures, as indicated by MICP (mercury injection capillary pressure) analyses in equivalent Montney facies in the NMJV area of northeastern British Columbia ([Figure 11](#)) (Moslow and Haverslew, 2015). Macro- and crypto-bioturbation preserves intergranular porosity and enhances vertical permeability by inhibiting calcite cementation. Intergranular porosity and permeability play a key role in reservoir quality and deliverability (Moslow and Haverslew, 2015).

Reservoir Quality

The lateral distribution of the bioclastic intervals forms reservoir “sweet spots” within the Montney Formation. MICP analysis and thin section petrology reveal that the bioclastic beds are densely calcite cemented with minimal measurable porosity (1-2%) and only rarely naturally fractured ([Figure 12](#)) (Moslow et al., 2016). However, the interbeds of siltstone in both successions are highly bituminous (TOC range 2-4%)

and of relatively high total porosity averaging 5-7%. It is concluded that the hydrocarbon deliverability of the bioclastic reservoirs has less to do with primary or secondary reservoir quality and more a function of geomechanical rock properties attributable to the high frequency interbedding of brittle-ductile facies resulting in significant permeability and geomechanical anisotropy leading to more effective reservoir stimulation through hydraulic fracturing. While reservoir quality for the Claraia Biostrome facies association is lower for the two bioclastic intervals, hydrocarbon deliverability and ability to hydraulically fracture is much higher and among the best for the Montney in the study area. Likely this is a product of fabric selective or lithologically controlled geomechanical anisotropy. Horizontal fracture growth through shear activation of bedding-parallel fabrics (i.e. bioclastic/bituminous siltstone) can be a preferred fracture propagation mechanism in the Montney.

Reservoir permeability, K_h/K_v , and shear strength/stress anisotropy is fabric selective, thus mapable and predictable. Anisotropy exists but has never been mapped and related to a basin wide sedimentology model. With no rock mechanics plug recoveries it has not yet been quantified. However, the fact that it has been thus far impossible to recover an in-tact plug for triaxial testing after having tried every lab in Canada, a few in the USA, and one from Europe leads to the conclusion that the zones coincident with the bioclasts have an increased “bioclastic micro-anisotropy”. These zones are also principal target intervals and yield the highest productivity while having porosity values up to 25% less than the zones directly above or below them ([Figure 12](#)). If primary reservoir parameters do not drive the play, does this bioclastic micro-anisotropy, which is beyond the resolution of available tools, point to a new unconventional driver?

For siliciclastic facies, mercury injection porosimetry plots display distinctive distributions of pore throat apertures which are directly related to grain size distribution, physical and biogenic sedimentary structures (i.e. cyptobioturbation) and diagenesis (i.e. calcite cementation). Mercury injection porosimetry plots display distinctive distributions of pore throat apertures which are directly related to grain size distribution, physical and biogenic sedimentary structures (i.e. cyptobioturbation) and diagenesis (i.e. calcite cementation) ([Figure 13](#)).

Conclusions

Bioclastic beds are densely calcite cemented with minimal measurable porosity (1-2%). Interbeds of siltstone in both successions are highly bituminous (TOC 2-4%) and of relatively high total porosity averaging 5-6%. Hydrocarbon deliverability is a function of geomechanical rock properties attributable to high frequency interbedding of brittle/ductile facies resulting in significant permeability and geomechanical anisotropy leading to more effective reservoir stimulation through hydraulic fracturing. Spathian siliciclastic prograding shoreface facies associations are associated with a selective control on reservoir quality, pore throat size distribution and permeability anisotropy. Variability in sedimentary fabric is linked directly to sedimentary facies. Mercury injection porosimetry plots display distinctive distributions of pore throat apertures which are directly related to grain size distribution, physical and biogenic sedimentary structures (i.e. cyptobioturbation) and diagenesis. As such, a predictive framework has been derived for the distribution of better/best reservoir quality facies that are mapable through calibration of facies to well log response and character.

References Cited

Davies, G.R., and D. Hume, 2016, Lowstand /slope onlap wedges in the Montney: stratigraphic and sequence framework, reservoir significance: Canadian Society of Petroleum Geologists Geo Convention Program with Extended Abstracts, Calgary, Alberta.

Davies, G.R., T.F. Moslow, and M.D. Sherwin, 1997, The Lower Triassic Montney Formation, west central Alberta: Bulletin of Canadian Petroleum Geology, v. 45, p. 474-505.

Davies, G.R., T.F. Moslow, and M.D. Sherwin, 1997, Ganoid fish *Albertonia* sp. from the Lower Triassic Montney Formation, Western Canada Sedimentary Basin: Bulletin of Canadian Petroleum Geology, v. 45, p 715-718.

Euzen, T., T.F. Moslow, V. Crombez, and S. Rohais, in press, Regional stratigraphic architecture of the Spathian Deposits in Western Canada: Bulletin of Canadian Petroleum Geology.

Furlong, C., M.K. Gingras, T.F. Moslow, and J.P. Zonneveld, in press, The Sunset Prairie Formation: Designation of a New Middle Triassic Formation between the Lower Triassic Montney Formation and Middle Triassic Doig Formation in the Western Canada Sedimentary Basin.

Golding, M.L., M.J. Orchard, J.P. Zonneveld, C.M. Henderson, and L. Dunn, 2014, An exceptional record of the sedimentology and biostratigraphy of the Montney and Doig formations in British Columbia: Bulletin of Canadian Petroleum Geology, v.62/3, p. 157-176.

Moslow, T.F., and B. Haverslew, 2015, Fabric selective impacts on reservoir quality and permeability anisotropy in sedimentary facies of the Montney Formation, northeast British Columbia: British Columbia Unconventional Resources Symposium, British Columbia Oil and Gas Commission, Victoria, B.C., June, 2015, Program with Abstracts.

Moslow, T.F., M.G. Adams, and T. Terzuoli, 2016, [Bioclastic Reservoirs of the Distal Montney “Shale” Play, Search and Discovery Article #80548](#).

Moslow, T.F., B. Haverslew, and C.M. Henderson, in press, Sedimentary facies, petrology, conodont biostratigraphy and reservoir quality of a continuous (395 m) full diameter core of the Lower Triassic Montney Formation, Northeastern British Columbia: Bulletin of Canadian Petroleum Geology, Special Volume on the Montney Formation: Deposition to Development.

