

Influence of Diagenetic Fluids on Mississippian Carbonate Rock Properties in the Southern Midcontinent*

Sahar Mohammadi Dehcheshmehi¹, Jay M. Gregg¹, Kevin L. Shelton² and Martin S. Appold²

Search and Discovery Article #51165 (2015)**

Posted October 13, 2015

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

**Datapages © 2015 Serial rights given by author. For all other rights contact author directly.

¹Boone Pickens School of Geology, Oklahoma State University, Stillwater, Oklahoma (smoham@okstate.edu)

²Department of Geological Sciences, University of Missouri, Columbia, Missouri

Abstract

Petrographic, geochemical, and fluid inclusion analyses of dolomite and calcite cements have been made on Mississippian carbonates collected from the surface and subsurface of the southern Midcontinent (Oklahoma, Missouri, Kansas and Arkansas). Limestone porosity is largely occluded by early marine and meteoric calcite cement. Fracture and vuggy porosity are filled with calcite, chert, and dolomite cements. Both early and late blocky ferroan calcite cements were formed in the deep phreatic zone. Saddle dolomite cements are late diagenetic, possibly related to the nearby Tri-State Mississippi Valley-type mineral district, which in turn is genetically associated with petroleum migration in the region. Carbon and oxygen isotope compositions of dolomite cements range from $\delta^{18}\text{O}(\text{VPDB}) = -2.7\text{‰}$ to -9.5‰ , and $\delta^{13}\text{C}(\text{VPDB}) = -0.4\text{‰}$ to -4‰ . Calcite cements range from $\delta^{18}\text{O}(\text{VPDB}) = -1.9\text{‰}$ to -11.6‰ , and $\delta^{13}\text{C}(\text{VPDB}) = 4.6\text{‰}$ to -12.12‰ . Isotope values are consistent with three diagenetic waters: meteoric water, seawater modified by meteoric water, and basinal water. Analysis of two-phase fluid inclusions (water and vapor) in late calcite and dolomite cements indicate the presence of both dilute and high salinity fluid end members (calculated values ranging from 0 to 25 equivalent weight % NaCl) at homogenization temperatures ranging from 50° to 175°C. These temperatures and salinities indicate a saline basinal fluid possibly mixing with a dilute fluid of meteoric or mixed seawater/meteoric origin. Elevated fluid inclusion temperatures over a broad region, not just in the mineral district, imply that the thermal maturity of Mississippian carbonate rocks may be higher than previously thought. This study indicates that the Mississippian carbonate resource play in the southern Midcontinent has a very complex diagenetic history, continuing long after early diagenetic cementation. Possibly the most important, and the least understood, diagenetic events affecting these rocks

occurred during burial and basinal fluid migration through these strata. Extension of this study into north-central Oklahoma will provide a better understanding of the porosity development (cementation history) and thermal maturity of Mississippian carbonate reservoirs in this area and should lead to more effective exploration strategies.

Selected References

Mazzullo, S. J., Boardman, D. R., II, Wilhite, B. W., Godwin, C., and Morris, B. T., 2013, Revisions of Outcrop Lithostratigraphic Nomenclature in the Lower to Middle Mississippian Subsystem (Kinderhookian to basal Meramecian Series) along the shelf-edge in southwest Missouri, Northwest Arkansas, and Northeast Oklahoma: *Shale Shaker*, v. 63, p. 414-452.

Mii, H.S., E.L. Grossman, and T.E. Yancey, 1999, Carboniferous isotope stratigraphies of North America: Implications for Carboniferous paleoceanography and Mississippian glaciation: *Geological Society of America Bulletin*, v. 111/7, p. 960–973.

Morris, B., S. Mazzullo, and B. White, 2013, Diagenesis and isotopic evidence of porosity evolution in reef reservoir-analog facies in outcrops of the St. Joe Group (Kinderhookian to basal Osagean) in SW Missouri and NW Arkansas: *Search and Discovery Article #50890* (2013)/ Website accessed September 29, 2015, http://www.searchanddiscovery.com/documents/2013/50890morris/ndx_morris.pdf.

Ragan, V.M., 1994, Mineralogy and fluid inclusion geochemistry of Tri-State-type mineralization in eastern Kansas: *Economic Geology*, v. 89, p. 1411–1418.

Ragan, V.M., R.M. Coveney, Jr., and J.C. Brannon, 1996, Migration paths for fluids and the northern limits of the Tri-State district from fluid inclusions and radiogenic isotopes, *in* D.F. Sangster, editor, *Carbonate-hosted lead-zinc deposits*: Society of Economic Geologists Special Publication 4, p. 419–431.

Thompson, T.L., 1986, Paleozoic succession in Missouri: Part 4. Mississippian System: Missouri Division of Natural Resources, Division of Geology and Land Survey Report of Investigations 70, 182p.

Young, E.M., 2010, Controls on reservoir character in carbonate-chert strata, Mississippian (Osagean-Meramecian), southeast Kansas: University of Kansas Master's Thesis, p. 1-207.

Wenz Z.J., M.S. Appold, K.L. Shelton, and S. Tesfaye, 2012, Geochemistry of Mississippi valley-type mineralizing fluids of the Ozark Plateau; a regional synthesis: American Journal of Science, v. 312, p. 22–80.

Influence of diagenetic fluids on Mississippian carbonate rock properties in the Southern Midcontinent

Sahar Mohammadi Dehcheshmehi

Doctoral Student in Geology
Oklahoma State University

Jay M. Gregg

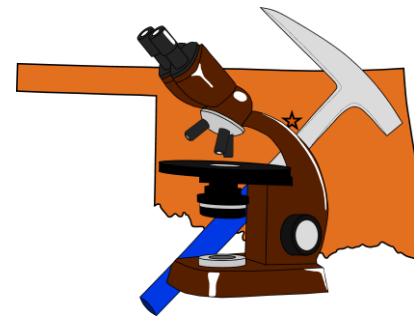
Oklahoma State University

Kevin L. Shelton

and

Martin S. Appold

University of Missouri



Acknowledgment is made to:

Reservoir Distribution and Characterization of Mid-Continent Mississippian Carbonates – A Major Unconventional Resource Play

**University – Industry Consortium
Boone Pickens School of Geology
Oklahoma State University**



**Maverick Brothers
Energy LLC**



Introduction

➤ **Problem:**

The Mississippian carbonate resource play in the southern Midcontinent has a very complex diagenetic history.

