Distinguishing Organic Matter Pores Associated With Depositional Organic Matter versus Migrated Organic Matter in Mudrocks*

Robert G. Loucks[1] and Robert M. Reed[1]

Search and Discovery Article #80477 (2015)**
Posted September 21, 2015

*Adapted from presentation at 2015 AAPG Convention & Exhibition, Denver, Colorado, May 31-June 3, 2015

[1]Bureau of Economic Geology, The University of Texas at Austin, Austin, Texas (bob.loucks@beg.utexas.edu)

Abstract

Organic-matter (OM) pores are an important constituent of mudrocks and comprise the dominant or subsidiary pore network of many shale-gas and shale-oil systems. New research suggests that OM pores form not only in kerogen, as originally proposed, but also in solid bitumen and pyrobitumen. Identifying the type of nanometer- to micrometer-sized organic matter that is present in mudrocks is extremely difficult, if not impossible, using a scanning electron microscope (SEM). However, distinguishing whether the OM-pore hosted organic material exists in-place or has migrated would allow the determination to be made whether the original organic material was kerogen or migrated bitumen. There are several SEM-based petrographic criteria that can be used to separate depositional versus migrated organic matter. These criteria include: (1) organic matter occurring after cementation in mineral pores, (2) fossil body-cavity voids filled with organic matter, (3) dense, spongy pore texture of the organic matter, (4) abundant contiguous pores filled with organic matter having a spongy pore network, (5) no alignment of pores in organic matter (aligned OM pores are present in kerogen), (6) cracks in organic matter related to devolatilization, and (7) anomalously larger bubbles associated with development of two hydrocarbon phases. It is important to recognize the difference between depositional organic-matter nanopores versus migrated-organic-matter nanopores because their distribution is different, and this has a profound effect on reservoir quality. Original depositional organic material is composed of kerogen, which can be transformed to bitumen and then oil, gas, solid bitumen, and pyrobitumen (char) during thermal maturation. When bitumen is produced from the kerogen, it can migrate into the mineral pore network and later transform to solid bitumen or pyrobitumen. The final pore network and associated reservoir quality within the mudrock are dependent on the proportions of the distribution of these two organic matter states. OM pores in isolated depositional organic matter may not be well connected and maynot form a continuous permeability pathway for the hydrocarbons. Migrated organic-matter-hosted pores mimic the three-dimensional distribution of the original mudrock mineral pore network and provide more extensive contiguous permeability pathways than isolated organic matter, thus providing a higher reservoir-quality mudstone system.

References Cited

Loucks, R.G., and R.M. Reed, 2014, Scanning-electron-microscope petrographic evidence for distinguishing organic matter pores associated with depositional organic matter versus migrated organic matter in mudrocks (abstract): Gulf Coast Association of Geological Societies Transactions, v. 64, p. 713.

Loucks, R.G., R.M. Reed, S.C. Ruppel, and U. Hammes, 2012, Spectrum of pore types and networks in mudrocks and a descriptive classification for matrix-related mudrock pores: AAPG Bulletin, v. 96/6, p. 1071–1098.

2015 AAPG Annual Meeting

Distinguishing Organic Matter Pores Associated with Depositional Organic Matter versus Migrated Organic Matter in Mudrocks

Robert Loucks and Robert Reed

TEXAS Geosciences
Bureau of Economic Geology
Jackson School of Geosciences
The University of Texas at Austin

Mudrock Systems Research Laboratory
MSRL

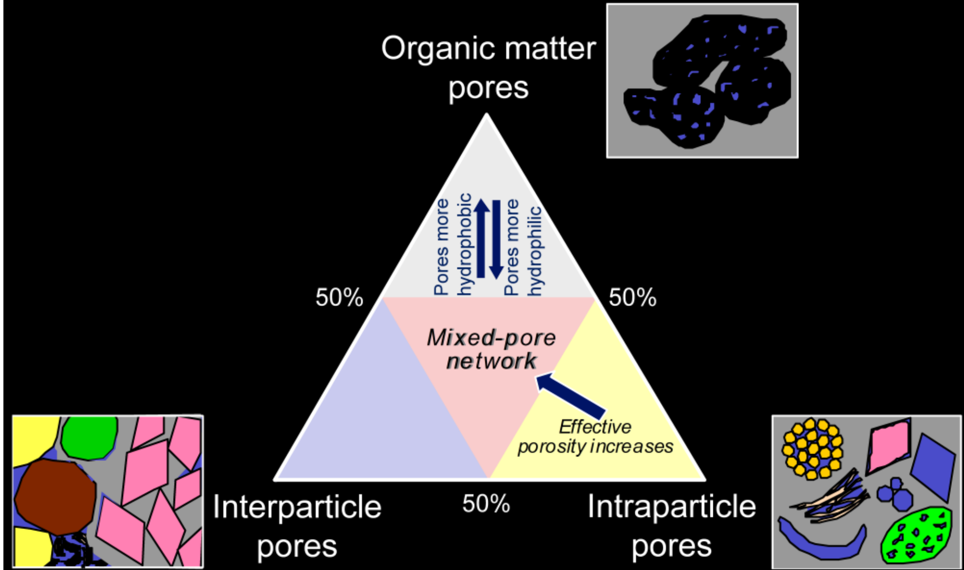
Major Concept

- Organic matter (OM) pores are an important pore type in many mudrock reservoirs
- OM pores can be in original depositional kerogen or in migrated bitumen products (solid bitumen or pyrobitumen)
- OM pores in migrated bitumen products form better connected pore systems

