Advanced Geomechanics – WP5 10/18/2023

3.6.2 Exercise 2: Depletion stress path

For this problem you have to use the geomechanical module of reservoir simulator CMG https://www.cmgl.ca/. The software is available to UT Austin students here: http://pge.utexas.edu/LRC/

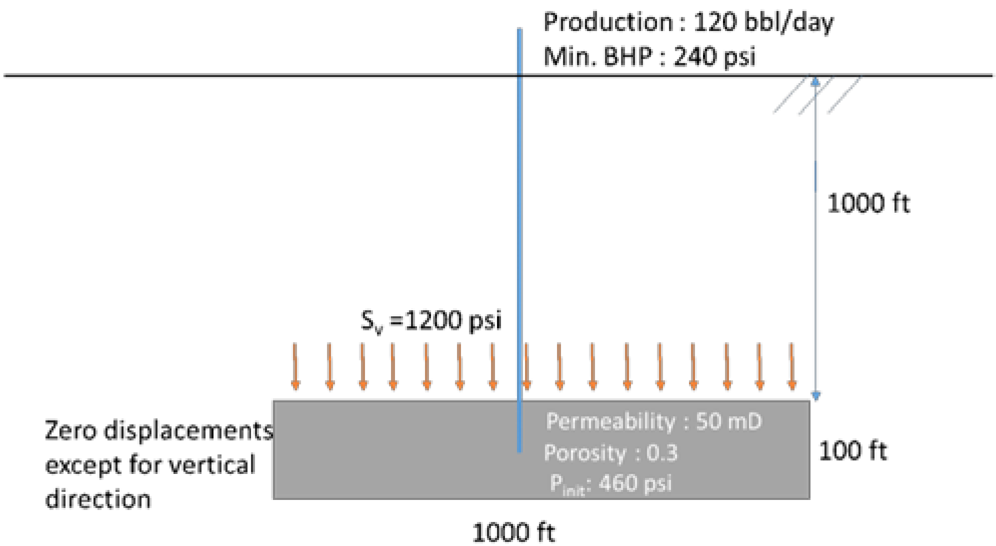
a. Review the files CMG_Geomechanics_Tutorial.pdf and CMG_Running_InputFile.pdf.

OK

b. Change the vertical stress and well schedule as shown in the figure below (example files: Injection1.dat and Production1.dat).

Used Production1.dat to simulate depletion.

Figure 3.28: Schematic cross section of reservoir model for depletion.



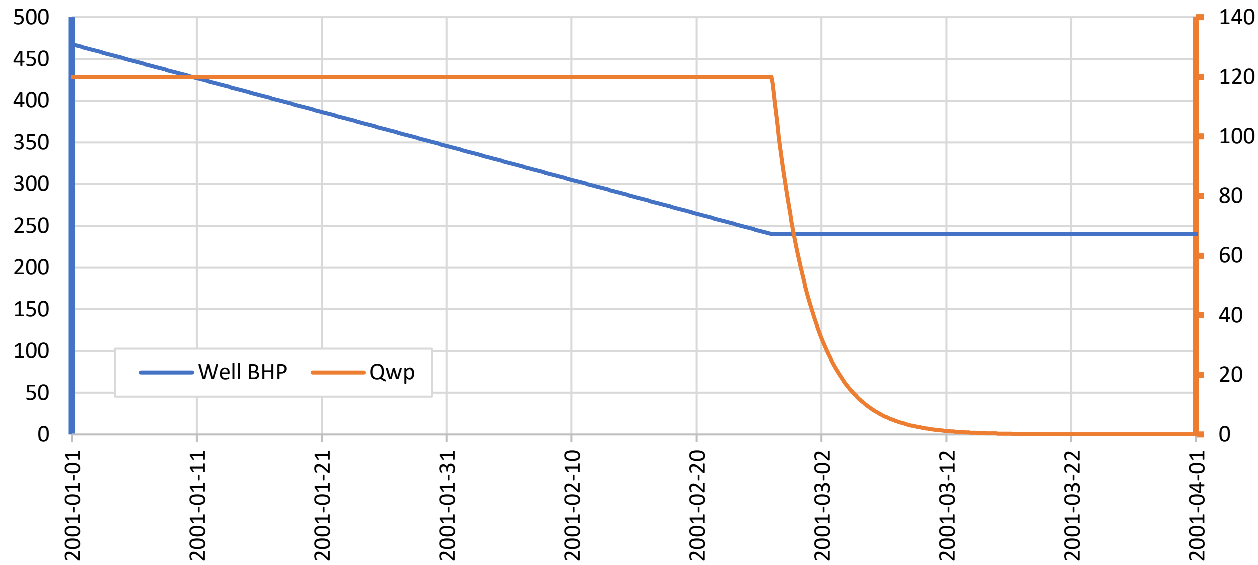
c. What is initial boundary condition in each direction? (i.e. constant stress or zero displacement).