Newell, N.D., and D.W. Boyd, 1995, Pectinoid bivalves of the Permian-Triassic crisis: Bulletin of the American Museum of Natural History, v. 227, p. 1-95.

Zonneveld, J.P., and T.F. Moslow, 2015, The geology of resource plays in the Montney Formation: western Canada sedimentary basin, Short Course Notebook: Solaster Geosciences, Edmonton, Alberta.

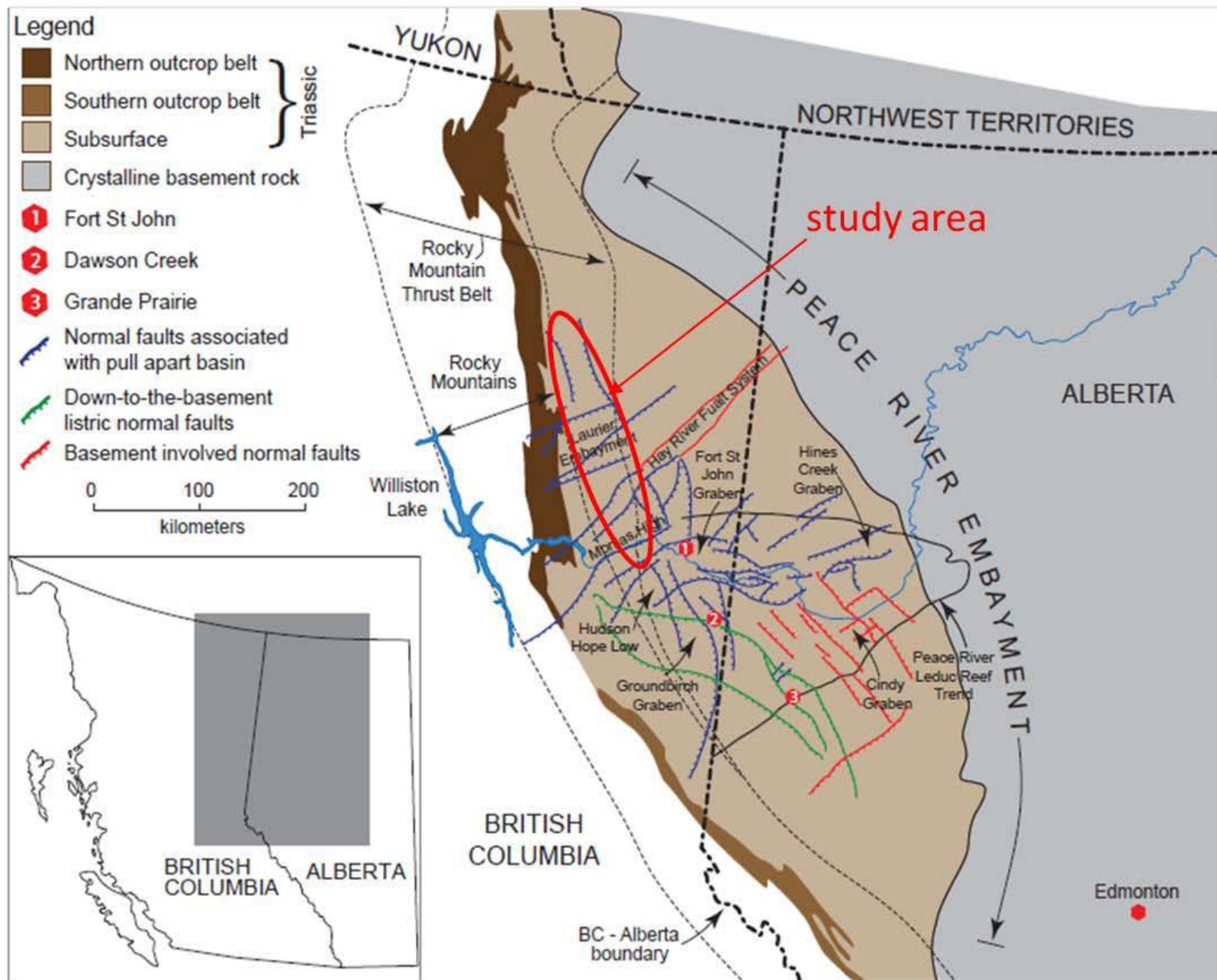


Figure 1. Map showing the outline of the Montney Depositional Basin and major structural elements within Alberta and Northeastern British Columbia (from Zonneveld and Moslow, 2015; in Furlong et al., in press.).

