

# LAB ACTIVITY - Simulating Ice Core Analysis to Identify Volcanic Eruptions in the Past

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**Purpose:** Simulate the process used in ice core analysis to identify prehistoric volcanic eruptions based on sulfate ion concentration

## Materials:

- Stock solution of  $\text{Na}_2\text{SO}_4$  (5,000 ppm) for dilution by students, **OR**
- 4 prepared standard solutions of  $\text{Na}_2\text{SO}_4$  (1000 ppm, 500 ppm, 100 ppm, 25 ppm)
- Distilled water rinse bottle (**fill your bottle before starting the lab!**)
- LabQuest 2 handheld interface unit and Conductivity sensor
- 5 beakers (150 or 250 mL, or combination of these sizes)
- 5 large test tubes
- Long/large forceps
- Tray of 'ice core' samples

## Introduction:

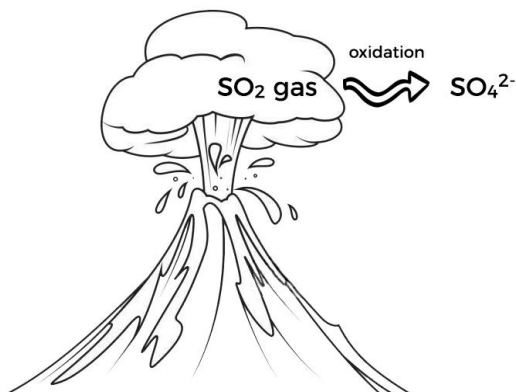
In this lab, you will analyze a set of ice core samples that will simulate an actual ice core collected at the Summit Station in Greenland. Scientists brave the unrelenting conditions of Greenland's ice sheet to collect ice core samples like the one you'll analyze so that we can learn more about the composition of Earth's snow and the atmosphere in which it formed hundreds, thousands, up to hundreds of thousands of years ago.

The oldest ice core samples so far date back to about 800,000 years ago!

Many materials can be studied within a small sample of ice, including many cations (positively-charged ions) and anions (negatively-charged ions). Among those anions is sulfate,  $\text{SO}_4^{2-}$ . This ion is always present in the ice record, but when its concentration is significantly higher for a short period, it can indicate that a significant volcanic eruption took place somewhere on Earth about 1-2 years earlier. By determining how deep in the ice core the sulfate ion concentration peak is found, we can estimate how many years ago an eruption took place.

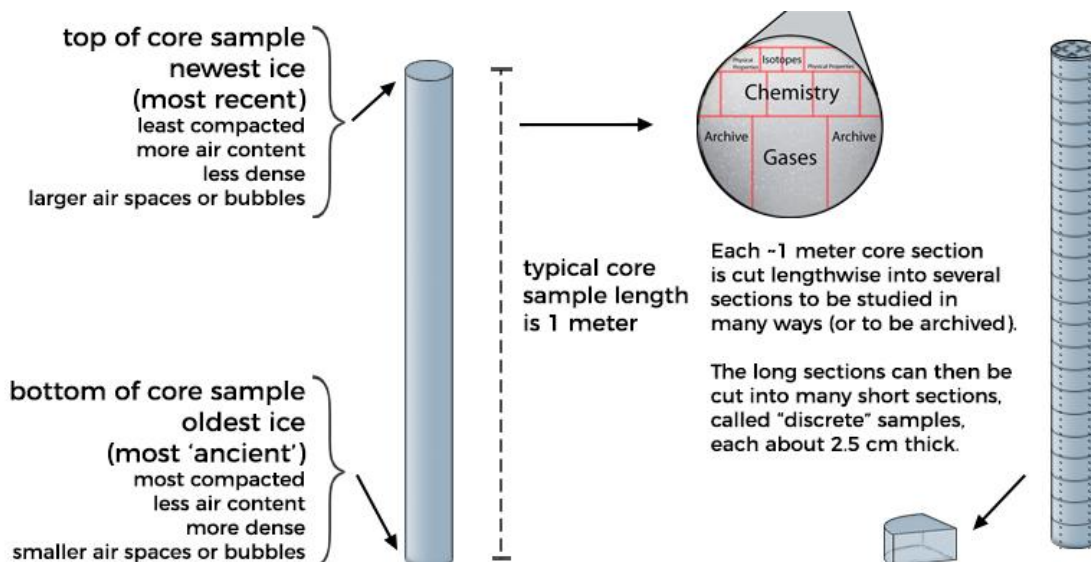


Those volcanic eruptions can be detected in ice cores from all over the ice sheet at the same depth - that is, at the same point in Earth's history.



Many other ions in the ice samples can tell us other important things about Earth's past, such as how the temperature has varied over a vast period of time - long before humans were around to make records of temperature, much less invent the thermometer! For today, we'll focus on the sulfate ions in your ice sample, and we'll assume that sulfate is the only ion in your ice core sample.

Image adapted from Getty Images



### Procedure, Part 1:

1. You will receive a set of ice core samples frozen in a tray. **Record your tray label (A-H) here: \_\_\_\_\_.** *Handle these samples with extreme care, caution, and respect, as they represent the efforts of nature to produce them over the course of hundreds, thousands, even hundreds of thousands of years. If they are damaged, contaminated, or otherwise rendered unusable, you can't just replace them!!* The numbers labeled on your tray reflect the depth (*in meters*) that correspond with each discrete sample. Carefully loosen them from the tray, but don't remove them all at once. Since your core pieces are pre-cut into portions, they are referred to as "discrete samples."
2. Rinse the tips of your forceps with distilled water. Shake off the excess water. Gently remove the first core sample (at the shallowest depth labeled) using your forceps, and rinse it carefully over the sink. This removes any contaminants that may have been left on the sample while it was being cored from the Greenland ice sheet or cut into samples to be analyzed. Place each rinsed core sample into its own beaker; be sure to label the beaker with the matching core depth from your tray.
3. After each core sample is in its own beaker, leave these aside to allow the sample to melt completely
4. Label five test tubes to correspond with standard "zero" (distilled water) and the four conductivity standards listed in your data table. From the classroom set of standard solutions, fill your test tubes about half-full with the standard.

Note: the standards are labeled with sulfate ( $\text{SO}_4^{2-}$ ) concentrations,  $[\text{SO}_4^{2-}]$ , in units of "parts per million," or "ppm." (*This unit is essentially a much smaller version of percent concentration, and is usually based on masses and/or volumes of the solute and the solution instead of moles or molarity.*) Distilled water can be considered to be 0 ppm and labeled as "Standard 0."

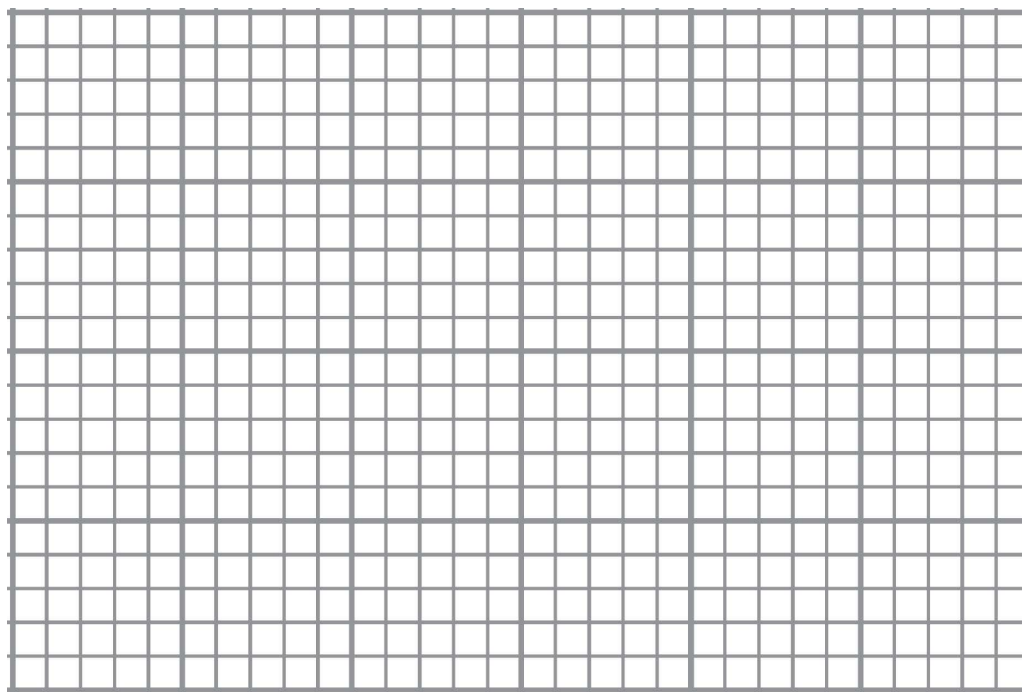
5. Obtain a LabQuest 2 and conductivity probe; set the units to microsiemens ( $\mu\text{S}$ ), and the range to 0-2000. Measure and record the conductivity of each standard in the table below. Use Standard 0 to calibrate your probe to Zero. Be sure to rinse the tip of the conductivity probe with distilled water after each standard is tested; the tip can be rinsed into the sink. After collecting your data, empty the test tubes and rinse them with distilled water into your sink. Shake out as much of the distilled water as possible.

