

Organic Petrography of the Ordovician Red River Kukersite Tight Oil and Gas Play, Williston Basin, North Dakota, U.S.A.

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Search and Discovery Article #11358 (2022)**

Posted August 5, 2022

*Adapted from extended abstract based on oral presentation given at 2022 AAPG Rocky Mountain Section Meeting, Denver Colorado, July 24-27, 2022

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Abstract

An organic petrographic study was conducted to supplement previously published geochemical data as part of an evaluation of a conceptual Upper Ordovician kukersite tight oil and gas play in the Williston Basin, North Dakota. The kukersite interval of the lower Red River member is an organic-rich (average 3.8wt% TOC) dolomitic limestone that has been documented as the source rock for hydrocarbons produced from porous dolomite zones in the overlying upper Red River member in conventional structural and stratigraphic traps. Basin modeling studies of the Red River petroleum system suggest that only a small fraction of the generated petroleum has been produced from the conventional fields, and that a significant resource may remain trapped within low permeability carbonates associated with the kukersite source rock in the lower Red River member. The maceral composition of the kukersite is predominately oil-prone algal and amorphous kerogen where thermally immature (bitumen reflectance (BRo) <0.30% BRo) that grades to 100% solid bitumen by 0.63% BRo and pyrobitumen at BRo > 1.5%, and completely fills the mineral interparticle pore space in the studied samples. Only a few nanopores were observed in the organic matter by SEM examination, including the gas mature samples (up to 3.50% BRo). The organic matter in the thermally mature samples often exhibited a volatile response when probed by the electron beam, indicating that the general lack of observed organic matter pores may be due to the presence of altered residual oil.

Summary

- Red River tight oil & gas play area defined by presence of thermally mature kukersite (*G. prisca* source rock)
- Kerogen composition is primarily fluorescent AOM that converts to 100% solid bitumen by about 0.60 %BRo
- Observed organic matter porosity is rare, even in gas mature samples

- Volatile organic matter observed in dolomite intraparticle pores and within void-filling solid bitumen
- Volatile organic matter interpreted as residual oil that may occlude visible organic matter pores

References

- Anna, L., R.M. Pollastro, S.B. Gaswirth, P. Lillis, L.N. Roberts and T. Cook, 2009, Assessment of undiscovered oil and gas resources of the Williston Basin Province of North Dakota, Montana and South Dakota: AAPG [Search and Discovery Article 10201](#), 23 p.
- Camp, W.K., J. Schieber, M. Mastalerz, and T.O. Nesheim, 2022, Organic petrography of the Upper Ordovician Red River kukersite tight oil and gas play, Williston Basin, North Dakota, U.S.A.: AAPG Bull. (in review).
- Lillis, P.G., Review of oil families and their petroleum systems of the Williston Basin: The Mountain Geologist, v. 50, p. 5-31.
- Nesheim, T.O., 2017, Stratigraphic and geochemical investigation of kukersites (petroleum source beds) within the Ordovician Red River Formation, Williston Basin: AAPG Bull., v. 101, p. 1445-1471.



Organic Petrology Ordovician Red River Kukersite Tight Oil and Gas Play

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AAPG ROCKY MOUNTAIN SECTION MEETING
DENVER COLORADO, JULY 24-27, 2022

Acknowledgements

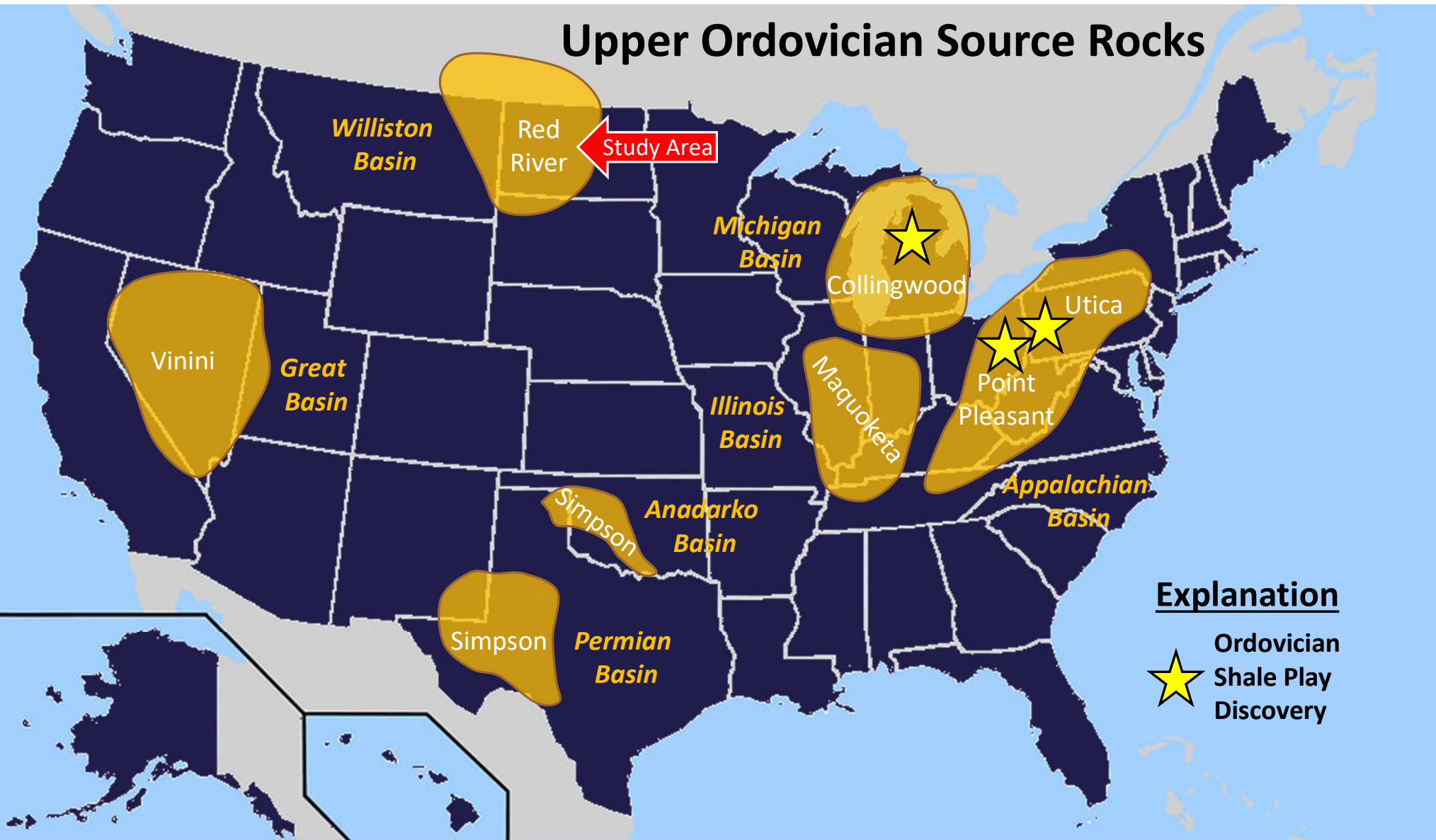
- ▶ Juergen Schieber - Indiana University
- ▶ Maria Mastalerz - Indiana Geological Survey
- ▶ Timothy Nesheim - North Dakota Geological Survey
- ▶ Occidental Petroleum (Anadarko)

Presentation Outline

- ▶ Introduction
- ▶ Optical Organic Petrology
 - ▶ maceral composition
 - ▶ thermal maturity
- ▶ Scanning Electron Microscopy
 - ▶ mineral & organic composition
 - ▶ porosity
- ▶ Summary

INTRODUCTION

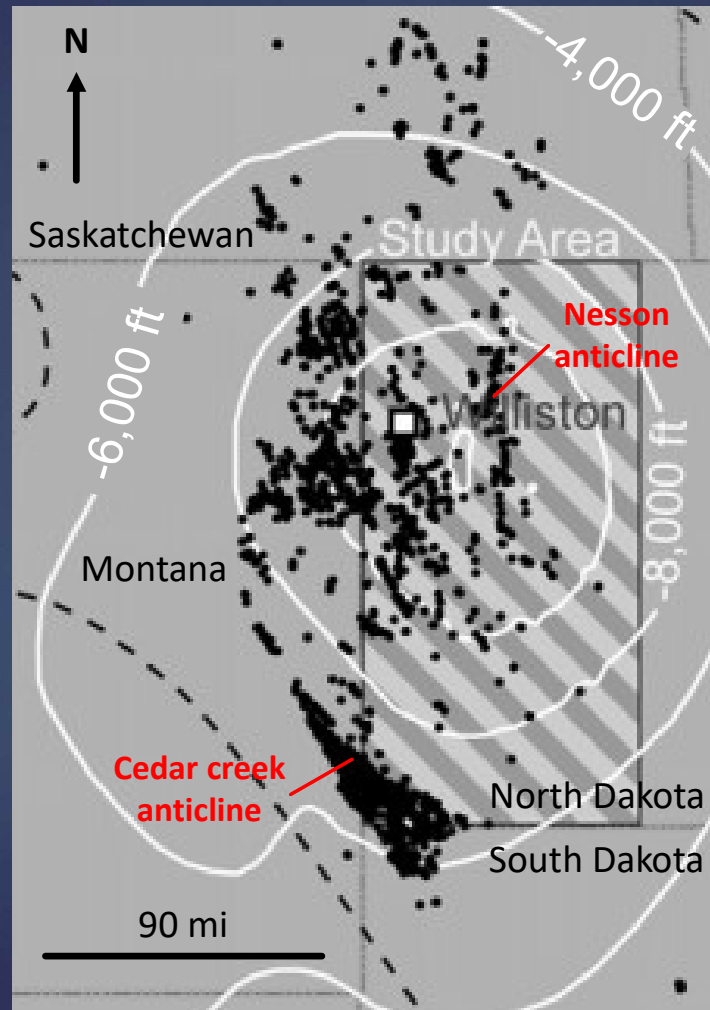
Upper Ordovician Source Rocks



Red River Conventional Production

- Migrated oil accumulations
- Structural & stratigraphic traps
- Associated water production

Structure top
Red River Formation
C.I.= 2,000 ft



- ▶ 2,800 + producing wells
- ▶ Depth 4,200-12,000 ft subsea
- ▶ Peak Annual 18.6 MMBO (2007)
- ▶ Current Annual 4.7 MMBO (2020)
- ▶ Cumulative 560 MMBO & 1.1 TCFG

Modified from Nesheim (2017)

Source Rock

Williston Basin 8 Petroleum Systems

Tertiary Cretaceous	CBM Shallow Biogenic
Triassic	Spearfish
Permian	Minnikahta Opeche
Pennsylvanian	Minnelusa Amsden
	Tyler
	Otter
	Kibbey
Mississippian	Charles
	Mission Canyon
	Lodgepole
	Bakken
	Three Forks
	Birdbear
	Duperow
Devonian	Souris River
	Dawson Bay
	Prarie Evaporite
	Winnipegosis
	Ashern
Silurian	Interlake
	Stonewall
	Gunton Stony Mountain
Ordovician	Red River
	Winnipeg
Cambrian	Deadwood



Tyler shale play (non-commercial)



Bakken-Three Forks tight oil play
(cum: 4 BBO + 4 BBO undiscovered oil)



Red River kukersite



Established unconventional play

After Anna et al. (2009) and Lillis (2013)

Kukersite

- ▶ Ordovician marine oil shale
- ▶ Kukruse mining district, northern Estonia
- ▶ Named by Mikhail Zalessky in 1917
- ▶ TOC 15-50 (avg 40) wt%
- ▶ *Gloeocapsomorpha prisca*
- ▶ Also found in North America & Australia



<https://en.wikipedia.org/wiki/Kukersite>

Red River Kukersite

Terra Resources BNRR #1-17 (NDIC: 7218, API: 33-053-00955-00-00)

Upper Ordovician				Nomenclature	Schematic Lithology
				Sask. N.D.	
Winnipeg	Group	Icebox	Fm.	Winnipeg	
				Winnipeg	
				Winnipeg	
				Winnipeg	
Yeoman	Formation	Red River	lower Red River	Yeoman	
				Yeoman	
				Yeoman	
				Yeoman	
Herald	Fm.	Red River	upper Red River	Herald	
				Herald	
				Herald	
				Herald	
Stoney	Mtn. Fm.	Stoughton	Mbr.	Stoney	
				Stoney	
				Stoney	
				Stoney	