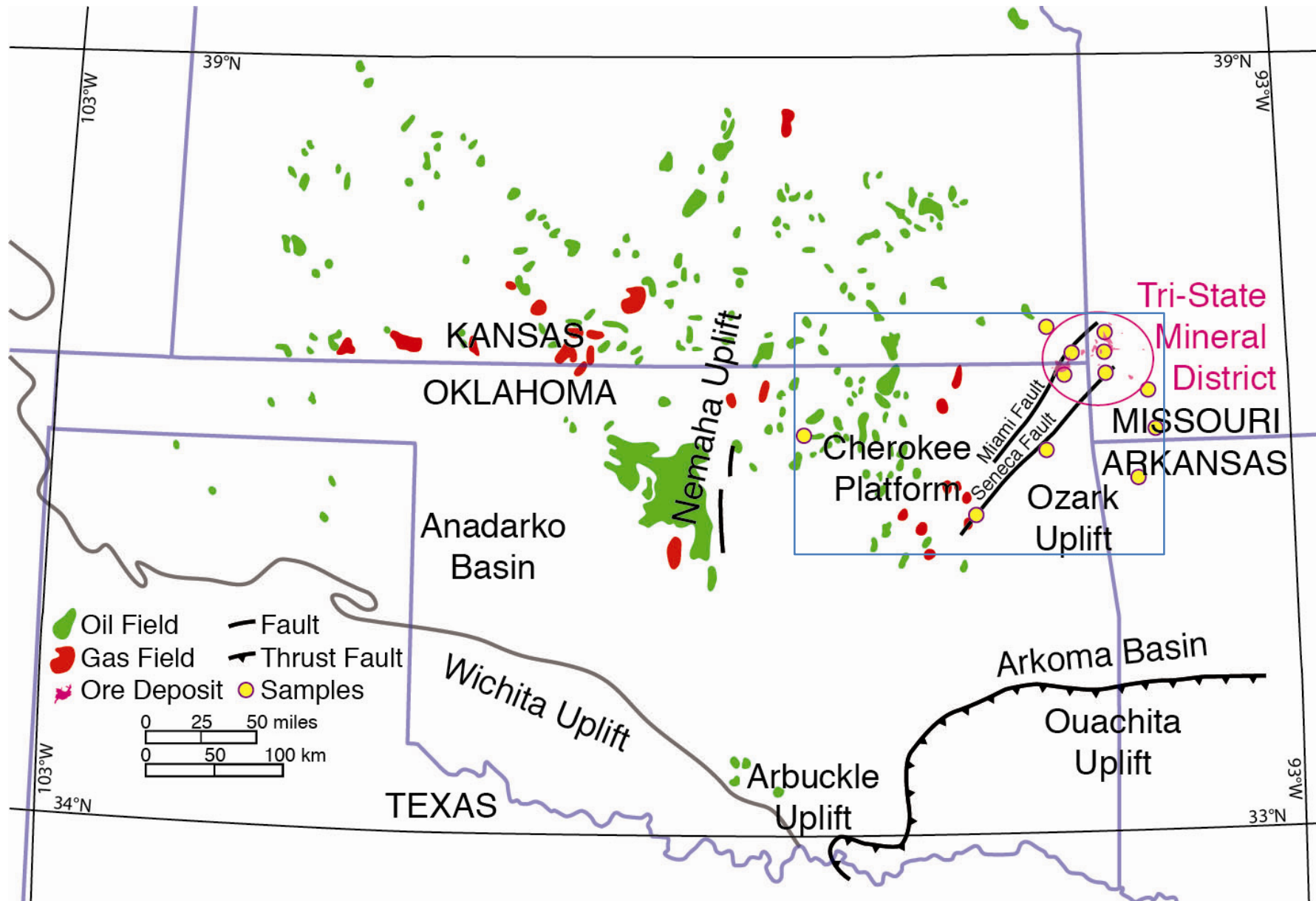
➤ **Hypothesis:**

Mississippian carbonates were regionally affected by basinal fluids that affected their reservoir properties.

➤ **Impact**

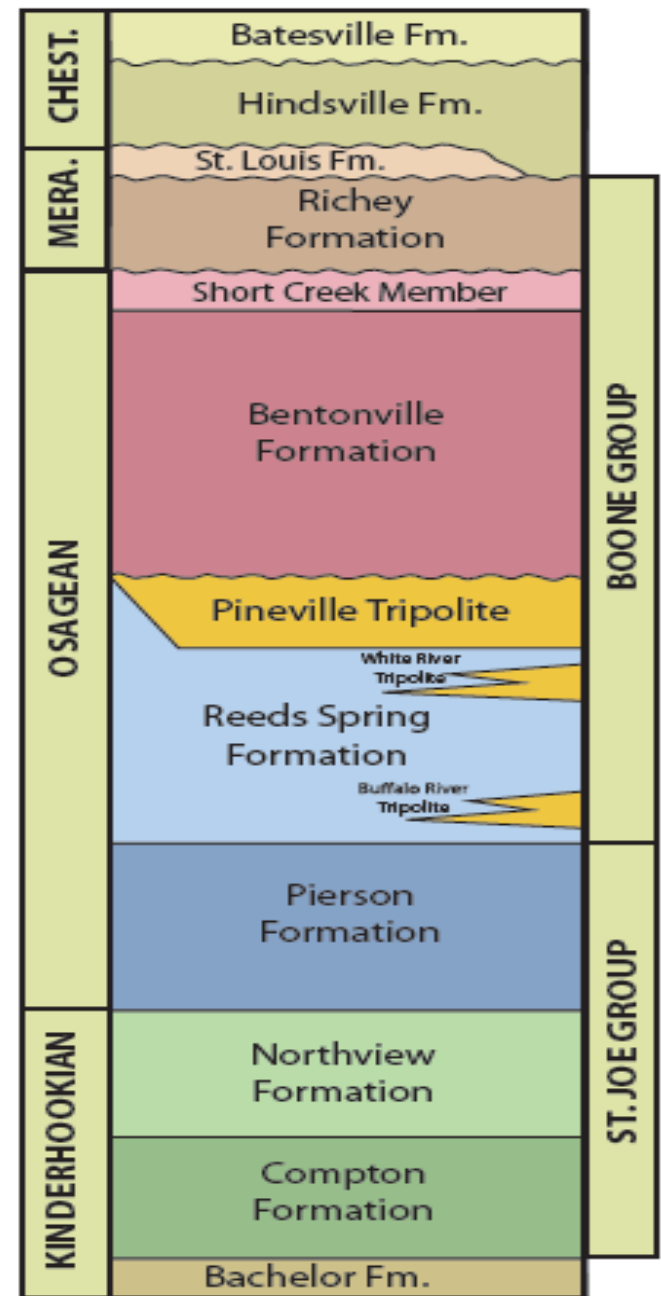
This study increases the understanding of the evolution of petroleum reservoirs in the Mississippian section of the southern Midcontinent.

Study Area



Global			U.S	NW Arkansas, SE Missouri & NE Oklahoma
System	Sub-system	Stage	Stage	
Carboniferous	Mississippian	Serpukhovian	Chesterian	Imo Formation Fayetteville Fm.
		Viséan		Batesville Formation Hindsville Formation
			Meramecian	St. Louis Limestone Salem Formation Warsaw Formation
				Osagean
		Tournaisian	Reeds Spring Limestone	
			Pierson Limestone	
			Kinderhookian	Northview Shale
				Compton Limestone
			Bachelor Formation	
Devonian	Famennian	Famennian	Chattanooga Shale	

Modified from Thompson, 1986



Modified from Mazzullo et al., 2013

Methods

➤ **Thin-section petrography and cathodoluminescence (CL):**

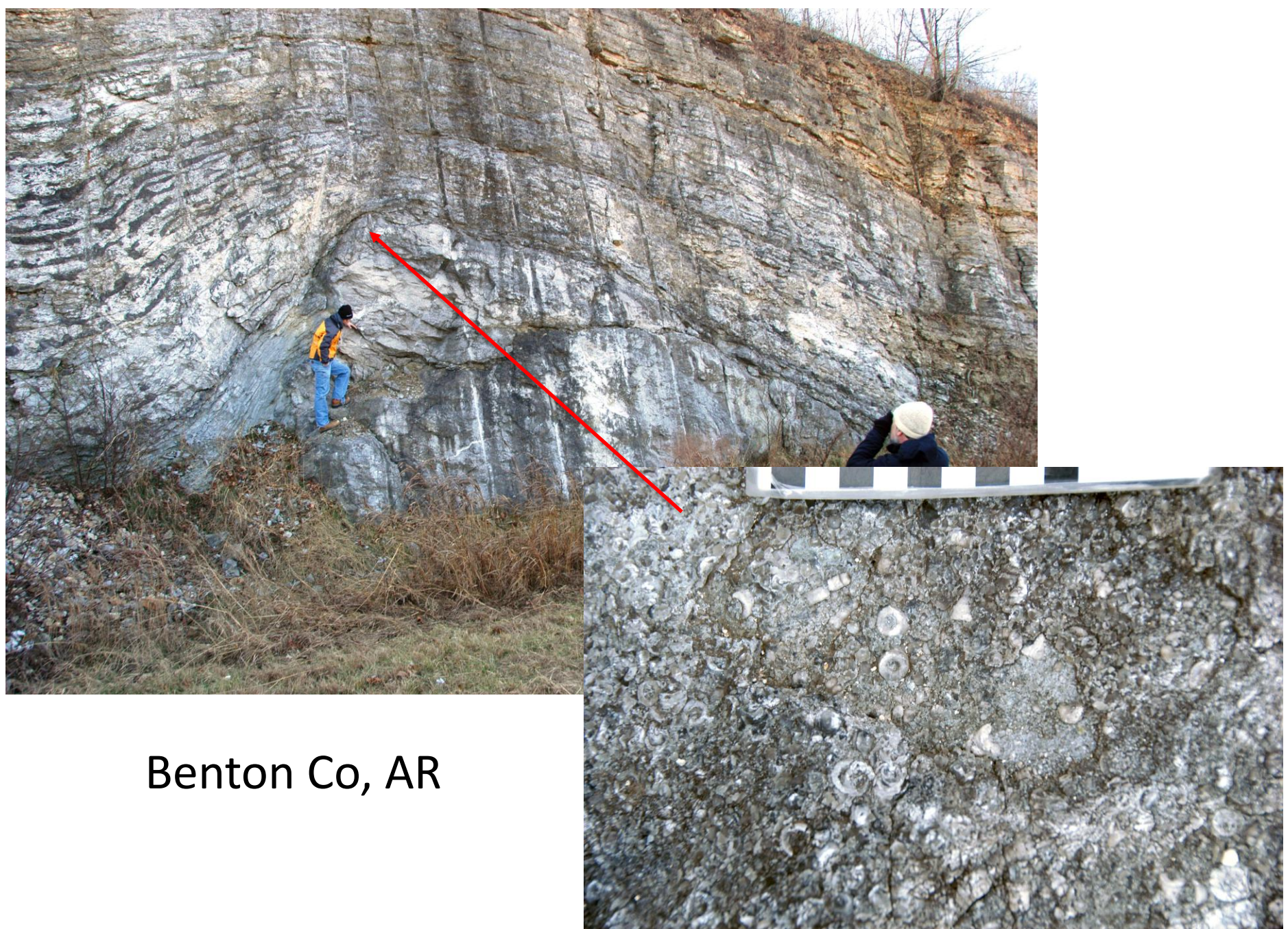
Olympus-BX51 microscopes and a CITL mk5 cold cathode CL system