Outline

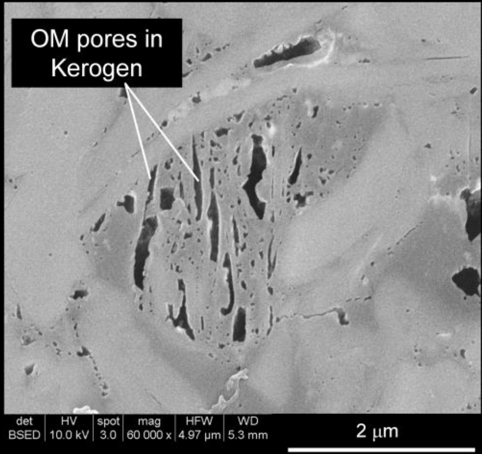
- Introduction to OM pores
- Recognizing in-place OM pores vs. OM pores in a migrated bitumen products
- Mudrock pore network end members

Mudrock Pore Network Classification

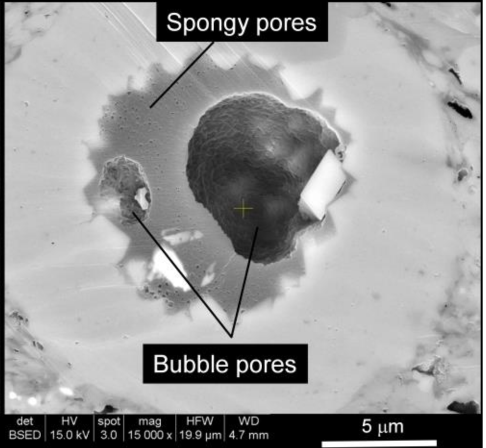


Mod. From Loucks et al. 2012

General OM Pore Types

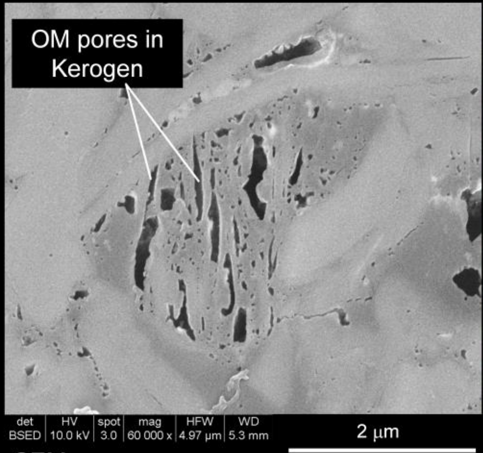


Primary pores in organic matter

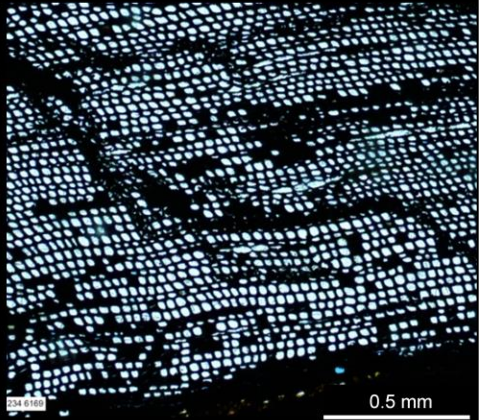


Secondary pores in organic matter

Pore Types
Primary OM Pores



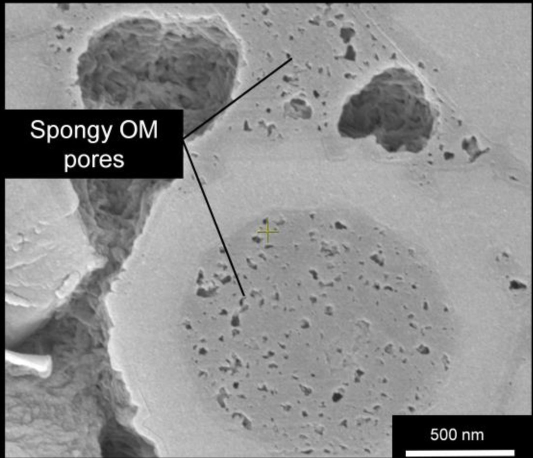
SEM



Thin section

- ➢ Examples of primary OM pores

Pore Types
Organic-Matter Spongy Pores

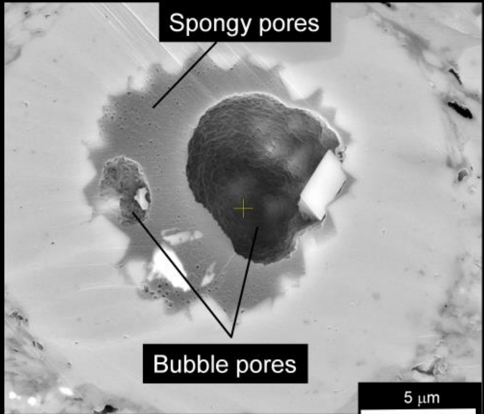


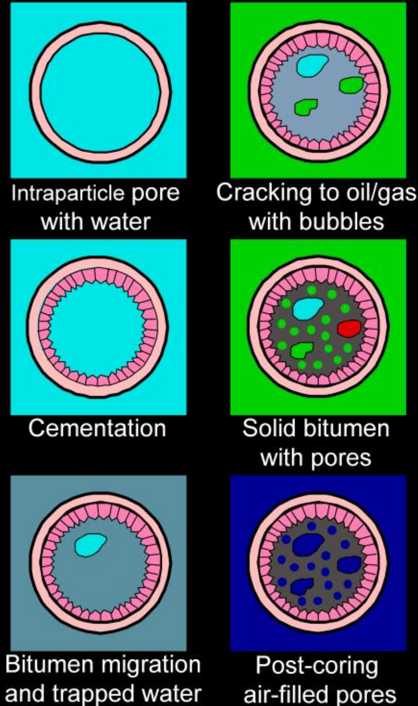
- Generated during thermal maturation of bitumen

