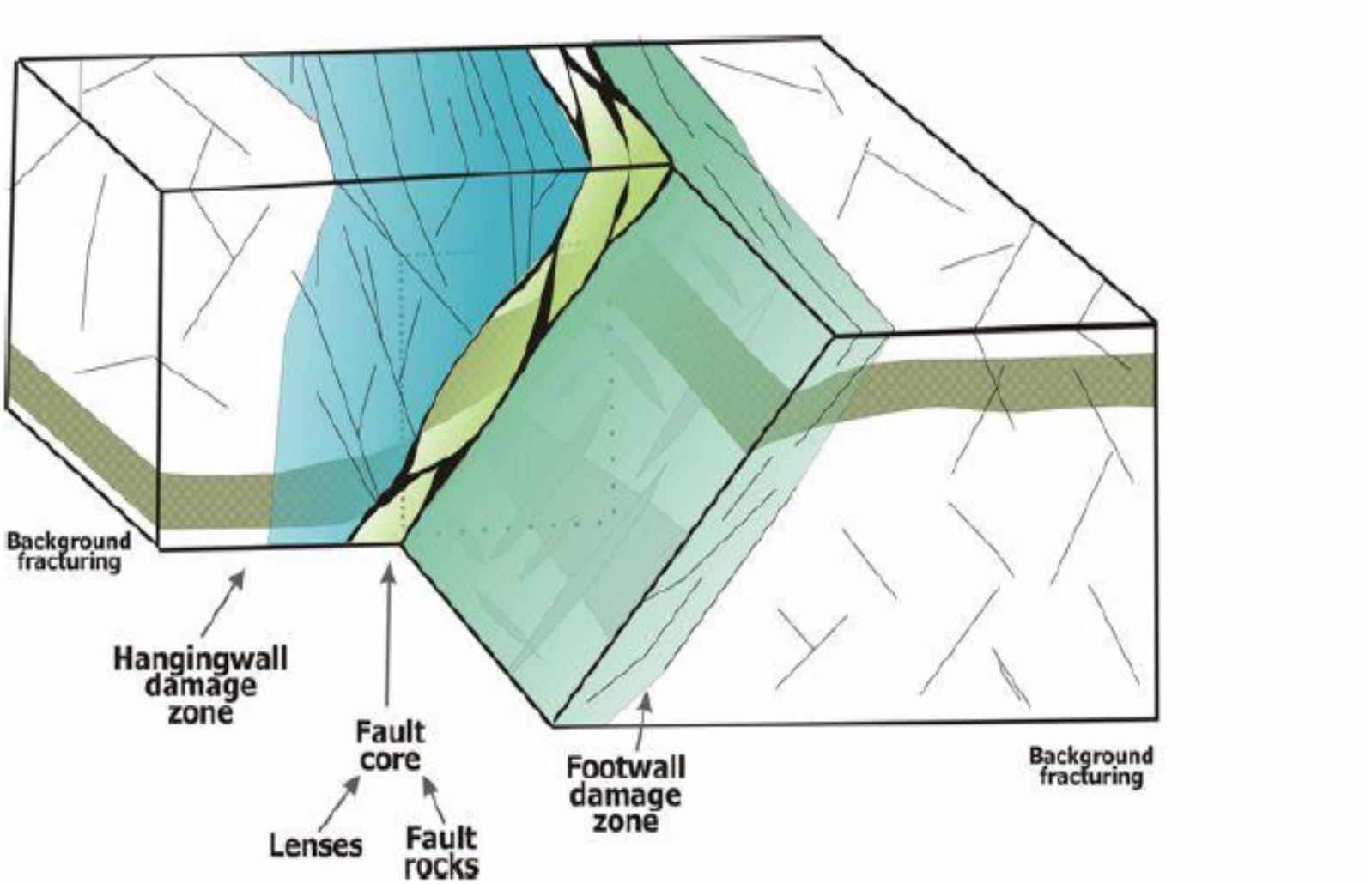
