Structure and Stratigraphy of the Mississippian System, East of the Nemaha Uplift in Oklahoma*

Charles W. Wickstrom¹ and Christopher L. Johnson²

Search and Discovery Article #10442 (2012)
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Conclusions

--In Oklahoma, the Woodford shale was the source of much of the hydrocarbons produced in the Anadarko and Arkoma basins (with abundant gas) and also on the Cherokee Platform (with abundant oil), where extensive wrench fault systems exist. ---They are present in Osage County, where Precambrian basin(s) formed.

--The Mississippian section of northeast Oklahoma can be correlated to the section on outcrop on the Ozark Plateau.
--Silica content in the subsurface is very significant in the Osagean section.
--The Mississippian section has multiple reservoir potential. With respect to stratigraphy and reservoir types reservoirs may be categorized as follows:

  • Stratigraphy
    o Joplin       Possibly in Northern Kay
    o Grand Falls  Northern Noble, Kay and Central Osage Counties
    o Reeds Spring Prevalent Everywhere
    o St. Joe      Compton – Northview -- Pierson

  • Reservoir Types
    o Tripolitic Chert
    o Fractured Chert
    o Cowley
    o Silicified Limestone

--The origin of the chert is considered to have been syndepositional, with silica from continental source.
Final Comments

• What’s old can be new when viewed from a different angle: horizontal versus vertical.
• Unconventional thinking is what we have been paid to do all along and maybe we just didn’t realize it was “Unconventional.”

Selected References


Tulsa Geological Society

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Spyglass Energy Group, LLC
Christopher L. Johnson
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THE MISSISSIPPIAN SYSTEM REVISTED 2012

“It’s like déjà vu all over again”

TGS Digest Vol. 27 1959
Part III “Symposium of the Mississippian of Oklahoma and Kansas”
Pages 85-205
<table>
<thead>
<tr>
<th>Formation</th>
<th>Bed</th>
<th>Description</th>
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<tbody>
<tr>
<td>Moccasin Bend Member</td>
<td>0-140</td>
<td>Alternating chert and fine- to medium-grained brown limestone, some cotton rock; chert conspicuously brown and blue in lower part, paler above.</td>
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<td>Baxter Springs Member</td>
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STRUCTURE OF THE MISSISSIPPIAN SYSTEM EAST OF THE NEMAHA RIDGE IN OKLAHOMA

Presentation in 3 Parts

• On the Shoulders of Giants
• Philosophical Aspects of Unconventional Thinking
• Structural Analysis and Data
  – Subsurface Mapping
  – Aeromagnetic Data and Gravity Data
  – 3D Seismic Data Structure and Attributes
ON THE SHOULDERS OF GIANTS

• CHARLES W. OLIPHANT: CEJA
• JACK M. GRAVES: CALUMET
• FINANCIAL BACKERS:
  • Michael L. Graves
  • Nadel & Gussman
Philosophical Aspects of Unconventional Thinking

- “Method of Multiple Working Hypotheses”
  T. C. Chamberlain “Science” 1890

- George Mitchell “Unconventionalist Extraordinaire” He gave us a model on which to base future exploration.

Unconventionalist as a Pan American Oil Scout: Bill Pemberton 1908
Parke A. Dickey

• “We usually find oil in new places with old ideas. Sometimes we find oil in an old place with a new idea, but we seldom find oil in an old place with an old idea. Several times in the past we thought we were running out of oil whereas we were actually only running out of ideas,”
The Woodford Shale was the source for much of the hydrocarbons produced in the Anadarko and Arkoma basins.

- The deep Anadarko basin produced gas-weighted hydrocarbons
- The Arkoma Basin was shallower and produced oil-weighted volumes
Structure: Control of HC in Reservoir

Mississippian Overview – Oil Migration and Distribution

This production distribution map shows that western Oklahoma’s fields are pervasively gassy, with hydrocarbon sources in the Anadarko Basin; while fields in the eastern portion of the state tend to be more oily.
Structure: Subsurface
The Osage gravity high on the Bouguer anomaly map on the right is so large that it masks the signatures of shallower features in the upper basement and sedimentary column. Thus, in order to obtain a better picture of the shallow structure in the Osage County region, we are building a 3-D earth model of the region.
Structure: Seismic

Asset Overview – Geological Model

3D seismic shows evidence of extensive wrench fault systems. This data has been integrated with well log and surface geology to establish clear evidence of tectonic activity resulting in fracture development.