Eagle Ford

Pore Types

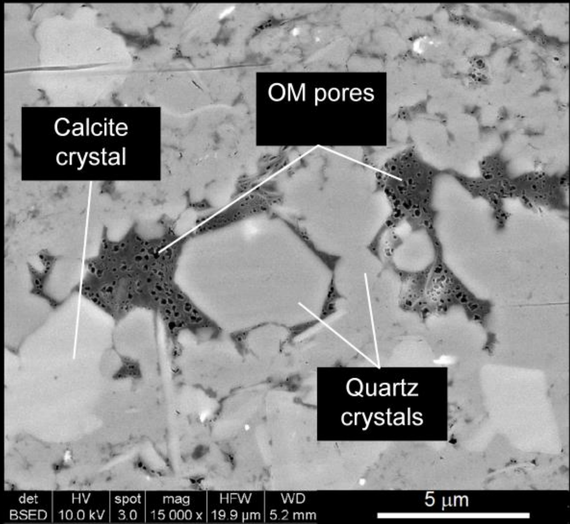
Organic-Matter Bubble Pores





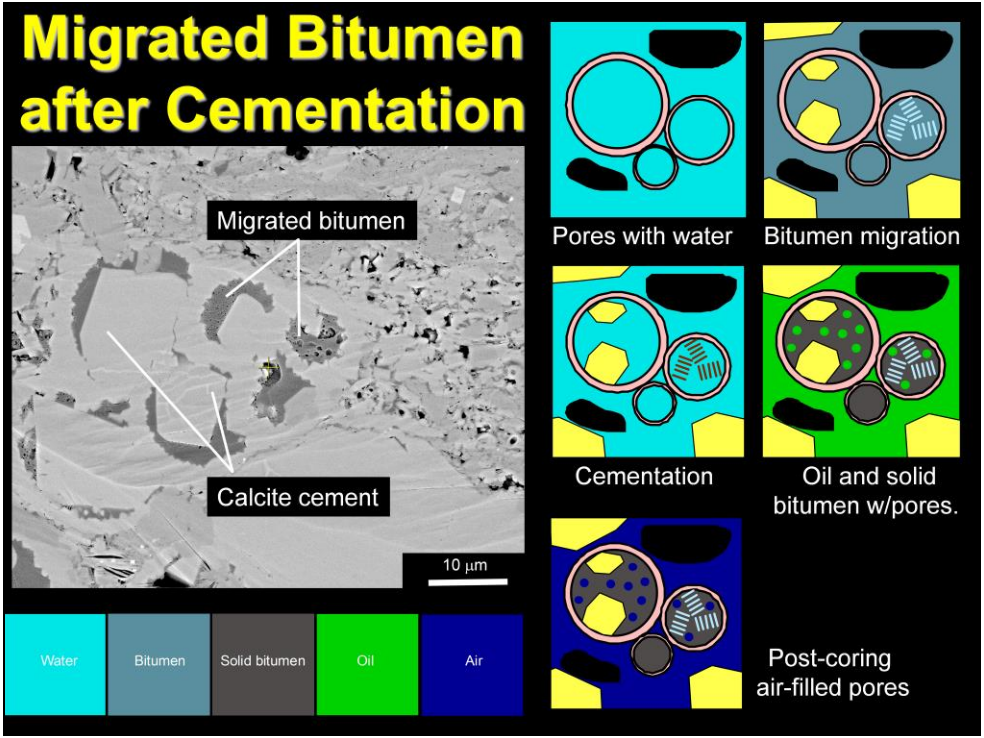
SEM Petrographic Criteria for Recognizing Depositional (In-Place) vs. Migrated Organic Matter Related Pores

Criterion 1: Migrated Organic Matter Occurring after Cementation in Mineral Pores



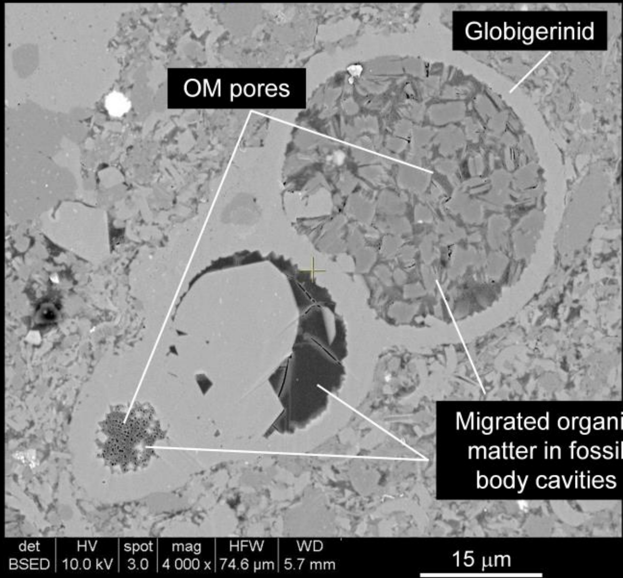
- Cemented mineral pores with migrated organic matter numerous OM pores

