Stratigraphic and Facies Control on Porosity and Pore Types of Mississippian Limestone and Chert Reservoirs: An Example from North-Central Oklahoma*

Fnu Suriamin[1] and Matthew J. Pranter[1]

Search and Discovery Article #11058 (2017)**
Posted March 12, 2017

*Adapted from oral presentation given at 2017 AAPG Mid-Continent Section Meeting, Oklahoma City, Oklahoma, September 30 - October 3, 2017.

[1]University of Oklahoma, Norman, Oklahoma (fnu.suriamin-1@ou.edu)

Abstract

Mississippian limestone and chert reservoirs in north-central Oklahoma include lithofacies that form upward-shallowing cycles that commonly transition from more mud- to grain-dominated and are typically capped by deposits indicative of subaerial exposure. Mississippian-age rocks in the study area consist of 17 lithofacies that were deposited on a distally steepened ramp. Vertical lithofacies stacking reveals 28 higher order cycles, and cycle thickness varies from 1 ft (0.3 m) to 100 ft (30.5 m). Most cycles (22 of 28) are asymmetric, regressive cycles with an average thickness of 21 ft (6.4 m).

Digital-image analysis (DIA) illustrates that most lithofacies exhibit nanopores (1 $nm^2 < A < 62.5\ \mu m^2$) and micropores ($62.5\ \mu m^2 < A < 500\ \mu m^2$) with five major pore types including interparticle, intraparticle, vuggy, channel, and microfracture. DIA-porosity quantification yields a reliable result to predict porosity with somewhat higher values as compare to core-measured porosity. The discrepancy is likely due to several factors including the internal pore network, diagenetic alteration, unconnected microfracture network, and isolated pores. The combination of thickness and high reservoir quality make most grain-dominated lithofacies the most prospective. Moreover, reservoirs with higher porosity and permeability are commonly associated with the upper intervals of higher order regressive cycles.

References Cited

Blakey, 2013, Paleography Map of North America during Early Mississippian (Kinderhookian): Colorado Plateau Geosystems, Phoenix, AZ.

Campbell, J.A., C.J. Mankin, A.B. Schwarzkopf, and J.J. Raymer, 1988, Habitat of petroleum in Permian rocks of the Midcontinent Region, *in* W.A. Morgan and J.A. Babcock, eds., Permian rocks of the Midcontinent: Midcontinent Society of Economic Paleontologists and Mineralogists, Special Publication No. 1, p. 13-35.

Dutton, S.P., 1984, Fan-Delta Granite Wash of the Texas Panhandle: Oklahoma City Geological Society, Short Course Notes, p. 1-44.

Harris, S.A., 1975, Hydrocarbon accumulation in "Meramec-Osage" (Mississippian) rocks, Sooner Trend, Northwest-Central Oklahoma: AAPG Bulletin, v. 59/4, p. 633-664.

Johnson, K.S., and K.V. Luza, 2008, Earth Sciences and Mineral Resources of Oklahoma: Educational Publication 9, Oklahoma Geological Survey, 22 p.

LoCricchio, E., 2012, Granite Wash Play Overview, Anadarko Basin: Stratigraphic Framework and Controls on Pennsylvanian Granite Wash Production, Anadarko Basin, Texas and Oklahoma: AAPG Annual Convention and Exhibition, Long Beach, California, April 22-25, 2012, Search and Discovery Article #110163 (2012). Website accessed March 4, 2018.

Mazzullo, S.J., B.W. Wilhite, D.R. Boardman, B.T. Morris, and C.J. Godwin, 2016, Stratigraphic architecture and petroleum reservoirs in Lower to Middle Mississippian strata (Kinderhookian to Basal Meramecian) in Subsurface Central to Southern Kansas and Northern Oklahoma: Shale Shaker, v. 67, p. 20-49.

Mazzullo, S.J., B. Wilhite, and D.R. Boardman, II, 2011, Lithostratigraphic architecture of the Mississippian Reeds Spring Formation (Middle Osagean) in Southwest Missouri, Northwest Arkansas, and Northeast Oklahoma Outcrop Analog of Subsurface Petroleum Reservoirs: Shale Shaker, v. 61/5, p. 254-269.

Mazzullo, S.J., B.W. Wilhite, and I.W. Woolsey, 2009, Petroleum reservoirs within a spiculite-dominated Depositional sequence: Cowley Formation (Mississippian: Lower Carboniferous), South-Central Kansas: AAPG Bulletin, v. 93/12, p. 1649-1689.

Northcutt, R.A., and J.A. Campbell., 1995, Geologic Provinces of Oklahoma: Oklahoma Geological Survey Open-File Report 5-95, 1 sheet, scale 1:750,000, 6-page explanation and bibliography.

Stratigraphic and facies control on porosity and pore types of Mississippian limestone and chert reservoirs: an example from north-central Oklahoma

Fnu Suriamin and Matthew J. Pranter

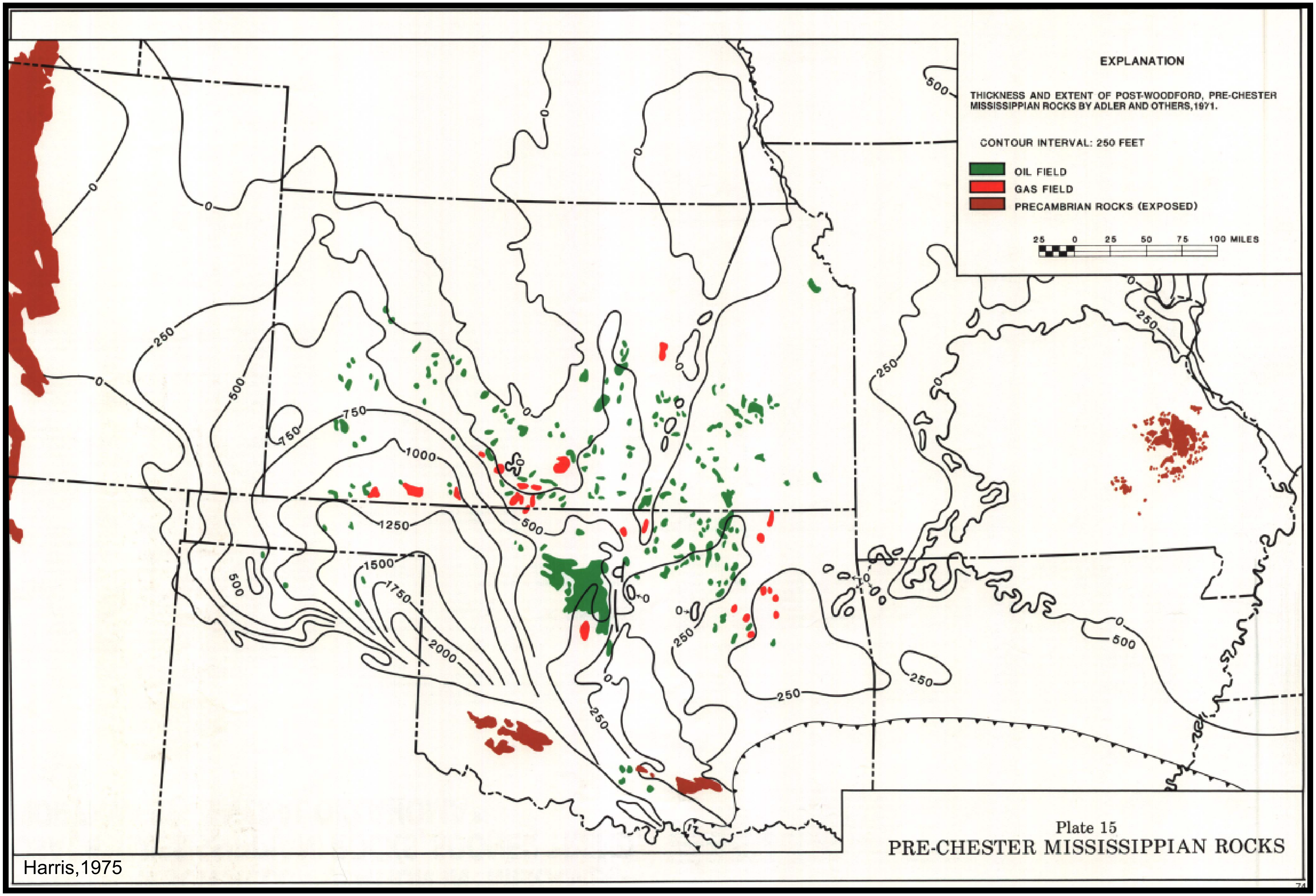
ConocoPhillips School of Geology and Geophysics