➤ **Fluid inclusion microthermometry:**

Linkam THMSG 600 heating and cooling stage mounted on an Olympus BX41 microscope

➤ **Stable carbon and oxygen isotope ratios on selected samples:**

Delta Plus XL isotope ratio mass spectrometer



Benton Co, AR

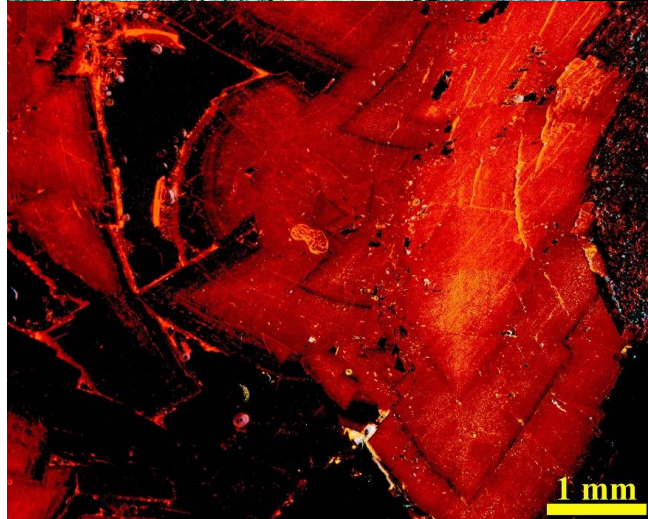
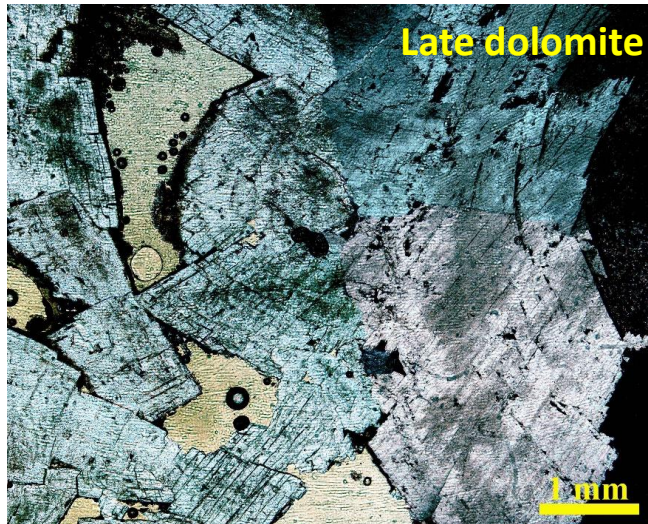


Wagoner Co, OK

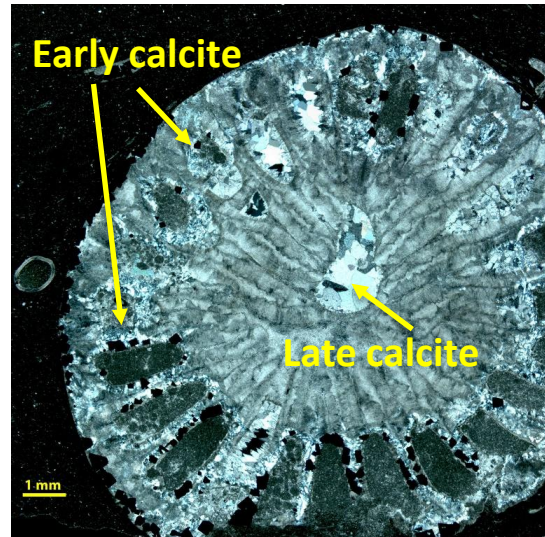


Payne Co, OK

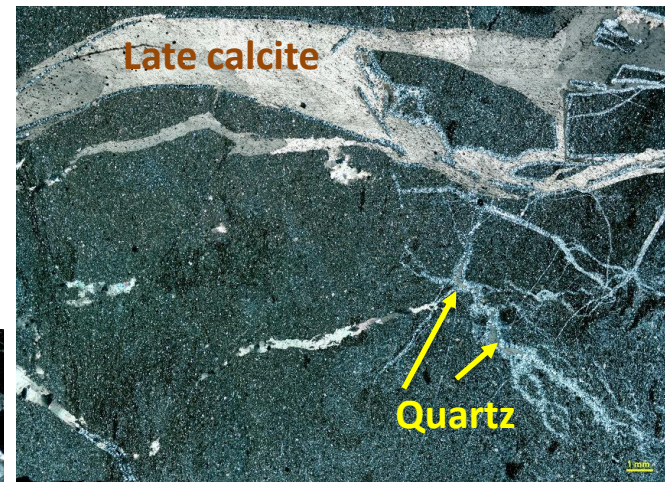
Petrography:



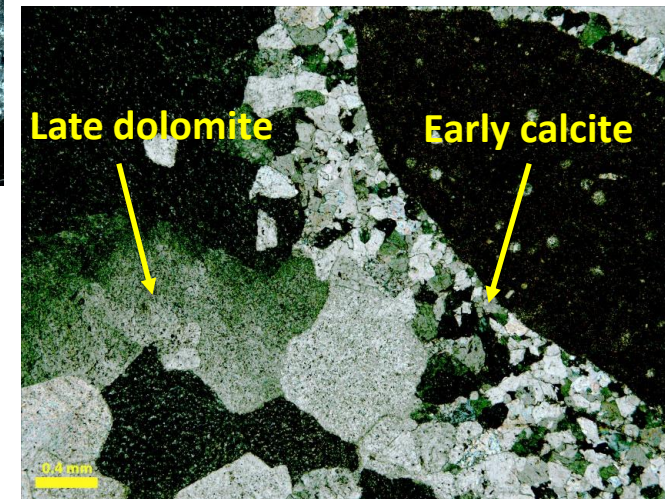
Tri-State, Picher "Field," OK



1 mm
North-central, Osage Co, OK

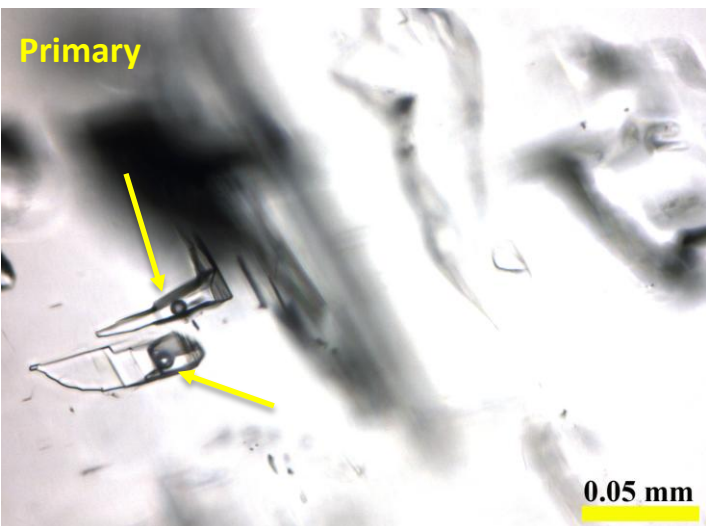


North-central, Osage Co, OK 2 mm

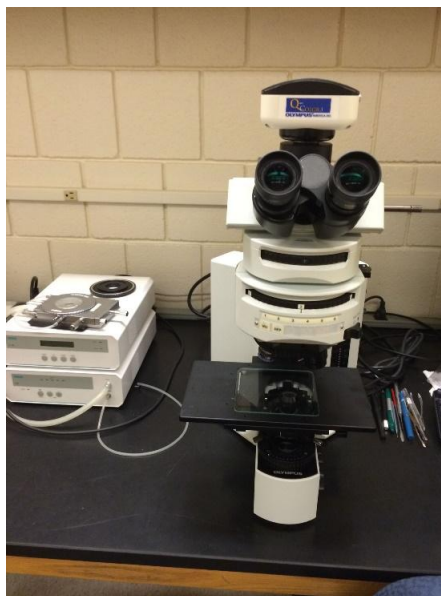


Mayes Co, Oklahoma 0.4 mm

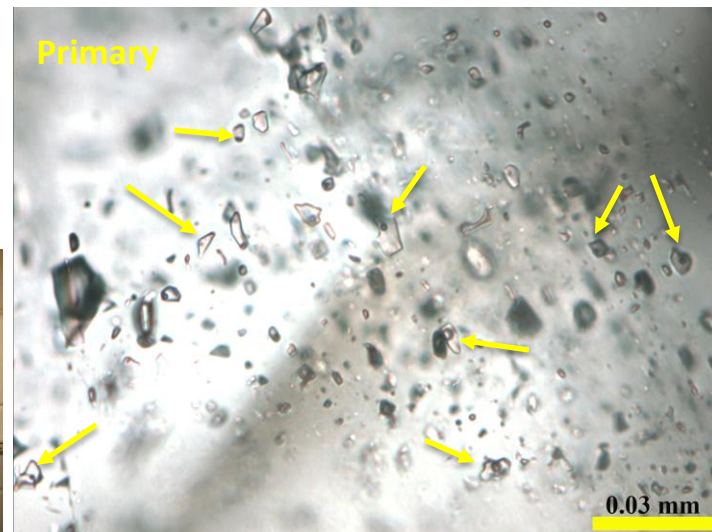
Primary



Fluid Inclusions:

