BETTER THAN A POROSITY CUT-OFF: THE ROCK FABRIC APPROACH TO UNDERSTANDING POROSITY AND PERMEABILITY IN THE LOWER CLEAR FORK AND WICHITA

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PROBLEMS WITH USING POROSITY CUT-OFFS IN CARBONATES

- Selecting cut-off
- Varying fabrics
- Varying lithologies
- Porosity ≠ permeability
EXAMPLES: POROSITY ≠ PERMEABILITY

Grain-dominated dolopackstone
- Interparticle porosity

FCU 5927: 6930'

\[ k = 2.21 \text{ md} \]
Both \( \phi = 9.64\% \)

Lime grainstone
- Separate vug porosity

FCU 5927: 6924'

\[ k = 0.33 \text{ md} \]

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EXAMPLES: POROSITY ≠ PERMEABILITY

Grain-dominated dolopackstone
- Interparticle porosity

\[ \phi = 14.26\% \]
\[ k = 33.7 \text{ md} \]

Lime grainstone
- Separate vug porosity

\[ \phi = 14.46\% \]
\[ k = 0.94 \text{ md} \]

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THE ROCK FABRIC APPROACH

- Thin section calibration

- Lithology, fabric, pore type and crystal size

- Multiple porosity-permeability transforms based on petrophysical class

- High-quality data set: thin sections and core analysis from same sample
GLOBAL POROSITY–PERMEABILITY TRANSFORMS NONVUGGY CARBONATES

Global transform equation: \( \log_{10}(k) = (9.7982 - (12.0838 \times \log_{10}(\text{RFN}))) + (8.6711 - (8.2965 \times \log_{10}(\text{RFN}))) \times \log_{10}(\phi) \)
SAMPLING TECHNIQUE

• Foot-by-foot samples
  – Unbiased sample location, e.g., center of each foot in the center of the core
  – Slightly adjust locations to avoid fractures and large anhydrite nodules

• Cut plugs with wafer for thin section from end

• Reputable core analysis with careful cleaning
QUAILITY OF CORE ANALYSIS

Large low porosity data cloud

Few points in this area

Poor quality

Good quality

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CORE SAMPLED

- FCU 5927 plus FCU 6429 for continuous foot-by-foot record
- Rock fabric calibration
- Saturation model
THIN SECTION DESCRIPTION

• Lithology and mineralogy
  - 80% dolomite or more = dolostone
  - <80% dolomite = limestone
  - Percent anhydrite

• Pore type percentages
  - Interparticle (intergrain, intercrystalline)
  - Separate vug (moldic, intrafossil)
  - Touching vug (fenestral, fracture)

• Rock fabric
  - Grainstone, grain-dominated packstone, mud-dominated packstone, wackestone, mudstone
  - Grain- or mud-dominated tidal flat facies, brecciation

• Measure dolomite crystal size

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DOLOSTONE PETROPHYSICAL CLASSIFICATION

- Grain or mud-dominated fabric?
- Measure crystal size

<table>
<thead>
<tr>
<th>Grain-dominated</th>
<th>Mud-dominated</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grainstone = class 1</td>
<td>&gt;100 μm = class 1</td>
</tr>
<tr>
<td>Gddp = class 2</td>
<td>20-100 μm = class 2</td>
</tr>
<tr>
<td>&gt;100 μm = class 1</td>
<td>&lt;20 μm = class 3</td>
</tr>
</tbody>
</table>
ALL DOLOSTONE SAMPLES FROM FOOT-BY-FOOT CALIBRATION

To use petrophysical classification in modeling:

• Relate to stratigraphic framework
• Assess both vertical and lateral variations
• Calculate transforms

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DOLOSTONE CLASSIFICATION RELATED TO STRATIGRAPHY

- L2.2 Lower Clear Fork
- L2.1 Lower Clear Fork
- L1 Wichita mudstones

- RFN 2 transform for sequence L2.1
- RFN 3 transform for L1 Wichita
- Statistical transform for sequence L2.2

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ROLE OF POIKILOTOPIC ANHYDRITE IN L2.2 DOLOSTONES

L2.2 dolostones are class 2 but many plot as class 1 due to poikilotopic anhydrite

Statistical transform for sequence L2.2

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POIKILOTOTOPIC ANHYDRITE IN THIN SECTION

Reduced porosity, permeability maintained

Anhydrite filling interparticle porosity in some areas only

FCU 6429: 6845°, φ = 8.1%, k = 9.02 md
LIMESTONE PETROPHYSICAL CLASSIFICATION

• Grain or mud-dominated fabric?

• If grain-dominated:
  Grainstone = class 1
  Grain-dominated packstone = class 2

• If mud-dominated:
  Mud-dominated packstone, wackestone, mudstone = class 3
L2.2 LIMESTONE SAMPLES

Class 1 and 2 samples tend to be moldic and do not plot in expected regions.

Class 3 data plots in class 3 field.

-RFN 2 transform

-RFN 3 transform

- Class 1 and 2 samples tend to be moldic and do not plot in expected regions.
- Class 3 data plots in class 3 field.
SPECIAL CONSIDERATIONS FOR MOLDIC LIMESTONES

- Rock fabric approach assumes all porosity to be interparticle
- Limestones commonly moldic (separate vug porosity)
- Will plot as lower class than expected due to separate vugs
- May require special transform

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DISTINCT INTERVAL OF MOLDIC LIME GRAINSTONES IN L2.2, NW AREA ONLY

- Samples are moldic and plot in a lower class region than expected
- Special transform required for this distinct interval in mapped area

Lime grainstones would normally plot in this region

RFN 2.5 transform

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TIDAL FLAT FACIES

- Generally separate vug porosity (molds) or touching vug porosity (fenestrae)
- Poor or little continuity
- Anhydrite or late calcite plugging much of porosity
- Small crystal size (<20 μm)
TIDAL FLAT FACIES
BRECCIAS

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BRECCIAS

- Extremely variable and unpredictable
- Anhydrite or late calcite filling most or all space between lithoclasts
- Small crystal size (<20 microns)
- Fracture porosity?
BRECCIAS

No suitable transform

Highly varied porosity-permeability relationship

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CONCLUSIONS

• Rock fabric approach yields improved understanding of porosity-permeability relationship

• Lower Clear Fork and Wichita reservoirs consist of mostly petrophysical classes 2 and 3
  – Class 2 rocks are grain-dominated and medium crystal dolostones
  – Class 3 rocks are mud-dominated dolostones, mud-dominated limestones, and tidal flat facies

• Special consideration must be given to grain-dominated limestones (moldic) and dolostones with poikilotopic anhydrite