Reservoir Characterization and Modeling Laboratory

RCML

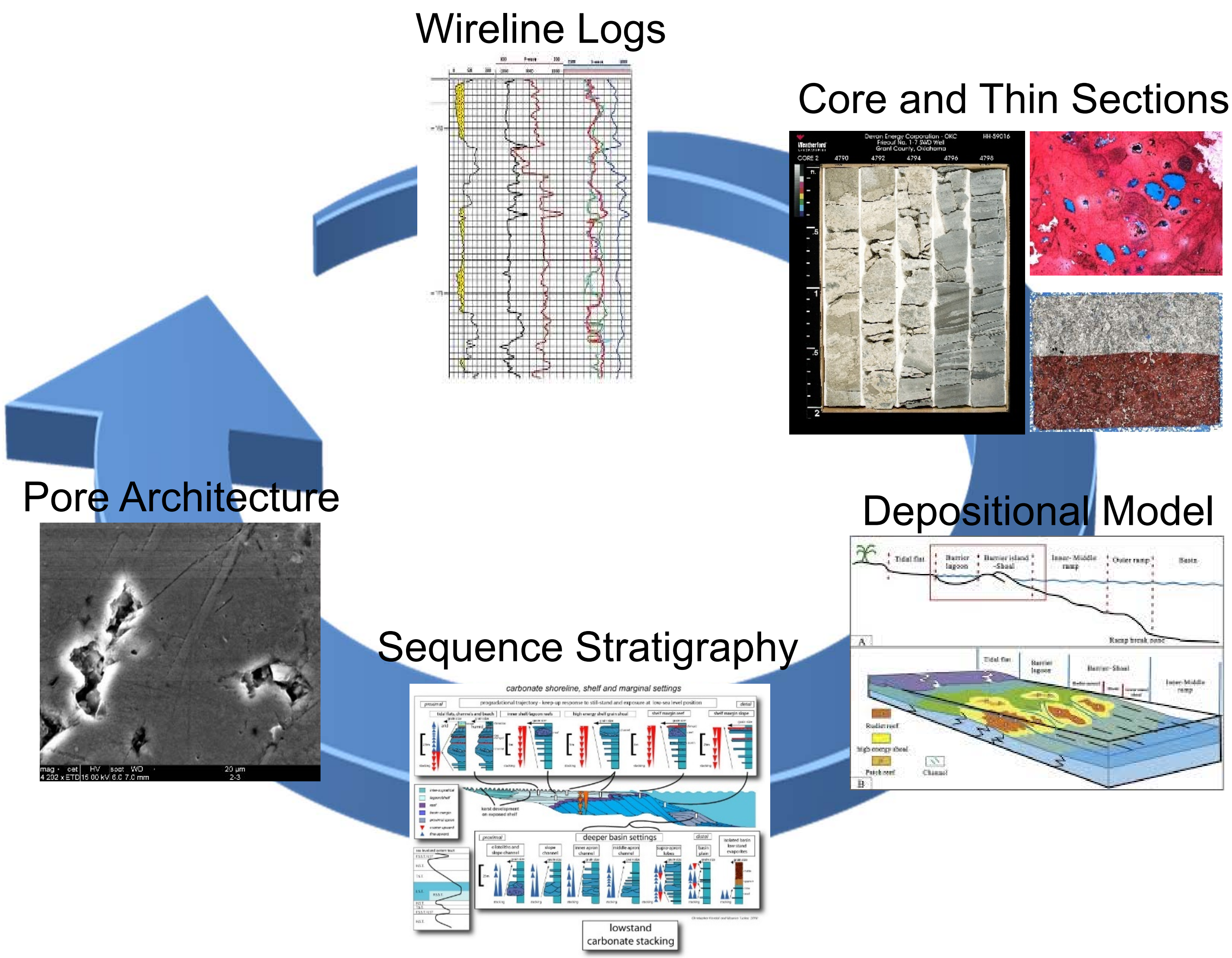
University of Oklahoma

Mid-Continent "Mississippian Limestone and Chert Reservoirs" Play Potential

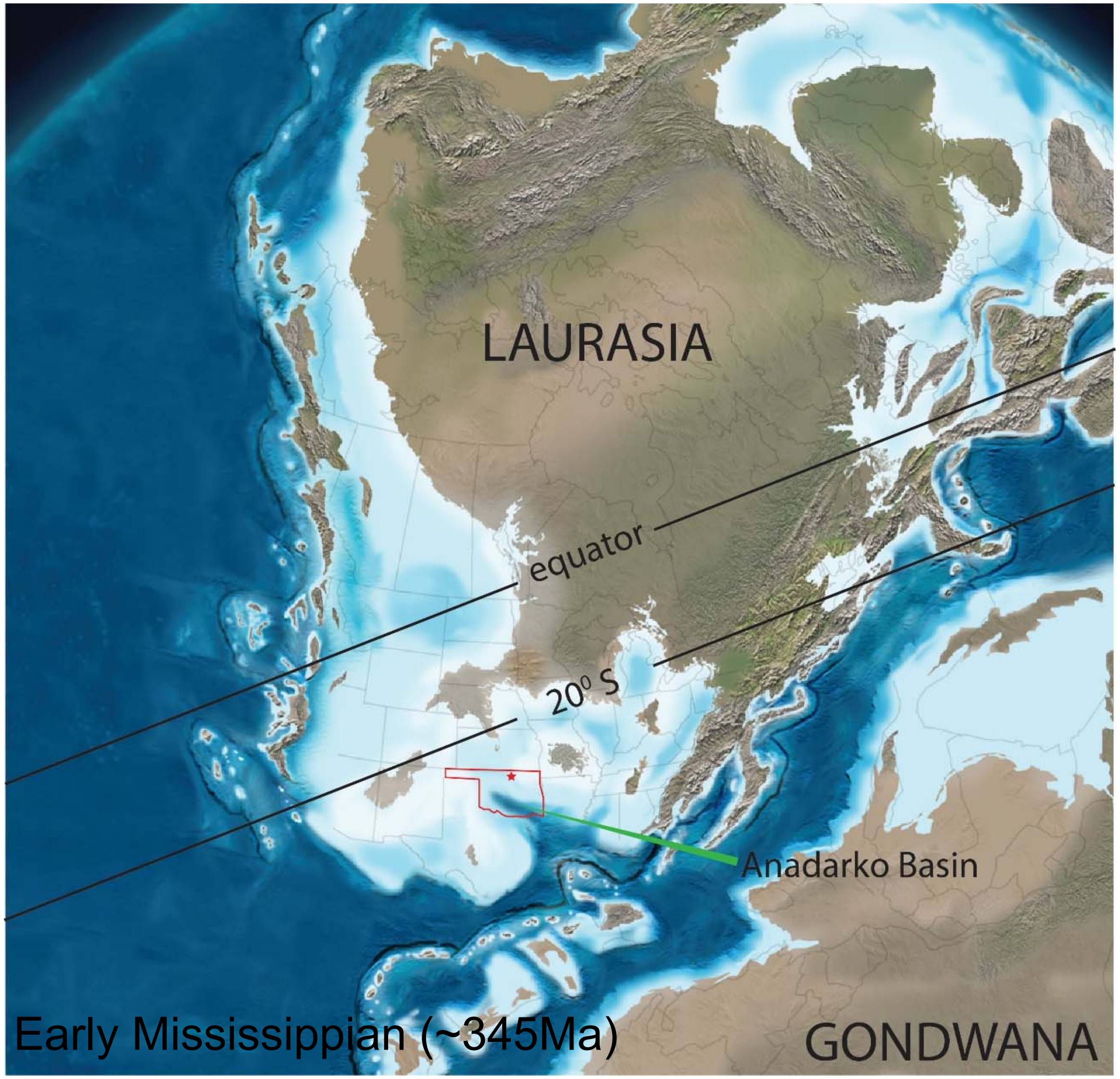


Harris,1975

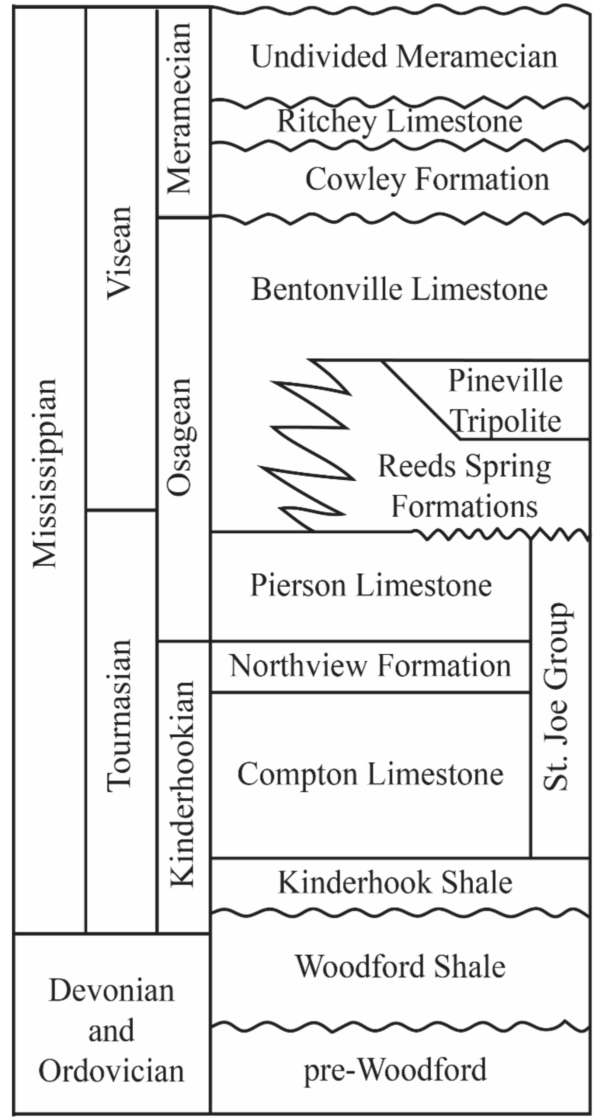
Integrated Reservoir Characterization



Paleogeography and Stratigraphy

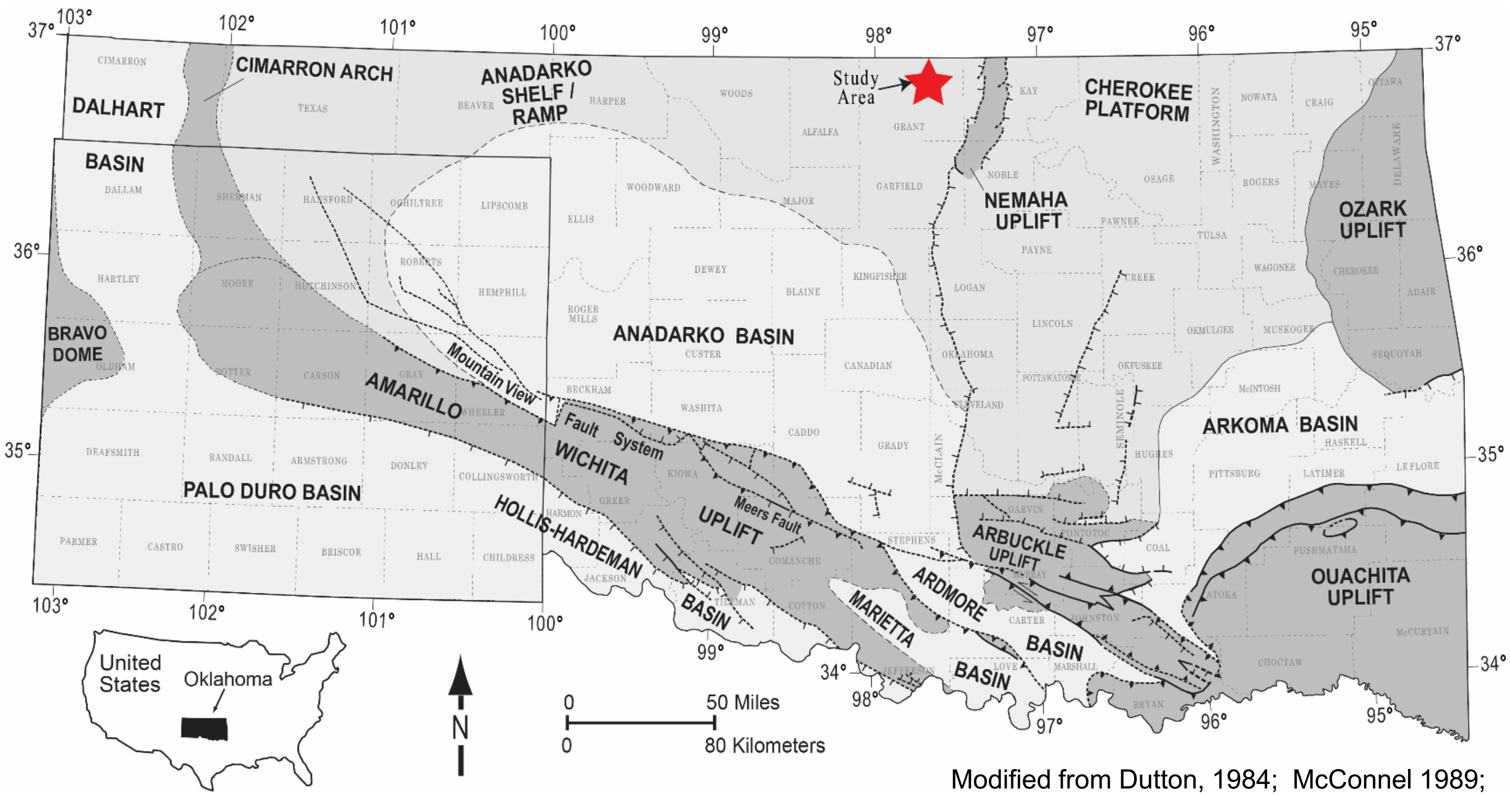


Blakey, 2013



Modified After Mazzullo 2011, Mazzullo et al., 2011, and Mazzullo et al., 2016

Core Location and Data

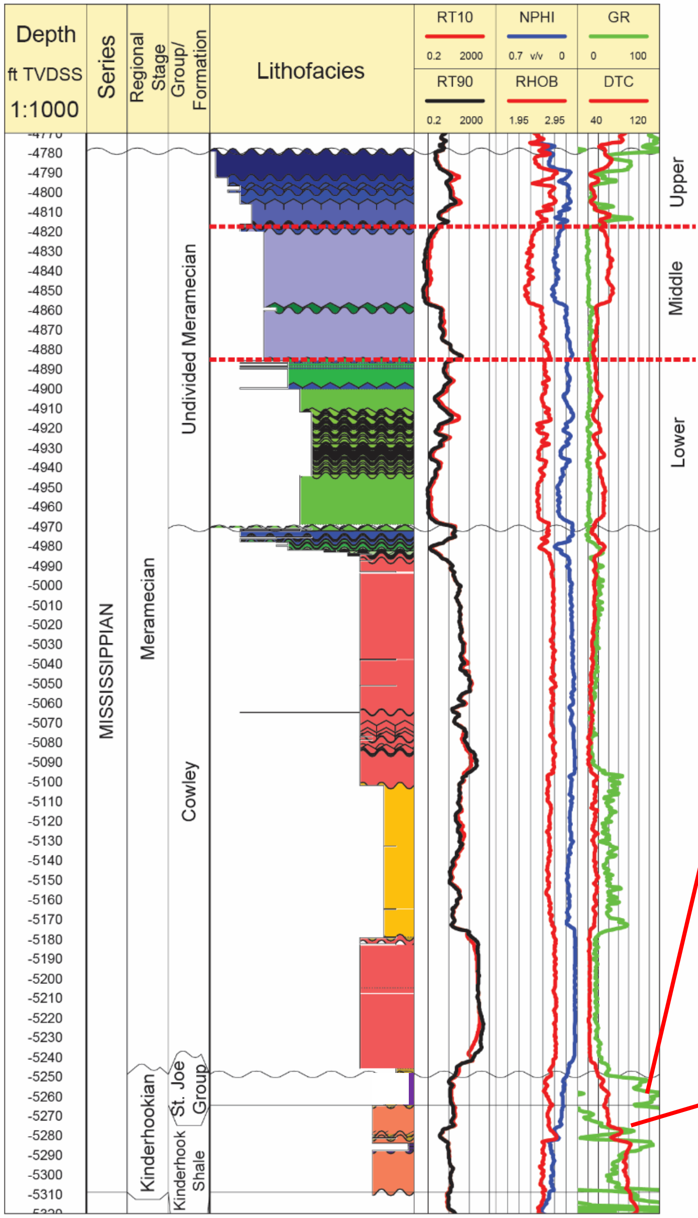