Red River D zone

Tight dolomitic limestone interbedded with kukersite

Depth: 9,000-13,500+ ft

Thickness: 50-70 ft gross
0-12 ft net (> 0.5 wt% TOC)

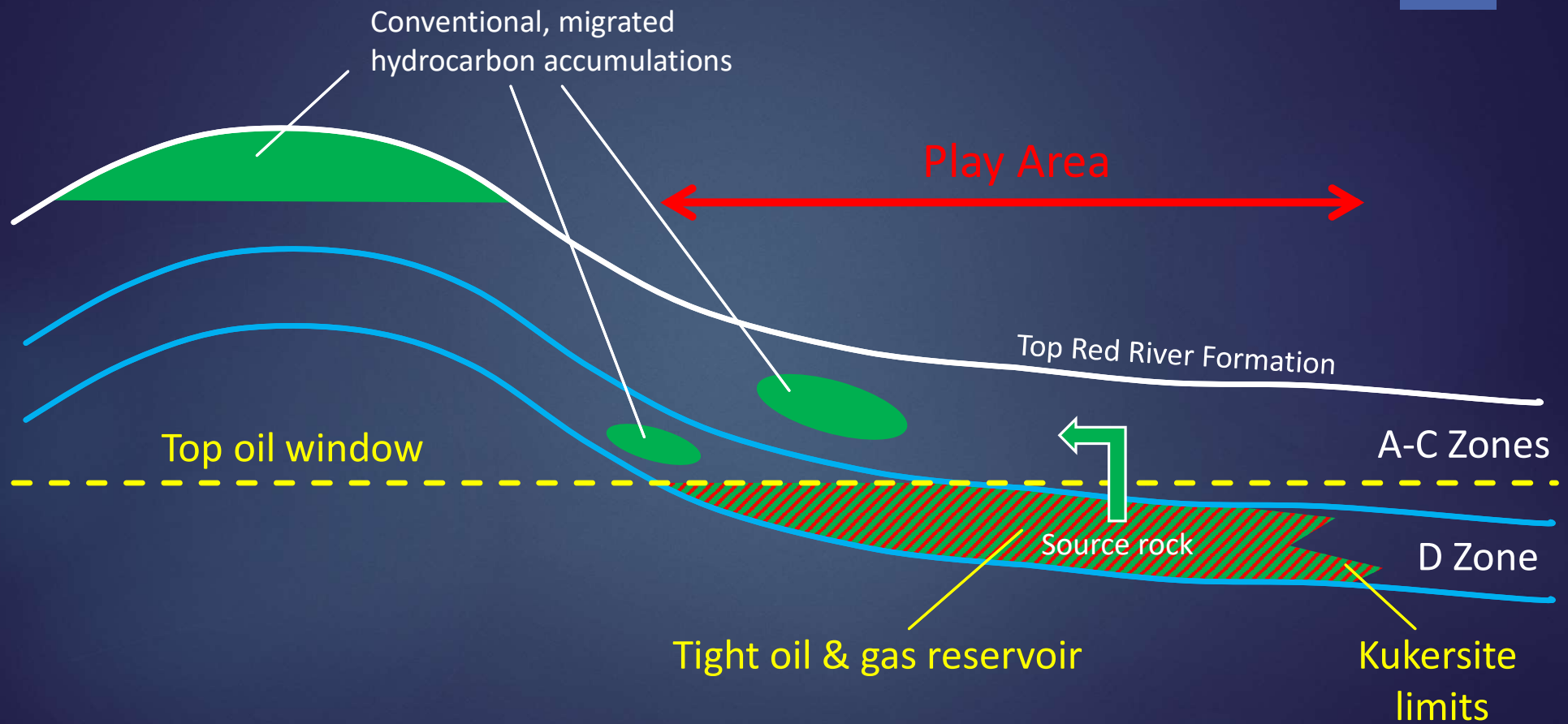
TOC: 0.5-30 (avg 3.8) wt%

HI: 100-900 mg HC/g TOC

Nesheim et al. (2016)

Nesheim (2017)

