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What Does a CO₂ Plume Look Like: Implications for Geophysical Monitoring

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Carbon Dioxide Capture and Geologic Storage is one Way to Reduce Emissions
Some Key Questions

- What fraction of the pore space is used for CO₂ storage?
- How far has the CO₂ move from the injection site?
- Has CO₂ leaked out of the storage reservoir?
- Geophysical monitoring is the primary tool used to answer these questions

So, what does a CO₂ plume look like?
Examples: Seismic Data Collected at Sleipner

From IPCC, 2005, after Chadwick, 2004
Frio Formation
Cross-well Seismic Data

From T. Daley, LBNL
Multi-Phase Flow Dynamics
Key to “What a Plume Looks Like”

At the pore scale, CO₂ occupies the large connected pores. Water occupies the small pores.

Micro-tomogram of a CO₂ and water-filled rock: From L. Tomutsa, LBNL
Schematic of Multi-Phase Flow Apparatus

- pressure transducer
- relief valve
- manual on/off valve
- electric on/off valve
- filter
- check valve
- 3-way valve

**CO₂ tank**

**CO₂**

**CO₂**

**Brine**

**Brine**

**T°= 5°C**

**T°res**

**T°res**

**T° room**

**T° room**

**core holder**

**D**

**confining pressure**

**Pres**

**back pressure**

**Ppore**

**3-way valve**

**back pressure**

**brine**

**separator**

**T° room**

**T° room**
Multi-Phase Flow Laboratory

Replicate *in situ* conditions
- Pressure
- Temperature
- Brine composition
Influence of Rock Heterogeneity

Low porosity layers have low CO$_2$ saturations

$S_{\text{CO}_2} = 41.40\%$

Waare C Sandstone
Influence of Heterogeneity and Structure

Low porosity units act as capillary barriers diverting CO$_2$ to the top of the core.

CO$_2$ Saturation

Porosity

CO$_2$ saturation

5 cm
Influence of Gravity

In “homogeneous cores”, gravity override diverts CO$_2$ to the top of the core, leaving the lower portions water saturated.

Berea sandstone – “Homogeneous”
Implications for Geophysical Modeling

- CO₂ saturations are variable at a hierarchy of spatial scales, from the pore scale to field scale
- CO₂ saturations are lower than expected when gravity override and heterogeneity are neglected
- Core-scale studies can elucidate primary factors that control small scale variations (10’s of cm)
- Conceptual models capturing realistic variability can be developed based on measurements and modeling at a hierarchy of scales