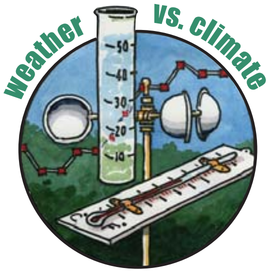


Ice Cores—Exploring the History of Climate Change

learning objectives

Students will:

- *Understand climate is a fluctuating system.*
- *Demonstrate how scientists estimate historical climate data using ice cores.*
- *Predict outcomes of a scientific investigation and then conduct the investigation.*
- *Analyze the results of their scientific investigation.*

subjects

Science

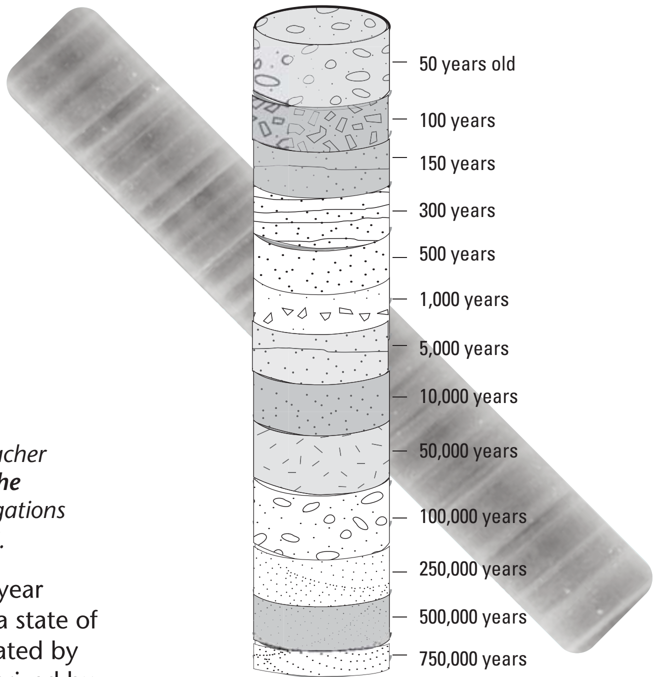
WISCONSIN MODEL ACADEMIC STANDARDS

SCIENCE
C.8.4, C.8.6,
D.8.1, D.12.5,
E.8.1, E.8.4, E.8.5

materials

- ☐ Plastic graduated cylinders (50 ml) – one for each group
- ☐ Food coloring – various colors
- ☐ Carbonated sparkling water
- ☐ Acid (vinegar or lemon juice drops)
- ☐ Particles (ashes, cat litter, or other dusty material)
- ☐ Freezer with enough space to store cylinders upright
- ☐ pH test kit (or phenolphthalein & sodium hydroxide) to measure pH
- ☐ Rulers
- ☐ Electronic balance
- ☐ Hot plates with water baths to melt ice core or warm tap water
- ☐ Worksheet included in this activity

AGE OF ICE CORE LAYERS



Background

*This activity has been adapted from teacher Tracey Leider of Oregon High School, **The Habitable Planet**, and Ice Core Investigations by Antarctic Climate & Ecosystems CRC.*

Throughout much of its 4.5 billion year history, Earth's climate has been in a state of fluctuation. Some eras were dominated by coldness while others were characterized by warmth. Some of these periods included drastic fluctuations while others remained fairly stable for millions of years.

Four major continental glaciations are recorded in North America. The last (Wisconsin) began about 70,000 years ago and ended 10,000 years ago. Much of Wisconsin's geological landscape was influenced by glaciation. The northern half of the state is mixed hardwood and coniferous forests. Farmland and prairies exist primarily in the southern half where the glaciers dropped sediment that made the land nutrient rich. The bluffs and narrow valleys of the Driftless Area, in the south-western corner of the state, are places where the last glaciers did not reach and, thus, the landscape was not scraped or leveled.

The polar regions of the world have held ice throughout and between these glacial periods. Like rings of trees in temperate parts of the world, ice layers in polar regions and glaciers also create layered historical records. Layers of snow become compacted into ice, which are laid atop previous layers of ice to create these records of the past.

To analyze historical climate changes, scientists drill down into the ancient ice where information about the atmosphere has been captured. Scientists extract the ice core and use it to analyze atmospheric physical and chemical characteristics to create scientific snapshots of Earth during single points in time.

Small bubbles in the ice hold trapped atmospheric gases from hundreds of thousands of years ago. When scientists analyze the composition of those trapped gases they are measuring the concentrations of gases in Earth's atmosphere when each layer was formed, including the concen-tration of carbon dioxide (CO_2), a greenhouse gas. In addition, the water in each layer of the ice holds oxygen and hydrogen isotopes. The relative concentrations of these isotopes will vary depending on the temperature when the layer was created. Thus, the scientists are able to determine the historical record of the temperature as well.