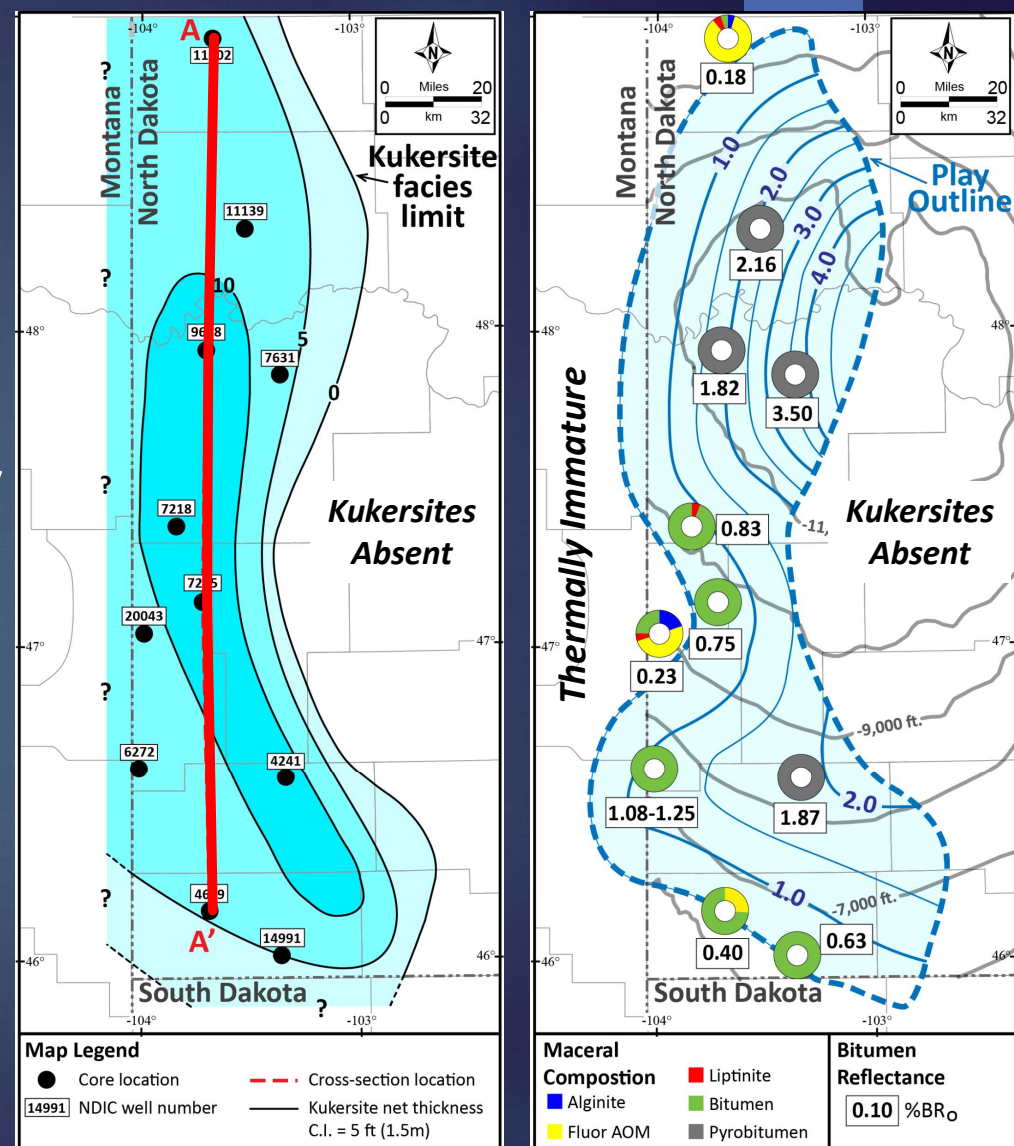
Red River Tight Oil & Gas Play Concept

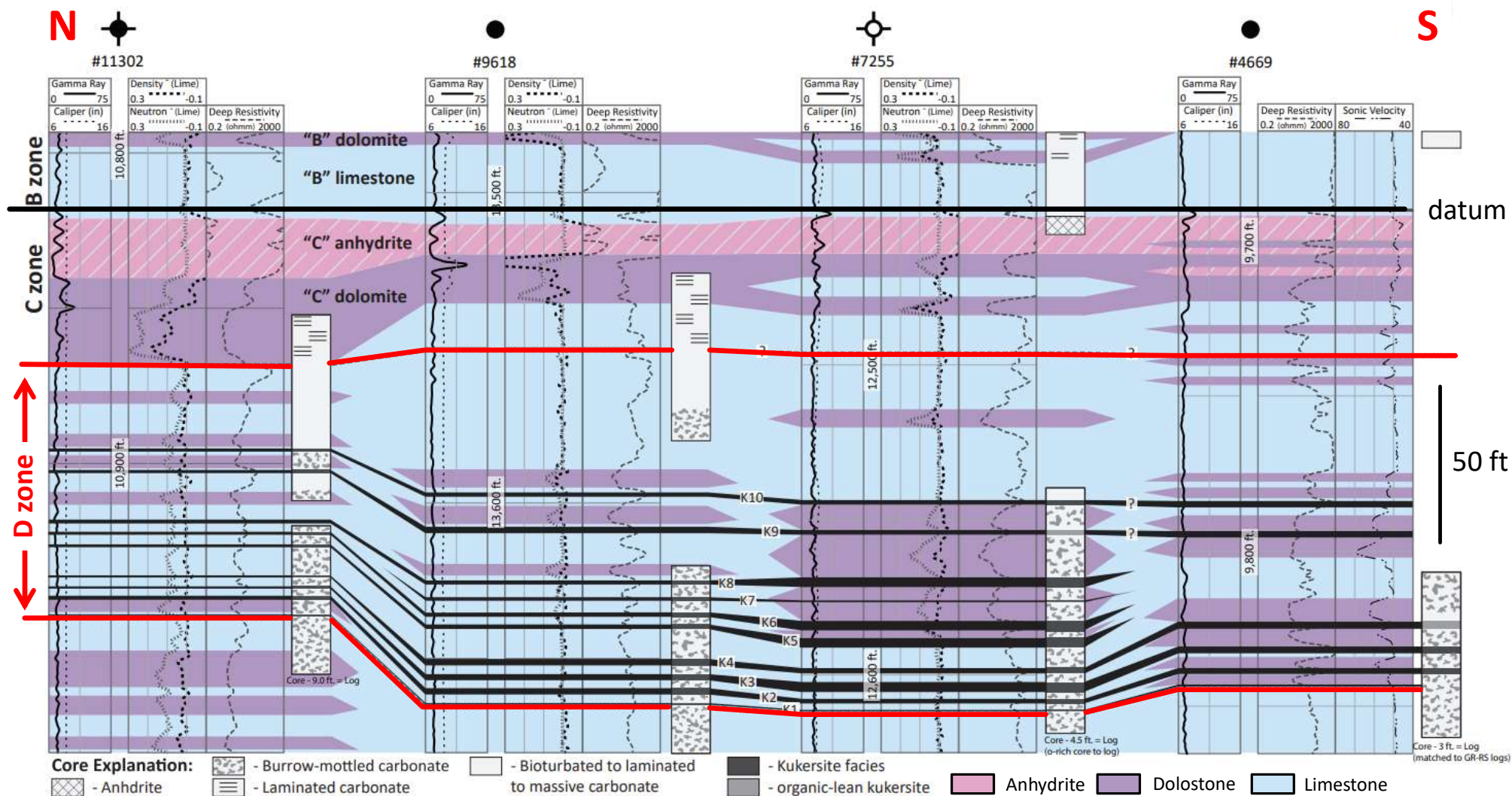


Play Area Definition

- ▶ Thermally mature kukersite
- ▶ 25-60 mi wide x 200 mi long fairway

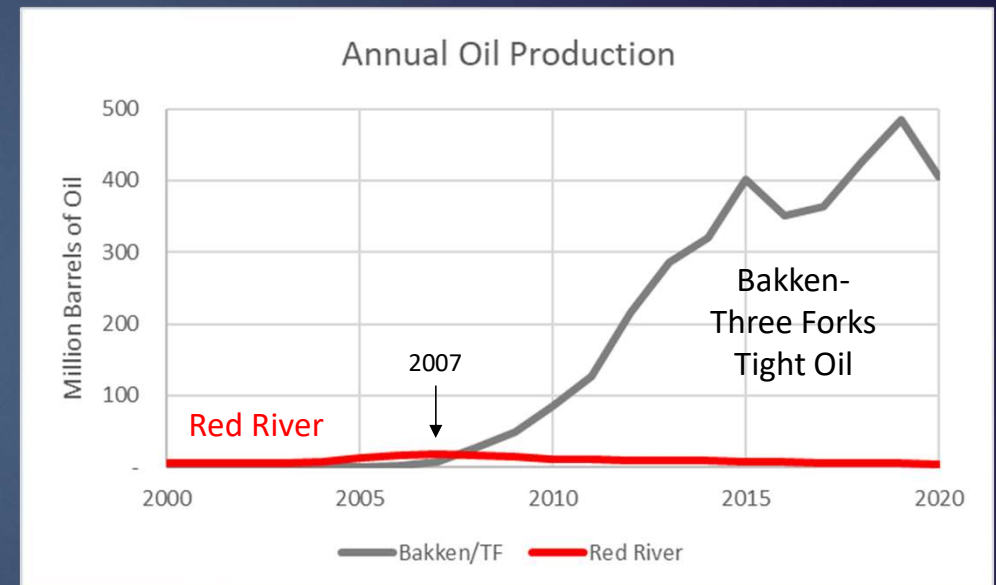
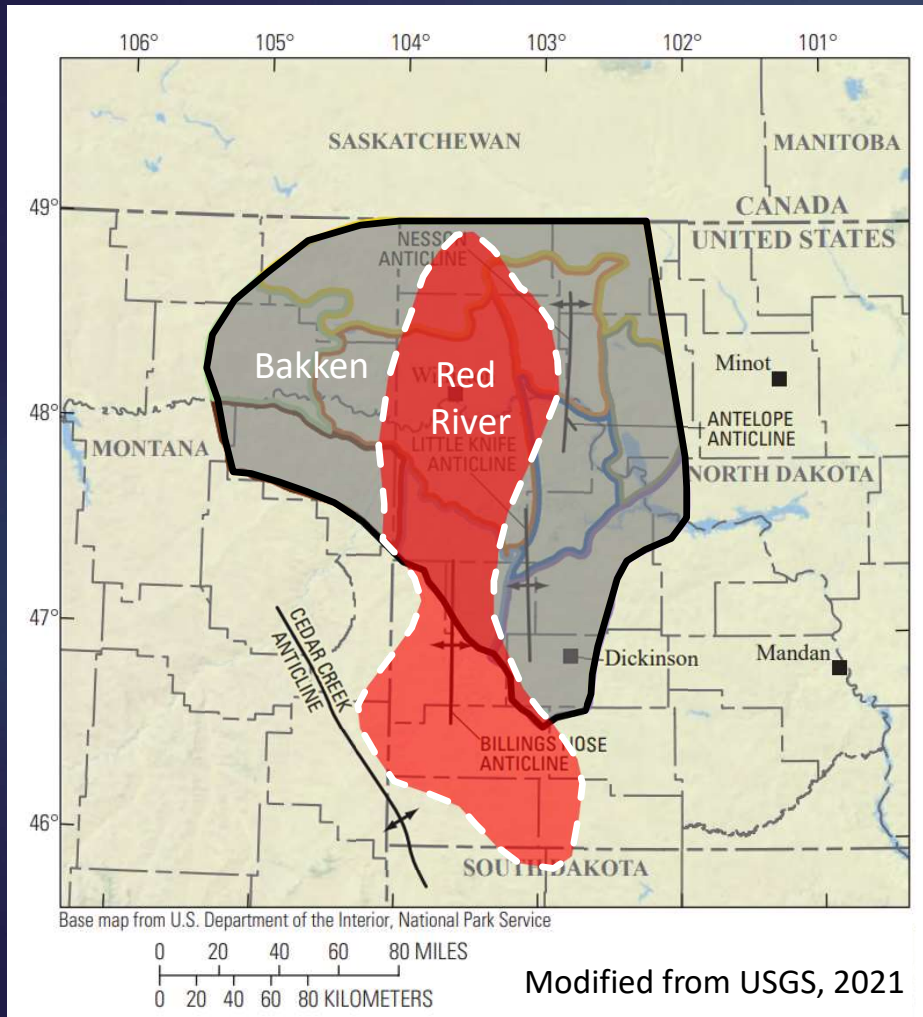
Camp et al. (in review)





Camp et al. (in review)

Bakken-Three Forks Comparison



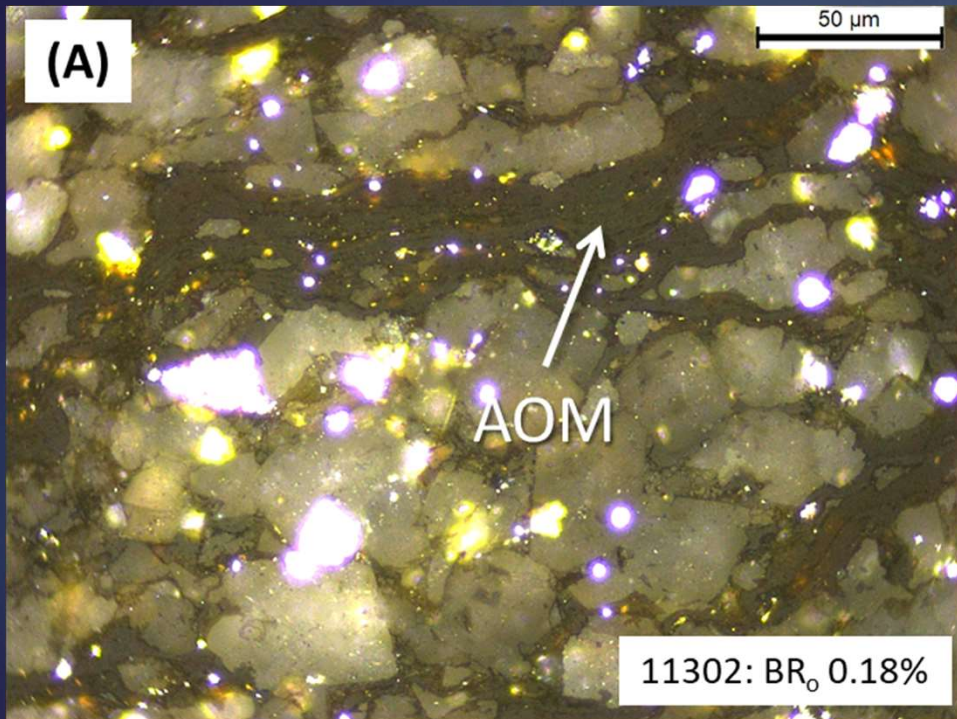
Data source: NDGS, 2021

- Bakken/Three Forks 1.2 MMBO/d (EIA, July 2022)

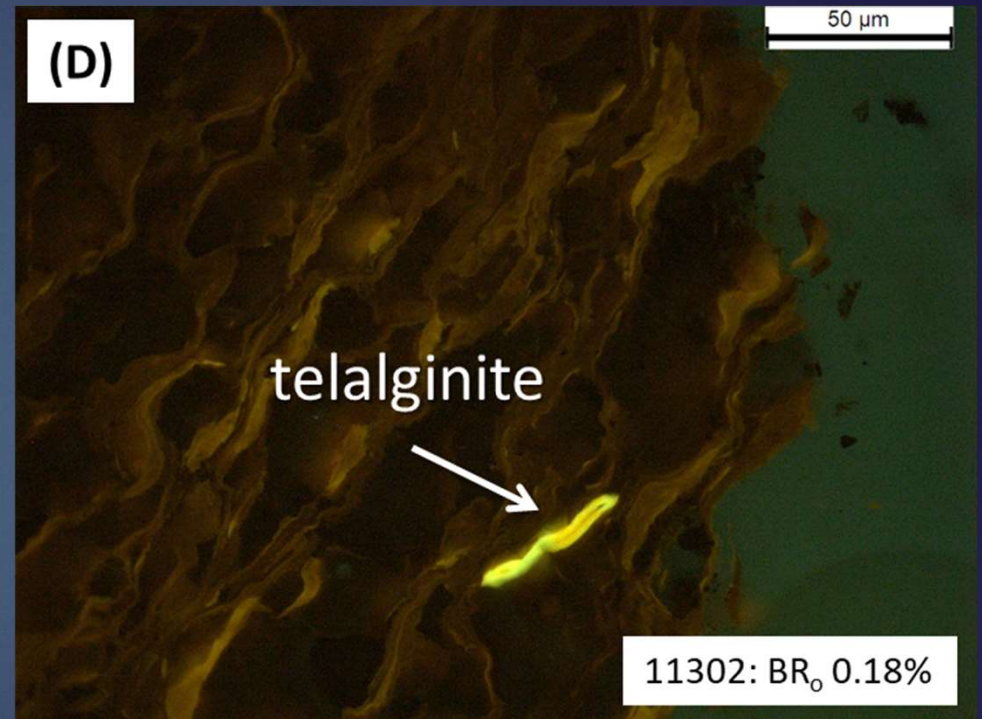
OPTICAL ORGANIC PETROLOGY

Camp et al. (in review)

