LAB

Viscosity of the Mantle:
Constraints from Post-glacial Rebound

With the use of a scale model, this lab investigates flow in the mantle in response to the rapid removal of a surface load by melting of a glacier. We will use a relatively viscous fluid initially loaded with a large weight as models for the mantle and the glacier. We will monitor and plot the displacement of the fluid as function of time as the fluid returns toward isostatic equilibrium. The position of the surface of the fluid is measured with a *direct current displacement transducer* (DCDT), as illustrated in Figure 1.

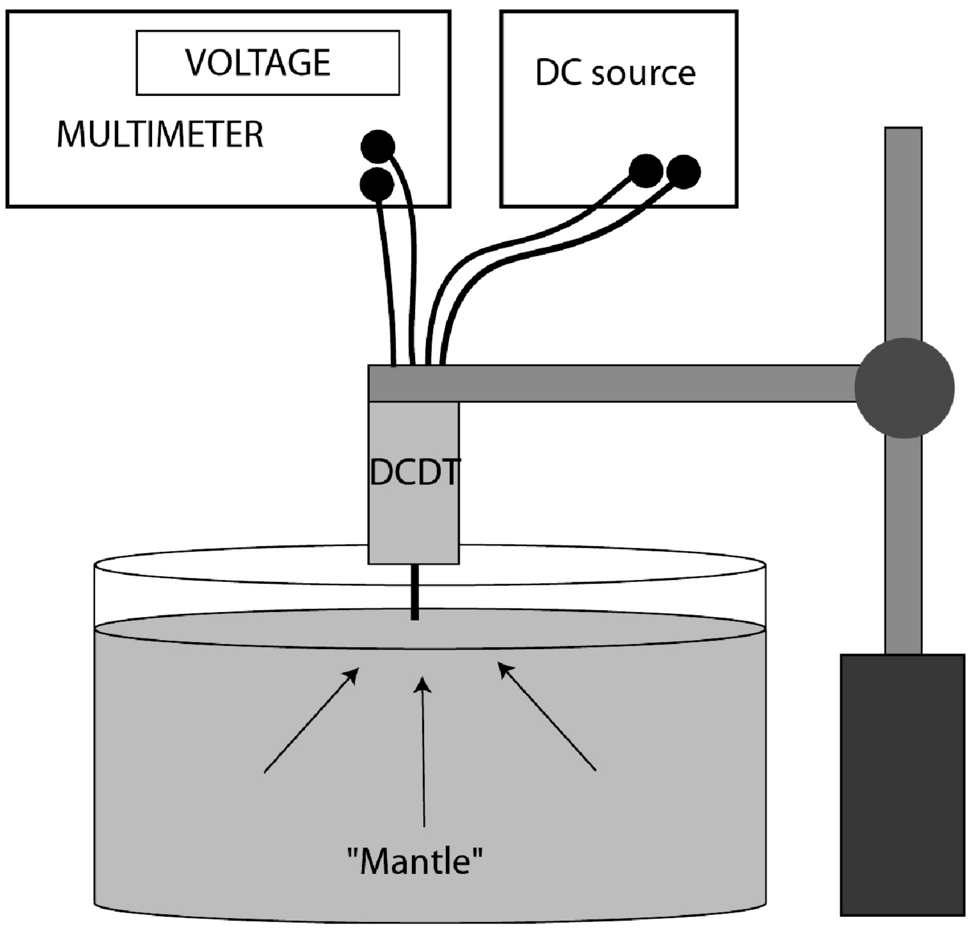

Figure 1: Sketch of the experimental design. The position of the surface of a viscous silicone gel contained in a large petridish is monitored with a DCDT that is supported by clamps attached to a ring stand. A DC voltage is used to excite the DCDT , while a digital multimeter is used to measure the output from the DCDT.

The viscous silicone gel will be loaded prior to class to allow time for the load to settle into an equilibrium position, just as glacier causes the mantle to flow until isostatic equilibrium is attained. In the lab, a small petridish containing an aluminum disc provides the initial load. The sudden removal of the aluminum disc simulates rapid melting of glacial ice. We will use the DCDT to monitor the position of the surface of the gel at the center of the depression made by the load as a function of time as the small petridish slowly moves toward its new equilibrium position.

Displacement data will be read as a voltage from the DCDT on a digital voltmeter. Data will be gathered every 10 s. As the rate of rebound is faster at the start than at the finish, you might choose to collect data more frequently early in the experiment and less frequently later. Voltages are converted to positions since the DCDT changes 5 V for every one millimeter of displacement (i.e., 5 V/mm). When you calculate the position of the surface, keep in mind the fact that a reading of 0 V does not necessarily correspond to a position of 0 mm.

Your assignment is to determine the relaxation time, T, for the silicone gel ('mantle') to move by $1/e$ of its original displacement. As discussed in lecture, the return to equilibrium is an exponential function in time. T is related to the viscosity, μ, and density, ρ, of the silicone gel as well as to the wavelength, λ, of the depression caused by the loaded petridish ('glacier'): $T = \ \pi \quad \rho g \lambda$, where g is the acceleration due to gravity. After you have determined T, calculate μ.

First plot the position of the surface versus time and examine the nature of the curve. Second plot the natural logarithm of position versus time (a semi-log plot); again, examine the nature of the curve. From these plots, determined T and then calculate μ. The density, , of the silicone is 843 kg/m^3.

Repeat the above experiment using a larger petridish for the load to test the dependence of T on λ.

Points to consider in your lab report:
(a) Does the expression $T = \ \pi \quad \rho g \lambda$ have dimensions of time?
(b) Does the relaxation time have the expected dependence on size of the loaded area (i.e., λ)?
(c) Does your value for viscosity make physical sense? How does it compare to the viscosity of water? Of magma? Of convecting mantle rock?
(d) What approximations have been made in our model experiment that would not apply to the real post-glacial rebound problem?