GLACIOLOGY LAB – ICE

Introduction

The objective of this lab is to learn techniques and experimentally characterize properties of ice most relevant to glacial geology. These include (1) investigating the degree of exclusion/incorporation of fine grained material by ice, (2) modeling glaciers using plaster of Paris, or (3) making thin sections of ice to study and photograph them.

EXPERIMENT A - Exclusion of Material by Ice

Introduction

In this experiment, NaCl is used to experimentally determine the amount of salt exclusion as a function of the freezing rate. In the case of rapid freezing, much salt is trapped between the small ice crystals but during slow freezing, the salty solution is pushed aside by the growing crystals and concentrated around the edges or bottom of the container. Students prepare their own standards and analyse them to produce a standard curve of salinity relative to conductivity. Once the curve has been produced, the salt content of unknown samples can be determined.

Because the experiment may take some time (2 or 3 hours) outside of the laboratory period it is wise to work in groups.

Equipment

- 2 or 3 freezers set at different temperatures. Temperatures of –5°C to –20°C are suitable. Walk-in freezers are nice, but not essential.
- NaCl stock solution (0.1M). The instructor can mix this up ahead of time by using 5.84g NaCl in a 1L volumetric flask
- Styrofoam blocks with test-tube holes (Fig. 1)
- Large plastic test-tubes. It is important to use plastic tubes to avoid breakage during freezing.
- 10mL pipettes
- 100mL volumetric flasks. These are used for making standards. Each group of students will need 5.
- Conductivity meter
- Paper cups
- Wooden stir sticks or popsicle sticks

Figure 1. Plastic test tubes in styrofoam blocks. Also shown are plastic stir sticks used for removing ice from the test tubes and paper cups used for collecting meltwater and measuring conductivity.

Procedure

To prepare the samples, fill the plastic test-tubes with the stock NaCl (0.1M) solution and place them in the small holes in the top of the styrofoam blocks (Fig. 1). At least 3 samples should be put in each styrofoam block to ensure valid results. Make sure to put a stir stick in each tube before freezing so that samples can be removed easily. Freezing the samples in styrofoam block holders ensures that the solutions freeze from the top down, similar to natural conditions.

Put the test tubes in freezers of various temperature. It is important to have at least 2 freezing rates; at fast one which can be generated in a freezer set at about –20°C and a slower one in a –5°C freezer. Another intermediate freezing rate can be used as well if a suitable freezer is available. The filled test tubes in their holders should be put into the freezers as early as possible so that freezing will have taken place by the end of the lab period (at least for the fast freezing sample).
The next step is to make up a series of NaCl standards with concentrations of 0.1, 0.01, 0.001, 0.0001, and 0.00001 molar. This is done by making a series of dilutions. For example, to produce 0.01M NaCl, take 10 mL of the stock solution (0.1M) using the 10mL pipette and add it to a 100mL volumetric flask, then make the volume in the 100mL flask up to exactly 100mL using distilled water. Repeat the procedure for the next dilution but start with the 0.01M standard instead of the stock solution. Make sure to take great care producing these standards since any error is cumulative. Measure the conductivity of each standard using a conductivity meter and draw the curve of concentration (M) vs. conductivity (mS/cm) on the graph paper provided (Fig. 2). The data should plot approximately as a straight line on the logarithmic probability graph paper with concentrated salt solutions showing high electrical conductivity and dilute solutions having much lower conductivity. This standard curve can then be used to calculate the amount of NaCl included in the ice at each freezing rate.

After preparation of the standard curve of conductivity and salt concentration, the samples frozen in the various freezers can be analyzed. When looking at the samples, notice that there is ice at the top of the test-tube and an NaCl enriched fluid (brine) at the bottom. To analyse the NaCl content of the ice, remove the ice from the tube (it comes out like a small salty popsicle), rinse the outside of it it quickly with distilled water, and place the ice in a paper cup and allow it to melt. The resulting fluid can be analyzed using the conductivity meter and the NaCl content of the ice can be calculated using the standard curve already prepared. Repeat this procedure for as many freezing rates (freezers set at different temperatures) as possible in the time period allowed.