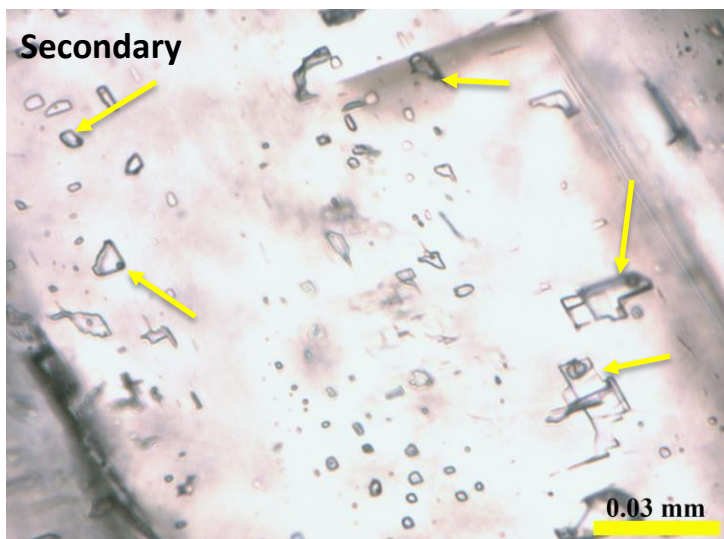


Primary



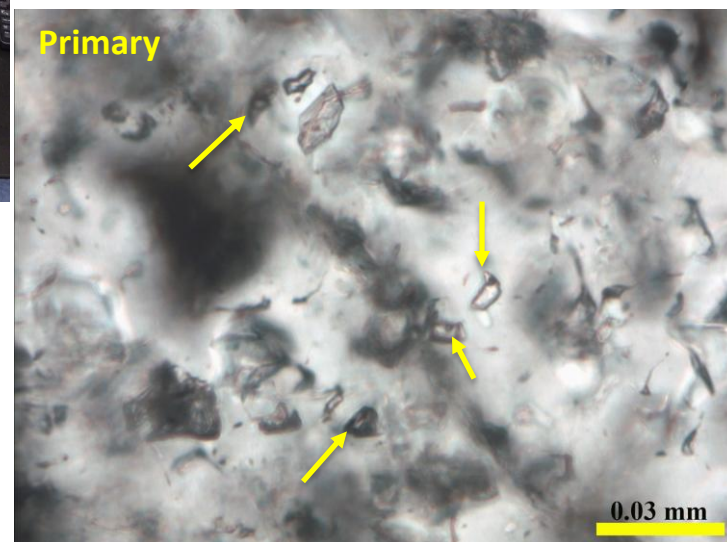
Quartz, Osage Co, Oklahoma

Secondary

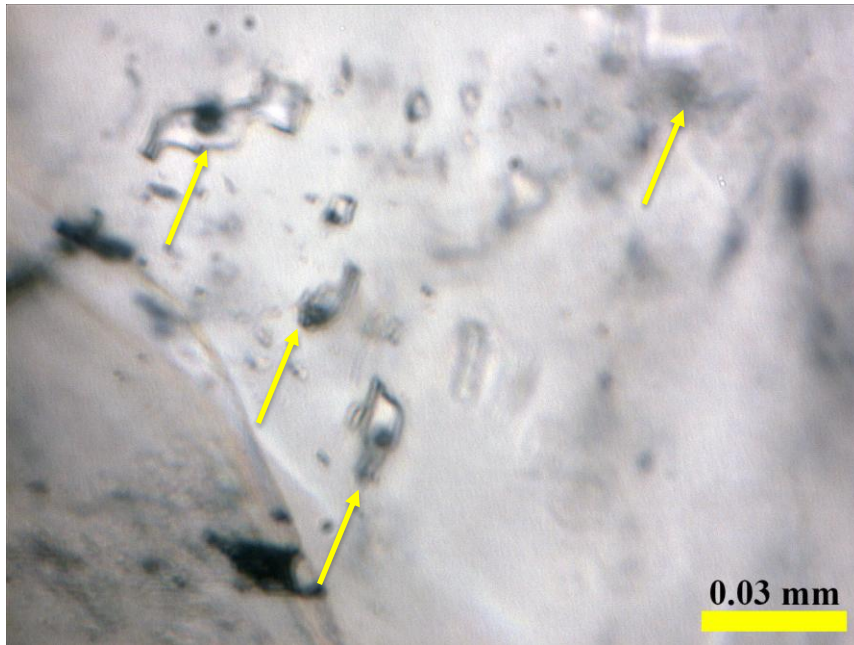


Calcite cement, Mayes Co,
Oklahoma

Primary



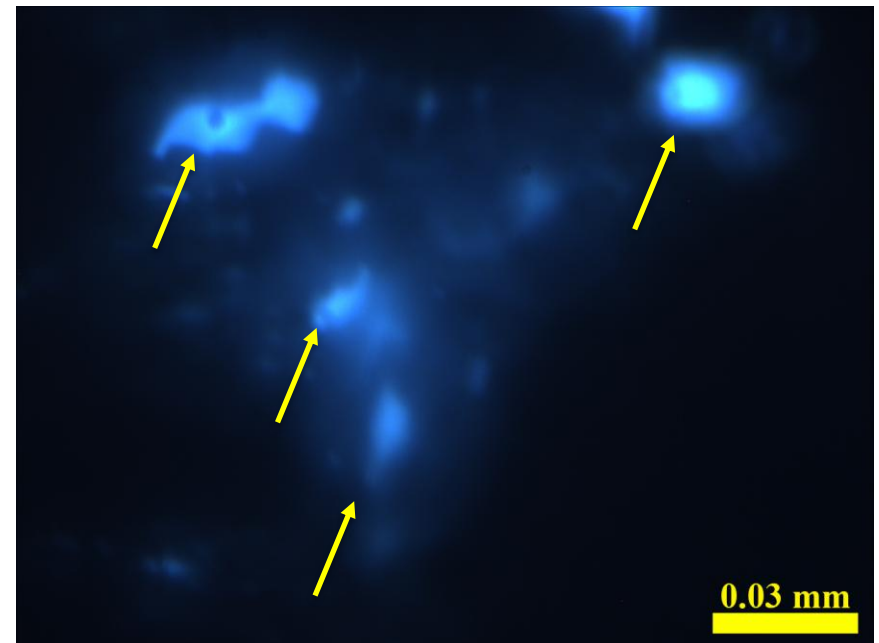
Dolomite cement, Mayes Co,
Oklahoma

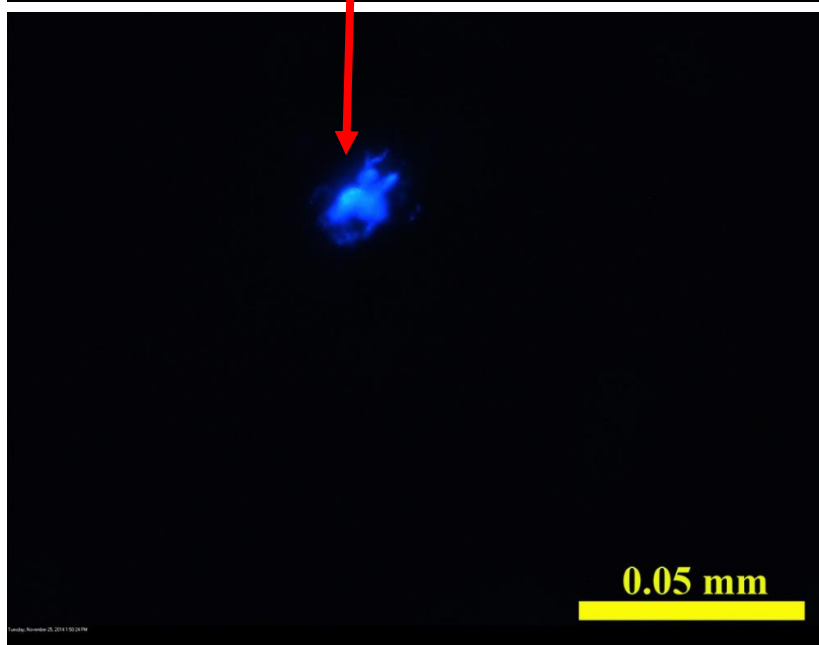
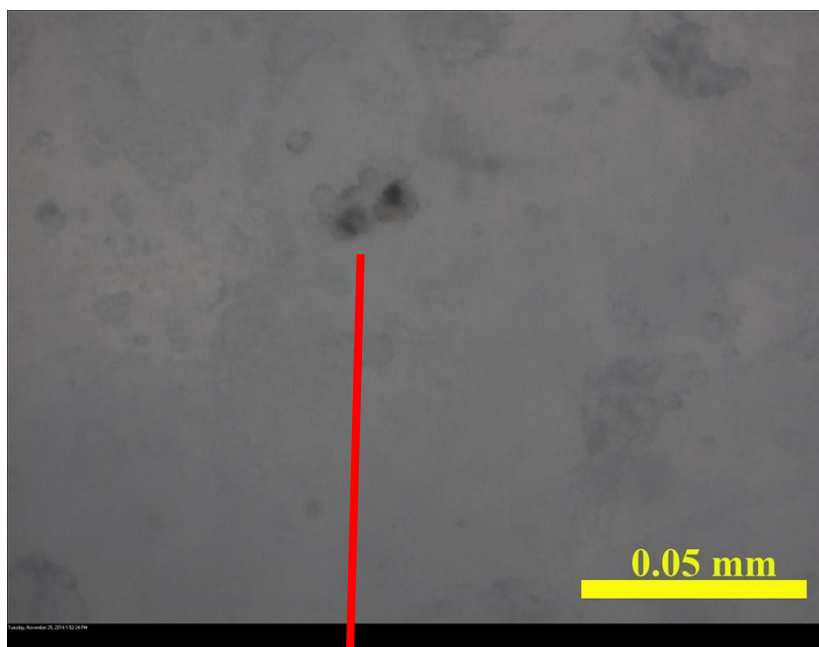