Standard	SO <sub>4</sub> <sup>2-</sup> concentration (ppm)	Conductivity (μS)
0		
1		
2		
3		
4		

### Analysis, Part 1: Constructing your calibration curve

6. Using your choice of software (Google Sheets, Microsoft Excel, Graphical Analysis, Desmos, etc.) or your graphing calculator, neatly construct a scatter plot from your data, add a best-fit line (trendline), and determine the slope-intercept equation (in the form of  $y = mx + b$ ) for the best-fit line for your data.

**SO<sub>4</sub><sup>2-</sup> concentration is plotted on the x-axis; conductivity is the dependent variable and is plotted on the y-axis.** Provide a rough sketch of your graph and record your equation below. *Make sure to label your axes.*



**Equation:**

7. You'll be using your best-fit line to determine sulfate ion concentration, so carefully rearrange the slope-intercept equation for your best-fit line to solve for x (i.e. "get x by itself"). Write your rearranged equation below.

**Rearranged equation:**

**Procedure, Part 2:**

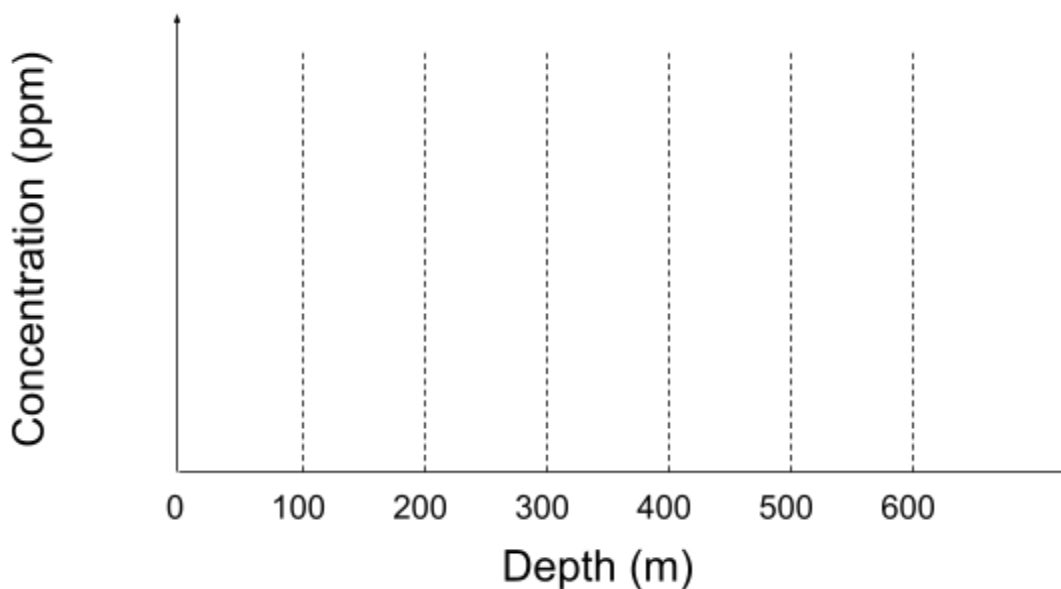
- Label your test tubes to match your core sample depths. When your ice core samples are completely melted, carefully transfer the meltwater into the matching test tube.
- Measure and record the conductivity of the meltwater for each ice core sample. Using your calibration curve, calculate the concentration (in ppm) of each sample from your ice core using the measured conductivity. Record the concentrations in your data table.

