GEOL 275-375 Rock Deformation:
Outline of Paper 2021.

Details of content may change depending on class progress.

Communication: will be through blackboard.

Breadth: It will be impossible to cover all areas of rock deformation in 13 weeks! Topics covered in this paper will include:

- The geometry, kinematics and dynamics of rock deformation.
- Stress and strain.
- Faults and shear zones.
- Strain paths and ductile fabrics.
- Folds.
- Rock rheology.
- Experimental rock deformation.
- Deformation mechanisms and microstructure.

Learning Outcomes: Students should leave this paper with a level of knowledge of rock deformation which include the specific skills listed below:

- Ability to characterise and quantify the geometry of common geological structures (faults, folds, shear zones, fabrics) on a range of scales from maps, through outcrop and hand samples to microscopic.
- Understand the basic physics of rock deformation including stress-strain relationships and how they may be measured.
- Ability to develop kinematic models from geometrical data. Understanding of what is needed to develop a dynamic model.
- Ability to design their own structural investigation of deformed rocks.
- Appreciation of observational science, including fieldwork, experimental approaches and modeling as tools to understand rock deformation.
- Quantitative techniques and problem solving.
- Scientific literacy

Objective of lectures. The lectures are designed primarily to interest students in the subject area, to outline what is important to know and understand and to help students' understanding of issues that they would otherwise find difficult. The lectures will not be the primary source of knowledge for students.

Objective of reading. The reading of book chapters, scientific papers and some other media provides the primary source of knowledge for students and support for understanding. The content of reading material will not be repeated in lectures although aspects of assigned reading that students find difficult to understand may be discussed. Exam questions will require students to include material from reading that has not been covered in lectures or practical classes.

Objective of laboratory practical classes. The laboratory practical classes are designed to reinforce understanding of issues covered in the lectures and in reading through the analysis of data and the construction of analytical, numerical and analogue models. Hopefully they will also be fun!

Field Trip. There will be a one-day field trip to Brighton. This will be on weekend of 14h & 15th August, or on Friday 13th, Monday 16th? (will consult)

Assessment.

1. An A3 graphic poster to illustrate multi-scale geometry and kinematic interpretations of the Otago Schist outcrops at Brighton. Individual exercise. ***10%*** of paper.
2. An interactive powerpoint (or equivalent) showing the results of sandbox experiments to investigate fault and fold geometry and kinematics. Group exercise. ***10%*** of paper.
3. A lab-book with all the details of a series of ice creep experiments conducted by an individual group. Groups will also submit tables of data for each experiment they conduct. Group exercise. ***10%*** of paper.
4. An A2 poster to show a mechanical and microstructural analysis of the ice creep data from the whole class (all groups experiments). Individual exercise. ***20%*** of paper.
5. Preparation of additional reading lists of elected scientific papers. Each (there will be three) gives a **bonus 2%.**
6. An examination. Students will choose to answer three questions from a selection of five in 2 hours. 375 students will be expected to show a broader range of knowledge and a deeper understanding. It is expected that exam answers will demonstrate knowledge and understanding gained from reading, lectures and laboratory classes. The exam is worth ***50%*** of the paper.

Groups.

These will be assigned, based on a skills audit.

Reading Material.

I will give specific advice on reading. You will need to balance breadth and detail.

Course text book. "Structural Geology" by Haakon Fossen.

Online resources for this book at: http://folk.uib.no/nglhe/StructuralGeoBook.html.

Another useful text (rent for $10 for 5 months): http://psgt.earth.lsa.umich.edu/.
A very useful website: https://www.uwgb.edu/dutchs/structge/labman.htm

Assigned scientific papers: see list below

Elected scientific papers: Students need to choose some extra papers, in three particular topics, based on citations to or from assigned reading or based on other search mechanisms.

- 275 students will need to select five extra papers in each topic. At least one of these should relate to a New Zealand example, one to an experimental study and one to a numerical modeling study.

- 375 students will need to select ten extra papers in each topic. At least two of these should relate to a New Zealand example, two to an experimental study and two to a numerical modeling study.
- Topics for 2021 1) Fault geometry and kinematics. 2) Foliation and lineation. 3) Microstructure and rheology. Students will be required to send lists of elected scientific papers by given deadlines.

Assigned scientific papers. I will give some guidance on what to try and get out of these:

Bell, T. H., and Rubenach, M. J., 1983, Sequential porphyroblast growth and crenulation cleavage development during progressive deformation: Tectonophysics, v. 92, no. 1-3, p. 171-194.