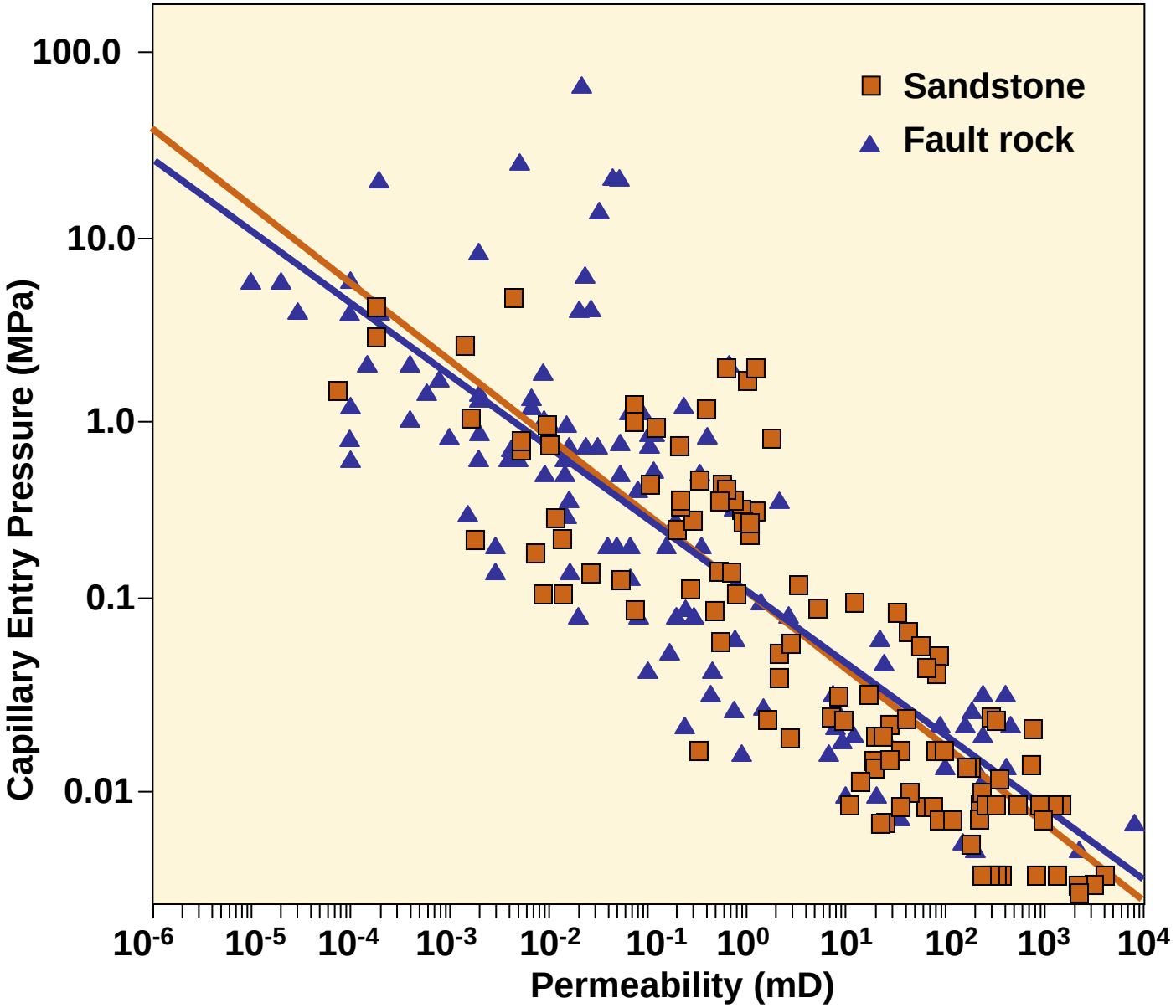
