Controls on Hydrocarbon Entrapment and Reservoir Distribution: the Pennsylvanian Big Lime and Oswego Limestone in the Putnam Field Area, Anadarko Basin, Oklahoma

James R. Geary
Hess Corporation

February 25, 2008 – HGS North American Dinner Meeting
ACKNOWLEDGMENTS

• Baylor University
  – Dr. Stacy Atchley
• Apache Corporation
  – Brad Johnson
• Spartan Resources, LLC
  – Tim Munson
• Duncan Oil Properties
  – Brian Branesky
• Oklahoma Geological Survey
• Riley Electric Log
• Hess Corporation
Abstract

Putnam Field, located along the northern margin of the Anadarko Basin and extending through Custer and Dewey counties in western Oklahoma, USA, has produced over 400 BCF and 13 MMBO from the Pennsylvanian (Desmoinesian) Oswego Limestone and Big Lime. Hydrocarbons are stratigraphically trapped within phylloid algal mound complexes that are isolated within shallowing-upward parasequence sets; mound complexes generally trend west-east across the study area parallel to the northern structural margin of the Anadarko Basin. Reservoir quality within phylloid algal mounds is controlled by variations in the abundance of moldic, vuggy, and fracture pore types (average porosity = 2%, median permeability = 0.2 md). Eleven parasequence sets occur within the study interval and from the section base to top stack progradationally within the Oswego Limestone, and aggradationally to retrogradationally within the overlying Big Lime. The change from progradational to retrogradational stacking of parasequence sets most likely reflects an accelerating rate of subsidence during deposition that was induced by thrust-loading along the Ouachita foldbelt. Furthermore, retrogradational stacking within the Big Lime suggests that undiscovered hydrocarbon reserves may exist updip (northward) of the Putnam Trend in slightly younger deposits.

Detailed maps of structure, facies, gross pay, and pore volume were generated for each parasequence set, and compared with the spatial distribution of producing wells and their associated drainage radii. From these attributes, a geologic risk assessment was completed across the Putnam Trend to determine the most prospective areas for future step-out development.
PURPOSE

Determine the development potential within the Pennsylvanian Big Lime and Oswego Limestone of Dewey County, Oklahoma.
KEY QUESTIONS

• What is the depositional model and controls on reservoir quality?

• How are reservoir quality facies distributed within a three-dimensional framework?

• What are the most favorable geographic location(s) for future development potential?
HOLLIS BASIN

WICHITA MOUNTAINS

ANADARKO BASIN

NORTHERN SHELF

STUDY AREA

Vertical Exaggeration, 10X

(modified from Johnson, 1989)
• 1523 feet of core from 22 wells
• Analyzed 100 wells
<table>
<thead>
<tr>
<th>SYSTEM</th>
<th>SERIES</th>
<th>GROUP</th>
<th>FORMATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>PENNSYLVANIAN</td>
<td>MISSOURIAN</td>
<td>PLEASANTON</td>
<td>CHECKERBOARD</td>
</tr>
<tr>
<td></td>
<td></td>
<td>MARMATON</td>
<td>CLEVELAND</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>BIG LIME</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>OSWEGO</td>
</tr>
<tr>
<td>DESMOINESIAN</td>
<td></td>
<td></td>
<td>PRUE</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>VERDIGRIS</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>SKINNER</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>RED FORK</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>PINK LIME</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>INOLA</td>
</tr>
</tbody>
</table>

(modified from Derstine, 1989)
~ 700 wells in study area
~ 200 Big Lime and Oswego producers
Cumulative production exceeds 400 BCF & 14 MMBO
<table>
<thead>
<tr>
<th>Discovery Information Parameters</th>
<th>Reservoir Characteristics Parameters</th>
<th>Production Information Parameters</th>
</tr>
</thead>
<tbody>
<tr>
<td>Year discovered</td>
<td>Depth to reservoir 8120-9926 feet</td>
<td>Study area 201600 acres, 315 mi²</td>
</tr>
<tr>
<td>Initial producer</td>
<td>Average gross interval 123 feet</td>
<td>Estimated well count 700</td>
</tr>
<tr>
<td>Average elevation</td>
<td>Average porosity range 1-10%</td>
<td>Formaation value factor 1.697</td>
</tr>
<tr>
<td>Oil gravity</td>
<td>Average permeability range 0.01-10 mD</td>
<td>Recovery factor (gas) 0.88</td>
</tr>
<tr>
<td>Gas gravity</td>
<td>Average S_w 30%</td>
<td>Expansion factor 0.0038</td>
</tr>
<tr>
<td>Drive mechanism</td>
<td>Gravity</td>
<td>Cumulative production (as of 5/02)</td>
</tr>
<tr>
<td>Reservoir Pressure</td>
<td></td>
<td>Big Lime 239 MBO, 12 Bcf</td>
</tr>
<tr>
<td>Reservoir Temperature</td>
<td></td>
<td>Oswego 13MMBO, 395 Bcf</td>
</tr>
<tr>
<td>Trap</td>
<td></td>
<td>(Brown, 1963; Swanson, 1967; Zagaar, 1965; and IHS Energy)</td>
</tr>
</tbody>
</table>

