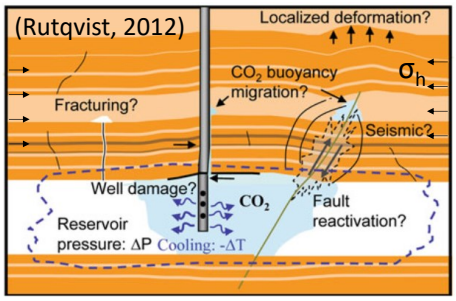
Determination of Geomechanical Parameters using In-situ Pressuremeter Testing

Lang Liu,
Formation Physics Group, SINTEF
Rick Chalaturnyk
Reservoir Geomechanics Research Group, University of Alberta

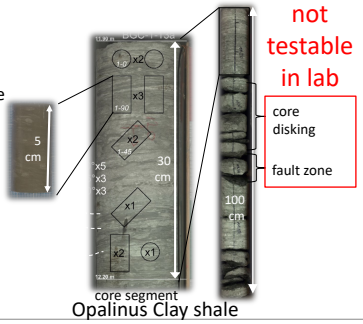
Geomechanical Challenges and Assessment for CO_2 Storage



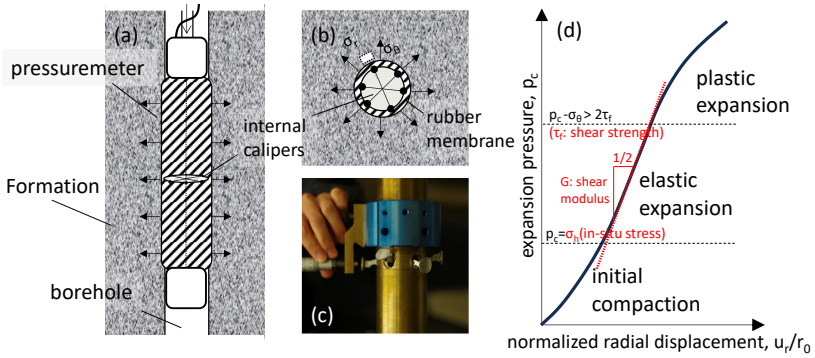
Geological Setting → Geomechanical Model → Integrity Assessment

- Geological Setting: Reservoir, Caprock, Faults
- Geomechanical Model: Physical properties, **Stiffness parameters**, **Strength parameters**, Hydraulic parameters, Pore pressure and **In-situ stress**, ...
- Injection History

geomechanical testing on small core specimen in lab



In-situ Pressuremeter Testing



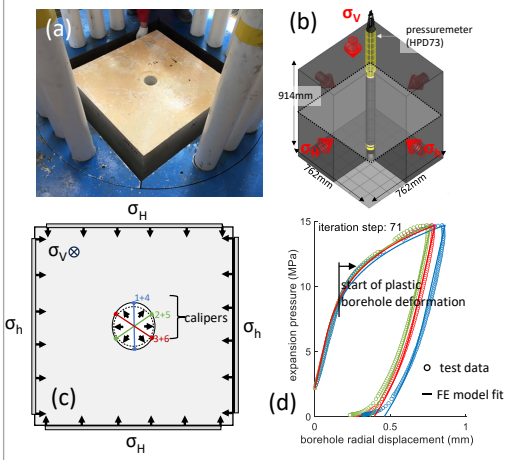
Schematics of in-situ pressuremeter testing in the borehole **(a)** side and **(b)** cross-section views; **(c)** calibration of high-resolution internal calipers; **(d)** typical test data in weak rocks at one caliper.

Compared to geomechanical testing on laboratory specimens, in-situ testing offers the advantages of:

- **Efficient determination** of in-situ ground properties;
- Assessment of material behavior at **larger scales** (decimeter to meter);
- **Less disturbance** to material and more preservation of **in-situ condition**.