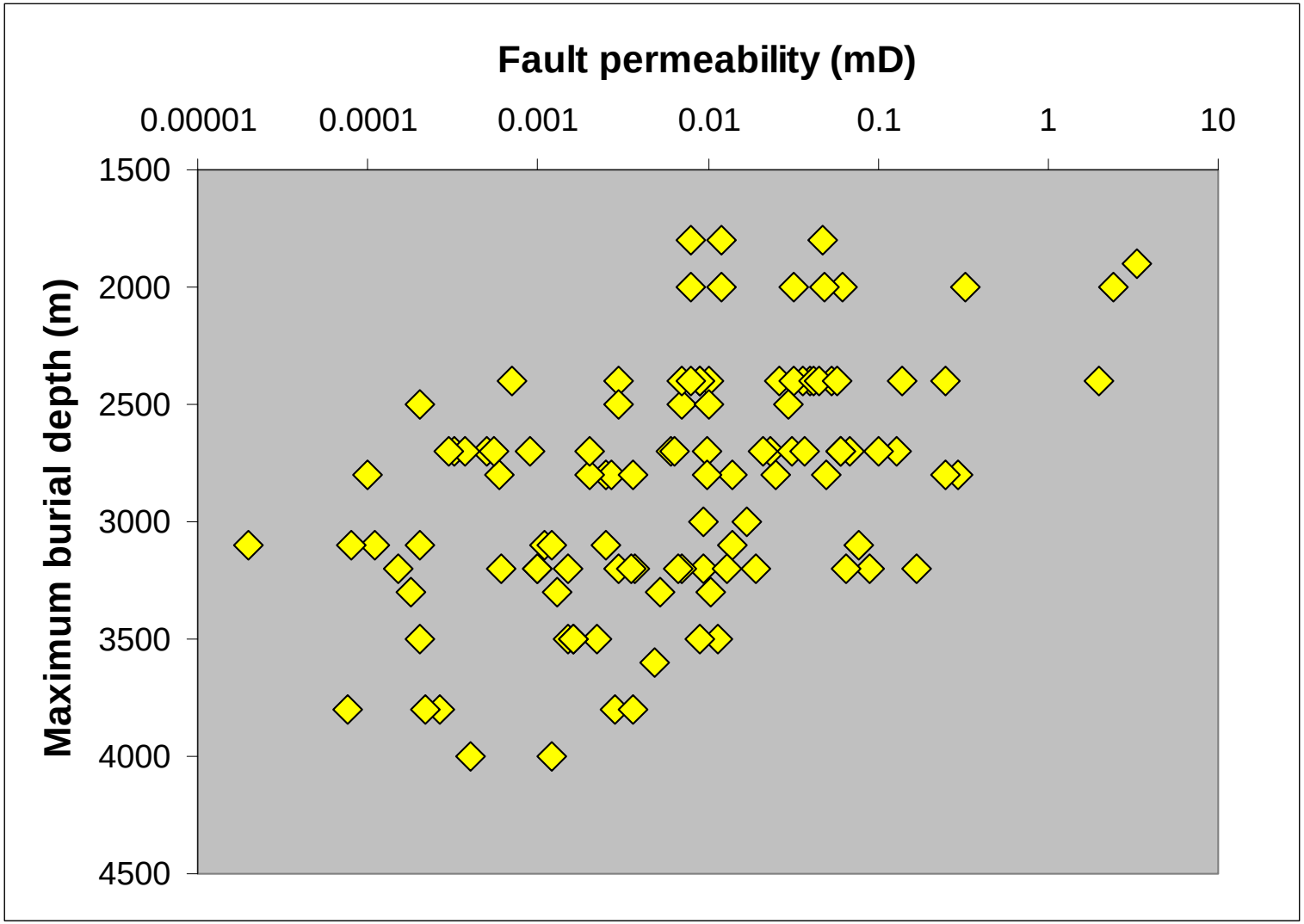
Fault Damage Zones