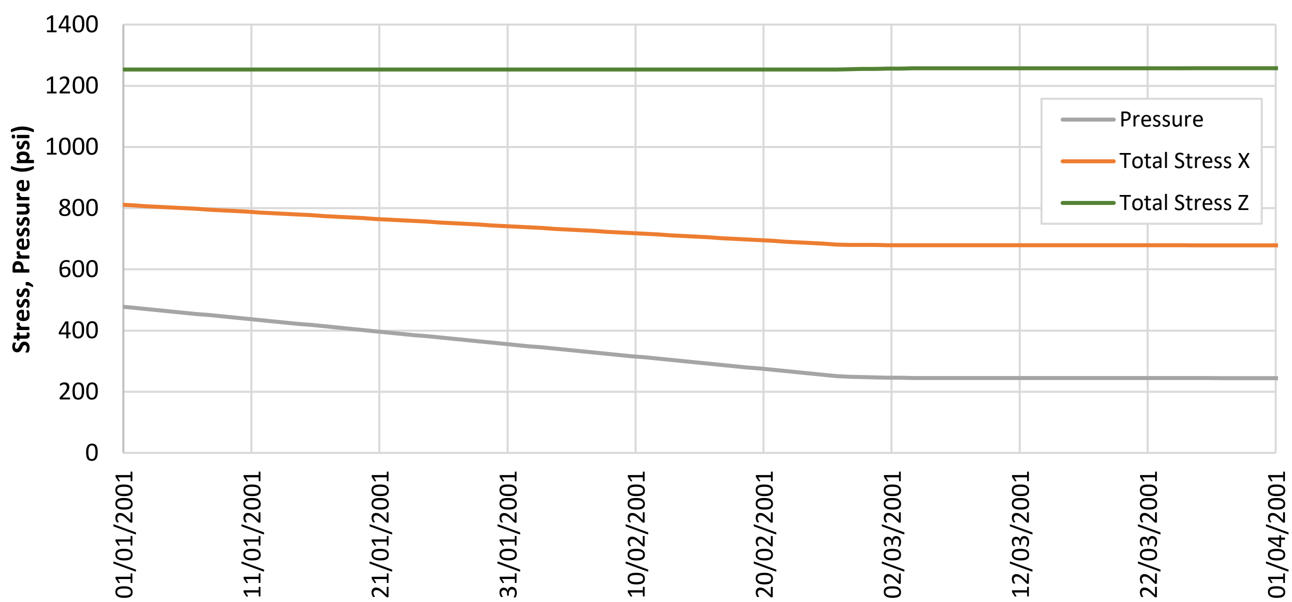
No displacement at front, back, bottom, left and right.
We set constant total stress on top of the reservoir.

```
*RCONBT *ALL ** On the bottom
*RCONLF *ALL ** On the left
*RCONRT *ALL ** On the right
*RCONBK *ALL ** On the back
*RCONFT *ALL ** On the front
```

```
*DLOADBC3D
*IJK 1:21 1:21 1 **top
** node1 node2 node3 node4 load
1      2      3      4      86.455 ** tonf/m2
```

d. Plot 1 - Plot minimum principal total stress (Total stress I), vertical total stress (Total stress K), and pore pressure (Pressure) vs time. (**Note: Please remove initial data (time = 0) when you plot).





