Please note: Some of the graphics and references needed for this lesson are not included, and will be added by March 25, 2009.

The Key to the Core

Lesson Overview:

This lesson uses the 5E method to engage students with ancient climate records that have been obtained from tropical ice cores around the world.

Students will:

Engage: Watch a slideshow from a 2006 research expedition to the Himalayas of Tibet
Explore: Predict where ice cores might be obtained; plot the actual locations of ice core drill sites, compare the depths of the ice at each location
Explain: Describe the types of information that can be obtained from ice cores
Extend: Create a mock core that illustrates the primary types of evidence that can be obtained from ice cores
Evaluate: Present a summary (by group) describing what their analysis of a mock core has revealed.

Background Information:

Ice Core Definition

An ice core is a cylinder of ice that is 4 inches (10cm) in diameter. Lengths of ice cores vary. Scientists often try to drill an ice core down to the rock underneath the ice (bedrock). In Antarctica, ice cores have been drilled to over 3,600 meters long – through 2.2 miles of ice (the Vostok core). An ice core from the Concordia Ice Dome in Antarctica has given us climate data covering the past 650,000 years. Ice cores from Antarctica and Greenland can be very long and give us long climate records. Ice cores from tropical glaciers are usually much shorter than those from Antarctica, perhaps only 1,500 meters. The ice core records from the tropical glaciers may go back only a few thousand years, but the information that they provide is more detailed than the information from Antarctica or Greenland. Since ice cores cannot be transported or stored in their full length, they are usually cut into one meter sections, which are much easier to move, store, and study.

Ice cores are drilled all around the world because of the climate records they contain. Ice moves under its own weight, so scientists try to drill in areas where the ice does not move - that is why they have to drill in the ice sheets close to the mountaintops or in the interior of Greenland or the interior of Antarctica. Glacier ice is not good for ice cores because the tops and centers of a glacier move faster than the bottom and sides of the glacier. This type of motion can disrupt the layers, so cores obtained from glaciers are not as easy to interpret as cores taken from large ice fields. (See definitions below.)

Ice Core Records

Ice cores are drilled because they contain the history of the environment in which they were formed.

1) Ice cores can be used to create **records of temperature** that are determined from oxygen isotopes. Some oxygen atoms are heavier than other oxygen atoms. When a heavier oxygen atom is in a water molecule, the water molecule is heavier. Heavier water is harder to evaporate from the ocean. It also falls out of the clouds as rain or snow much easier and more quickly than the water molecules with the lighter oxygen atoms. Scientists use these facts to calculate the temperature of the environment at the time the snow fell to form the ice.

2) **Atmospheric chemistry –** When the snow turns to ice, tiny bubbles of air are trapped in the ice. When scientists examine the air from within these trapped bubbles, they can measure the concentrations of the gases in the air at the time the bubble formed. This is one way scientists have determined that greenhouse gas concentrations in the air are increasing.

3) **Net accumulation –** The ice also records how much precipitation occurred in an area. If there was a drought, the layer of ice for that year will be very thin. If there was a lot of precipitation, the layer of ice for that year will be much thicker. Scientists can use this information to track climate changes and weather patterns.

