CRUSTAL DEFORMATION (TTh, 1:10-2:25, 603 Schermerhorn),
second half: Ductile plate deformation (14 lectures)
Ben Holtzman (benh@ldeo.columbia.edu), Lamont, Seismology Bldg, room 220.

course work:
2 MATLAB-based homework/projects
Research project (either individual paper or group experiment)
1 final exam

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lecture 1 (March 9): Overview
Design and philosophy of the course:
moving between empirical, phenomenological & mechanistic approaches.
Overview of relevant length and time scales for processes in question.
Overall driving questions:
How do rocks, as earth materials deform at all scales?
A comparative approach applied to real orogens and rifts:
What kinds of structural / dynamic features do we want to be able to explain ?

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PART 1: Deformation mechanisms and rock fabrics
By what processes does stress cause deformation in earth materials?

lecture 2 (Mar 11): Diffusion Creep
What is "High Temperature"?:
Atomic motion and diffusion (brief statistical mechanics perspective);
How does stress cause diffusion and shape change?
Pressure solution and diffusion creep, lattice and grain boundary diffusion
Rock textures associated with diffusion creep.
(in class: Rock & micrograph observation)
Experimental data, Flow Law and Deformation mechanism maps (for only D.C.)

[Spring Break]

lecture 3 (Mar 23): Dislocation creep
Single dislocations (TEM images)
Dislocation organization, work hardening and annealing
Theory: stress field around a dislocation, energetics of organization
Recrystallization mechanisms and LPO development
Flow law and mechanism map (add to diffusion creep map)

Experimental and natural observations of textures:
(in class: Rock & micrograph observation)
Quartz: regimes in experiment (Hirth & Tullis) and field (Hirth, Dunlap & Teyssier).
Olivine: Stress estimates from experiments and nature: Xenoliths &
Moine thrust (Kohlstedt and Weathers), (ice, if interest?)

MATLAB Homework/Project 1: *calculate and modify deformation mechanism maps (3D projection to 2D) for different minerals (quartz, feldspar, olivine, pyroxene), extract trends with changes in stress, grain size, temperature, etc ...*

lecture 4 (Mar 25): Complex patterns in real rocks
Interactions of deformation mechanisms in monophase rocks
Rocks as polyphase materials:
Rheologically contrasting phases
Strain partitioning & Localization:
Ductile fabrics & Multi-scale/fractal organization of shear zones
Effects of fluids / melt:
Deformed granites: magmatic vs solid state
Stress-driven organization of melt

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PART 2: Dynamics and Rheology

How do we describe dynamic behavior of materials and evolution of strain ?

lecture 5 (Mar 30): Large Strain in the Earth
Pure shear, Simple shear, General Shear (MATLAB + appendix)
Shear Zones, Folds, Diaprism, Convection (many scales)

MATLAB Homework/Project 2: *Calculations of rheological evolution with zero-D shear zones, increasing in rheological complexity over the next two lectures.*

lecture 6 (Apr 1): Phenomenological Rheology
Viscoelasticity, Plasticity, Viscoelastoplasticity
(The Cheese Lecture)

lecture 7 (Apr 6): Thermodynamics of shear zones
Zero-D shear zones (ODEs), with intro to non-equilibrium thermodynamics:
Stored and dissipated energy, illustrated with metals (Chrysocoos experiments).
Phenomenological and empirical flow laws, i.e. elastic loading and plastic yielding.
Description of real evolution processes: Grain size evolution and shear heating.

lecture 8 (Apr 8): Rheological structure of plates
Thermal structure of plates and strength profiles (and their limitations).
Develop a 1-D thermal diffusion code for lithospheric temperature profile;
Map stress using flow laws to construct "strength profiles";
Focus on the assumptions that go into the meaning of strength profiles
and their limitations.. Consider other ways of looking at "strength".

***Research Projects: Decide on topics, hand in one-page proposals*

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PART 3: Applications to Plate Deformation on Earth
With ideas from previous two sections, and Chris's part of the course, how do we interpret geological structures in terms of deformation processes and rheological evolution ?

lecture 9 (Apr 13): Appalachians
Historical overview of the orogens; "thin/thick skin" deformation. How do we compare deeply exhumed belts vs modern ones ?

lecture 10 (Apr 15): Western North America: Laramide/Cordillera/SAF
Historical overview, Evolution of SAF, ala Tanya Atwater.
Present structure from EARTHSCOPE seismology and geodesy.

lecture 11 (Apr 20): Alps/Himalaya
Compare/contrast deformation styles along the length of the whole system.
Review numerical models of himalaya ?

lecture 12 (Apr 22): Extensional systems: East African Rift / Basin & Range
comparison of initial lithospheric structure and tectonic boundary conditions.

lecture 13 (Apr 27): Extensional systems
continued...

lecture 14 (Apr 29): Synthesis, large open questions...
10-minute presentations of research projects

FINAL EXAM (May ??)

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Books on reserve

"Microtectonics", Passchier & Truow
"Creep of Crystals", Nicolas & Poirier
"Deformation of earth materials", Karato
"Fault-related rocks : a photographic atlas", Snoke, Tullis & Todd
"Structural Geology", Twiss & Moores