Mississippian Oil Reservoirs in the Southern Midcontinent: New Exploration Concepts for a Mature Reservoir Objective*

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Abstract

The Mississippian has been a long sought-after reservoir objective in Kansas and Oklahoma, where it has produced several billion barrels of oil since early in the 20th century. Despite hundreds of thousands of wells having been drilled throughout these states into these rocks, their stratigraphy and fundamental controls on reservoir occurrence have remained elusive, enigmatic, and confusing for decades. Recent studies of outcrops of Lower Mississippian (Kinderhookian and Osagean) rocks in Missouri, Arkansas, and Oklahoma have clarified the lithostratigraphy and sequence stratigraphy of the section and have resulted in the generation of stratigraphic and structural exploration models that are directly applicable to the subsurface. Continued study and exploration of these rocks in the subsurface have further clarified regional lithostratigraphic relationships and have resulted in the identification of several hot, new plays that currently are the object of intense leasing and exploration throughout Kansas and Oklahoma. Such plays may very well extend into central and west Texas. In this article I illustrate what we have learned about the Lower Mississippian from outcrop studies, how outcrop models pertain to subsurface exploration, and describe the new Mississippian plays and their possible extension into Texas.
MISSISSIPPIAN OIL RESERVOIRS IN THE SOUTHERN MIDCONTINENT: NEW EXPLORATION CONCEPTS FOR A MATURE RESERVOIR OBJECTIVE

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REVISED REGIONAL PALEOFACIES MODEL

TRANSCONTINENTAL ARCH

KANOKA RIDGE

inner shelf

main shelf

shelf margin

Amarillo Arch

main shelf

novaculitic magnafacies

no upper Kindj Osage

BORDEN DELTA

OZARK DOME

200 mi
area of volcanic activity during the Mississippian

Transcontinental Arch

equator

Anadarko Basin

Caballos-Arkansas chert island chain
TYPE LOG, SOUTH-CENTRAL KANSAS
FORE-BULGE TECTONICS MODEL

S-SW

CONVERGENT PLATE BOUNDARY

reference sea level

FORE-DEEP

BACK-BULGE SHALLOW BASIN

uplift and marine to subaerial unconformities

accommodation increase and sediment thickening

ref point

CRATON-WARD

LOADING (COMPRESSIONAL) PHASE

down-lapping and dislodged beds

unconformity

uplift and subaerial unconformities

accommodation decrease and sediment erosion

LOAD-RELAXATION PHASE
LITHOSTRATIGRAPHIC REFLECTION OF 
SYNDEPOSITIONAL TECTONISM

Northward dipping, resedimented limestones 
in the Compton, including reefs

PROBABLY NOT MAJOR EXPLORATION OBJECTIVES
tectonically-displaced, northward downlapping beds with displaced reefs
LITHOSTRATIGRAPHIC REFLECTION OF SYNDEPOSITIONAL TECTONISM

- Northward dipping, resedimented limestones in the Compton, including reefs
  PROBABLY NOT MAJOR EXPLORATION OBJECTIVES

- Northward dipping Pierson Fm carbonates (limestones and dolomites) that are erosionally truncated along the north side of the Kanoka Ridge
  LIKELY EXPLORATION OBJECTIVE

14' porous Pierson dolomite

Northview
EROSION OF UPPER PIersen ON LOCAL SYNDEPOSITIONAL HIGHS, HIGHWAY 71, SW MISSOURI
LITHOSTRATIGRAPHIC REFLECTION OF SYNDEPOSITIONAL TECTONISM

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  LIKELY EXPLORATION OBJECTIVE

- In-place reefs in the Compton and Pierson Formations (which locally are oil-stained or oil-saturated on the outcrop)
  LIKELY EXPLORATION OBJECTIVES
Compton Reefs

marine-cemented but with clear evidence of subaerial exposure and leaching/porosity formation
also evidence of subaerial exposure and leaching/porosity formation...and oil-saturated on the outcrop
SUBSURFACE COMPTON & PIERSON REEFS?

WELL LOGS FROM NORTH OF THE KANOKA RIDGE, IN KANSAS, SHOWING POROSITY DEVELOPMENT IN THE COMPTON AND THE PIERSON -- PERHAPS REEFS?
LITHOSTRATIGRAPHIC REFLECTION OF SYNDEPOSITIONAL TECTONISM

- Northward dipping, resedimented limestones in the Compton, including reefs
  PROBABLY NOT MAJOR EXPLORATION OBJECTIVES

- Northward dipping Pierson Fm carbonates (limestones and dolomites) that are erosionally truncated along the north side of the Kanoka Ridge
  LIKELY EXPLORATION OBJECTIVE

- In-place reefs in the Compton and Pierson Formations (which locally are oil-stained or oil-saturated on the outcrop)
  LIKELY EXPLORATION OBJECTIVES

- Nearshore, shallow-marine carbonate and/or sandstone facies in the Northview Fm
  LIKELY EXPLORATION OBJECTIVES?
NEARSHORE FACIES IN THE NORTHVIEW FM

Burlington-Keokuk Limestone

Pierson Fm.

