Biostratigraphically Constrained Ages of Mississippian Mixed Carbonate-Siliciclastic Sequences, STACK Play, Andadarko Basin, Oklahoma

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Outline

- Overview & Significance
- Background
- Data & Methods
- Results
  - Facies Associations & Depositional Environments
  - Sequence Stratigraphic Correlation
  - Biostratigraphic Constraints
- Conclusions
- Questions

Objectives & Significance

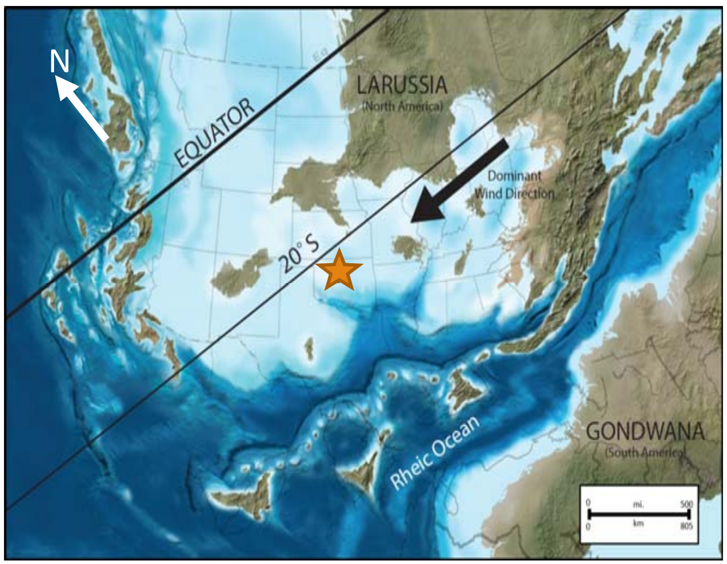
Constrain the ages of Mississippian mixed carbonate-siliciclastic sequences in the study area through conodont biostratigraphy and sequence stratigraphy

1. Establish a sequence stratigraphic framework based on depositional facies and vertical stacking patterns within the Pan American, Barnes D-2 core
2. Correlate the sequence stratigraphic framework to four principal conodont biozones and electrofacies from wireline logs
3. Illustrate the Mississippian stratigraphic architecture in the study area by construction of a wireline log cross section oriented subparallel to paleodip

➢ Results of this study provide a mechanism for better constraining ages of Mississippian intervals in the study area. This allows for development of more temporally accurate depositional models of the STACK play.

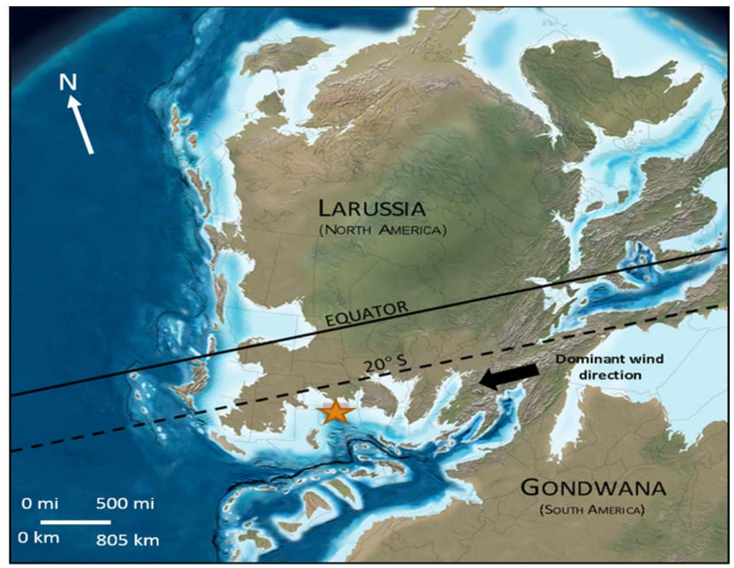
Geological Background

EARLY MISSISSIPPIAN (345 MYA)



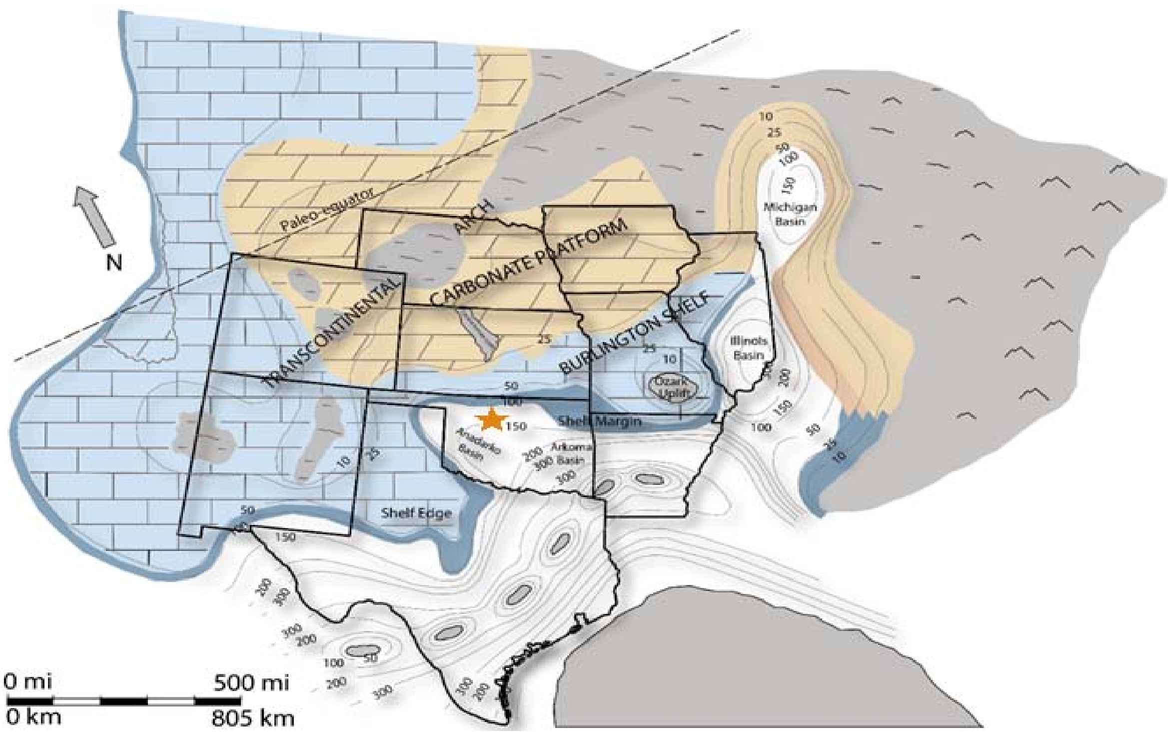
Modified from Blakey, 2014

LATE MISSISSIPPIAN (325 MYA)