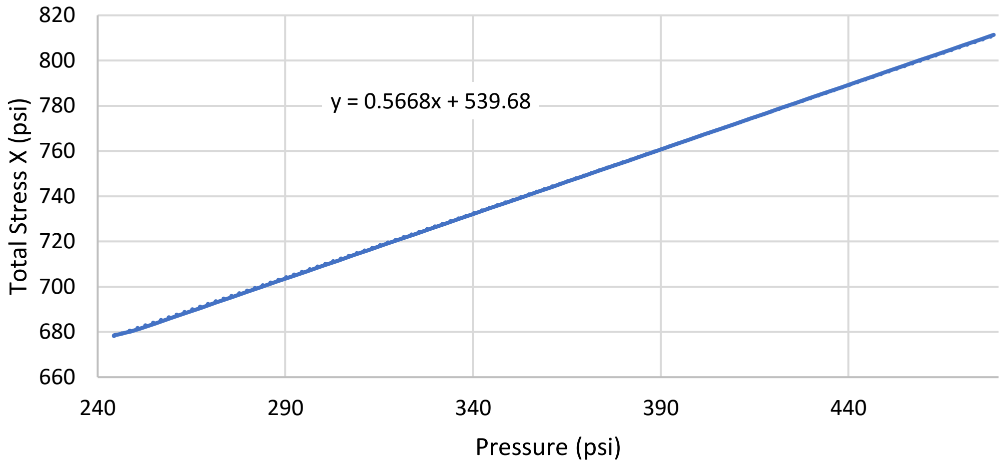
e. Plot 2 - Plot minimum principal stress (y-axis) vs pore pressure (x-axis), and verify the slope of the curve is similar with $\alpha \frac{1-2\nu}{1-\nu}$ (α is the Biot coefficient and ν is Poisson's ratio)

**Note: Please remove initial data (time = 0) when you plot pressure and stresses).

$$\boldsymbol{\sigma_{min} = 0.5668\, P_p + 539.84 \quad \Longrightarrow \quad \frac{d\sigma_{min}}{dP_p} = 0.5668}$$

