Frac Fluids on Organic Shales: What We Know, What We Don’t, and What Can We Do About It

George Waters, Schlumberger
Frac Fluids on Organic Shales: What We Know

First of All: Hydraulic fracturing with large volumes of water works!
Frac Fluids on Organic Shales: What We Know

Shales are Reactive

Introduction of fresh water brings the system into non-equilibrium:
- Fluid Imbibition and Leakoff
- Chemo – Mechanical Rock Alteration
- Salt Diffusion
- Mineral Dissolution and Reprecipitation
Frac Fluids on Organic Shales: What We Know

Frac fluid imbibes into rock matrix

Slide 4
Frac Fluids on Organic Shales: What We Know

Imbibition reduces matrix permeability (but it can recover with time)
Imbibition is a function of mineralogy
Imbibition alters the rock
Frac Fluids on Organic Shales: What We Know

Imbibition alters the rock

Eagle Ford Shale Creep

URTeC 167245

SPE 171569

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Frac Fluids on Organic Shales: What We Know

Pore throats are small
- Fraction of a micron
Frac Fluids on Organic Shales: What We Know

Capillary Pressures are High

Can be thousands of psi:
- Variable contact angles (wettability)
- Small pore throat radii (fraction of microns)
- Variable surface tension
  - Surfactants?

\[ P_c = L \rho g = \frac{2 \gamma \cos \theta}{r} \]

\( \gamma \) – Surface Tension
\( \theta \) – Contact Angle
\( r \) – Capillary Tube (Pore Throat) Radius
Frac Fluids on Organic Shales: **What We Know**

Shales have a Variety of Pore Systems: Mixed Wettability

- 1a – Water saturated inorganic pore
- 1b – Water wet, gas saturated inorganic pore
- 2a – Gas in fractures
- 2b – Water in fractures
- 3 – Gas in organic pores

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Eagle Ford Shale
- Organic Pores
- Conventional Pores

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Williams (2012)
Frac Fluids on Organic Shales: What We Know

High Salinity Environment: Desiccated Marine Shales

Graph showing TDS (mg/L) and Flow (bpd) over time for different wells.

SPE Asia Pacific Hydraulic Fracturing Conference

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Frac Fluids on Organic Shales: What We Know

A lot of scale can form quickly: Sulphates, Salts…
Frac Fluids on Organic Shales: What We Don’t Know

How do we quantify frac fluid compatibility?
- Qualitative indicators only

Fluids must be low viscosity and conductive
Relevant for flowing fluids only

Capillary Suction Time
Roller Oven

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Frac Fluids on Organic Shales: What We Don’t Know

How do we quantify frac fluid compatibility?
- Alternative procedures
- Test before and after water exposure

<table>
<thead>
<tr>
<th>Sample</th>
<th>Hardness Pre</th>
<th>Hardness Post</th>
<th>Hardness Ratio</th>
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</thead>
<tbody>
<tr>
<td>Pierre</td>
<td>5.37</td>
<td>1.42</td>
<td>0.26</td>
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<tr>
<td>Mancos</td>
<td>9.70</td>
<td>7.08</td>
<td>0.73</td>
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<tr>
<td>Fayetteville</td>
<td>3.55</td>
<td>1.63</td>
<td>0.46</td>
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Hardness = \( \frac{L}{(\pi)(B)(Pen)} \)

- L – Applied Load (kg)
- B – Ball Diameter (mm)
- Pen – Ball Penetration (mm)
Frac Fluids on Organic Shales: **What We Don’t Know**

Does imbibition impact:
- Frac geometry?

Imbibition dramatically reduces effective stress ($\sigma_n'$).

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Frac Fluids on Organic Shales: What We Don’t Know

Does imbibition impact:

- Casing integrity?
Frac Fluids on Organic Shales: What We Don’t Know

Where is all the frac water?
- In the matrix?