Inclusions with low-density petroleum

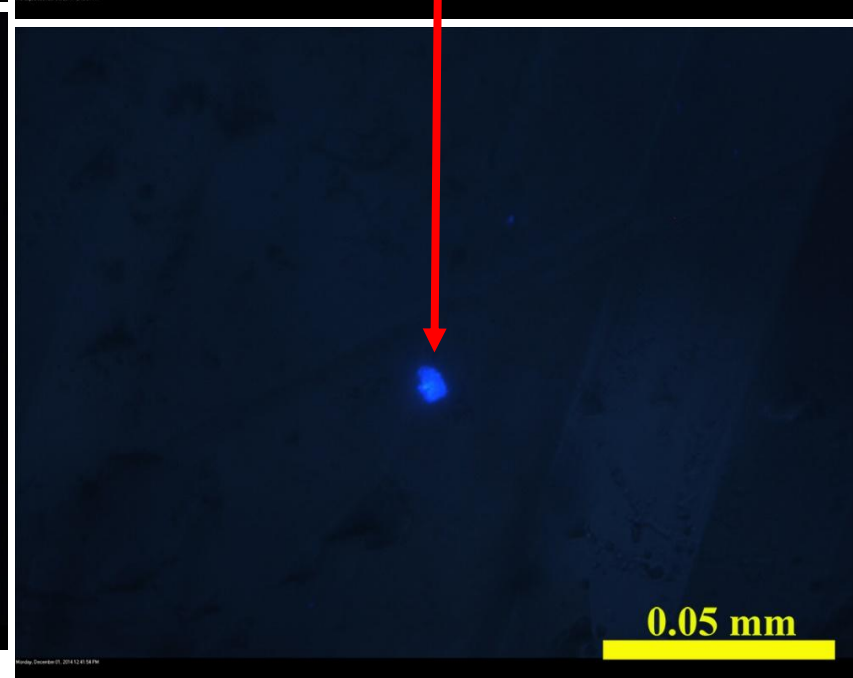
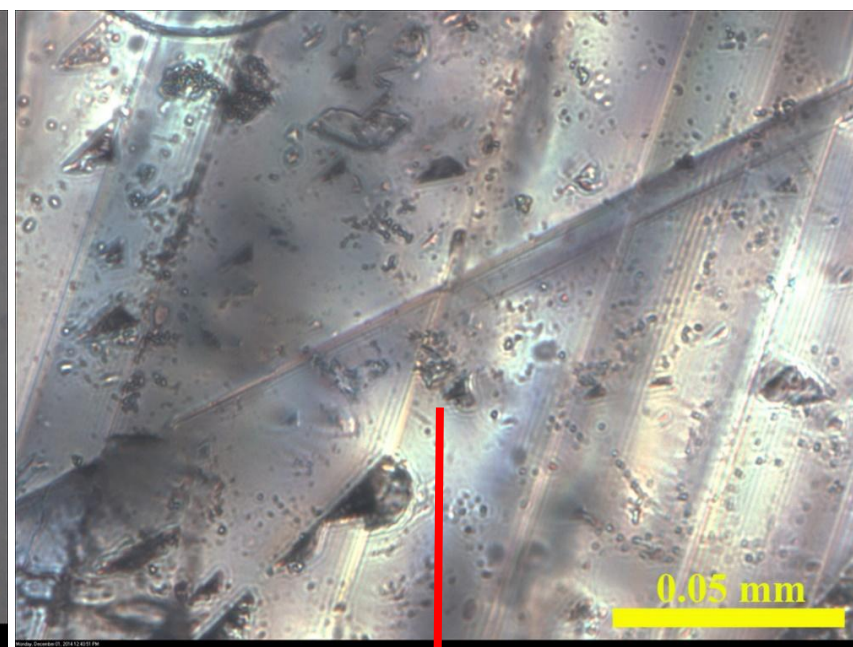
Plane-polarized light