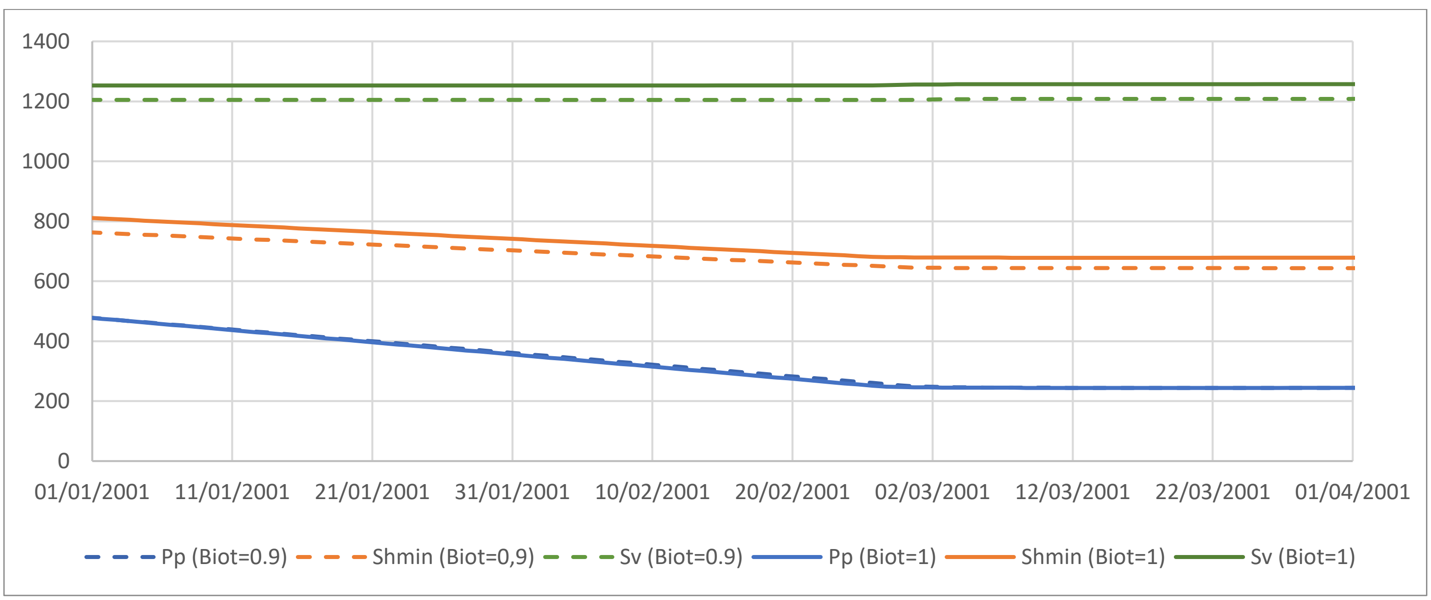
$$\boldsymbol{\alpha = 1 \qquad \nu = 0.3 \quad \Longrightarrow \quad \alpha \frac{1-2\nu}{1-\nu} = 0.5714}$$

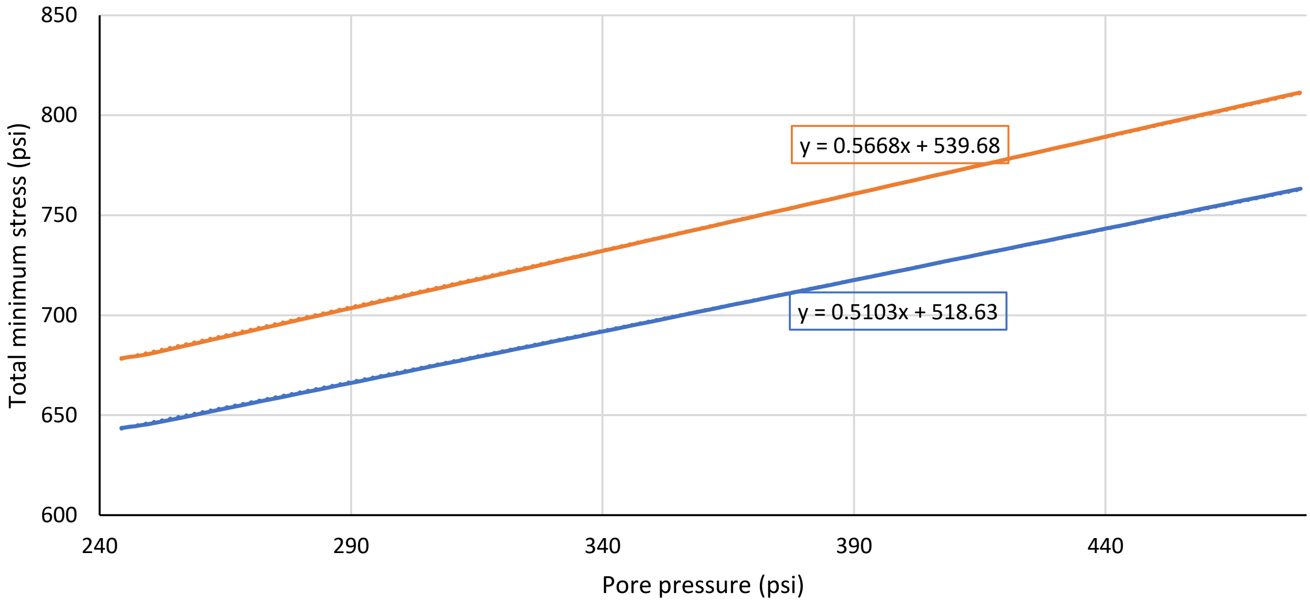
We can see that the slope is similar to $\left[\alpha \frac{1-2\nu}{1-\nu}\right]$.



