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

Charles W. Wickstrom[1] and Christopher L. Johnson[2]

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
  - Joplin — Possibly in Northern Kay
  - Grand Falls — Northern Noble, Kay and Central Osage Counties
  - Reeds Spring — Prevalent Everywhere
  - St. Joe — Compton – Northview -- Pierson
- Reservoir Types
  - Tripolitic Chert
  - Fractured Chert
  - Cowley
  - 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."

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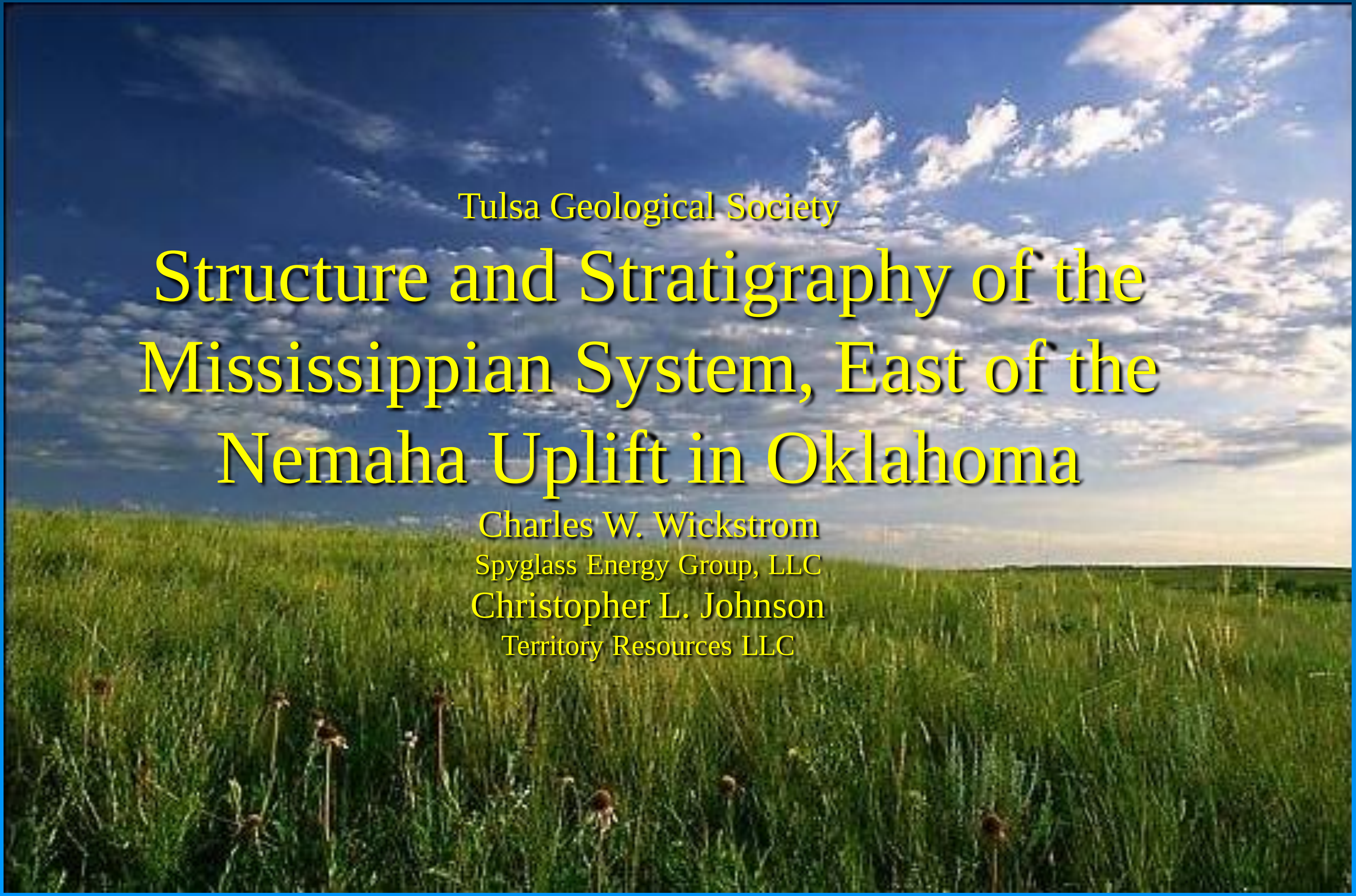

Tulsa Geological Society

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

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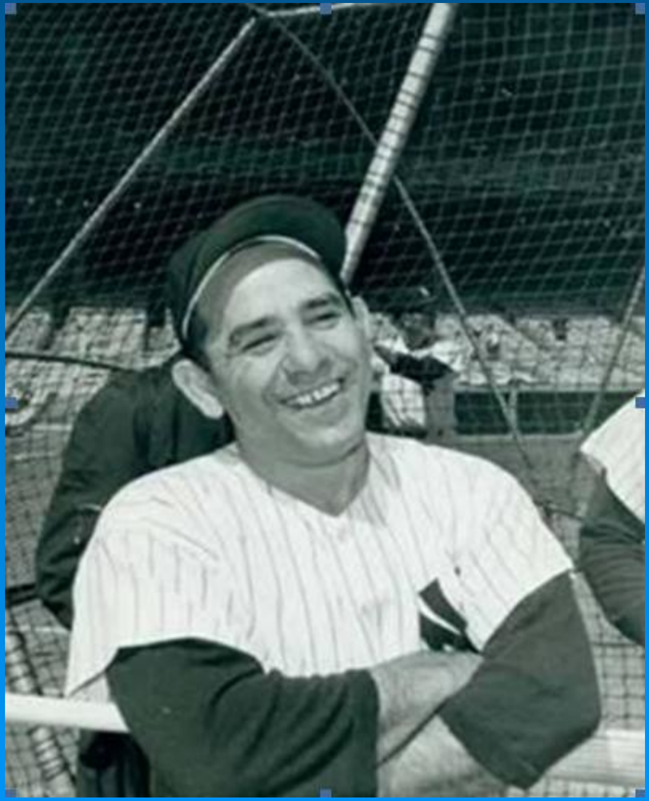
THE MISSISSIPPIAN SYSTEM REVISTED 2012

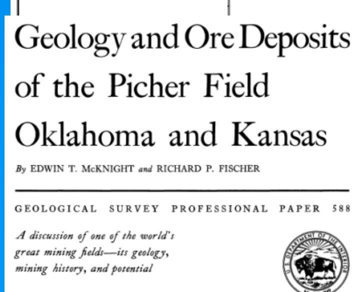


"It's like déjà vu all over again"

TGS Digest Vol. 27 1959 Part III "Symposium of the Mississippian of Oklahoma and Kansas" Pages 85-205

Stratigraphic Column USGS 588

MISSISSIPPIAN	Meramec	Boone Formation	Moccasin 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 0-51 0-60	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.
			DISCONFORMITY		
	Osage		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.



1970

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.
- J. R. "Bill" Pemberton, Pan American Oil Co circa 1908. A personal hero of mine.