Capillary Entry Pressure V. Permeability



Compiled by Sorkhabi and Tsuji (2004)


Fault permeability (mD)
0.00001
0.0001
0.001
0.01
0.1
1
10
Maximum burial depth (m)
1500
2000
2500
3000
3500
4000
4500

Rules of Thumb for Faults Seals

- Deeper faults more likely sealing than shallow faults
- Faults with larger displacement more likely sealing
- Faults that cut shales may have better seals than those that do not
- Faults that cut feldspar bearing sands more likely sealing than pure quartz sands

Geomechanics

Applied to Combined CO_2 EOR and Sequestration

QUESTION:

Suppose I want to convert my CO_2 EOR project to a CO_2 sequestration project….

In Texas my injection will have to be repermited by TCEQ.

Key question regulators will have is “Will the planned CO_2 injection exceed the fracture strength of the top seal or the reservoir”

EPA Rules of Thumb on Fracture Strength

“Some limited data are available which indicate that closure pressure is, on average, 18 percent less than ISIP converted to a formation-face pressure. Based on these data, Region 5 recommends that, when in-situ stress tests or step rate tests are not available or cannot be performed, a pressure 18 percent less than ISIP be used to estimate fracture closure pressure. If more data become available, these recommendations may be updated”.

Estimating Fracture Strength

Need two types of information:

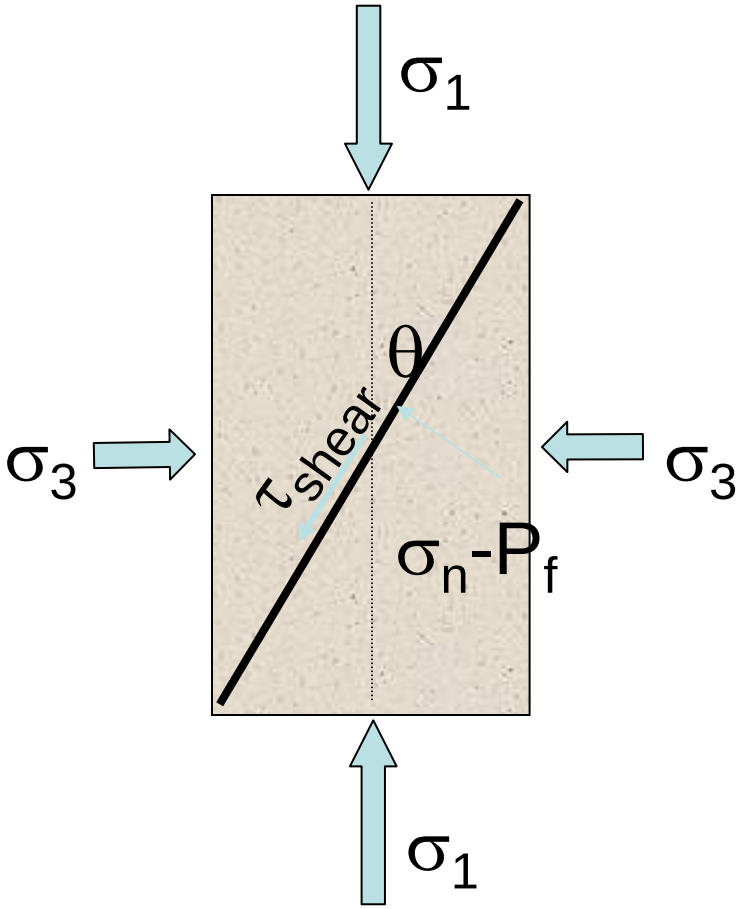
(1) Rock Strength Envelope

(best determined by lab experiments on core sample of the cap rock and reservoir rocks, but often approximated by average properties for the specific rock types)

(2) State of stress

(best measured in-situ by micro-frac tests etc but often approximated from regional averages).