Maceral Composition

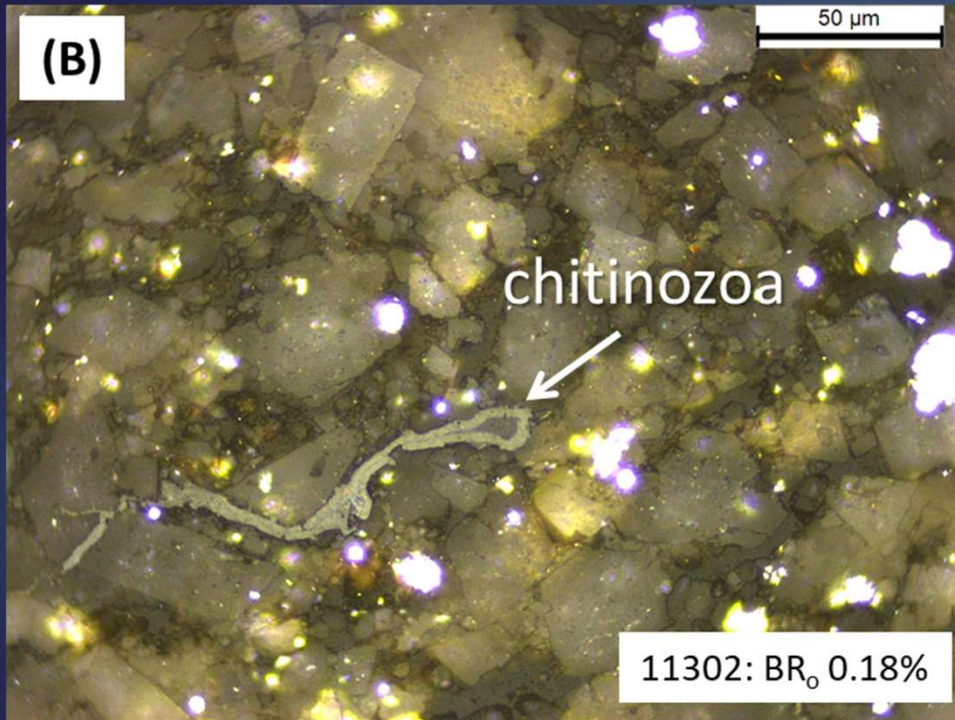


Reflected white light

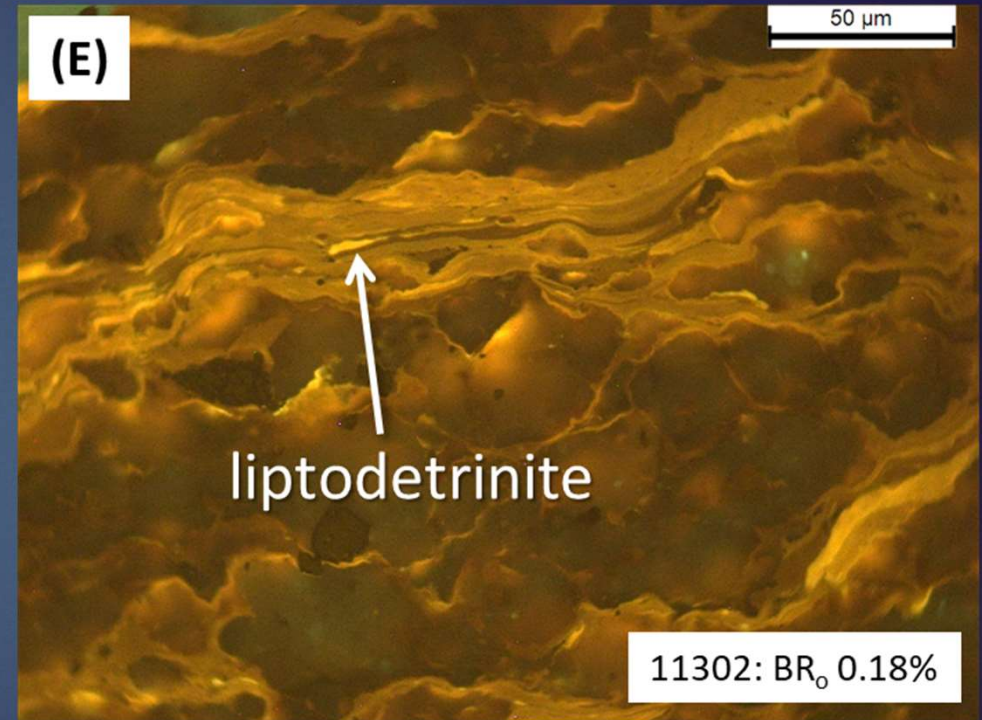


Ultraviolet light

Maceral Composition

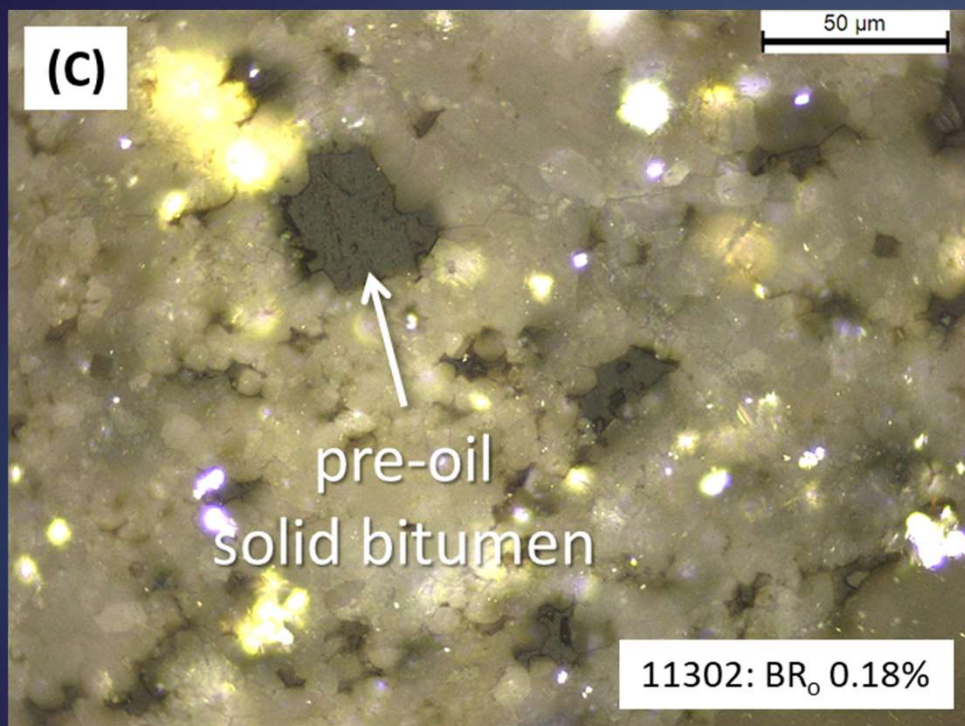


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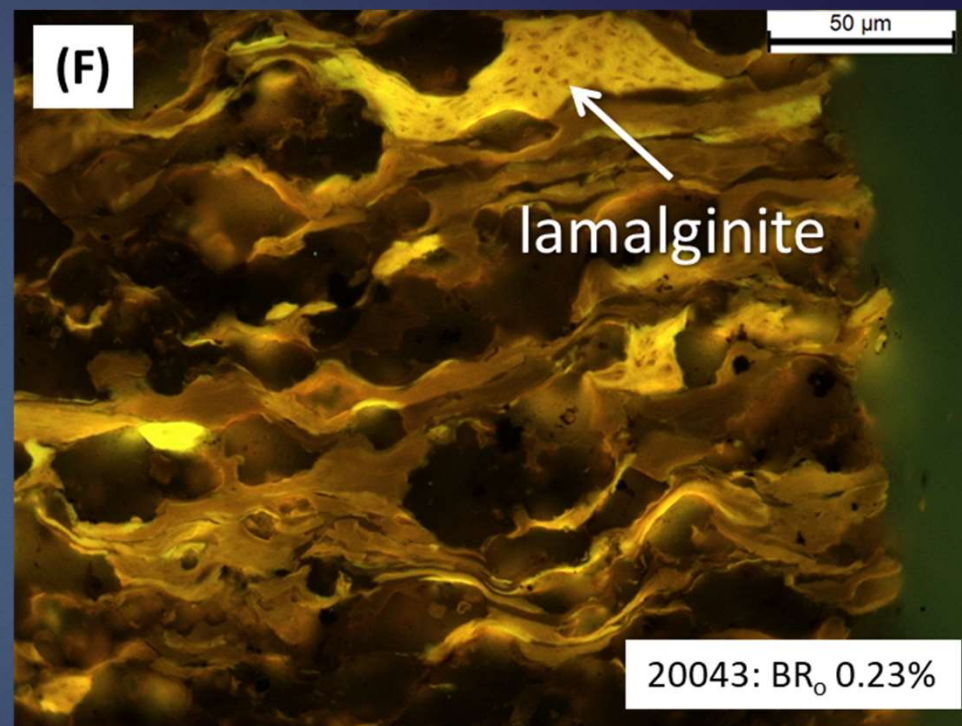


Ultraviolet light

Maceral Composition



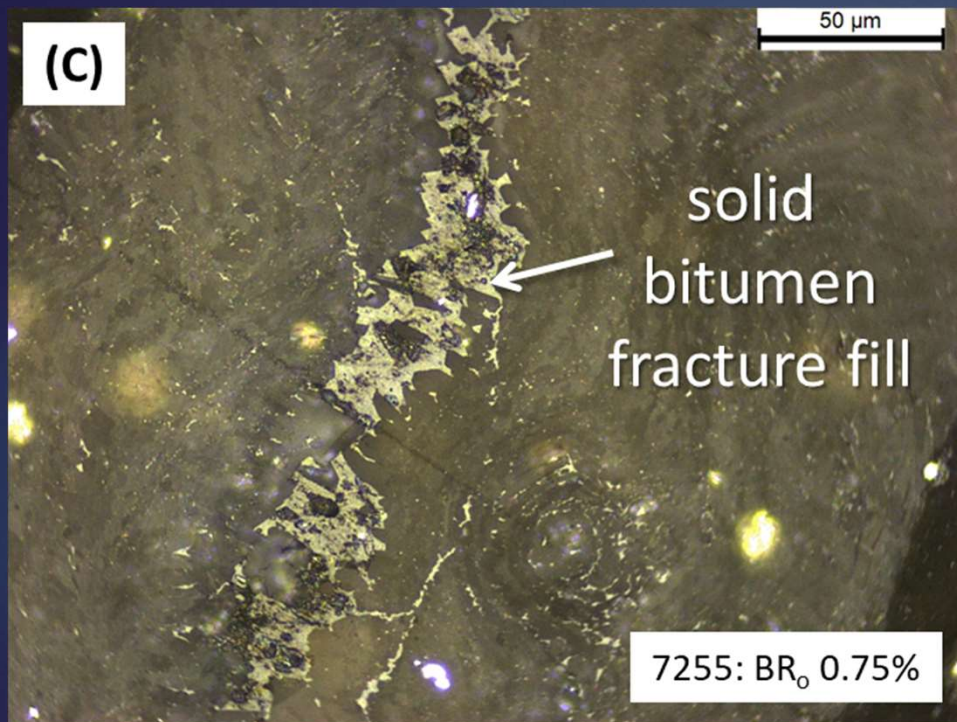
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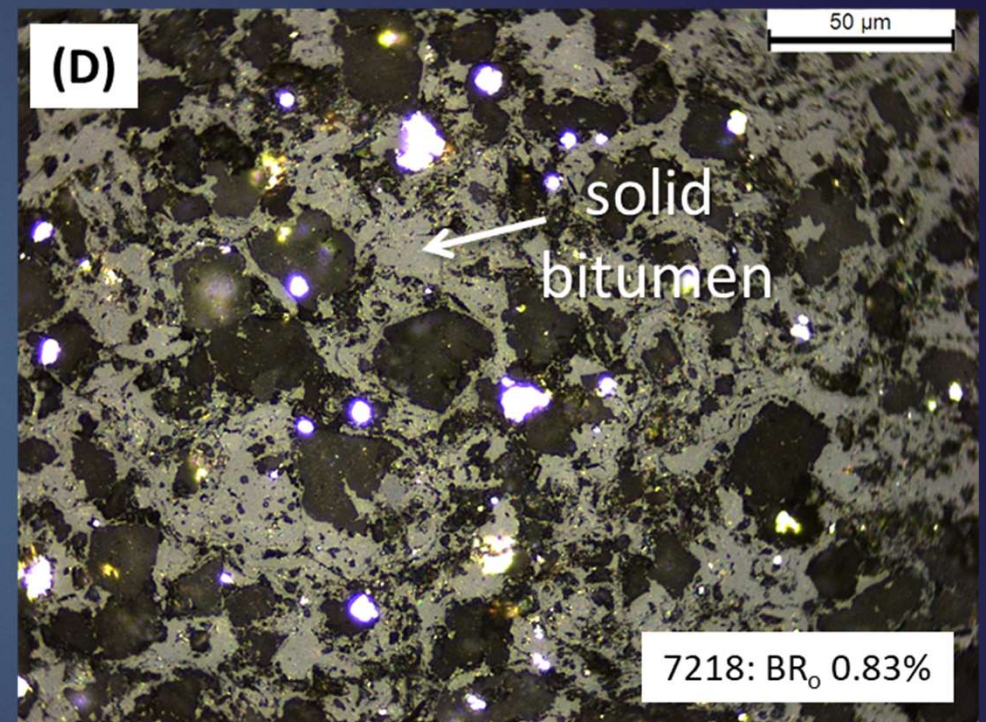
Ultraviolet light

Camp et al. (in review)