Unconventionalist as a Pan American Oil Scout: Bill Pemberton 1908

Oil On Their Shoes AAPG 1985

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,”**

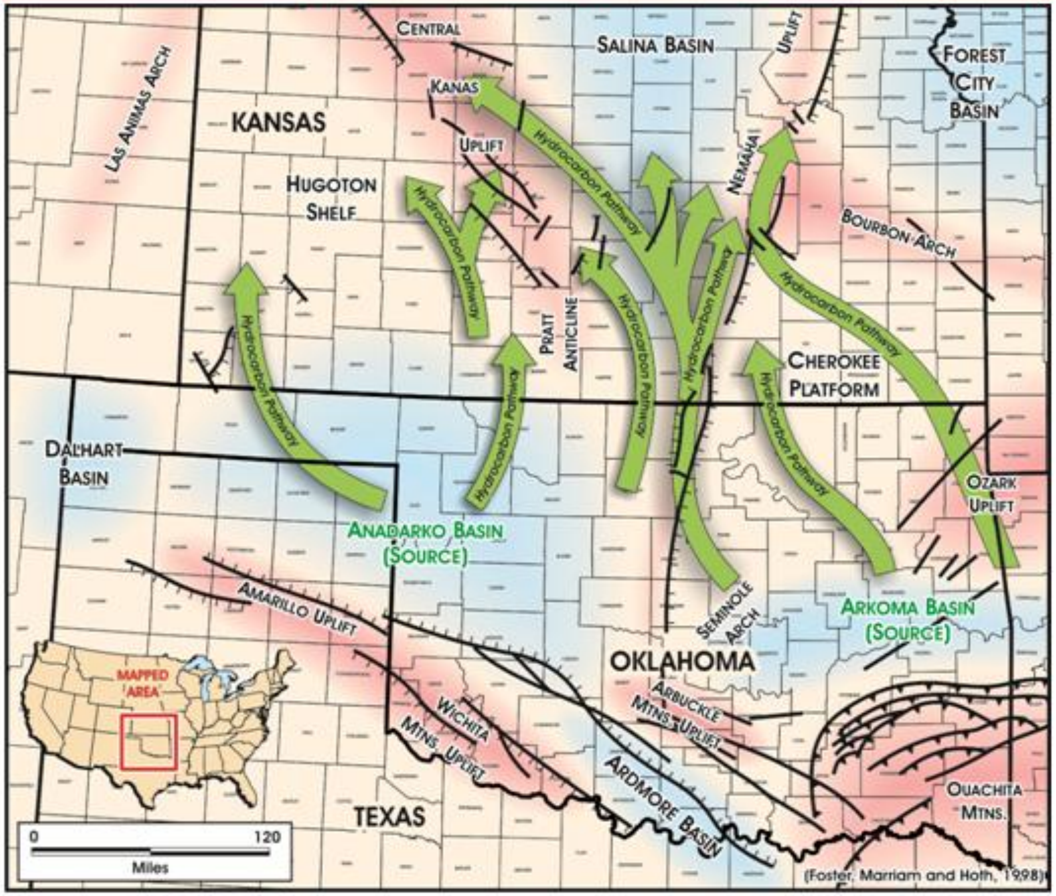
Location Map

Mississippian Overview – Oil Migration and Distribution

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

Woodford Shale - Migration Paths



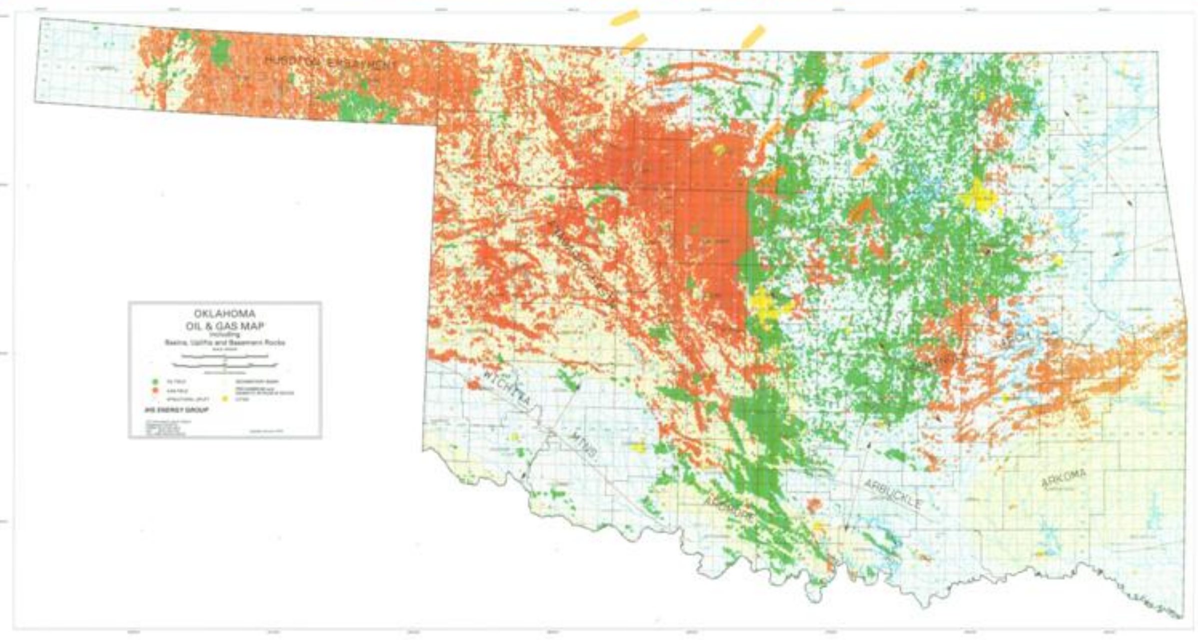
Modified from Gerhard, L. KGS Bull 250

Structure: Control of HC in Reservoir

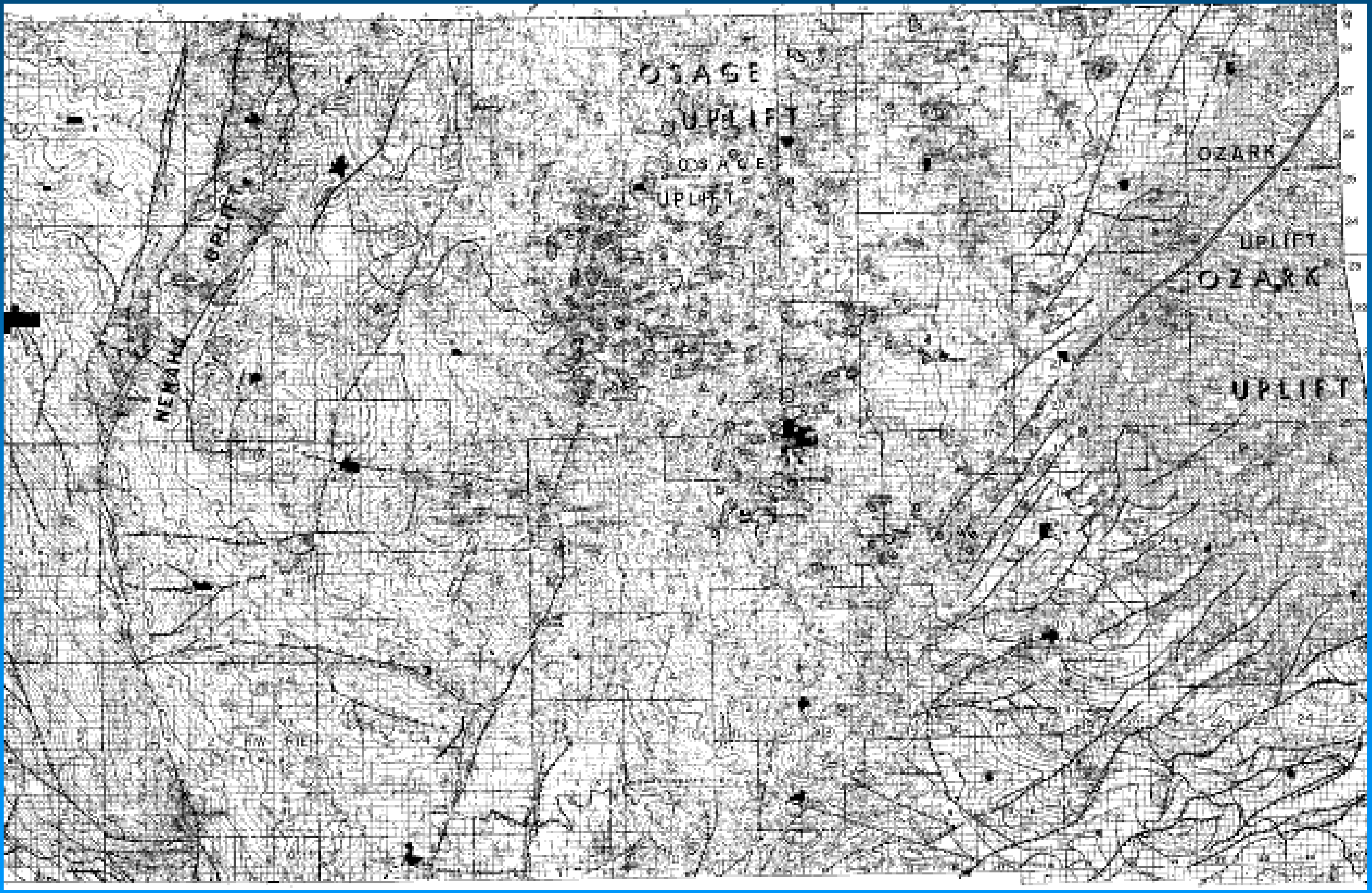
Mississippian Overview – Oil Migration and Distribution

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.

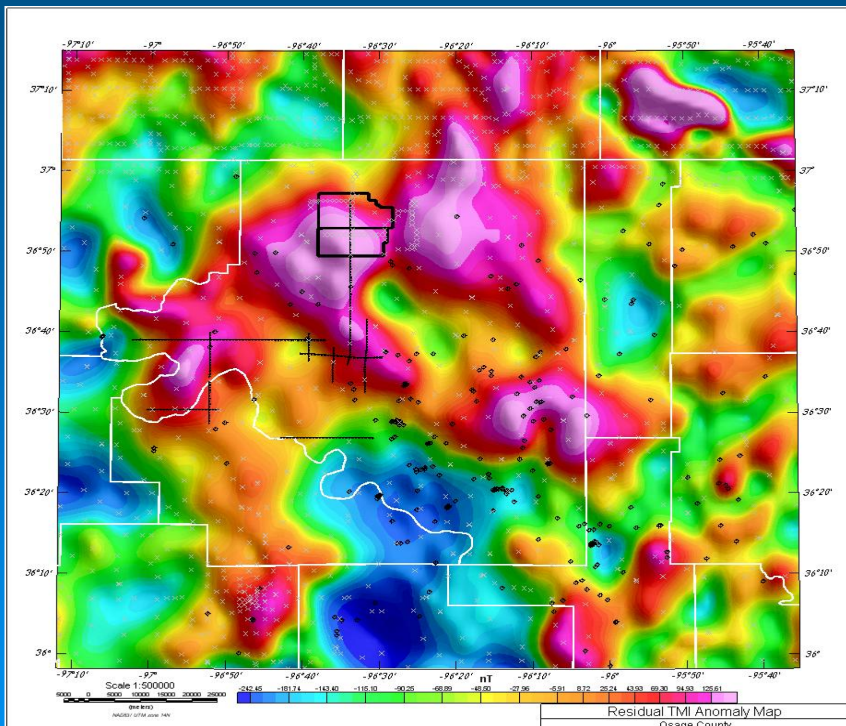
State of Oklahoma Gas and Oil Distribution

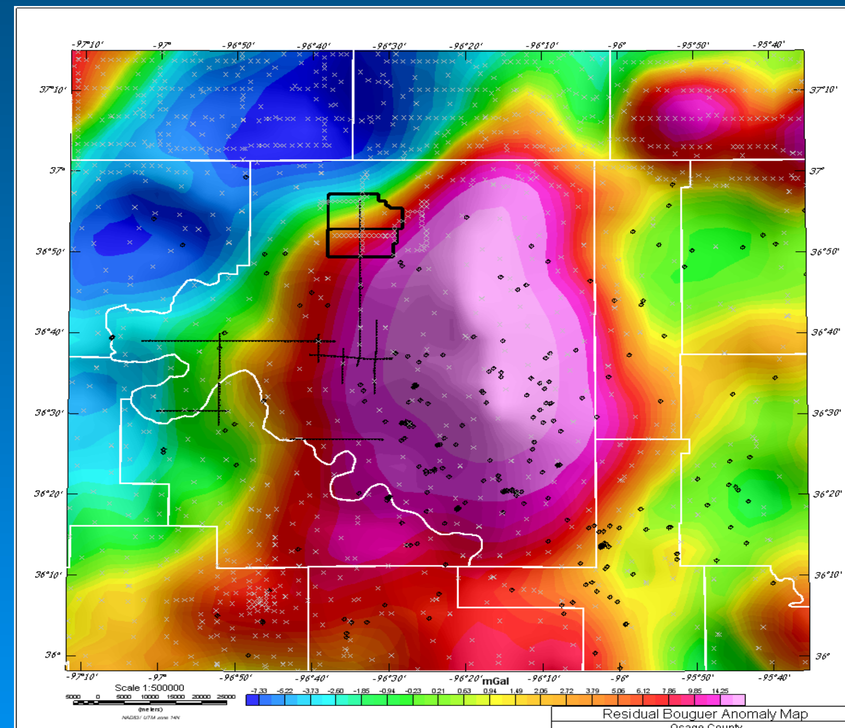


Structure: Subsurface



Residual Magnetic (left) and Gravity (right) Anomalies in the Osage County Region





Randy Keller OGS 2011

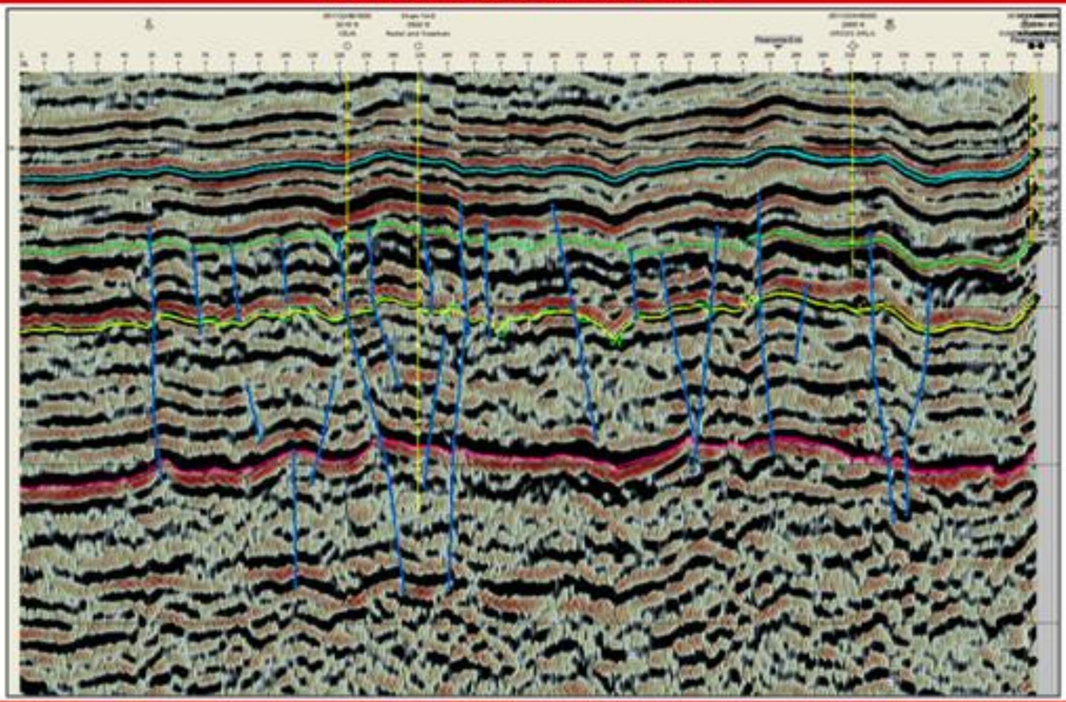
The Osage gravity high on the Bouguer anomaly map on the right is so large that it masks the signatures of shallower features in the upper basement and sedimentary column. Thus, in order to obtain a better picture of the shallow structure in the Osage County region, we are building a 3-D earth model 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