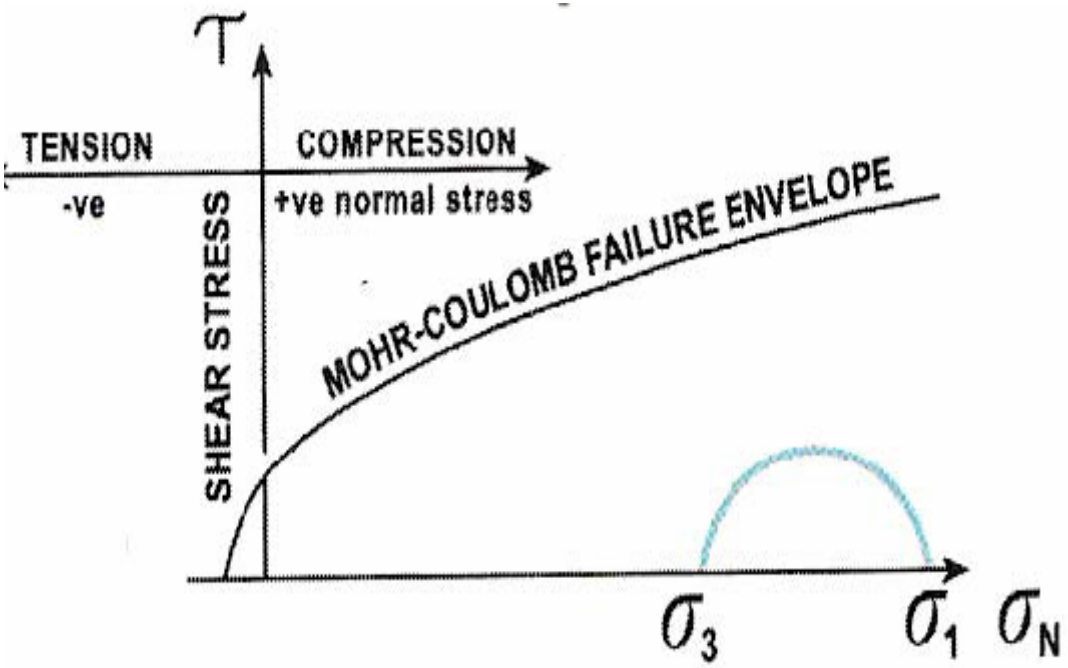
The state of stress can be viewed as the sum of the stress state created by the action of gravity and an imposed tectonic component.



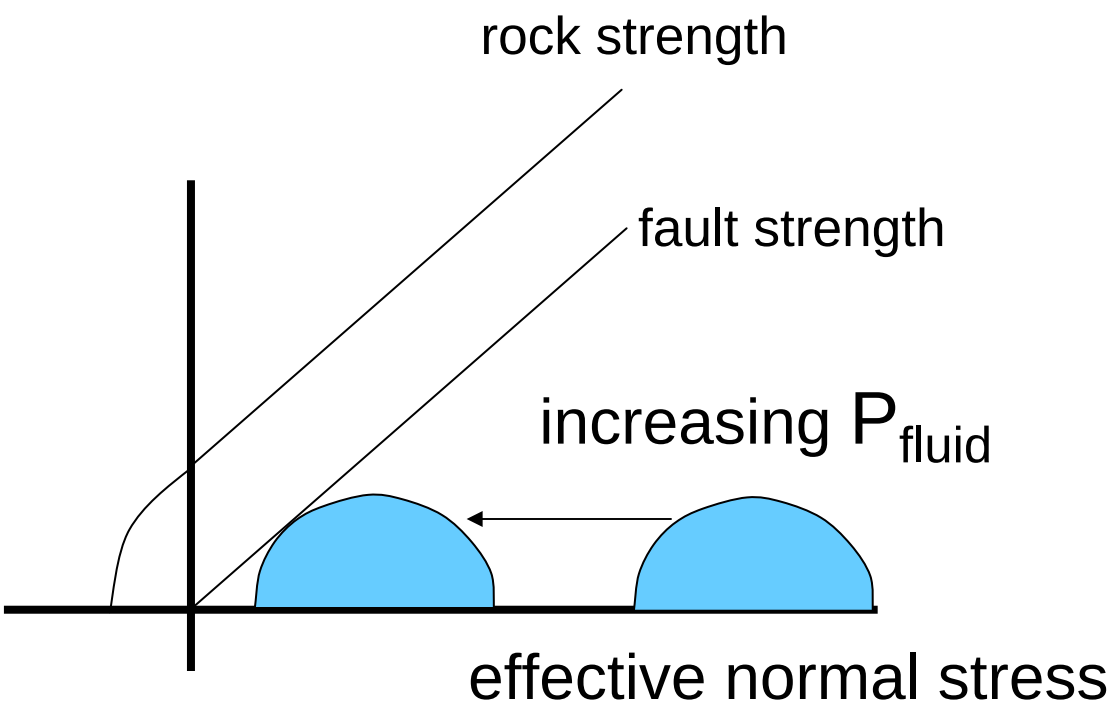
(Streit and Hillis, 2003)

Mohr's Circle

Strength Envelope and Stress State



Affect of Increasing Fluid Pressure on Effective Stress



Poro-elasticity

Porous rocks are composed of a solid skeleton containing open pores.

