Unconventional Reservoir Geomechanics
Spring 2020

Homework 1: State of Stress in Unconventional Reservoirs

Part 1: Vertical stress and vertical stress gradient

a) Plot density as a function of depth. Put density on the x-axis and depth on an inverted y-axis.

b) Divide the density profile into 5 blocks. Compute the average density in each block and plot blocked density on the same axes as (a).

c) Calculate the vertical stress. Calculate a hydrostatic pore pressure gradient.

d) Calculate the vertical stress gradient.

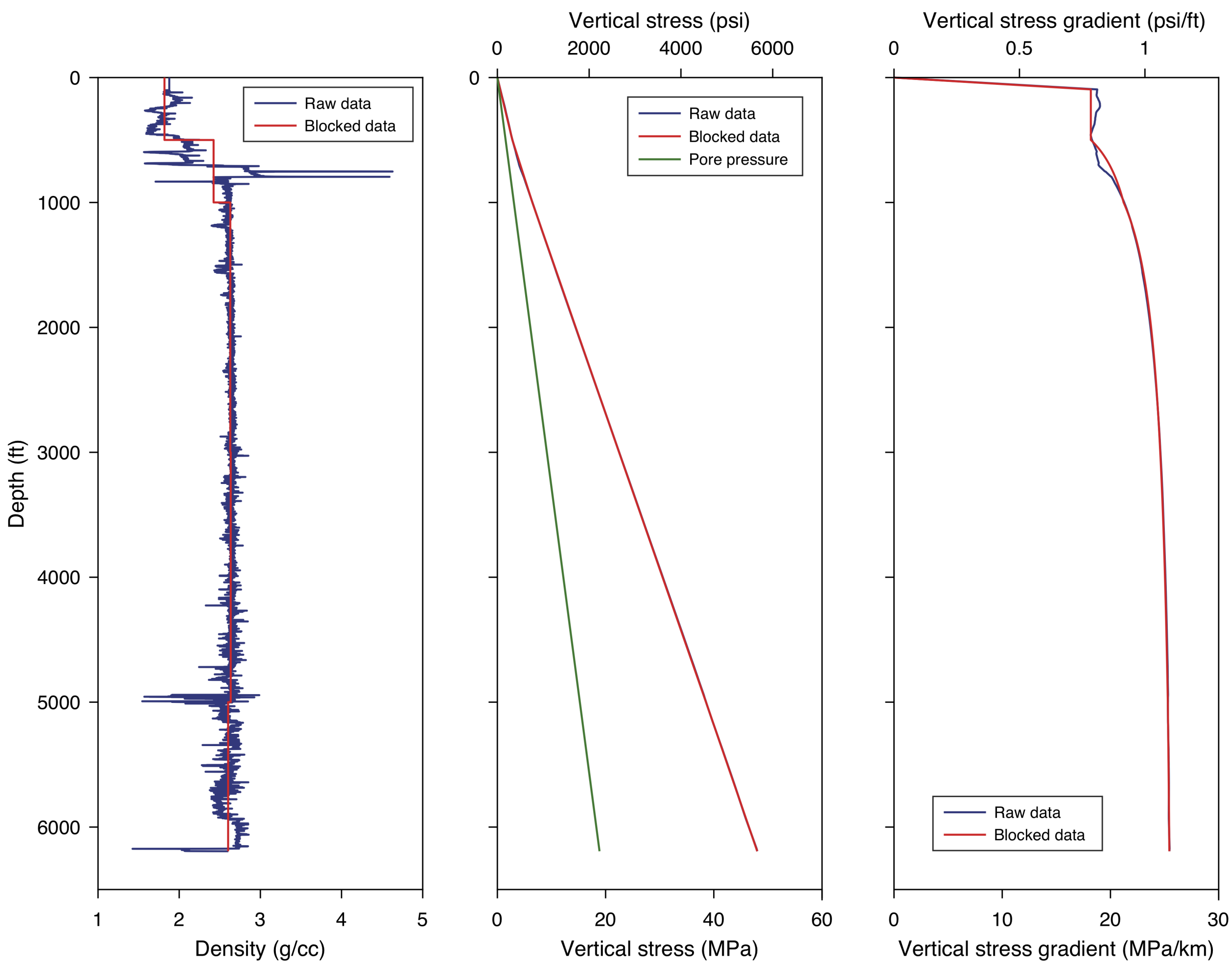

Figure 1: (a)Blocked density log. (b) Vertical stress and pore pressure. (c) Vertical stress gradient.

Part 2: Stress polygon

a) Calculate stress magnitude constraints for each faulting regime.

Reverse faulting ($S_{Hmax} > S_{hmin} > S_V$)

$$\frac{S_{Hmax} - P_p}{S_V - P_p} = (\sqrt{\mu^2 + 1} + \mu)^2$$

S_{V} at 5500 ft is 42.52 MPa, P_p at 5500 ft is 18.96 MPa. The upper bound for S_{Hmax} in the reverse faulting regime is 92.00 MPa.