Modified from Blakey, 2014

Geological Background

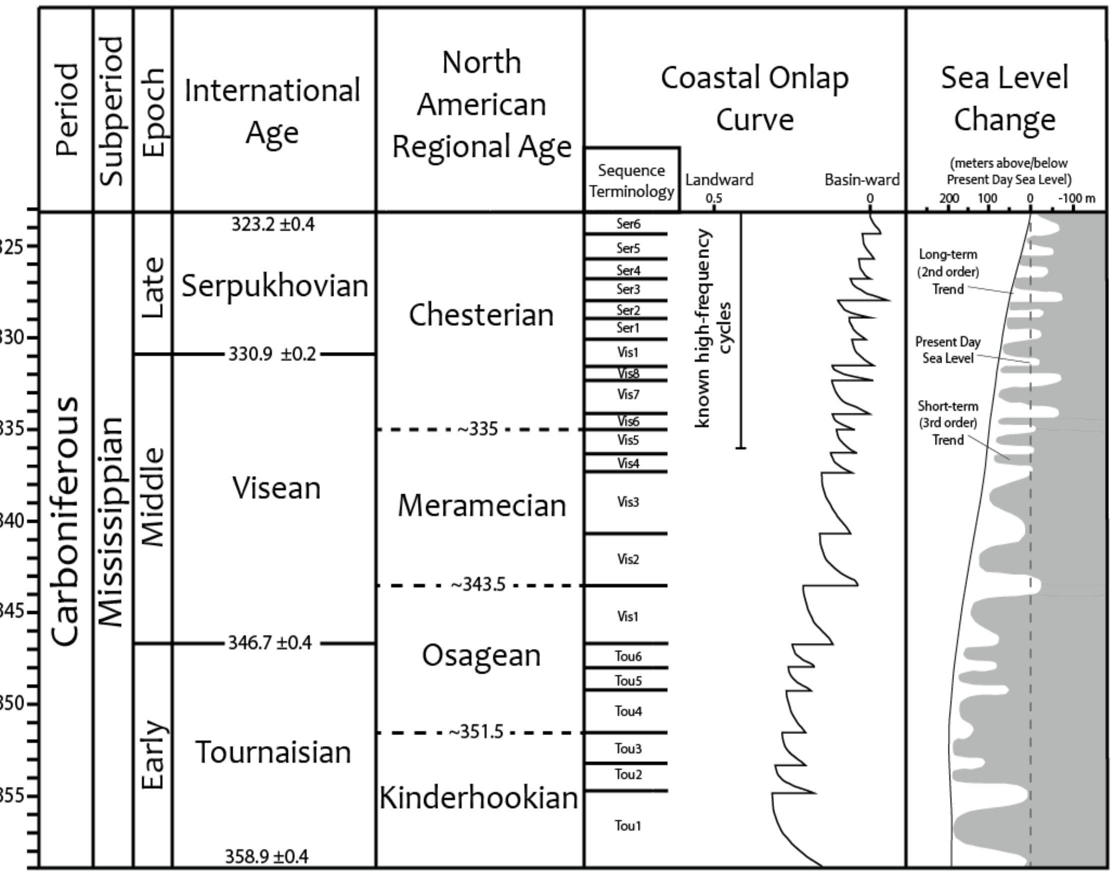


Paleogeographic time-slice map during middle Osagean. Modified from Gutschick and Sandberg, 1983; and LeBlanc, 2014

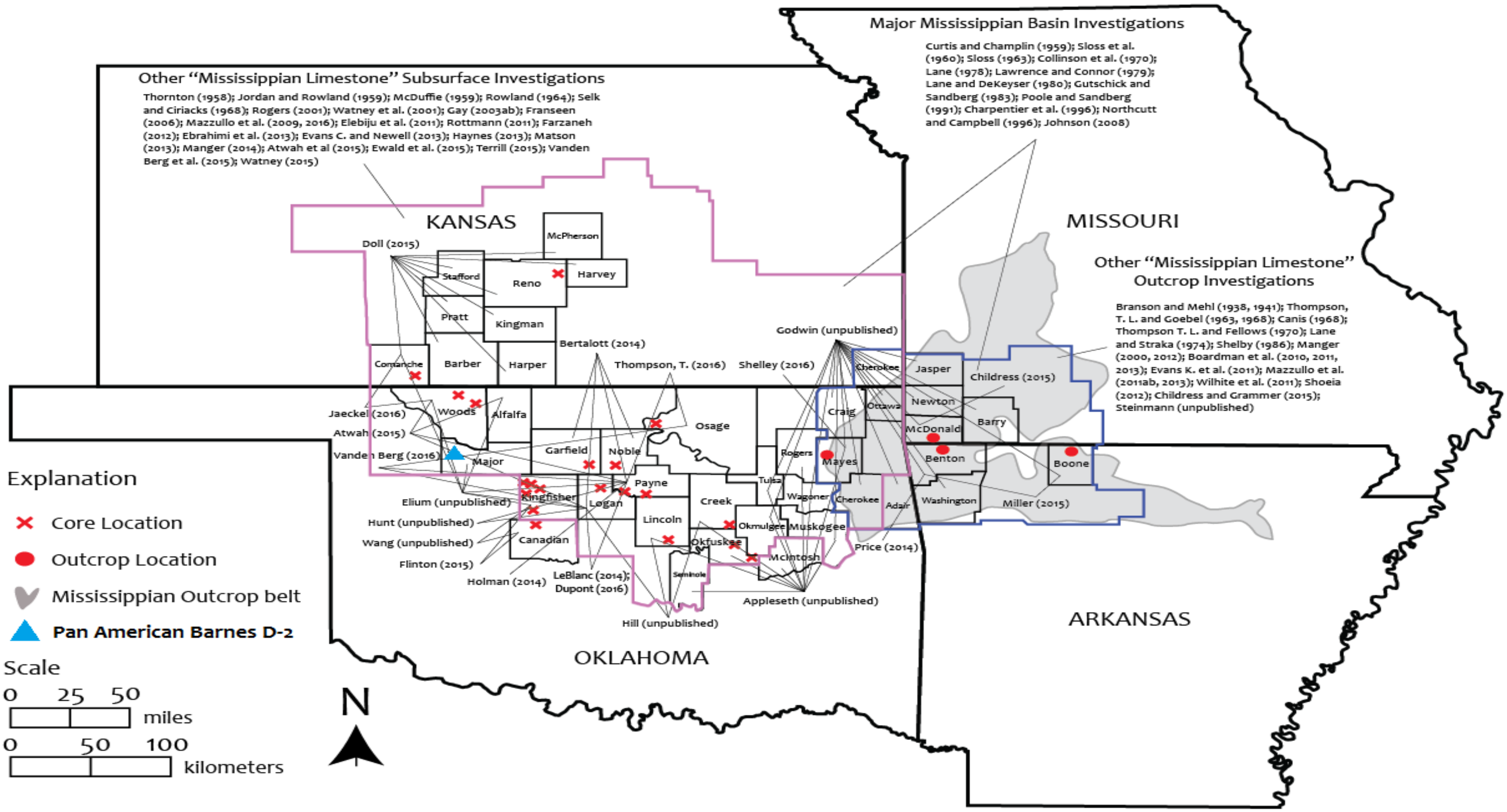
Mississippian Sea Level

- Transitional from Devonian greenhouse to Gondwana icehouse
- Overall decline throughout Mississippian
- Known high-frequency cycles during mid to late Mississippian

(OSU Mississippian Consortium, 2017)



Modified from Gradstein et al., 2012; Haq and Schutter, 2008; and Hunt, 2017



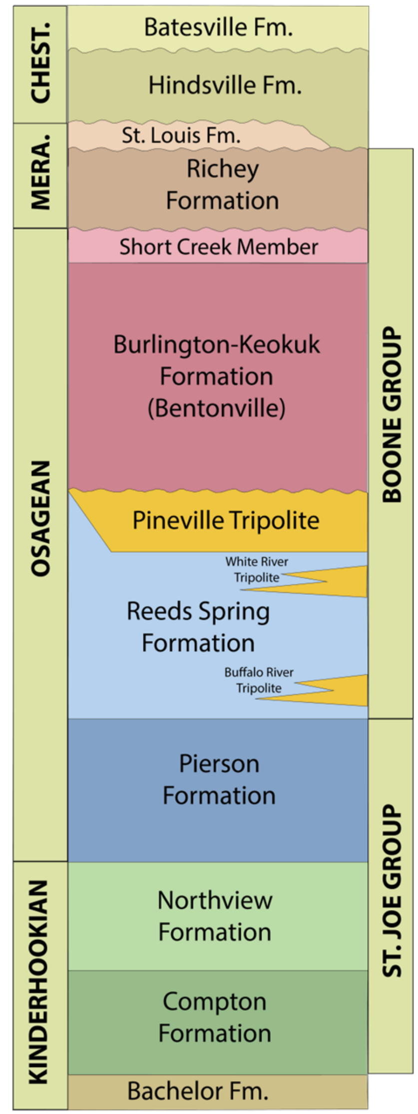
SOURCE DATA
State and county lines created from the Oklahoma University (OSU) Library's McCasland Map Collection (Map ID: G4020 1975). Simplified outline of the informally known Mississippian outcrop belt patterned after Mazzullo et al. (2011). Areas with core or outcrop control depicted by compiling their locations onto this map with permission from all on-going and prior workers of the OSU-Industry Mississippian Consortium.

