Stanford | ONLINE

Unconventional Reservoir Geomechanics
Spring 2019

Homework 6: Induced Fault Slip

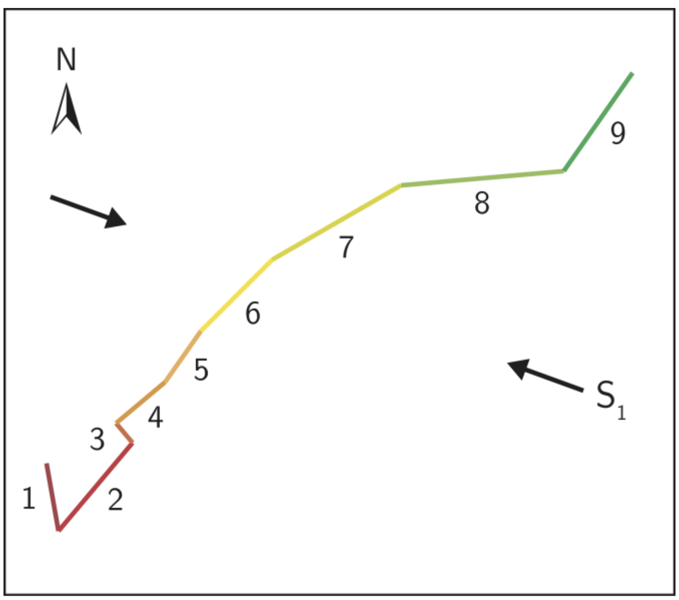
Due June 10, 2019 at 08:00 UTC
Please direct any questions to the Piazza Discussion Forum on the course page

Background

In this assignment we will look at how pore pressure can induce slip on faults of various orientations. We will perform a 2-D, simplified version of the analysis in a case study of hydraulic fracturing-induced fault slip in the Sichuan Basin, China (Chen et al., 2018).

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: Pore pressure required to induce slip on faults



Fault	Azimuth (w.r.t North)
1	350
2	40
3	320
4	50
5	35
6	45
7	60
8	85
9	30

Figure 1. Map view of a large, segmented fault. Fault azimuth with respect to North is provided in the adjacent table.

As seen in Figure 8 in Chen et al. (2018), large faults in reservoirs are complex surfaces that can be discretized into segments in order to determine the probability of induced fault slip. Figure 1 above represents a simplified, 2-D version of the fault map in Figure 8c of Chen et al. Use the following information about the stress state to determine the pore pressure perturbation required to induce slip on each fault segment.

Assume a strike-slip faulting stress state. The maximum and minimum principal stresses are S_1 = 50 MPa, S_3 = 26.5 MPa. The azimuth of S_1 w.r.t North is 110°. The azimuth of the fault segments is provided in the table above. Note that these values represent the angular difference measured clockwise from North. Pore pressure, P_p = 15 MPa. Assume a coefficient of sliding friction, μ = 0.6.

a) Calculate the resolved shear and effective normal stress on each fault segment by finding the angle (0-90°) between the fault normal direction and S_1 azimuth. See Unit 8 Section 1 for a review.

b) Plot the principal stresses and frictional failure line on a 2-D Mohr diagram. Plot the resolved shear and effective normal stress on each fault segment. The points should all plot on the Mohr circle. Color the points by the value of the Coulomb Failure Function (CFF).

c) Using the Coulomb failure criterion, determine the magnitude of the pore pressure perturbation required to induce slip on each fault segment.

d) Repeat steps (a-c) using an S_1 azimuth of 20°.

Part 2 (optional)

If you are interested in exploring this topic further, you can access the software used in the analysis of Chen et al. (2018) at the Stanford Center for Induced and Triggered Seismicity website (https://scits.stanford.edu/fault-slip-potential). The Fault Slip Potential (FSP) tool provides probabilistic estimates of injection-induced fault slip by considering the uncertainty in key geomechanical parameters such as the coefficient of friction and the state of stress. See Unit 19 Section 1 for details.

Part 3

Use the plots and calculations from Part 1 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.