Strike-slip faulting ($S_{Hmax} > S_V > S_{hmin}$)

$$\frac{S_{Hmax} - P_p}{S_{hmin} - P_p} = (\sqrt{\mu^2 + 1} + \mu)^2$$

$$S_{Hmax} = 3.1(S_{hmin} - 18.96 \text{ MPa}) + 18.96 \text{ MPa}$$

Normal faulting ($S_V > S_{Hmax} > S_{hmin}$)

$$\frac{S_V - P_p}{S_{hmin} - P_p} = (\sqrt{\mu^2 + 1} + \mu)^2$$

The lower bound for S_{hmin} in the normal faulting regime is 26.56 MPa.

The instantaneous shut-in pressure (ISIP) approximates the minimum principal stress, S_3.

$$\frac{S_1 - P_p}{S_3 - P_p} = (\sqrt{\mu^2 + 1} + \mu)^2$$

S_1 can range from 38 MPa to 77.98 MPa. Given that $S_V > S_3$, this area of the reservoir is likely in a strike-slip or normal faulting stress state.

b) Repeat (a) for an ISIP of 28 MPa. If the reservoir is in frictional equilibrium and has both active normal and strike-slip faults, what are the range of allowable values of S_{Hmax} and S_{hmin}?

For $S_3 = 28$ MPa, the upper bound on S_1 is:

$S_1 = 3.1(28 - 18.96) + 18.96 = 46.98$ MPa

For SS/NF, $S_{Hmax} \approx S_V = 42.52$. This represents a lower bound.

c) Construct the stress polygon. Plot your results from (a) on S_{Hmax} vs. S_{hmin} axes in units of MPa. Plot S_{v} on the same axes and draw in the boundaries between the faulting regimes as illustrated in Unit 3.

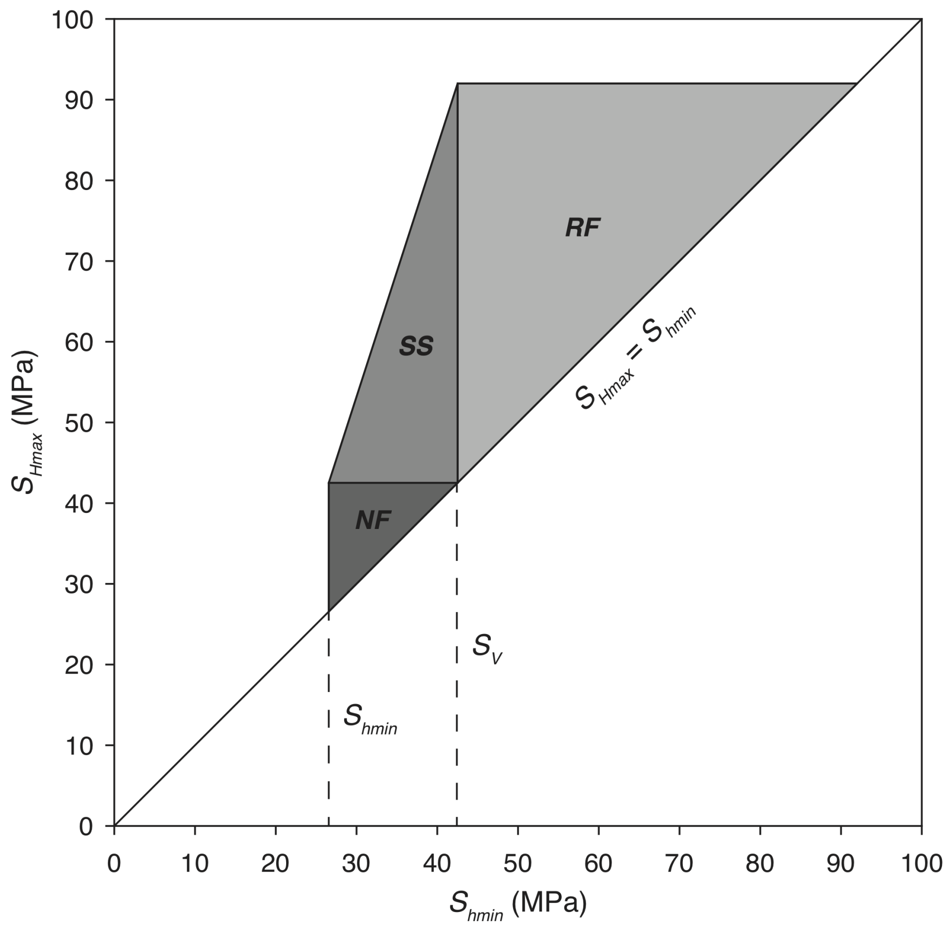

Figure 2: Stress polygon for Part 2a.

d) Repeat (a) and (c) using a pore pressure gradient of 0.7 psi/ft. What is the effect of overpressure on the stress polygon and the range of allowable stress states?

