Geological Sciences 101
Lab #6 - Exploring Earth's Inaccessible Interior

INTRODUCTION

Last week you made measurements that allow us to calculate the size of the Earth, even though we cannot measure its size directly. This week, we are exploring other fundamental properties of the Earth, such as its age, composition, mass, density and viscosity. The problem is this: the deep interior of the Earth is virtually inaccessible. In fact, 99.9% of the mass of the Earth is hidden from view. So how do we explore this remote part of the planet?

We'll begin with some analogies. In one activity, a small black box will represent the Earth. In another we'll use liquids of various compositions and temperatures; we'll also use a collection of glacial erratics to represent the rocks of the Earth's surface. This lab has four activities. They may be done in any order—in fact each team will need to rotate through the different activities since there are not sufficient resources for everyone to do the same thing at the same time. Plan your time so that you have 30 minutes at the end of the lab period to present the results of your research. Have fun!

PART I: THE BLACK BOX

Each lab team has a small black box. Your assignment is to find out as much as you can about the contents of your black box. You may use any equipment or materials that are available in the lab room, and you can ask for things that you don’t see. You should perform as many tests as you can think of that will help you determine the properties of the interior of your box. You may also suggest tests that you would like to do given sufficient time and equipment.

As you work you should make a chart with two columns. The first column should be something like, "What we did." The second column should be, "What we learned/discovered."

At the end of the exercise you will share your results, with the goal of having the other groups figure out—only from your data—what is in your box. Thus the team that "wins" is the one that has presented the most comprehensive set of tests on their box; not necessarily the team that correctly guesses the contents of their box! Your TA will be assessing your work, thus you should strive to make an effective presentation.

• Write up a table of your group's results on an overhead transparency and be prepared to present your findings to the class. Do not tell the class what you think is in your box! (Please list every group member's name on your transparency).

QUESTIONS

(1) Think about the Earth in the same way that you just thought about your black box. Make a similar table, listing at least four tests that could be done to infer something about the interior of the Earth. Be as specific as possible (i.e., don't just say, "weigh it").
PART II - DENSITY

The density of an object is defined as its mass per unit volume; thus density = mass/volume. The Greek letter \( \rho \) is commonly used to signify density and the units of density are either gm/cm\(^3\) or kg/m\(^3\). Density is related to mass, but is often a more convenient property since it is independent of the amount of material present; thus all samples of granite may have different masses, but they will all have the same density.

We will make an estimate of the density of rocks by examining a group of small samples. We'll take advantage of the fact that the Pleistocene glaciers have carried a suite of commonly-occurring rocks to the Ithaca area.

- Select a group of samples from the box provided.
- Use the small lab scale to measure the mass of the group (put them all in the tray together); try to find a group of samples with a cumulative mass of 200-400 grams.
- Find the volume of each sample by immersing the samples in water using a large graduated cylinder.
  \( 1 \text{ ml} = 1 \text{ cm}^3 \).
- Find the total volume of the sample group that you weighed.
- Calculate the density in units of g/cm\(^3\).

2) What density did you calculate? Show your work.

PART III - VISCOSITY

Viscosity \((\eta)\) is defined as the resistance of a fluid to flow. Fluids with low viscosities flow very easily, fluids with high viscosities flow only very slowly. We can measure viscosity by measuring the speed at which objects fall through fluids. You will test the viscosity of water, mineral oil, honey and glycerin by dropping small steel weights into these fluids and timing their descent. Viscosity is measured in units of force and time (force x time, which is called a Pascal-second, or Pa\(\cdot\)s).

Fill the largest glass graduated cylinder (1000 ml) with water, nearly to the top (you don't need to know the volume this time). Get your stopwatch ready. Carefully drop a steel bead into the cylinder so that it does not hit the sides (although you may find this difficult…). Time the descent of the bead as best you can. Velocity is measured in units of m/s (meters per second). Measure the distance that you allowed the bead to fall (you can measure in cm and then convert to m \( 1 \text{ m} = 100 \text{ cm} \)). Repeat this measurement three or more times and average your results.

3) Calculate the velocity of the bead in water.

