Understanding Mississippi Dolomite Reservoirs in Central Kansas

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We wish to acknowledge support by U.S. Department of Energy and Mull Drilling Company, Inc.

Kansas Geological Society Meeting, November 20, 2003
Focus on Facies in Dolomites

HIGHLIGHTS

- Petrophysical properties are facies dependent (original texture)
- Identifying facies critical to reservoir modeling and understanding
- Logs and sample descriptions are enablers
- Understanding leads to more effective exploitation

Note: Facies as used in this paper is the original facies, prior to dolomitization.

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23-16S-26W, Ness Co.
Significant Challenges

PROBLEMS

1. Limited amount of core
2. Relatively few deep penetrations hinders correlations
3. Diagenetic overprint
   - Early dissolution and extensive dolomitization
   - Micro and macro scale karst
4. Erosional truncation (angular unconformity)

TOOLS

1. Leverage available core
2. Sample descriptions (well cuttings)
3. By understanding relationships of primary facies, petrophysical properties and log response patterns one can better determine facies from limited data
Mississippi Dolomite: an Important Kansas reservoir

Pre-Penn. Subcrop Map of Kansas

Miss Oil Production in Green

From Mississippi
- 1 Billion BO Cum.
- 33% of Current

Gerlach, 1998

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Structural and Subcrop Setting

Modified after Gerlach, et al., 1998
Lower Mississippi Ramp Depositional Environments

Byrnes, Franseen, Watney and Dubois, 2003

Osagean depositional facies model. Spergen-Warsaw similar except for having less sponge and evaporite.
Facies and Petrophysical Properties

- Original Facies (primary texture and grain size) control pore geometry
- Pore geometry determines pore throat size which in turn controls permeability and capillary pressure relationships

FOR A SET OF ROCKS OF DIFFERING ORIGINAL FACIES BUT HAVING SAME POROSITY

Those with larger grains (and less mud), generally have larger pores, larger pore throats, lower threshold pressures for saturating the rock with oil and higher oil saturations for a given height above free water.

(Original texture (pre-dolomitization) indicated)

Byrnes, Franseen, Watney and Dubois, 2003

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Permeability vs Porosity

\[ k = A \phi^{3.45} \]

**Lithofacies**

<table>
<thead>
<tr>
<th>Lithofacies</th>
<th>A</th>
</tr>
</thead>
<tbody>
<tr>
<td>Packstone</td>
<td>0.00525</td>
</tr>
<tr>
<td>Pack-Wackestone</td>
<td>0.00150</td>
</tr>
<tr>
<td>Wackestone</td>
<td>0.00043</td>
</tr>
<tr>
<td>Mud-Wackestone</td>
<td>0.00012</td>
</tr>
<tr>
<td>Mudstone</td>
<td>0.00004</td>
</tr>
<tr>
<td>Shaly Mudstone</td>
<td>0.00001</td>
</tr>
</tbody>
</table>

**Multiplier**

|        | 3.5 |

**Curves Dependent on**

- ± 5X
- Lithofacies
- Grain type
  - Echinoderm
  - Sponge spicule
- Moldic content

*Work of Alan Byrnes*
Permeability vs Pore Throat Diameter

\[ y = 2.5959x^{0.4422} \]

\[ R^2 = 0.9286 \]

In situ Klinkenberg Permeability (md) vs Principal Pore Throat Diameter (\(\mu m\))

- **Miss. Packstones**
- **Miss. Mudstones**

- Undifferentiated Sandstones & Carbonates
- Lansing-Kansas City
- Mississippian

*Work of Alan Byrnes*  
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Capillary Pressure vs Lithofacies
(Example for porosity = 18%)

Modeled Pc & Height curves

Water Saturation (fraction)

In situ Oil-Water Capillary Pressure (psia)

In situ Height Above Free Water (ft)

Packstone
Pack-Wackestone
Wackestone
Mud-Wackestone
Mudstone

13% 20% 33% 56% 95%

Work of Alan Byrnes
Core Facies to Log Curve Patterns

#6-23 Boyd, 23-16S-26W

Mississippian

Dolomite

Appx. O/W Contact

5FT CGO, 221FT
OCM, 94FT SOCM;
1076-931#

4600 30 20 15 10 5

Pay

Grnst  Pkst  Wkst  Mdst

Subsequent Slides, top to bottom
Mudstone-Wackestone

4548 (log)

Phi  20.6 %
Perm  5.05 md
Dens  2.84 g/cc
Sw %  63% (log)

1 cm
Packstone-Grainstone

4551 (log)

Phi 27.9%
Perm 350.7 md
Dens 2.84 g/cc
Sw % 29% (log)
Mudstone

4561 (log)
Phi 17.6%
Perm 0.7 md
Dens 2.81 g/cc
Sw % 78% (log)

1 cm
Packstone-Wackestone

(Representative sample. Not from this core.)

Byrnes, Franseen, Watney and Dubois, 2003

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Log curves and samples provide clues to facies and layering

Excerpts from sample descriptions

- LS, off-wh, foss
- Dol, gray, vfxln and dol sucrosic, strks w/ stn and ssfo
- Dol, brwn stnd, vfxln, gd vuggy por, ssfo
- Dol, brwn stnd, vfxln, fr-gd vuggy por, fr-gd sfo, fr odor

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Sw calculations consistent with interpreted facies

Zones that could be perforated

<table>
<thead>
<tr>
<th>Probable Facies</th>
<th>Phi</th>
<th>Rt</th>
<th>Archie SW</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wk-Pkst</td>
<td>0.18</td>
<td>17</td>
<td>0.467</td>
</tr>
<tr>
<td>Mudstone</td>
<td>0.19</td>
<td>7</td>
<td>0.689</td>
</tr>
<tr>
<td>Wk-Pkst</td>
<td>0.2</td>
<td>15</td>
<td>0.447</td>
</tr>
<tr>
<td>Mudstone</td>
<td>0.2</td>
<td>5</td>
<td>0.775</td>
</tr>
<tr>
<td>Packstone</td>
<td>0.19</td>
<td>18</td>
<td>0.430</td>
</tr>
</tbody>
</table>

Rw = 0.12
m & n = 2

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Bypassed pay in Pfannenstiel 2-24

Mississippi (Spergen)

Warsaw?

O/W

1975 perfs

2001 perfs

Pay
Recognition of log responses to facies enables correlations for more effective geomodels and simulations.
Ness City North Cellular Models

Facies recognition is critical to reservoir characterization, geomodeling and reservoir simulation.

4-Layer Model, 110 foot grid cells

Work of Saibal Bhattacharya
Reservoir Heterogeneity

Strong Horizontal Heterogeneity
- 10’ - 100’ Interval
- Karst Controlled
- Result Poor Lateral Drainage

Solution enhanced, shale-filled, vertical fractures (feet to tens of feet) are additional complexities to consider.
Concluding Remarks on Mississippi Dolomites, Central Kansas

- Understanding finer scale facies geometries of reservoir units is desirable and possible
- Facies (original texture) and rock properties are intrinsically linked
- Electric log curve patterns aid facies recognition especially when augmented with cuttings descriptions
- Better facies models enables more effective exploitation of Mississippian Dolomite reservoirs

We wish to acknowledge support by U.S. Department of Energy and Mull Drilling Company, Inc. and we thank other “Mississippi scientists”, Lynn Watney, Tim Carr, Evan Franseen and Paul Gerlach, from whom we borrowed heavily.