Wagoner Co, OK, Calcite



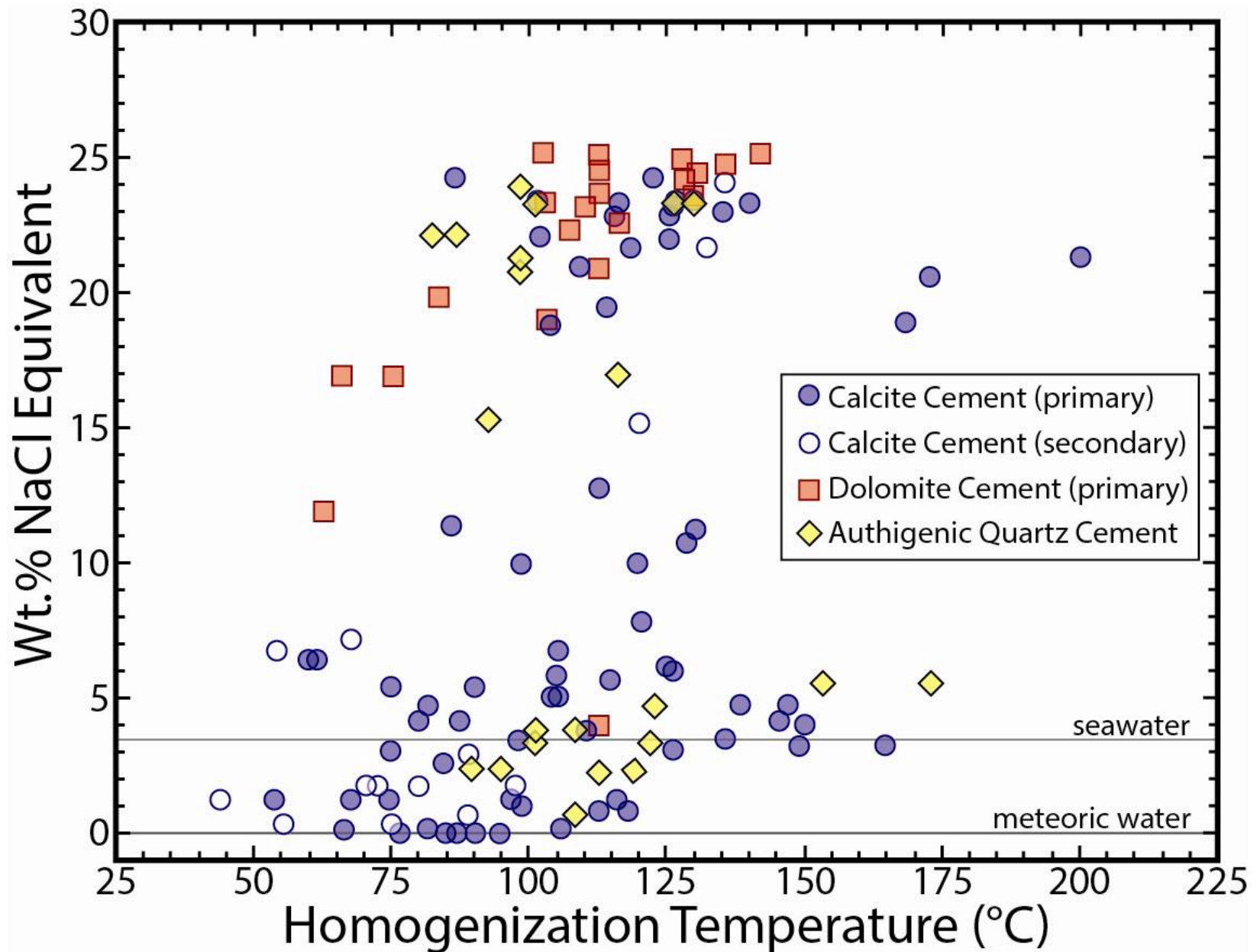


Tri-State Picher "Field," Dolomite

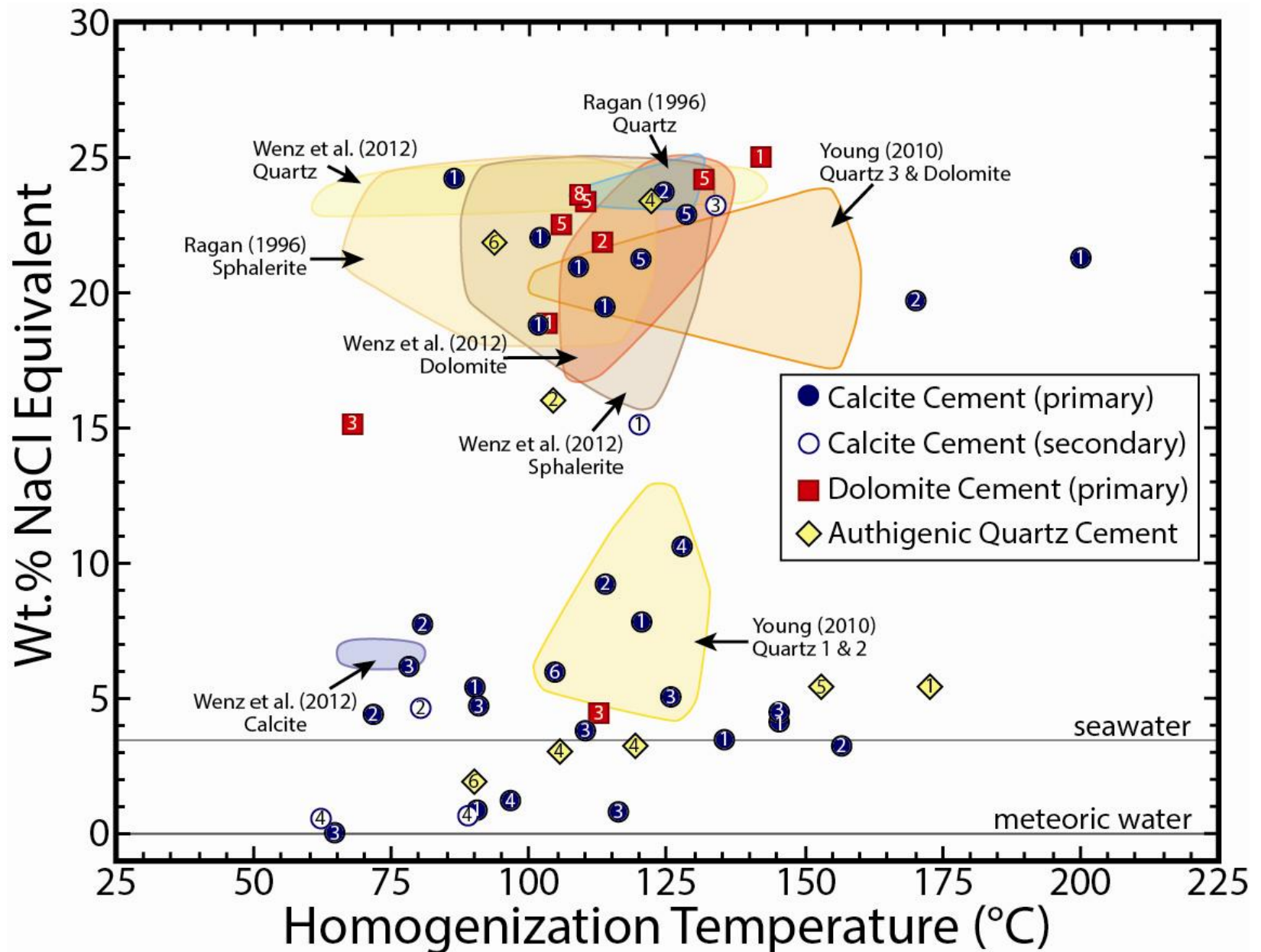


Wagoner, OK, Calcite

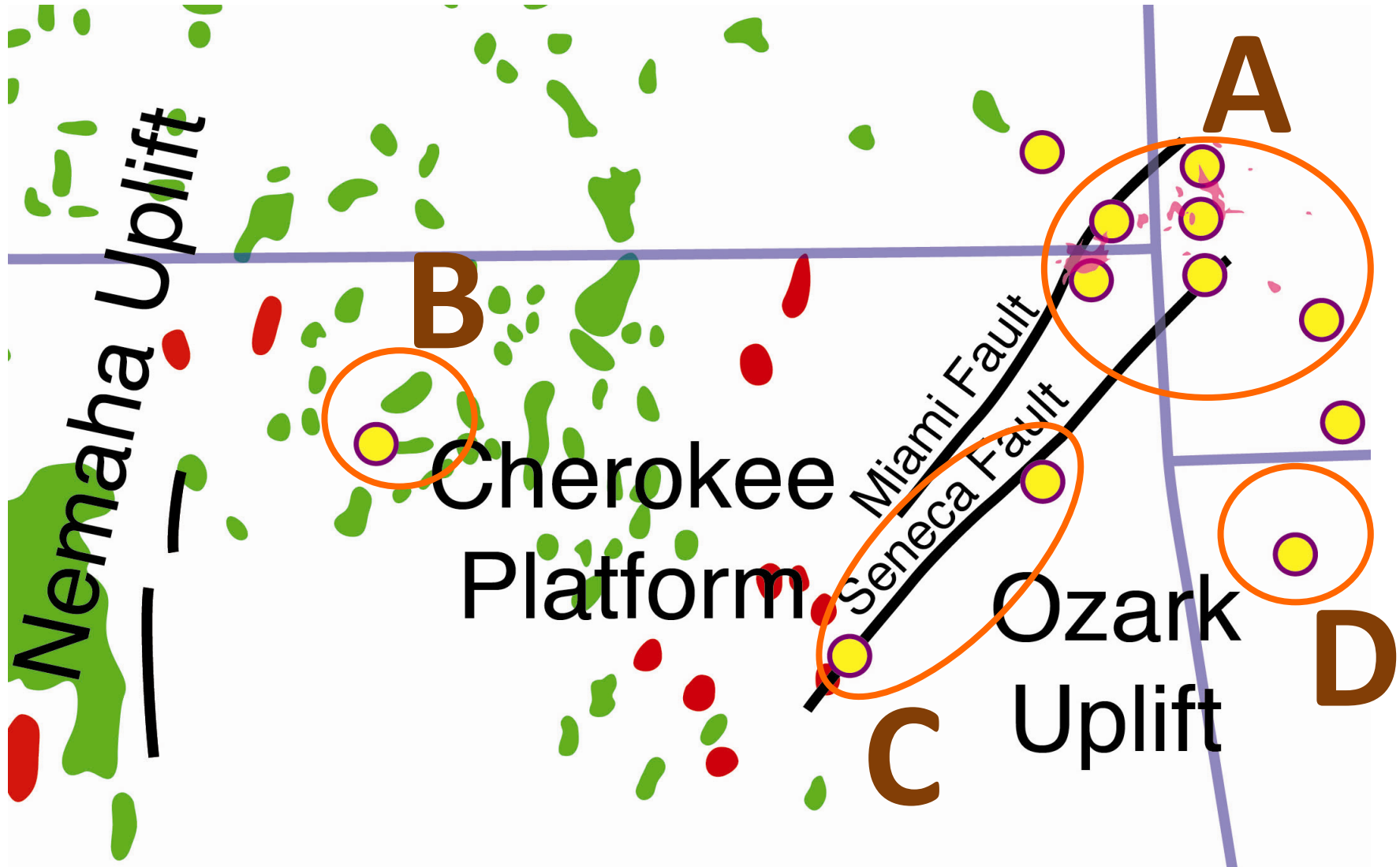