Modified from Hunt, 2016

Regional Stratigraphy

- Outcrop research by Mazzullo et al. (2013) developed modifications to Mississippian section nomenclature to standardize group, formation , and member names within the region

- Biostratigraphic research identified various conodont zones within outcrop belt
  - Thompson and Fellows (1970)
  - Boardman et al. (2013)
  - Godwin (2018)



Stratigraphic column of the Mississippian system. From Mazzullo et al., 2013

Data

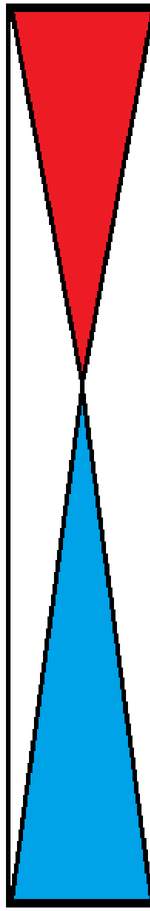
- Core
  - Pan American Barnes unit D-2
  - Section 23, T. 22N., R.16W in Major County, OK
  - 1,188 linear feet of core with raster images provided by OPIC
- Biostratigraphic Data
  - Godwin (2018) identified four principal conodont biozones in Meramecian and Chesterian strata in NE Oklahoma
  - Recognized the four principal biozones in the Pan American Barnes D-2 core
- Thin Sections
  - 25 thin section photomicrographs supplied by OPIC
  - 11 thin sections prepared from reclamation plugs supplied by OPIC
- Wireline Logs
  - 30 wells including digital gamma-ray and resistivity curves
  - Well and digital log data imported from IHS Energy

Methods

- Establish a sequence stratigraphic framework based on depositional facies and vertical stacking patterns within the Pan American, Barnes D-2 core
- Correlate the sequence stratigraphic framework to four principal conodont biozones and electrofacies from wireline logs
- Illustrate the Mississippian stratigraphic architecture in the study area by construction of a wireline log cross section oriented subparallel to paleodip

Idealized Facies Stacking Pattern

- The six facies identified in the Pan Am. Barnes D-2 core
- Representative of facies deposited during one complete rise and fall of sea level
- Blue triangle represents the transgressive phase and the red triangle represents the regressive phase

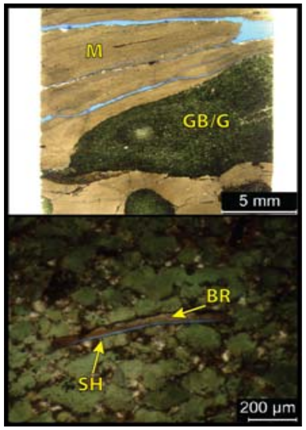


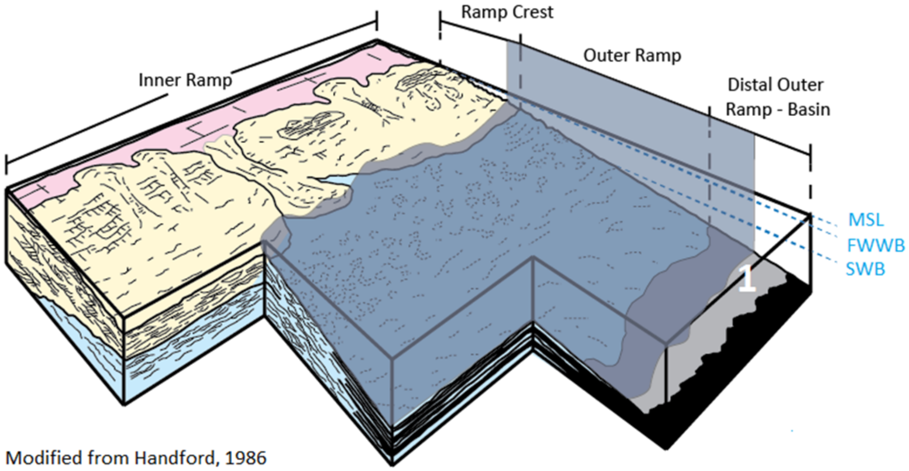
6	Skeletal Packstone
5	Wackstone-Packstone
4	Silty Mudstone-Wackestone / Siltstone
3	Dolomitic Mudstone-Wackestone
2	Shale
1	Glauconitic Shale

SBC1

Facies Associations

FACIES 1: Glauconitic Shale / Sandstone





Modified from Handford, 1986

- Glauconite grains (G)
- Brachiopod (BR) with shelter porosity (SH)

- Deposited during initial transgression
- Deep water setting, below SWB

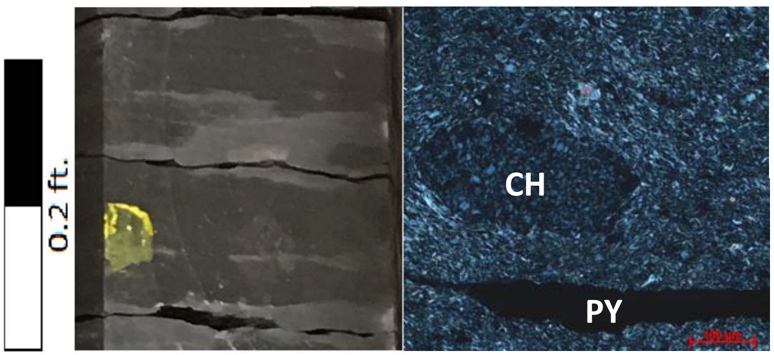
Example from Pan American Droke Unit 1, Kingfisher County, OK (Flinton, 2016)

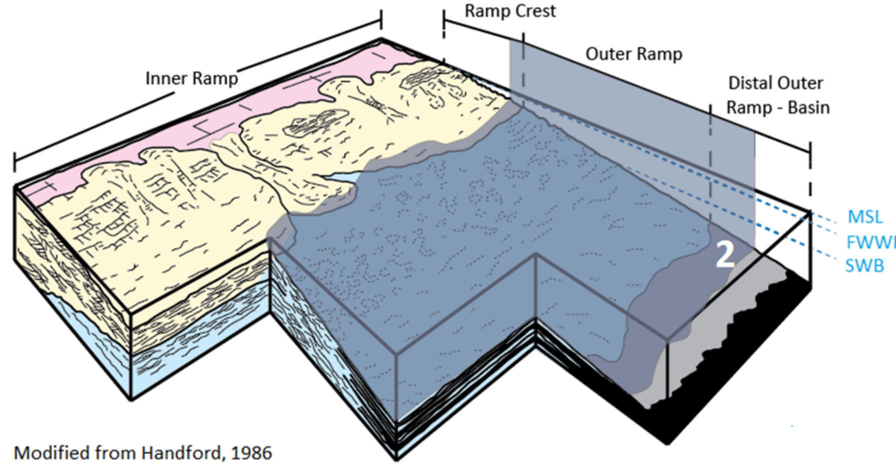
Slide 12

SBC1 Stukey, Brandon Chase, 9/1/2018

Facies Associations

FACIES 2: Shale



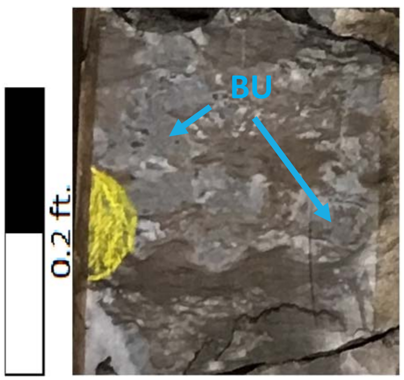


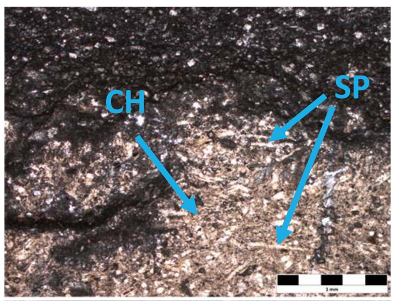
- Illite (surrounding chert filled void/burrow)
- Pyrite (PY)
- Chert (CH) filled voids/burrows

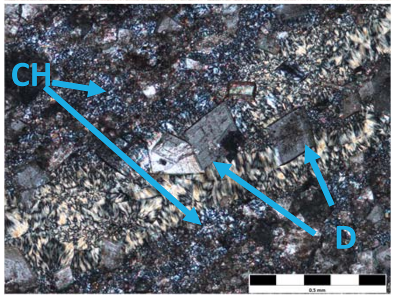
- Continued transgression
- Distal outer ramp – basin, below SWB
- Restricted, low energy setting