Bestmann, M., and Prior, D. J., 2003, Intragranular dynamic recrystallization in naturally deformed calcite marble: diffusion accommodated grain boundary sliding as a result of subgrain rotation recrystallization: Journal of Structural Geology, v. 25, no. 10, p. 1597-1613.

Cobbold, P. R., and Quinquis, H., 1980, Development of sheath folds in shear regimes: Journal of Structural Geology, v. 2, no. 1-2, p. 119-126.

Fan, S., Hager, T. F., Prior, D. J., Cross, A. J., Goldsby, D. L., Qi, C., Negrini, M., and Wheeler, J., 2020, Temperature and strain controls on ice deformation mechanisms: insights from the microstructures of samples deformed to progressively higher strains at −10, −20 and −30°C: The Cryosphere, v. 14, no. 11, p. 3875-3905.

Fossen, H., and Cavalcante, G. C. G., 2017, Shear zones - A review: Earth-Science Reviews, v. 171, p. 434-455.

Gibbs, A. D., 1984, Structural evolution of extensional basin margins: Journal of the Geological Society, v. 141, no. JUL, p. 609-620.

Gillam, B. G., Little, T. A., Smith, E., and Toy, V. G., 2013, Extensional shear band development on the outer margin of the Alpine mylonite zone, Tatare Stream, Southern Alps, New Zealand: Journal Of Structural Geology, v. 54, p. 1-20.

Hickman, S. H., 1991, Stress in the lithosphere and the strength of active faults: Reviews of Geophysics, v. 29, p. 759-775.

Hirth, G., Teyssier, C., and Dunlap, W. J., 2001, An evaluation of quartzite flow laws based on comparisons between experimentally and naturally deformed rocks: International Journal of Earth Sciences, v. 90, no. 1, p. 77-87.

Hubbert, M. K., and Rubey, W. W., 1959, Role of fluid pressure in mechanics of overthrust faulting .1. mechanics of fluid-filled porous solids and its application to overthrust faulting: Geological Society of America Bulletin, v. 70, no. 2, p. 115-166.

Hudleston, P. J., and Treagus, S. H., 2010, Information from folds: A review: Journal of Structural Geology, v. 32, no. 12, p. 2042-2071.

Kohlstedt, D. L., Evans, B., and Mackwell, S. J., 1995, Strength of the lithosphere - constraints imposed by laboratory experiments: Journal Of Geophysical Research-Solid Earth, v. 100, no. B9, p. 17587-17602.

Law, R. D., 1990, Crystallographic fabrics: a selective review of their applications to research in structural geology, *in* Knipe, R. J., and Rutter, E. H., eds., Deformation Mechanisms, Rheology and Tectonics, Volume 54: London, Geological Society of London, p. 335-352.

-, 2014, Deformation thermometry based on quartz c-axis fabrics and recrystallization microstructures: A review: Journal of Structural Geology, v. 66, p. 129-161.

Ramsay, J. G., 1980, Shear zone geometry - a review: Journal of Structural Geology, v. 2, no. 1-2, p. 83-99.

Sibson, R. H., 1989, Earthquake Faulting as a Structural Process: Journal of Structural Geology, v. 11, no. 1-2, p. 1-14.

Stipp, M., Stunitz, H., Heilbronner, R., and Schmid, S. M., 2002, The eastern Tonale fault zone: a 'natural laboratory' for crystal plastic deformation of quartz over a temperature range from 250 to 700 degrees C: Journal of Structural Geology, v. 24, no. 12, p. 1861-1884.

Toy, V. G., Prior, D. J., and Norris, R. J., 2008, Quartz fabrics in the Alpine Fault mylonites: Influence of pre-existing preferred orientations on fabric development during progressive uplift: Journal Of Structural Geology, v. 30, no. 5, p. 602-621.

Toy, V. G., Prior, D. J., Norris, R. J., Cooper, A. F., and Walrond, M., 2012, Relationships between kinematic indicators and strain during syn-deformational exhumation of an oblique slip, transpressive, plate boundary shear zone: The Alpine Fault, New Zealand: Earth and Planetary Science Letters, v. 333, p. 282-292.

Walsh, J. J., and Watterson, J., 1989, Displacement gradients on fault surfaces: Journal of Structural Geology, v. 11, no. 3, p. 307-316.

Wilson, C. J. L., Peternell, M., Piazolo, S., and Luzin, V., 2014, Microstructure and fabric development in ice: Lessons learned from in situ experiments and implications for understanding rock evolution: Journal Of Structural Geology, v. 61, p. 50-77.