Barnett Shale, 14,676':
R_o ~ 1.25%



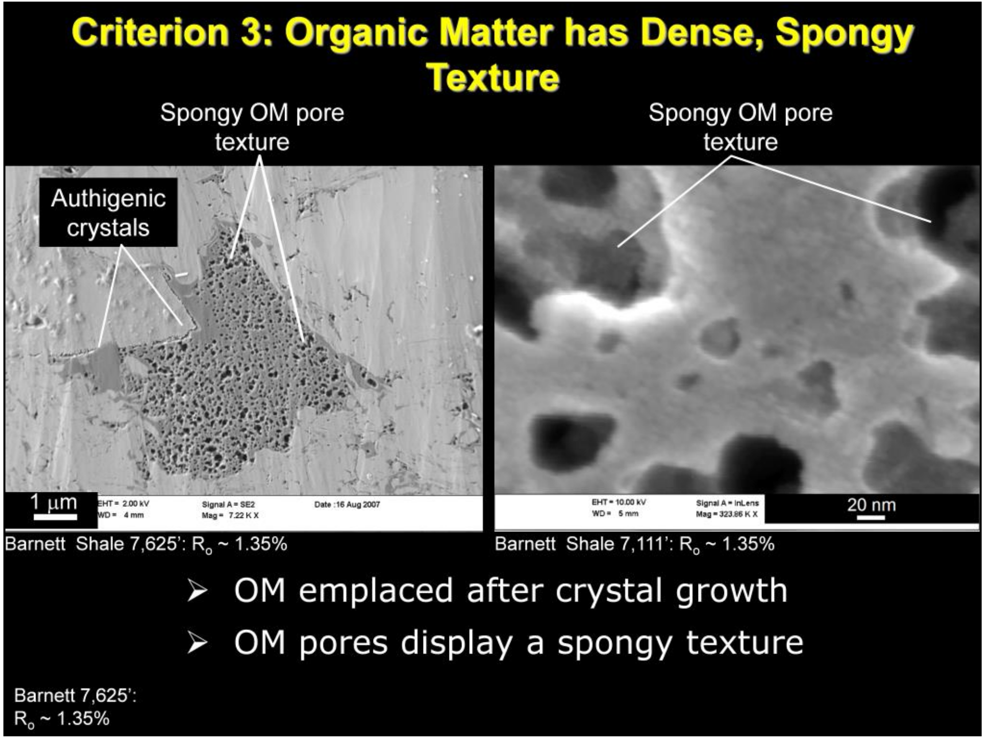
Migrated Bitumen after Cementation
Migrated bitumen
Calcite cement
10 μm
Water
Bitumen
Solid bitumen
Oil
Air
Pores with water
Bitumen migration
Cementation
Oil and solid bitumen w/pores.
Post-coring air-filled pores

Criterion 2: Fossil Body-Cavity Voids Filled with Organic Matter



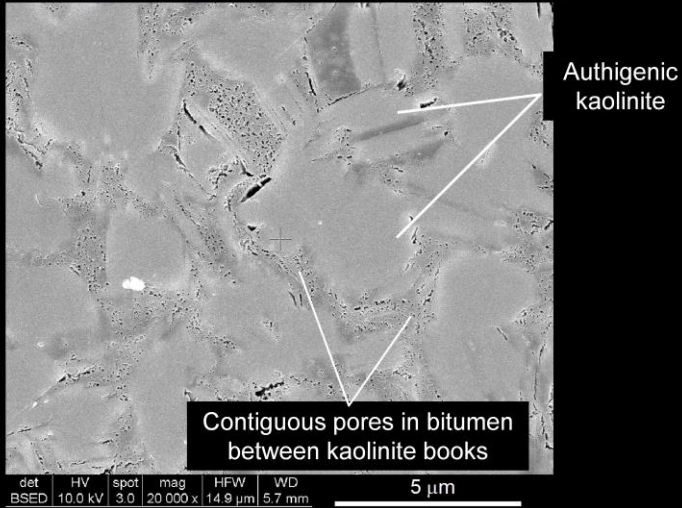
Eagle Ford Fm., 6214': $R_o \sim 0.8\%$

- Bitumen migrated into fossil



Presenter's notes: In both the Permian Basin and the Ft. Worth Basin, in high and low maturity samples, especially in framboids, there is a strange association of pores and pyrite. VRo ~ 1.2.

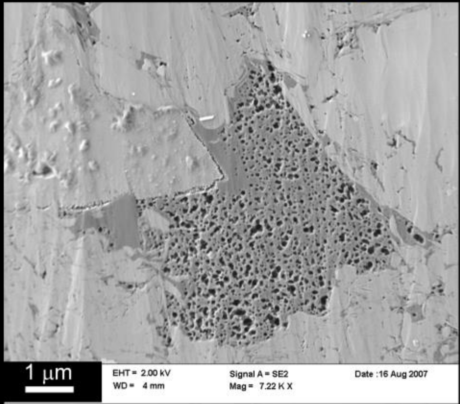
Criterion 4: Filling of adjacent Pores with Spongy Texture (Contiguous Pore Network)

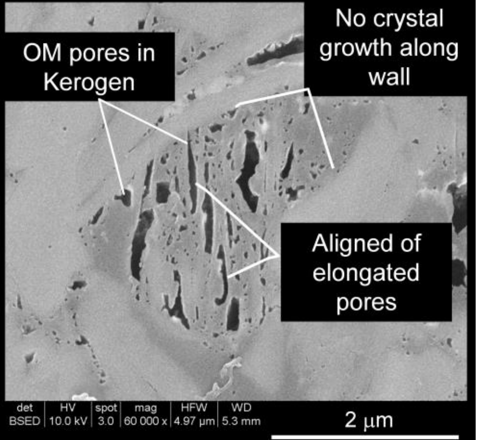


- OM pores have very spongy texture
- Organic matter is contiguous between former mineral pores

