Fractures and Faults in the Earth

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This lecture-seminar course focuses on the most widespread geologic structures in the earth's crust: fractures. Lectures in the first third of the course address underlying principals of elasticity theory and fracture mechanics. The middle third of the course concerns boundary element modeling, an extremely versatile and useful method to numerically model fractures. In the last third of the course we will discuss topics such as formation of joints, dike propagation, mechanics of mid-ocean ridges, and fault mechanics. The course as a whole should provide students with a working knowledge of fracture mechanics theory and an appreciation of its broad application to geologic phenomena.

We will develop a significant numbers of key solutions from fundamentals so that we can have confidence in them, gain insight into them, and understand the assumptions behind them. As a result, students will be able to use this material in other classes and as a foundation for further independent work on fractures. However, some solutions (notably on 3-D fractures) which are difficult to derive will simply be presented.

Grades will be based on homework problems (50%), and class presentations of journal papers (40%) and class participation (10%). Homeworks and the presentations will emphasize use of Matlab.

Textbooks: These are all outstanding books

Barber, J.R., 1993, Elasticity: Kluwer Academic Publishers, Boston, 293 p.

Chou, P.C., and Pagano, N.J., 1967, Elasticity: Dover, New York, 290 p. (optional)

Class notes will supplement the texts and papers.

Table of Contents/Tentative Schedule

Week	Topics	Reading (Tentative)
1	Introduction; Vectors	Barber Intro,1.1; Chou & Pagano 8.1,8.2, 11.1,11.2, Barber 1.1.2, 1.1.3
2	Tensors; Stress;	Chou & Pagano 8.3; Chou & Pagano 1, 9.1, Barber 1.1
3	Cauchy's Formula; Strain	Chou & Pagano 9.2,; Barber 1.2, 1.3; Chou & Pagano 2
4	Equilibrium & Compatibility; Boundary value problems;	Chou & Pagano 3,4.1, 4.2, 4.3 Barber 2.1, 2.2,3
5	Stress Functions; Elasticity: polar coordinates (I & II)	Barber 3,4 Barber 8.1, 8.2, 8.3, 8.4,
6	Stresses around holes; Dislocations;	Barber 9.2, 9.3; Barber 13.1, 13.2
7	Stress fields around 2-D fractures; Westergaard stress functions;	Barber 13.3 Atkinson 8.1, 8.2 Westergaard paper Atkinson 8.3, 8.4, 8.5 Handouts
8	Stress Intensity factors; Fracture energy release rate; 3-D fractures	Barber 13; Atkinson 1.2.3, 8.5.1 Atkinson 1.2.4 Handouts
9	Boundary elements	Crouch & Starfield 3,4,5
10	Boundary elements	Crouch & Starfield 3,4,5
11	Joints	Secor, 1965; Pollard, 1976; Pollard & Muller, 1976; DeGraff & Aydin, 1988
12	Joints Joints Dikes	Pollard & Aydin, 1988; Pollard et al., 1983 Olson & Pollard, 1989 Delaney & Pollard, 1981
13	Dikes Dikes Mid-ocean ridges	Delaney et al., 1986; Rubin, 1995 Pollard and Aydin, 1984
14	Faults Faults Faults	Segall and Pollard, 1980 Bilham & King, 1989 Burgmann et al., 1994

15	Faults Arches at Arches National Park Stylolites	Martel, 1996 Aydin, 1994; Fletcher and Pollard, 1975;

INTRODUCTION (01)

<u>I Main topics</u>

- **A Why are fractures important?**
- **B What is a fracture?**
- **C Geologic application of engineering fracture mechanics**
- **D Quantitative methods for predicting fracture patterns**

<u>II Why are fractures important?</u>

- **A Most common structures in the earth's crust (i.e., where we live)**
- **B Fractures define plate boundaries (essential tectonic structures)**
- **C Fractures dictate and record intra-plate deformation**
- **D Fractures generate earthquakes**
- **E Fractures locally dominate mass and fluid flow in the earth's crust**
  - <u>1 Groundwater</u>
    - a Drinking water
    - b Nuclear waste disposal
    - c Chemical waste disposal
    - d Solid waste disposal
  - <u>2 Geothermal fluids (energy)</u>
  - <u>3 Hydrothermal fluids (ores)</u>
  - <u>4 Petroleum and natural gas (energy)</u>
  - <u>5 Magma (dikes)</u>
- **F They control the strength of rock masses (engineering scale)**
- **G Fracture signal incipient failure of slopes**

III What is a fracture?

A A discontinuity in the deformation field

B Relatively planar structure

C Bounded structure

IV Geologic application of engineering fracture mechanics

A Nucleation

B Propagation

C Termination

V Quantitative methods for predicting fracture patterns

References

Pollard, D.D. & Segall, P. 1987. Theoretical displacements and stresses near fractures in rock. In: *Fracture Mechanics of Rock*, (edited by Atkinson, B.K.). Academic Press, London, 277-349.