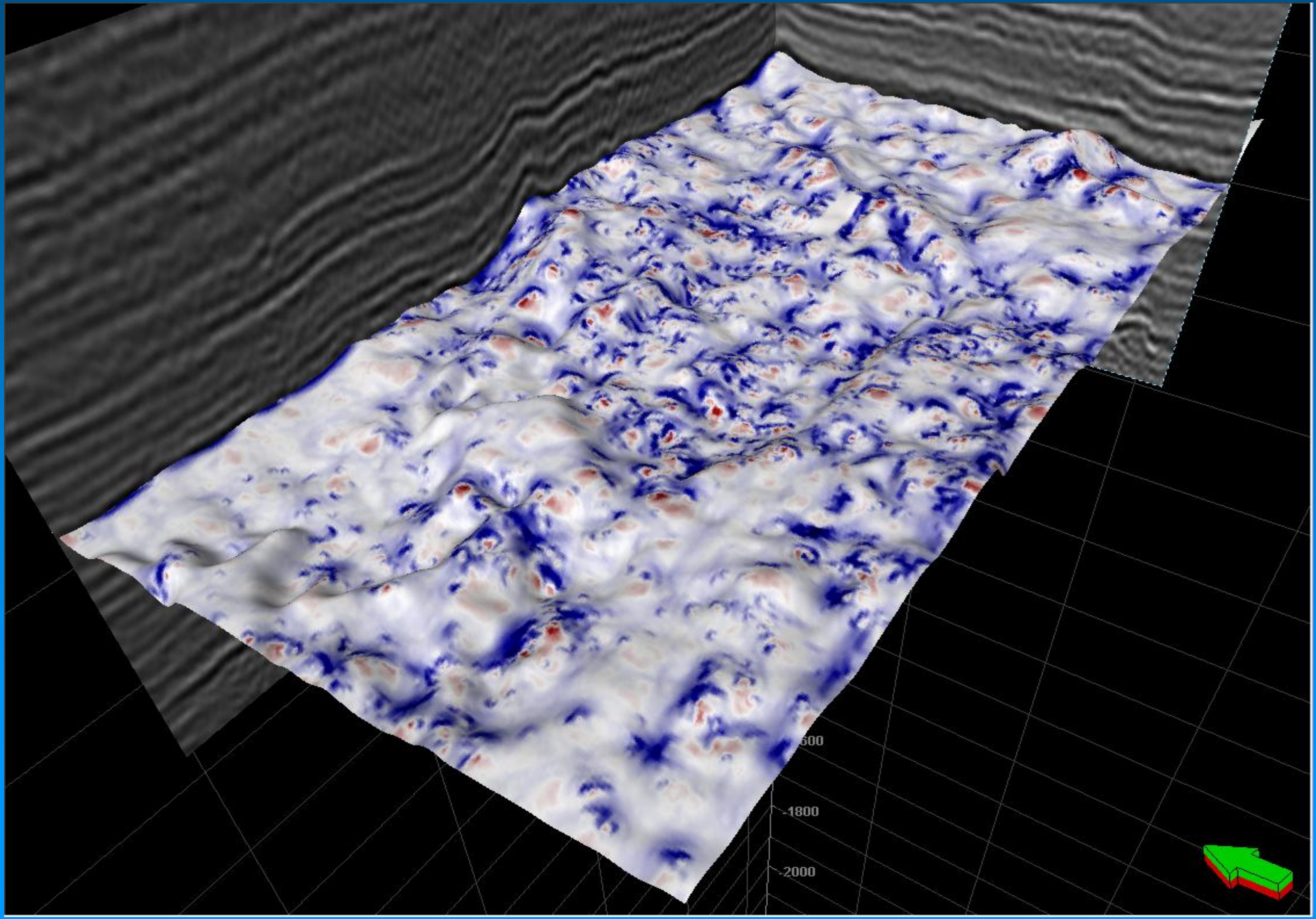
Tripolite Sub-Crop Seismic Section



8 Miles

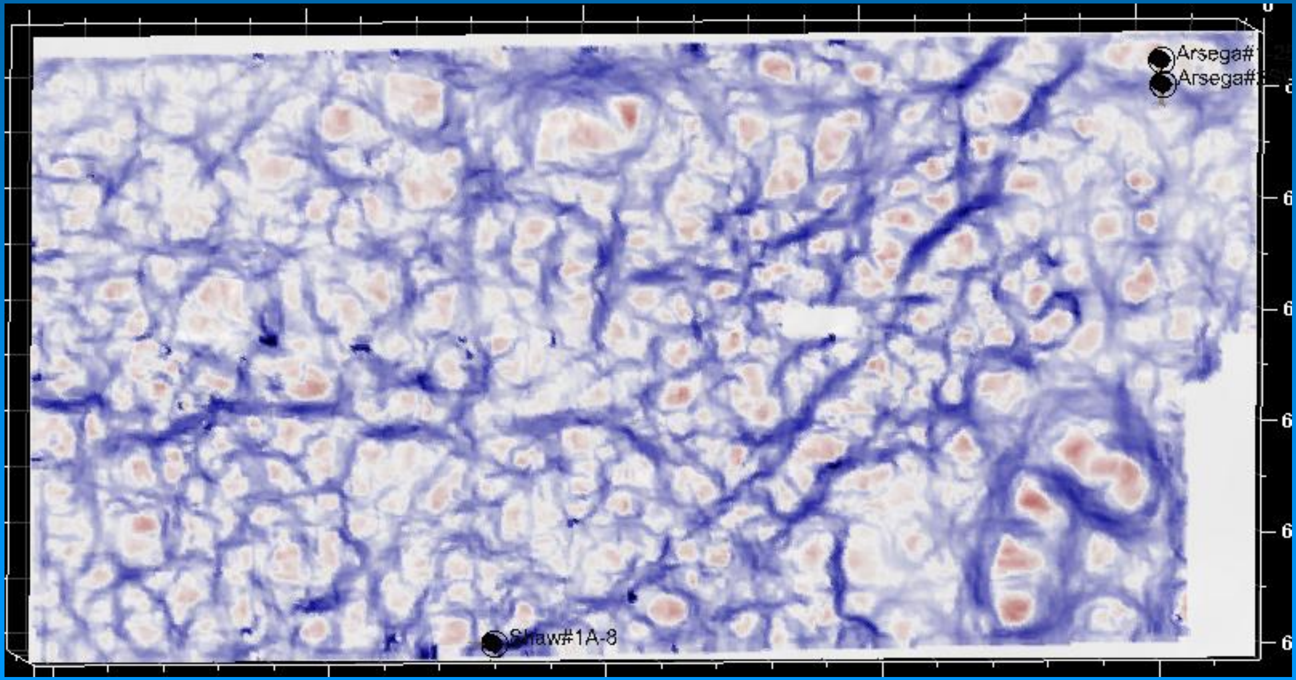
Wrench Fault Tectonics

Structure: Seismic



Seismic Attributes

K Negative Curvature



8 Miles

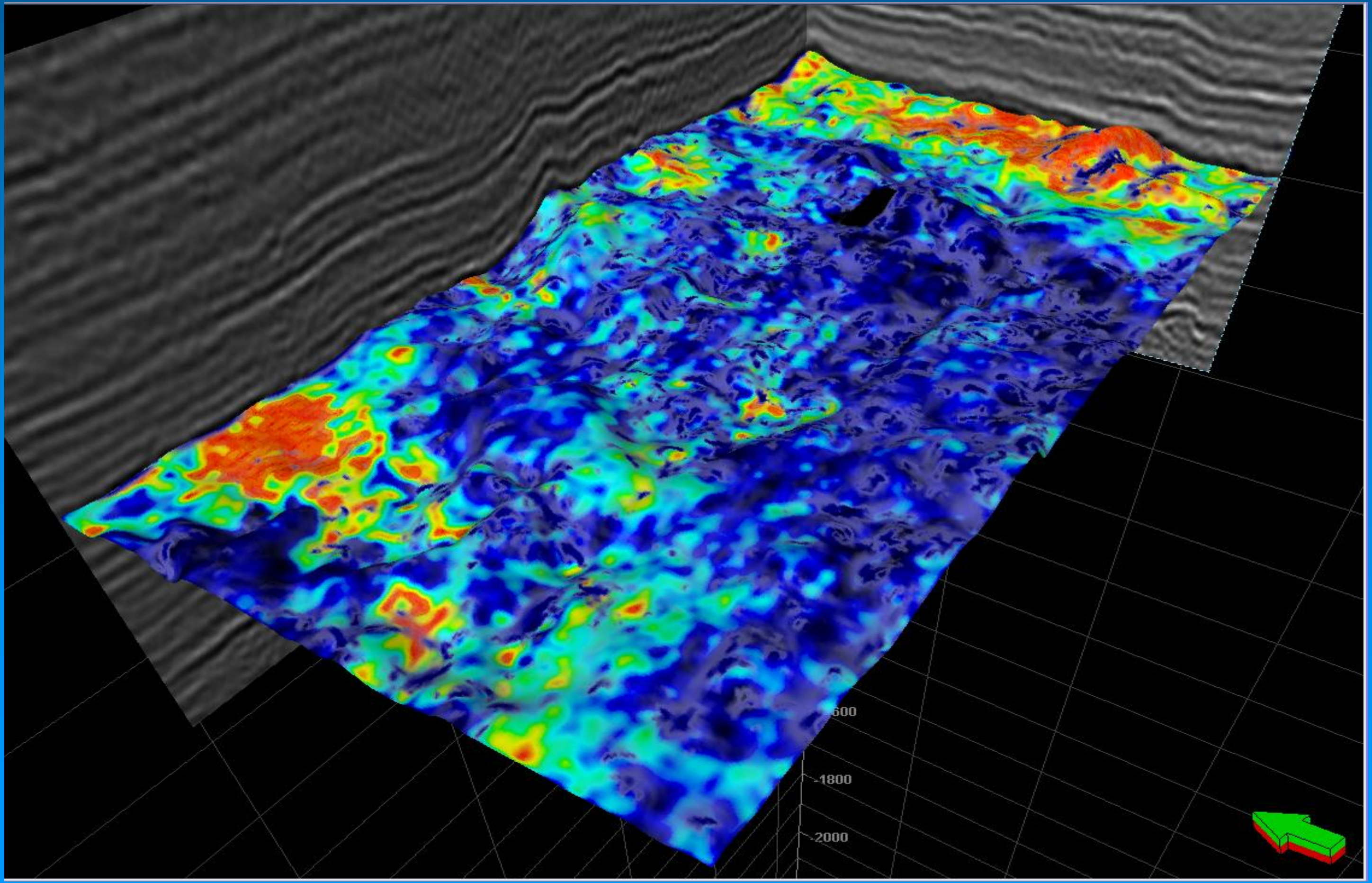
Seismic Attributes

"Ant Tracking"

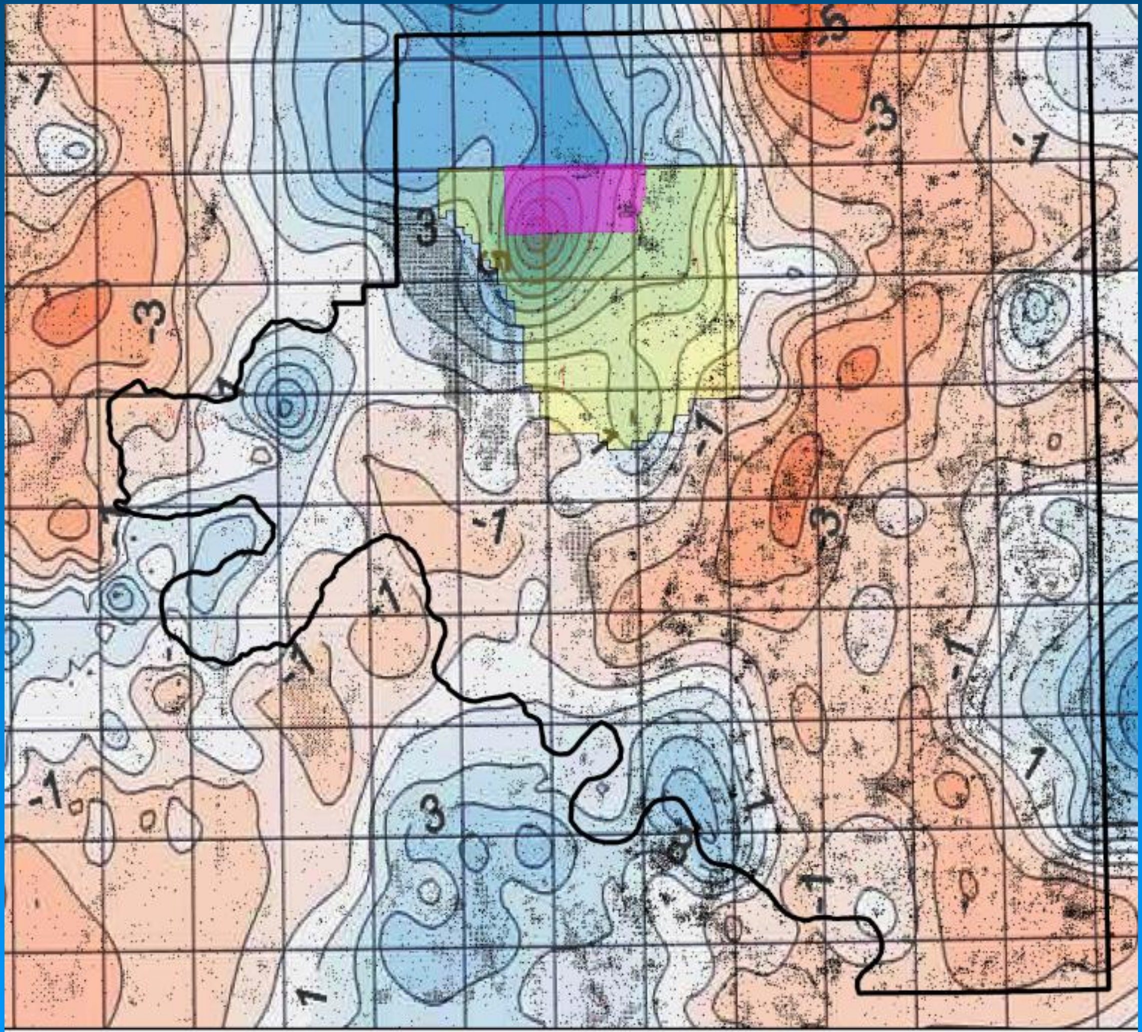
8 Miles

Seismic Attributes

"Combination"



Structure: Gravity

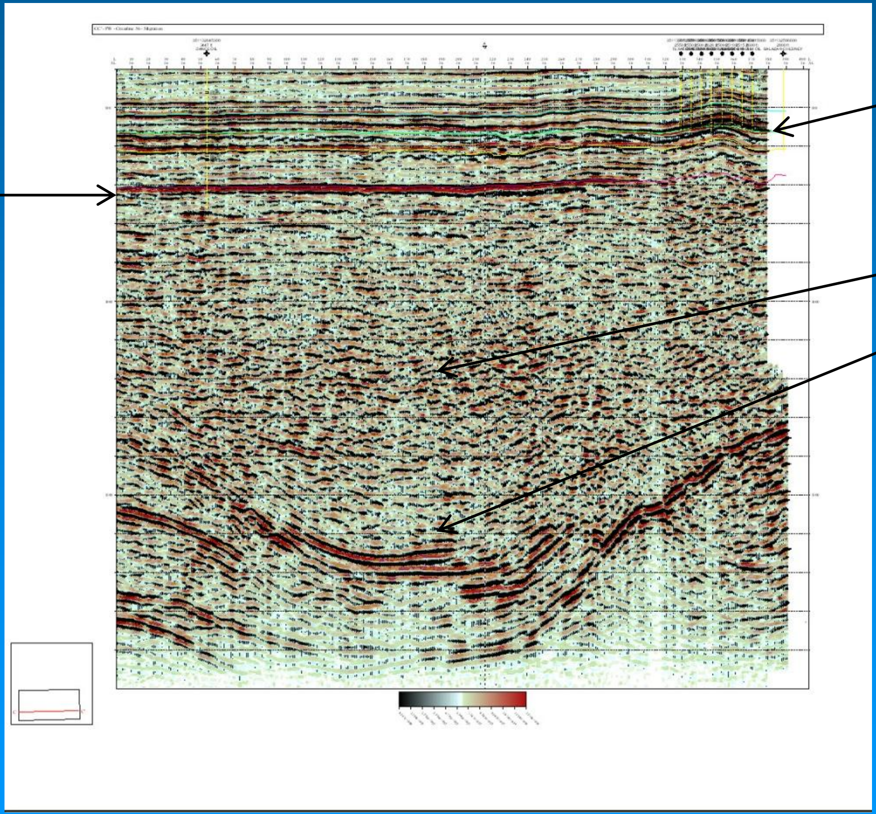


Residual gravity anomalies derived by subtracting the calculated values from the observed Free Air anomaly values. Many of the anomalies on this map appear to correlate with known features in the sedimentary section.

Randy Keller
OGS 2012

Structure: Subsurface

New Idea in an Old Area



Foraker Field Miss Chert 2500’