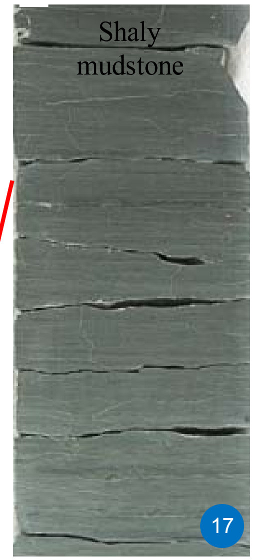
Modified from Dutton, 1984; McConnel 1989; Campbell et al., 1988; Northcutt and Campbell, 1995; Johnson and Luza, 2008; LoCriccho, 2012.

- Devon Energy Frieouf 1-7 SWD
- Anadarko Ramp
- Thickness 528 ft (~161m)
- Depth 4780 ft SS (~1457 m)

- Wireline logs
- Porosity and Permeability
- 57 Thin Sections
- ~23500 SEM photomicrographs

Lithofacies Characterization – Kinderhookian





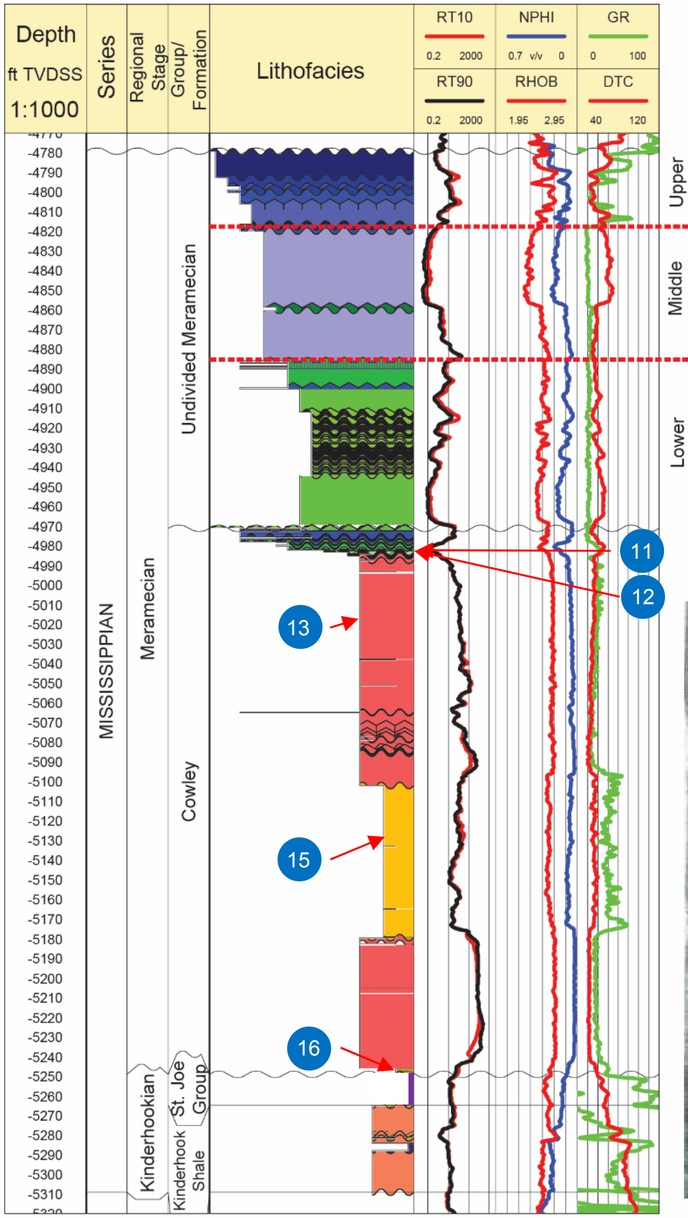
St. Joe Group

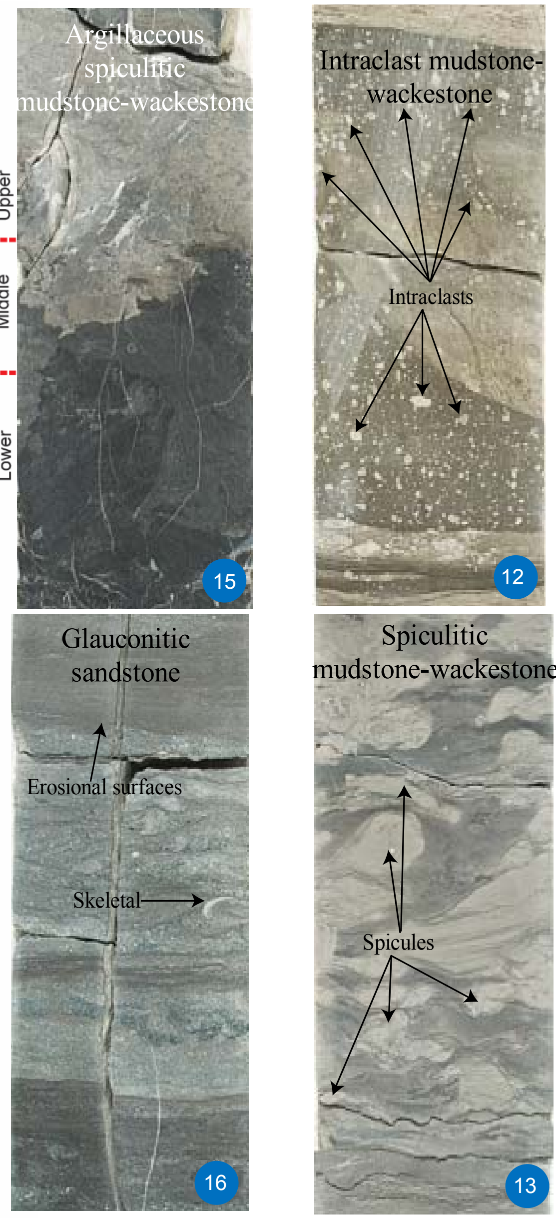
- GR : 60 – 100 GAPI
- 22 ft (~6.7 m)
- Light color mudstone to shaly mudstone