Eagle Ford Fm., 6214':
R_o ~ 0.8%

Criterion 5: No Alignment of OM Pores in Migrated Bitumen





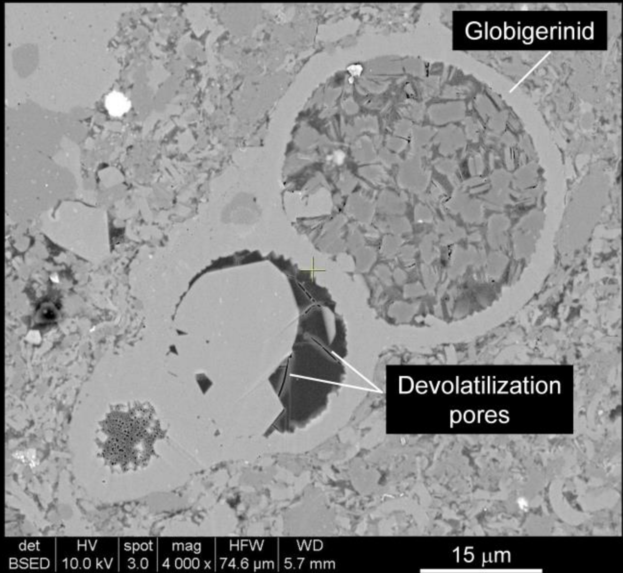
- No alignment of OM pores in migrated organic matter

- Alignment of OM pores in depositional kerogen (in-place organic matter)

Barnett Shale 7111: R_o ~ 1.35%

Eagle Ford Fm. 13,814' :R_o ~ 1.4%

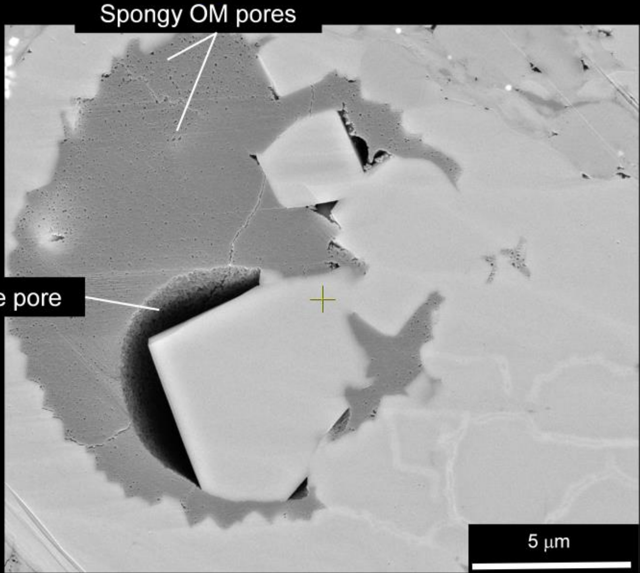
Criterion 6: Cracks in Organic Matter Related to Devolatilization