1.3 BYO Rhyolite Basement 4000’

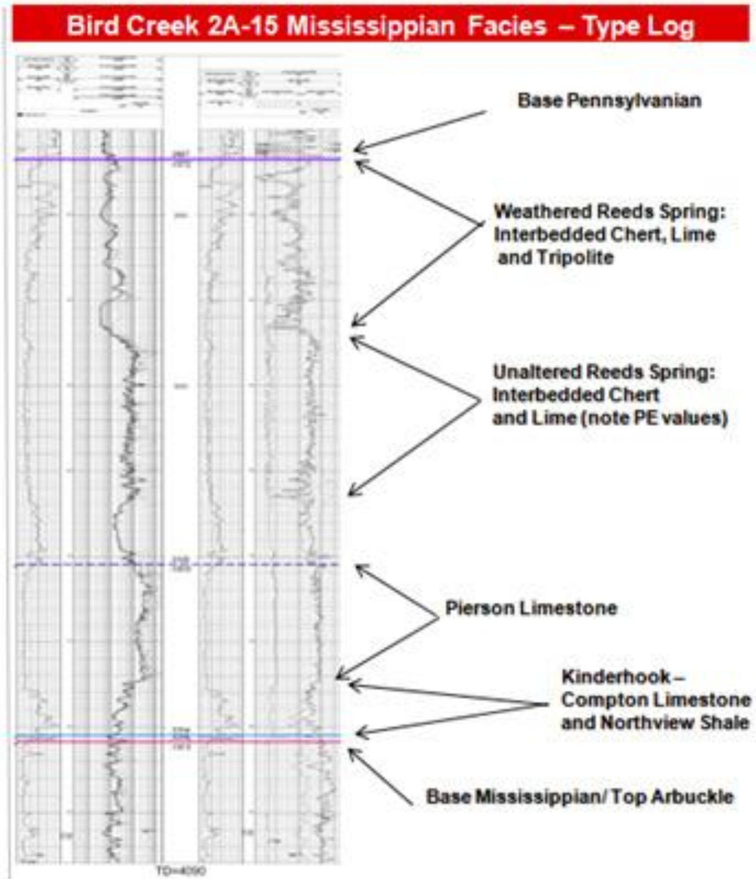
Terra incognito 10,00 to 15,000’ TVD

Wha-zha-zhi Basin Osage Co OK

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



Overview – Stratigraphy & Reservoirs

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  - Syndepositional with Silica from Continental source
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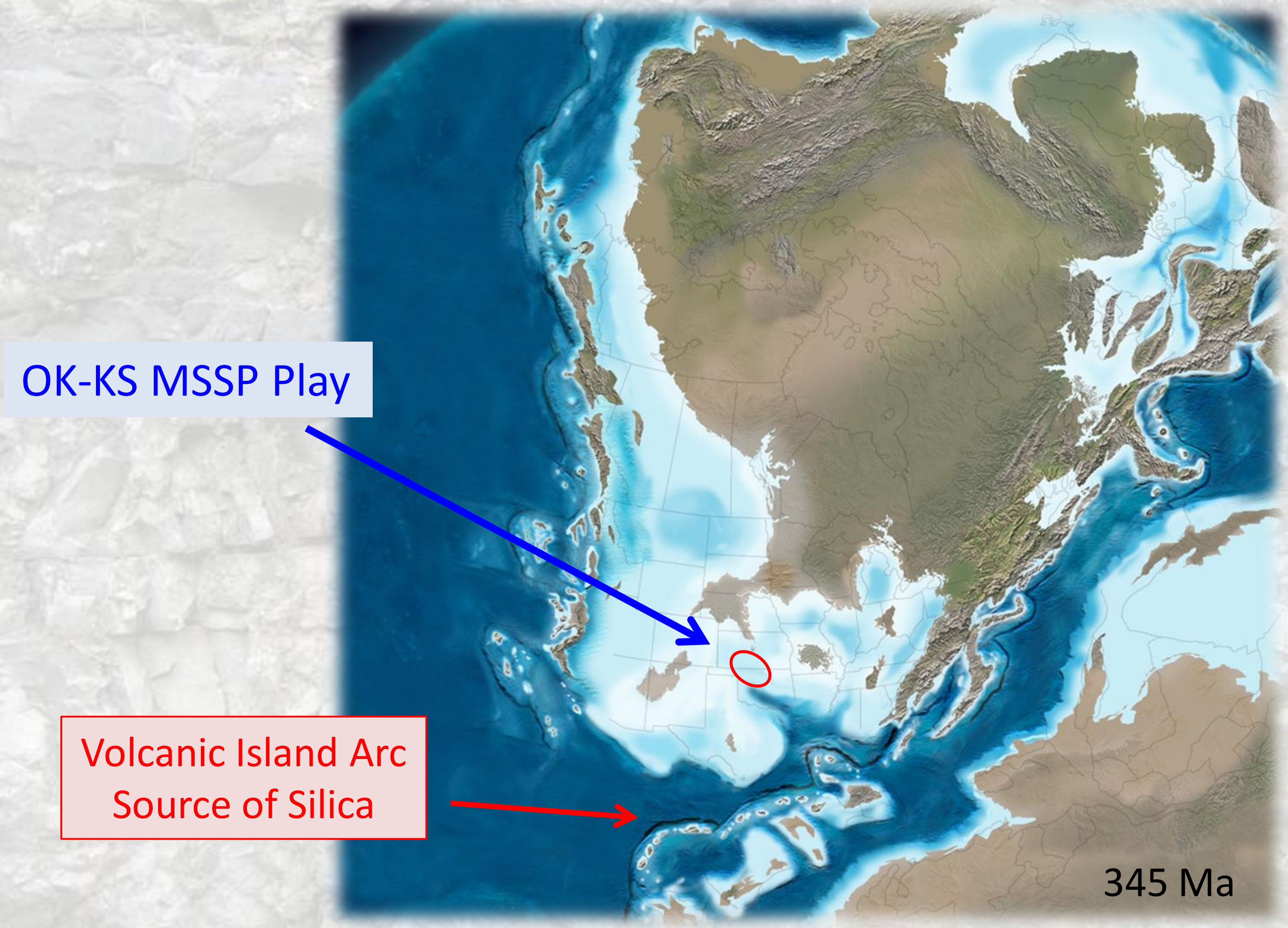
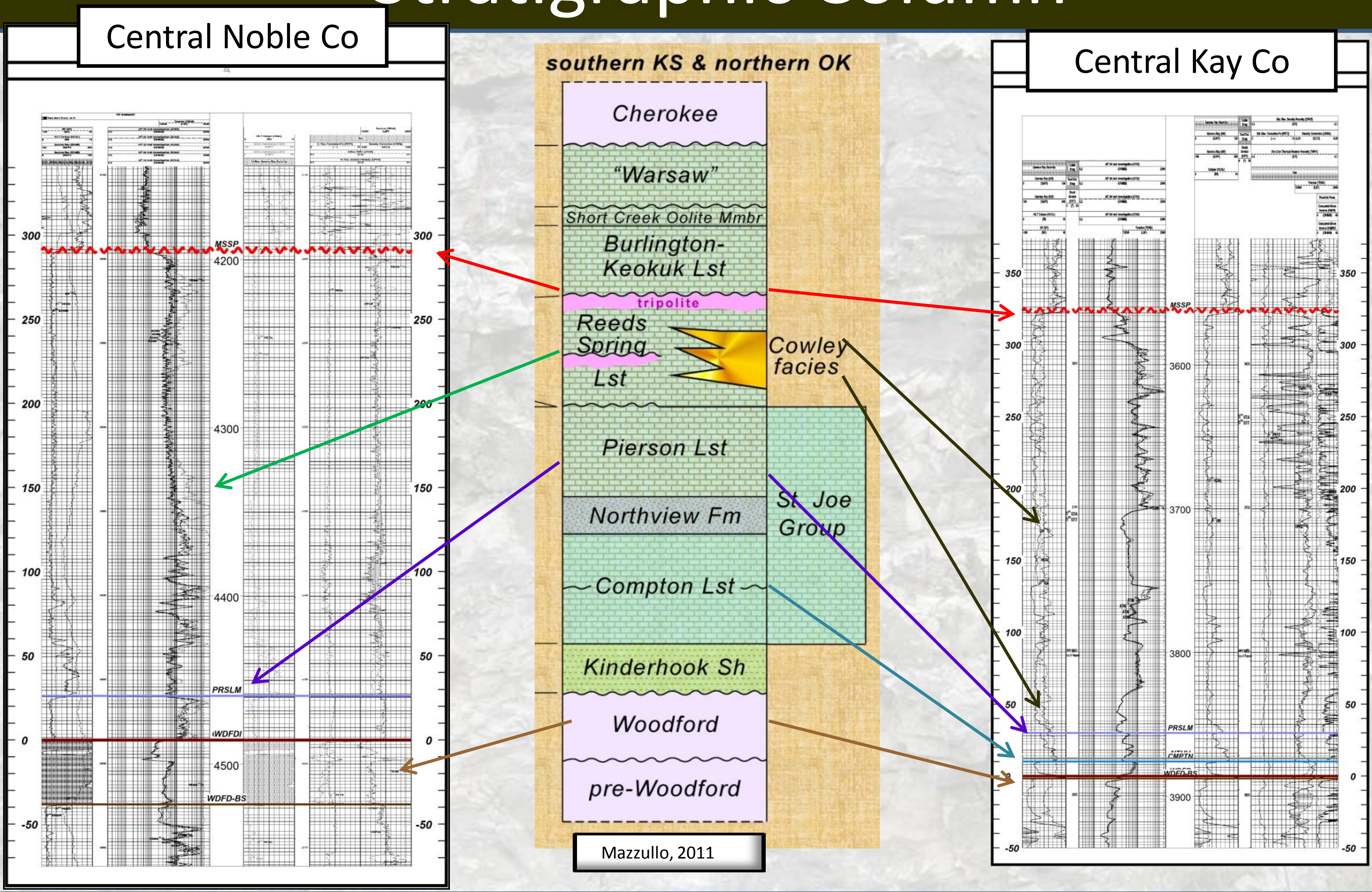
Early Mississippian Time



R. Blakey, 2012

Stratigraphic Column



Stratigraphic Column USGS 588

System	Series	Formation	Member	Thickness	Description
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Geology and Ore Deposits of the Picher Field Oklahoma and Kansas

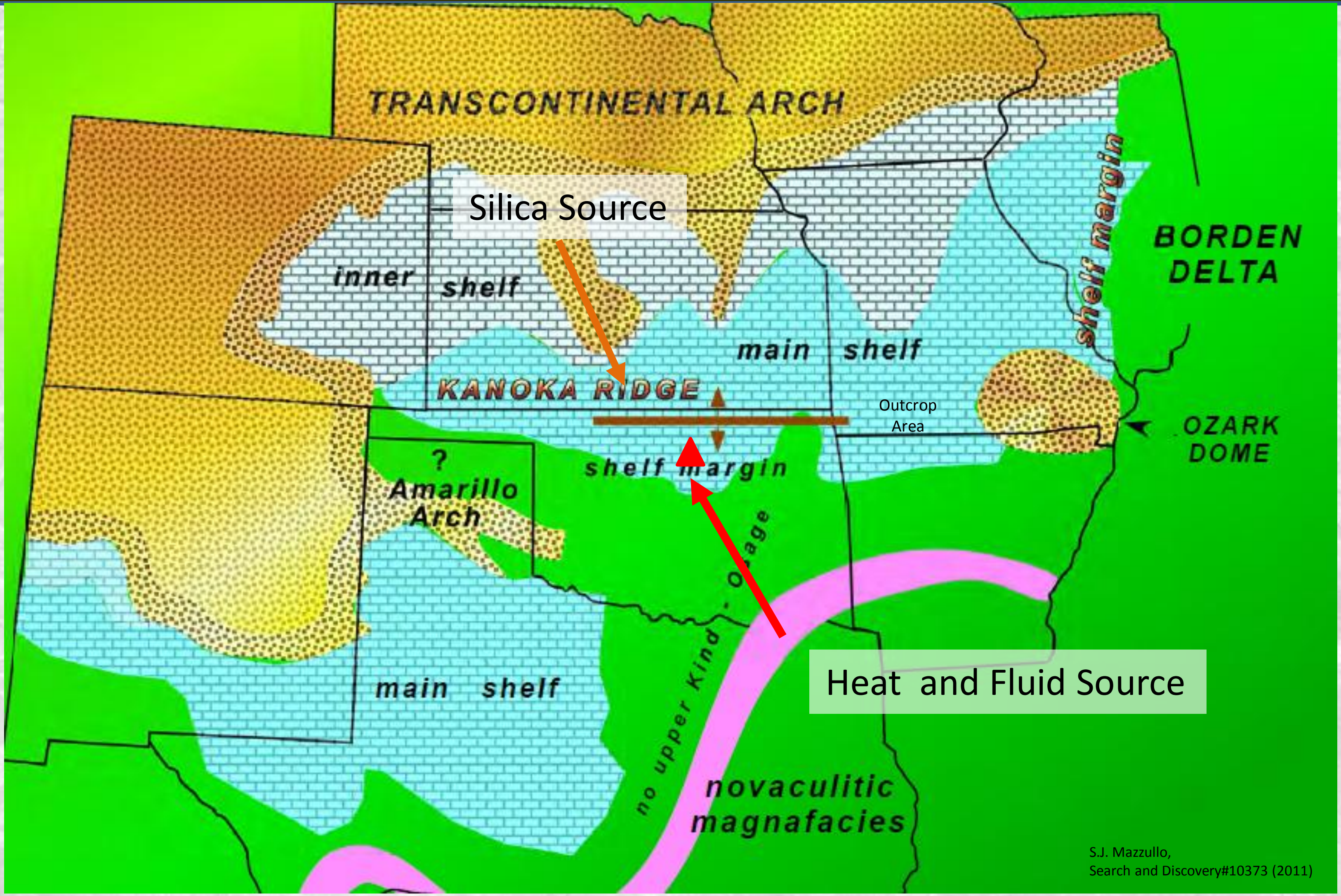
By EDWIN T. McKNIGHT and RICHARD P. FISCHER

GEOLOGICAL SURVEY PROFESSIONAL PAPER 588

A discussion of one of the world's great mining fields—its geology, mining history, and potential

1970

Mississippian Regional Paleofacies



Overview

- **Stratigraphy**

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

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  - Syndepositional with Silica from Continental source
- **Reservoir Types**
  - Tripolitic Chert
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  - Cowley
  - *Silicified LS*

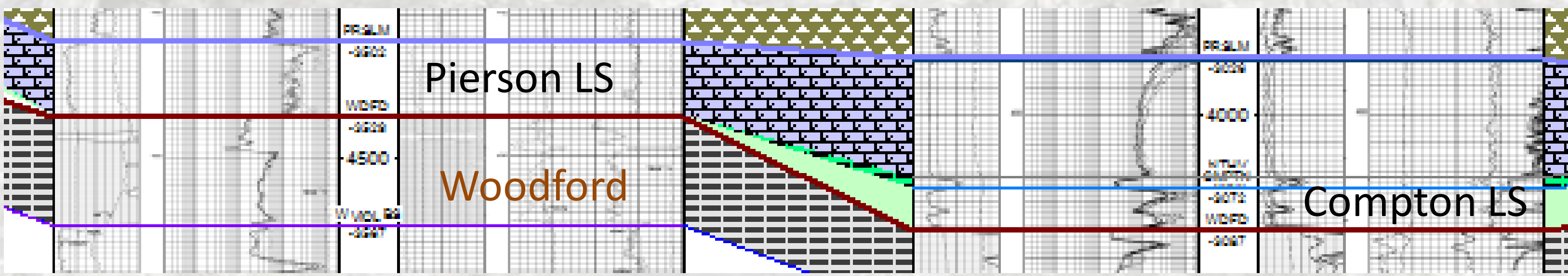
St. Joe Stratigraphy

			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.