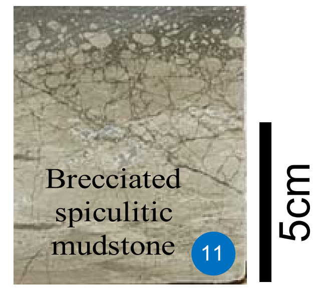
Kinderhook Shale

- GR : 100 – 190 GAPI
- 38 ft (~12 m)
- Structureless shale

Lithofacies Characterization - Meramecian



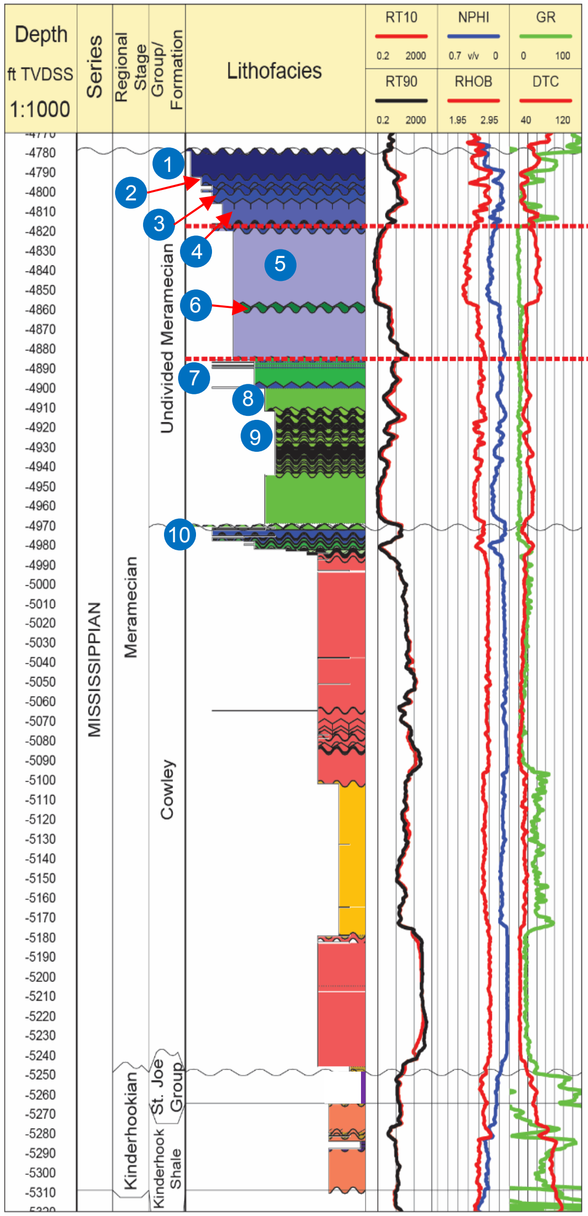




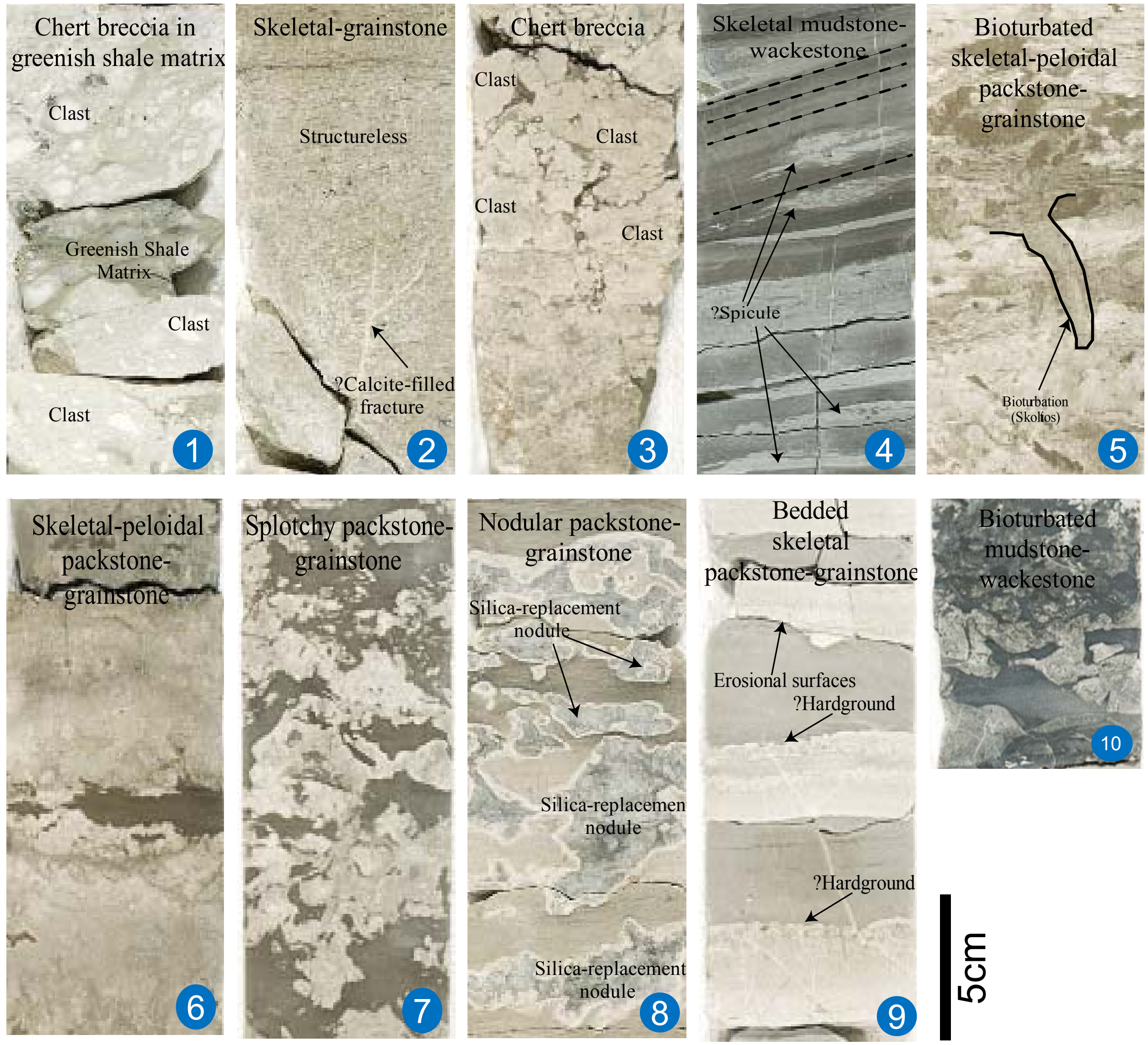
Cowley Formation

- GR : 15 – 50 GAPI
- 268 ft (~ 81 m)
- Glauconitic sandstone at the base
- Subaerial exposure atop of the Cowley Formation

Lithofacies Characterization - Meramecian



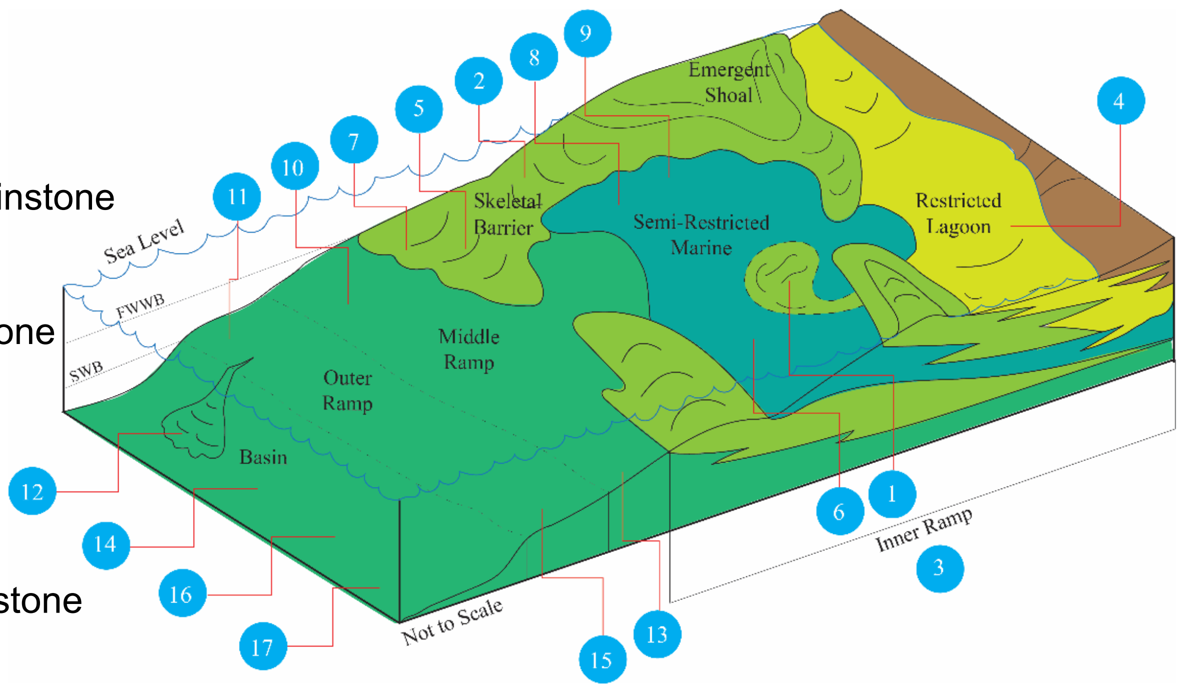
Undivided Meramecian



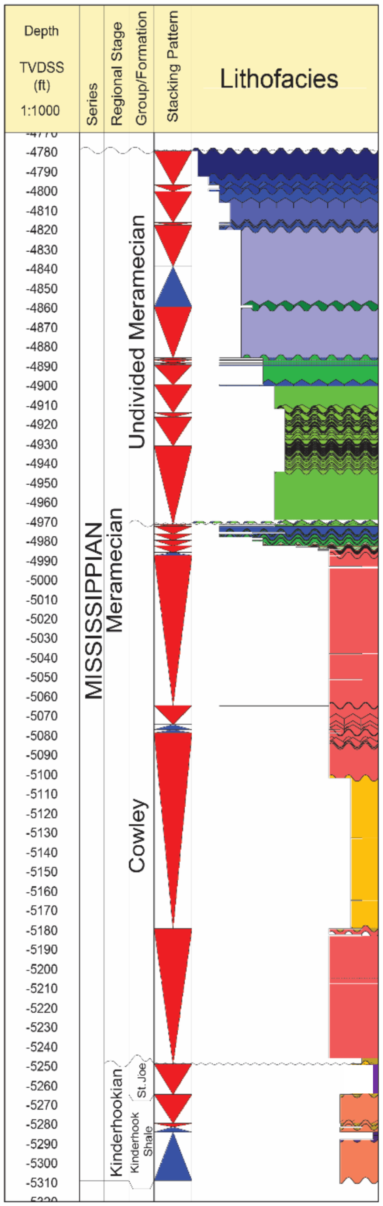
Spatial Distribution of Lithofacies

1 Chert breccia in greenish shale matrix
2 Skeletal grainstone
3 Chert breccia
4 Skeletal mudstone-wackestone
5 Bioturbated skeletal peloidal packstone-grainstone
6 Skeletal peloidal packstone-grainstone
7 Splotchy packstone-grainstone
8 Nodular packstone-grainstone
9 Bedded skeletal peloidal packstone-grainstone
10 Bioturbated mudstone-wackestone
11 Brecciated spiculitic mudstone-wackestone
12 Intraclast mudstone-wackestone
13 Spiculitic mudstone-wackestone
14 Shale
15 Argillaceous spiculitic mudstone-wackestone
16 Glauconitic sandstone
17 Shaly mudstone