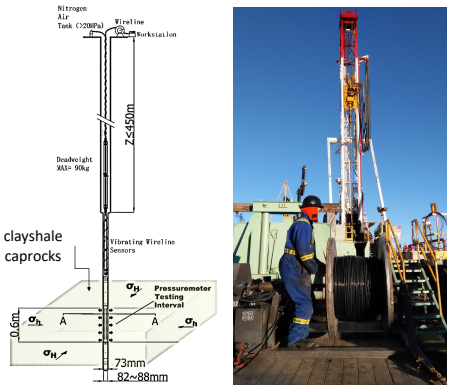
Desired for rocks with relatively low strengths and **high sensitivities** to environmental and stress changes, such as **shale caprocks, fault gouges**, etc., that are critical parts of geological settings in the CO_2 storage design.

Experiment in Polyaxial Loading Facility

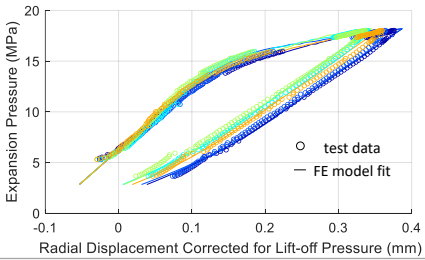


An experimental program was implemented at the CNPC polyaxial loading facility to test the pressuremeter performance in a cubic cement specimen under prescribed boundary stresses simulating in-situ stresses. For the test above with **boundary stresses σ_H=3.25 MPa and σ_h=2.15 MPa**, a divergence of borehole deformation after yielding was observed at the three different caliper axes. A finite element model was built but with σ_H and σ_h regarded as unknowns. σ_H=2.86 MPa and σ_h=2.17 MPa (**with errors of 12% and 1%, respectively**) were determined through an inversion procedure to match the test data obtained at all three axes with predicted borehole deformation.

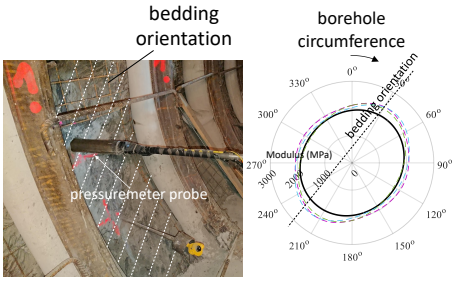
Tests in Deep Clayshale Caprock



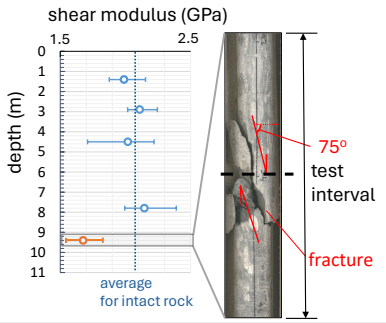
A field program of deep pressuremeter testing test was implemented at CNRL cyclic steam stimulation site at cold lake, Alberta. The tests were conducted at 5 depths in 3 caprock formations. The example below shows the best fit from numerical model on the test data obtained at the depth of 259m, with the fit model parameters: ***G*= 1316 MPa, τ_f= 4.04 Mpa, σ_H= 7.29 MPa, σ_h= 6.09 Mpa.**



Tests in Shale Formation with Fractures



Pressuremeter tests were conducted in the Opalinus Clay shale at Mont Terri Rock Laboratory in Switzerland with **strong anisotropy**. The anisotropic stiffness can be interpreted using the multi-caliper measurement from the tests in in the borehole oriented parallel to bedding (figure above). **Reduced modulus** was determined from the test in the depth interval with a cutting fracture (figure below).



References:

- Rutqvist J (2012) The Geomechanics of CO2 Storage in Deep Sedimentary Formations. Geotech Geol Eng 30:525–551. - Liu L, Martin D, Giger SB, et al. Assessment of
- Liu L, Giger SB, Martin D, et al (2022) In-situ Shear Modulus Determination by Pressuremeter Tests in Opalinus Clay and Reconciliation with Laboratory Tests. Rock Mech Rock Eng 55:4615–4635.
- Liu L, Chalaturnyk R, Deisman N, Zambrano-Narvaez G (2021) Anisotropic borehole response from pressuremeter testing in deep clay shale formations. Can Geotech J 58:1159–1179.

Acknowledgment for collaboration and support from: