Unconventional Reservoir Geomechanics
Spring 2020

Homework 2: Composition, Elasticity, and Ductility

Due April 27, 2020 00:00 PST

Instructions

This assignment focuses on understanding the relationships between the composition, microstructure, and mechanical properties of unconventional reservoir rocks.

Part 1: Composition, microstructure, and elastic properties

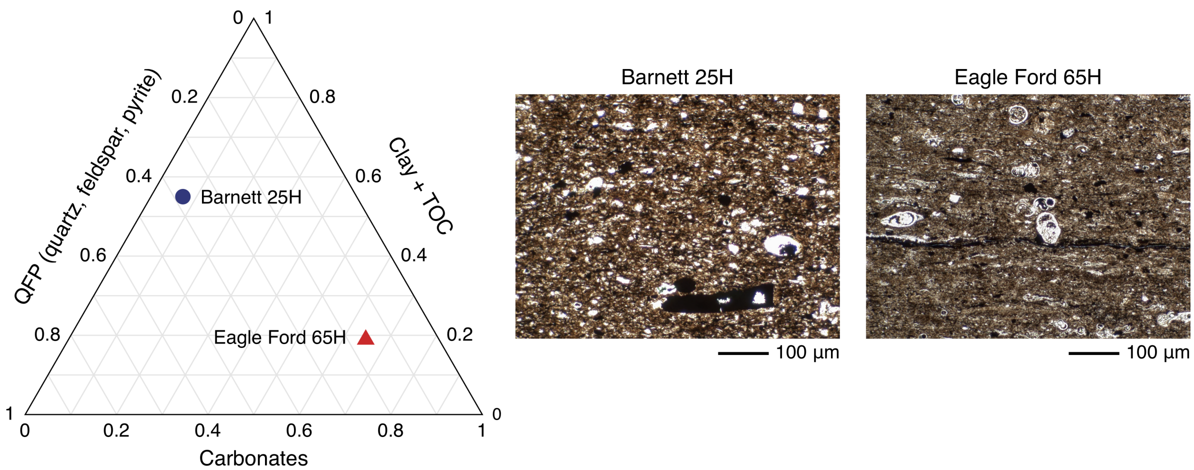


Figure 1: (Left) Ternary composition of two shale samples in wt%. (Right) Optical micrographs of Barnett 25H and Eagle Ford 65H in plane polarized light. Bedding is horizontal.

Table 1: Mineral elastic moduli and densities

	Bulk modulus (GPa)	Shear modulus (GPa)	Density (g/cm^3)
Quartz	37	44	2.65
Carbonates	70.2	29	2.71
Clay + TOC	8.5	4.5	1.95

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

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.

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.

d) Calculate effective elastic moduli. The effective modulus can be calculated by summing the contributions from the individual component moduli, where M_i and f_i are the modulus and the fraction of the ith component, and M_{eff} is the effective modulus of the composite:

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

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

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

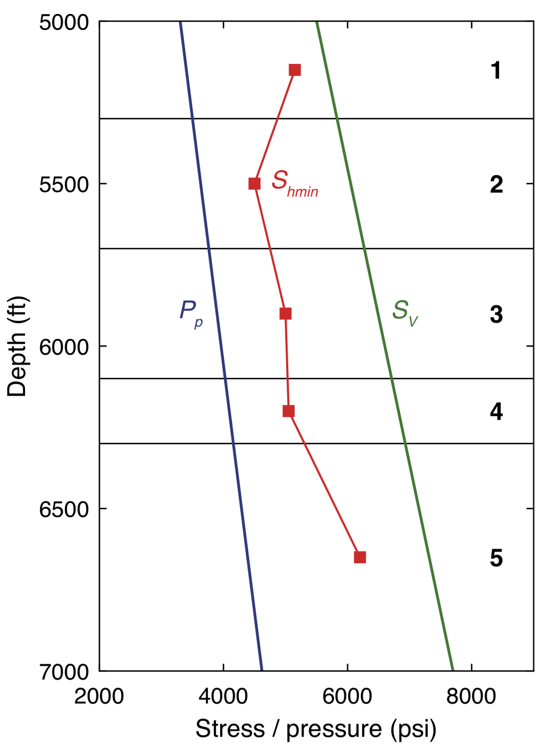
Part 2: Hydraulic fracture propagation in layered media

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.

$$K_{IC} = (P - S_3)\pi\sqrt{l}$$

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?

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	Depth (ft)	S_{hmin} (psi)	K_{IC} (psi·ft$^{1/2}$)
1	5150	5150	500
2	5500	4500	300
3	5900	5000	600
4	6200	5050	200
5	6650	6200	400

Figure 2: (Left) A hypothetical layered sequence in a normal faulting environment in which S_{hmin} varies as a function of depth. (Right) Values of S_{hmin} and K_{IC} at the center of each layer.

Part 3: Answer the questions in edX

Use the plots and calculations from Parts 1 and 2 to answer the questions on the page below. The solutions will be posted after the due date. Numerical entry types responses have a limited range of accepted values and are graded automatically, so follow the directions closely and adhere to the given values of constants to prevent misgrading of your submissions.