Eagle Ford Fm., 6214':
R_o ~ 0.8%

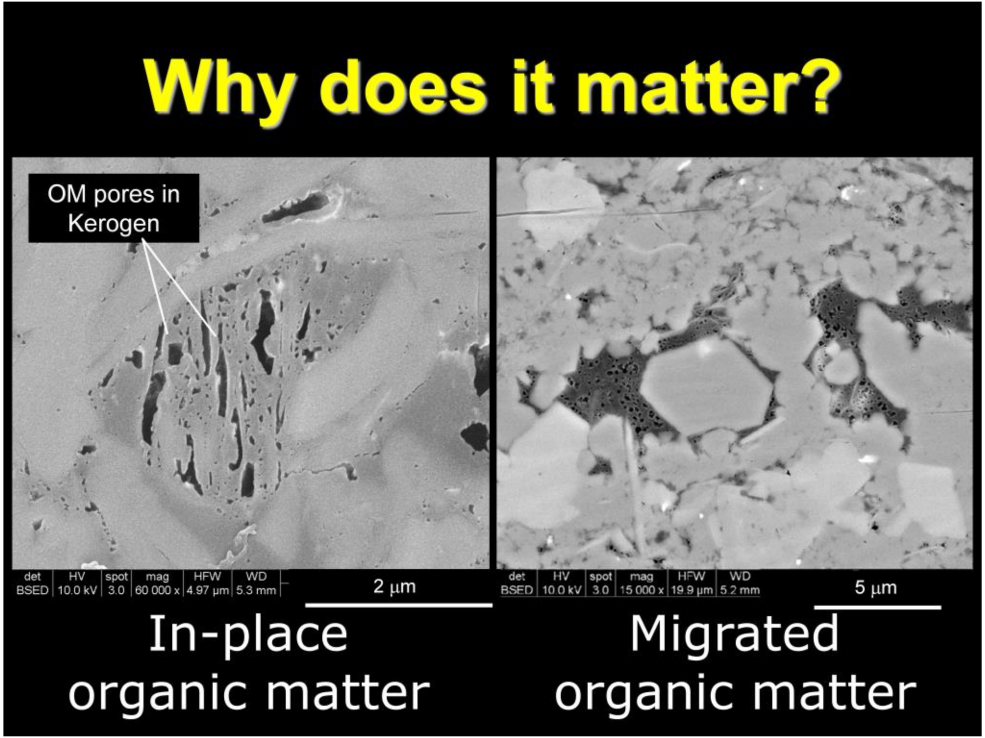
- Interpreted to form after coring

Criterion 7: Large Two-Phase Bubble Pores

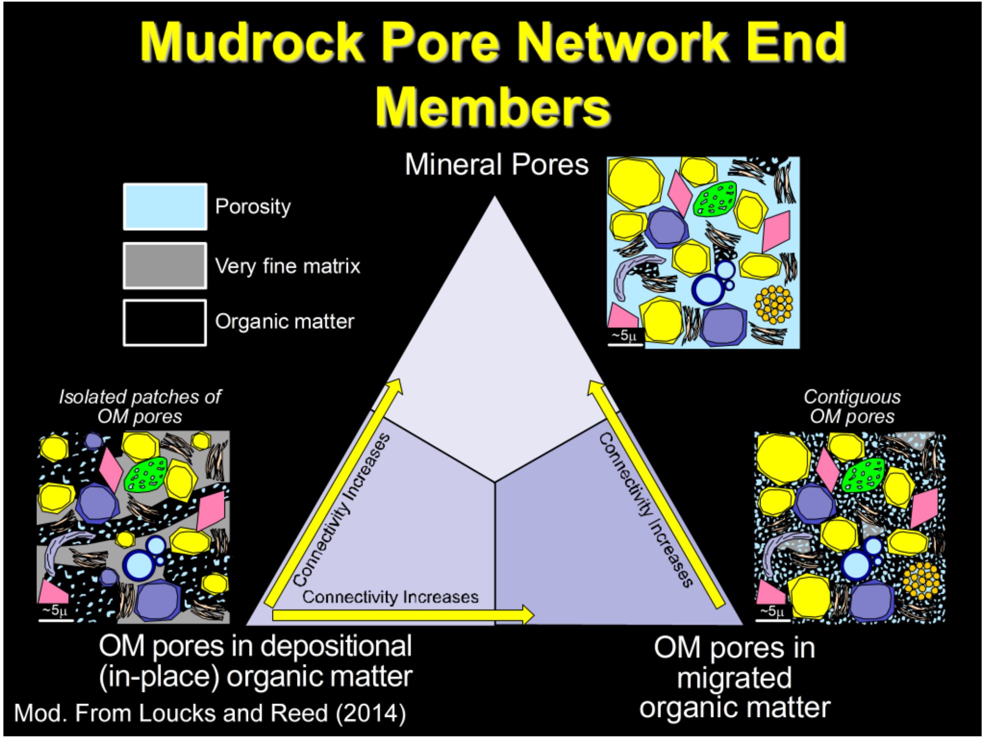


- Solid bitumen with bubble in center may be product of two phases (water, oil, or gas)

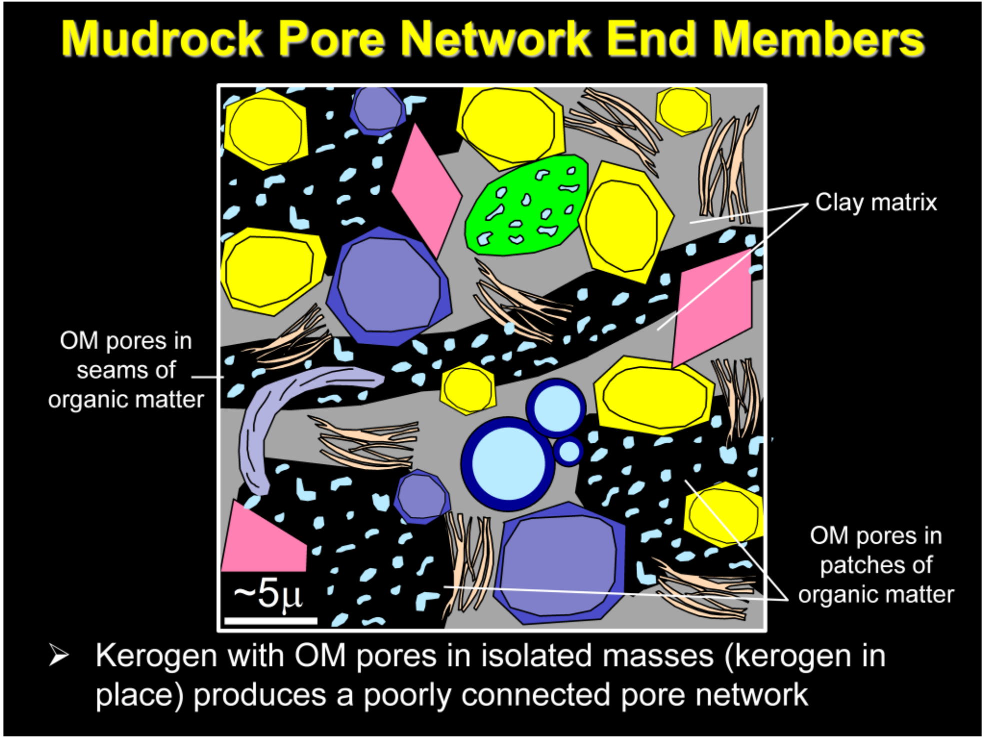
Pearsall Shale 9700':
R_o ~ 0.78%



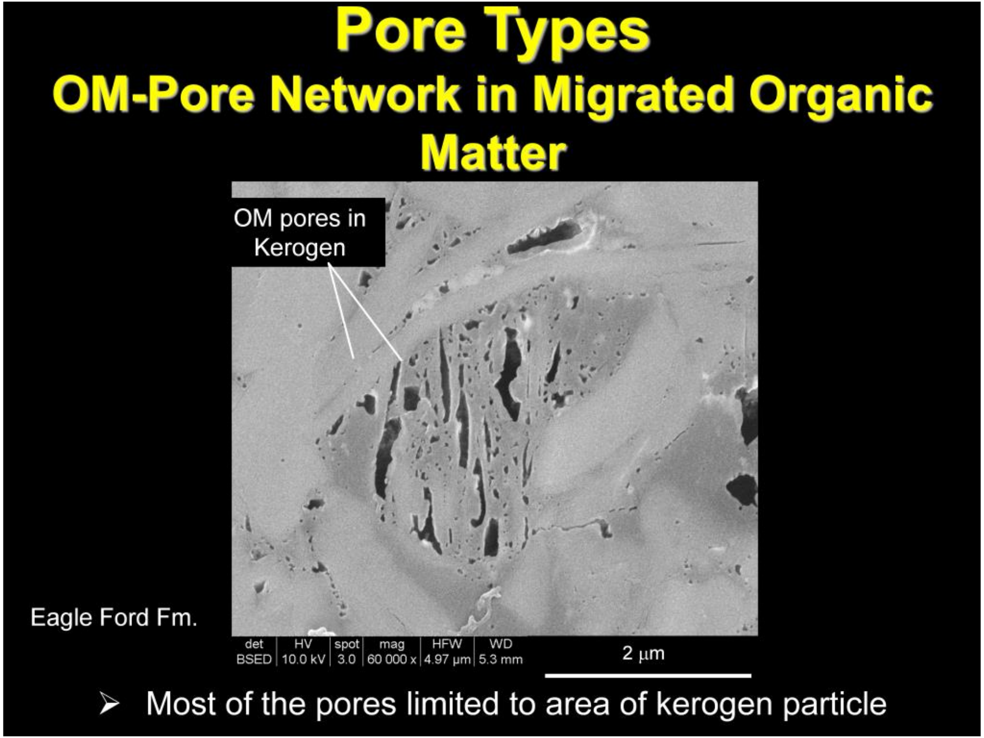
Presenter's notes: In both the Permian Basin and the Ft. Worth Basin, in high and low maturity samples, especially in framboids, there is a strange association of pores and pyrite. VRo ~ 1.2.



