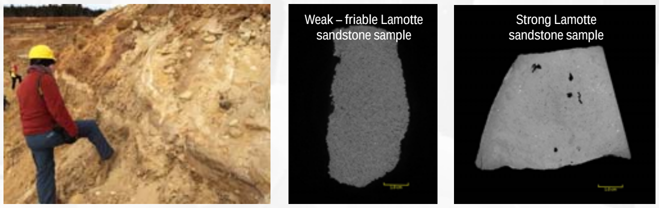
GSCO2 Geomechanics Theme: Investigating Injection-Induced Pressure Transients

Volker Oye[1], Robert Bauer[2], Bettina Goertz-Allmann[1], Sergey Stanchits[3], Pierre Cerasi[4], Robert Will[3], Don Lee[3]
Center for Geologic Storage of CO_2 (a US DOE Energy Frontier Research Center)
1) NORSAR, Kjeller, Norway; 2) University of Illinois, USA; 3) Schlumberger, USA 4) SINTEF, Trondheim, Norway

Abstract

The GSCO2 Geomechanics theme is focused on understanding the geologic features and mechanisms that cause microseismicity and how to predict and control it. Consequently, an improved understanding of coupled stress, strain, and flow response to injection-induced pressure transients at all scales will be investigated. Laboratory experiments will discover the mechanism(s) accountable for potential changes to porous media given specific, externally applied stresses and injection conditions (e.g., slow slipping deformation, grain crushing, microseismic events). Furthermore, laboratory experiments will illustrate which attribute(s) trigger microseismicity, and the results will be related to field-scale observations of microseismicity. Detailed characterization of the type of microseismicity (e.g., source mechanism, stress drops, ratio between radiated seismic energy to seismic moment, spatial-temporal distribution of b-values) will provide constraints on the pressure changes, extent, and stress front changes in the geologic storage formation associated with injection of CO_2. Additionally, methods will be developed and tested that lead to locating more of the measured events. The GSCO2 Geomechanics research will lead to technology that will reduce CO_2 storage risk, assist in risk mitigation related to felt earthquakes, and inform the public.

Field work and acoustic emission tests in the rock mechanics lab



We are analyzing small rock samples acquired on a Missouri field trip. One strong sample from a road cut and one friable, weak sample from the Summit Proppant quarry were Scratch tested, porosity and permeability, thin section, bulk X-ray diffraction (XRD), and µCT imaging. Photos - SINTEF

What field problem do we want to better understand?

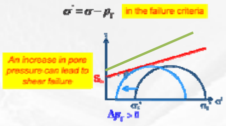
- A hydraulic fracturing test per se is not going to reproduce the field conditions responsible for microseismicity.
  - *In these tests, fluid is injected from a central borehole at high rate to induce fracturing from the borehole outwards.*
  - *It is known that acoustic emissions (AE) occur far from the well, for low injection pressure, with no fracturing at the well.*

S. Pradhan *et al.*, ARMA 14-7442

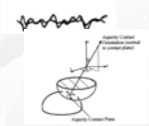
Plane of weakness

Probable scenario: µ-seismicity occurs at locations with critically stressed planes, such as faults or natural fractures.

- Pressure increase as injection proceeds lowers mean effective stress.
  - *Shear stress may then exceed local shear strength.*
- Pressure reduction may lead to fracture closing.
  - *If opening was in shear mode, asperities may break.*



E. Fjær *et al.*, Petroleum Related Rock Mechanics. 2nd Ed. Elsevier, 2008



A. Misra. Engineering Fracture Mechanics, Elsevier, 2002, 69, pp.1997 - 2014.

True triaxial testing

Play on effective stress path

- Next generation cell and frame to arrive in 2016.
- At first we use polyaxial frame and cell.
  - *No possibility to control pore pressure as in Terratek/Messtek biaxial frames.*
  - *Original plan was to inject viscous fluid from borehole.*
- Solution: change stresses as expected from field analysis to mimic increase in pore pressure.