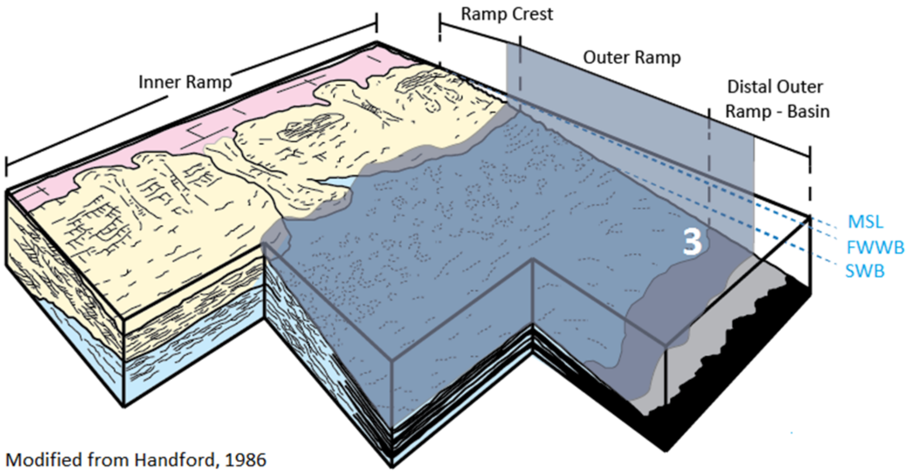
Facies Associations

FACIES 3: Dolomitic Mudstone-Wackestone







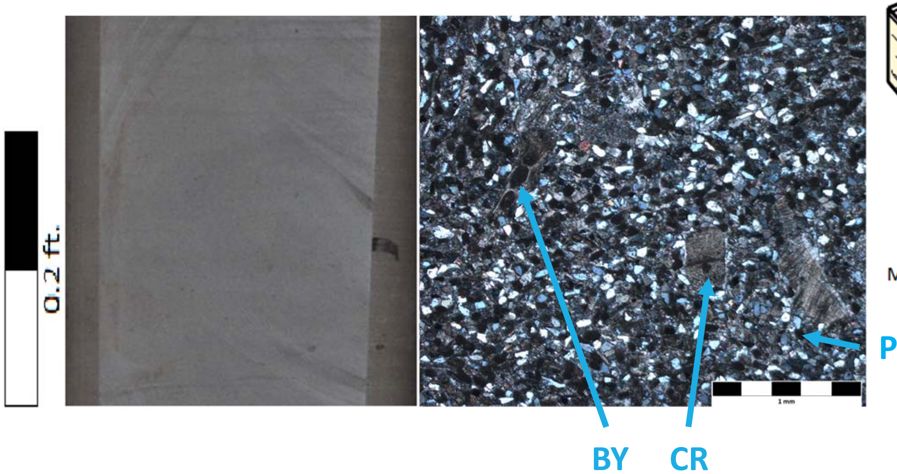


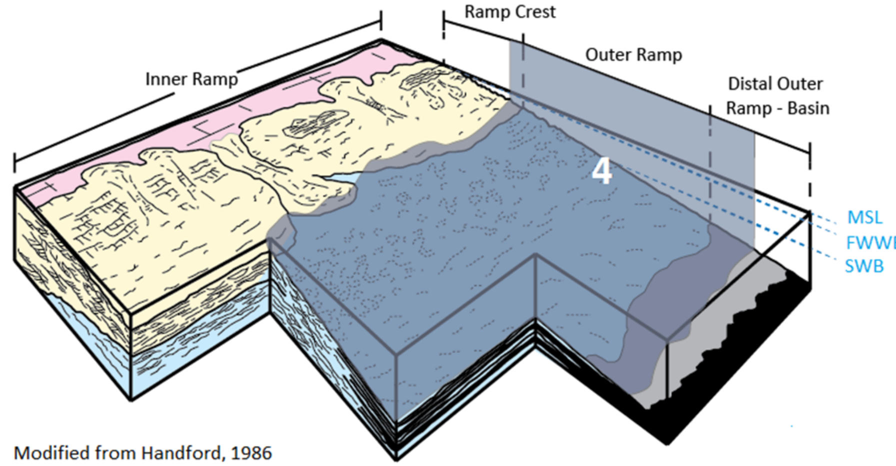
Modified from Handford, 1986

- Bioturbation
- Chert filling burrows (BU)
- Sponge spicules (SP), dolomite (D)
- Outer ramp, below SWB

Facies Association

FACIES 4: Calcareous Siltstone / Silty Wackestone



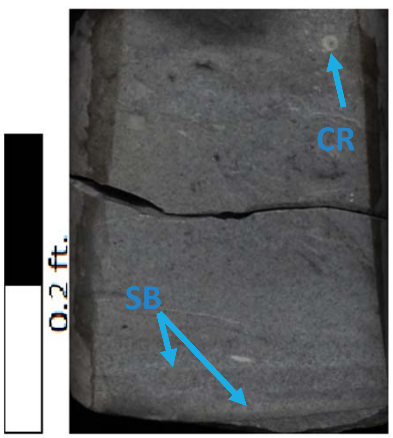


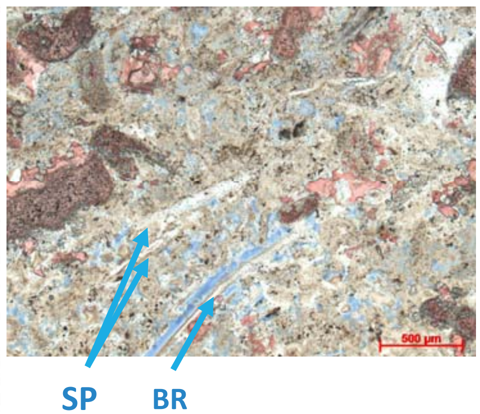
Modified from Handford, 1986

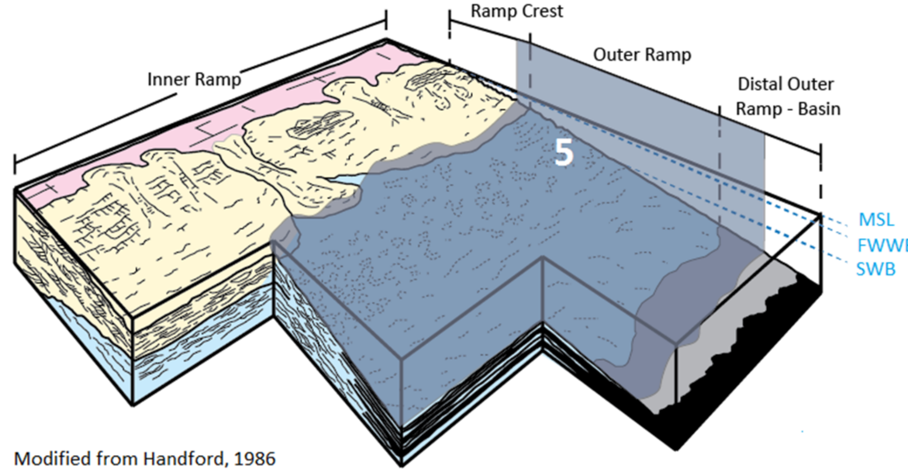
- Crinoids (CR), bryozoan (BY), peloids (P)
- Calcite cement
- Suspension lamination
- Periodic traction-current laminae
- Periodic storm influence
- Outer ramp, at or below SWB