In addition to the quantitative analysis of salt exclusion, qualitative observations can be made by observing specimens through the microscope. If a walk-in freezer is available, the freezing process can be observed and the pathways of salt exclusion can be examined. The heat produced by normal incandescent microscope lightbulbs will prevent freezing so a cold light source (fibre optic) must be used (Fig. 3B).
Figure 2. Logarithmic probability graph paper (4 x 5 cycles) used for plotting electrical conductivity against salt concentration.
Figure 3. A. Thin section of ice showing impurities and water (arrows) between the ice crystals; B. A polarizing petrographic microscope and fibre optic light source.

References

Professor H. Douglas Goff, Ph.D. Theoretical aspects of the Freezing process
http://www.foodsci.uoquelph.ca/dairyedu/freeztheor.html


Kuajic, G. et. al., 1968, Rejection of Impurities by Growing Ice from a Melt. Symposium in Physics of Ice, p. 120


EXPERIMENT B - Glacier modeling

Introduction

This experiment should only take one laboratory period although the final models should be retained intact for further analysis. Each student will be required to record the procedure used, observations, and comparison of the features seen with those naturally occurring in alpine glaciers.

Equipment

- Plastic or cardboard pipe. A tube about 10cm in diameter can be cut in half lengthwise to form two U-shaped troughs. Suitable materials are PVC drainage pipe or the cardboard tubing used to roll new carpeting. The latter can be found as a waste product at a local carpet installer.
- Open-topped box for reservoir. This can be made from plywood and is attached to the head of the trough. If a 10cm diameter trough is used, the dimensions should be approximately 20cm x 20cm by 10cm deep.
- Aluminum foil or plastic food wrap
- Stand and clamps for positioning the plastic or cardboard trough to simulate a U-shaped glacial valley
- Tape to hold the model valley together
- Plaster. Quick-set plaster (Plaster of Paris) and slow-set plaster are both available from a local masonry supplier. Experiment with small amounts of these to find the right proportions of quick-set:slow-set:water. The approximate ratio of quick-set:slow-set:water is about 14:9:10.
- Bucket for mixing the plaster
- Ink (optional)
- Sand and pebbles (optional)

Procedure

Set up an end-to-end arrangement of troughs to simulate a U shaped glacial valley (Fig 16.4). Retort stands, clamps and tape are required for assembly. Try to model a
variety of features found in alpine glacier valleys such as the confluence of two glaciers, a break in the slope of the glacial valley, an unrestricted plain at the lower end of the valley, and other similar features. Once the model valley has been set up, line it with aluminum foil or plastic food wrap. This is to allow easy removal of the hardened plaster once the experiment has been completed. Record the length, width and slope of the model valley.

Figure 4. A model of the glacial valley showing from right to left; the cirque box, the U-shaped trough with gradually declining steepness, an ice-fall and finally a piedmont lobe. (Photograph by Brent Raymond).

Mix the plaster and water in a bucket after experimenting with small amounts to find the exact proportions required; too much water and the plaster may surge rapidly to the base of the valley and leave only a thin, relatively featureless deposit which will not harden properly, and too much quick-set and the mixture will solidify prematurely. The plaster should be added to the water slowly with vigorous stirring. It is also advisable to mix the slow plaster in first so that the mixture doesn’t harden before pouring can begin. A thick fluid that will flow freely down the length of the trough and solidify shortly thereafter (10 min) is required. After the plaster has been mixed, pour it into the wooden reservoir at the top of the trough and allow it to flow down the valley. The mixture must be poured up-valley (toward the back of the cirque box) at a slow and consistent rate to prevent an artificially fast downvalley surge. If the plaster does not flow freely do not attempt to manually push it along. Compressive pressure from a source other than the weight of the
plaster itself will create artificial, sharply peaked ridges. If the plaster is too thick it is best to scoop it back into the bucket, add a bit more water and try again.

Some features of alpine glaciers that can be modeled using this technique are icefalls, wave ogives (WO), transverse (T) and marginal (M) and splay (S) crevasses and piedmont lobes (Fig. 5). Some processes can be seen as the plaster is flowing down-valley, other can be seen best in the hardened surface of the plaster and still others can be seen by breaking the model apart to look at its internal characteristics.