Depth (m)	Conductivity ( $\mu\text{S}$ )	$\text{SO}_4^{2-}$ concentration (ppm)
100		
200		
300		
400		
500		
600		

- You can empty your test tubes into the sink, and thoroughly rinse your test tubes and ice cube tray with distilled water. All samples & rinse water can go down the drain for this lab.

**Analysis, Part 2:**

- Construct a graph in the space provided to show the relationship between the depth of the ice core sample and the sulfate concentration. You should neatly plot points for your data, but don't connect the dots or try to come up with a best fit line. *Make sure to scale your y-axis appropriately based on the range of  $\text{SO}_4^{2-}$  concentrations you calculated.*



12. Investigate the table of historical data for volcanic eruptions provided. These eruptions have taken place at many different points in Earth's history over the last few millennia.

When volcanoes erupt, they eject many materials, including lava, pumice, tephra, ash, water vapor, carbon dioxide, and sulfur dioxide. Sulfur dioxide from volcanoes is dispersed into the atmosphere where it is oxidized to produce sulfate ions,  $\text{SO}_4^{2-}$ .

These ions accumulate in polar ice and are trapped for us to examine many years later - like you are now! To identify a historical volcanic eruption, you need only look for a significant amount of sulfate in an ice core sample.

To determine how long ago the eruption occurred, we use the depth of the ice core. **Let's assume that for the ice core sample you are studying, 100 years of time is represented by 26.6 meters of ice.**

Use this ratio to convert the depth of the ice core sample that shows a noticeable 'spike' in sulfate ion concentration to determine the approximate year in Earth's past when the eruption that emitted the  $\text{SO}_2$  gas took place.

Show your work here:

Location	Last known eruption year	Latitude
Nemrut Dađı, Turkey	1650 A.D.	39°N
Andahua-Orcopampa, Peru	1490 A.D.	15°S
Jocotitlán, Mexico	1270 A.D.	20°N
Yate, Chile	1090 A.D.	42°S
Ata, Japan	885 A.D.	31°N
Newberry, Oregon	690 A.D.	44°N
Lanín, Chile	560 A.D.	40°S
Chimborazo, Ecuador	550 A.D.	1°S
Dubbi, Eritrea	520 A.D.	14°N
Khodutka, Russia	300 A.D.	52°N
Milos, Greece	140 A.D.	37°N
Aluto, Ethiopia	50 B.C.	8°N
Udokan Plateau, Russia	220 B.C.	56°N
Antillanca, Chile	230 B.C.	41°S

13. One more factor to consider is that the ice sheets in Greenland typically aren't able to show evidence of eruptions for the entire globe. The emissions from volcanoes that are too far south on Earth's surface don't reach the far northern latitude of Greenland. To appear in the ice cores collected at Summit, the volcano should be found no further south than around 30°S latitude. If you determine that there are multiple volcanic events that correspond to the sulfate peak at a specific depth in your ice core, you may be able to select the most likely eruption based on latitude.



Once you have identified one (or more) eruptions that you might have detected in your core samples, add a mark on the globe image above in the approximate location of that volcano. If you need to research locations online, go for it! If you detected more than one eruption event, mark each of them, and then identify the most likely eruption identified by your core sample.

Core Sample ID (A through H) \_\_\_\_\_

Depth where sulfate peak was detected \_\_\_\_\_

Approximate year represented at that depth \_\_\_\_\_

Summarize the most likely volcanic eruption(s), location, year, and latitude below:

### Extension Questions:

1. Why do you think you were specifically instructed to NOT connect the dots or add a best-fit line for your sulfate concentration vs ppm data?
2. Suppose you analyze another deeper core sample from 1050 meters and detect a sulfate ion peak. Do some research to determine which of the following volcanoes is the most likely site of the related eruption: Mt. Eliso (Ecuador), Mt. Etna (Italy), Mt. Dana (USA), or Mt. Griggs (USA).