Fluid inclusion data



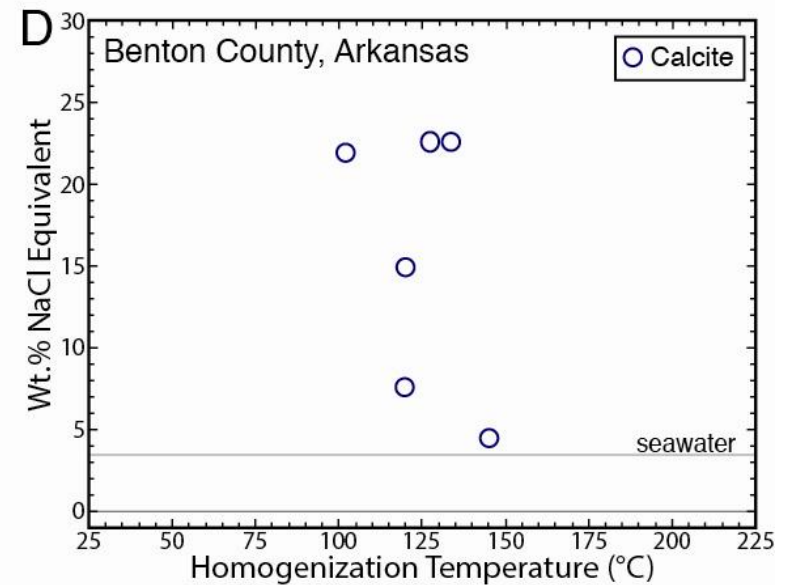
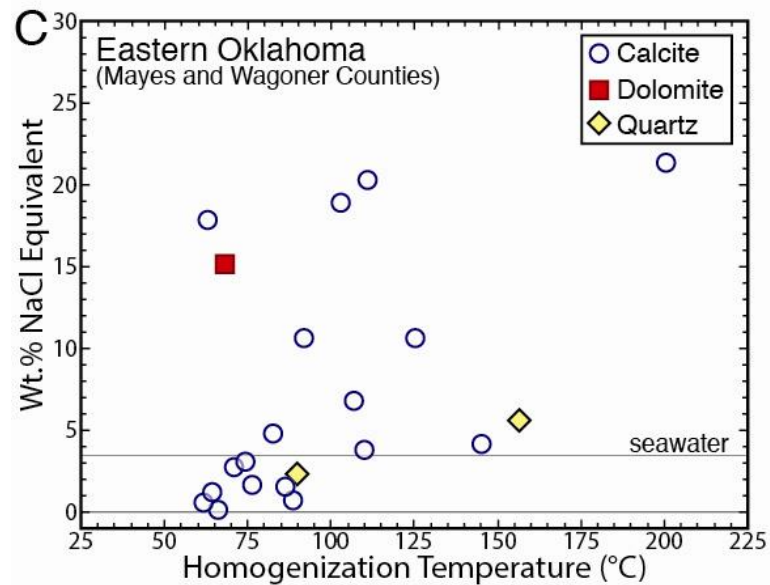
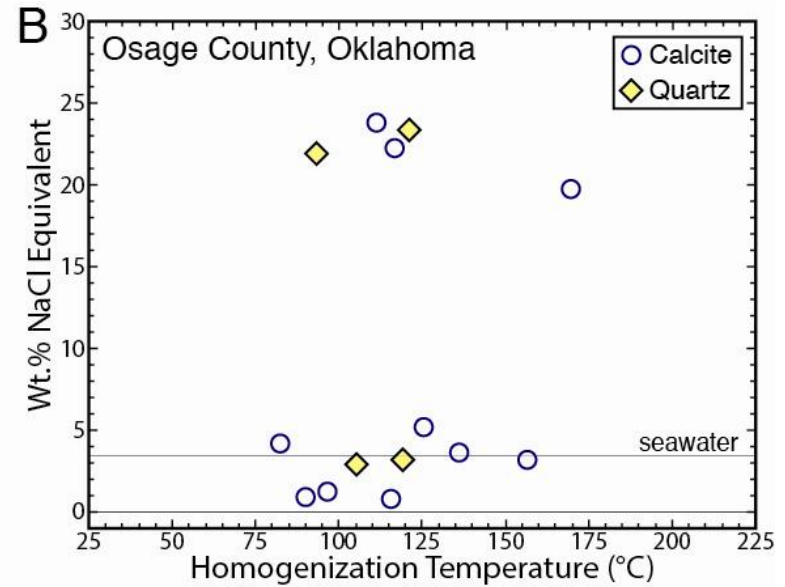
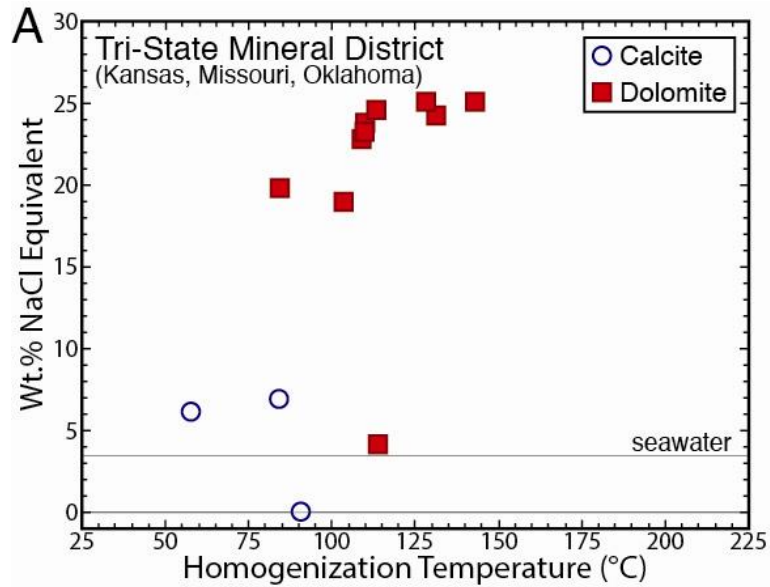
Fluid inclusion data