SW

NE

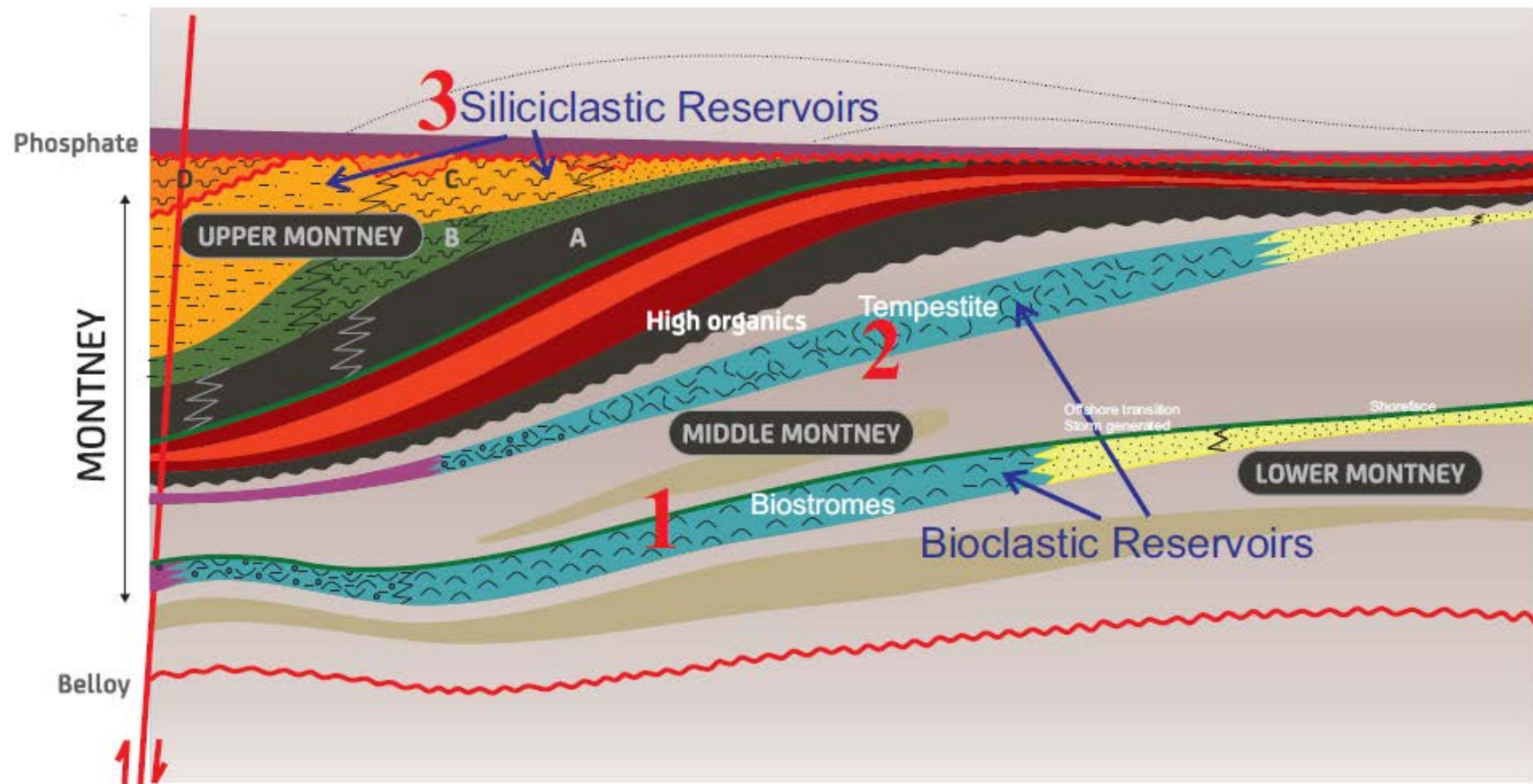
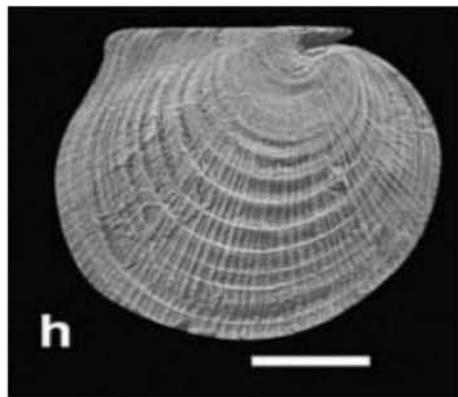


Figure 3. Schematic cross-section and depositional model of the Montney in Northeastern B.C. including the study area providing an identification of Montney stratigraphic nomenclature and primary bioclastic and siliciclastic reservoir intervals.

-  **F-C Siltstone**
(Offshore Transition)
-  **Bituminous F-M Siltstone**
(Offshore)
-  **Calcspheritic Dolo-siltstone**
(Hemipelagites)
-  **Laminated to Planar Bedded** (*Claraia* sp. Life Assemblage)
Bioclasts in a F-C Bituminous Siltstone Matrix



Claraia claraia
Griesbachian,
Brazeau River, AB.
(GSC 14196;
Newell & Boyd, 1995)

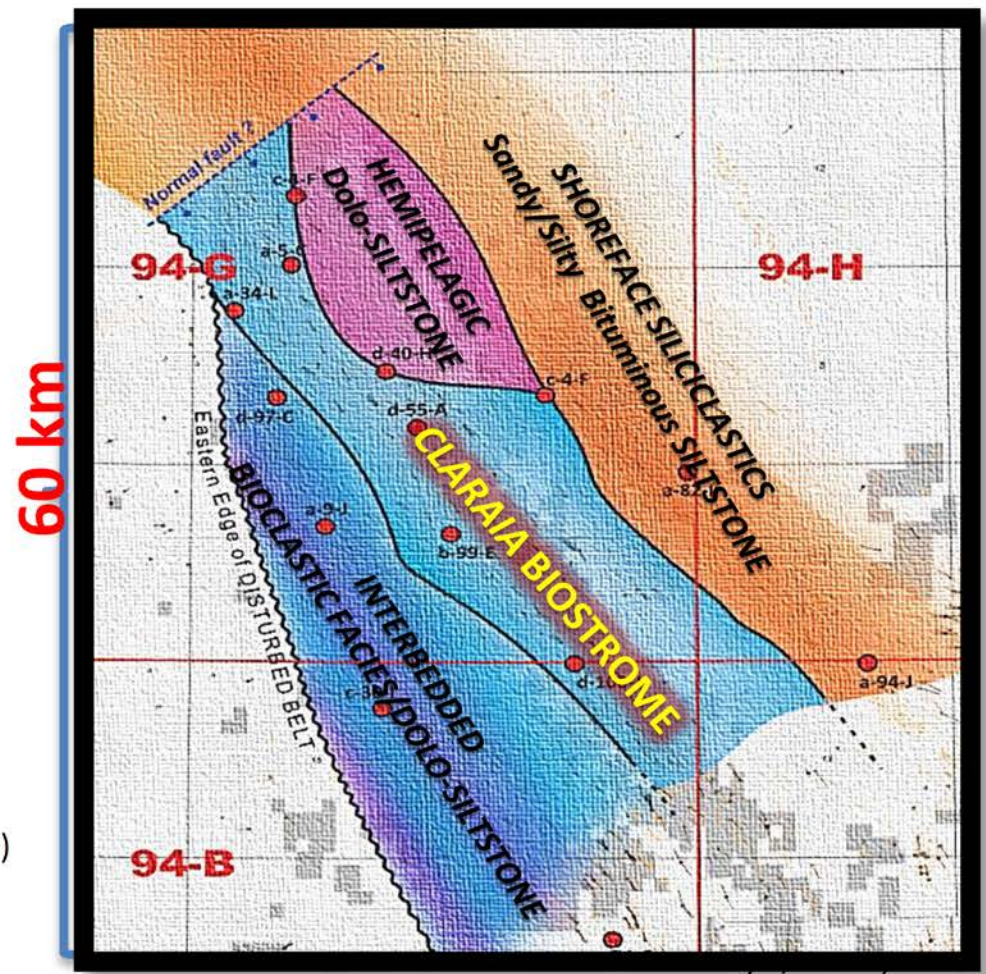


Figure 5. Map of *Claraia* biostrome facies tracts. Inset photo is of *Claraia claraia* from the Griesbachian, Brazeau River, AB. (GSC 14196; Newell and Boyd, 1995).