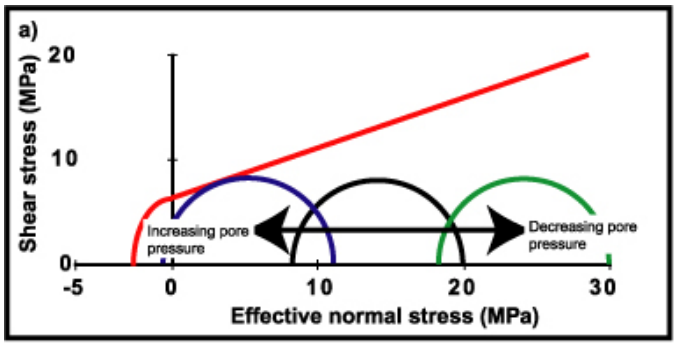
Porous rocks have very different elastic behavior to solid or pore free materials.

Poro-elasticity was developed by the applied mathematician Biot about 50 years ago and scientists are still arguing over what he did.

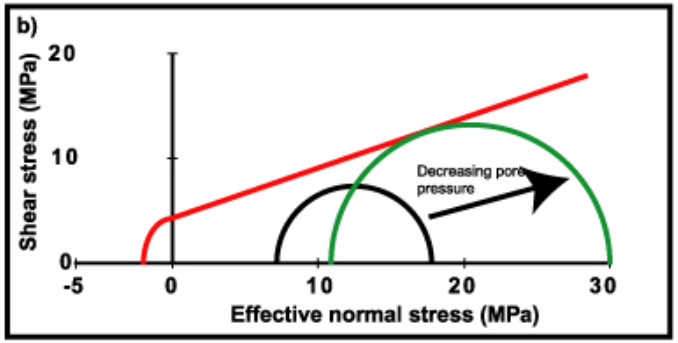
Poro-elastic affects are critical to understanding stress evolution in reservoirs and may prove to be a key to accurate flow simulations in sequestration reservoirs.

Stress path – P_p/S_h coupling

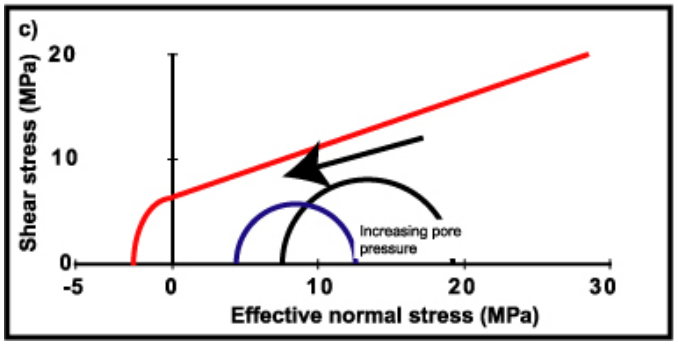
- If Mohr circle didn't change shape during overpressure development then shear fractures would always form
- Poroelastic effect means that S_{hmin} increases with P_p



