Lab 5: The Earthquake Cycle

This lab will introduce you to the basic quantitative concepts of the earthquake cycle for a vertical strike-slip fault. Most of your time will be spent calculating and plotting things using Maple. This document describes what you will need to hand in for credit.

Part I: Analytical Models of the Earthquake Cycle

1) Download the Maple worksheet from the course website and open the file with Maple. The worksheet provides a step-by-step walk-through of what you need to do. Feel free to write in notes and observations, but keep in mind that you will not hand in your Maple file.

2) When you have completed the Maple worksheet, you will hand in the following plots with brief, but well-written captions typed into a Word document. I have provided instructions in the Maple worksheet for exporting high quality plots into Microsoft Word. You must hand in a printed copy. Electronic submissions will not be accepted.

Figure 1: Plot of interseismic surface velocities around a strike-slip fault for 3 different fault slip rates.

Figure 2: Plot of interseismic surface velocities around a strike-slip fault for 3 different locking depths.

Figure 3: Plot of provided southern California GPS data and a best-fitting interseismic fault model. Be sure to describe your model parameters (slip rate, locking depth, and location of the fault) and RMS error in your caption.

Figure 4: Plot of interseismic/coseismic shear strain. Make sure to state what the maximum strain rate is, where this occurs. This figure is optional and will count as extra credit if you complete it correctly.

Part II: Final Questions

Your final task is to answer the following questions in the spaces provided. If you answer does not fit into the provided space, you should consider condensing your response.

1) Does figure 1 show a right-lateral or left-lateral strike slip fault? How do you know? If it helps, you can assume that the fault is trending N/S and any motion in the north direction is positive.
2) Given the pattern of surface velocities in Figures 1-2, at what distance from the fault will the maximum surface velocity theoretically occur? Fill in the blank below. Do not limit your response to the plot area. All plots must have a finite range.

Max interseismic surface velocity is located at \( x = \) ________________

3) If a strike-slip fault slips at 10 mm/yr what will be the maximum surface velocity that a GPS site could theoretically measure during the interseismic period? Assume that a GPS site directly on top of the fault records zero velocity. This is what your plots assume. Fill in the blank below.

For a slip rate of 10 mm/yr:
The max surface velocity on each side of the fault is ______________________

4) Fill in the blank below with a simple equation that relates the max surface velocity, \( U_{\text{max}} \), to the fault slip rate, \( b \). Hint: This equation will not be complex. Below your equation, write no more than two sentences to explain why this equation makes sense, conceptually.

\[ U_{\text{max}} = \] ________________

5) Using what you have learned from your interseismic plots, and the previous questions, where would you put GPS sites relative to a fault to figure out the fault slip rate during the interseismic period? Why? At least how many sites would you need? You can draw a sketch if that helps you make your point.
6) Where would you put GPS stations during the **interseismic period** to determine the **fault's locking depth**? Why? How many would you need? You can include a sketch if it helps you make your point.

7) Engineering shear strain, $\gamma$, is defined as: $\gamma = \frac{\partial u}{\partial x}$

Hey, wait, that’s the same thing as the slope of our surface velocity plots! Therefore, for a given slip rate, what type of locking depth (shallow, deep, or medium) produces the largest surface shear strain rates? What type of locking depth produces the most localized shear strain rates? You can include a sketch if it helps you make your point. The extra credit strain plots may help you with this, but you should be able to figure this out without the strain plots just by looking at your figure 2 plot.
8) What fault parameters did you use for your best-fitting model of the San Andreas fault? Fill in the blanks below.

   Slip Rate (in mm/yr): ______________________

   Locking Depth (in km): ______________________

   Fault Location (km): ______________________

   RMS Error (mm/yr): ______________________

9) What is one assumption/limitation of this fault model? There are many, but you should discuss just one way that the analytical solution is a simplification compared to a real fault. Recall that the assumptions of the analytical interseismic model were given in the Maple sheet and in lecture.

10) For what rock types is your model appropriate? Hint: Is there a rock type parameter in the interseismic equation? How would this model change if the fault were in mudstone vs granite?
11) Let’s say you have only two GPS sites and you want to be able to measure the slip in the next earthquake on a strike-slip fault. Where would you put your two GPS sites relative to the fault in order to best measure future coseismic slip events? You can include a sketch if it helps you make your point.

12) Using Figure 4 or similar plots shown in lecture, where are the max/min shear strain during the interseismic and coseismic periods? Recall that shear strain is the slope of our surface velocity plots. Hint: Only consider the absolute value of strain since a negative sign just changes the direction of the shearing, not the amount of shearing.

Max interseismic shear strain occurs at x = __________________

Zero interseismic shear strain occurs at x = __________________

Max coseismic shear strain occurs at x = __________________

Zero coseismic shear strain occurs at x = __________________

13) How much strain is there in the long term if the coseismic slip is equal to the total accumulated interseismic slip? Hint: What is the slope of the long term or geologic timescale plot shown in lecture?

Long-Term (geologic timescale) shear strain = __________________