St. Joe *Compton – Northview -- Pierson*

Noble Co

Osage Co



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Reeds Spring Stratigraphy

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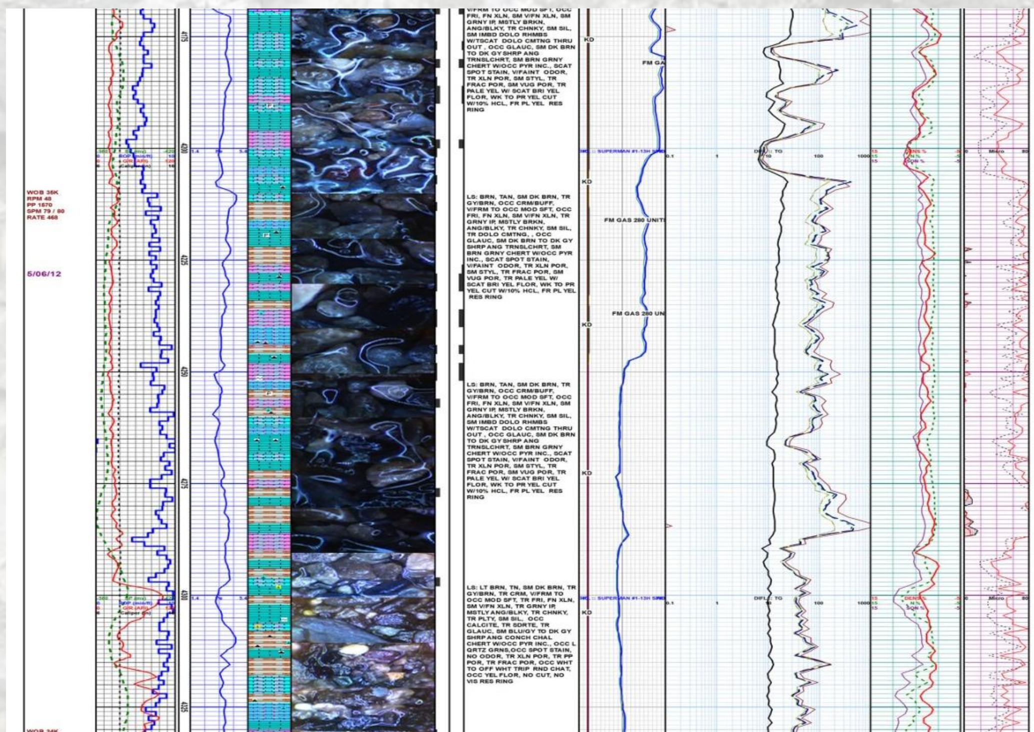
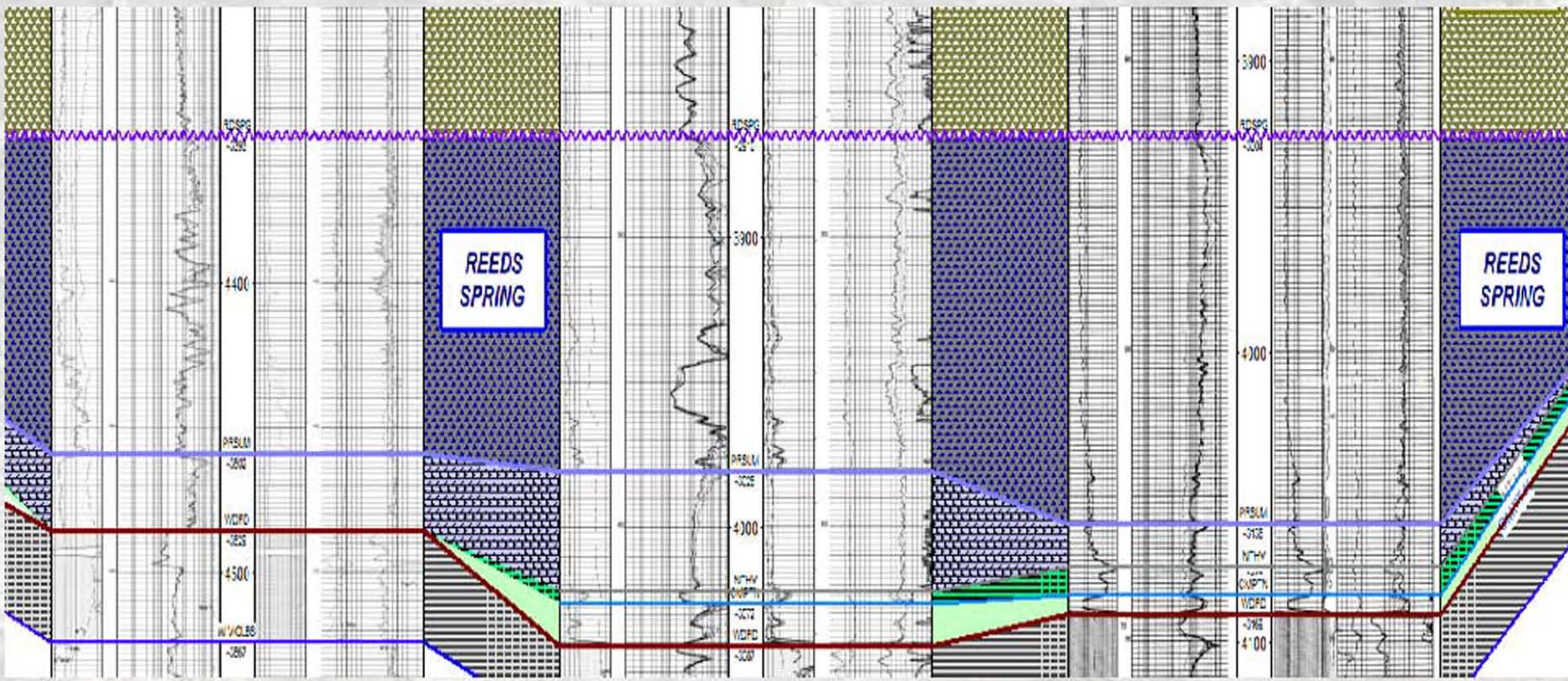


Reeds Spring Stratigraphy

Noble Co Osage Co Pawnee Co



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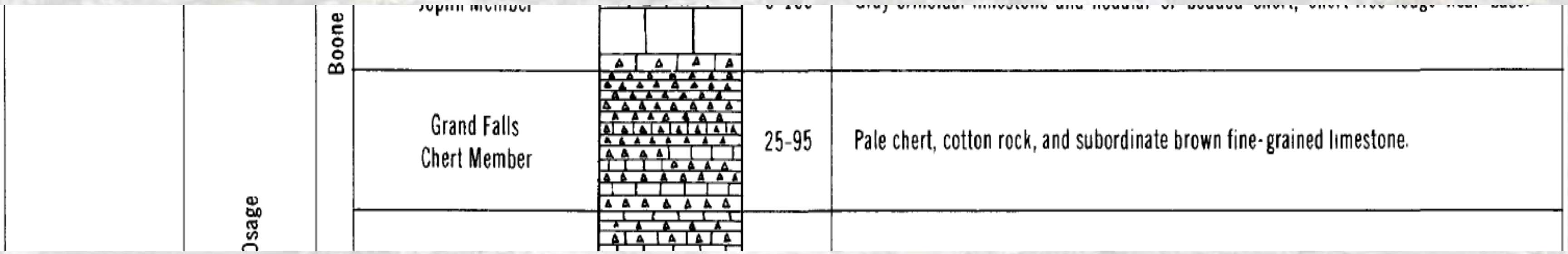
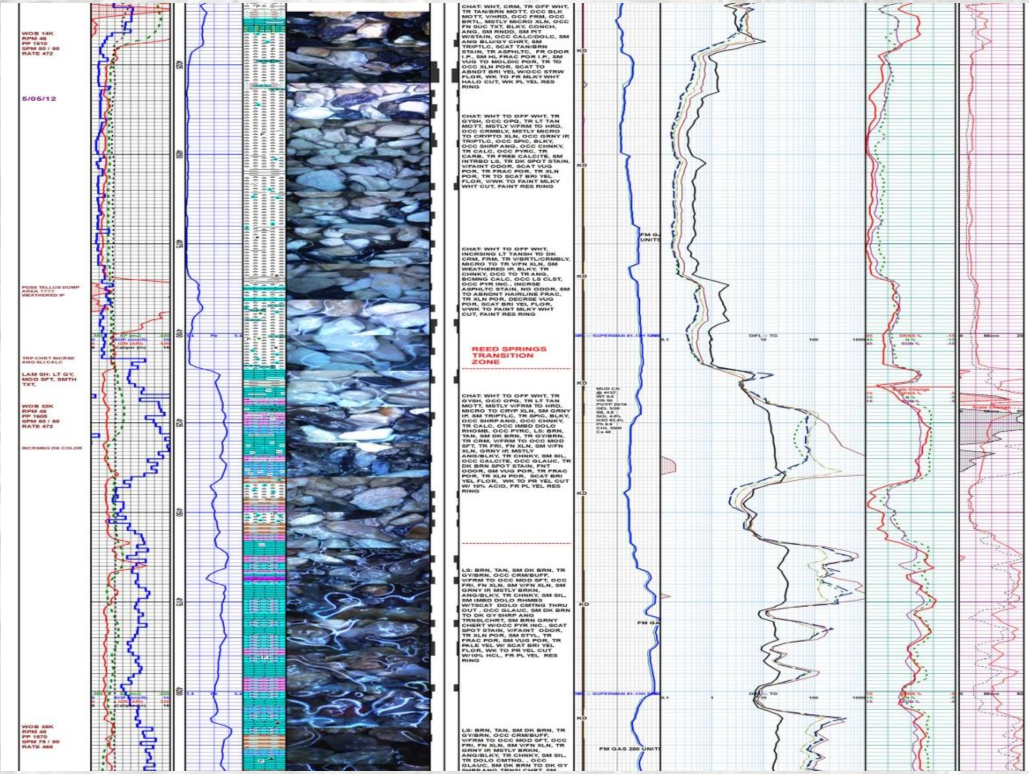
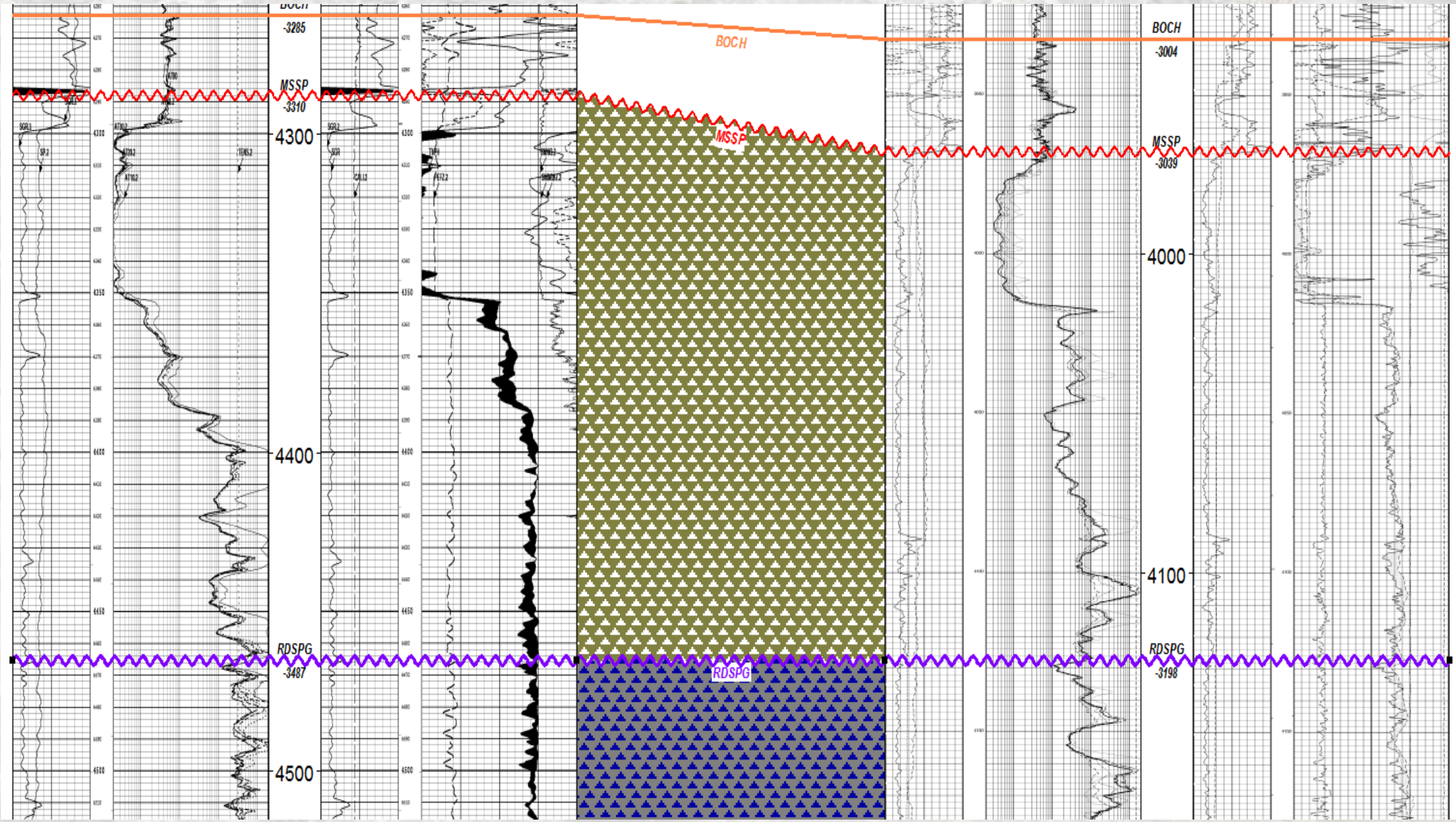
Grand Falls Stratigraphy