## Teacher Notes

**Stock solution preparation notes:** Any soluble salt can be used for this lab, so feel free to use whatever you have on hand. Simply prepare a solution that gives you a reasonable conductivity as measured by the probe or meter you have available, and then dilute the solution to give whatever series of standards you'd like. We used Vernier Conductivity sensors for our preparation. For instance, our stock solution (5000 ppm sulfate) had a conductivity of about 8000 microsiemens ( $\mu\text{S}$ ).

We prepared a 5000 parts per million sulfate (5000 ppm  $\text{SO}_4^{2-}$ ) solution and then diluted this stock to the required concentrations for our standards. We also used the 5000 ppm stock solution to prepare our group samples in the ice cube trays.

To prepare 5000 ppm sulfate solution from solid  $\text{Na}_2\text{SO}_4$ , there are two common options:

1. From **anhydrous**  $\text{Na}_2\text{SO}_4$ , dissolve 7.39 g solid into enough distilled water to yield a final volume of 1.00 L in a volumetric flask or other precise container.
2. From sodium sulfate **decahydrate** ( $\text{Na}_2\text{SO}_4 \cdot 10\text{H}_2\text{O}$ ), dissolve 16.77 g  $\text{Na}_2\text{SO}_4 \cdot 10\text{H}_2\text{O}$  into enough distilled water to yield a final volume of 1.00 L in a volumetric flask or other precise container.

(Alternatively, you can prepare a 1000 ppm  $\text{SO}_4^{2-}$  stock solution (which is also the highest concentration among the standards used for the standardization curve) and dilute that solution to prepare the other standards using one-fifth the amounts listed above for 1.00 L of solution.)

We prepared our standards at 1000 ppm, 500 ppm, 100 ppm, and 25 ppm. Volumes of 100 mL were prepared for each standard using volumetric flasks; another appropriately precise container could be used. Students took small amounts of each standard solution for measurement to establish their own calibration curves; if you're doing this lab with several sections, a larger amount of each standard solution may be necessary.

Standard	ppm sulfate	Volume of 5000 ppm stock solution used to prepare 100 mL standard*	Sample conductivity data ( $\mu\text{S}$ )
1	1000	20 mL	1602
2	500	10 mL	834
3	100	2 mL	174
4	25	0.5 mL	58
5	0	0 mL (distilled water blank)	0 (zeroed on sensor)

\* The smallest volumes (standards 3 and 4) were dispensed with an adjustable micropipette. If one is not readily available, the concentrations for your standards can be adjusted to higher amounts and prepared using other equipment.

**How to prepare “ice cores” for students/groups:**

We purchased plastic ice cube trays (14 cube size) and cut them in half to produce two half-trays with room for six cubes each. The trays were labeled (A through H) to log the contents of the specific samples given to each group, and the wells in each tray were labeled to reflect depths (100m through 600m); any range of depths could be selected. The wells in each half-tray were filled about halfway with distilled water, and a small amount of the 5000 ppm stock solution was added to each well and logged in a table like the one below. You can add an amount controlled by an adjustable micropipette (in microliters) or simply count the number of drops you add to each well. Add a drop or two (~25-50 microliters) to most of the wells to represent the “normal baseline” amount of sulfate present in ice at all times; add 8-10 drops (~200-250 microliters) to one (or two) of the wells to represent the sulfate peak that shows a volcanic eruption. (If you wish, you could also select a well to represent a minor or more distant eruption and add a median amount of the stock solution.)

	Amount of 5000 ppm sulfate standard added per prepared sample					
TRAY LABEL	100 m	200 m	300 m	400 m	500 m	600 m
A						
B						
C						
D						
E						
F						
G						
H						

**Data Table:** The table here is offered as an editable version of the table included in the student pages. The information included could easily be edited to include other eruptions or locations of interest to reflect current events, etc., or completely altered to reflect more southern hemisphere volcanic events and to change the perspective of the lab to an Antarctic ice coring location, like the WAIS Divide.

You could also choose to increase the rigor somewhat by removing the table altogether and requiring students to do research to discover the volcanic eruptions that may have occurred at the time determined by the ice core.

Table 1: Selected historical volcanic eruptions on Earth		
Location	Last known eruption year	Latitude
Nemrut Dağı, Turkey	1650 A.D.	39°N
Andahua-Orcopampa, Peru	1490 A.D.	15°S
Jocotitlán, Mexico	1270 A.D.	20°N
Yate, Chile	1090 A.D.	42°S
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