Facies Association

FACIES 5: Wackestone-Packstone







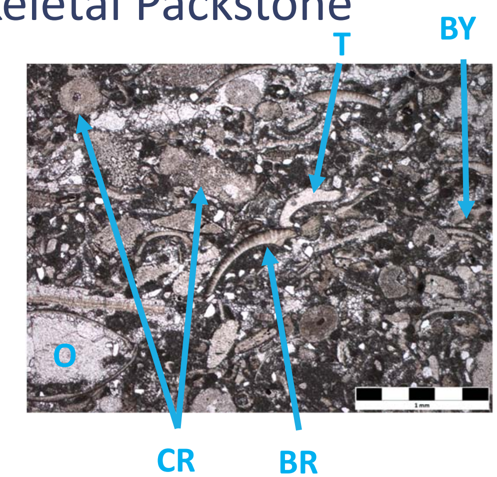
Modified from Handford, 1986

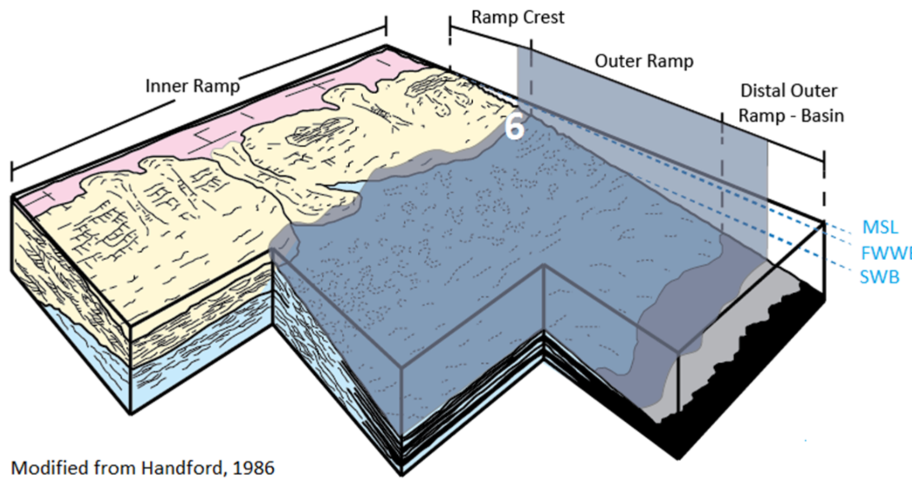
- Crinoids (CR), brachiopods (BR), sponge spicules (SP)
- Partially silicified (siliceous banding (SB))

- Middle to outer ramp
- Between FWWB and SWB

Facies Association

FACIES 6: Skeletal Packstone





Modified from Handford, 1986

- Crinoids (CR), ostracodes (O), bryozoan (BY), trilobite (T) fragments
- Vuggy porosity in areas
- Oil staining

- Proximal outer ramp to distal ramp crest
- Below or near FWWB

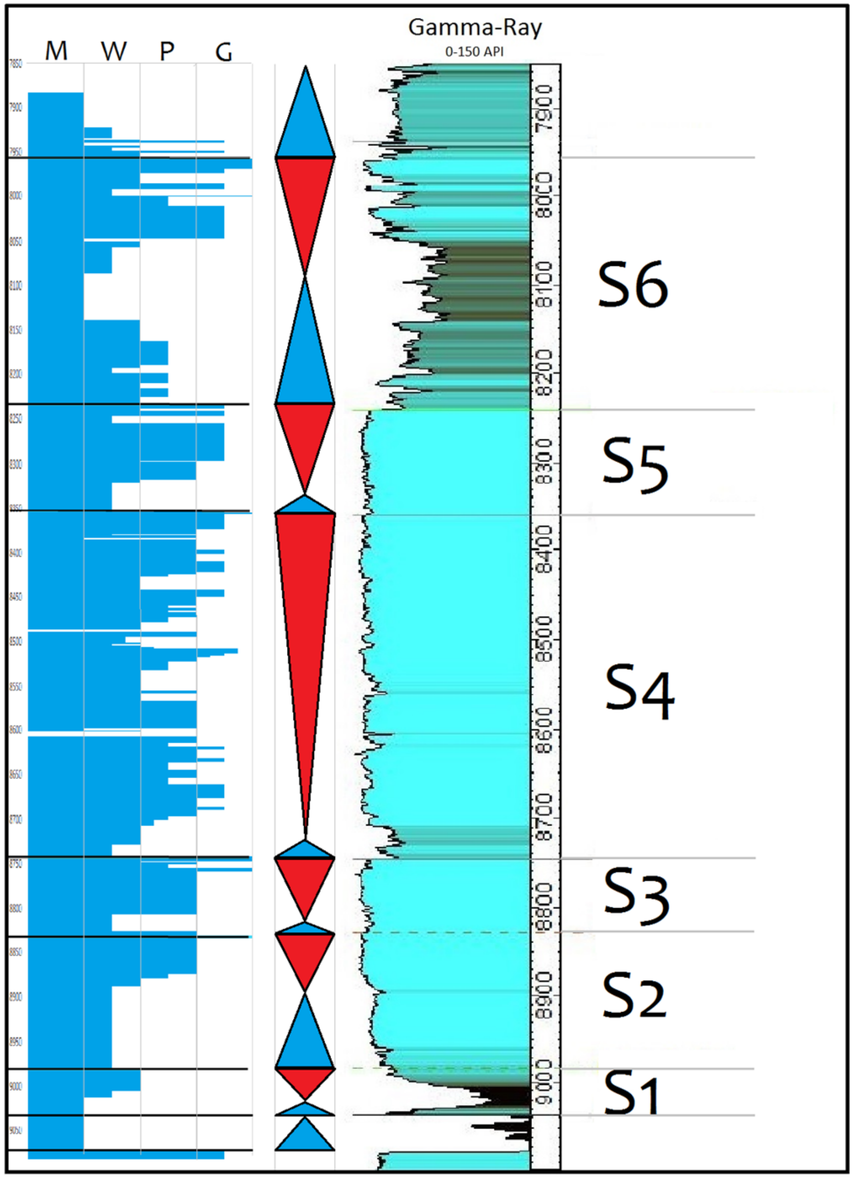
Sequence Stratigraphic Hierarchy

- Overall shallowing upward "2nd Order" super sequence
- Six composite sequences "3rd Order"
- Noticeable higher frequency "4th Order" cycles starting in S4 composite sequence

Figure to the right depicts a generalized facies log based off Dunham classification (left) correlated with the Barnes D-2 gamma-ray log to the right.

Blue triangle = sea level rise
Red triangle = sea level fall

(After Flinton (2016), Jaeckel (2016), and LeBlanc (2014))



Biostratigraphic Constraints

- Conodont Recovery from Pan-Am Barnes D-2 core
- Godwin's (2018) principal conodont biozones identified in Barnes core

4 Distinct conodont biozones

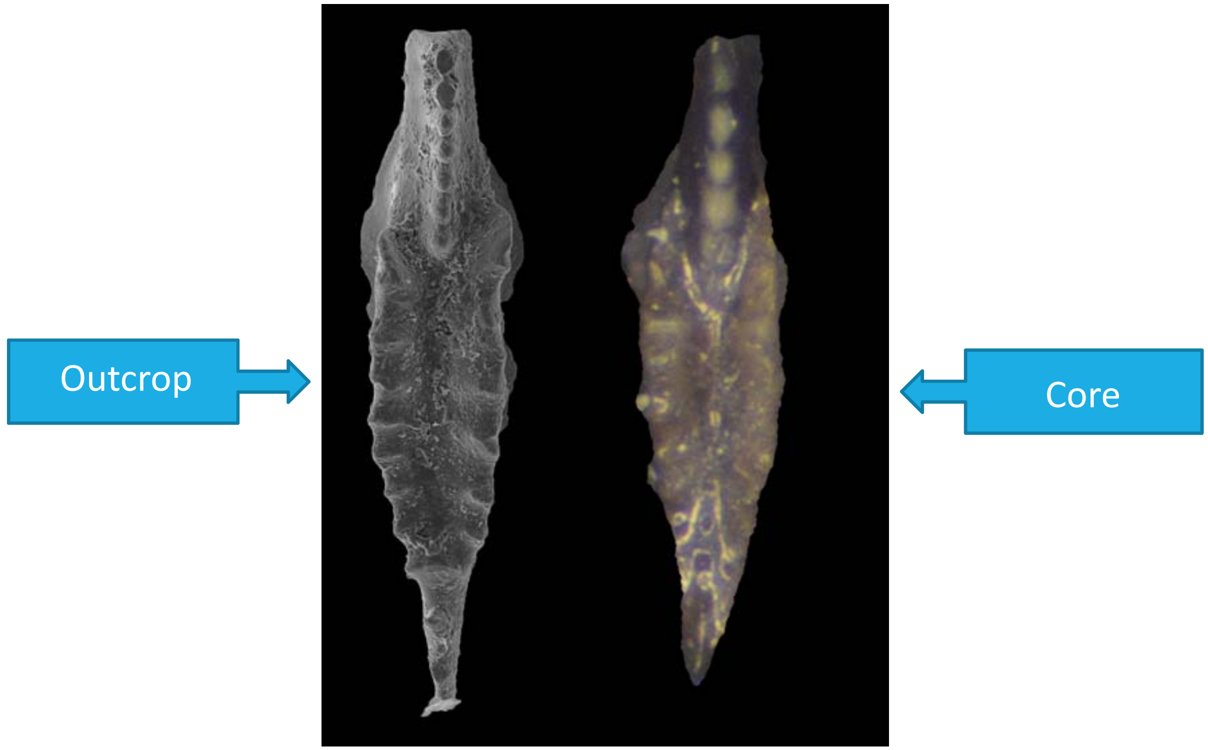
Sample No.	Depth (ft.)	Older Forms	G. Texanus	G.pseudosemiglaber	L. homopunctatus	Taphrognathus	Transition form	Cavusgnathus	H.cristula	Hd. Spiculus	G. bilineatus	Godwin Biozones
45	7921.7-7922							X	X			4 Biozone 4 Chesterian
100								X				
139								X				
170								X				
196								X			X	
209			X					X				
212			X					X		X		
275	8207.6-8208.2							X			X	
306	8236-8236.5							X				3 Biozone 3 Upper St. Louis Fm.
308								X	X			
313	8241.6-8242							X				
316								X				
341								X				
351	8271.8							X				
366								X				
370								X				
378								X				
395								X				
417								X				
437								X				
446								X				
472	8345.1-8345.6				X			X				
497	8424-8424.4							X				2 Biozone 2 Lower St. Louis Fm.
515							X					
575								X				
592	8528.3-8528.8							X				
600			X									
610			X					X				
623								X				
632									X			
637			X					X				
640			X									
648			X					X				
659			X		X			X				
672												
678								X				
684	8689.1-8689.9		X					X				
687	8698.1-8698.7							X				
707	8741.3		X	X		X						1 Biozone 1 Ritchey Fm.
711			X	X	X	X						
716												
719			X			X						
725			X			X						
728			X			X						
736			X	X		X						
742			X			X						
746			X			X						
751			X			X						
755			X			X						
760	8858.5-8859.5					X						
832	9035?	X										