Grand Falls Stratigraphy



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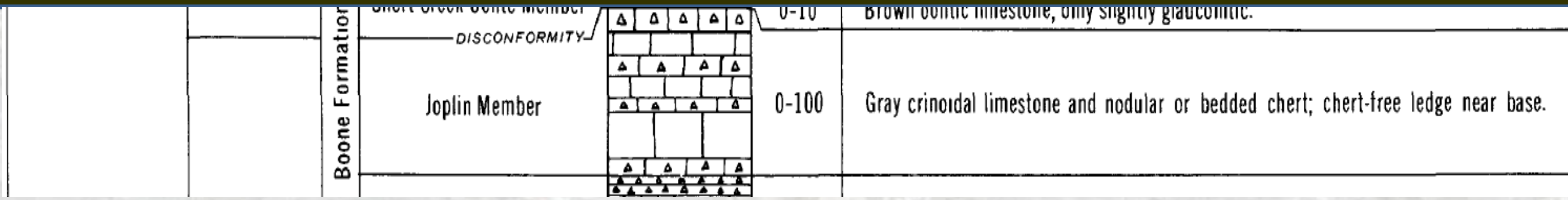
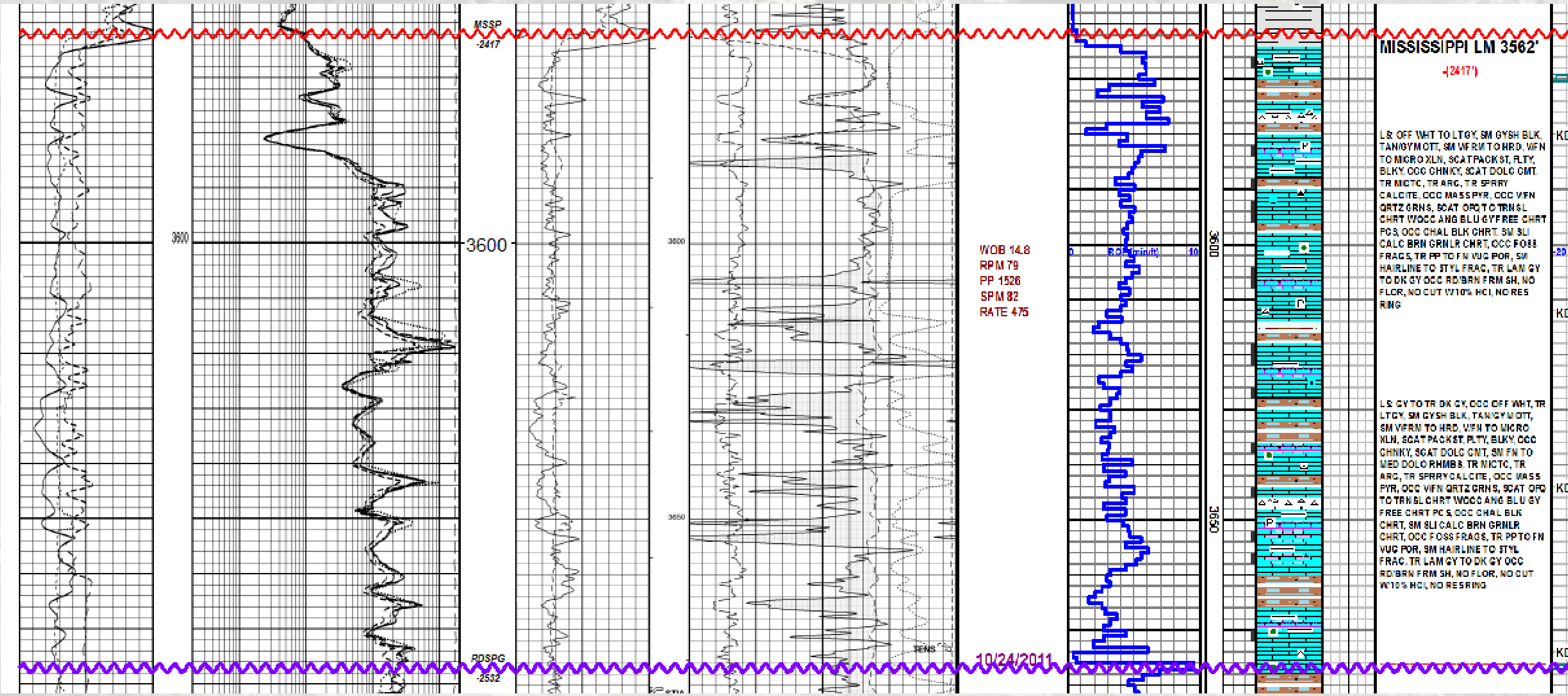
Joplin Member Stratigraphy



Central Kay Co



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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).

Origin of Chert

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.

“On the Origin of Cherts”, Christoph Laschet, Aschen. Erlangen, 1984

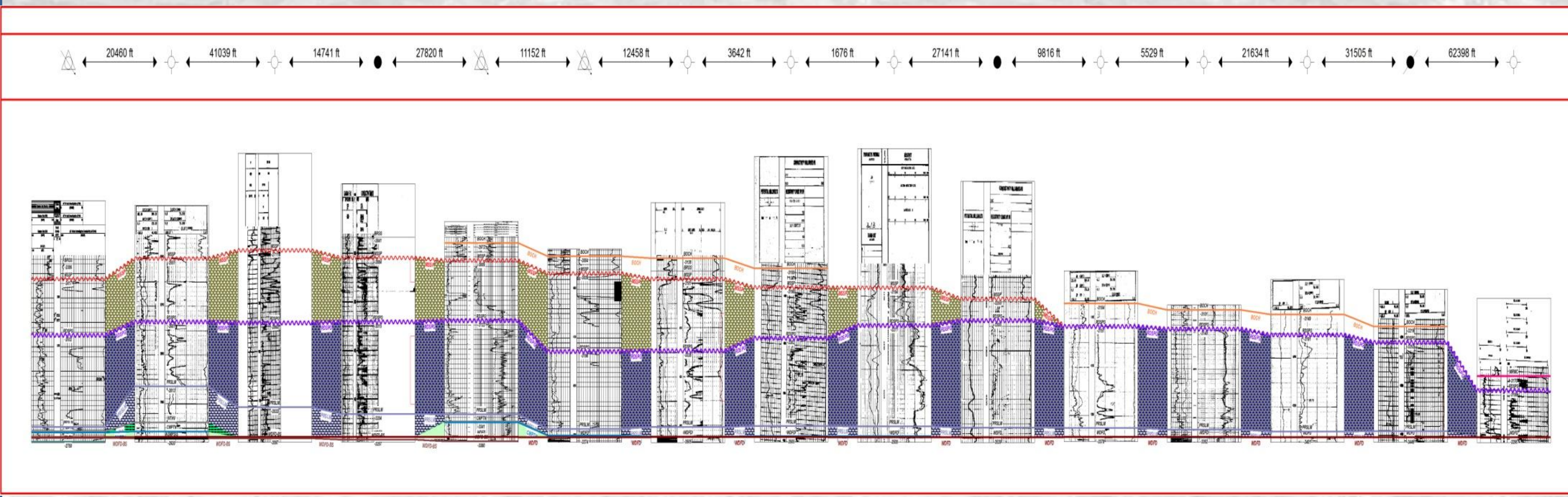
Origin of Cherts

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.

“On the Origin of Cherts”, Christoph Laschet, Aschen. Erlangen, 1984

Origin of Cherts

Kay Co Noble Co Pawnee Co Payne Co



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

Overview

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  - Cowley
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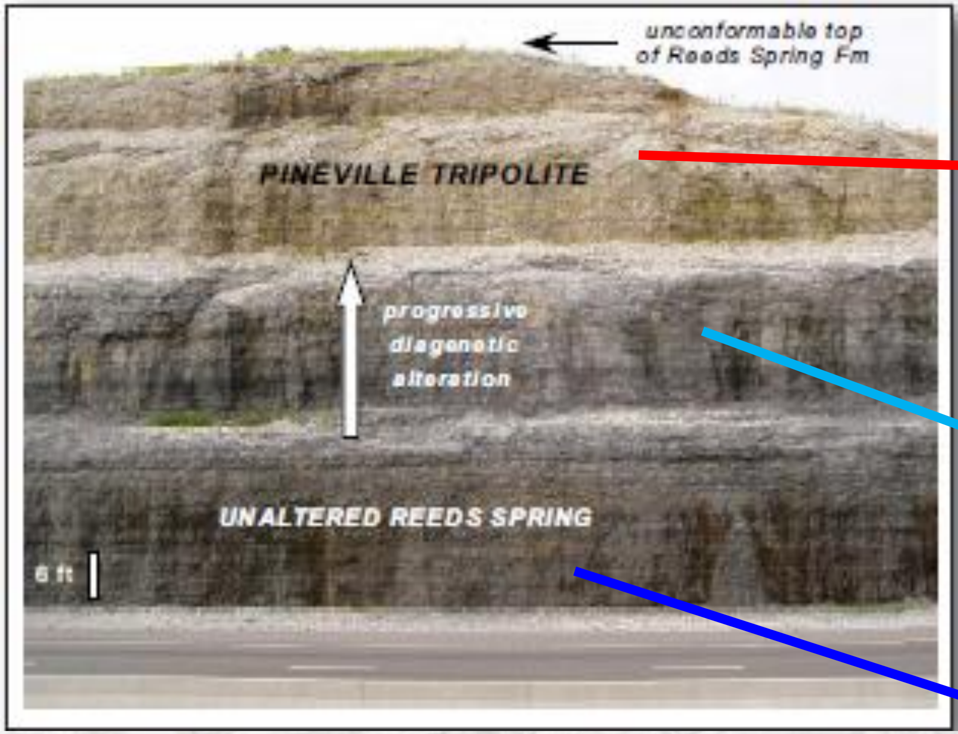
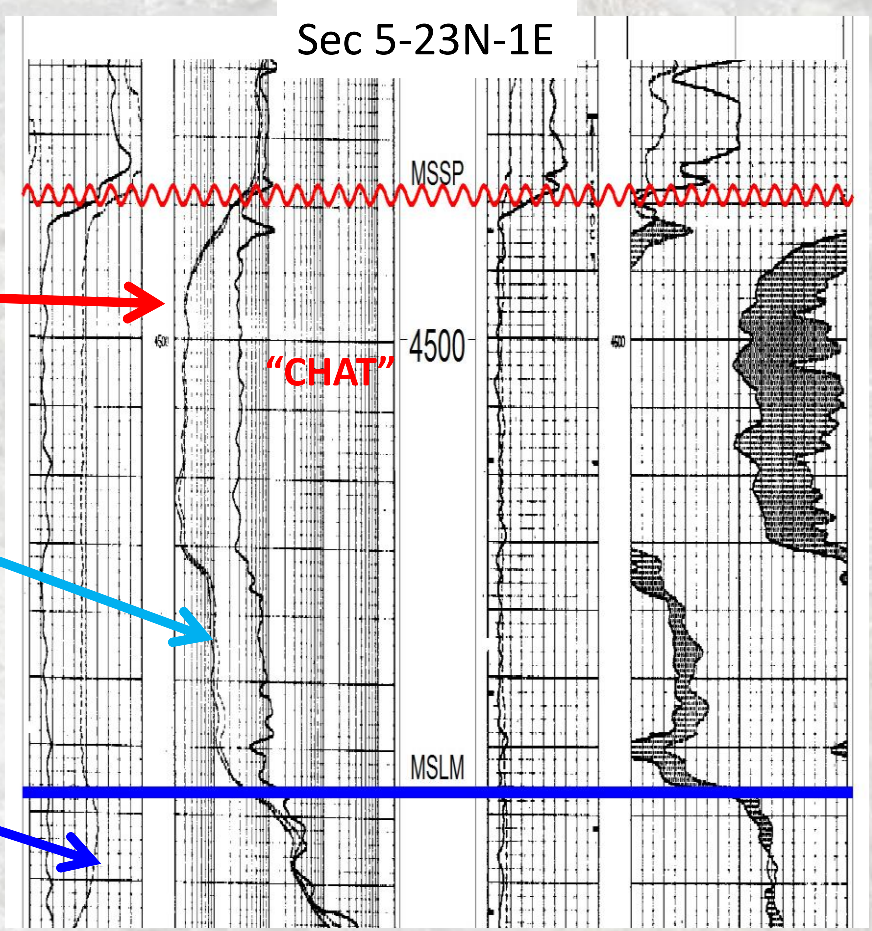
Tripolitic Chert