Perhaps the most famous study of this type is the Vostok ice cores from Antarctica *(see e-Appendix for references)*. These data are often cited in climate change articles. By showing a correlation between global temperatures and atmospheric CO_2 levels, scientists find evidence that changing the concentration of CO_2 in the atmosphere can change the global temperature and climate.

In this activity, students will not be able to measure directly the CO_2 of trapped atmospheric gases or the relative oxygen and hydrogen isotopes of the water. However, they can analyze other physical parameters to get a sense for how scientists learn about the past from ice cores and also the studies done related to climate change.

activity

ICE CORES

Exploring the History of Climate Change

Students will analyze fabricated ice cores and record their physical and chemical characteristics.

Procedure

Preparation

1) Home Assignment: Have students prepare for the lab part of this activity by learning how scientists analyze ice cores for information on changes in Earth's atmosphere over time. References to the Vostok ice cores and other information sources can be found in the *e-Appendix.* You can provide students with materials to read or have them do their own research on the topic. This preparatory work will give students a broader understanding of how this research is conducted and the opportunity to analyze evidence of the link between atmospheric CO_2 and global temperatures.

2) Make ice cores *(Note:* Allow up to 5 days for preparation of this activity before you present it to students)

- Several days before class, make an ice core for each group of 2-3 lab partners. Use 50 ml graduated cylinders or other long narrow containers to make the ice cores: they should be able to stand upright in the freezer. You will make the cores with at least 3 different layers. After mixing up and adding each layer to each ice core, you will need to freeze the ice core completely before adding the next layer, so plan several days of preparation time.
- Plan to give each layer a unique color (to help students separate the layers), volume (to simulate varying levels of precipitation), dissolved solids (to simulate both pollution and ash from volcanic eruptions), dissolved CO_2, and pH.
- Mix up a solution for the first layer. Add a small amount of solids (ashes, ground up cat litter, or other dry or dusty substance) to tap water and some food coloring for dye to this first layer. Record the amount of sediment you added and measure and record the pH of the solution. Stir the solution to suspend the solids and pour the same amount of the solution into each cylinder. Freeze overnight or until solid.
- Mix up the next solution, this time adding carbonated sparkling water to the tap water (perhaps 10% sparkling water and 90% tap), a different amount of solids, and a different color of dye. *(Note:* the solids could represent pollution or volcanic action, so you may want more solids in the topmost layers to represent pollution from industrialization as well as solids in an earlier layer to represent a geologic time with much volcanic activity.) Again, measure the pH and record the composition of this layer. (If the pH is not different from the first layer, try adding more sparkling water or some vinegar to reduce the pH.) Add this solution on top of each of the frozen cylinders. Refreeze overnight.

- Continue making additional layers, varying the parameters and freezing between each addition. To simulate increased CO_2 in the atmosphere, have the last layer be a solution of 50% carbonated sparkling water and 50% tap water. You could also add more solids to this layer to simulate increased pollution from industrialization.
- Bring the ice core samples to class (packing them in ice and dishtowels in a cooler helps protect them until class time). Distribute one ice core per 2-3 students.

Investigation

1) The class will investigate the chemical and physical characteristics of each layer.

2) Begin with a class discussion of ice core analysis and how ice core data is used. Refer to the research or readings assigned prior to this lab. Some general inquiry-based questions might include:

- What do scientists measure when they are studying ice cores?
- What types of atmospheric data might be useful if we're looking for evidence of climate change? What can be measured?
- How might scientists correlate a given layer of ice with a given time period? How would they know the age of each layer?

3) Students should:

- Separate layers
  - First tell students which colored layer represents the top, or most recent, layer of the ice sheet they are analyzing.
  - Remove the cores from the cylinder by pouring warm water over the cylinder or by setting it briefly in a warm water bath. At this point, only melt enough of the outer part of the core to remove it from the cylinder.
  - Gently break each ice core layer apart. Using a small saw or serrated knife will provide more accurate separation of the layers.
- Compare precipitation in each layer
  - Measure the mass of each layer and record the results on the *Ice Core Research Worksheet*.
  - Measure the volume of each layer and record the results.
  - *Optional:* Density can be calculated once the mass and volume are known.
- Compare pH and CO_2. First explain to the students that CO_2 in solution with water becomes carbonic acid, dropping the pH, so measuring relative pH should indicate relative levels of CO_2.
  - Before measuring for pH, have students predict which layers will have the highest and lowest pH and record their predictions.
  - Melt the ice and collect the resulting solution for each layer.
  - Measure the pH of the layer by using a pH test kit.
  - Alternatively, measure comparative pH by putting 5 ml of each layer in a separate test tube. Add a few drops of the indicator phenolphthalein (clear in acid, pink in alkali). Add measured amounts of sodium hydroxide solution to neutralize the acid. Stop as soon as the solution turns pink. Record the final volume of sodium hydroxide needed to neutralize the solution and compare results for different layers.
- Measure particulates
  - Before measuring for the suspended solids or particulates, hypothesize the relative amounts of particulates in each layer and record their predictions. Do students guess that the more recent layers will have more particles and pollution because of the industrial revolution?
  - Measure and record how many ml of each layer they will test for particulates. Evaporate this amount of each layer in a pre-weighted container. Reweigh the container to get a weight for the remaining solids.
  - Alternatively, weigh filters for each layer, recording the weight. Then filter the liquid in each layer, dry the filters, and reweigh the filters to calculate the weight of particulates.
  - Record results as grams of particulates per milliliter of liquid. Convert this to

grams of particulates per liter.

Discussion Questions

On the board, large pieces of paper, or overhead projector, have all students report their results. Construct a class data table for recording volume, weight, density, pH, and particulates and have the students:

- Compare their group data to the overall class data.
- Determine sources of error for the overall experiment and per group. Were there better, more accurate ways to conduct the ice core experiment? How could the investigation have been done differently to improve results?
- What conclusions can they draw? Which layers represent wet or dry years? How do you know? Were some layers more acidic than others? Why and what is the relation to climate change? Did the level of particulates vary? What might be the sources of these particulates in the atmosphere?

Going Beyond

1) Have students research the methods used by scientists to figure out dates of ice core samples. Why would this be important for climate change research?

2) Add other parameters to the ice cores for the students to measure. For example, to simulate heavy metals in the atmosphere from pollution, you can add about 1% by volume of 0.1M copper chloride solution to a layer. Students can analyze layers for the presence of copper by adding a small amount of dilute sodium hydroxide to a portion of the melted layer and observing the result over a white background. The presence of copper will turn the resulting solution a faint blue. To detect a difference in color, students should compare the portion they treated with sodium hydroxide to the untreated portion. However, if you used dye in the layers this will be hard to detect, so you may want to add the copper chloride to a clear layer.

activity Ice Core Research

ICE CORES

NAME ____________________ CLASS ____________________

TEACHER ____________________ DATE ____________________

TEAM MEMBERS ____

ICE CORE SAMPLE

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You have been chosen to join an Arctic expedition to study ice cores.

To prepare you will need to research and read what other scientists have found. Your team will examine ice core layers for volume, pH, and evidence of pollution. Then you will report your findings to a national scientific community (your class) at their annual meeting (next class period). You have to take detailed notes as you proceed so you can accurately report your findings and the possible implications you unearth. Good Luck!

1) From your reading and research, how do scientists learn about Earth's past from ice sheets and glaciers? What kinds of information do they gather?

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2) How do scientists estimate temperature and carbon dioxide levels from thousands of years ago, using their ice core analyses?

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3) How do scientists estimate the age of a given layer in an ice core?

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4) Measure each layer in centimeters and draw a diagram of your ice core in the space below.

worksheet

5) *Based on prior knowledge and reading, predict which layers will have the highest and lowest pH and the highest and lowest particulate contents. What is the rationale behind your predictions?*

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6) *Separate each layer from others by gently cutting or breaking them apart.*

7) *Measure the mass of each layer on the balance to the nearest tenth of a gram. Record your results in the data table.*

8) *Measure the volume of each sample using the method provided by your teacher. Record the results in the data table. Calculate the density.*

9) *After predicting the relative pH for the various layers, measure and record the pH of the sample, using the method provided by your teacher. How does the measured pH compare with your predictions? Do the results surprise you? Why or why not?*

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10) *After predicting the pollution levels, weigh and record the amount of particulates or solids in each sample using the method provided by your teacher. Were your predictions accurate? If not, what might be a reason for the discrepancy? What can cause particles and soot in the air?*

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ICE CORE DATA for Sample # ______________________

Layer COLOR	Predicted relative pH H= HIGHEST L= LOWEST	Predicted relative particulates 1= LOWEST	Mass (g)	Volume of layer (ml)	Volume converted to liters	Density of layer (g/l)	Actual pH	Actual weight of particulates	Actual concentration of particulate matter (g/l)