# Unconventional Reservoir Geomechanics
# Spring 2020

Homework 5: Reservoir Seismology

Due June 1, 2020 00:00 PST

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### Instructions

This assignment focuses on concepts of reservoir seismology and shear stimulation of faults. We will study a catalog of microseismic events associated with hydraulic stimulation of 4 wells in the Woodford and Mississippi Lime formations. The .txt files on the course page contain the time, date, position, and magnitude of microseismic events from Wells A-D. The details of this case study are presented in Ma & Zoback (2017).

### Part 1: Gutenberg-Richter analysis

a) Plot the Gutenberg-Richter curves for each of the 4 wells using the expression below:

   $\log(N >= M) = a - bM$

   where $N$ is the total number of earthquakes greater than minimum magnitude $M$, $a$ is the y-intercept and $b$ represents the relative number of large vs. small earthquakes. The plots will have the log cumulative number of earthquakes above a certain magnitude on the y-axis and the magnitude on the x-axis. Refer to Unit 12 Section 4 for examples.

b) Determine the magnitude of completeness for the 4 wells. Consider this to be the lowest magnitude at which the cumulative number of events is 5% of the total number of events.

c) Determine the b-values for the 4 wells. How do these b-values compare to those observed in active tectonic areas?

d) Compare the number of events and the b-values in the Woodford and Mississippi Lime formations. Keep in the magnitude of completeness in mind while making the comparison. Are there any systematic differences in earthquake statistics with respect to the geologic characteristics of these formations?

**Part 2: Seismic moment and surface area**

Determine the seismic moment, $M_0$, of the earthquakes from the provided moment magnitudes, $M_w$, using the following equation:

$$M_w = \frac{2}{3}\left(\log_{10} M_0 - 9\right)$$

Calculate the total surface area, $S$, created by the displacements from the microseismic events associated with each well using the following equation. Assume a stress drop of $\Delta\tau = 0.5$ MPa.

$$S = \pi\left(\frac{7M_0}{16\Delta\tau}\right)^{2/3}$$

Calculate the total surface area, $S$, created by the displacements from the microseismic events associated with each well using the following equation from Hakso & Zoback (2019) that assumes a circular fault patch. Use a stress drop of $\Delta\tau = 0.5$ MPa.

a) How much area was created in the stimulated fracture networks in each well?

b) In which well was the most surface area created?

c) Based your answers above, which formation was stimulated most effectively?