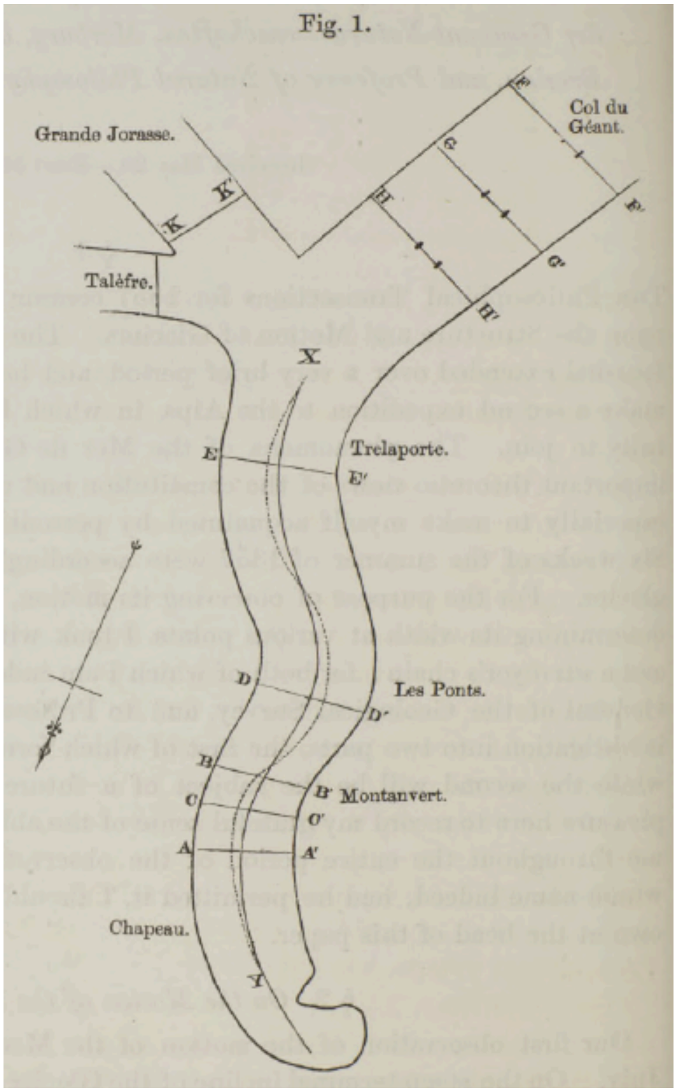
Glaciology lab 1: Non-Newtonian flow



Background information

Glacier ice flows, but very slowly and not in the way water flows. Early glaciologists measured ice flow by setting markers on the surface of the ice and measuring their motion over set periods of time. (And in a sense, modern glaciologists still do this when we set GPS stations on the surface of a moving glacier!) The figure at left comes from John Tyndall's 1857 paper describing his observations of Mer de Glace. In this lab, we will investigate the flow of "glacier goo", a material that deforms in a similar way, using methods inspired by classic glaciology.

It will be useful to think about the average velocity

$$v = d / t$$

where v is the velocity, d is the distance travelled, and t is the elapsed time.

Materials

•1 bag of glacier goo
•Cake decorating sprinkles
•Toothpick flags
•"Valley" made of PVC pipe
•Measuring stick
•Dry erase marker
•Books or other means of keeping the PVC pipe valley inclined
•Watch (or stopwatch app on phone)
•Camera (or second phone)
•Slope packet: protractor
•Bumpy bed packet: small rocks and blu-tack

Pre-lab questions

1. In lecture, we discussed glacier ice as a non-Newtonian fluid. Based on what you know so far, how do you expect the flow of glacier ice to differ from a Newtonian fluid such as water?
2. List a few variables that you expect to play an important role in setting glacier velocity, and outline what effect you expect them to have.

Procedure

Part A: Nonlinear flow

1. Prop up one end of the PVC valley so that it is angled downward.
2. Hold your glacier goo at the top of the valley and mark where the front of the goo is.
3. Take a picture of the initial state.
4. Set your timer for 5 minutes.
5. Release the goo and start the timer.
6. Take photos or video of the process of the goo.
7. At the end of the 5 minute period, photograph and mark the position of the front of the goo:
   a. In the center of the valley
   b. At the left-hand edge of the valley
   c. At the right-hand edge of the valley
8. Measure how far each side of the glacier goo has travelled during the period.
9. Calculate the average velocity of the goo over this period.
10. Record your results and answer questions 1 and 2 below.

Part B: Visualizing deformation

1. With the PVC valley in the same configuration as Part A, return the glacier goo to its starting position and hold it there.
2. Use your sprinkles to form one or more lines *across* the surface of your glacier goo, perpendicular to the sides of the valley. See Tyndall's diagram of transects (A-A', B-B', etc.) for an example.
3. Stick several toothpick flags vertically into the goo to form a line down its center, parallel to the sides of the valley. See Tyndall's centerline X-Y for an example.
4. Photograph this initial state.
5. Repeat the 5-minute flow procedure from Part A.
6. Answer question 3 below.

Part C: The role of the glacier bed

7. Pick up either packet I ("slope") or packet II ("bumpy bed") from the front of the lab.
   I. Slope packet: use the included protractor to set your PVC valley at 3 defined angles different from those you used for Parts A-B. Record the velocity of the glacier goo at each inclination.
   II. Bumpy bed packet: use the blu-tack provided to install rock obstacles in your PVC valley. Perform 3 flow experiments similar to Parts A-B; (1) single small rock obstacle; (2) single larger rock obstacle; (3) multiple rock obstacles of your choice.
8. Find a lab group that performed the opposite set of Part C experiments. Present your results to each other and discuss what you can conclude from combining your insights.

Questions

1. Describe the shape of the glacier goo when you first put it at the top of the valley.
2. Describe the shape of the glacier goo at the end of the experiment.
3. Draw two graphs: one of the goo velocity profile across flow, and one of the expected goo velocity profile with depth. What evidence from the experiment supports your intuition?
4. What relationship did you see between the bed topography and the velocity of the goo?
5. How do the results of this experiment differ from what you would expect with a fluid like water?
6. What differences do you expect between these results and the flow of a real glacier?
7. Select one of the variables you listed in Pre-lab Question 2. Describe how you would modify this experiment, or design a new experiment, to measure the effect of this variable on glacier flow.