Maceral Identification



Reflected white light

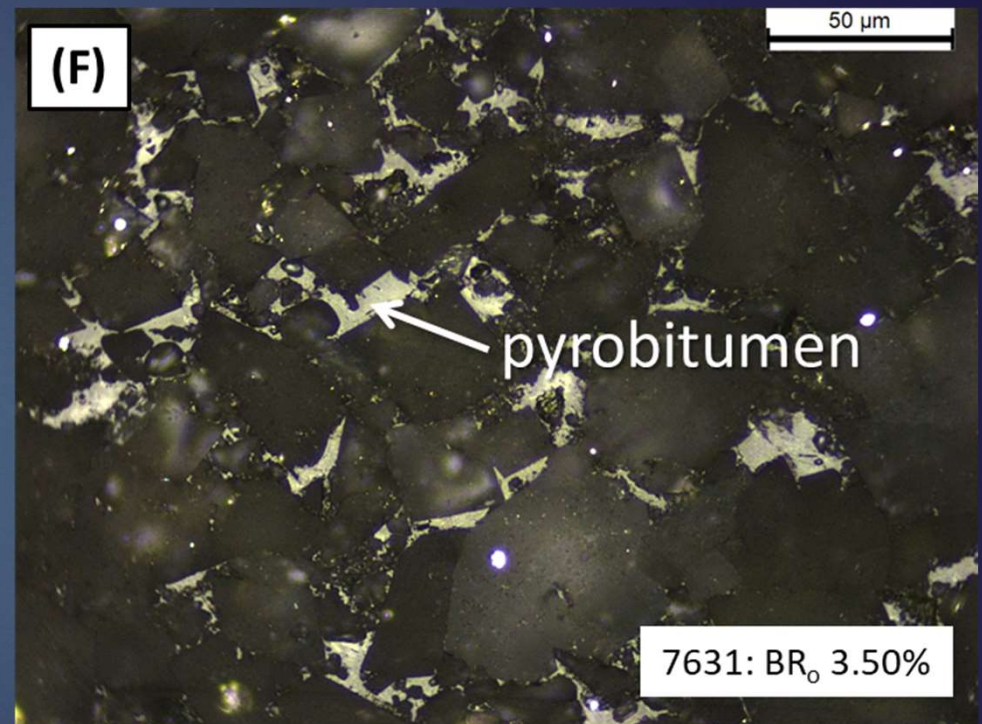


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Maceral Composition



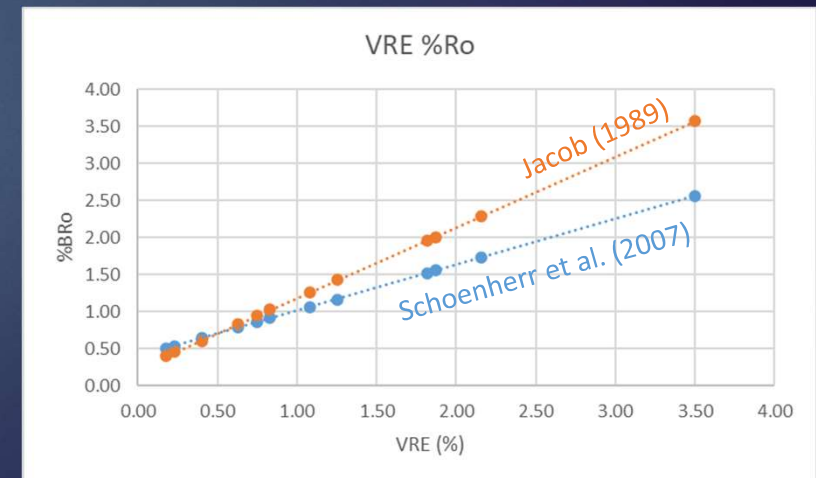
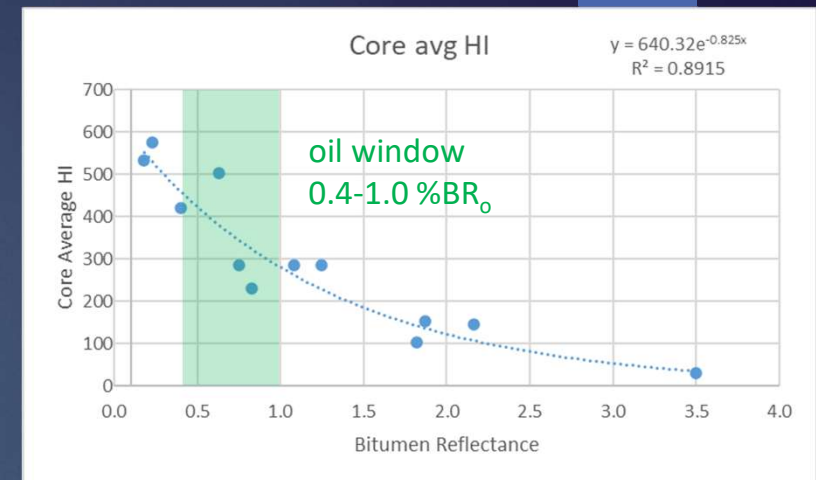
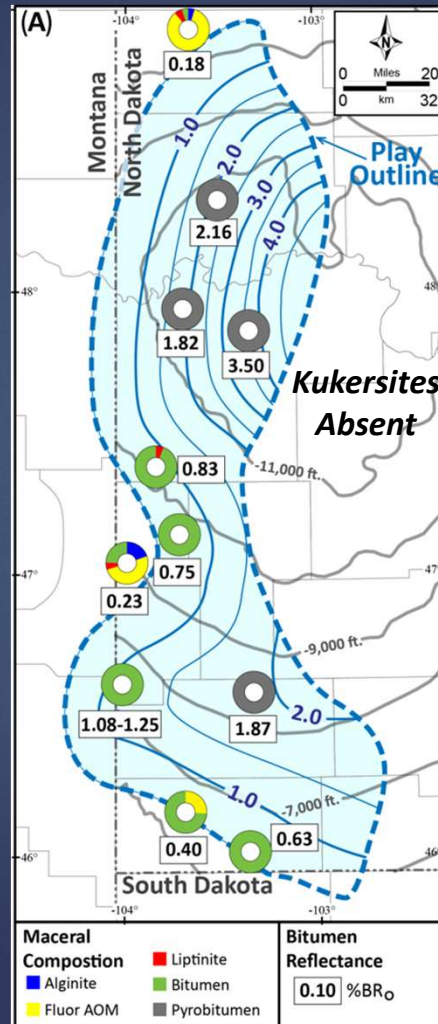
Reflected white light



Reflected white light

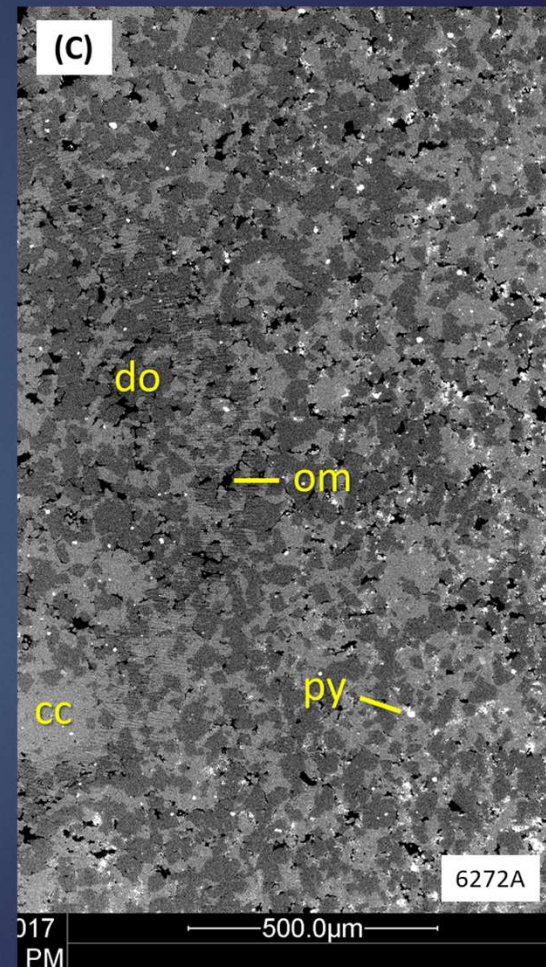
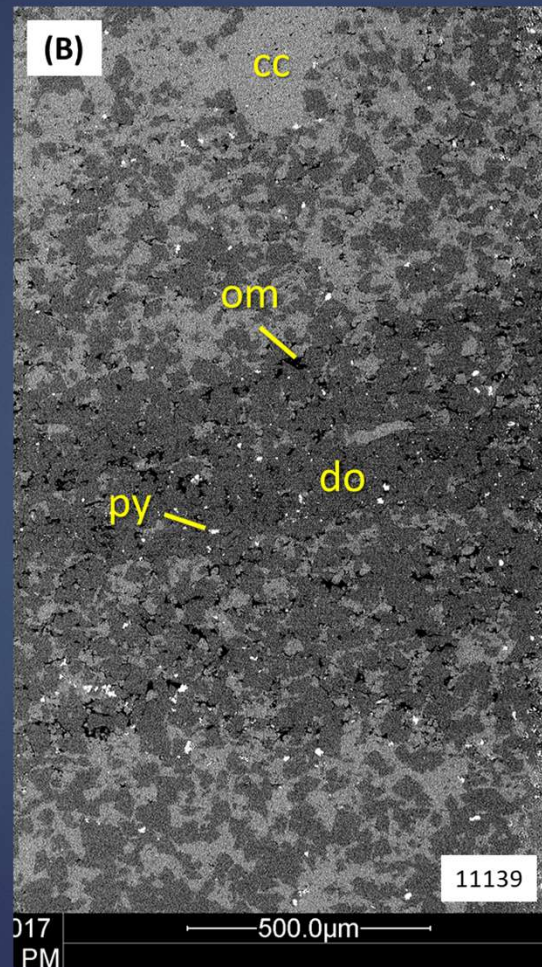
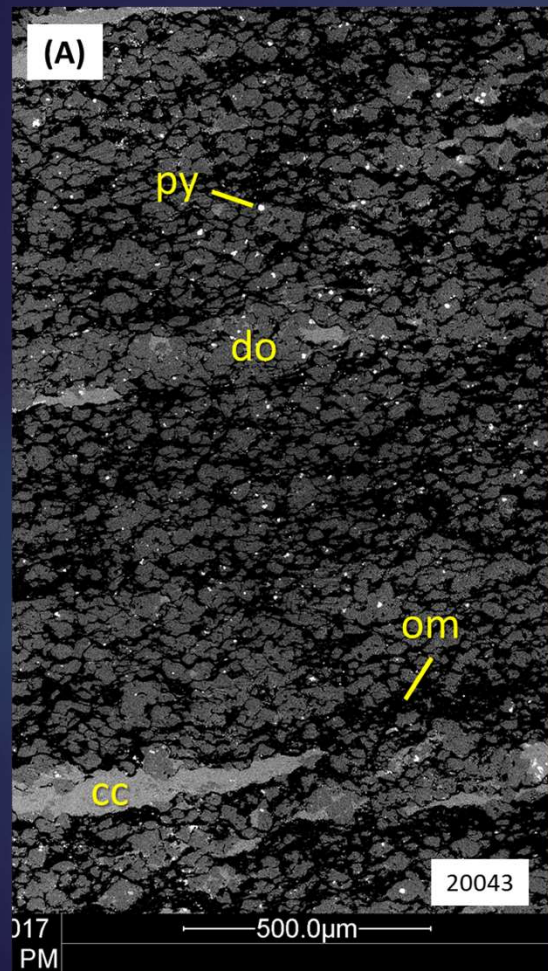
Thermal Maturity