![Figure 5. Plaster models of glacial features. A. A straight section of the U-shaped valley showing wave ogives and marginal crevasses; B. An ice-fall zone showing marginal (M) and transverse (T) crevasses leading to a piedmont lobe showing wave ogives (WO) and splay crevasses (S). (Photographs by Brent Raymond).](image)

The processes involved in formation and deformation of marginal crevasses can be seen in areas of relatively rapid flow. A new crevasse opens, is rotated due to differential flow and may close again as tension is released. The rotation of marginal crevasses
imprints the edges of rapidly flowing parts of the plaster with a characteristic criss-cross pattern.

Transverse crevasses can be seen forming in the icefall (break in slope) due to rapidly extending flow. The upper layer of the plaster is unable to adjust to the tension rapidly enough and transverse crevasses form.

Ogives are swells and swales that can be seen forming perpendicular to the maximum stress at the surface of the glacier model. As the speed of the glacier decreases, the plaster ogives decrease in size and become more closely spaced.

All these features and more can be seen in the hardened glacier model as well, but it is useful to watch the plaster in motion so that some insight can be gained into the processes that form each surface feature. Although the glacier model can simulate some processes and features found in glaciers, only those related to the actual physical movement of the ice are relevant. Many others such as basal slip (wet based process), freeze-thaw, plucking and erosion, ablation and the like can not be modeled by plaster of Paris.

References


Lewis and Miller, Kaolin Model Glaciers. Journal of Glaciology. V. 2, p. 533-538
EXPERIMENT C - Making thin sections for the petrographic study of ice

Introduction

This study is most useful for students who already know how to use a petrographic microscope for the study of rocks and minerals. Ice is an anisotropic mineral like any other and as such, displays interference phenomena as well as a wide variety of crystal habits depending on freezing rate and impurities.

Equipment

- Walk in freezer. This is essential so that a desk and microscope can be set up under sub-freezing conditions.
- Glass microscope slides
- Scalpel
- Petrographic microscope. Ideally the microscope should be equipped with a camera so that students can keep an accurate record of their samples more easily.
- Cold light source. This is useful because the regular incandescent light source will melt thin sections relatively quickly. This type of light is normally used for the study of biologic specimens that are prone to drying out. A fibre optic cable is used to transmit the light from the bulb to the microscope stage
- Salt solutions
- Clay suspension
- Natural ice (lakes, rivers, icicles, cubes)
- Thin strips of acetate sheet

Procedure

One of the best ways to examine and describe natural and artificially produced ice in detail is to look at thin sections using a petrographic microscope (Fig. 3). To prepare a thin section from solution (either distilled water, salt water or clay suspension) it must be pipetted onto a glass microscope slide, covered with another slide and frozen. Spacing between the 2 slides can be achieved by inserting strips of acetate sheet along the edges
of the slide. The freezing can be done both quickly (-20°C) and slowly (-5°C) so that the effect of freezing rate on ice formation can be studied.

The technique for thin sectioning natural ice is to place the ice on a microscope slide at room temperature and allow slight melting until the contact between the ice and the glass is flat. The slide and ice can then be frozen, in effect gluing the ice to the slide. Ideally for petrographic studies the section thickness should be about 30µm but for the purposes of this exercise the excess ice can be scraped away using a scalpel until a thin sheet remains frozen to the slide. Alternatively the sample can be melted down to near the desired thickness using a second warm glass slide and finished off by scraping.

For both natural and artificial ice sections, the slide must be examined immediately otherwise the ice will evaporate (sublimate). If needed, the prepared slides can be stored for a short time in a sealed container. Use the petrographic microscope in the controlled environment room and make observations of crystal size, % matrix (if a sediment suspension is used), association of matrix to crystals, grain contact morphology, crystal morphology and crystal orientation. To help in the description of the ice, labeled diagrams or photographs should be made, making sure to include the scale. The effect of impurities and freezing rate on the ice should be discussed.

References