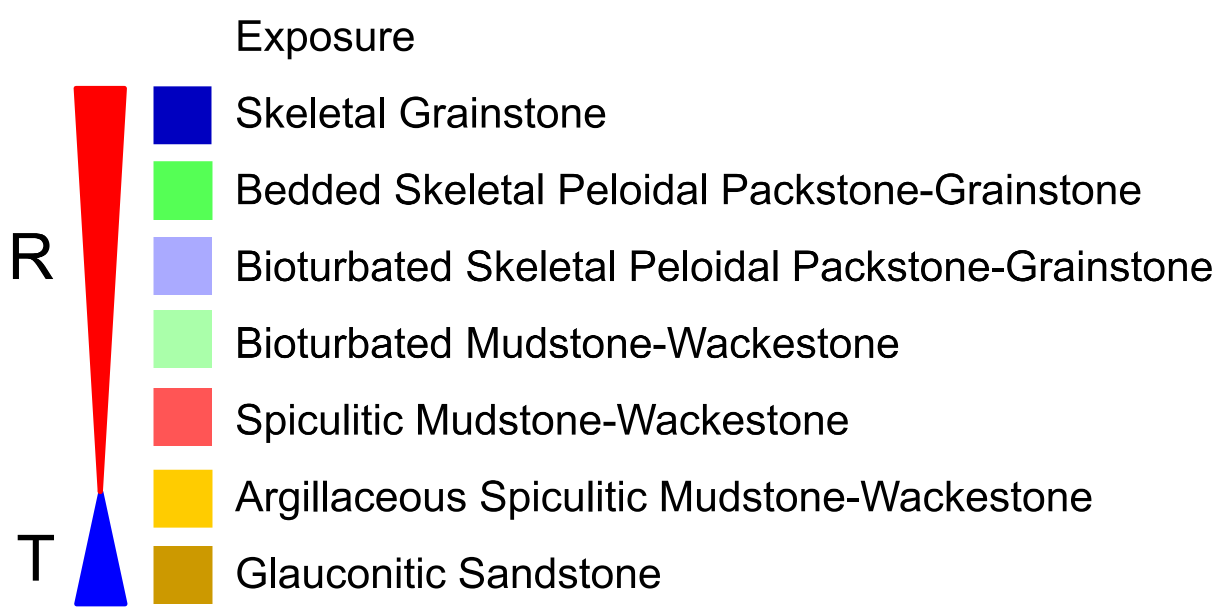
1 - 10 : Undivided Meramecian
11 – 16 : Cowley Formation
14* and 17 : Kinderhook



Mississippian – Sequence Stratigraphy

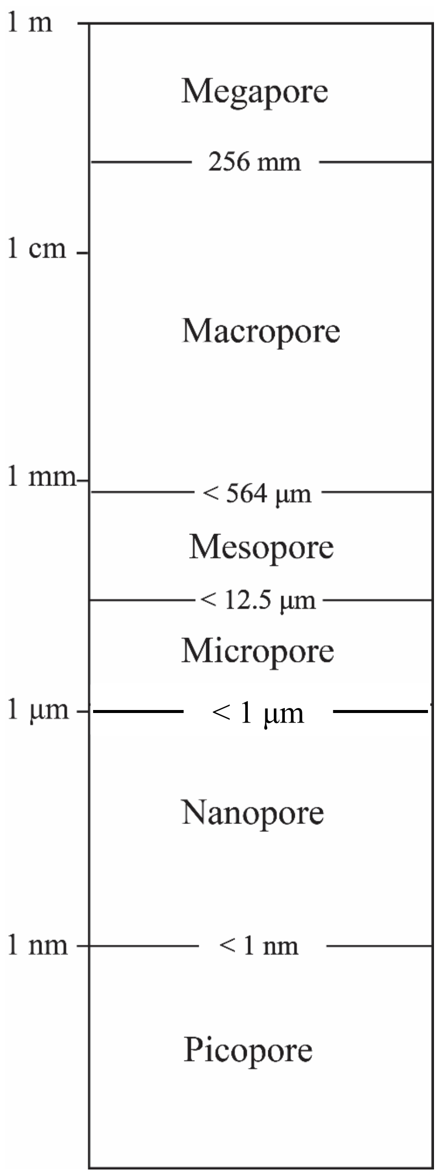


Idealized vertical lithofacies succession (Meramecian):

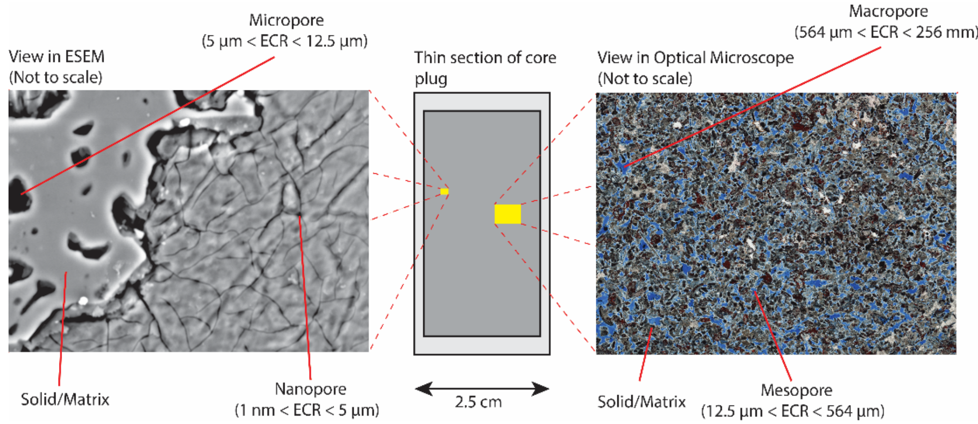


- 32 relatively high frequency cycles
- 1 – 100 ft (0.3 – 30.5m)
- 24 of 32 = asymmetric
- regressive > transgressive
- Kinderhook = 5 cycles, avg thickness 12 ft
- Cowley = 12 cycles, thickness > 60 ft
- Undivided Meramecian = 15 cycles, avg thickness 13 ft

Quantifying Pores – Digital Image Analysis

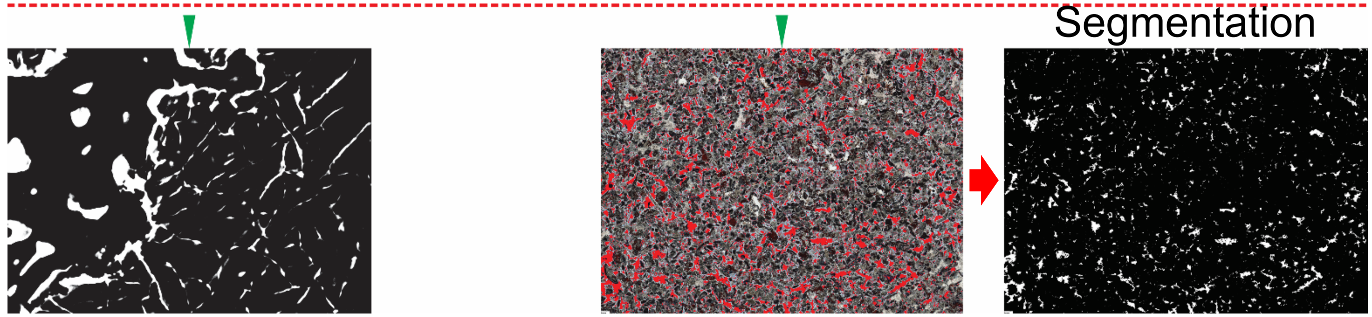


Modified after Loucks et al., 2012



Photomicrograph acquisition

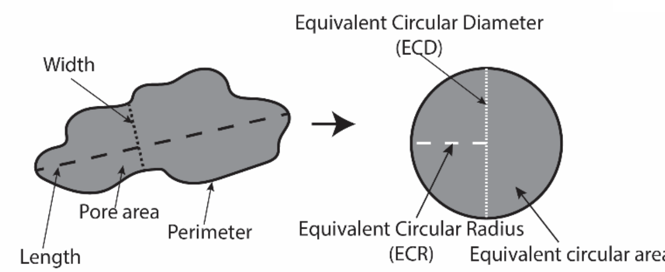
Segmentation



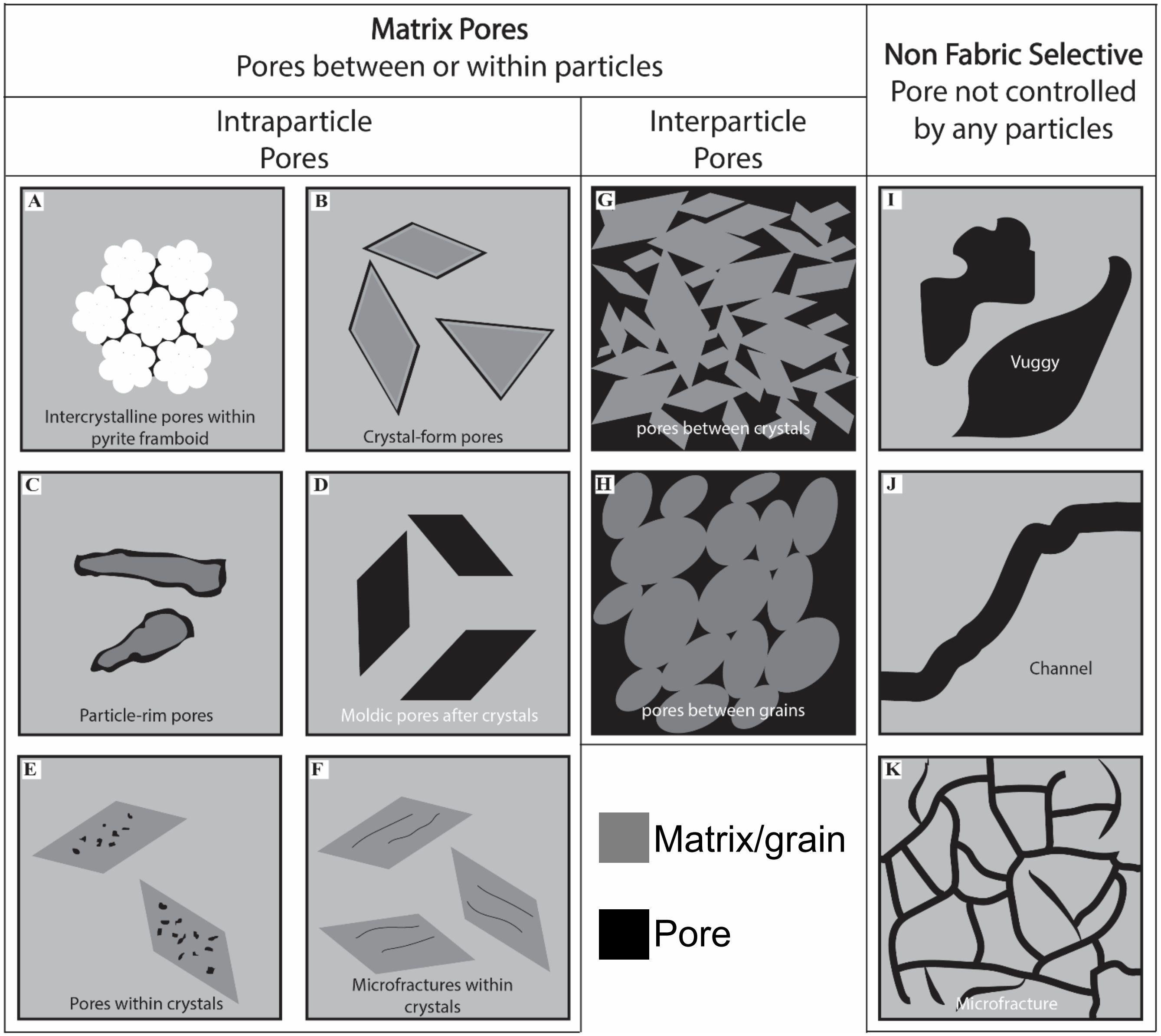
Pore extraction and measurement

$$Circularity = \sqrt{\frac{4\pi A}{P^2}}$$

Pore Paremeters:
a. Area (A)
b. Perimeter (P)
c. Length (L)
d. Width (W)
e. Equivalent Circular Diameter (ECD)
g. Circularity
h. Porosity