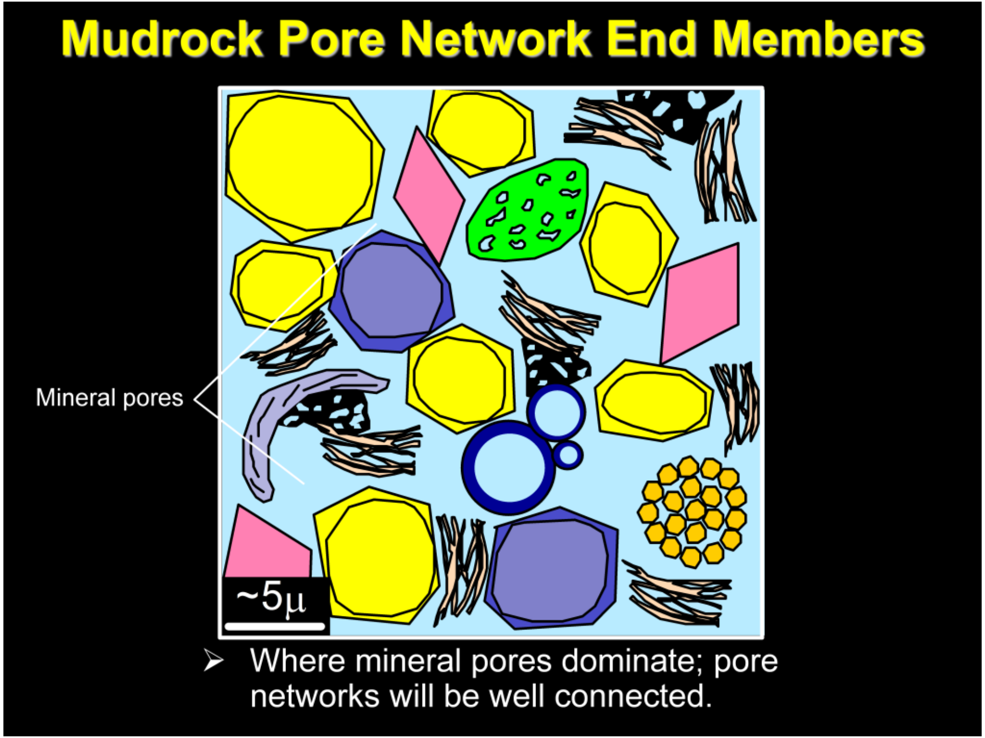
Mudrock Pore Network End Members
Mineral Pores
Porosity
Very fine matrix
Organic matter
~5μ
Isolated patches of OM pores
~5μ
Contiguous OM pores
~5μ
Connectivity Increases
Connectivity Increases
Connectivity Increases
OM pores in depositional (in-place) organic matter
OM pores in migrated organic matter
Mod. From Loucks and Reed (2014)



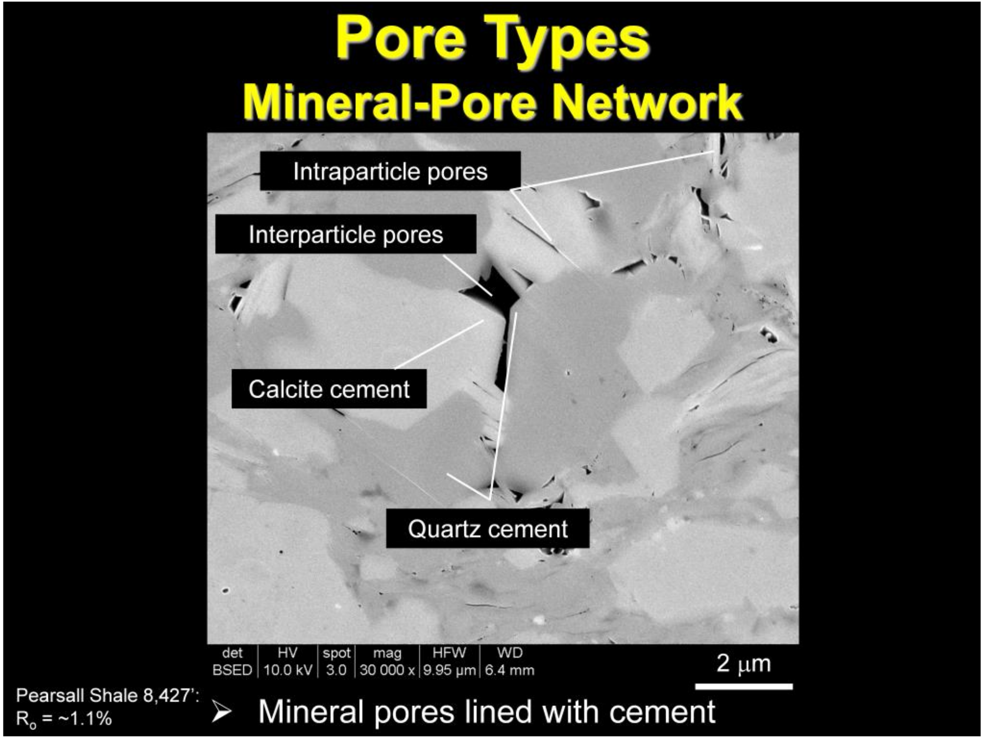
Presenter's notes: It suggests that it may be thermal methane that drives the formation of nanopores, not just any hydrocarbon.



