Unconventional Reservoir Geomechanics
Spring 2020

Homework 2: Composition, Elasticity, and Ductility

Part 1: Composition, microstructure, and elastic properties

a) Reading ternary diagrams. For each of samples plotted in Figure 1, determine the percentage by weight of each components (clay + TOC, QFP, carbonates).

Barnett 25H - 38% QFP, 7% carbonate, 55% clay + TOC
Eagle Ford 65H - 16% QFP, 65% carbonate, 19% clay + TOC

b) Estimate the density for each sample. Using the component densities provided in Table 1 and the wt% values from (a) to calculate an approximate density for each sample.

$\rho_{sample} = \rho_{qfp}x_{qfp} + \rho_{carb}x_{carb} + \rho_{clay+toc}x_{clay+toc}$

Barnett 25H - 2.27 g/cc; Eagle Ford 65H - 2.56 g/cc

c) Calculate elastic moduli. Ultrasonic laboratory measurements indicate that the compressional wave velocities of the Eagle Ford and Barnett sample are 6.0 and 5.0 km/s, and the shear wave velocities are 3.3 and 3.2 km/s. Using the densities determined in (b), calculate the bulk and shear moduli.

Bulk modulus, $K = \rho V_p^2 - (4/3)G$ Shear modulus, $G = \rho V_s^2$

$K_{Barnett} = 25.75$ GPa, $G_{Barnett} = 23.24$ GPa

$K_{Eagle} = 54.90$ GPa; $G_{Eagle} = 27.83$ GPa

d) Calculate effective elastic moduli.

$$M_{eff} = \sum f_i M_i \quad \text{(Iso-strain)}$$

$$\frac{1}{M_{eff}} = \sum f_i \frac{1}{M_i} \quad \text{(Iso-stress)}$$

Barnett 25H - $K_{iso-strain} = 23.65$ GPa, $G_{iso-strain} = 21.23$ GPa; $K_{iso-stress} = 13.16$ GPa, $G_{iso-stress} = 7.50$ GPa

Eagle 65H - $K_{iso-strain} = 53.17$ GPa, $G_{iso-strain} = 26.75$ GPa; $K_{iso-stress} = 27.83$ GPa, $G_{iso-stress} = 14.65$ GPa

e) Compare your answers for (c) and (d). Do the ultrasonic measurements reflect stiffness components parallel or perpendicular to bedding?

The ultrasonic measurements reflect stiffness components parallel to bedding because they are very close to the theoretical iso-strain values.

Part 2: Hydraulic fracture propagation in layered media

a) Net pressure required for hydraulic fracture propagation. Use the expression for the critical stress intensity factor for mode I cracks (K_{IC}) to determine the net pressure ($P - S_3$) required to propagate a hydraulic fracture as a function of length (l). Perform the calculation for each layer using the K_{IC} values in the table and plot results on the same axes.

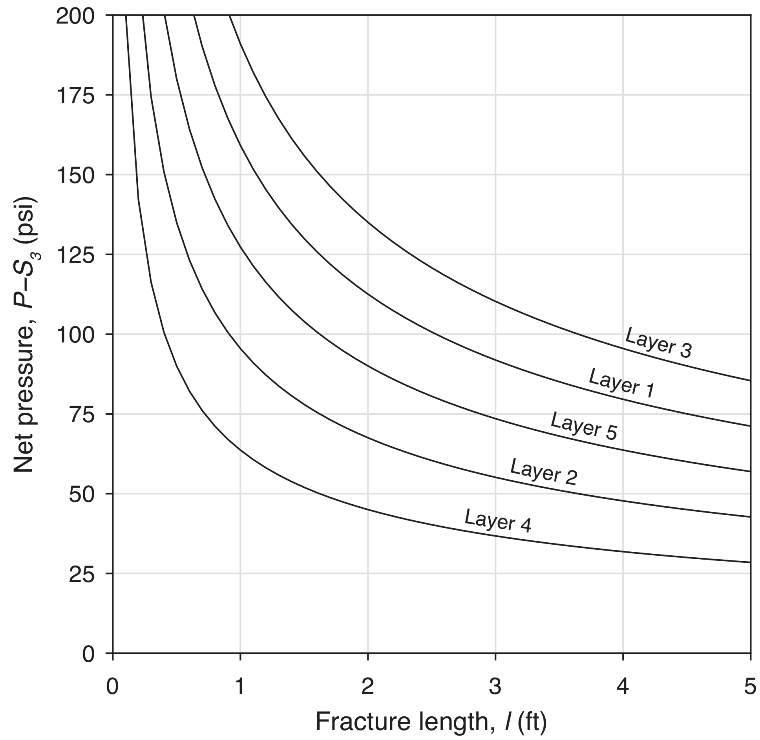

Figure 1: Net pressure required to propagate a fracture of length l.

b) Compare the net pressure values in each layer for a fracture of length $l = 3$ ft. How important is rock tensile strength to hydraulic fracture propagation once fractures begin to propagate?

Once the fracture reaches 3 ft in length ($\sim$1 m) the net pressure required to propagate the fracture is 30-100 psi, which is quite small compared to the pore pressure at depth. Variations in rock tensile strength are not important for fracture growth once the fracture has begun to propagate.

c) Consider the stress profile in Figure 3. If we apply sufficient pressure to propagate a hydraulic fracture of length $l = 1$ ft in layer 3, would we expect the fracture to grow vertically into any of the surrounding layers? Which ones and why?

Layer 2 - The minimum horizontal stress in Layer 2 is less than that in Layer 3, so any pressures above S_{hmin} in Layer 3 would enable the fracture to grow into Layer 2.

Layer 4 - The net pressure required to propagate the fracture in Layer 3 exceeds the difference between the minimum horizontal stress in Layers 3 and 4.