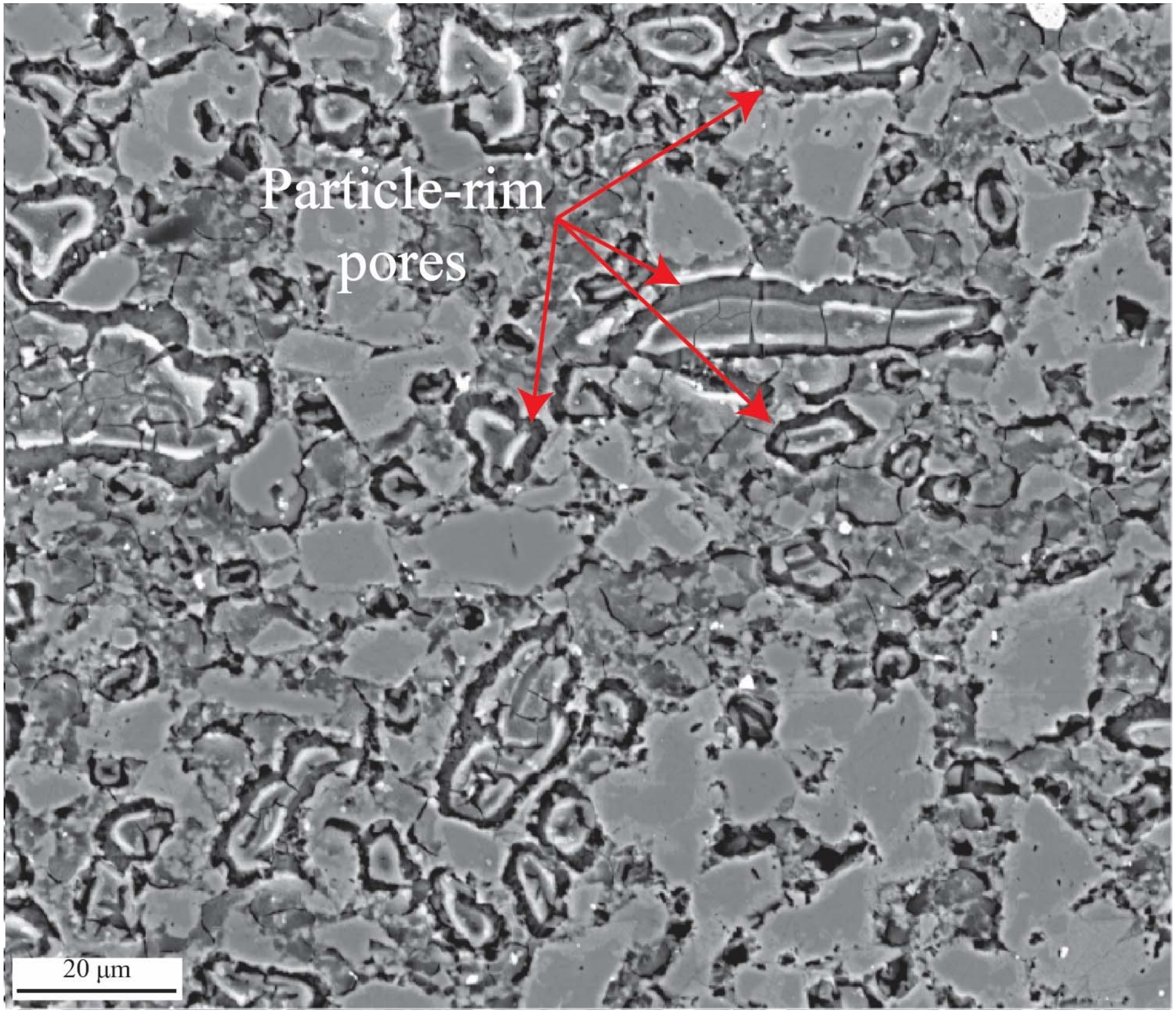


Pore Types

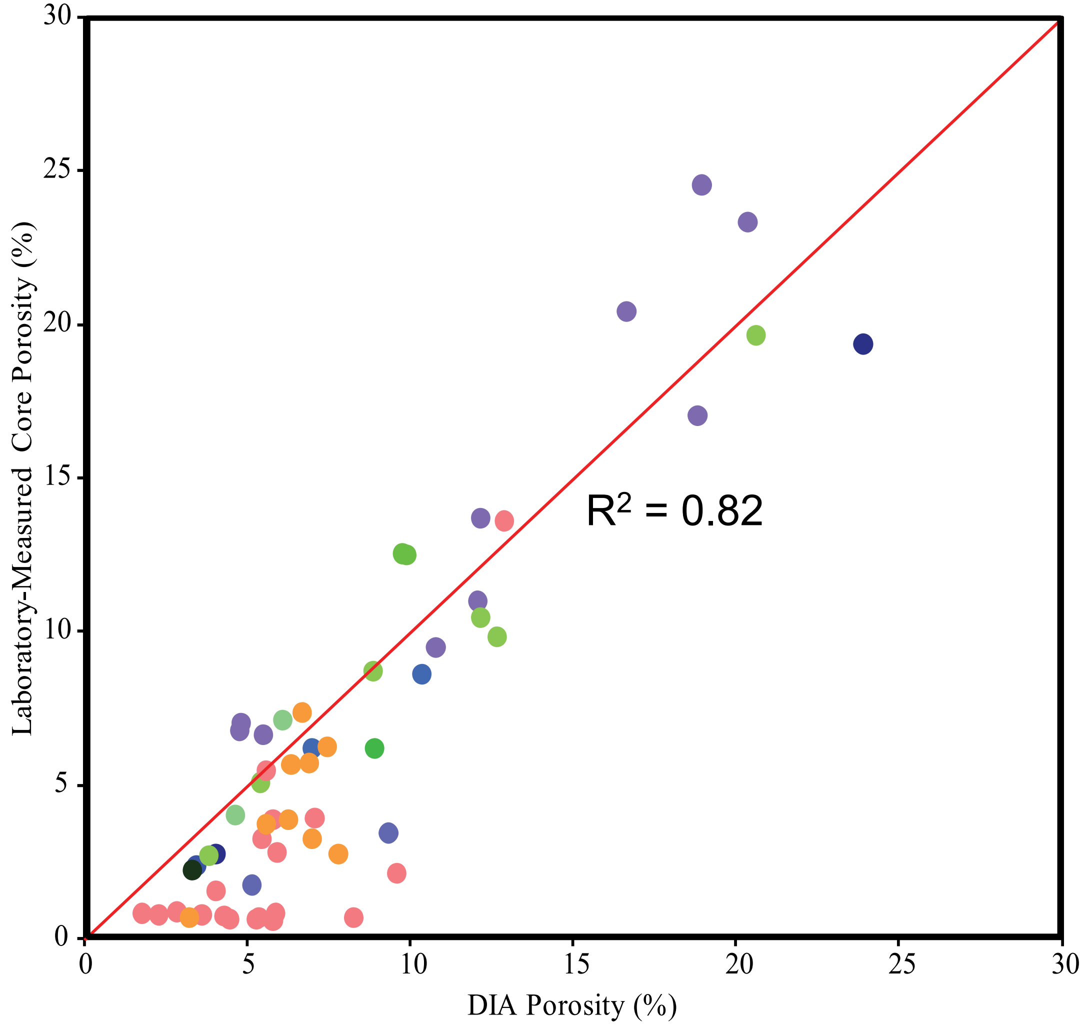


Not to Scale

Pore Types



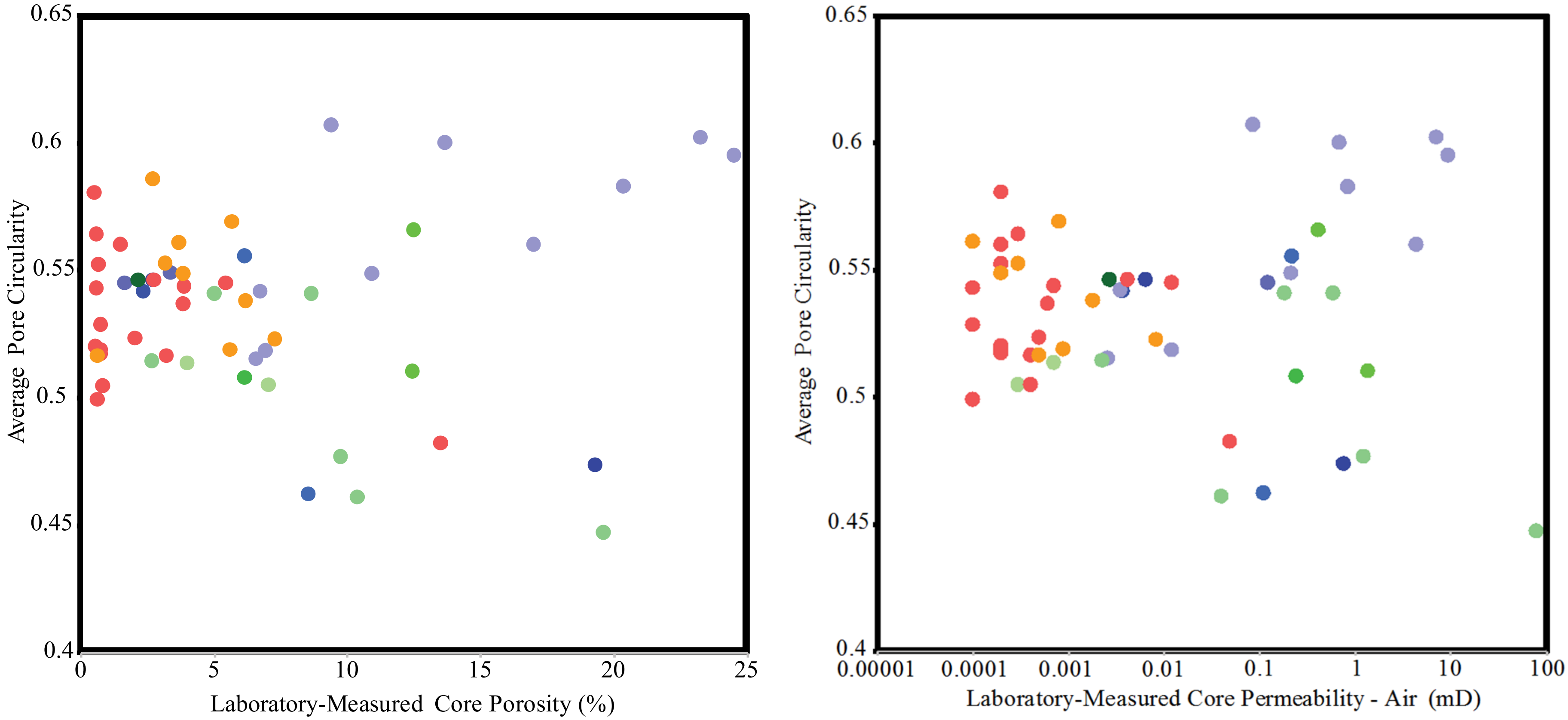
DIA: Quantitative Analysis - Porosity



- Sampling bias
- Grayscale/color threshold subjectivity
- Grain plucking
- $\phi_{tot} >< \phi_{eff}$