Amount of Water Imbibed into Pore System

- Injected Volume = 20,000 m³
- Hydraulic Frac Width = 0.50 cm
- Frac Surface Area = 4,000,000 m²
- Effective Porosity = 8%
- Initial Sw = 30%
- Imbibed Sw = 80%
- Imbibed Length = 15 mm
- Volume of Imbibed Pore System = 60,000 m³
- Pore Volume = 4,800 m³
- Imbibed Volume = 2,400 m³

Imbibed Volume as a % of Injected Volume = 12%
Frac Fluids on Organic Shales: What We Don’t Know

Where is all the frac water?
- In hydraulic fractures?

Amount of Water Imbied into Pore and Hydraulic Fracture System

- Injected Volume = 20,000 m³
- Hydraulic Frac Width = 0.50 cm
- Frac Surface Area = 4,000,000 m²
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- Volume of Imbibed Pore System = 60,000 m³
- Pore Volume = 4,800 m³
- Imbibed Volume = 2,400 m³
- Imbibed Volume as a % of Injected Volume = 12%
- Residual Frac Width = 0.125 mm
- % of Water Trapped Hydraulic Fracture = 20%
- Volume of Trapped Water = 100 m³
- % of Injected Water that is Trapped = 0.5%

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### Frac Fluids on Organic Shales:

**Where is all the frac water?**

- In natural fractures?

#### Amount of Water Imbibed into Pore, Hydraulic and Natural Fracture Systems

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<td>Natural Fracture Width</td>
<td>0.075 mm</td>
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<tr>
<td>% of Injected Water that is Trapped</td>
<td>20%</td>
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<tr>
<td>Required Natural Fracture Area</td>
<td>5.3E+07 m²</td>
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Frac Fluids on Organic Shales: What We Don’t Know

How does the residual water impact well performance?
• Is water a “proppant?” – SPE 147603
• Does water reduce fracture conductivity?

Barnett Shale Conductivity Test

SPE 173473

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Frac Fluids on Organic Shales: What We Don’t Know

How does the residual water impact well performance?

• Does water reduce effective fracture height?
Frac Fluids on Organic Shales: What Can We Do About It?

Frac Fluid and Additive Selection:
- Produced water
  - Inherently compatible
  - Potential additive compatibility
- Wettability
  - Water wetting surface tension reducers
    - Lower capillary pressure, but increases leakoff
  - Hydrocarbon wetting surfactants
    - Leakoff into organic pores: good or bad?
- Inhibitors
  - Scale and salt
- Organic solvents
  - Bitumen removal
Frac Fluids on Organic Shales: What Can We Do About It?

Frac Fluid and Additive Selection:
- Nonaqueous frac fluids
  - Crude oil, diesel, LPG, CO$_2$, CH$_4$...
Frac Fluids on Organic Shales: What Can We Do About It?

Early Flowback
• Minimize time of imbibition, osmotic forces…

Extended Shut Ins
• Allow time for recovery of effective permeability as Sw declines

Surfactants more appropriate for extended shutins
• Accelerate relative permeability recovery
Frac Fluids on Organic Shales: *What Can We Do About It?*

Manage drawdowns to minimize effective stress on pores and proppant

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*Organic Shale Permeability Decline*

*Hydraulic Fracture Conductivity Decline*
Frac Fluids on Organic Shales: **What Can We Do About It?**

Lateral landing point selection

Eagle Ford Shale Ash Beds

- Smectite-rich altered ash beds (0.1 inch)
- Kaolinite-rich altered ash beds (0.1 inch)
- Smectite-rich altered ash beds (0.2 inch)
- Kaolinite-rich altered ash beds (0.1 inch)
Summary and Conclusions

What We Know:
- Current industry practices have worked
- But we know all of the hydraulic fracture does not produce

What We Do Not Know
- Where is all the frac water
- What impact is it having on productivity

What Can We Do About It?
- Industry standard practices for tight sand fracturing are applicable to shales
  - Propped fractures
  - Managed drawdowns
Thank You and Questions?