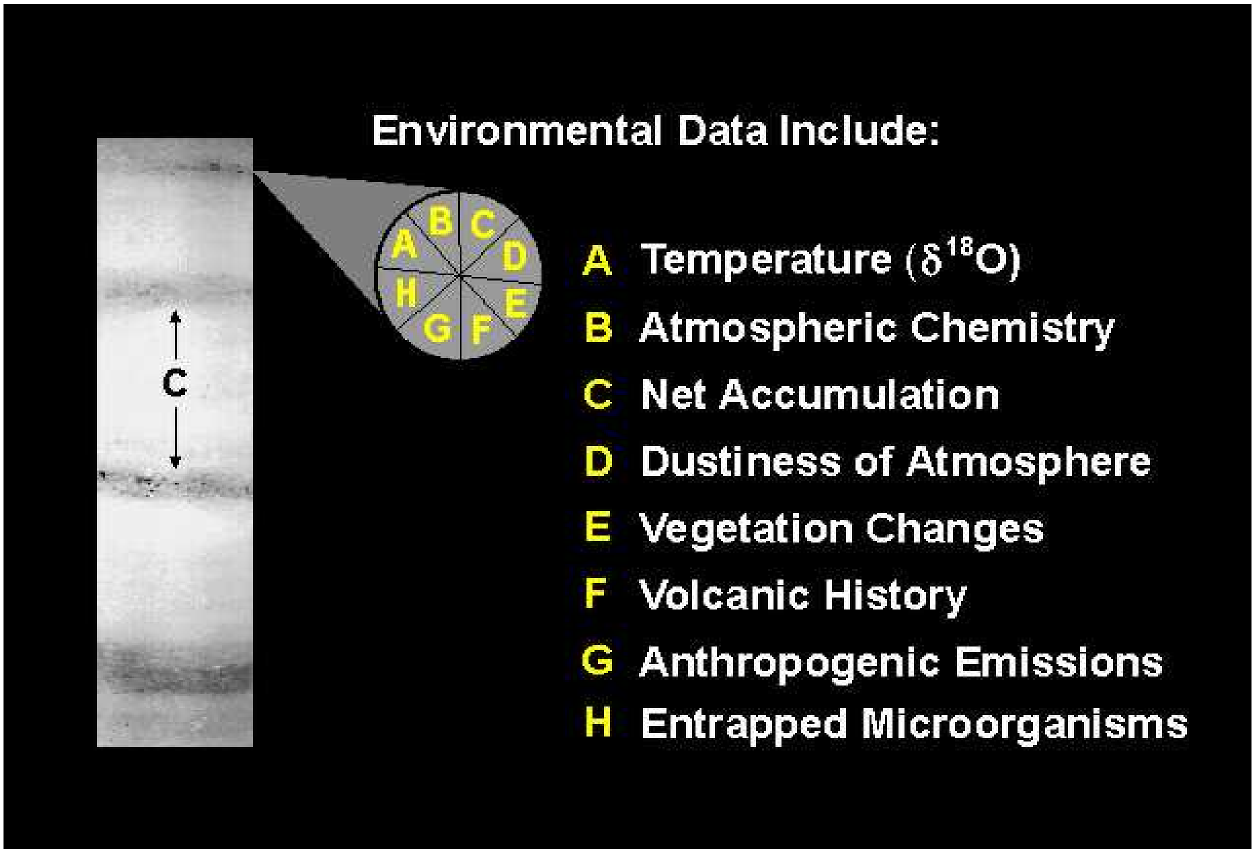
4) **Dustiness of the atmosphere –** Dust, although it is very small and may float for a long time in the atmosphere, eventually falls out due to its weight. Many times a large dust layer will be combined with a thinner ice layer - more evidence of a drought at that time. Sometimes fine particles of dust (especially from Africa) are blown into the air and travel for thousands of miles before they fall out of the air. Sometimes a dust layer in an ice core indicates a drought in another part of the world.

5) **Vegetation changes –** Pollen, from plants, may be very light and travel a long way on wind currents. Scientists can determine what types of plants were growing in a region by looking at the pollen grains that are preserved in the ice. Scientists can track the changes in the plant populations in an area by tracking the changes in the pollen preserved by the ice.

6) **Volcanic history –** Every volcano has a different chemical signal because it has a different proportion of elements and minerals in its magma. Scientists can determine which volcano erupted by looking at its chemical signal. Scientists can also use volcano eruptions to tell the date of a particular layer in the ice. By comparing the written history of an area's volcanic eruptions to the volcanic layers in the ice, scientists can tell the age of the ice. Also, if scientists know how old the ice is and they find a volcano record in the ice, they may have found evidence of an eruption that had not been recorded yet by people.

7) **Atmospheric emissions –** Ice also preserves records of what humans do to the environment. For example, the ice in Greenland provides a record of the increased use of nitrates for fertilizer. The ice records also show when lead was taken out of American gasoline.

8) **Entrapped microorganisms –** Sometimes scientists will discover small insects in the ice that were blown onto the ice and preserved. Sometimes biologists will take the ice, melt it, and use it to try to grow bacteria and mold (in covered petri dishes). If the scientists are successful in growing microorganisms from the ice water, they compare the microorganisms from the ice to microorganisms that are alive today to see if there have been any genetic changes or if that species has become extinct.



(Slide courtesy of Dr. Ellen Mosley-Thompson, Byrd Polar Research Center)

Types of ice:

(http://www.homepage.montana.edu/~geol445/hyperglac/morphology2/)

1) Ice sheets and ice caps are not controlled by topography (local land formations including mountains, hills, and valleys) except, perhaps at their edges. Ice sheets and ice caps can cover both mountains and valleys, making the area look like a flat area of snow and ice.

   a) Ice sheets - Ice sheets are larger than ice caps. Ice sheets are larger than 50,000 square kilometers – 19,300 square miles. At their edges, ice sheets may follow the local land formations.

   b) Ice caps - Ice caps are smaller than 50,000 square kilometers – 19,300 square miles. Topography may or may not control the position of ice caps. However ice caps, too, can be thin enough at their edges to follow local land formations.

   c) Ice fields – Ice fields are smaller areas of ice that have accumulated between neighboring mountain tops.

2) Glaciers are constrained or controlled by topography. Glaciers are rivers of ice. They often flow out of ice sheets or ice caps, following valleys.

