Poroelastic aspects of fracture transport as a function of shear displacement

Yves Gensterblum and Mark Zoback

Transport properties of fractures
Geomechanics, CCS and shale gas

- How likely is it that the change in pressure resulting from CO₂ injection induces slip on faults?
- How much CO₂ would leak out along re-activated fracture?
- How does the clay content influence the transport properties?
- How does induced slip affect permeability during shale gas production?

Fracture illustrated by using an asperity model

- Low normal stress → high pore pressure → Easy to slide
- High normal stress → Low pore pressure → hard to slide
- Normal stress
  - High pore pressure
  - Low pore pressure
- Shear stress
Field scale
mechanically active ≈ hydraulically active

Townend and Zoback, 2001

Previous work

Laboratory testing of sheared joints in...

Granite (very low porosity <1%)

Conf. pressure

Sandstone (porosity = ~10%)

Increase in fracture permeability with shear deformation

Decrease in fracture permeability with shear deformation

Chen et al., Int. J. of Rock Mechanics & Mining Sciences (2000)

Teufel, ARMA (1987)
**Experimental approach**

Confining pressure (MPa)
Mean pore pressure (MPa)
Fracture displacement (mm)

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**Haynesville shale**

<table>
<thead>
<tr>
<th>XRD Data (wt%)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Quartz</strong></td>
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<td><strong>Calcite</strong></td>
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**Eagle Ford shale**

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**Experimental approach**
Apparent permeability

constant confining stress of 7.5 MPa

argon
carbon dioxide
argon (post CO2)
CO2

Apparent permeability as a fn of shearing

constant confining stress of 7.5 MPa

11% clay
22% clay

Eagle Ford
Haynesville
Poroelasticity of fracture transport

Normal stress

High pore pressure

Low pore pressure

Argon poroelasticity of fracture flow

\[ k = k_0 e^{-c \sigma_{\text{eff}}} \]
Argon poroelasticity of fracture flow

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<th>Shear displacement (mm)</th>
<th>Fracture compressibility (MPa$^{-1}$)</th>
<th>Intrinsic permeability (mD)</th>
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<tr>
<td>0</td>
<td>0.082 ± 0.008</td>
<td>162.6 ± 32</td>
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<td>0.29 ± 0.03</td>
<td>0.072 ± 0.023</td>
<td>5.8 ± 1.5</td>
</tr>
<tr>
<td>0.87 ± 0.03</td>
<td>0.103 ± 0.008</td>
<td>2.8 ± 0.5</td>
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CO$_2$ permeability stress equilibration

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<th>Fracture compressibility (MPa$^{-1}$)</th>
<th>Intrinsic permeability (mD)</th>
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<tbody>
<tr>
<td>0</td>
<td>0.091 ± 0.011</td>
<td>38.8 ± 32</td>
</tr>
<tr>
<td>0.29 ± 0.03</td>
<td>0.104 ± 0.023</td>
<td>5.8 ± 1.5</td>
</tr>
<tr>
<td>0.87 ± 0.03</td>
<td>0.095 ± 0.017</td>
<td>1.2 ± 0.5</td>
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</table>
Poroelasticity with fracture displacement

Gas type sequence:
1) Argon
2) CO2
3) Argon
4) Argon
5) CO2

Poroelasticity with fracture displacement

Eagle Ford

Haynesville

22% clay

11% clay
**Interpretation hypothesis**

\[
a(z, t(\sigma)) = a_{\text{hydraulic}}(z, t)
\]

\[
a_{\text{hydraulic}}(z, \sigma_{\text{eff}}) \propto k(z, \sigma_{\text{eff}})
\]

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**Geomechanics, CCS and shale gas**

- How likely is that the change in pressure resulting from CO\(_2\) injection induces slip on faults?
- How much CO\(_2\) would leak out along re-activated fracture?
- How does the clay content influence the transport properties?
- How does induced slip affect permeability during shale gas production?
Thank you very much for your attention!