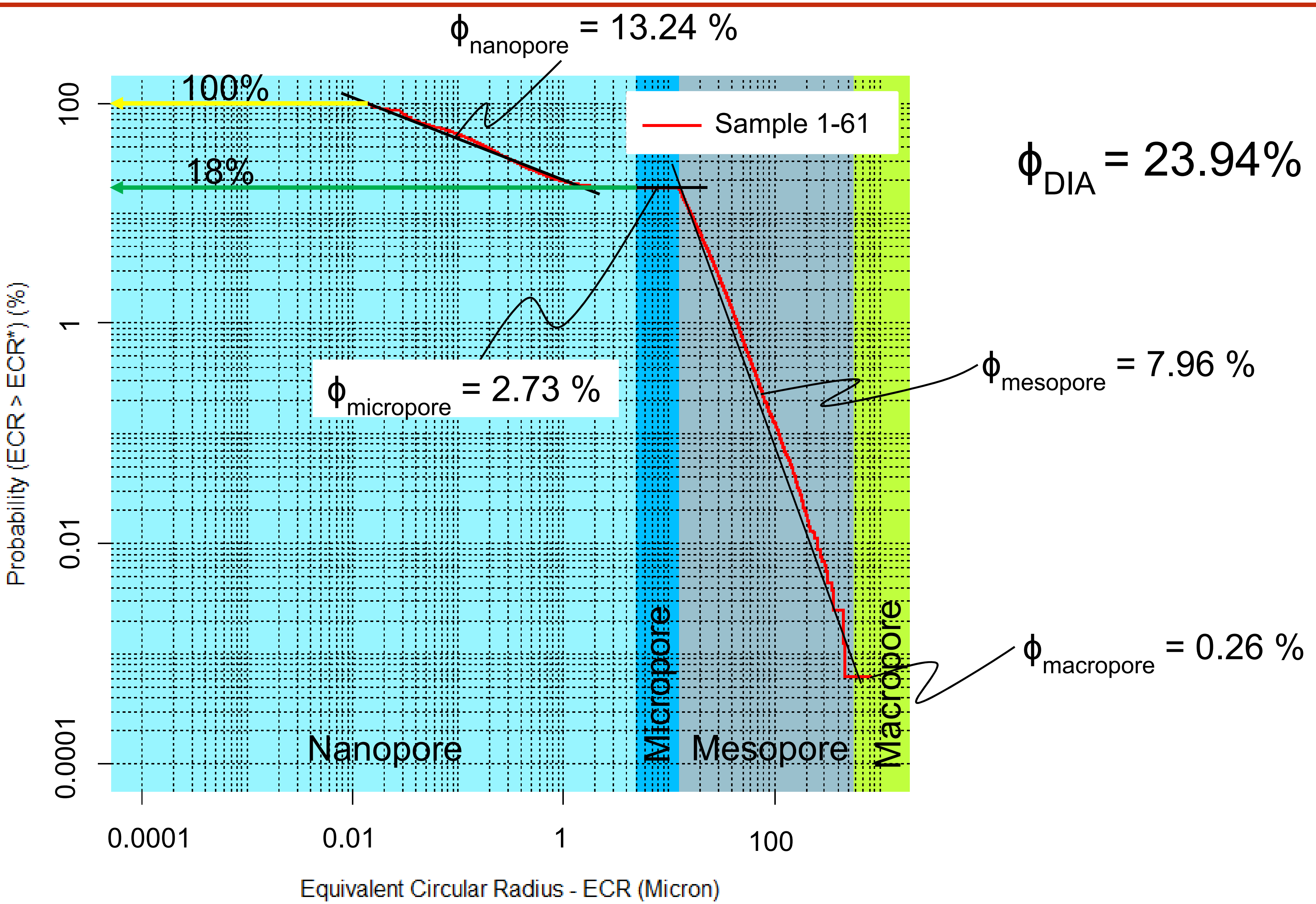
Lithofacies: 1 2 3 4 5 6 7 8 9 10 13 15

DIA : Quantitative Analysis - Circularity

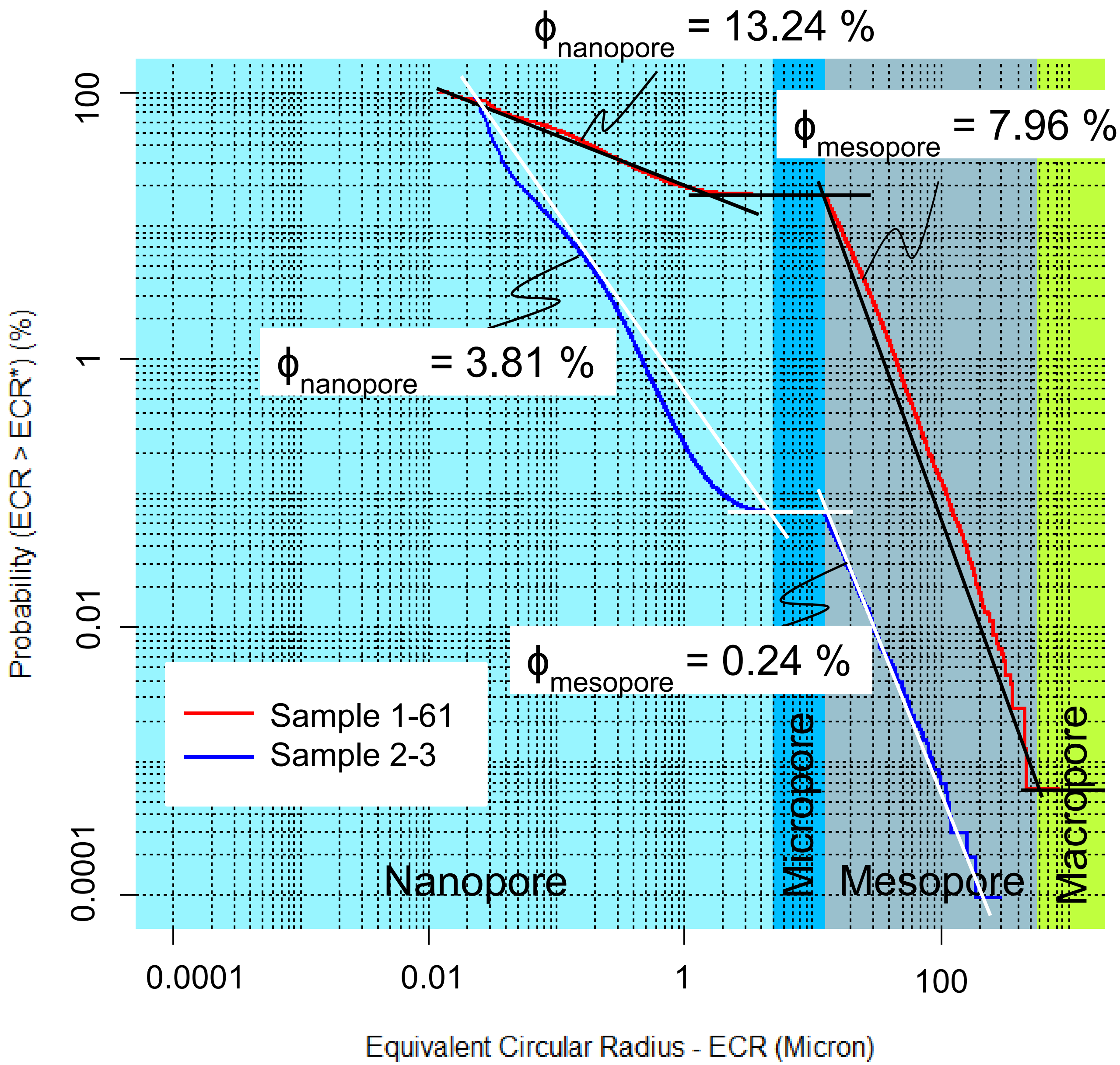


Lithofacies: 1 2 3 4 5 6 7 8 9 10 13 15

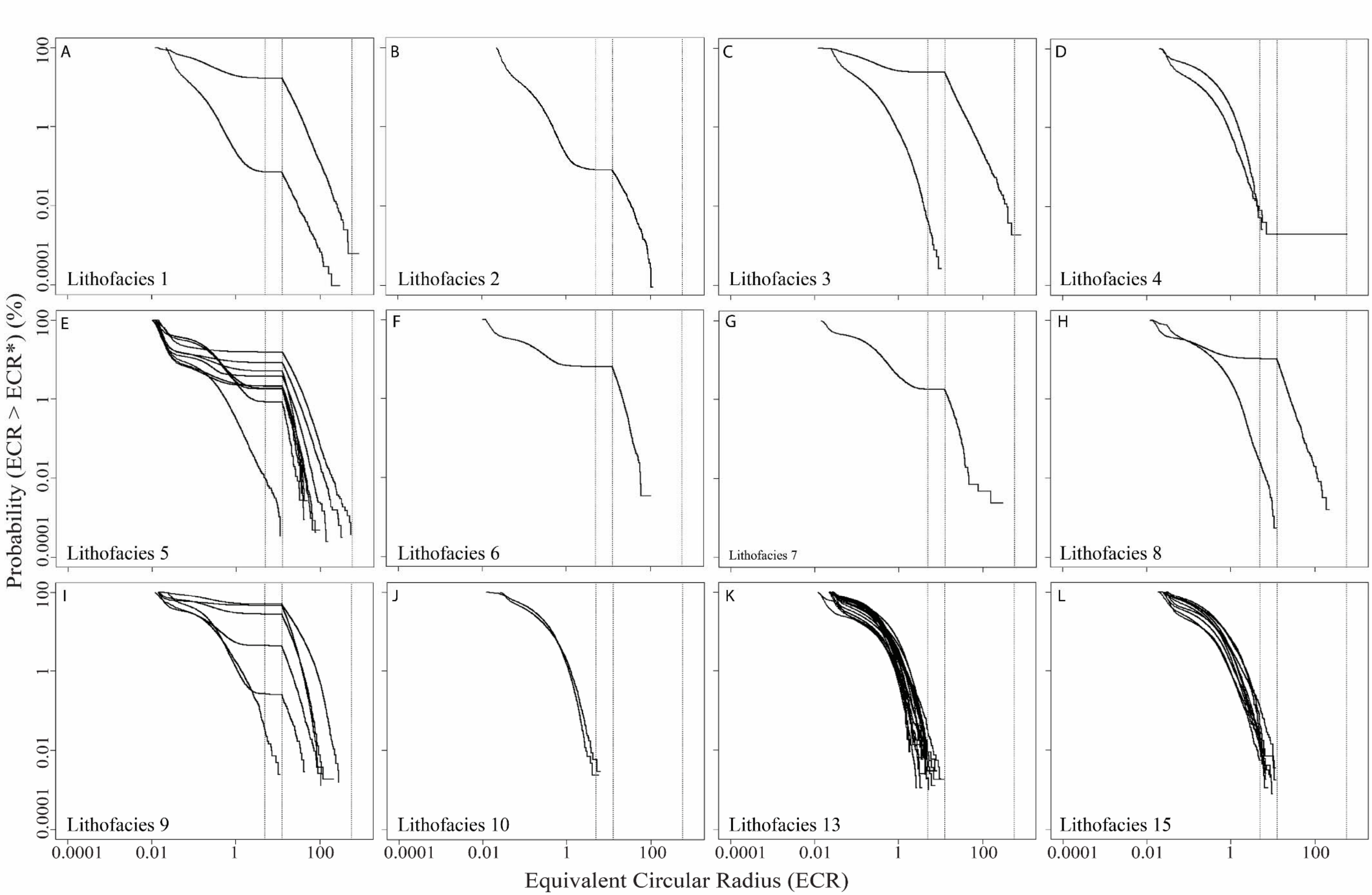
DIA : Quantitative Analysis – Pore Size Distribution



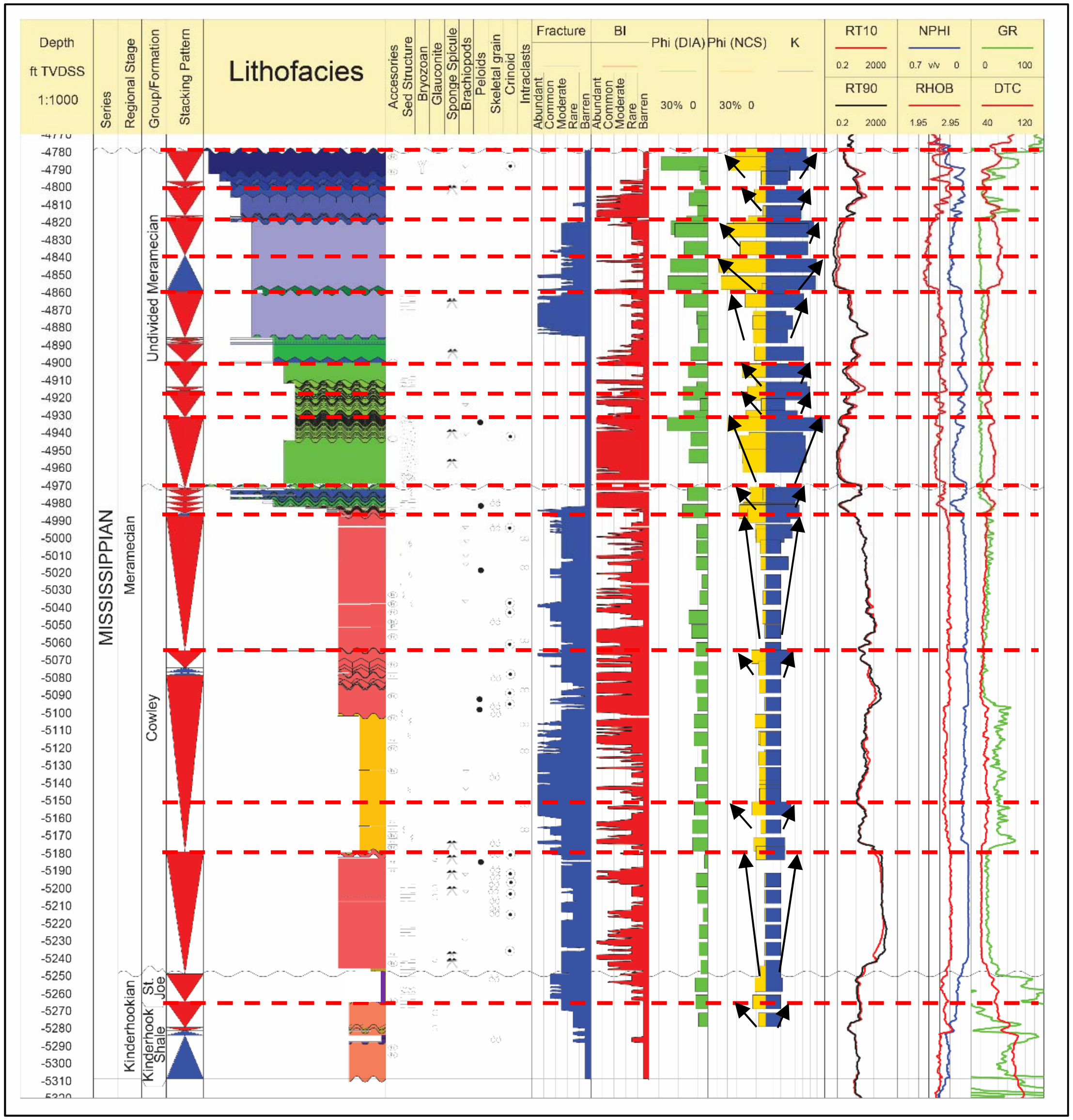
DIA : Quantitative Analysis – Pore Size Distribution



DIA: Pore Size Distribution



Integration



Devon Energy Frieouf 1-7 SWD:

- Predictable correlation with sequence-stratigraphic framework, porosity, and permeability.