- ▶ No vitrinite
- ▶ Mean %BR₀ 0.18-3.50
- ▶ VRE_j 0.51-2.56
- ▶ VRE_s 0.40-3.57

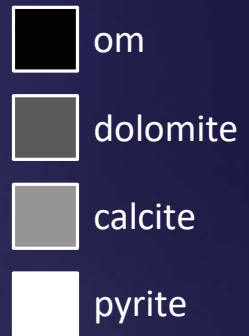


SCANNING ELECTRON MICROSCOPY

BSE SEM Composition

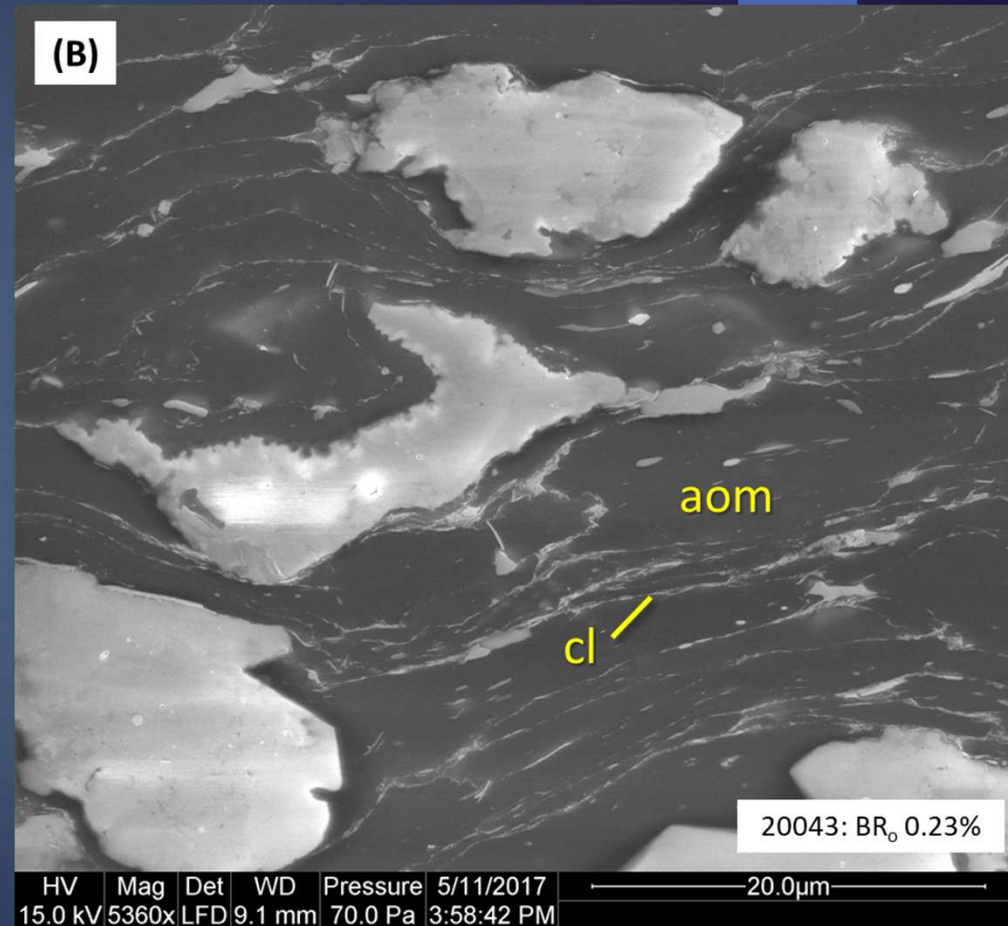
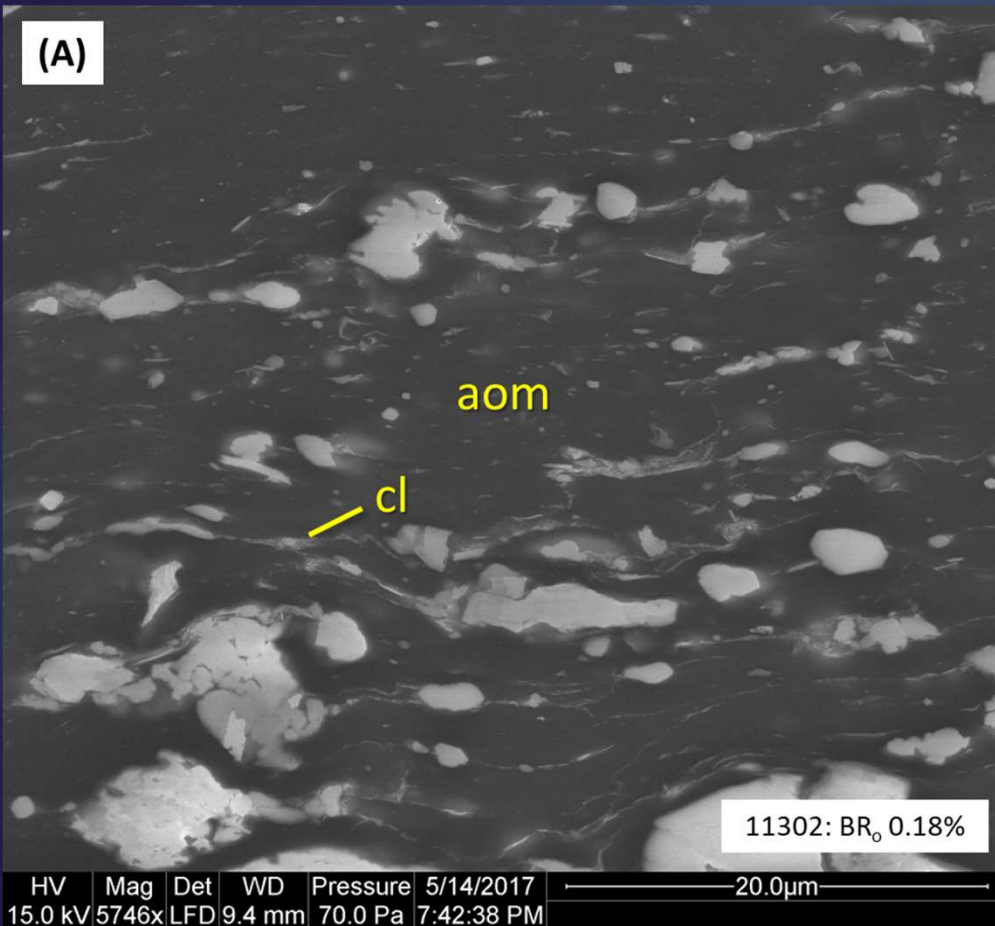


SEM Grayscale



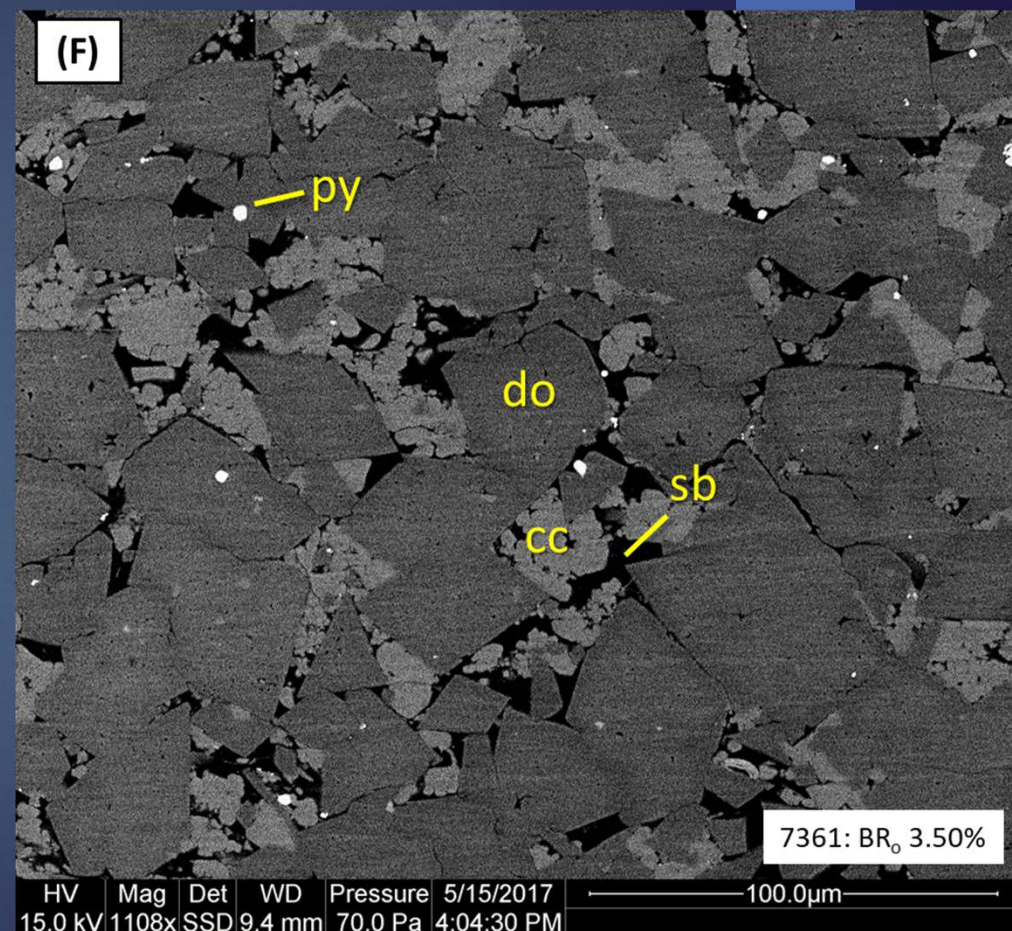
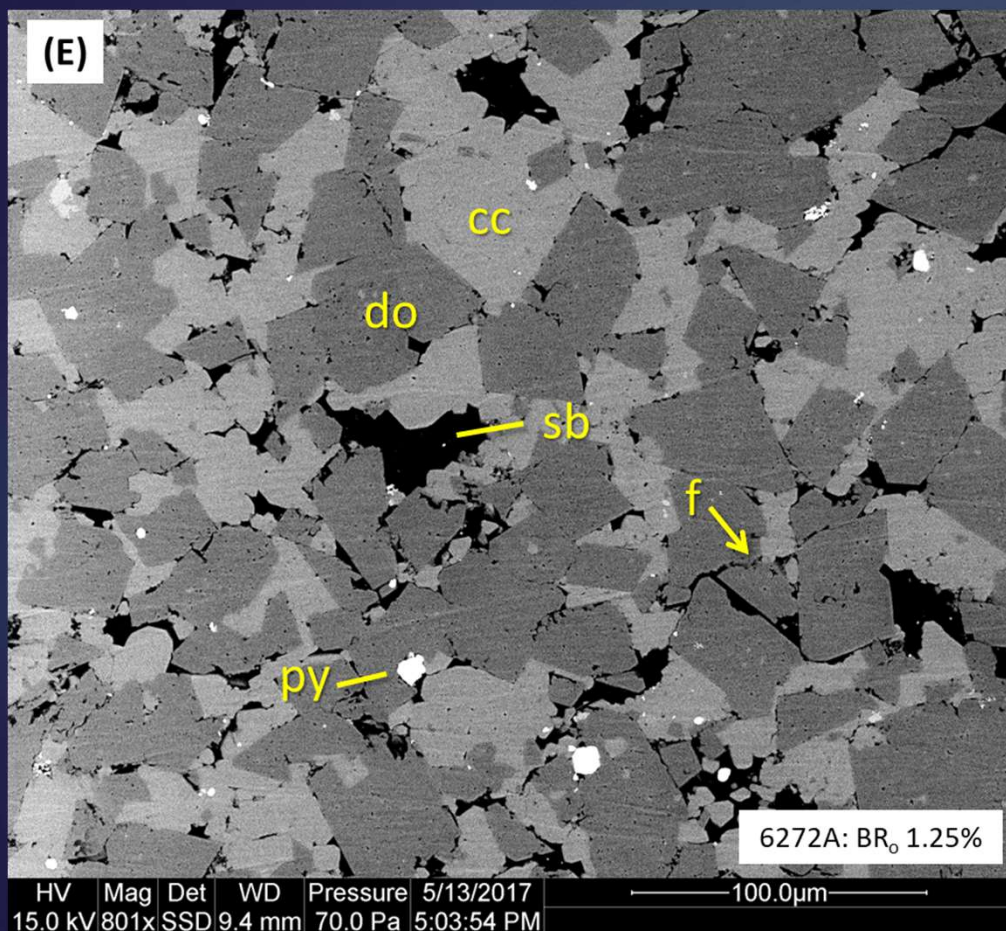
Camp et al. (in review)

Amorphous Organic Matter



Camp et al. (in review)