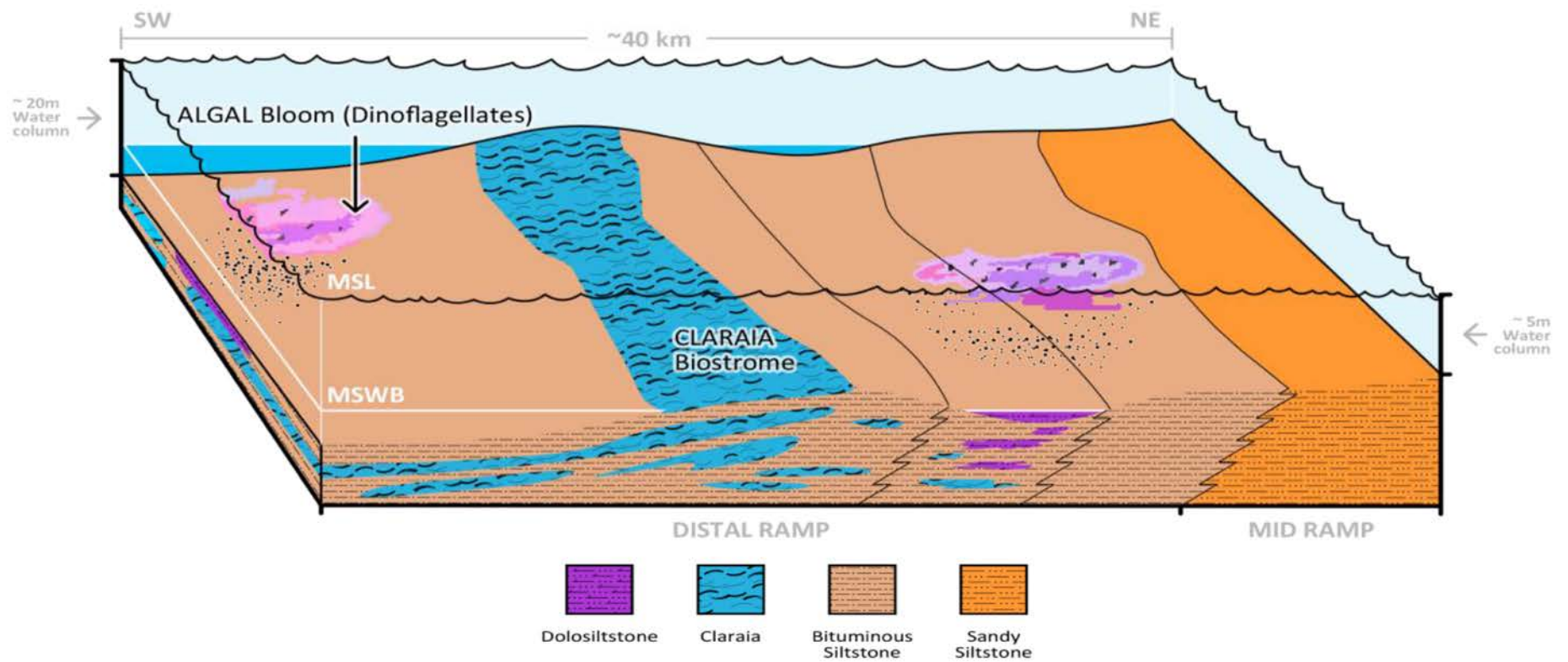


Figure 6. *Claraia sp.* biostrome depositional model displaying three-dimensional facies variability.