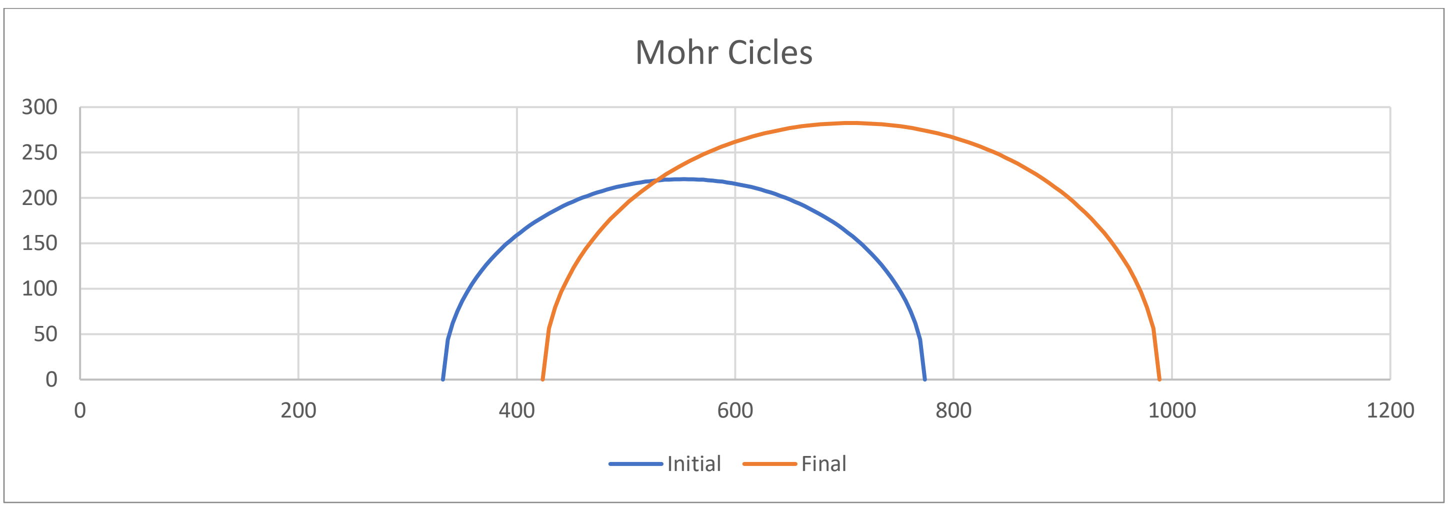
f. Run the simulation again using Biot coefficient from the previous laboratory problem, repeat the question "d" using the new simulation result and plot on the same figure.

Running with $\alpha = 0.9$ ($\alpha\frac{1-2\nu}{1-\nu} = 0.5143$), we get the following plots, and $\frac{d\sigma_{min}}{P_p} = 0.5103$, as expected.