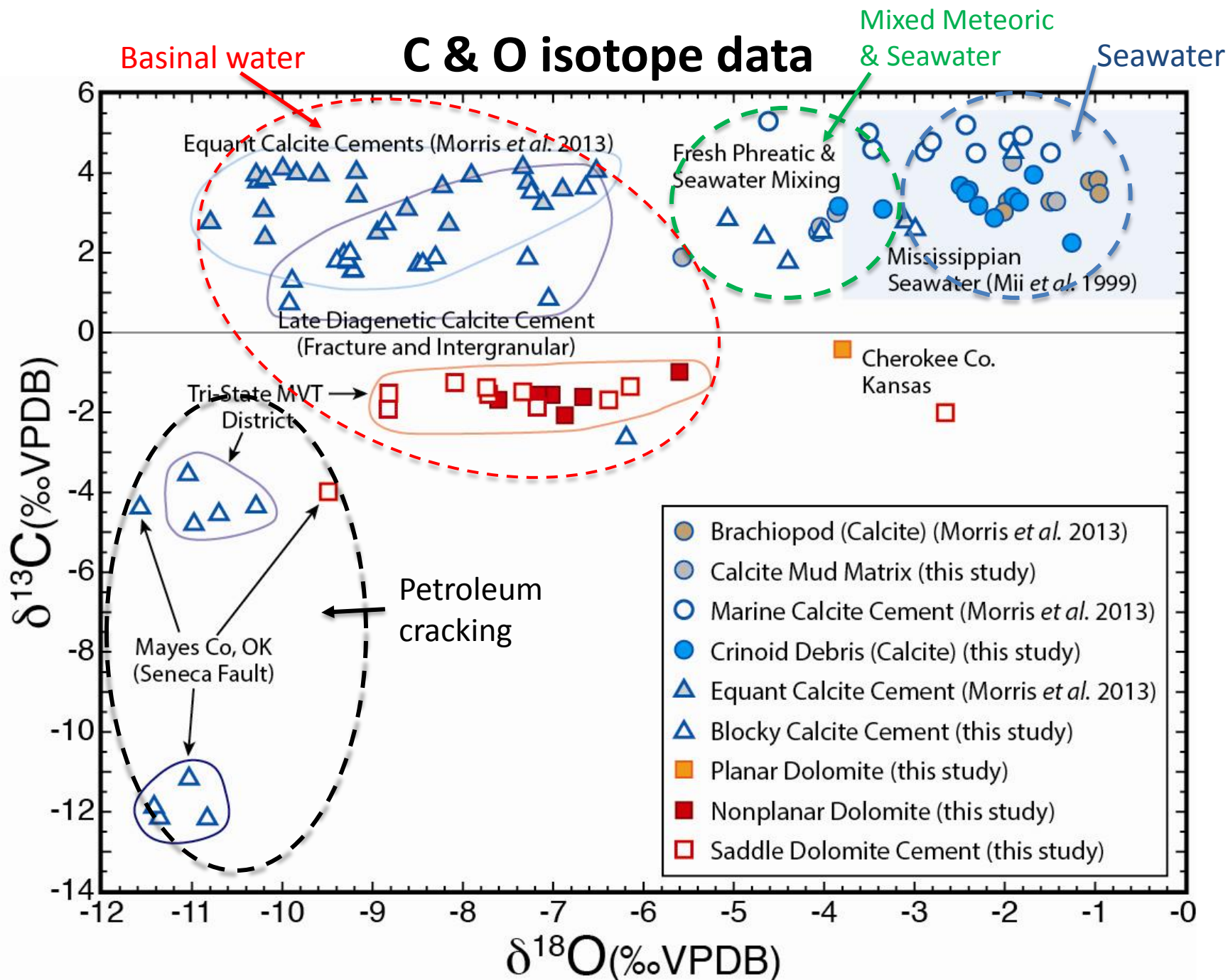
Study Area



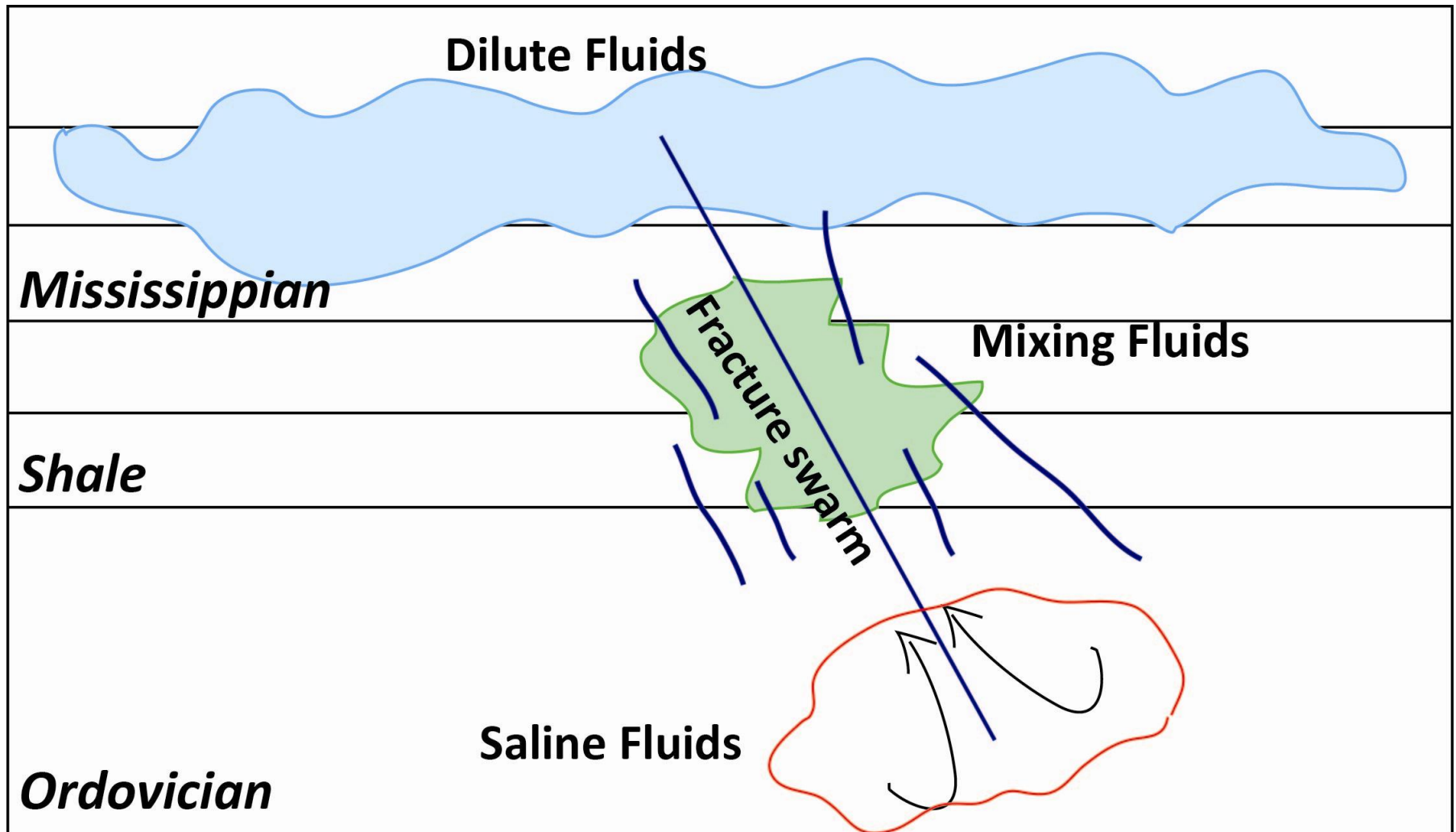
Fluid inclusion data



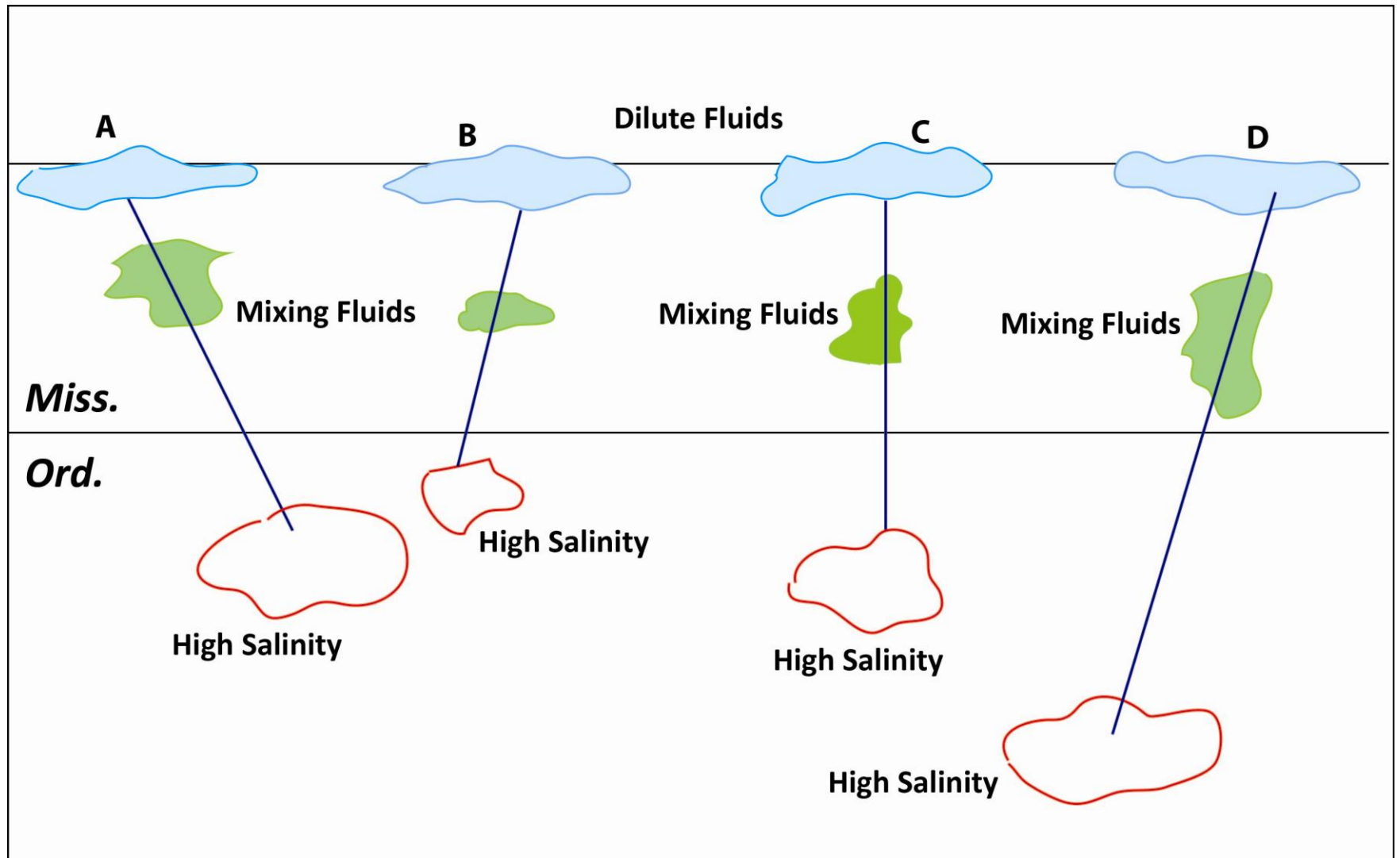
C & O isotope data



Conceptual model



Realistic model



Conclusions

- Extensive carbonate cementation filling intra- and intergranular porosity, vugs, and fractures began during early diagenesis and continued after burial and into the period of petroleum migration.
- Much of the cement is late diagenetic, not early diagenetic. This means that the Mississippian carbonates retained much of their porosity until late in their diagenetic history.
- Calcite, quartz and (saddle) dolomite cements were observed to contain two-phase (liquid and vapor) fluid inclusions with homogenization temperatures ranging from $\sim 50^{\circ}$ to 175°C and salinities ranging from 0 to 25 wt % NaCl equivalent.
- Fluid inclusions for calcite, quartz and dolomite cements represent both dilute and saline basinal waters.
- Carbon and oxygen isotope values for water, calculated from data obtained from calcite cements, are consistent with three diagenetic waters: a) meteoric water, b) seawater modified by meteoric water, c) basinal water.

Continued research

- Strontium isotope analysis to better determine the source of the fluids.
- Similar studies will be conducted on samples from the Nemaha uplift area in central Oklahoma and comparison of them with those in Ozark uplift area.

Thank you for your attention