polyaxial load frame

Terratek load frame

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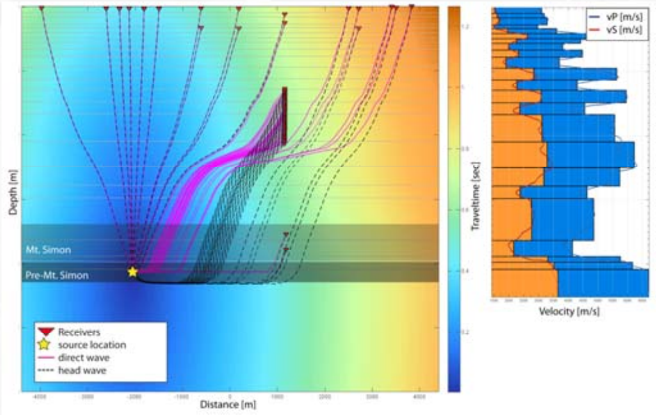
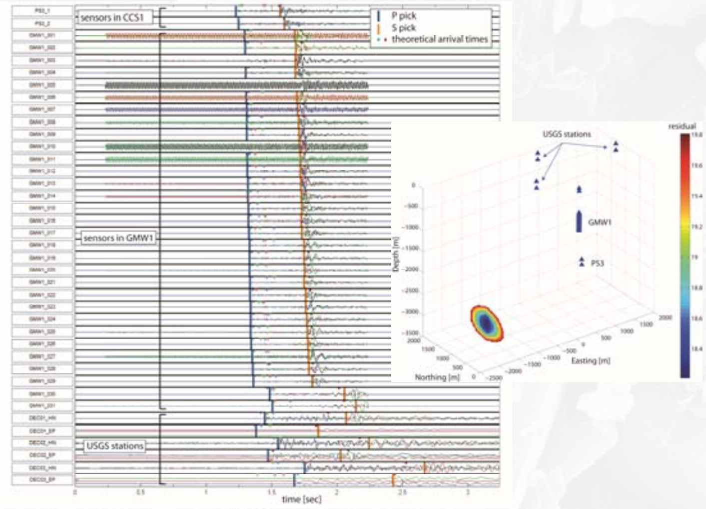
Analysis of microseismicity – evaluation of location accuracy

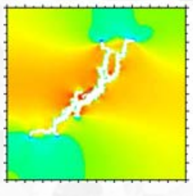


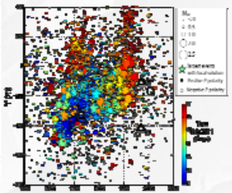
Ray-paths for an example microseismic event at the Decatur injection site, originating in the Pre-Mt. Simon formation and received at downhole stations as well as surface and shallow borehole stations (vertically exaggerated). The lower figure shows corresponding real waveform data from the deep sensors at CCS1, the borehole sensors in GMW1, and 6 surface stations. P- and S-wave picks with different quality weighting determine the event location (inlet, right) with uncertainty volume.



Bridging the gap between laboratory and reservoir scales using numerical modeling

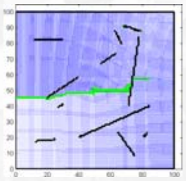
Fluid injection is simulated here in a heterogeneous rock using the FEM code by Wangen et al. (2013). The background is colored by the effective stress; note the irregular and branching growth of the fracture. Fracture aperture exaggerated for visibility. The figure to the right shows real field observations (Australia) in spatio-temporal distribution of microseismic events related to fluid stimulation. The general growth of the microseismic cloud (blue to red) is first developing along one direction, but later branching into two fault segments (Albaric et al. 2012).





Discrete element modeling can also help to understand fracture creation and propagation. Natural fractures may cause hydraulic-fracture arrests or offsets, resulting in proppant screen-outs and less efficient reservoir stimulation.

But: "Activation" of a natural-fracture network may result in enhanced reservoir stimulation, here modeled by SINTEF.



Kaiser et al., 2013 HF conference