Physics of Earthquakes
ES 290J

Professor: Emily Brodsky
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9-1854

Meeting: M/W 12:00-1:45 PM
With exceptional times as noted below.

The goal of this class is to provide a systematic introduction to the study of earthquakes. One class each week will be primarily lecture. The second half of the other class will be discussion of a major paper on the topic of the week's lectures.

Class assignments
Problems will be assigned during lecture. Problems are for your benefit. You may hand in any problems that you like for comment, but there is no formal grading of the problems.

Student Requirements

- Active participation in reading discussions
- Short summary (1 paragraph) + 3 questions/comments on each assigned paper - due at the beginning of discussion

Recommended sources
Kanamori and Brodsky, The Physics of Earthquakes, *Rep. Prog. Phys.* **67**, 1429-1496, 2004. (Available at www.pmc.ucsc.edu/~brodsky/)

Jaeger, Cook and Zimmerman, *Fundamentals of Rock Mechanics,* Wiley-Blackwell, 2007.

Scholz, C. *The Mechanics of Earthquakes and Faulting*, 2nd ed. Cambridge Univ. Press, 2002.

Course Outline

1/4 Stress in the crust & Andersonian mechanics
Assignments: Derive Mohr circle, optimal angle and reactivation angle
1/6 Focal mechanisms
Reading: Célérier. Seeking Anderson's faulting in seismicity: A centennial celebration. *Reviews of Geophysics* (2008)

1/11 Strain, Elasticitiy, Earthquake source representation and scaling: double couples, seismic moment, stress drop, rupture length (TENTATIVE DATE – MAY BE RESCHEDULED)
Assignments: Compare dilatational strain to infinitesmal limit, Derive shear stresses in terms of principal stresses for pure shear
1/13 Magnitudes, source time functions and source spectra (including Haskell model)
Assignment: Plot Haskell source spectrum in matlab
Reading: Kanamori and Anderson. Theoretical basis of some empirical relations in seismology. *Bulletin Of The Seismological Society Of America* (1975) vol. 65 (5) pp. 1073

1/18 MLK DAY – NO CLASSES
1/20 Real area of contact, rate-state friction
Assignment: Derive long-term asymptote of friction after a velocity step

1/25 Slider blocks and frictional stability
Reading: Brace and Byerlee. Stick-slip as a mechanism for earthquakes. *Science* (1966) vol. 153 pp. 990-992
Scholz. Earthquakes and friction laws. Nature (1998) vol. 391 (6662) pp. 37-42
1/27 Quasi-static fracture mechanics: Modes, Critical Nucleation Size, Stress intensity, energy release rate

2/1 Dynamic fracture mechanics: Kinetic energy and the energy release rate, limited velocities
Assignment: Use stress intensity to connect stress drop to fracture energy for steady-state, quasi-static crack; calculate magnitude of earthquake corresponding to critical crack nucleation length
2/3 Reading: Atkinson, *Fracture Mechanics of Rocks*, 1987, Chapt. 1

2/8 Energy Balance – connecting crack and frictional descriptions SUBSTITUTED FIELD TRIP AND SHIFTED ALL CLASSES BY 1
2/10 High velocity friction – flash heating, melting
Assignment: Calculate minimum slip for melting
Reading: Kanamori, H. and Rivera, L., 2006, Energy partitioning during an earthquake: AGU Chapman Volume, AGU Chapman Volume, Geophysical Monograph Series 170, "Earthquakes: Radiated Energy and the Physics of Faulting."

2/15 PRESIDENTS DAY – NO CLASSES
2/17High velocity friction, lubrication (including intro to fluid mechanics)

2/22 Earthquake statistics – Gutenberg-Richter, Omori's Law, Aftershock productivity, Spatial Decay
Assignment: Download catalog from somewhere and plot magnitude-frequency & aftershock decay
2/24 Deriving a constitutive law for seismicity
Reading: Dieterich, J. A Constitutive Law For Rate Of Earthquake Production And Its Application To Earthquake Clustering. *Journal Of Geophysical Research* (1994) Vol. 99 (B2) p. 2601-2618

2/29 Explanations for aftershock decay: Static stress, cascades, pore pressure diffusion (including effective pressure), afterslip, viscoelasticity
3/2 Rock rheology: microscopic origin of elasticity /viscosity
Reading: Brace and Kohlstedt. Limits on lithospheric stress imposed by laboratory experiments. *J. geophys. Res* (1980) vol. 85 pp. 6248–6252

THURSDAY 3/3 (NOTE TIME AND LET ME KNOW IF THERE IS ANY CONFLICT) Measuring locking depth – Dislocation models
Viscoelastic diffusion for coupled elastic/viscous layers (the Elsasser problem)

3/7- Induced earthquakes & Prediction (including paleoseismology)
Reading: Raleigh et al. Experiment in earthquake control at Rangely, Colorado. *Science* (1976) vol. 191 (4233) pp. 1230-1237