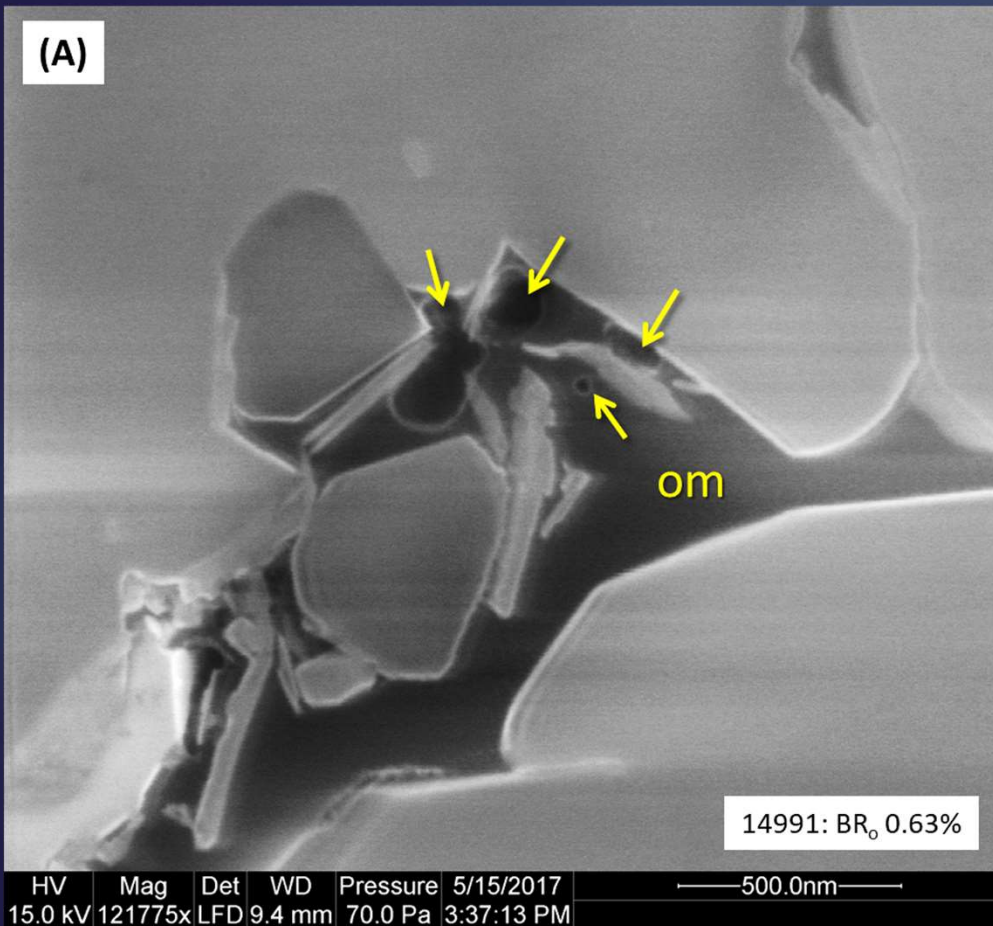
Solid Bitumen



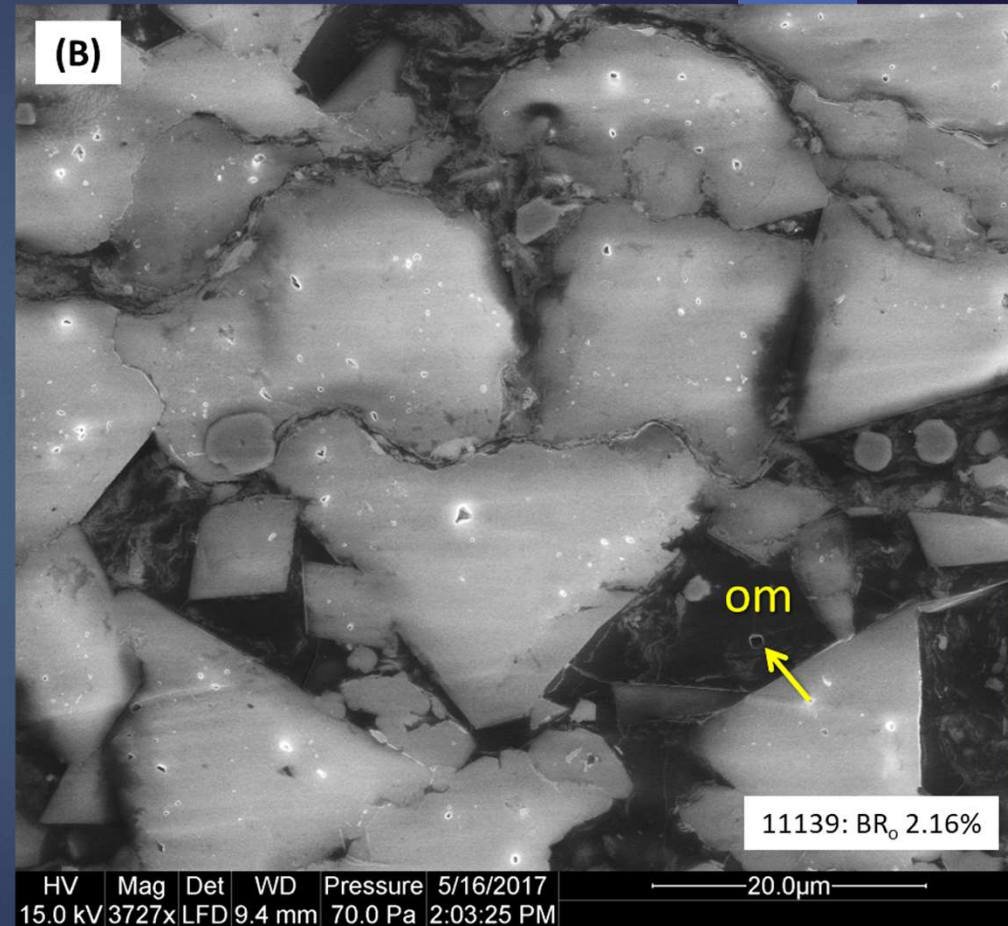
Camp et al. (in review)

Organic Matter Pores

(A)

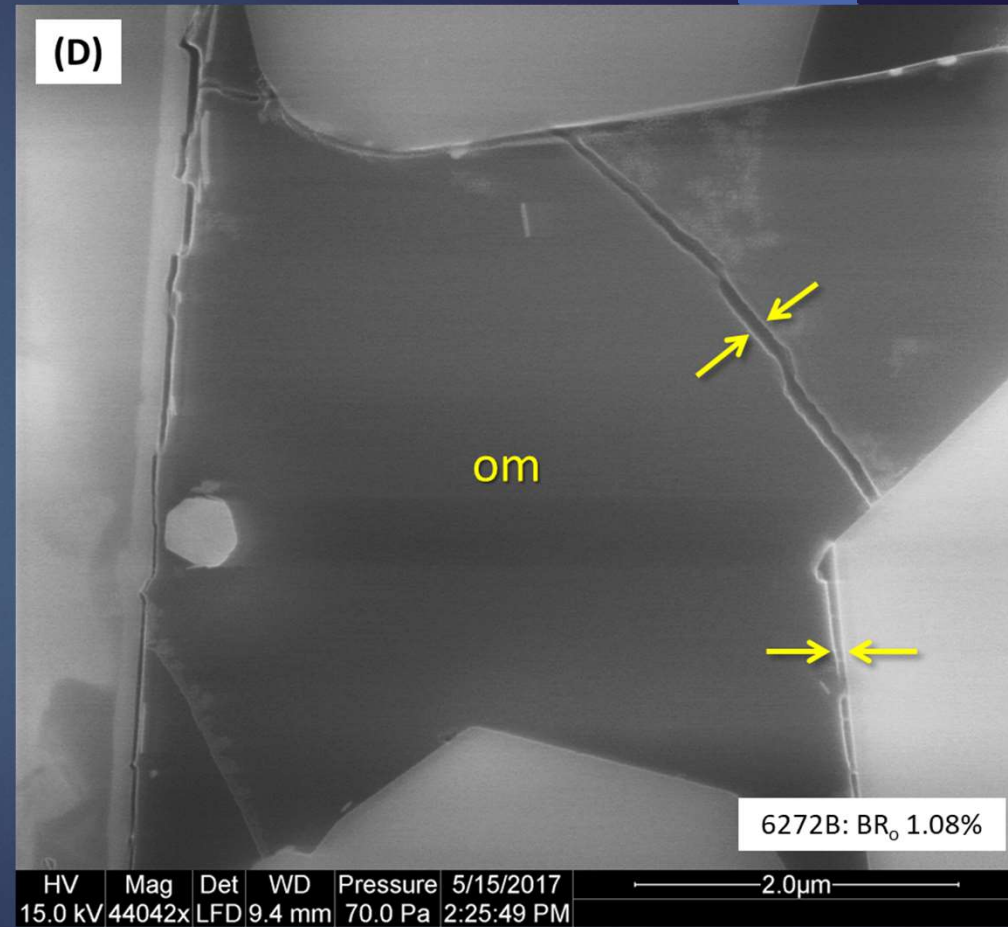
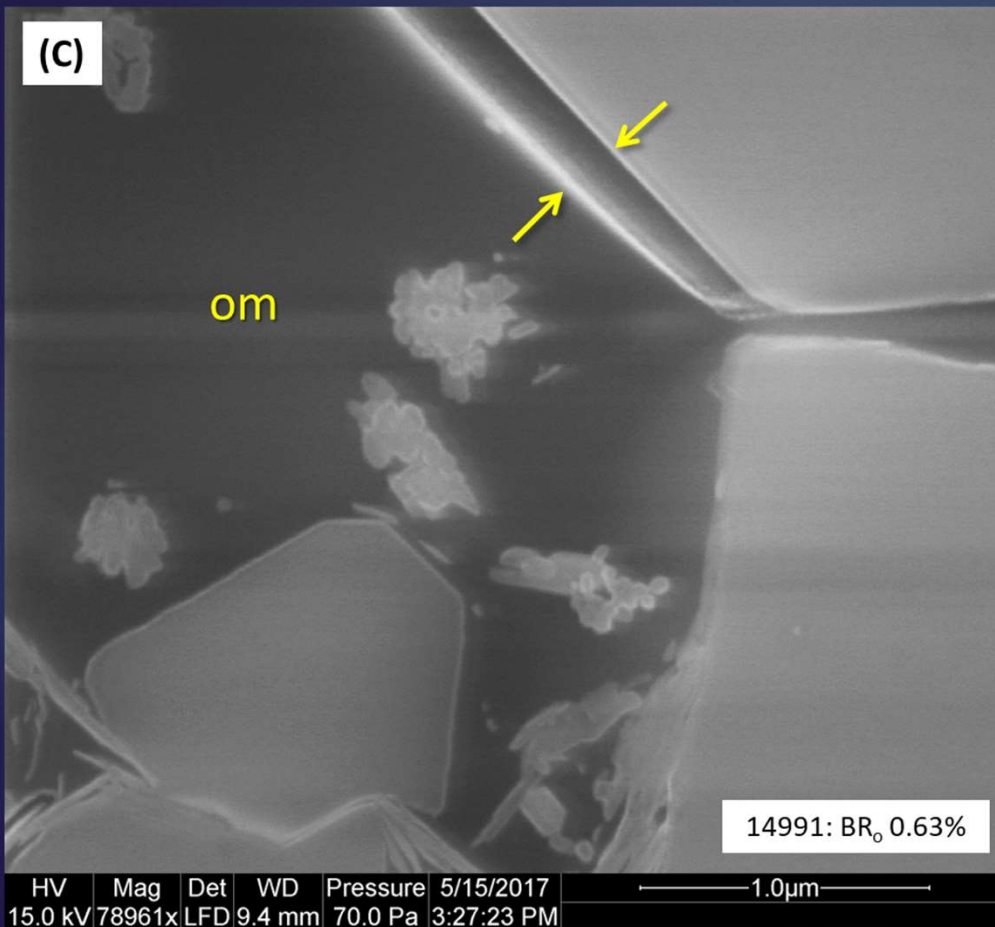


(B)