Tripolite Sub-Crop Seismic Section

8 Miles

Wrench Fault Tectonics
Structure: Seismic
Seismic Attributes

K Negative Curvature

8 Miles
Seismic Attributes

“Ant Tracking”

8 Miles
Seismic Attributes

“Combination”
Residual gravity anomalies derived by subtracting the calculated values from the observed Free Air anomaly values. Many of the anomalies on this map appear to correlate with known features in the sedimentary section.
Structure: Subsurface

New Idea in an Old Area

Wha-zha-zhi Basin Osage Co OK

1.3 BYO Rhyolite Basement 4000’

Foraker Field Miss Chert 2500’

Terra incognito 10,00 to 15,000’ TVD
MULTIPLE RESERVOIRS WITH DIFFERENT LITHOLOGIES

Asset Overview – Geological Model

- The Mississippian (Kinderhook to Osagean) section of northeast Oklahoma can be correlated directly to the Mississippian Outcrop Belt of the Ozark Plateau
- Silica content in subsurface is very significant in the Osagean section
  - Understood early and well by geologists working in the section
- Interval from the base Pennsylvanian unconformity to the base Mississippian has multiple reservoir potential
  - Weathered Reeds Spring Limestone: interbedded chert, lime and tripolite
  - Unaltered Reeds Spring Limestone: interbedded chert and lime
  - Pierson Limestone

Bird Creek 2A-15 Mississippian Facies – Type Log

- Base Pennsylvanian
- Weathered Reeds Spring: interbedded chert, lime and tripolite
- Unaltered Reeds Spring: interbedded chert and lime (note PE values)
- Pierson Limestone
- Kinderhook–Compton Limestone and Northview Shale
- Base Mississippian/Top Arbuckle
Overview – Stratigraphy & Reservoirs

• Stratigraphy
  – Joplin Possibly in Northern Kay
  – Grand Falls N Noble, Kay and Central Osage Counties
  – Reeds Spring Prevalent Everywhere
  – St. Joe Compton – Northview -- Pierson

• Origin of Chert
  – Syndepositional with Silica from Continental source

• Reservoir Types
  – Tripolitic Chert
  – Fractured Chert
  – Cowley
  – Silicified LS
Early Mississippian Time

OK-KS MSSP Play

Volcanic Island Arc
Source of Silica

345 Ma

R. Blakey, 2012
Geology and Ore Deposits of the Picher Field
Oklahoma and Kansas

Stratigraphic Column USGS 588

**Mississippian**

- **Mocassin Bend Member**
  - 0-140: Alternating chert and fine- to medium-grained brown limestone, some cotton rock; chert conspicuously brown and blue in lower part, paler above.

- **Baxter Springs Member**
  - 0-5: At base, bedded to massive pale chert or cotton rock, glauconitic at base (L bed); overlain and overlapped regionally by crinoidal glauconitic limestone and variegated chert, the limestone locally shaly or containing glauconitic oolite and phosphate nodules (K bed); topped by thin phosphatic and highly glauconitic crinoidal limestone containing variegated and, in part, very dark chert (J bed).

- **Short Creek Oolite Member**
  - 0-10: Brown oolitic limestone, only slightly glauconitic.

- **Joplin Member**
  - 0-100: Gray crinoidal limestone and nodular or bedded chert; chert-free ledge near base.

- **Grand Falls Chert Member**
  - 25-95: Pale chert, cotton rock, and subordinate brown fine-grained limestone.

- **Reeds Spring Member**
  - 70-105: Blue, gray, and brown chert alternating with gray and brown fine-grained limestone; crinoidal bioherms locally at base.

- **St Joe Limestone Member**
  - 10-32: Gray to pink crinoidal limestone with massive ledge at top and greenish shaly zone below middle; sparse blue to gray chert.
Mississippian Regional Paleofacies

S.J. Mazzullo,
Search and Discovery#10373 (2011)
Overview

• Stratigraphy
  – Joplin       Possibly in Northern Kay
  – Grand Falls  N Noble, Kay and Central Osage Counties
  – Reeds Spring Prevalent Everywhere
  – **St. Joe**  Compton – Northview -- Pierson

• Origin of Chert
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• Reservoir Types
  – Tripolitic Chert
  – Fractured Chert
  – Cowley
  – *Silicified LS*
St. Joe Stratigraphy

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**St. Joe**  Compton – Northview -- Pierson

Noble Co  Osage Co
Overview

• **Stratigraphy**
  – Joplin
  – Grand Falls
  – *Reeds Spring* Prevalent Everywhere
  – St. Joe

• **Origin of Chert**
  – Syndepositional with Silica from Continental source

• **Reservoir Types**
  – Tripolitic Chert
  – Fractured Chert
  – Cowley
  – *Silicified LS*
<table>
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<tr>
<th>Age</th>
<th>Reeds Spring Member</th>
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<td>70-105</td>
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Reeds Spring Stratigraphy

Noble Co  Osage Co  Pawnee Co
Overview

• Stratigraphy
  – Joplin
  – **Grand Falls**  N Noble, Kay and Central Osage Counties
  – Reeds Spring
  – St. Joe
  – Compton – Northview -- Pierson

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<th>Usage</th>
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<td>Grand Falls Chert Member</td>
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Pale chert, cotton rock, and subordinate brown fine-grained limestone.
Grand Falls Stratigraphy
Overview

- **Stratigraphy**
  - Joplin
  - Grand Falls
  - Reeds Spring
  - St. Joe
  - Possibly in Northern Kay
  - N Noble, Kay and Central Osage Counties
  - Prevalent Everywhere
  - Compton – Northview -- Pierson