Notable Conodont Taxa

Taphrognathus

- Once absent, no older than Upper St. Louis
- If present, Lower St. Louis or older (Biozone 1 , 2)

(C. Godwin, personal communication, August 4, 2018)



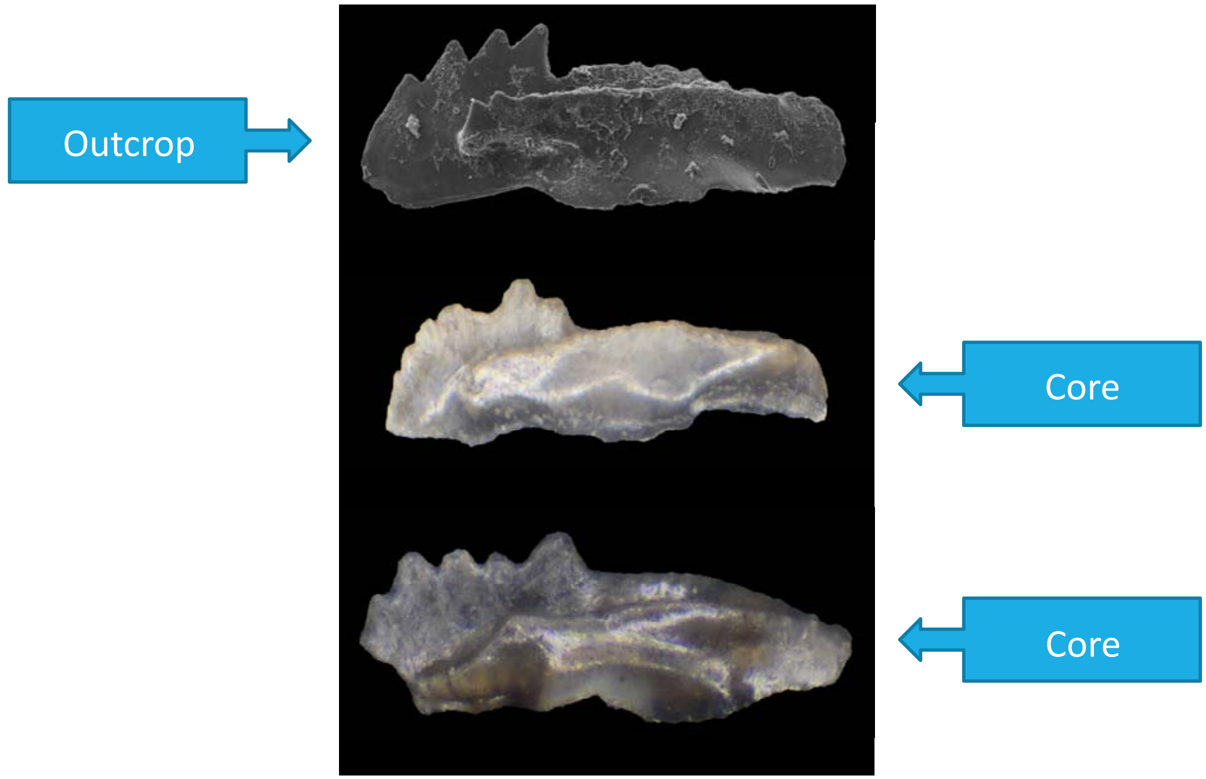
SEM photo (left) and macrophoto (right) of *Taphrognathus* recovered from the Mississippian outcrop belt in northeastern Oklahoma and the Pan American Barnes D-2 core, respectively.

Notable Conodont Taxa

Cavusgnathus

- First appears at base of St. Louis Formation
- If present, no older than St. Louis (upper Meramecian)

(C. Godwin, personal communication, August 4, 2018)



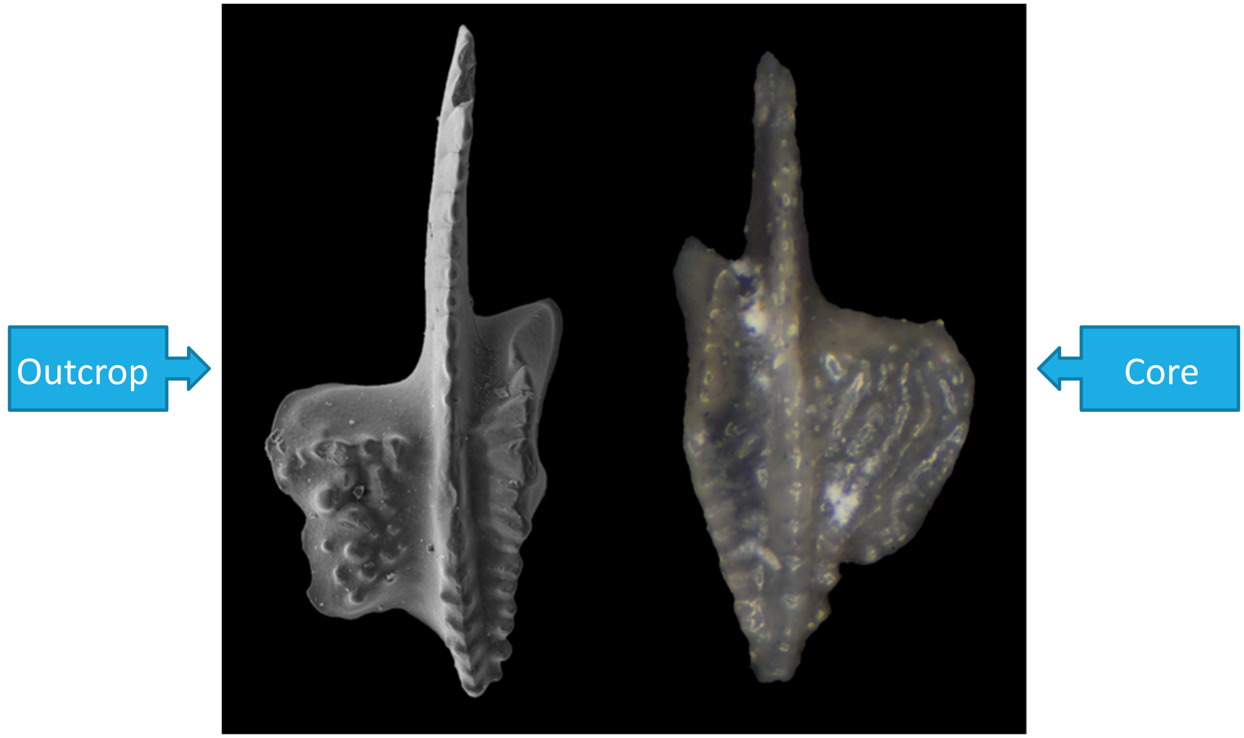
SEM photo (top) and macrophotos (middle and bottom) of *Cavusgnathus* recovered from the Mississippian outcrop belt in northeastern Oklahoma and the Pan American Barnes D-2 core, respectively.