Presenter’s notes: Grain outline based on backscattered electron image, BL 7206’.

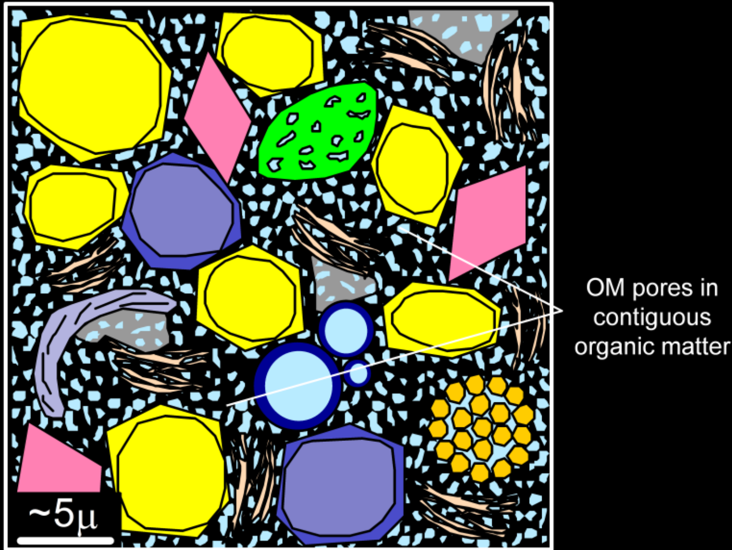


Presenter’s notes: It suggests that it may be thermal methane that drives the formation of nanopores, not just any hydrocarbon.



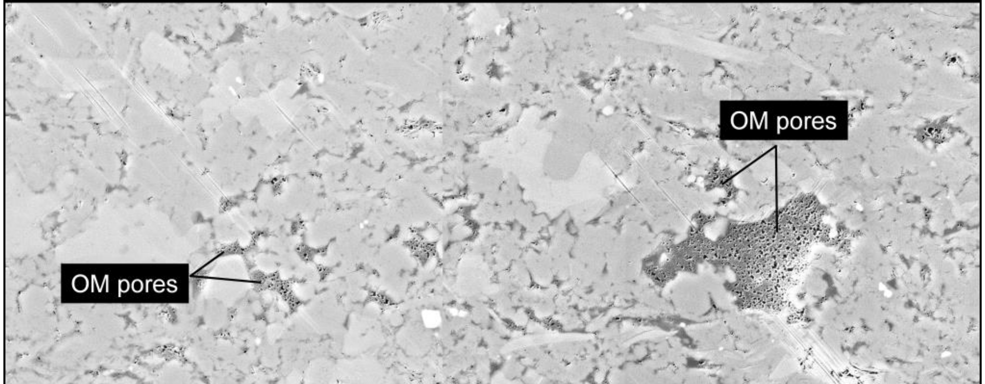
Presenter's notes: Grain outline based on backscattered electron image, BL 7206'.

Mudrock Pore Network End Members



- Contiguous migrated organic matter with OM pores will produce a well connected pore network

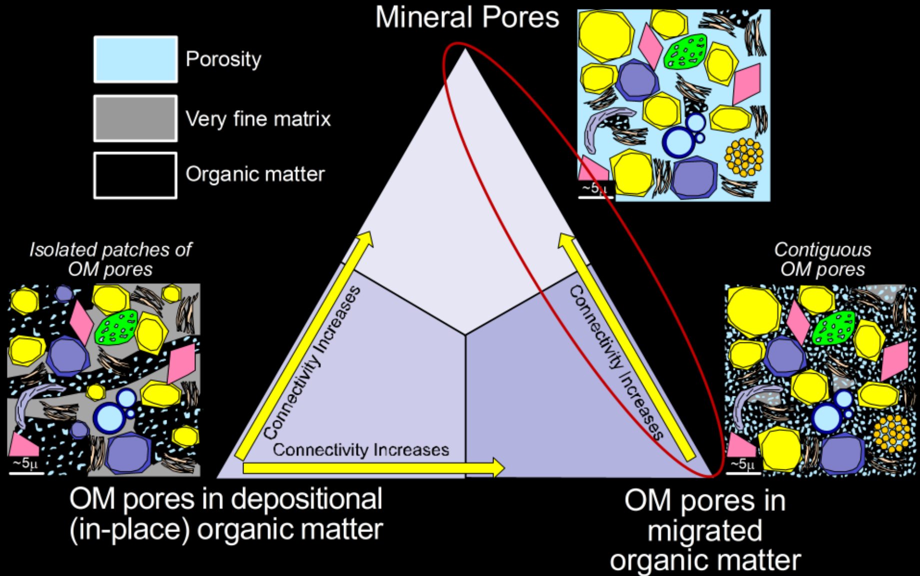
Pore Types
OM-Pore Network in Migrated Organic Matter



- Pore network dominated by OM pores in migrated bitumen

Barnett Shale 7,111’

Mudrock Pore-Network End Members



From Loucks and Reed (2014)

Remembering Sal

- He was a wonderful friend
- He was an exceptional scientist
- He was interesting