ResGeo 202 Reservoir Geomechanics
Spring 2017, Stanford Online

Homework 8 – Identifying Critically-Stressed Faults
Due 6 June 2017, 07:30 UTC

Please direct any questions to the Piazza discussion forum on the course website

Note that the deadline is in Coordinated Universal Time (UTC). If you want to see the current time in UTC, please google: "Current time in UTC."

Background

In previous assignments, you have constrained stresses in the Barnett Shale well and analyzed fracture orientations. Now we will put these two types of information together, resolving the stresses on each fracture to see which fractures are critically stressed.

While this is a 3D problem in the subsurface, requiring the full stress tensor as you have constrained it in the previous homework assignments, in this assignment we will solve the problem in 2D. We will do this by resolving the stress state (stress gradients) observed at corner number 1 from Homework 6 on all fractures. In this stress state, $S_{hmin} = S_{Hmax} = S_3$, and $S_V = S_1$. This means we are in the radial extension stress state, and fracture strike does not matter—only fracture dip. This simplifies the Mohr circle into 2D. It also means that the fracture dip is equal to β (the angle between fracture normal and S_1).

You will use the given stresses in combination with fracture data to determine which fractures are critically stressed. You will also use this analysis to determine the pore pressure perturbation necessary to activate slip on mis-oriented faults. The fracture orientation data is the same as that from Homework 5, and can be downloaded again by clicking the link above this .PDF document.

Utilize a scientific computing or plotting program such as Microsoft Excel or MATLAB to follow the steps below. **Then, answer the questions on the webpage below this .PDF document.**

Instructions

Part 1: Stress State Information

Use the stress state information below to plot the corresponding Mohr-Coulomb failure envelope. These are the stresses at corner number 1 in Homework 6. Apply them to all fractures regardless of what you find in Homework 7. Refer to Unit 5, slides 6 and 7 for information about plotting the Mohr-Coulomb failure in 2D, and refer to Homework 6 for any additional parameters that you need.

S_V (= S_1) gradient (psi/ft)	S_{hmin} (= S_3) gradient (psi/ft)	P_P gradient (psi/ft)	μ (coefficient of friction)
1.10	0.701	0.53	0.67

For each fracture, calculate the shear stress and effective normal stress acting on it using the equations below. Plot this as it is done in Lecture 14, slide 12, Figure 11.3 (horizontal axis is σ_n in psi and vertical axis is τ in psi).

$$\tau = 0.5\,(\sigma_1 - \sigma_3)\sin 2\beta \qquad \text{(Equation 4.1)}$$
$$\sigma_n = 0.5\,(\sigma_1 + \sigma_3) + 0.5\,(\sigma_1 - \sigma_3)\cos 2\beta \qquad \text{(Equation 4.2)}$$

where $\sigma_k = S_k - P_P$ for k = 1 to 3. Note that there is a typo on Unit 5 slide 6, so use the equations as presented here. If possible, color each fracture by its dip angle. A common pitfall here is to mix degrees and radians in these calculations. Beware of this.

Part 2: Shear Slip on Faults

Plot the shear failure envelope for $\tau = \mu\,\sigma_n$. Calculate the magnitude of the increase in pore pressure that would cause each fracture to fail. On a second figure, make a histogram of this parameter.

On a third figure, plot fracture depth (in ft) on the vertical axis, and pore pressure to failure (in psi) on the horizontal axis. If possible, color these points by fracture dip angle.

Lastly, calculate the τ/σ_n ratio for all fractures.

How many fractures are critically stressed (within 145 psi fluid pressure increase from the failure envelope)? How many fractures are within 1450 psi? What are the dip angles of the critically stressed fractures? In what formation are the critically stressed fractures (see Homework 3 data for formation depth intervals)? What coefficient of friction μ would be required for the fracture **least** likely to slip in the current stress state to be critically stressed? (Hint: how does μ relate to τ and σ_n?)

Part 3: Answer the questions on the page below

Use your plots and calculations from Parts 1–2 to answer the questions on the page below. The answers will be posted after the due date. Numerical entry type responses have only a range of acceptable values and are graded electronically, so please adhere to the value of constants given here to prevent misgrading of your submissions.

Lastly, please remember to take the post-course survey when it becomes available.