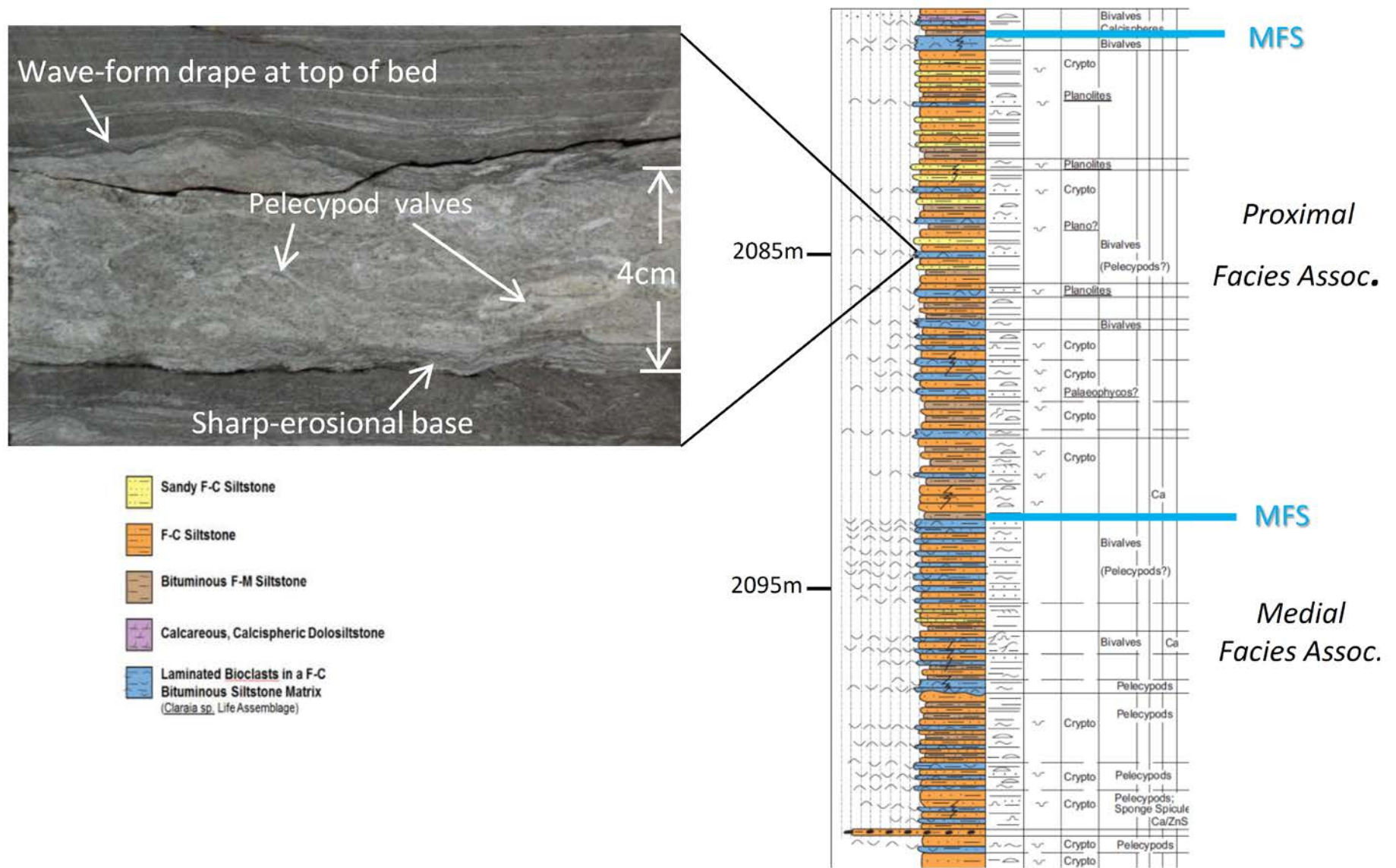


Figure 7. Facies Association 2: bioclastic tempestite hybrid siliciclastic - carbonate ramp from the d-40-H/94-G-7.

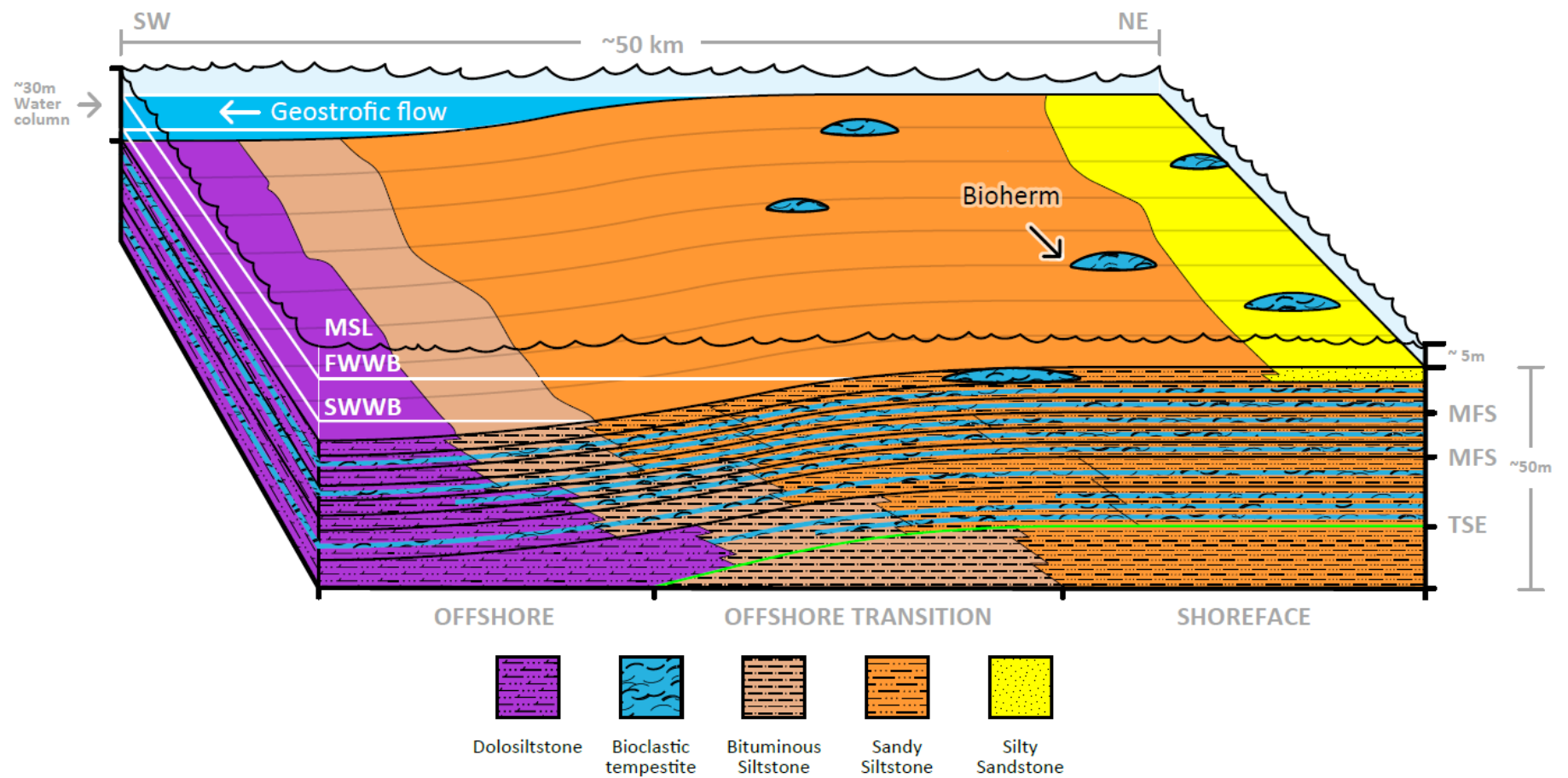


Figure 8. Bioclastic tempestite depositional model displaying three-dimensional facies variability.