The viscosity of water is .001 Pa\(\cdot\)s \((\eta = .001 \text{ Pa\(\cdot\)s} = .001 \text{ kg/m\(\cdot\)s})\). We can compare the viscosity of other fluids to water by comparing the velocities of beads as they fall through these other fluids. The difference in velocity \((V)\) is inversely proportional to the difference in viscosity:

\[
\frac{V_{\text{water}}}{V_{\text{oil}}} = \frac{\eta_{\text{oil}}}{\eta_{\text{water}}}
\]

4) Find the velocity of beads in mineral oil, honey and glycerin (use the medium-sized graduated cylinders for oil (250 or 500 ml) & glycerin (100 ml), the smallest for honey (25 ml)). Calculate the viscosity of
these fluids. Present all of your data in a table (avg. time, distance, velocity and viscosity). Rank the liquids according to their viscosities.

- Explore the effect of changing temperature on the viscosity of honey. Fill a large beaker with water and place it on the hot plate (set on high) until it just begins to boil. Place your cylinder of honey in the water for a few minutes and record its temperature (the water, not the honey--they should be the same). The level of the honey and water should be about the same (to get all the honey warm). Remove the honey and quickly repeat the viscosity measurement!

- Finally, place a cylinder of room-temperature honey in an ice-water bath. Leave it there a few minutes, and again remove it and try to repeat the viscosity measurement.

(5) Record your temperature results and present them in table form as above. What relationship can you discern between the temperature of a substance and its viscosity?

(6) Consider a sample of Silly Putty. Mold a small cone or cube out of Silly Putty. Observe your Silly Putty after appx. 30 minutes. Where would you place its viscosity with respect to the other substances you've measured? Try to estimate its viscosity in Pa s, and add Silly Putty to your chart from Q(4).

### Viscosity Activities to do at Home

In a few weeks when we examine volcanoes and the way that they erupt, you will see that viscosity turns out to be very important. Unfortunately, not only is the temperature of most volcanic lavas quite high, but their viscosities are very high as well, making it difficult to perform in-class experiments. To get around this obstacle, we've designed two web-based activities that will allow you to explore materials with higher viscosities than those that you've worked with today.

First we'll watch a movie showing the behavior of two kinds of basaltic lava – ‘a’a and pahoehoe. Go to [http://www.geo.cornell.edu/geology/classes/Geo101/movies/viscosity.html](http://www.geo.cornell.edu/geology/classes/Geo101/movies/viscosity.html)

The movie is available in 3 different resolutions – you’ll have to experiment to see what works best on your computer. Within the 3-minute film are two sequences of flowing lava. The first is a lavafall of pahoehoe and the second an ‘a’a flow.

![Pahoehoe](image1.png)  
Pahoehoe – height of frame = 2 meters

![‘A’a](image2.png)  
‘A’a – width of frame = 1 meter
(7) Pick a point to watch, and time a feature or blob of lava as it moves across the frame. Note the size of the fields of view in the two images. Estimate the distance that the lava moved in the time that you measured. Then calculate the relative viscosities of the two lavas. Note: using this method you cannot calculate the actual value of the viscosity – just the difference in viscosity between the two materials.

Second, use your web browser to go to http://atlas.geo.cornell.edu/education/student/viscosity.html

In the experiment presented here, the velocity of the bead in water is 0.667 m/s and the height of the cylinder is 20 cm. The viscosities of other materials are indicated.

(8) How long would you have to wait for the bead to fall 20 cm through:

• Pahoehoe lava
• ‘A’a lava
• Andesite lava

HINT: Don’t let your computer run all night! Use the numerical values and calculate the answer to this question

PART IV - CONVECTION

The process of convection occurs when a fluid is heated from below and cooled from above. You have probably observed convection within a pot of soup on a hot stove. Use the clear plastic containers to set up and observe a convection experiment as follows (see figure on next page):

• Fill 2 containers with cold water to a depth of appx. 6 cm.
• Invert 8 paper cups and set each container on a set of 4 "legs."
• Allow the water to become motionless.
• Using the small plastic pipette, place a drop of food coloring on the bottom center of one container. See figure below.
• Place two drops in the other container, one on the bottom just off-center, and the other on the top of the water, off-center to the other side.
• Fill 2 other cups with very hot water and gently slide them under the containers until they are centered.

(9) Observe the containers carefully and make a series of sketches that illustrate what happens to the food coloring. Holding a sheet of white paper behind the container will make it easier to observe the experiment. Describe, then explain your observations.
Set-up for convection experiment:

(10) You've been asked to design a display for the Ithaca Sciencenter (the Sciencenter is the local science museum that provides hands-on and interactive science displays for children). Your display will describe density, viscosity and convection, and the relationship between them. Write a draft of the text that you would use to accompany the display, relating the three properties/phenomena of density, viscosity and convection. You may also describe or sketch what the display might look like, if it would help you make your point, but focus on relationships.