- Best reservoir quality at the top of high-order regressive cycles.

Conclusions

- Pore Architecture Characterization - DIA:
  - DIA porosity vs. Laboratory Measured Porosity - positive
  - Pore shape vs. porosity and permeability - indeterminate
  - PSD: fine-grained vs. coarse-grained dominated lithofacies

- Reservoir quality – regressive cycles

- Sequence-stratigraphic analysis – best reservoir quality intervals

Acknowledgments

RCML

devon

QEP RESOURCES™

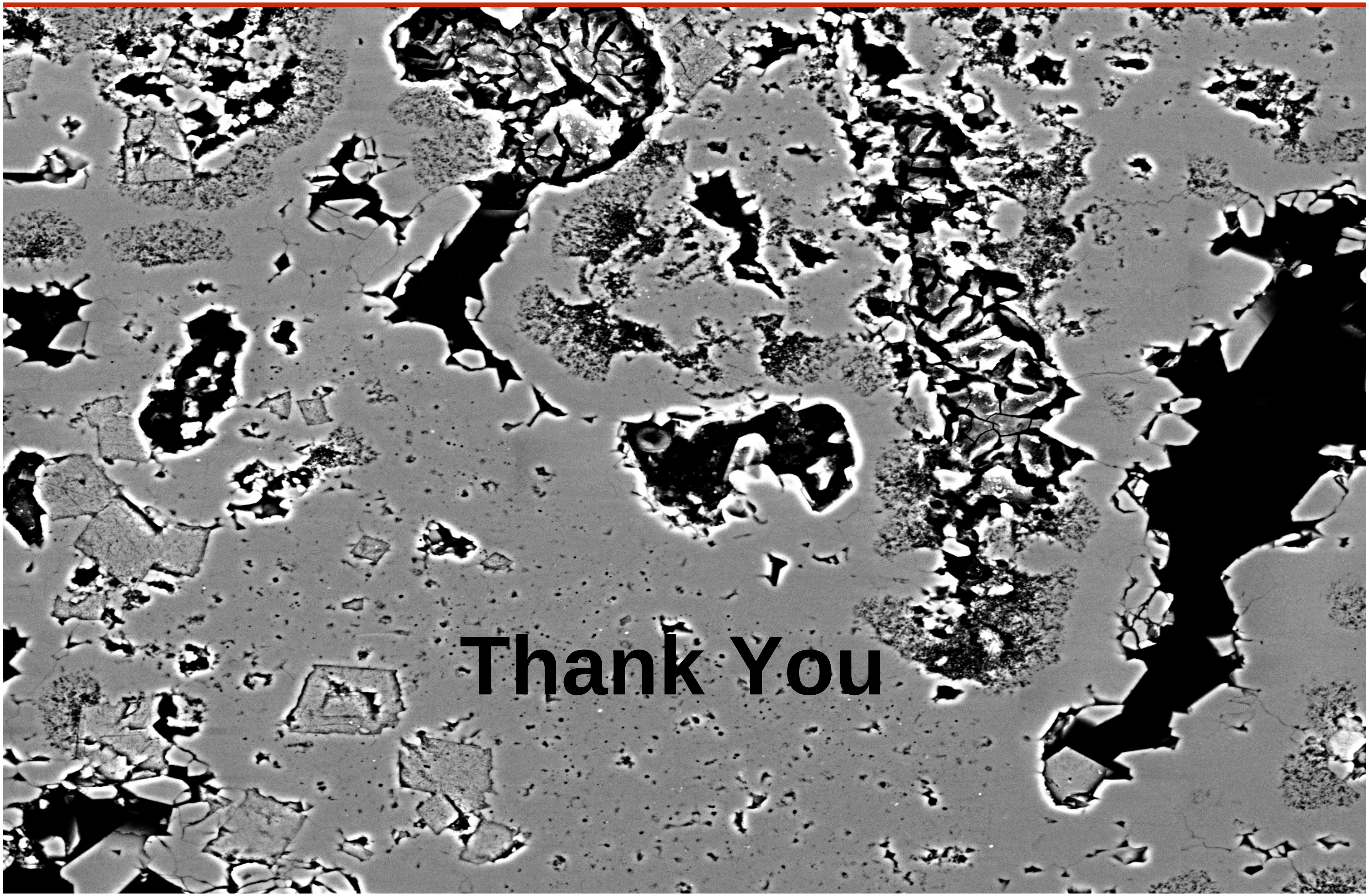
中国石化 SINOPEC

Chesapeake ENERGY

ALT Advanced Logic Technology

micro VISION

RCML



Thank You