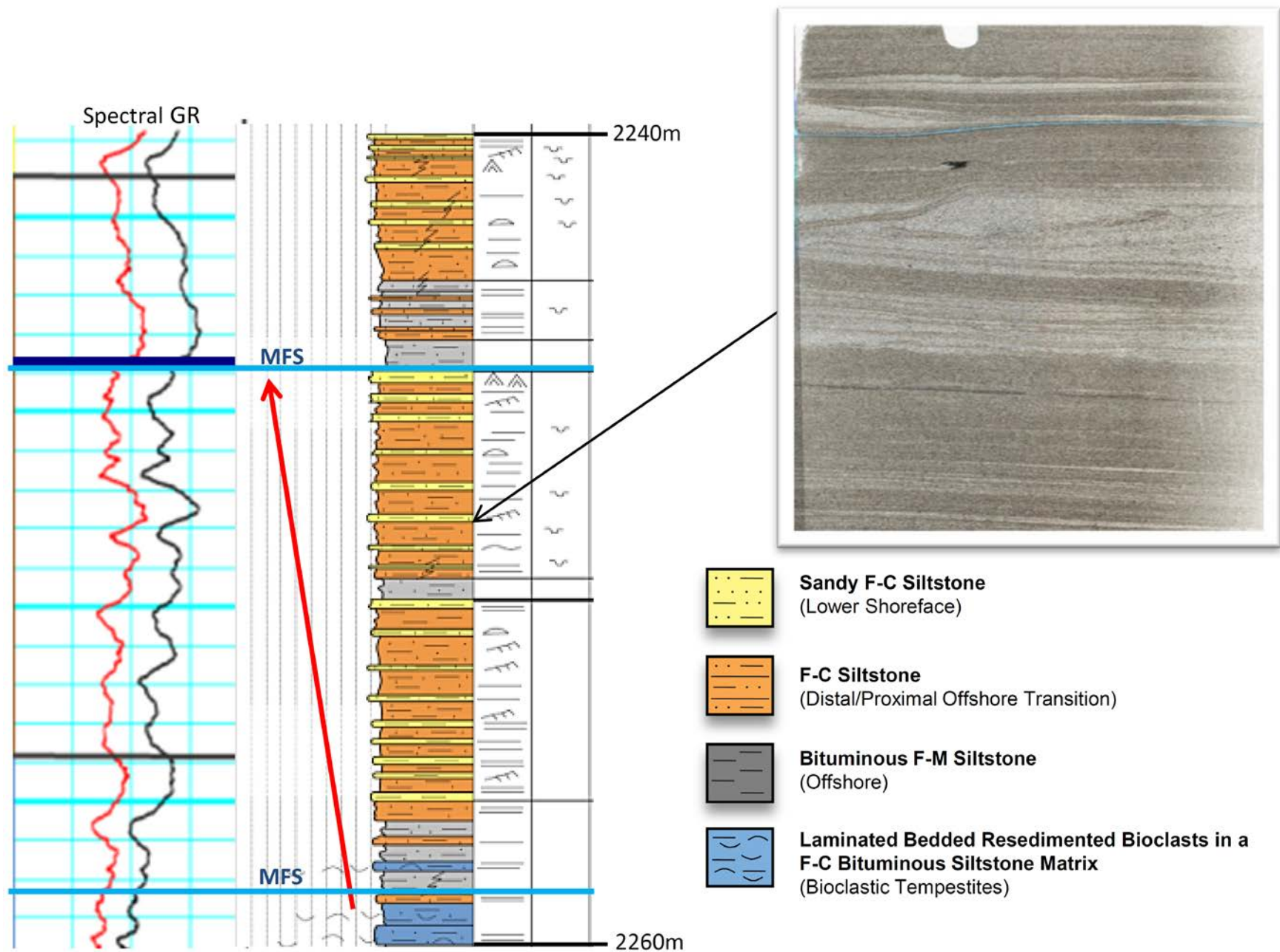


Figure 9. Spathian siliciclastic shoreface facies association. Inset core photo is of ripple to planar laminated and cryptobioturbated sandy coarse siltstone of the proximal offshore transition facies. bioturbated, ripple.

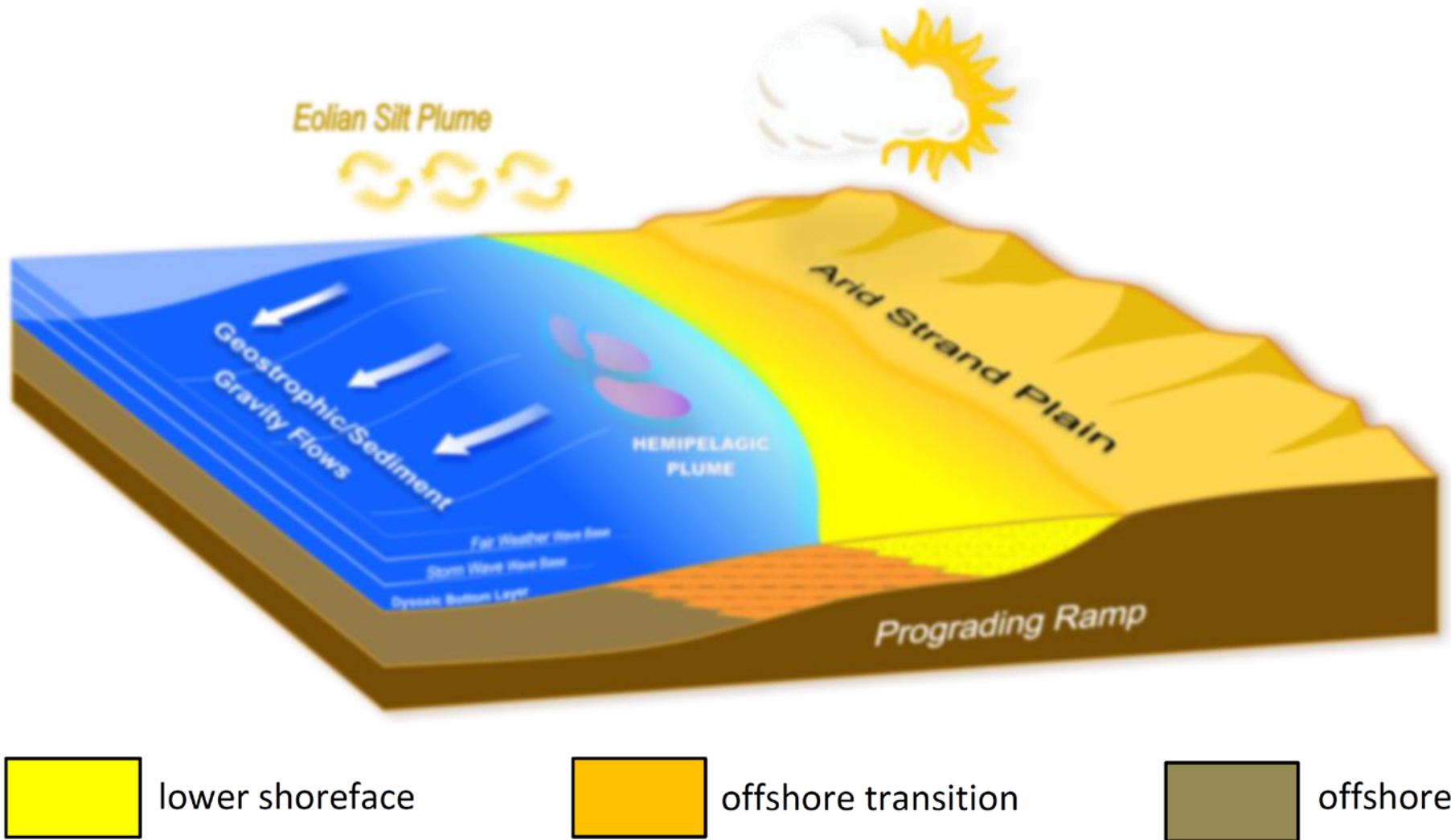


Figure 10. Upper Montney (Spathian) prograding shoreface facies association depositional model.