No P_p/S_h coupling



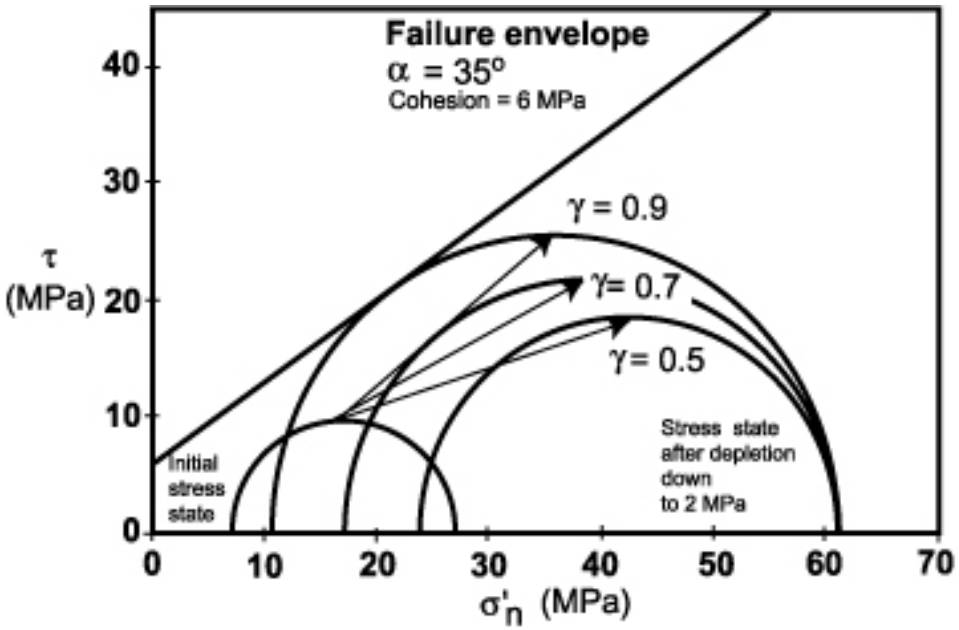
P_p/S_h coupling



P_p/S_h coupling

Stress path – P_p/S_h coupling

- Knowledge of stress path is needed to predict likelihood and type of failure during both depletion and inflation



- From Hettma et al., (1998) – SPE 63261

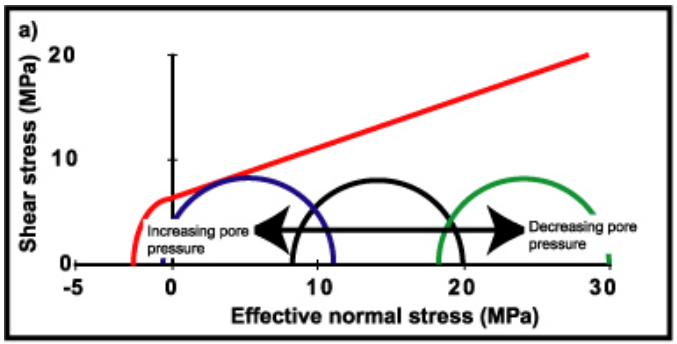
CONCLUSION:

Fracture Strength places a significant constraint on injection pressures in the sequestration phase.

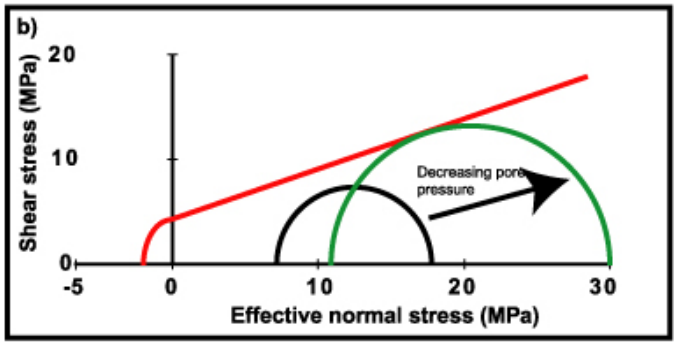
Are Micro-earthquake Possible Consequences of Sequestration Projects?

Stress path – P_p/S_f coupling

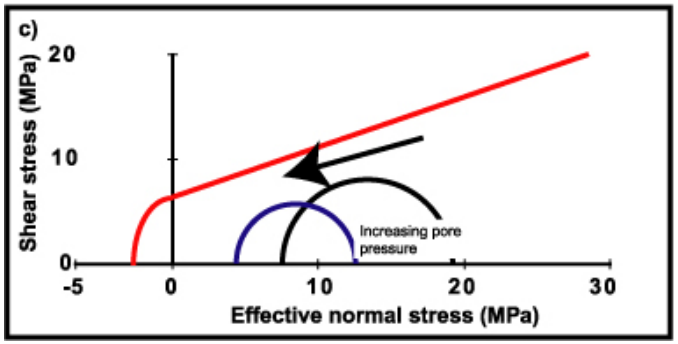
- If Mohr circle didn't change shape during overpressure development then shear fractures would always form
- Poro-elastic effect means that S_{hmin} increases with P_f



No P_f/S_h coupling



P_f/S_h coupling



P_f/S_h coupling

CONCLUSIONS

- **Fracture Strength is a key parameter in re-permitting CO_2 EOR projects as sequestration projects**

- **Geomechanics is becoming more important in understanding CO_2 sequestration**