Coupled flow and geomechanics model of jointed caprock

Scientific Achievement

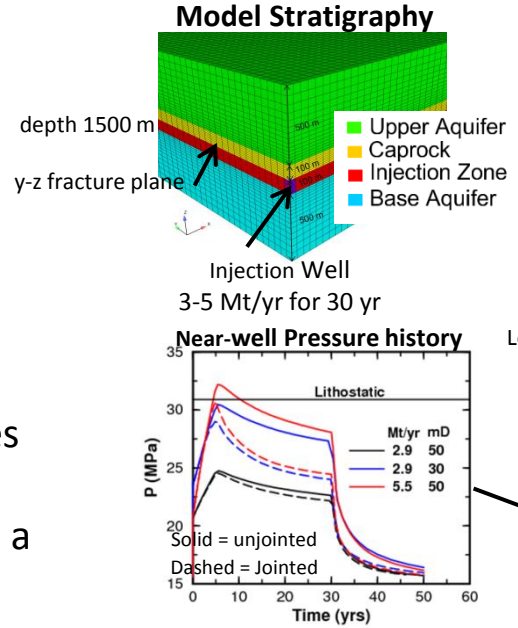
Developed a coupled flow and geomechanics model describing potential fluid pressure induced fracturing of caprock seals during CO_2 sequestration.

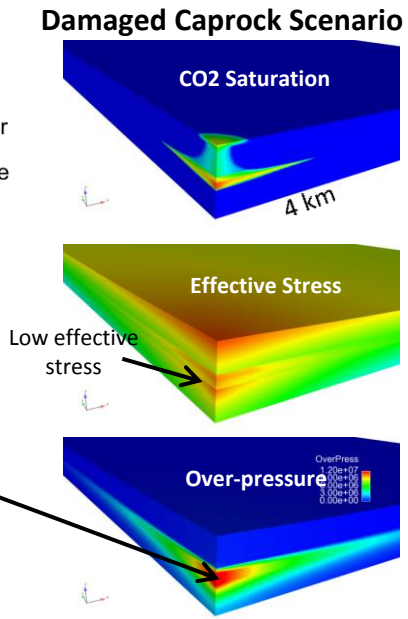
Significance and Impact

If accurately calibrated, the model can indicate acceptable ranges for injection rates and aquifer petrophysical properties to *suppress* joint reactivation.

Research Details

- A jointed rock model coupling flow and geomechanics is introduced to study injection pressurization effects on caprock integrity.
- The joint model describes effective stress dependent joint stiffness and joint aperture.
- Normal joint displacement induces enhanced anisotropic caprock permeability.
- The model can provide bounds on injection rates to suppress joint reactivation.
- When joints are reactivated, the model predicts a noticeable over-pressure reduction that could signal leakage.





Too high injection rates and/or too low storage aquifer permeability can lead to fracturing of the caprock, inducing leakage.

MJ Martinez, P Newell, JE Bishop, DZ Turner, Int. J. Greenhouse Gas Control, 17, 148-160 (2013)

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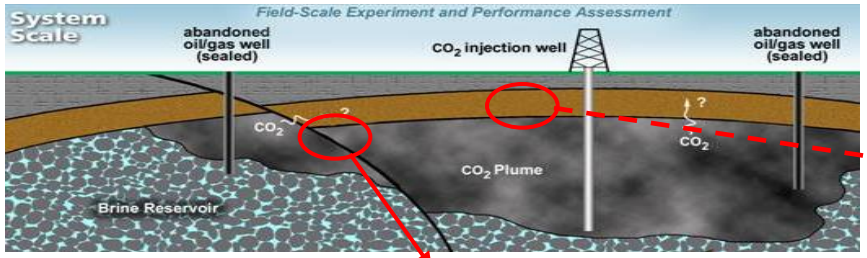
Coupled flow and geomechanics model of jointed rock
Joint model

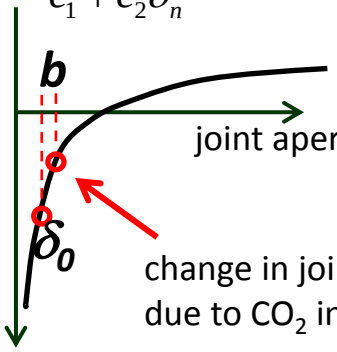
Change in joint aperture due to injection pressure induces a change in caprock permeability (anisotropic).



Caprock jointing

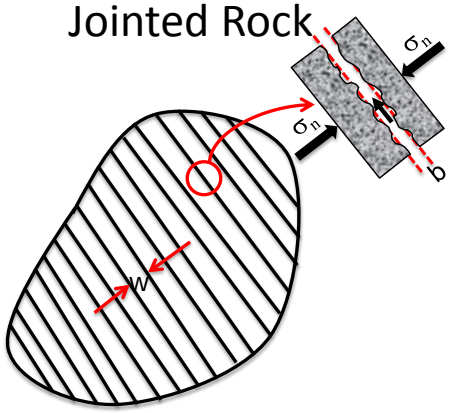
Stress vs. Joint aperture

$$\sigma_n^{eff} = \frac{\delta_n}{c_1 + c_2 \delta_n} \qquad \delta_n = \delta_0 + b$$



$$\mathbf{k}_{eff} = k\mathbf{I} + \frac{b^3}{12W}\left(\mathbf{I} - \mathbf{nn}^{\mathrm{T}}\right)$$

Conceptual Model of Jointed Rock



Multiple joints sets can be modeled

Change in effective stress due to CO_2 injection pressure causes a change in caprock stiffness, normal to fracture plane.

$$K_n = K_{ni}\left(1 - \frac{\sigma_n^{eff}}{K_{ni} V_m}\right)^2$$

$$\Delta\dot{\boldsymbol{\varepsilon}}^{\text{joint}} = \frac{1}{W K_n}\mathbf{P} \bullet \Delta\dot{\boldsymbol{\sigma}} \bullet \mathbf{P}$$

$$\mathbf{P} = \mathbf{nn}^{\mathrm{T}}$$