Mazzullo et al., 2011



Triplolitic Chert--Grand Falls Type

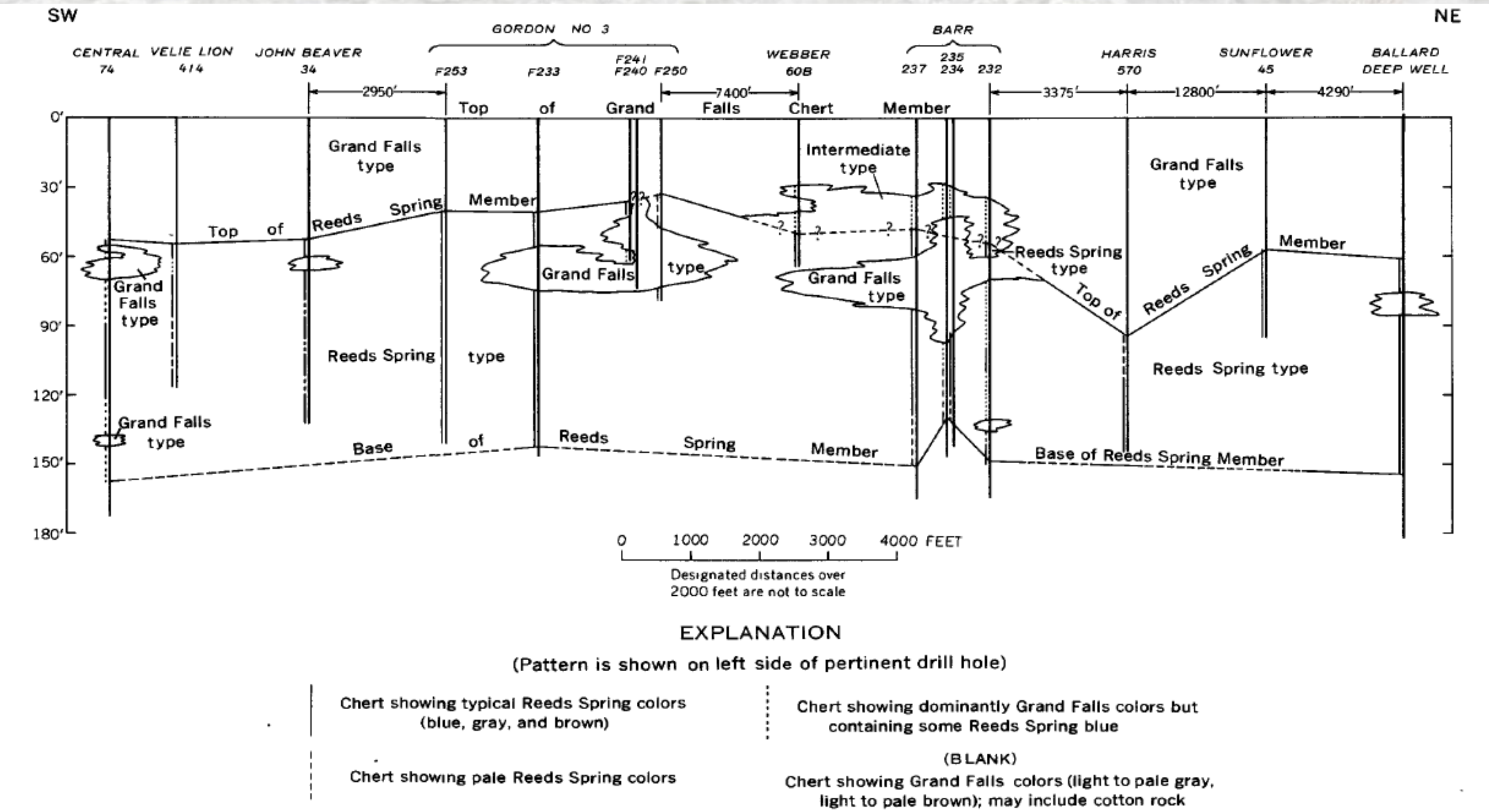


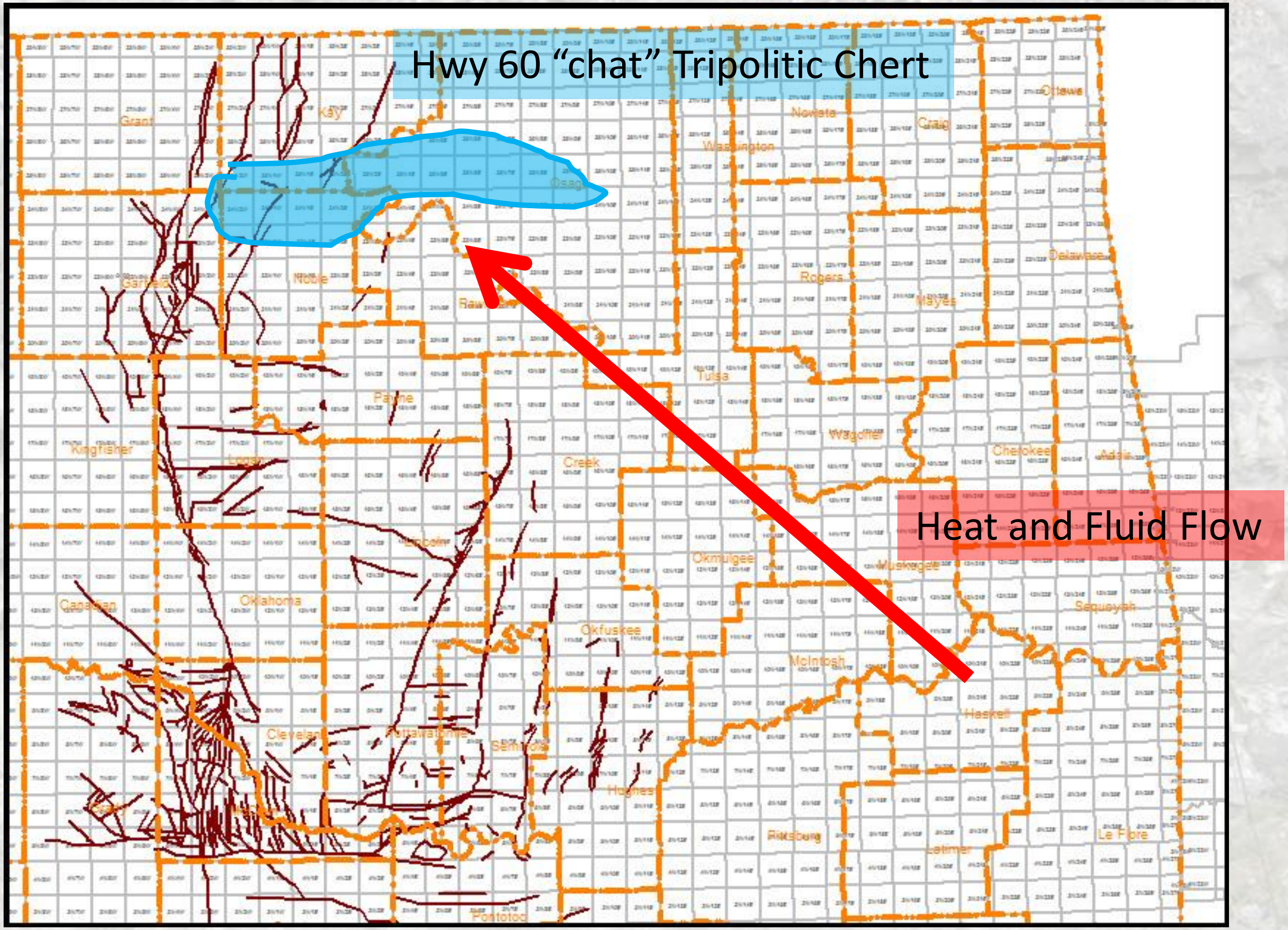
FIGURE 6.—Diagram showing distribution of chert colors in Grand Falls Chert Member and Reeds Spring Member of Boone Formation in selected drill holes between Cardin and Baxter Springs (SW–NE). Note alternation and intergradation of Grand Falls and Reeds Spring types. Details of the intertonguing shown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

Mazzullo et al., 2011

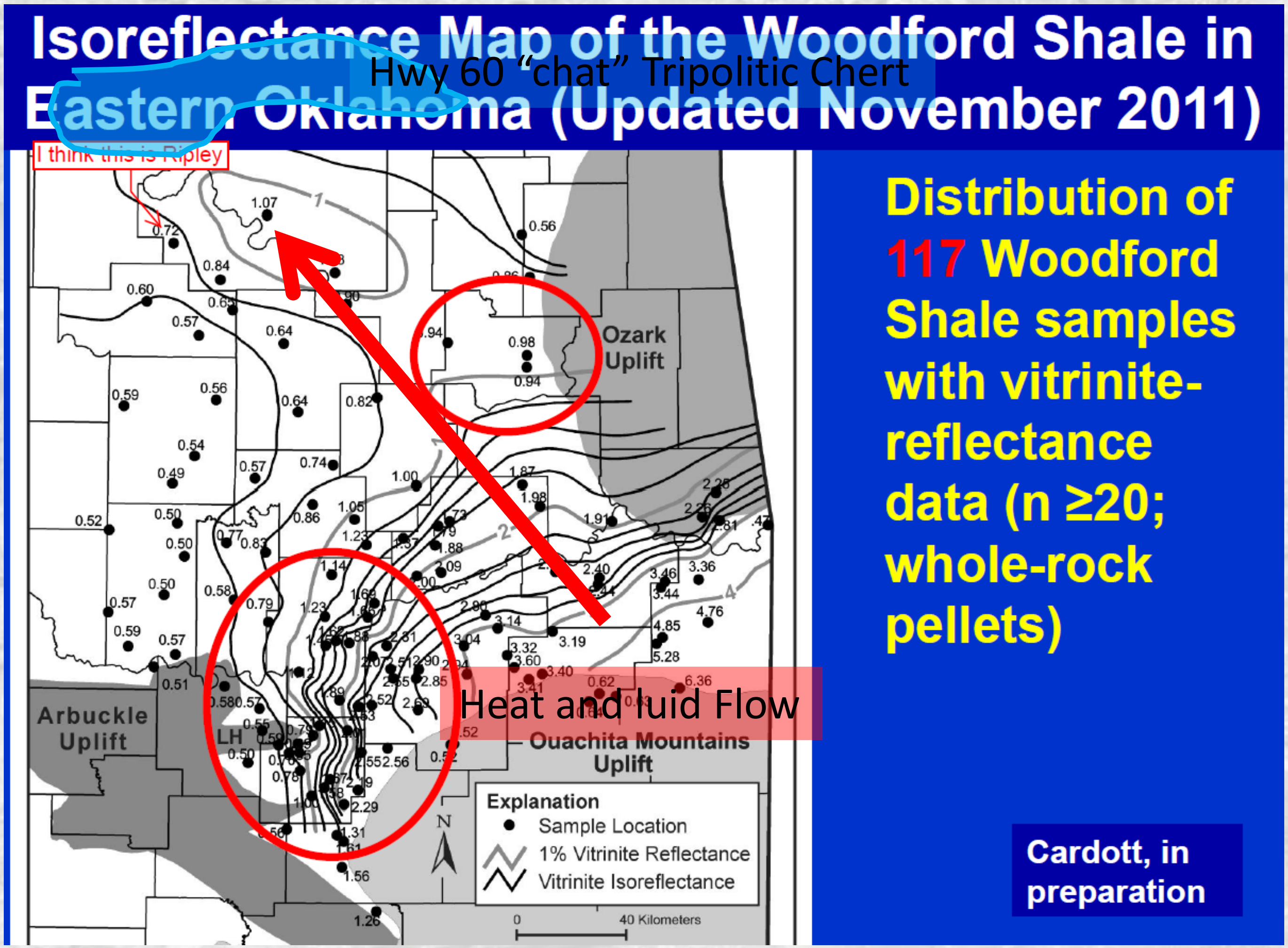
TERRITORY RESOURCES

Tripolitic Chert

Tripolitic Chert



Tripolitic Chert source of Hydrothermal Fluids



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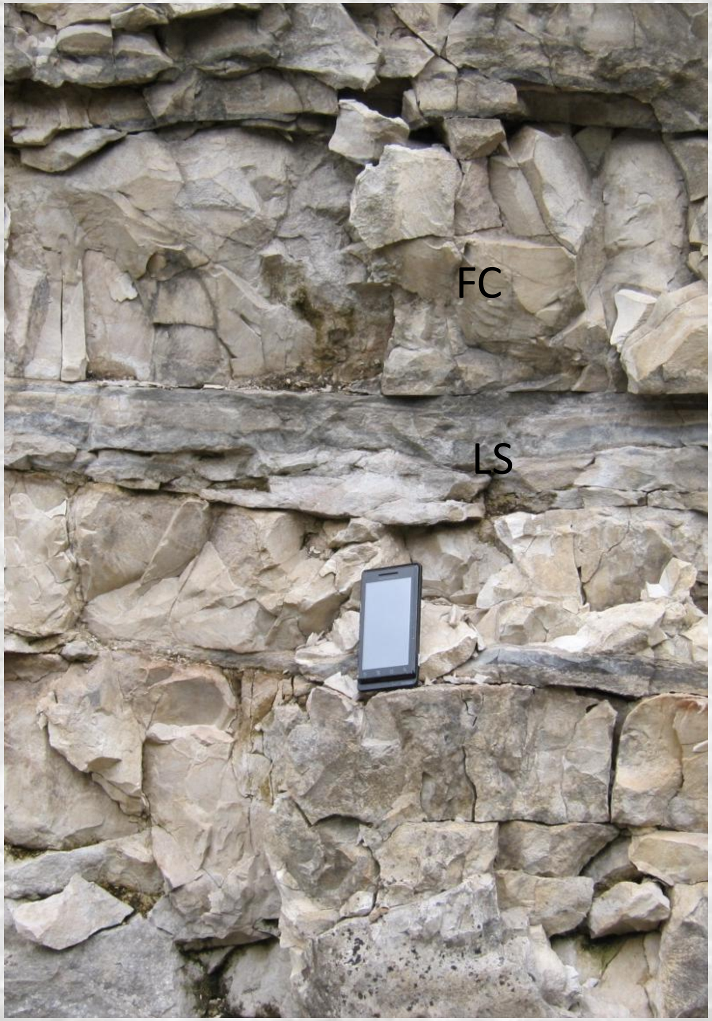
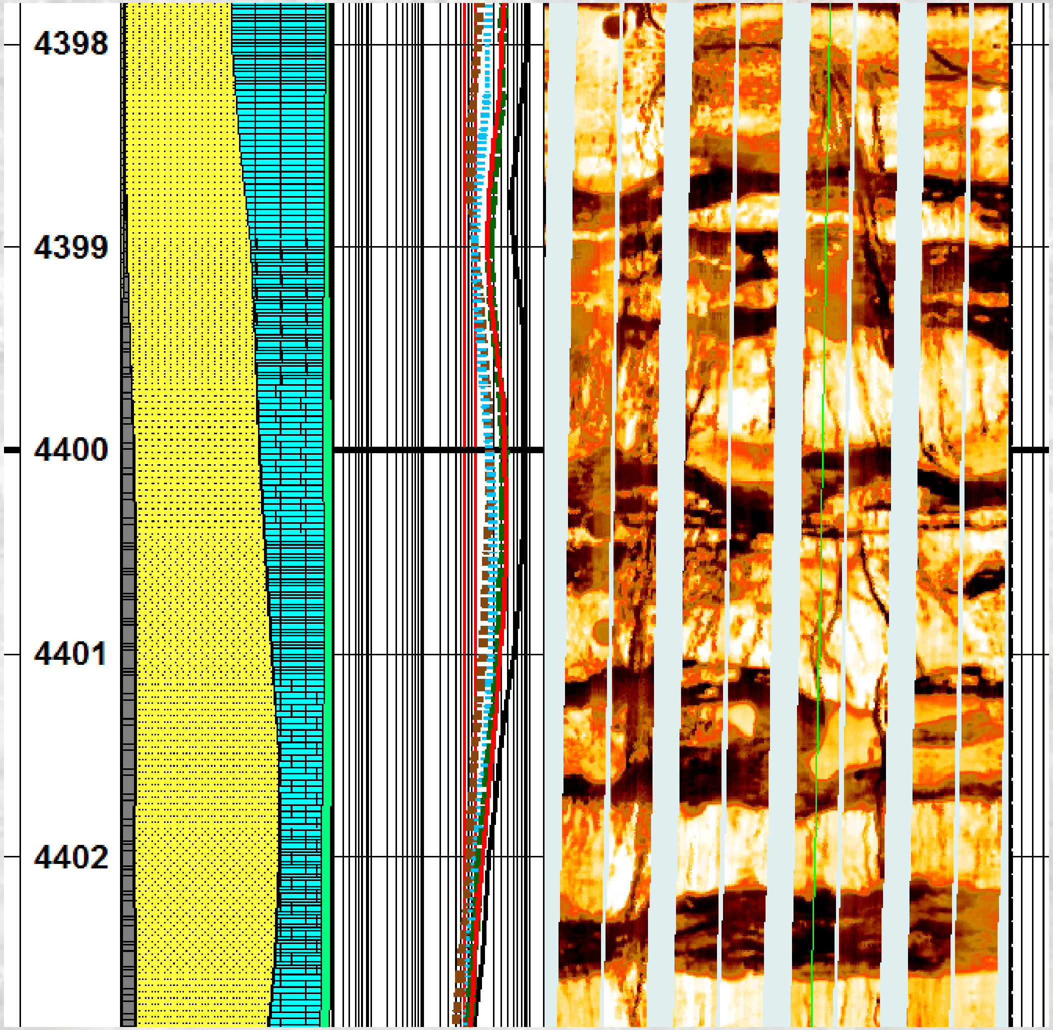
Fractured Chert