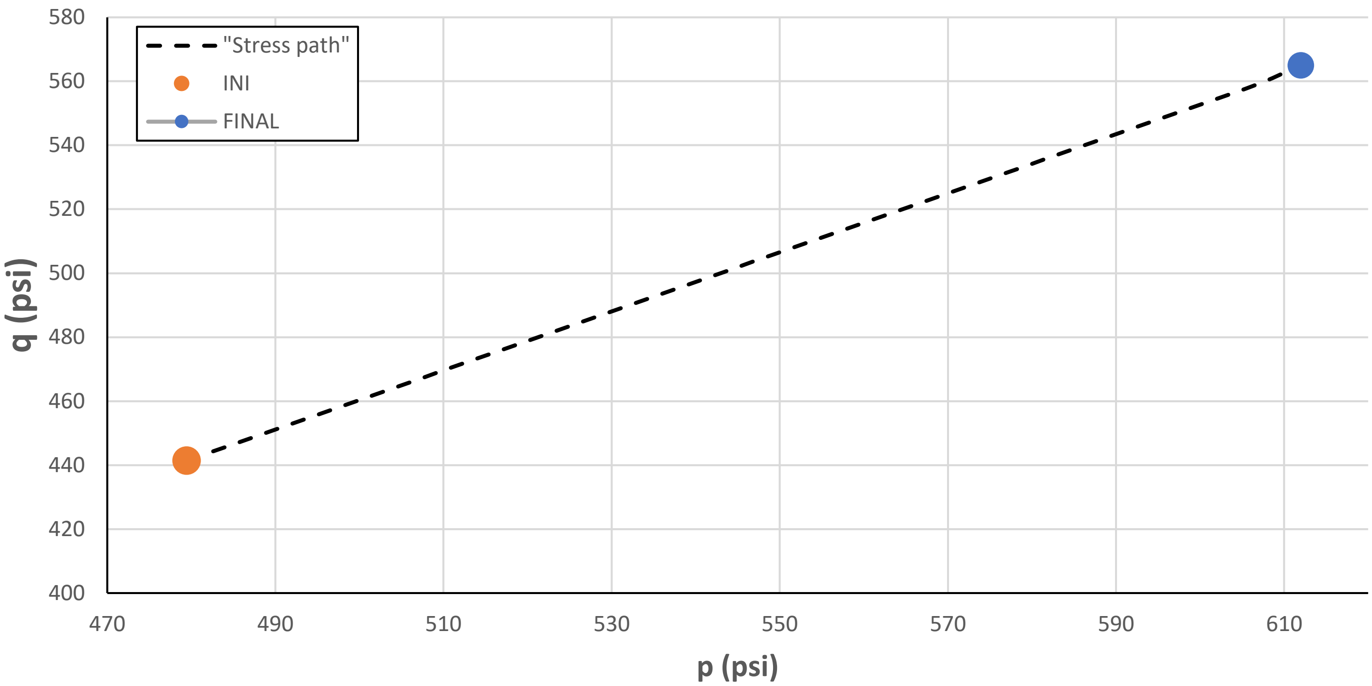


g. Plot the stress path with Mohr circles for the initial (0.1 days) and final time (100 days).



h. Plot the stress path in the (p', q) space for the same period of time.

$$p' = \frac{\sigma_1 + 2\,\sigma_3}{3}$$
$$q = \sigma_1 - \sigma_3$$



i. What is the absolute minimum pressure to create a hydraulic fracture (i.e. minimum principal total stress) at the end of the simulation when bottom-hole pressure is BHP = 240 psi? Compare with the analytical solution.

The total horizontal minimum stress in the end of the simulation is about $\mathbf{643\ psi}$, with $P_p = 244\text{psi}$. The minimum pressure to create a hydraulic fracture would thus be around 643psi.

The analytical estimates would be about $\mathbf{641.5\ psi}$ which is quite similar to the numerical results. The calculations are below.

$$\boldsymbol{S_{22} = \frac{\nu}{1-\nu} S_{33} + \alpha \frac{1-2\nu}{1-\nu} P_p}$$

$$\boldsymbol{S_{22} = \frac{0.3}{1-0.3} 1204 + 0.9 \frac{1-0.6}{1-0.3} 244 = 516 + 125.5 = 641.5\text{psi}}$$