Notable Conodont Taxa

G. bilineatus

- Definitively Chesterian (Biozone 4)

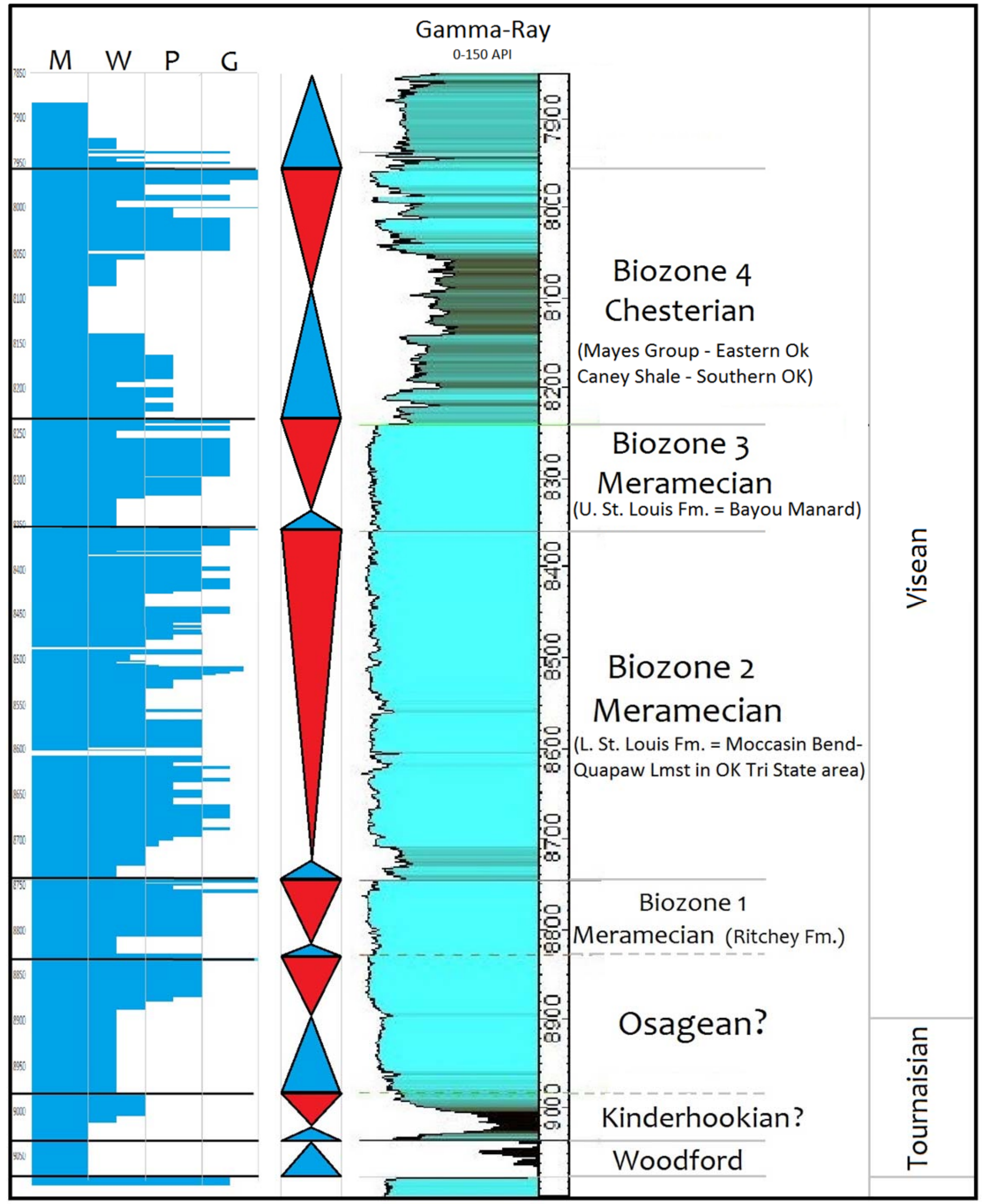
(C. Godwin, personal communication, August 4, 2018)

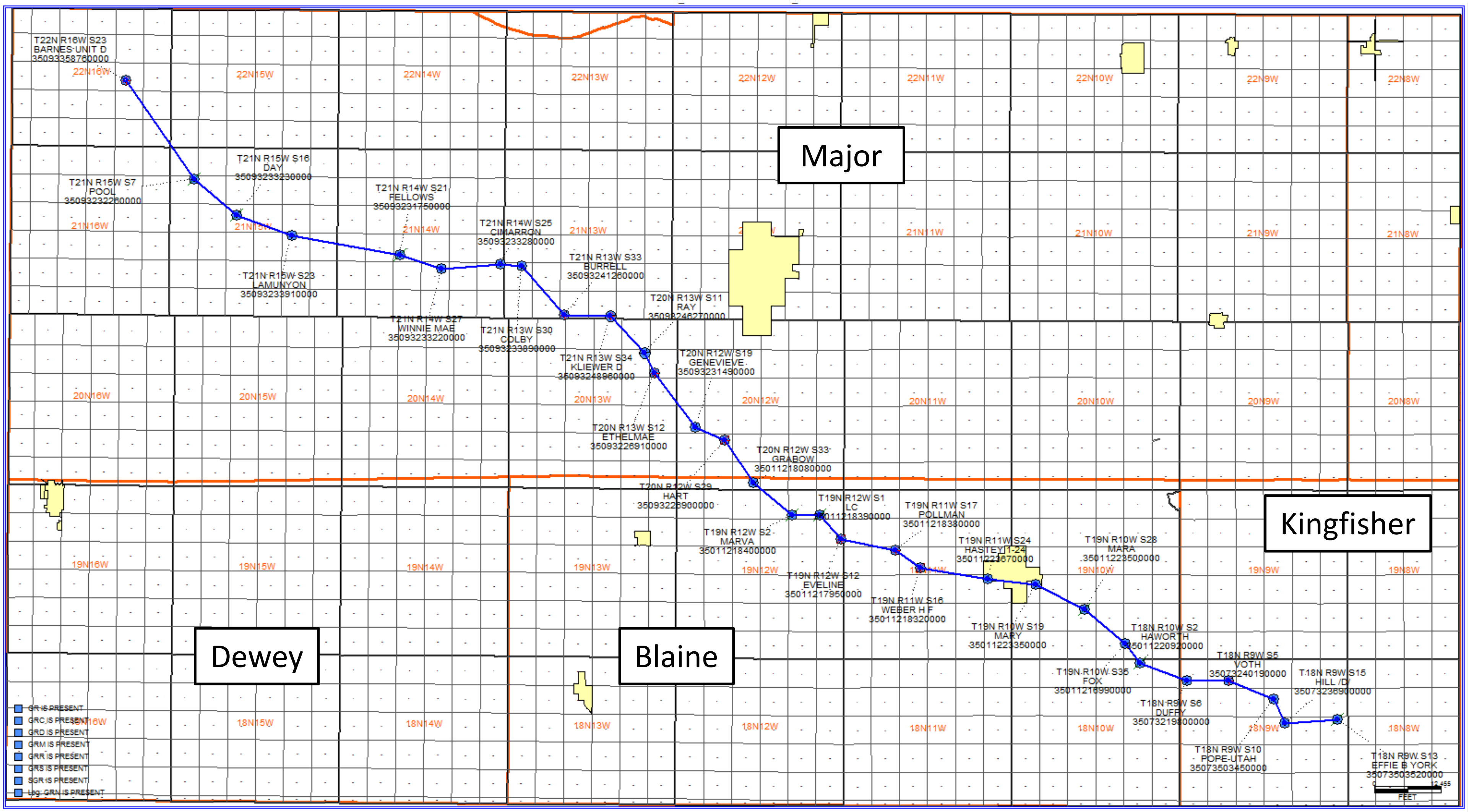


SEM photo (left) and macrophoto (right) of *Gnathodus bilineatus* recovered from the Mississippian outcrop belt in northeastern Oklahoma and the Pan American Barnes D-2 core, respectively.