Offshore Transition Facies

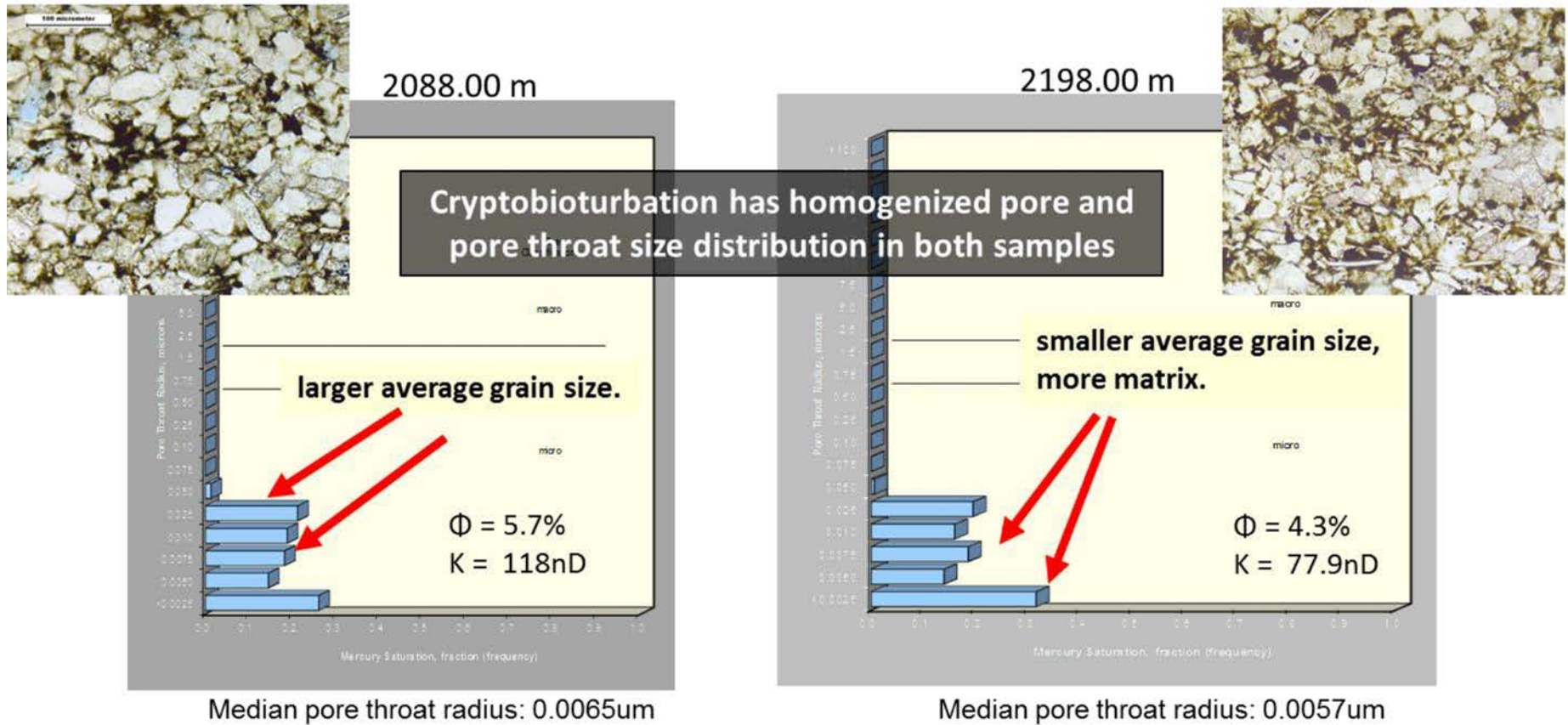


Figure 11. Mercury injection porosimetry pore plots for two samples of the offshore transition facies.