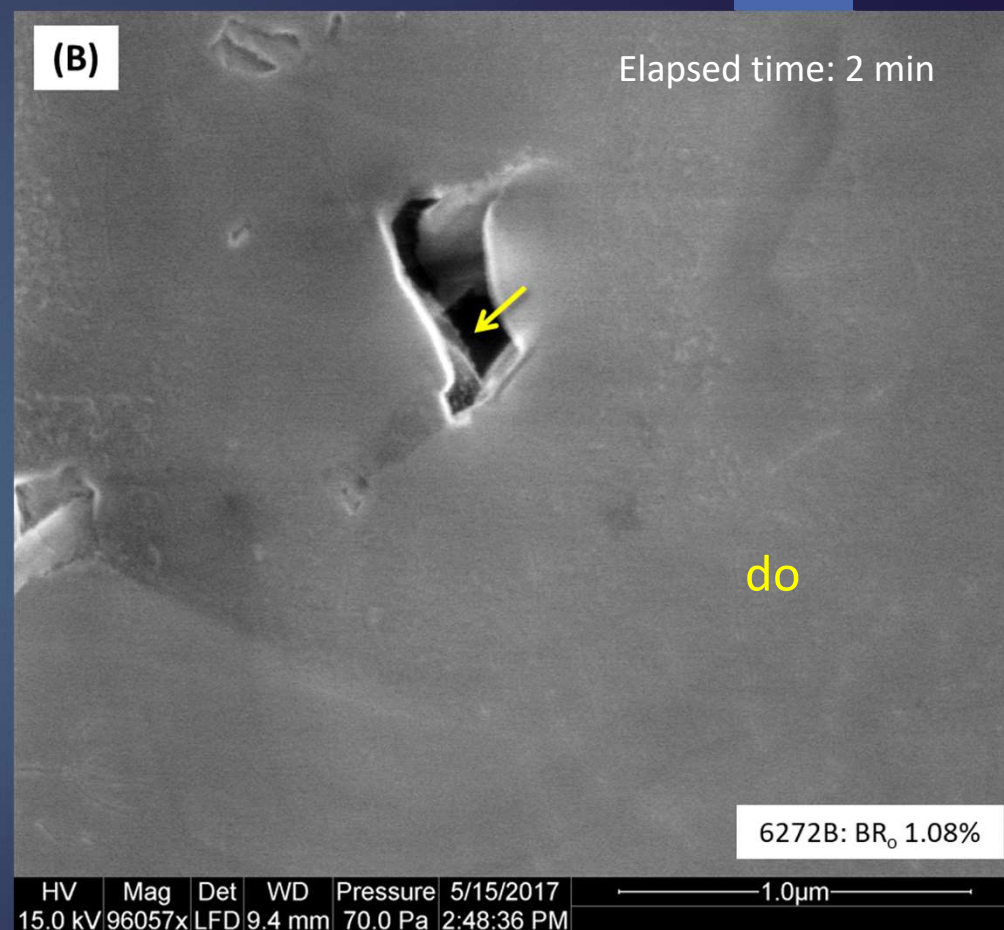
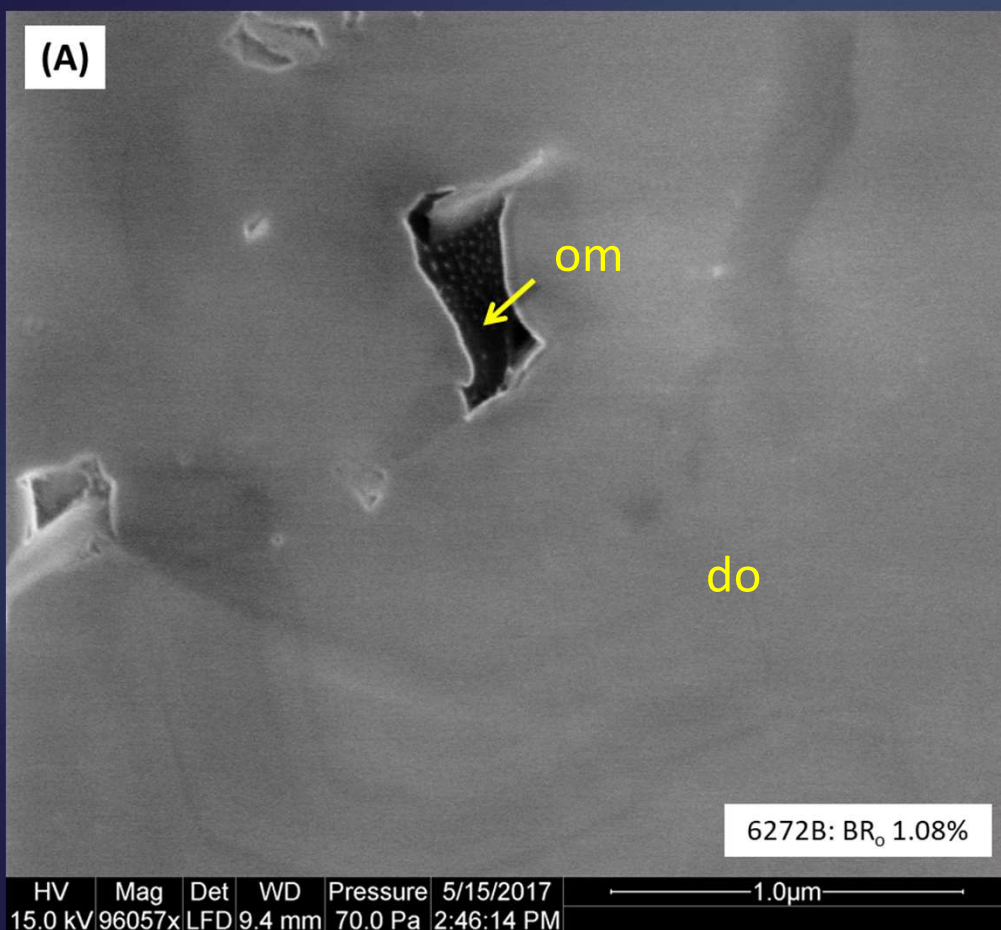
Camp et al. (in review)

Pore Artifacts (Cracks)

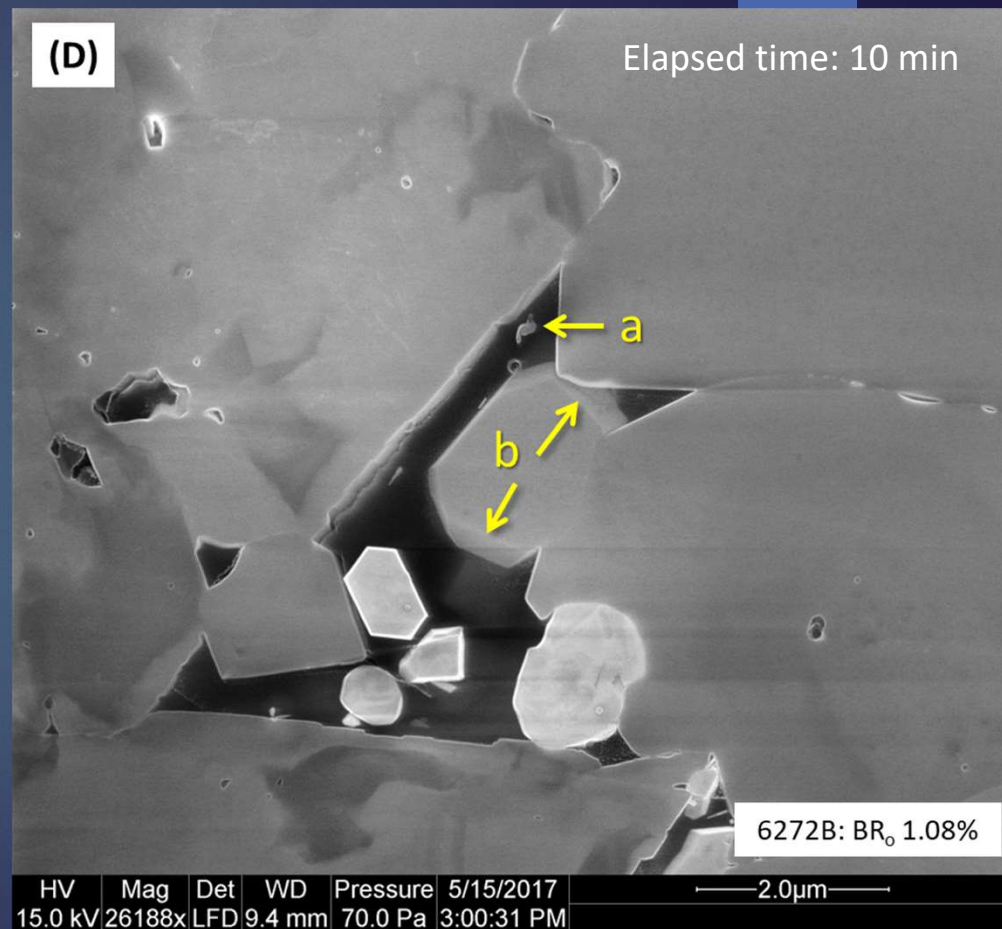
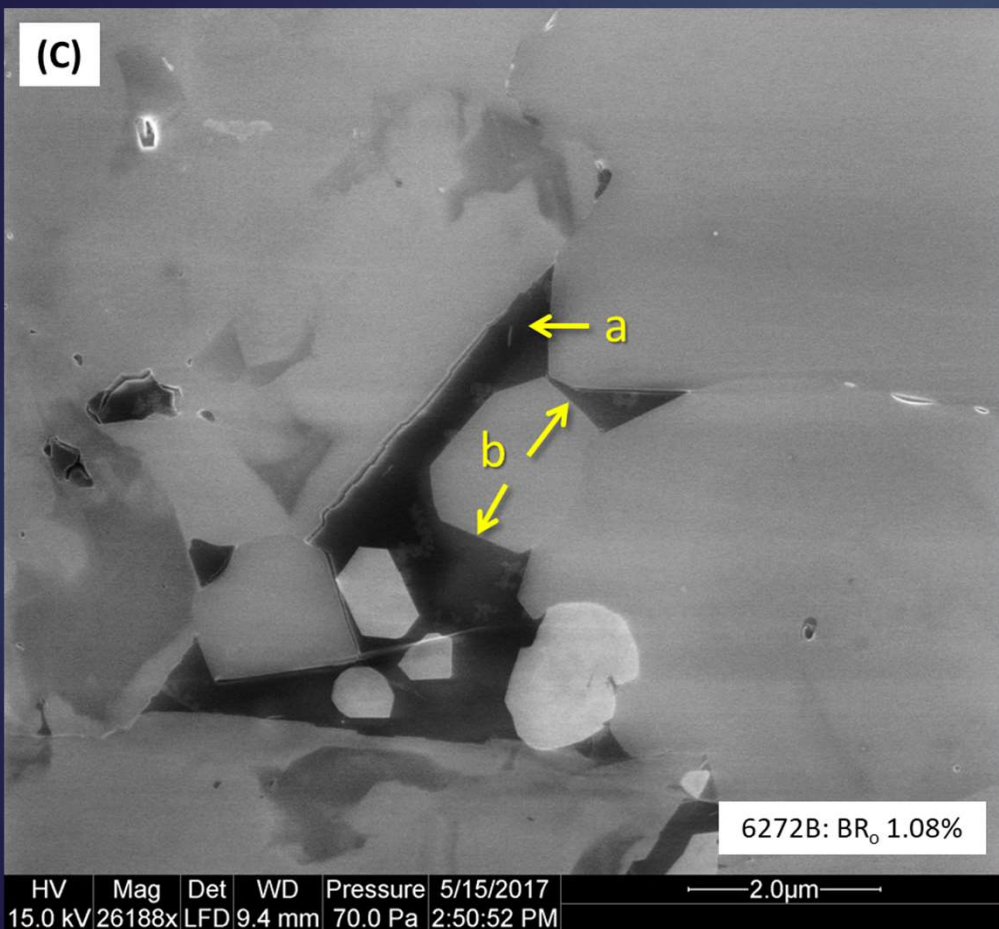


Camp et al. (in review)

OM Volatility (Intraparticle Pore)



OM Volatility (Solid Bitumen)



Camp et al. (in review)

SUMMARY

Summary

- ▶ Red River tight oil & gas play area defined by presence of thermally mature kukersite (*G. prisca* source rock)
- ▶ Kerogen composition is primarily fluorescent AOM that converts to 100% solid bitumen by about 0.60 %BR_o
- ▶ Observed organic matter porosity is rare, even in gas mature samples
- ▶ Volatile organic matter observed in dolomite intraparticle pores and within void-filling solid bitumen
- ▶ Volatile organic matter interpreted as residual oil that may occlude visible organic matter pores

Selected References

- ▶ Anna, L., R.M. Pollastro, S.B. Gaswirth, P. Lillis, L.N. Roberts and T. Cook, 2009, Assessment of undiscovered oil and gas resources of the Williston Basin Province of North Dakota, Montana and South Dakota: AAPG Search and Discovery Article 10201, 23 p.
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Questions

Photo by: Joanne Camp