- **Origin of Chert**
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- **Reservoir Types**
  - Tripolitic Chert
  - Fractured Chert
  - Cowley
  - *Silicified LS*
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<tr>
<th>Depth</th>
<th>Description</th>
</tr>
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<td>0-10</td>
<td>Brown calcite limestone, only slightly glauconitic.</td>
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<td>Gray crinoidal limestone and nodular or bedded chert; chert-free ledge near base.</td>
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Overview

• **Stratigraphy**
  – Joplin              Possibly in Northern Kay
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• **Origin of Chert**
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• **Reservoir Types**
  – Tripolitic Chert
  – Fractured Chert
  – Cowley
  – *Silicified LS*
Origin of Chert Beds in NEC OK MSSP
Origin of Chert

• **Chert** is a fine-grained silica-rich microcrystalline, cryptocrystalline or microfibrous sedimentary rock that may contain small fossils. It varies greatly in color (from white to black), but most often manifests as gray, brown, grayish brown and light green to rusty red; its color is an expression of trace elements present in the rock, and both red and green are most often related to traces of iron (in its oxidized and reduced forms respectively).
Explanations on the origin of the chert have been varied. Tarr (1926) proposed a syngenetic origin wherein the chert was precipitated on the sea floor as a colloidal silica gel at the time of sedimentation.
Origin of Cherts

• Dissolved silica, resulting from **continental chemical weathering**, is the **main** contributing silica source initiating chert formation. The rate of silica supply is controlled by extensive global palaeoclimatic zones with ferralitic weathering. Under these conditions the solubility of silica and silicates is increased, while the solubility of Al is low, and Al is, therefore, concentrated in residual deposits such as bauxite and laterite. The dissolved silica is supplied to ocean waters where it gives rise to increased Si/Al ratios in the chemical composition of the water.

Origin of Cherts

Biogenic silica cannot be considered as the primary silica source as chert formation can take place without the presence of biogenic silica. Also volcanic silica sources as well as other subordinate silica sources cannot supply a sufficient amount of dissolved silica to explain extensive chert formations as no relation of volcanism to many chert occurrences is readily apparent particularly in respect to secondary cherts in carbonates.

Cherts become progressively thinner and then absent, with just Limestone and Dolomite in the MSSP in southward direction.
Overview

• **Stratigraphy**
  – Joplin
  – Grand Falls
  – Reeds Spring
  – St. Joe

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  N Noble, Kay and Central Osage Counties
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• **Origin of Chert**
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• **Reservoir Types**
  – **Tripolitic Chert**
  – Fractured Chert
  – Cowley
  – *Silicified LS*
Tripolitic Chert

Mazzullo et al., 2011
Figure 6.—Diagram showing distribution of chert colors in Grand Falls Chert Member and Reeds Spring Member of Boone Formation in selected drill holes between Cardin and Baxter Springs (SW–NE). Note alternation and intergradation of Grand Falls and Reeds Spring types. Details of the intertonguing shown are conjectural.
Tripolitic Chert
Tripolitic Chert

Hwy 60 “chat” Tripolitic Chert

Heat and Fluid Flow
Tripolitic Chert source of Hydrothermal Fluids

Isoreflectance Map of the Woodford Shale in Eastern Oklahoma (Updated November 2011)

Distribution of 117 Woodford Shale samples with vitrinite-reflectance data (n ≥ 20; whole-rock pellets)

Cardott, in preparation
Overview

• **Stratigraphy**
  - Joplin
  - Grand Falls
  - Reeds Spring
  - St. Joe

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  - Tripolitic Chert
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    - Cowley
    - *Silicified LS*
Fractured Chert

FC
LS
Fractured Chert Clinoforms-Wedges in Outcrop

Height of Wedge in outcrop is > than 100’
Sub Unconformities

Impermeable Barrier

Fractured Chert

60' +- 40' +--
Overview

• **Stratigraphy**
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  – Cowley
  – *Silicified LS*
Silicified Limestone

Stained with alizarin red showing Calcite; white-clear is Silica.
Conclusions – Stratigraphy & Reservoirs

- **Stratigraphy**
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CONCLUSIONS (cont.) and Charles Wickstrom’s Acknowledgments

- What’s old can be new when viewed from a different angle: horizontal versus vertical.
- Unconventional thinking is what we have been paid to do all along and maybe we just didn’t realize it was “Unconventional.”
- Thank you to a great Spyglass team: Shane Matson, Kim Tacket, Steve Tilley.
- Special thanks to Dr. Kurt Marfurt OU and Dr. Randy Keller, Director of the OGS (Our Collective Intelligence).
Chris Johnson’s Acknowledgments:

• Ed Gallegos
  – Owner and President of Territory Resources LLC

• Ron Campbell
  – Mud Logger
  • President of XGP LLC
We leave you with this final thought:
This play is not “Stupid Proof” so when in doubt: THINK

So simple a monkey can do it!