How Artificial Fractures and Bedding Plane Influence the Fluid Movement in the Fracture-Matrix Dual-Connectivity System of Barnett Shale*

Qiming Wang1*, Xiaoming Zhang1,2, Qinhong Hu1, and Xiang Lin1,2

Abstract

Barnett Shale outcrop samples were collected. Artificial fractures were created with different apertures. Co-current spontaneous imbibition tests were conducted. Fluid leak-off demonstrated in laboratory was studied. Fluid flow was examined in the directions of both parallel and transverse to the bedding plane. Fluid flow was isolated in fracture, bedding plane, and the matrix.

References


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• Co-current spontaneous imbibition tests conducted
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Study Area

Methods & Workflow

Imbibition setup

Figure A. Lithofacies distribution in the San Saba area (modified from USGS TWSC, 2014). B. Stratigraphy cross-section of Fort Worth Basin (modified from Gasparrini et al. 2014). C. Structure map of Fort Worth Basin (modified from Loucks and Ruppel, 2007)

Theory

The wetting front in vertical direction for rocks with well-connected pore space is proportional to the square root of time: 1–t0.5 (Handy, 1960).

\[
l = \frac{V_{imb}}{A} = t^{0.5} \sqrt{\frac{2P_c k_w \phi S_w}{\mu_w}}
\]

l: wetting front, cm
V_{imb}: imbibed water volume, cm³
A: bottom area of sample, cm²
t: time of imbibition, s
P_c: capillary pressure, Pa
k_w: permeability to water, md
\phi: porosity, fraction
\mu_w: water viscosity, Pa.s

According to Hu et al. (2012), pore connectivity can be assessed from the slope of imbibition height vs. time in log-log scale:

- > 0.5: good connectivity
- 0.5~0.26: intermediate connectivity
- <0.26: poor connectivity

Results

Siliceous & Clay-rich (S&C) Sample Photos

Sample information

<table>
<thead>
<tr>
<th>Sample ID</th>
<th>Diameter (cm)</th>
<th>Height (cm)</th>
<th>Porosity (%)</th>
<th>Bulk density (g/cm³)</th>
<th>Grain density (g/unit)</th>
</tr>
</thead>
<tbody>
<tr>
<td>S&amp;C 1-T</td>
<td>2.504</td>
<td>2.021</td>
<td>13.775</td>
<td>1.809</td>
<td>2.167</td>
</tr>
<tr>
<td>S&amp;C 1-P</td>
<td>2.505</td>
<td>2.317</td>
<td>13.037</td>
<td>1.855</td>
<td>2.133</td>
</tr>
<tr>
<td>S&amp;C 2-T</td>
<td>2.505</td>
<td>2.227</td>
<td>12.452</td>
<td>1.849</td>
<td>2.112</td>
</tr>
<tr>
<td>S&amp;C 2-P</td>
<td>2.502</td>
<td>2.195</td>
<td>12.690</td>
<td>1.875</td>
<td>2.147</td>
</tr>
</tbody>
</table>

Mineral compositions

<table>
<thead>
<tr>
<th>Sample ID</th>
<th>Quartz</th>
<th>Orthoclase</th>
<th>Plagioclase</th>
<th>Calcite</th>
<th>Fluorapatite</th>
<th>Clay Minerals</th>
</tr>
</thead>
<tbody>
<tr>
<td>S&amp;C 1</td>
<td>37.5</td>
<td>0.7</td>
<td>0.9</td>
<td>5.3</td>
<td>13.8</td>
<td>41.8</td>
</tr>
<tr>
<td>S&amp;C 2</td>
<td>44.8</td>
<td>1.4</td>
<td>1.8</td>
<td>4.1</td>
<td>4.5</td>
<td>43.5</td>
</tr>
</tbody>
</table>

Sample top after 24 hours imbibition

<table>
<thead>
<tr>
<th>Sample ID</th>
<th>Original (non-fractured) sample</th>
<th>Fractured sample</th>
<th>Fractures-glued sample</th>
</tr>
</thead>
<tbody>
<tr>
<td>S&amp;C 1</td>
<td></td>
<td>Fractured sample</td>
<td></td>
</tr>
<tr>
<td>S&amp;C 2</td>
<td></td>
<td>Fractured sample</td>
<td></td>
</tr>
</tbody>
</table>
The outcrop Barnett S&C sample is well laminated.

**S&C 2T**

- Similar imbibition behavior indicating the wetting front cannot reach the artificial fracture

**S&C 1P**

- Fluid flows which FA=0 is similar as it in the unfractured sample
- When FA>0, the imbibed water volume show a large increase and the pore connectivity changes from intermediate to good connection

**S&C 2P**

- Channels for fluid flow in different samples:
  - Original (non-fractured): bedding plane and the matrix
  - Fractured: artificial fracture, bedding plane, and the matrix

**Conclusions**

- In original condition, the bedding planes provide preferential pathways for fluid flow
- Artificial fractures provide preferential pathways but limited storage space, while the matrix provides extra surface area for fluid imbibition
- The fluid flow stages in fractures, bedding planes, and the matrix can be delineated

**References**


Handy, L. L., 1960. Determination of effective capillary pressures for porous media from imbibition data. Transition of the AIME, 219, 01, 75-80.


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