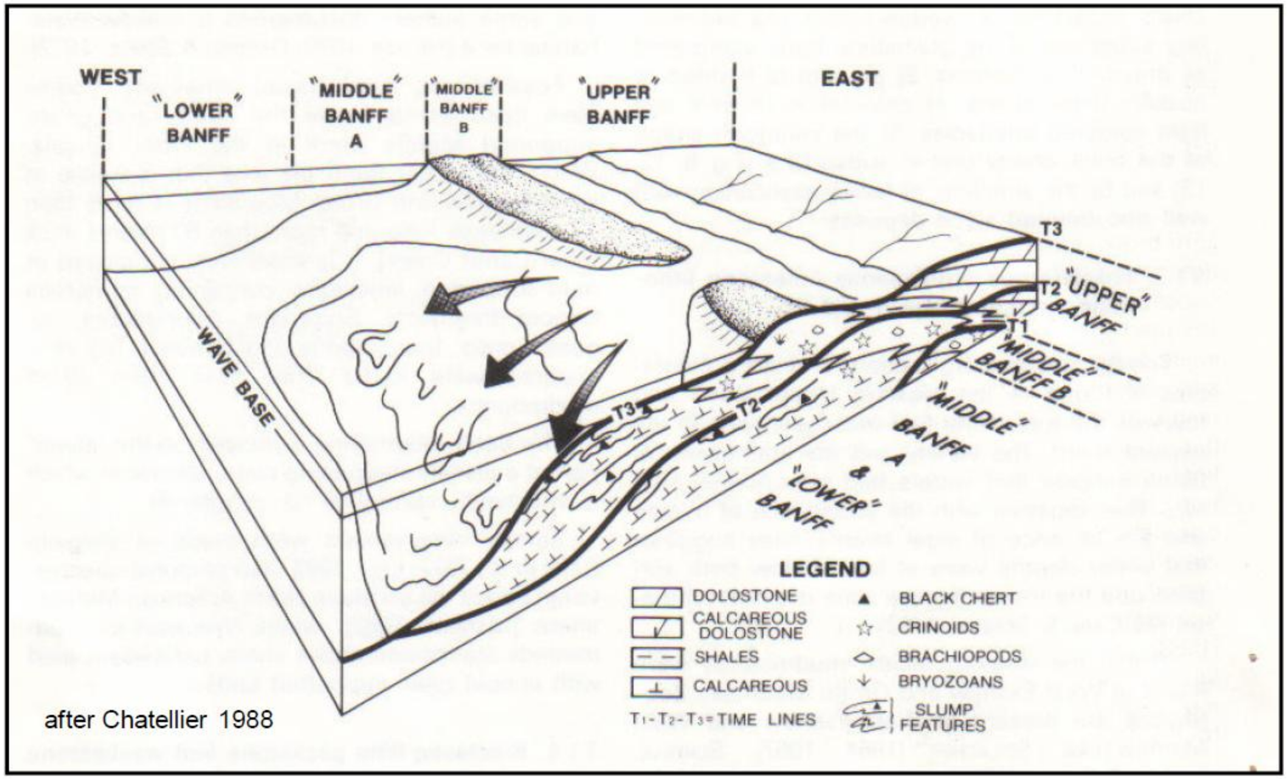


Fractured Chert Clinoforms-Wedges in Outcrop

Height of Wedge in outcrop is > than 100’

Clinoforms in 3D across Area

3-D proposed model



Genesis and Expression of a Clinoforming Carbonate Ramp from a Geological and Geophysical Perspective

Jean-Yves Chatellier, Jeff Closson, and Anne Hargreaves

Search and Discovery Article #50148 (2009)

Sub Unconformities

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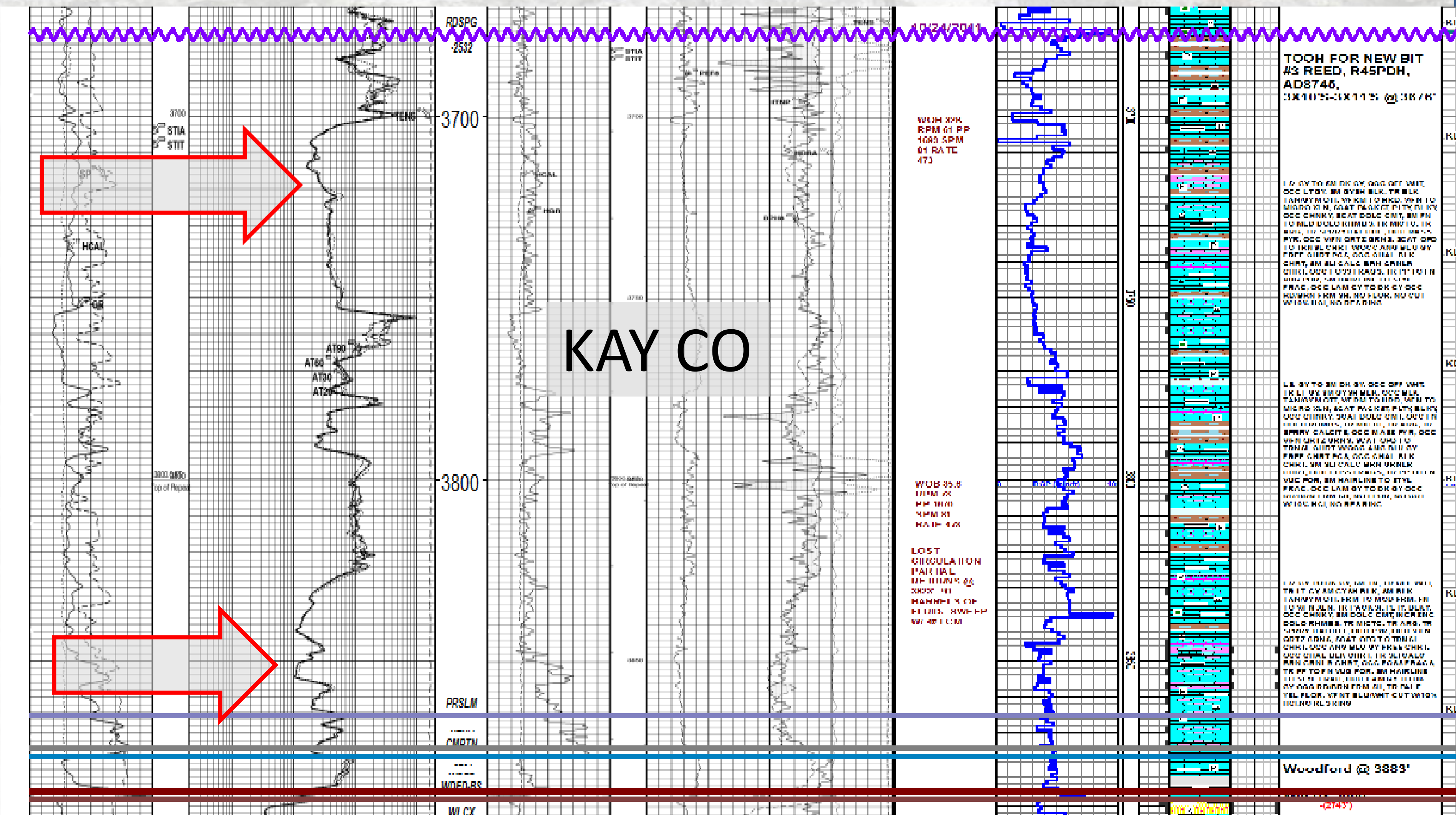
Cowley Reservoir Type



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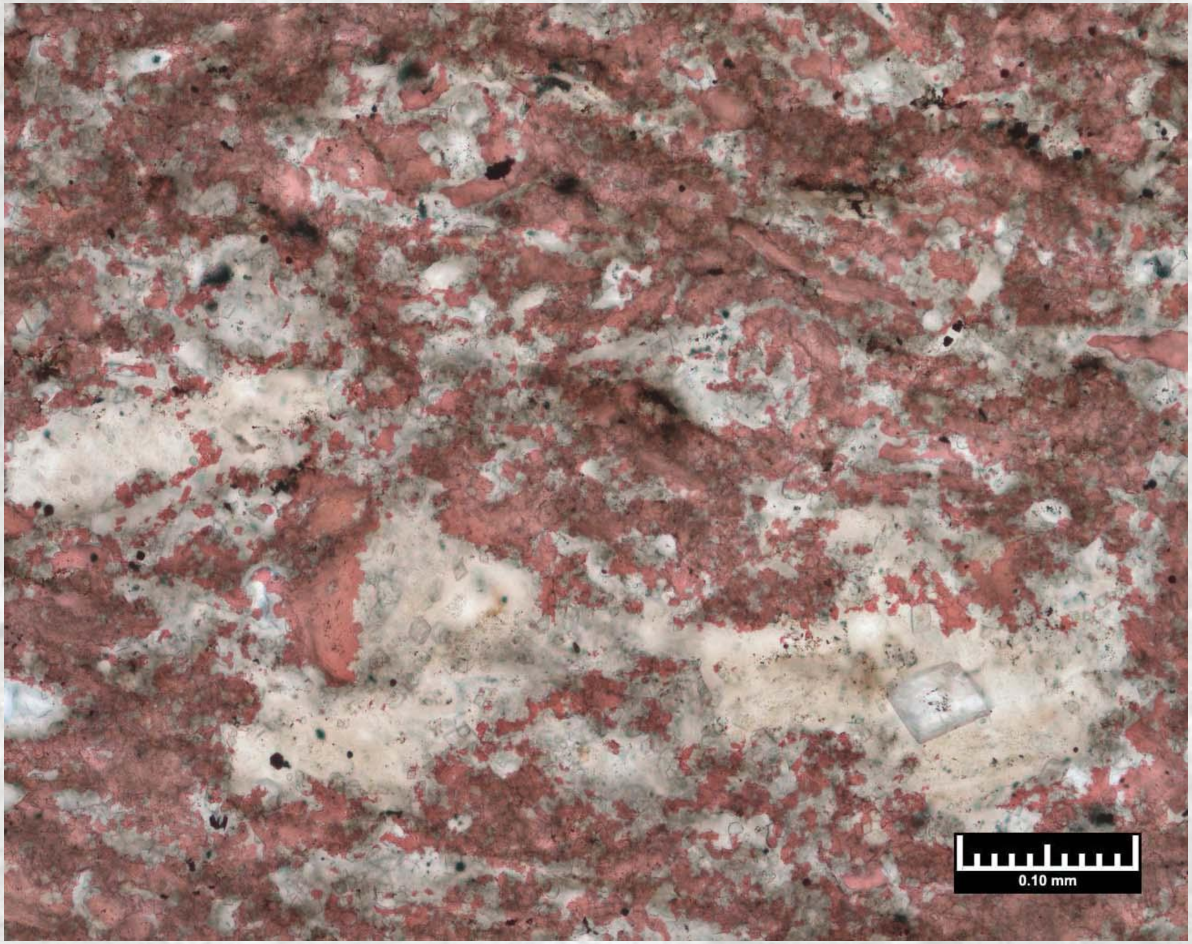
Silicified Limestone



Stained with alizarin red showing Calcite; white-clear is Silica.

Conclusions – Stratigraphy & Reservoirs

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CONCLUSIONS (cont.)
and Charles Wickstrom's Acknowledgments

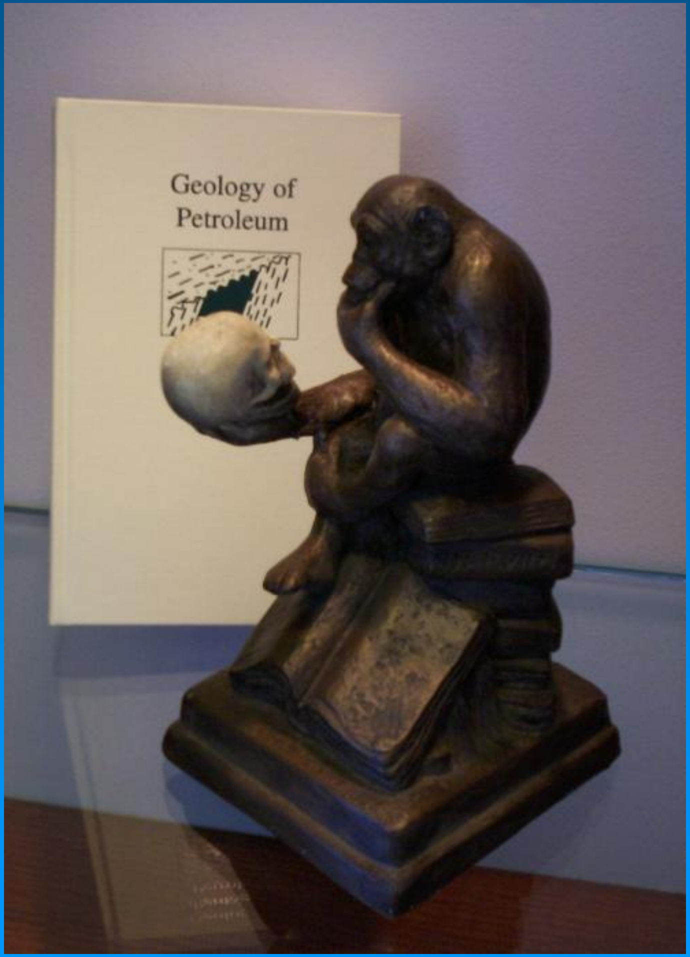
- What's old can be new when viewed from a different angle: horizontal versus vertical.
- Unconventional thinking is what we have been paid to do all along and maybe we just didn't realize it was "Unconventional."
- Thank you to a great Spyglass team: Shane Matson, Kim Tacket, Steve Tilley.
- Special 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!