Proppant/Rock Interactions

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Proppant / Rock Interactions

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**What is proppant?**

- Injected during hydraulic fracturing to maintain permeability following stimulation
- Intent to flow/place proppants into tributary fractures from main perforations and wellbore
- Typically sand but can be a combination of novel materials
  1. Sand, resin coated sand, ceramics, coated ceramics
- Variable mesh size and shape (sphericity & roundness)

<table>
<thead>
<tr>
<th>Mesh</th>
<th>70/140</th>
<th>20/40</th>
<th>10/20</th>
<th>8/12</th>
</tr>
</thead>
<tbody>
<tr>
<td>Screen (mm)</td>
<td>0.11 – 0.21</td>
<td>0.42 – 0.84</td>
<td>0.84 – 2</td>
<td>1.68 – 2.38</td>
</tr>
</tbody>
</table>

[https://www.energy.gov/fe/hydraulic-fracturing-technology](https://www.energy.gov/fe/hydraulic-fracturing-technology)
Experimental Goals & Intent

- Geochemical interactions in fractured unconventional reservoirs
- Proppant embedment/impingement and the influence of hydrofracturing additives
- Characterization of proppant behaviors under in-situ stress regimes in unconventional reservoir rock
- Time Permitting: Additional unconventional reservoir research
Geochemical Interactions

Test conditions set to approximate Marcellus shale reservoir conditions:
- Temperature 150°F (65.6°C)
- Confining (overburden) pressure 3,000 PSI (20.68 MPa)
- Pore pressure 2,800 PSI (19.3 MPa)
- Inject rate (Q) of 0.03 ml/min
- Injection bottle purged with N₂ to prevent oxidation

Aqueous Sampling:
- Samples collected at 2, 24, 48, 72, and 96 hours after injection start
- Aqueous samples analyzed by/for:
  1) Inductively Coupled Plasma Mass Spectroscopy (ICP-MS)
  2) Inductively Coupled Plasma Optical Emission Spectroscopy (ICP-OES)
  3) Ion Chromatography (IC)
  4) pH

Cores drilled to 4” x 1.5” and Brazilian fractured

Fractured

Proppant loaded
Proppant Embedment

- Marcellus shale, Bakken shale, Eagleford shale
- Confining pressure up to 3000 psi (20.9 Mpa), pore pressure <20 psi, room temperature, brine as pore fluid in second series with 5% KCl
- Tested wet and dry systems to evaluate impacts of hydration on embedment
- Saw cut fracture
- Results of dry and wet experiments show some proppant embedment in CT images and SEM

3 images below: Proppant embedded in core (reflected light)

![Mid Bakken](image)
![Eagleford](image)
![Marcellus](image)

Broken proppant (CT image)

SEM of same samples

![Mid Bakken Edge](image)
![Eagleford](image)
![Marcellus](image)
Proppant Embedment

- Marcellus shale from (MSEEL.org) MIP 3H well in Morgantown, WV, depth 7,488 feet
- Experiments under dry conditions, wet (deionized water) and exposed to fracturing fluid
- 2,400 psi (16.5 Mpa), room temperature
- Results of dry, DI wet and fracturing fluid exposure all show proppant embedment and gouging;
  highest density of embedment in samples exposed to fracturing fluid
- Secondary fractures form at site of proppant impingement
Collaborative study with LLNL to evaluate proppant movement and behavior under loading (Walsh et al. 2016)

I. Marcellus shale was artificially fractured with Brazilian technique

II. Resin-coated proppant 20-40 Mesh (⌀ ≈ 0.59 mm)

III. Sample was loaded into a Hassler style core holder within the industrial CT scanner at NETL

IV. Sample was stressed in sequential steps up to 10,000 PSI
   a. Samples were CT scanned at each step
   b. Relative slip was measured at each step (shear)
   c. Image registration and PIV was utilized to evaluate proppant movement
Stress Effects on Proppant Behavior Cont.

Event between 6,000 & 7,500 PSI
- Triggered large scale proppant movement
- Proppant motion reflects reorganization into more stable configuration
- No further motion between 7,500 and 10,000 PSI

Aperture reduction between 100 and 7,500 PSI

Relative motion vector between 100 and 7,500 PSI

Images modified from (Walsh et al. 2016)
Enhancing Hydrocarbon Recovery through Fundamental Knowledge of the Reservoir and Well System

Improve Fundamental Understanding of Shale to Enable Decision-Making for Enhanced Hydrocarbon Recovery

Ensure Wellbore Integrity during Drilling, Completions, and Production

Enhanced Recovery

Geomechanics
- Review of existing literature characterized data gap for laboratory experimental data needed to predict field performance of enhanced oil recovery techniques in shales
- How do geomechanical processes affect flow through fractures?
- Laboratory-based studies to address:
  - What is the impact of shale microfabric on sheared fracture alteration?
  - How do proppant embedment and clay/kerogen content influence shale fracture closure?
- Core characterization and cataloguing

Coupled Effects of Mechanics + Chemistry
- Which micro-scale geomechanical processes affect reservoir-scale processes (focus on HFTS)?
- Multilab Project – LBNI, LLNL, SLAG, NETL
- How effective are CO2 and natural gas in enhancing oil recovery from the Wolfcamp Shale (HFTS)?

Fracture Modeling
- How can dynamic pressure and temperature changes during hydraulic fracturing and primary production be incorporated into Nflow?

Coupled Effects of Chemistry + Biology
- When do geochemical and geological processes take precedence – during hydraulic fracturing or production (focus on HFTS)?
- Collaboration with GTI

Geology
- How can geophysical signals be better leveraged to develop an improved understanding of near-well fracture networks and hydrocarbon recovery?

Geophysics
- How do dynamic changes in pressure and temperature affect steel-cement-rock interfaces during the well’s lifetime?

Maximizing Hydrocarbon Value and Produced Water Beneficial Use

Current: Application of systems analysis to evaluate successful end-use strategies for hydrocarbons and water produced from the well.
Future: Leverage experimental and field capabilities to confirm results.
Resulting Data

Combined logs

Measurements performed at the US Department of Energy
National Energy Technology Laboratory
Morgantown, WV 2018

Analysis By: Dustin Crandall, Jonathan Meals,
and Jared Sine
Data Collection: Paige Mackey, Thomas Parahnian,
and Scott Weston
Project Oversight: Dustin McKenzie and Philip Dilloway

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Collaboration Opportunities

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Faculty

Postdoctoral

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Office of Science Graduate Student Research (SCGSR) Program