WHY AND HOW TO INCLUDE GRAIN-SCALE DEFORMATION MECHANISMS, MICROSTRUCTURES, AND RHEOLOGY IN UNDERGRADUATE STRUCTURAL GEOLOGY COURSES

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Abstract

Only 50% of the 70 structural geologists surveyed at the recent Cutting Edge workshop on Teaching Structural Geology in the 21st Century include grain-scale deformation mechanisms, microstructures, and rheology in their courses, yet the case for including these topics is strong. Fundamentally, microscopic processes accomplish all macroscopic deformation. There are only a few distinct grain-scale deformation mechanisms; each one dominates at different P,T conditions, produces characteristic microstructures, and has a different form of constitutive relation between stress and strain or strain rate. Understanding the different mechanisms informs the most fundamental questions in our discipline. Interpretation of the microstructures preserved in deformed rocks allows us to infer the physical conditions and history of deformation. Knowledge of rock rheology allows us to predict the deformation style and rock strength in different tectonic settings, and provides critical input to geodynamics questions.

The study of deformation mechanisms, microstructures and rheology allows students to correlate grain-scale features and processes to those developed at hand sample, outcrop and regional scales, and to confront how deformation rates relate to rock strength at different depths in the crust. Students trained to recognize and understand the actual processes of both brittle and ductile deformation are better able to critically analyze the bulk behavior of rocks in different geologic settings.

To facilitate the incorporation of deformation mechanisms and microstructures into structural geology courses, our working group has developed short teaching modules on critical concepts (e.g. cataclastic flow, diffusion and pressure solution, dislocation creep) that can be incorporated into existing courses during discussion of related topics (e.g. faults, foliations, folds). These modules include instructor's notes, key diagrams, annotated photos, possible handouts, and ideas for class or lab demonstrations and activities. The modules and supplemental resources (e.g. animations, analogs, articles) can be found at http://serc.carleton.edu/NAGTWorkshops/structure04. Additional contributions to this resource bank from all geoscientists are welcome.

Our Manifesto

IF YOU TEACH THAT…….,	THEN STUDENTS LEARN …..
All macroscopic deformation is accomplished by microscopic, grain-scale processes	To integrate deformation across a range of length scales
Different deformation mechanism predominate at different conditions	Why their observations of grain-scale & hand-sample scale features are significant
Rocks deformed under different conditions develop different suites of microstructures	How their own observations can constrain inferences of conditions at key points during a tectonic history
Rock rheology depends upon which deformation mechanism predominate	That they can infer rock behavior from microstructural observations even though they can't observe deformation in real time
Mathematical expressions describe & encapsulate rock rheology	To infer rock behavior & predict reasonable combinations of differential stress & strain rate at different times in a tectonic history
Particular combinations of rock type, temperature, pressure, pore fluid pressure, fluid phase composition, etc. yield characteristic suites of microstructures	To confront the difference between the current rigid character of rock & its former ductility & thereby integrate their observations across time
Microstructures link structural geology & tectonics to other geologic disciplines**	That all aspects of structural geology & tectonics are intrinsically connected

Our Goal

To make it possible, interesting and even fun for you to incorporate microstructures and deformation mechanisms into your structural geology courses!

The Modules

I. Instructor's notes
II. Classroom handouts
III. In-class demos & activities
IV. Additional resources

The Website

http://maps.google.com/maps?hl=en&ie=UTF8&ll=39.000000,-77.000000&spn=0.000000,0.000000&t=h&z=3&om=1

Our website will include

(1) teaching modules on:
- A. an overview of deformation mechanisms
- B. dislocation creep
- C. diffusion creep/diffusional mass transfer
- D. deformation twinning
- E. crack formation, coalescence, propagation
- F. cataclastic flow
- G. assessment of the relative importance of different mechanisms & deformation mechanism maps

(2) additional resources (including: instructor's notes, PowerPoint presentations, digital images, videos, animations, class demos, articles appropriate for undergraduates) accessible via topical, web-based searches.

http://www.sciencedirect.com/science/article/B6TB3-4TCR0...

http://www.virtualexplorer.com.au/VEjournal/2000/Volume/Volume2/www.mantleflow.com/

mica fish & oblique elongate recrystallized quartz grains in quartz mylonite indicating dextral shear

calcite twins

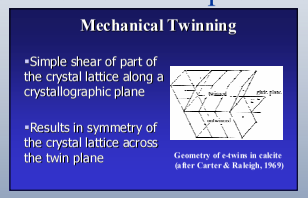
selvages and quartz fibers on magnetite grains

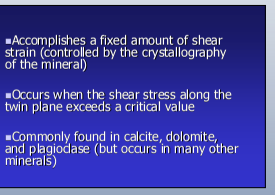
cataclasite

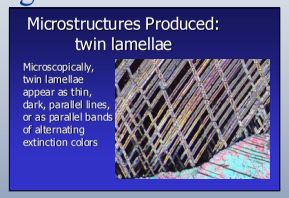
microcracks within a cataclasite zone

Examples

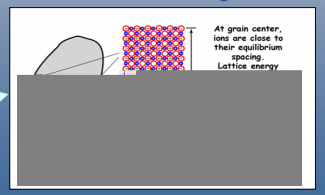
1. Slides from PPT presentations on Deformation Twinning

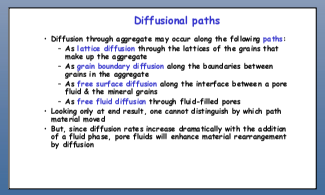




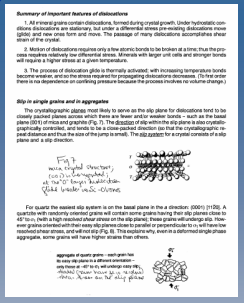


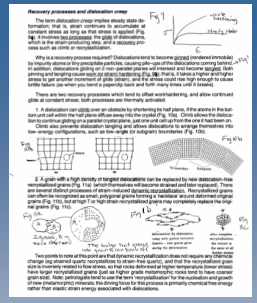
2. Slides from PPT presentations on Diffusive Mass Transfer

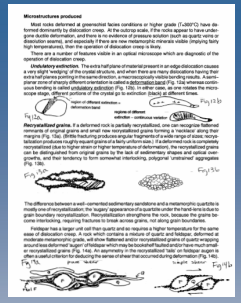




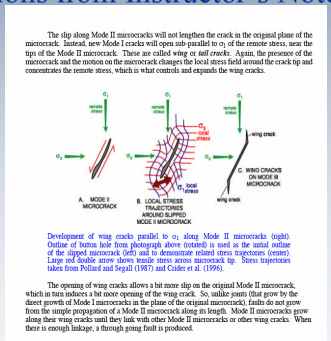
3. Pages from Student Handouts on Dislocation Creep

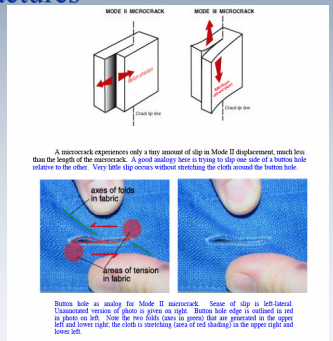






4. Selections from Instructor's Notes on Fractures





Getting Involved

1. Teach about microstructures in your classes!
2. Share your ideas with us!
3. Provide us with additional resources

Many thanks to our colleagues from the *Teaching Structural Geology in the 21st Century* Workshop!

Teaching Structural Geology in the 21st Century

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