Claraia Biostrome: d-40-H/94-G-7

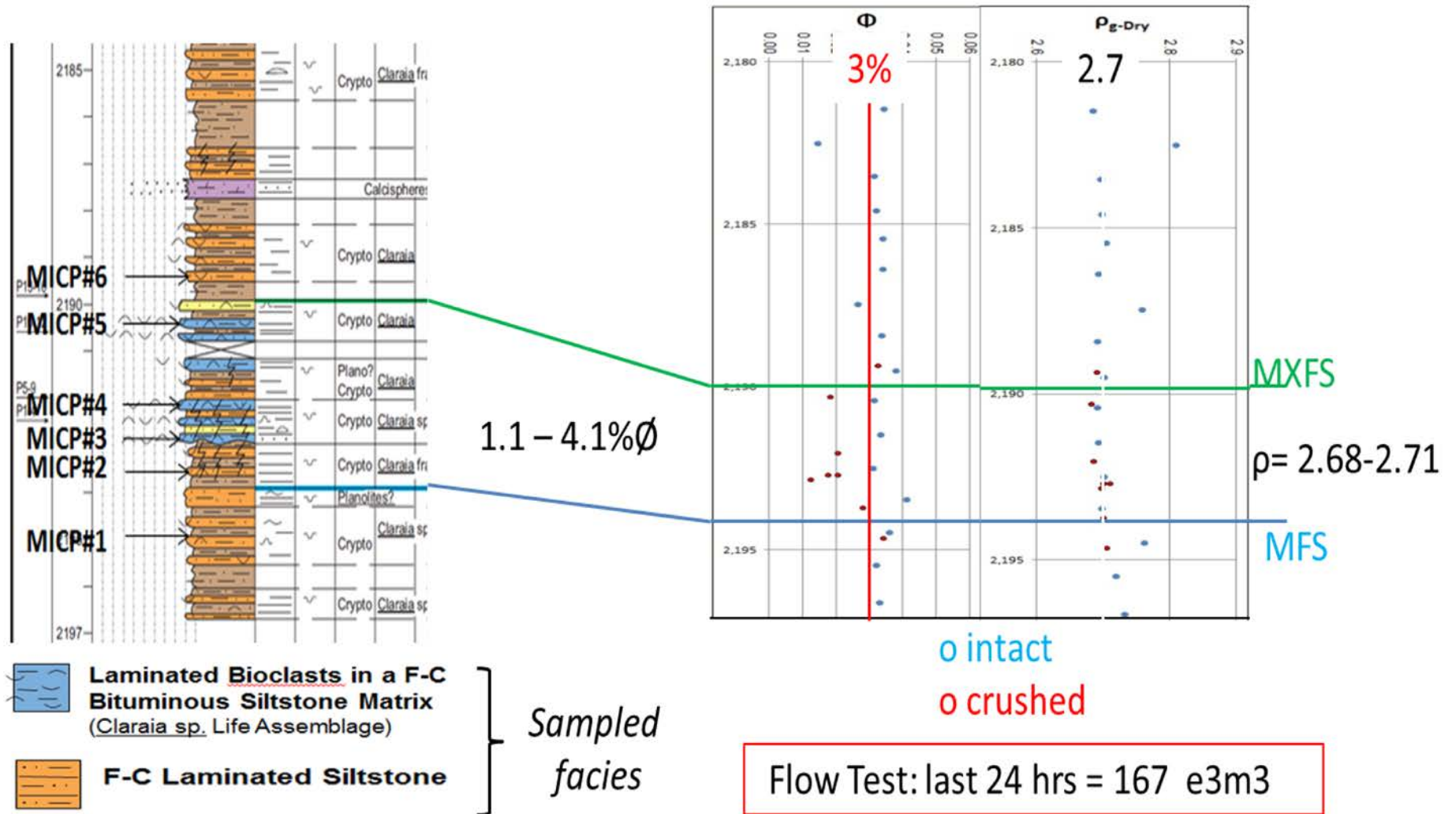


Figure 12. Porosity and density measurements of bioclastic facies from MICP analyses for the Claraia biostrome facies association in the d-40-H/94-G-7.

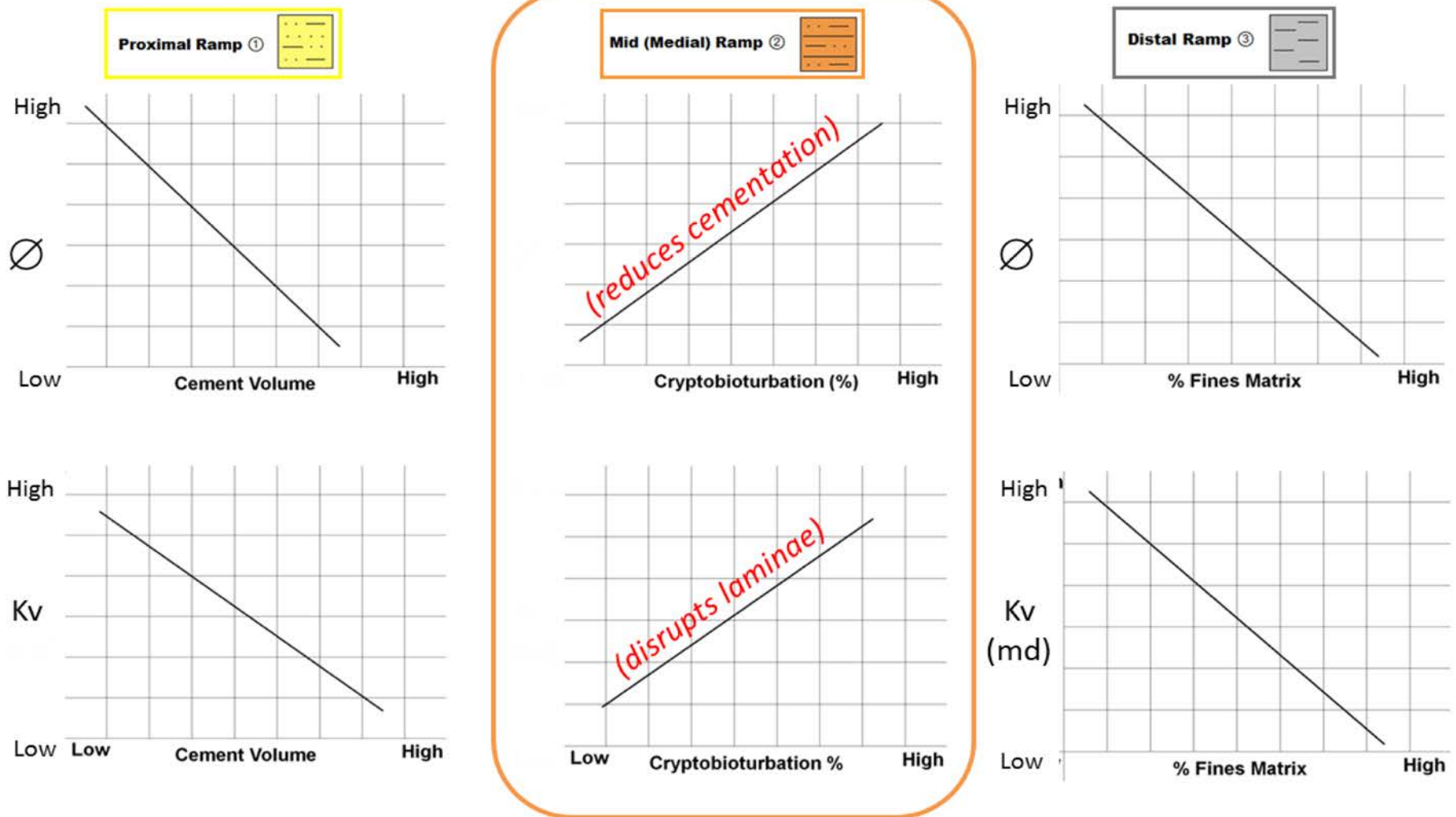


Figure 13. Siliciclastic facies reservoir quality plots of effective porosity (\emptyset) and vertical permeability (K_v) for siliciclastic facies of the Spathian Montney in the study area. Cryptobioturbation in the medial ramp facies association (orange) reduces cementation and disrupts laminae which enhances K_v and overall reservoir quality (from Moslow and Haverslew, 2015).