

## Earth Forces

### Problem set #4

due: March 31, 2008

1. In a certain region, we observe numerous vertical right-lateral faults with an average strike of N45°E, and several left-lateral vertical faults with a strike of N115°E.

- A) What are the  $\sigma_1$ ,  $\sigma_2$ , and  $\sigma_3$  orientations in this region?
- B) What is the angle of internal friction?
- C) What is the average frictional coefficient ( $\mu$ ) on the faults?

2. In a different region, assume that we know  $\sigma_1 = 100$  MPa, and  $\sigma_3 = 50$  MPa, and the angle of internal friction  $\phi = 30^\circ$ . The Department of Energy wants to inject nuclear waste under pressure into a well. How much pore pressure can be sustained before failure occurs? (Hint, use a Mohr circle construction)

3. The 1989 Loma Prieta "World Series" earthquake near San Francisco had fault dimensions of approximately 15 x 35 km and a seismic moment of  $2.5 \times 10^{19}$  N-m.

A) Assuming a shear modulus (rigidity) of  $3 \times 10^{10}$  N/m<sup>2</sup>, estimate the average displacement on the fault.

B) If the San Andreas Fault slips at a rate of 4.5 cm/yr in this region, how often (on the average) should earthquakes like the 1989 event occur? Assume that all the tectonic slip in this region is released in earthquakes similar to the 1989 event.

C) Do the same calculation for the 1906 San Francisco earthquake. This earthquake occurred north of the Loma Prieta earthquake and had fault dimensions of 15 x 300 km and a seismic moment of  $6 \times 10^{20}$  N-m. What was the displacement in this earthquake? How often should similar events occur along this section of the fault?

4. It is sometimes suggested that small earthquakes can act as a "safety valve" to release the plate motion slip that otherwise might cause a large, damaging earthquake. Consider a 200 km long section of the San Andreas fault that might cause an Mw 8.0 earthquake. Assume that the San Andreas fault is 15 km wide in the vertical direction.

A) How often would the Mw 8.0 earthquake occur if the rate of plate motion between North America and Pacific plates along the San Andreas is 5.5 cm/yr ?

B) How many Mw 6.0 earthquakes would have to occur during the same time period to release the same amount of slip? How about Mw 5.0 earthquakes?

C) How likely is it that small earthquakes can account for all the slip?

5. A) Using a stereonet, plot the P wave first motions and construct a focal mechanism for the following earthquake

Station	Distance (degrees)	Azimuth (degrees)	Take-off angle (deg)	polarity
Atlanta	46	307	25	dilatation
Madrid	40	45	27	compression
Bogota	34	263	28	compression
Caracas	26	274	30	dilatation
La Paz	38	227	27	compression
Trieste	58	42	22	compression
Brasilia	26	197	30	compression
Bermuda	32	318	29	dilatation
Nairobi	77	94	18	dilatation
Cape Town	75	120	18	dilatation

B) This earthquake occurred along the Mid-Atlantic Ridge. Which of the two nodal planes probably represents the fault plane? Give the strike, dip, and sense of motion along this fault. How accurately can you determine the fault plane? What tectonic interpretation would you give to this earthquake?