Reverse faulting ($S_{Hmax} > S_{hmin} > S_V$)

$$\frac{S_{Hmax} - P_p}{S_V - P_p} = (\sqrt{\mu^2 + 1} + \mu)^2$$

S_V at 5500 ft is 42.52 MPa, P_p at 5500 ft is 26.56 MPa. The upper bound for S_{Hmax} in the reverse faulting regime is 76.08 MPa.

Strike-slip faulting ($S_{Hmax} > S_V > S_{hmin}$)

$$\frac{S_{Hmax} - P_p}{S_{hmin} - P_p} = (\sqrt{\mu^2 + 1} + \mu)^2$$

$$S_{Hmax} = 3.1(S_{hmin} - 26.54 \text{ MPa}) + 26.54 \text{ MPa}$$

Normal faulting ($S_V > S_{Hmax} > S_{hmin}$)

$$\frac{S_V - P_p}{S_{hmin} - P_p} = (\sqrt{\mu^2 + 1} + \mu)^2$$

The lower bound for S_{hmin} in the normal faulting regime is 31.67 MPa.

The instantaneous shut-in pressure (ISIP) approximates the minimum principal stress, S_3.

$$\frac{S_1 - P_p}{S_3 - P_p} = (\sqrt{\mu^2 + 1} + \mu)^2$$

S_1 can range from 38 MPa to 62.06 MPa. Given that $S_V > S_3$, this area of the reservoir is likely in a strike-slip or normal faulting stress state. Increasing the pore pressure decreases the size of the stress polygon (reduces the range of allowable stress states).

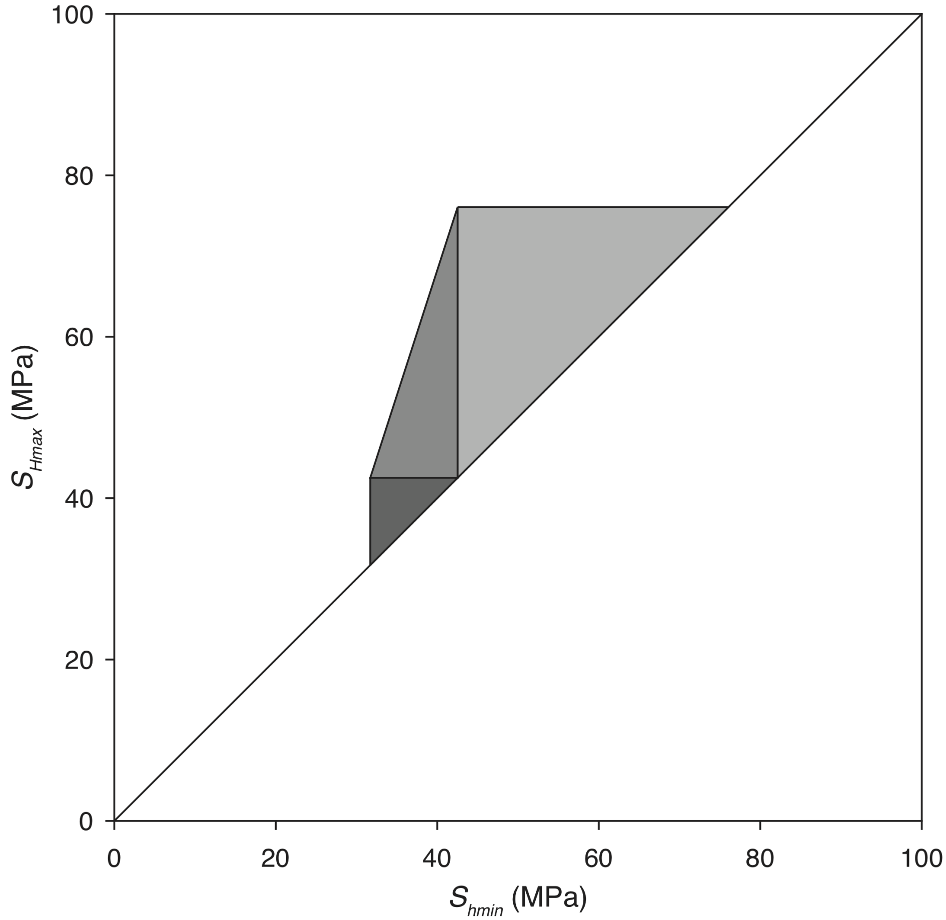

Figure 3: Stress polygon for Part 2d.

Part 3: Answer the questions in edX

See edX for answers to numerical entry and multiple choice questions