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

Brandon Stukey\textsuperscript{1}, Cory Godwin\textsuperscript{2}, James Puckette\textsuperscript{1}

\textsuperscript{1}Oklahoma State University, Boone Pickens School Of Geology, Stillwater, Oklahoma
\textsuperscript{2}Consulting Geologist, Tulsa, Oklahoma
Outline

• Overview & Significance
• Background
• Data & Methods
• Results
  o Facies Associations & Depositional Environments
  o Sequence Stratigraphic Correlation
  o 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)

LATE MISSISSIPPIAN (325 MYA)

Modified from Blakey, 2014

Modified from Blakey, 2014
Geological Background

Mississippian Sea Level

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

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

<table>
<thead>
<tr>
<th>Layer</th>
<th>Facies</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Glaucnonitic Shale</td>
</tr>
<tr>
<td>2</td>
<td>Shale</td>
</tr>
<tr>
<td>3</td>
<td>Dolomitic Mudstone-Wackestone</td>
</tr>
<tr>
<td>4</td>
<td>Silty Mudstone-Wackestone / Siltstone</td>
</tr>
<tr>
<td>5</td>
<td>Wackstone-Packstone</td>
</tr>
<tr>
<td>6</td>
<td>Skeletal Packstone</td>
</tr>
</tbody>
</table>
Facies Associations

**FACIES 1: Glauconitic Shale / Sandstone**

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

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

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

FACIES 2: Shale

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

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

FACIES 3: Dolomitic Mudstone-Wackestone

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

**FACIES 4: Calcareous Siltstone / Silty Wackestone**

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

Modified from Handford, 1986
Facies Association

FACIES 5: Wackestone-Packstone

- 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

- 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

<table>
<thead>
<tr>
<th>Sample No.</th>
<th>Depth (ft.)</th>
<th>Older Forms</th>
<th>G. Texanus</th>
<th>G. pseudosemiglaber</th>
<th>L. homopunctatus</th>
<th>Taphrognathus</th>
<th>Transition form</th>
<th>Cavusgnathus</th>
<th>H.cristula</th>
<th>Hd. Spiculus</th>
<th>G. bilineatus</th>
<th>Godwin Biozones</th>
</tr>
</thead>
<tbody>
<tr>
<td>45</td>
<td>7921.7-7922</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>100</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>139</td>
<td></td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>170</td>
<td></td>
<td></td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>190</td>
<td></td>
<td></td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>209</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>212</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>275</td>
<td>8207.6-8208.2</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>306</td>
<td>8235.5</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>308</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>313</td>
<td>8241.6-8242</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>316</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>341</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>351</td>
<td>8271.8</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>366</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>370</td>
<td></td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>378</td>
<td></td>
<td></td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>395</td>
<td></td>
<td></td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>417</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>427</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>446</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>472</td>
<td>8345.1-8345.6</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>515</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>575</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>592</td>
<td>8528.3-8528.8</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>600</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>610</td>
<td>X</td>
<td></td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>623</td>
<td></td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>634</td>
<td>X</td>
<td></td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>637</td>
<td>X</td>
<td></td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>640</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>648</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>659</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>672</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>678</td>
<td></td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>684</td>
<td>8661.1-8661.9</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>687</td>
<td>8668.1-8668.7</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>707</td>
<td>8741.3</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>711</td>
<td></td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>716</td>
<td></td>
<td></td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>719</td>
<td></td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>725</td>
<td></td>
<td></td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>728</td>
<td></td>
<td></td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>736</td>
<td></td>
<td></td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>742</td>
<td></td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>746</td>
<td></td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>751</td>
<td></td>
<td></td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>755</td>
<td></td>
<td></td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>760</td>
<td></td>
<td></td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>832</td>
<td></td>
<td></td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
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
Woodford Shale

Chesterian

Meramecian

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
References


Flinton, K.C., 2016, The effects of high-frequency cyclicity on reservoir characteristics of the “Mississippian Limestone”, Anadarko Basin, Kingfisher County, Oklahoma [M.S. Thesis]: Stillwater, Oklahoma State University, 414 p.


References Continued


Jaeckel, L., 2016, High-resolution sequence stratigraphy and reservoir characterization of Mid-Continent Mississippian carbonates in north-central Oklahoma and south-central Kansas [M.S. Thesis]: Stillwater, Oklahoma State University, 368 p.


Mazzullo, S.J., Boardman, D.R., Wilhite, B.W., 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: Oklahoma City Geological Society Shale Shaker, v. 63, p. 414-452.