Northview Fm

with siltstone channels
anomalously thick, porous, nearshore sandstones and carbonate sands (e.g., oolites)?
LOCATION OF ALL THESE POTENTIAL PLAYS

thickened section of Northview with nearshore carbonate and siliciclastic reservoir facies

Pierson dolomite & erosionally truncated limestones

Compton & Pierson reefs
POST-ST. JOE TECTONIC AND DEPOSITIONAL HISTORY

KINDERHOOKIAN TO EARLY OSAGEAN (ST. JOE) TIME

periodically emergent but otherwise positive Kanoka Ridge

back-bulge basin with thickened St. Joe section

fore-bulge basin

LATER OSAGEAN COWLEY-REEDS SPRING TIME

FOUNDERING OF THE Kanoka Ridge

subsidence, deepening, & deposition of Cowley-Reeds Spring prograding wedges with internal unconformities and porous tripolite(s)

Kanoka Ridge still periodically active
LOCATION OF COWLEY-REEDS SPRING PLAY

**Cowley-Reeds Spring play area**
**WHAT IS THE COWLEY?**

It is a lithologic unit comprising bedded spiculites and lenses of spicule in a shale or lime mud matrix. The spicules are 100-120 microns long, and they are very difficult (to impossible) to see with typical well-site microscopes. The rocks typically are slightly dolomitic. The component spicules are siliceous, hence the rocks are siliceous but only rarely are they cherty (just below unconformities). Cross-sectional views of the spicules are common, and give the appearance of being silt grains... ...and that is why the rocks are often referred to as "silty cherts", or "silty dolomites", or ...EVERYTHING BUT WHAT THEY ARE!
The Cowley was deposited on a low-angle ramp that graded seaward from relatively shallow to deeper-water environments.

These facies prograded seaward as a series of separate, time-transgressive wedges.

Such progradation is indicated on log cross-sections as well as on seismic lines!
Reeds Spring cherty limestones

Compton Limestone

Northview Shale

Bedded spiculite

L/N/F spiculite & shale or limestone

Basinal shale or dark lime mudstone

Pre-Pennsylvanian unconformities

Northview Shale

Kinderhook shale

Pre-Pennsylvanian unconformities

Northview Shale

Kinderhook shale

Sea-level at time 1

Sea-level at time 2

TST deposits

Kinderhook Sh

Tripolite

Reeds Spring Lst

Burlington-Keokuk Lst

“Warsaw”

Short Creek Oolite Mbr

Compton Lst

Pierson Lst

Northview Fm

St. Joe Group

Southern KS & Northern OK

Then progradation of Cowley wedges

Then progradation of Cowley wedges

Resulting Cowley-Reeds Spring stratigraphic relationship

Downlap on TST deposits

MFS

Downlap onto thin shale or unconformity

MFS

Unconformity in ~the middle Reeds Spring, then sea-level rise

Then sea-level rise

~middle Reeds Spring unconformity

TST deposits

Sea-level at time 1

Sea-level at time 2

TST deposits

MFS

MFS

MFS

MFS
short and longer vertical fractures enhance the inherent low permeability of these rocks, within which thick sections of the Cowley can be perforated (depending on the amount of spiculite lenses). Porosity in the Cowley is inter-spicule, intra-spicule, and vuggy.
REEDS SPRING RESERVOIRS

tripolite at top of Reeds Spring: RESERVOIR FACIES!!!

organic-rich, petroliferous chert and lime mudstone: THE RESOURCE PLAY

LOCALLY TWO TRIPOLITES WITHIN THE SECTION

subaerial meteoric erosion

BURLINGTON - KEOKUK

un altered Reeds Spring

tripolite
top of Reeds Spring unconformity

intra - Reeds Spring unconformity

un altered Reeds Spring

tripolite

cycle 1
cycle 2

WHITE RIVER LOCALITY
Beau Morris for scale, circled in red.
...and locally 2 tripolites in the subsurface (at least in southern Kansas)

- Tripolite with micro-interparticle pores, spiculite molds, and vugs (from Glick Field in Kiowa Co., KS)
- Micro-porous tripolite with remnant light colored, hard chert (Glick Field, Kiowa Co., KS)
- Thin-section photomicrograph (crossed nicols) of tripolites with abundant micro-pores (arrows). 40x magnification

CORE SAMPLES OF TRIPOLITE
DIRECTIONS OF REEDS SPRING AND COWLEY PROGRADATIONAL WEDGES -- THAT DEFINE “BASIN COMPARTMENTS”
MAP VIEW OF INDIVIDUAL WEDGES (RESERVOIRS) IN THE REEDS SPRING OR COWLEY

width of wedges dependent on angle of dip, and if present, extent of intraformational erosion

down-dip pinchout
THE NEED FOR SAMPLES

WHICH FORMATION IS THIS?

Woodford
CONCLUSIONS

★ There are several different play types, and areas of most potential play occurrence, in Mississippian strata depending on for which formation or formations one is exploring.

★ Hence, one needs to identify which formation or formations is/are the reservoir objective(s).

★ Since formation identification cannot be done unequivocally based on logs, sample analysis is imperative (cores or cuttings).

★ Drill each Miss well into the Kinderhook Shale (if it’s present) so that you have that stratigraphic marker for formation identification and correlation.

★ Considering that the Miss is “all the same”, or simply referring to the section as “chat” or “Miss lime” no longer suffices in the exploration effort.