1650 MCFD, 182 BOD
1901 feet
43°
0.7

201600 acres, 315 mi²
700
1.697
0.88
0.0038
KEY QUESTIONS

• What is the depositional model and controls on reservoir quality?

• How are reservoir quality facies distributed within a three-dimensional framework?

• What are the most favorable geographic location(s) for future development potential?
PELOID PACKSTONE
ENCrustING ALGAL BINDSTONE
PHYLLOID ALGAL FLOATSTONE/BAFFLESTONE
INTERMEDIATE SHALLOW

RUGOSE CORAL FLOATSTONE
INTERMEDIATE RESTRICTED
BLACK LAMINATED MUDSTONE OPEN
BLACK LAMINATED MUDSTONE RESTRICTED

(modified from Derstine, 1989)
BLACK LAMINATED MUDSTONE OPEN/RESTRICTED

- Dark gray to black laminated mudstone
- Open to restricted basinal environment, low energy
- “Poker chip”
INTERMEDIATE DEEP

• Gray to black wackestone to mudstone
• Low energy, open marine environment
• Minor amounts of:
  – Phylloid algae
  – Crinoid fragments
  – Rugose coral
  – Skeletal fragments
RUGOSE CORAL FLOATSTONE

- Dark gray to black rugose coral floatstone
- Associated within intermediate facies
- Low energy, open marine environment
- Crinoid fragments
INTERMEDIATE SHALLOW

- Light to dark gray wackestone to packstone
- Low to moderate energy open-marine platform
- Moldic and fracture pore types
- Structures include:
  - Organic binding
  - Stylolites
ENCRUSTING ALGAL BINDSTONE

- Moderate energy, open-marine platform
- Structures include:
  - Stylolites
  - Geopetals
  - Organic sediment binding
- Moldic and fracture pore types
PHYLLOID ALGAL FLOATSTONE / BAFFLESTONE

- Moderate energy, open-marine platform mound
- Structures include:
  - Organic sediment binding
  - Geopetals
  - Stylolites
- Moldic and fracture pore types
PELOID PACKSTONE

- Low to moderate energy, shallow subtidal to intertidal environment
- Fracture porosity
- Structures include:
  - Stylolites
  - Root traces
  - Laminae
KEY QUESTIONS

• What is the depositional model and controls on reservoir quality?

• **How are reservoir quality facies distributed within a three-dimensional framework?**

• What are the most favorable geographic location(s) for future development potential?
Progradational stacking of parasequence sets is characteristic of the platform adjacent the basin axis, and reflects subsidence rates exceeded by sedimentation.
Retrogradational stacking patterns common toward the basin axis and reflect subsidence rates exceeding sedimentation.
KEY QUESTIONS

• What is the depositional model and controls on reservoir quality?

• How are reservoir quality facies distributed within a three-dimensional framework?

• What are the most favorable geographic location(s) for future development potential?
FUTURE EXPLORATION AND DEVELOPMENT

• The occurrence of reservoir-prone phylloid algal facies within a retrogradational succession across the study area does not exclude the possibility that undiscovered gas reserves may still exist updip of the Putnam trend.
CONCLUSIONS

- Twelve depositional facies were recognized.
- Accumulated within basinal and platform interior environments (subtidal, intertidal and mound). Reservoir quality is preferentially associated within algal mound facies.
CONCLUSIONS

• Facies were partitioned within eleven parasequence sets. Parasequence set stacking controls the spatial distribution of reservoir facies and hydrocarbon distribution.