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Unconventional Reservoir Geomechanics
Spring 2019

Homework 2: Composition, Elasticity and Ductility

Due April 22, 2019 at 08:00 UTC
Please direct any questions to the Piazza Discussion Forum on the course page

Background

This assignment focuses on the compositional and mechanical properties of unconventional reservoir rocks. In the first part, you will interpret sample compositions from a ternary diagram and determine their elastic properties. In the second part, you will consider the relationships between ductility, the state of stress and hydraulic fracture propagation.

Utilize a scientific computing and/or plotting program such as MATLAB, Python or Excel to follow the steps below. Then, answer the questions on the page below.

Part 1: Composition and elastic properties

You may find the following article useful for your understanding and further reading:

Sone, H., and Zoback, M.D., 2013, Mechanical properties of shale-gas reservoir rocks — Part 1: Static and dynamic elastic properties and anisotropy: Geophysics, v. 78, no. 5, p. D381–D392, doi: 10.1190/geo2013-0050.1.

Refer to the ternary diagram given below and answer the questions that follow:

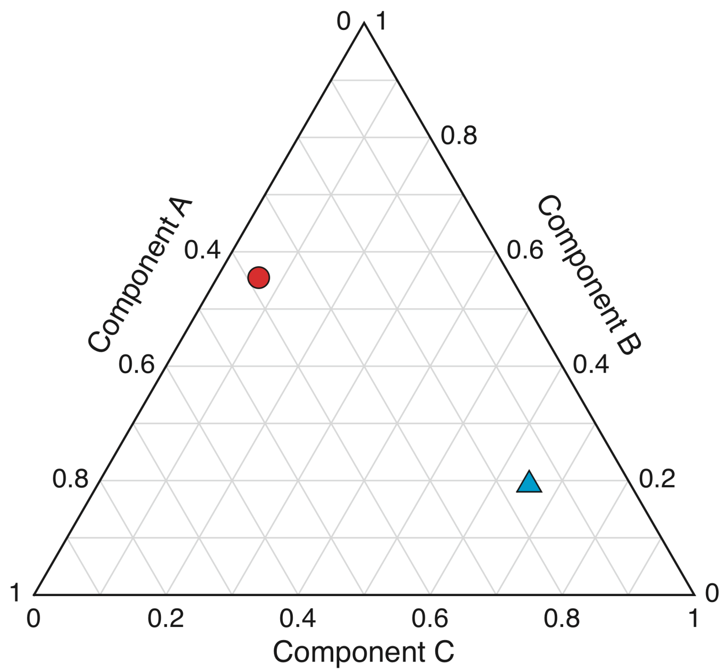

Figure 1

a. *Reading the ternary diagram.* For each sample, determine the percentage of each of the 3 unknown components A, B and C.

b. *Determine the unknown components based on the total density.* The measured densities of the two samples corresponding to the triangle and the circle are 2.53 g/cm^3 and 2.27 g/cm^3, respectively. The three unknown components in Figure 1 are clay + kerogen, calcite and quartz. Using the component densities provided in Table 1, identify components A, B and C.

Table 1

	K (GPa)	*G* (GPa)	Density g/cm^3
Quartz	37	44	2.650
Calcite	70.2	29	2.612
Clay + kerogen	8.5	4.5	1.650

c. *Effective bulk and shear moduli.* Sonic logs indicate that the compressional (P) wave velocities of the two samples corresponding to the triangle and the circle symbol are 6.01 and 5.38 km/s, and shear (S) wave velocities are 3.32 and 3.51 km/s. Using the effective densities provided in (b), calculate the effective shear (G) and bulk (K) moduli from the sonic velocities.

d. Do the calculated values reflect the iso-stress or the iso-strain case? The effective modulus in each case can be calculated by summing the contributions from the individual component moduli:

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

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

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.

e. Based on your answer to (d), do the sonic velocities reflect elastic stiffnesses perpendicular or parallel to layering (bedding planes or rock fabric)?

Part 2: Hydraulic fracture propagation in layered media

a. The plot below shows S_{hmin} magnitudes as a function of depth for a layered sequence. The rectangles represent measurements of S_{hmin}. Assuming a *strike-slip* faulting regime, which layer would you stimulate to achieve a wide, confined fracture with *limited* vertical extent?

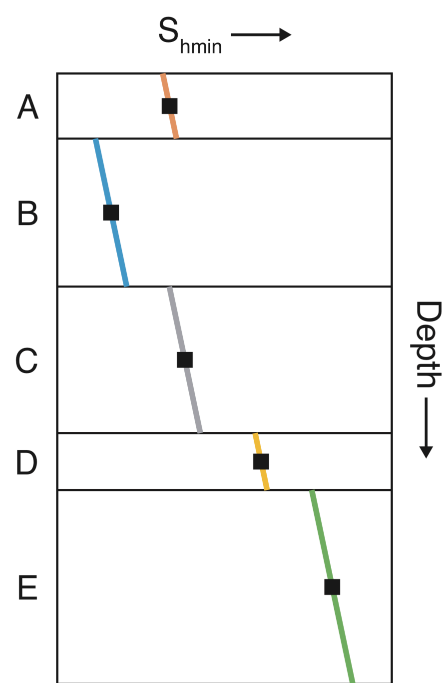

Figure 2

b. Suppose that stimulating layer E results in horizontal hydraulic fractures. What does this tell you about minimum horizontal stress S_{hmin} in layer E with respect to vertical stress S_V? *Hint: Recall frictional faulting equilibrium for strike-slip faults (Unit 3).*

c. What possible mechanisms could be responsible for the variations of the least principal stress (S_{hmin}) in the different layers?

d. Based on stress profile and your answer to (c), which formation do you expect to exhibit the least ductility (viscoplastic deformation)?

Part 3: Answer the questions on the page below

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