Biostratigraphically Constrained Ages in Barnes D-2 well

- Contact between biozones 3 & 4 correlates with top of “Miss Lime” or “Meramec-Osage”
- Biozone 2 (informally “Meramec-Osage”) is Meramecian
- Biozone 1 (Ritchey Formation) is still Meramecian
- No usable conodont data below dashed line at 8830 ft. If Osagean rocks are present, it would be within approximately 200 ft above the Woodford
- Formation names and their regional outcrop equivalency names shown in figure




Major
Dewey
Blaine
Kingfisher
22N16W
22N15W
22N14W
22N13W
22N12W
22N11W
22N10W
22N9W
22N8W
21N16W
21N15W
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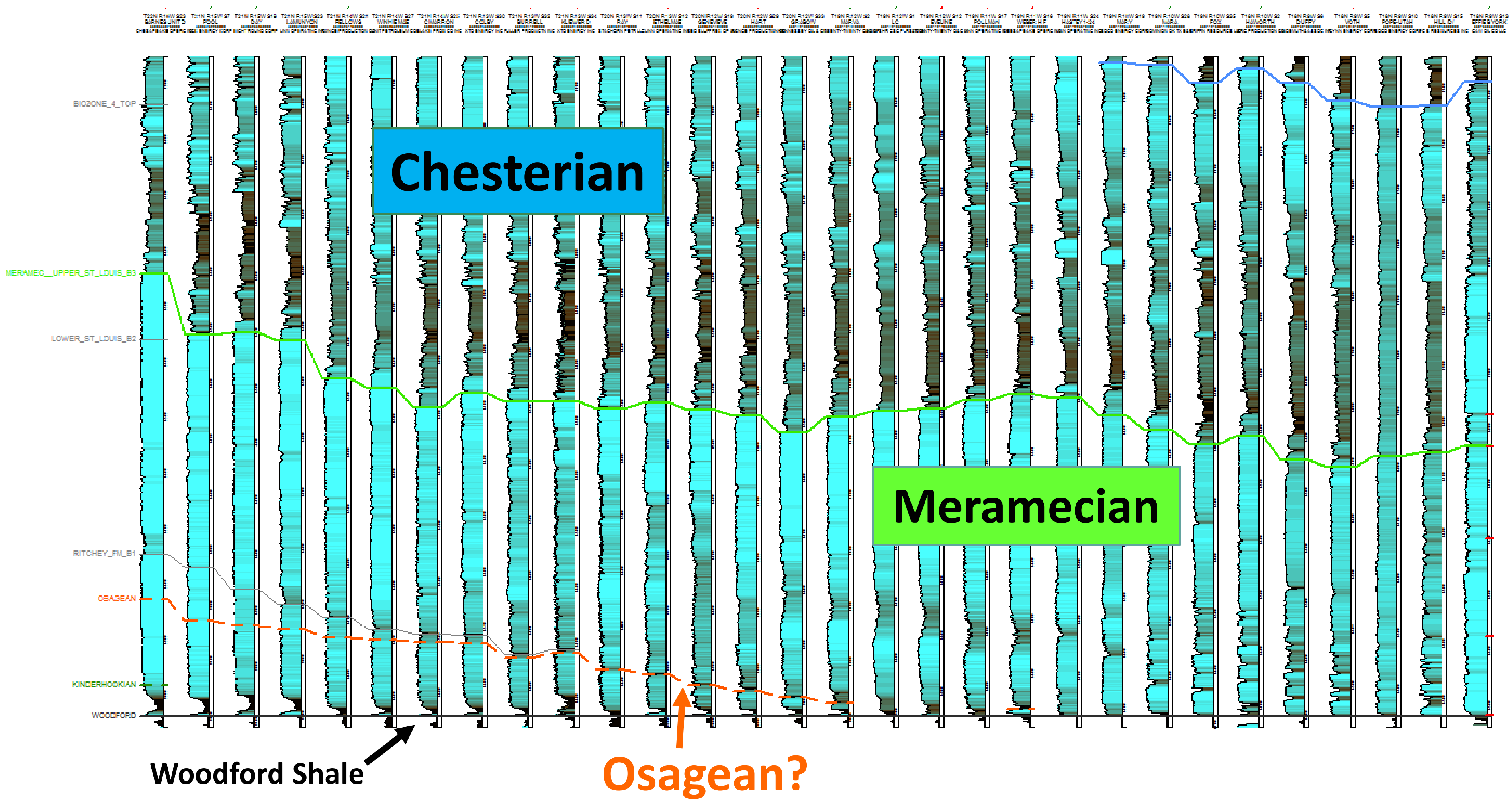
18N10W
18N9W
18N8W
T22N R16W S23 BARNES UNIT D 35093358760000
T21N R15W S7 POOL 35093232260000
T21N R15W S16 DAY 35093233230000
T21N R15W S23 LAMUNYON 35093233910000
T21N R14W S21 FELLOWS 35093231750000
T21N R14W S27 WINNIE MAE 35093233220000
T21N R14W S25 CIMARRON 35093233280000
T21N R13W S30 COLBY 35093233890000
T21N R13W S33 BURRELL 35093241260000
T21N R13W S34 KLIEWER D 35093248960000
T20N R13W S11 RAY 35093246270000
T20N R12W S19 GENEVIEVE 35093231490000
T20N R13W S12 ETHELMAE 35093226910000
T20N R12W S33 GRABOW 35011218080000
T20N R12W S29 HART 35093226900000
T19N R12W S1 LC 35011218390000
T19N R12W S2 MARVA 35011218400000
T19N R12W S12 EVELINE 35011217950000
T19N R11W S17 POLLMAN 35011218380000
T19N R11W S16 WEBER H F 35011218320000
T19N R11W S24 HASTEY 1-24 35011223670000
T19N R10W S28 MARA 35011223500000
T19N R10W S19 MARY 35011223350000
T18N R10W S2 HAWORTH 35011220920000
T19N R10W S35 FOX 35011216990000
T18N R9W S5 VOTH 35073240190000
T18N R9W S6 DUFFY 35073219800000
T18N R9W S15 HILL /D/ 35073236900000
T18N R9W S10 POPE-UTAH 35073503450000
T18N R9W S13 EFFIE B YORK 35073503520000
FEET
GR IS PRESENT
GRC IS PRESENT
GRD IS PRESENT
GRM IS PRESENT
GRR IS PRESENT
GRS IS PRESENT
SGR IS PRESENT
Log: GRN IS PRESENT


BIOZONE_4_TOP
MERAMEC__UPPER_ST_LOUIS_B3
LOWER_ST_LOUIS_B2
RITCHEY_FM_B1
OSAGEAN
KINDERHOOKIAN
WOODFORD
Chesterian
Meramecian
Woodford Shale
Osagean?

Conclusions

1. Conodonts in the Barnes D-2 core are the same as those identified from the outcrop.
2. 4 Principal conodont biozones
   1) Biozone 1 = Meramecian
   2) Biozone 2 = Meramecian
   3) Biozone 3 = Meramecian
   4) Biozone 4 = Chesterian
3. The Meramecian-Osagean boundary has not been resolved by conodonts
4. Based on the correlation from the Barnes D-2 well in Major County, Sec. 23, T. 22N., R.16W to the Effie B. York well in NW Kingfisher County, Sec. 13, T. 18N., R.9W, the “Miss Lime” section below the “Chester Shale” is mostly Meramecian.

Acknowledgments

- Dr. Jim Puckette
- Dr. Cory J. Godwin
- Carbonate research group at OSU and Dr. Mike Grammer
  - Keller Flinton, Lara Jaeckel, Stephanie LeBlanc
- Industry-Oklahoma State University Mississippian Consortium members
- OGS staff at the Oklahoma Petroleum Information Center
- University of Iowa Paleontological Repository
- Midwest Energy

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