Rheology is the study of how materials deform. This lab investigates some of the parameters (lithology, stress, temperature, confining pressure, and strain rate) that result in the deformation, or strain, that we see in rocks.

Directions:

You should work in small groups (three or four students), but each of you will need to turn in a complete set of answers. You should organize your answers in the same order that the experiments are organized in the lab handout, regardless of the order in which you conducted the experiments. Legibility, organization, and clarity of writing will all count in this lab. The parts that must be completed during the class period are outlined in boxes in the handout. For the in-class components, you may be able to answer the questions outside of class time.
PARAMETER 1: LITHOLOGY (i.e., composition, material)

**Part A: Analog**
Materials: play-doh, modeling clay, textbook

**Procedure**
1. Make identically-sized blocks out of play-doh and modeling clay. (The blocks should be at least 5 cm x 5 cm x 5 cm.) *Record the dimensions of your two blocks.*
2. Deform the two blocks by placing a textbook on top of each block and allowing the weight to deform the blocks. Use the same textbook in each case. Time the deformation.
3. Remove the textbook and *measure the dimensions of each of the blocks after deformation.*

**Questions**
1. What is the percent strain of each material? For each material, choose one axis on which to calculate strain, and draw a picture.
2. Was the applied stress equal for each deformation?
3. Does either material show signs of brittle deformation?
4. Do you expect the “stronger” (competent) material to behave more or less plastically than the “weaker” (incompetent) material?

**Part B: Rocks**
Photo from Sambagawa crystalline schist in Saitama Prefecture; Waseda University, Japan

**Questions**
1. Figure 1 shows a competent rock and an incompetent rock. Which is which? How can you tell? (Hint: think about which shows evidence for brittle deformation.)
2. There are several fractures within the boudinaged portion of the dike. How are these fractures oriented? Do the fractures indicate the orientation of stress or strain?

*(Recall: “Boudinage” is derived from the French for sausage, and refers to rocks that have been stretched or broken into blobs with thinner necks between.)*
PARAMETER 2: STRESS

Part A: Analog 1
Materials: play-doh, textbook, ruler.

Procedure
In PARAMETER 1 you made a tower of play-doh and deformed it with a textbook.
1. Calculate the stress on the play-doh tower from PARAMETER 1 (you may guess the mass of your textbook or you may weigh it).
2. Design a second experiment with play-doh and books that will produce twice the stress of your first experiment. *Draw a diagram, do the experiment, record the result.* Time the deformation.

Questions
1. What can you conclude about the effect of increasing stress on the resulting deformation?
2. Calculate the viscosity for PARAMETER 1 and for this experiment. Are they different? Do the values seem reasonable? Why or why not?

Part B: Analog 2
Materials: Imaginary spring.
Thought experiment about a metal spring. Recall that stress can produce compression (as above), tension, or shear.

Questions
1. Describe a way to deform a spring that results in elastic behavior.
2. Describe a way to deform a spring that results in plastic behavior.
3. Describe a way to deform a spring that results in fracture.
PARAMETER 3: TEMPERATURE

Part A: Analog
It’s difficult to devise an analog experiment that is easy to complete in a single class period and isn’t messy, so we’ll have to be satisfied with a thought experiment that draws on our culinary experience. Very briefly, describe the effect of temperature on the viscosity of honey.

Part B: Griggs et al. deformation experiment for basalt under various temperatures

Questions
1. Review Figure 3. Under what temperature is the basalt “strongest?”
2. Give the strain at which the basalt ruptured for each temperature experiment.
3. What was the stress at which the basalt at 25°, 300°, 500°, 700°, and 800° ruptured? Describe the general trend. What factors do you think might make this general trend an imperfect relationship?

Figure 3: Stress-strain diagram for basalt deformed at 5 kbar confining pressure under a variety of temperature conditions. From Griggs, Turner, and Heard (1960). Graph copied from Davis and Reynolds (1996).
PARAMETER 4: CONFINING PRESSURE

Part A: Donath’s experiments for rocks under various confining pressures

Figure 4 is from a famous experiment by Fred Donath. It shows specimens of limestone that were deformed to approximately the same total strain (15%) at different confining pressures.

This image has been removed due to copyright restrictions.

**Figure 4:** Specimens of limestone deformed to approximately the same total strain (about 15%) at different confining pressures. Increased confining pressure causes a transition in deformational mode from brittle to ductile faulting. From Donath (1970). Figure copied from Davis and Reynolds (1996).

Figure 5 is also from Donath’s experiment. It shows a graph between the differential stress and strain for the limestone deformation experiment (specimens shown above).

**Questions**
1. At what confining pressure is the rock “strongest”?
2. At what confining pressure is there more ductile deformation?

**Figure 5:** Stress-strain diagrams for limestone deformed at a variety of confining pressures. Tests conducted at room temperature. The magnitude of confining pressure (in MPa) for each run is shown next to each curve. Both strength and plasticity increase with greater confining pressure. From Donath (1970). Figure copied from Davis and Reynolds (1996).
PARAMETER 5: STRAIN RATE

Part A: Analog experiment
Materials: silly putty

Procedure
1. Roll the silly putty into a small sausage shape.
2. Pull QUICKLY on the silly putty and watch it deform.
3. Roll the silly putty into a small sausage shape.
4. Pull SLOWLY on the silly putty and watch it deform.

Questions
1. How does strain rate influence whether plastic or elastic deformation occurs?
2. What does the prevalence of lovely ductile deformation structures (such as shear zones) at depth within deformed regions of the crust suggest about strain rates within the earth?

Part B: Yule Marble deformation experiments
Review Figure 6.

Questions
1. Are rocks “stronger” or “weaker” at faster strain rates? Explain your answer.
2. Under the same stress, would you expect to measure more strain (such as in a deformed belemnite) at higher or lower strain rates?

References:

Figure 6. Stress-strain diagram for Yule marble deformed at different strain rate conditions. After Heard (1963). Figure copied from Davis and Reynolds (1996).
12.001 Introduction to Geology
Spring 2011

For information about citing these materials or our Terms of Use, visit: http://ocw.mit.edu/terms.