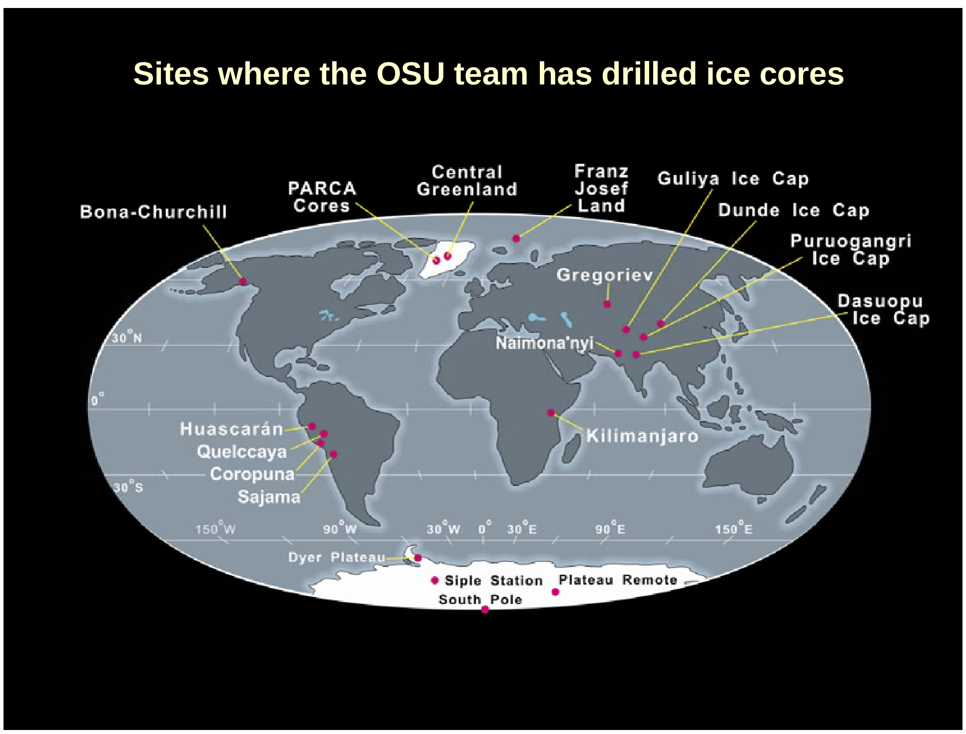
3) Sea ice, or marine ice, is ice that formed from seawater and is floating on the surface of the ocean. Sea ice increases in thickness for two reasons: seawater freezes at the surface of the water (sometimes on the underside of the existing sea ice layer) and snow accumulates on top of the ice layer. In order for sea ice to exist, the annual temperatures must be cold enough to freeze seawater. Sea ice that is frozen to the coast of a land mass, and is "fixed" (not floating away) is known as "fast ice". It is "held fast" at places where it is frozen to the land, called "anchor points".

4) Ice shelves can form when a glacier flows out onto the ocean from an ice cap or ice sheet on land.

5) Icebergs are chunks of ice that broke off from a glacier or ice shelf and float away. Icebergs are frozen precipitation. Therefore, they are made of fresh water ice. Most of an iceberg is under water.

Location of Ice Coring Sites

Researchers from the Ice Core Group at BPRC have cored in many locations around the world. Dr. Lonnie Thompson is the world's foremost expert on tropical ice cores. He studies ice from mountain glaciers in the subtropics and tropics. Dr. Thompson began his studies of tropical ice cores as a graduate student at The Ohio State University in the 1970s.



(Slide courtesy of Dr. Ellen Mosley-Thompson, Byrd Polar Research Center)

BPRC Ice Core Paleo-climate Group Drilling Sites

Asia

Year drilled	Core	Location	Coordinates	Altitude (m asl)	Depth to Bedrock
1987	Dunde	Qilian Shan	38°06’N, 96°24’E	5325	
1990	Gregoriev	Tien Shan, Kirghizia	41°59’N, 77°55’E	4609	
1992	Guliya	Kunlun Shan	35°17’N, 81°29’E	6200	
1997	Dasuopu	Himalayas	28°23’N, 85°43’E	7200	
2000	Puruogangri	Tanggula Shan	33°55’N, 89°05’E	6072	
2006	Naimona’nyi	Himalayas	30°27’N, 81°20’E	6100	

South American Andes

1983 & 2003	Quelccaya	Cordillera Vilconota, Southern Peru	13°56’S, 70°50’W	5670	
1993	Huascarán	Cordillera Blanca, Northern Peru	9°06’S, 77°36’W	6050	
1997	Sajama	Bolivia	18°06’S, 68°53’W	6542	
2003	Coropuna	Southern Peru	15°32’S, 72°39’W	6450	

Africa

2000	Kilimanjaro	Tanzania	3°05’S, 37°21’E	5893	

North America: Alaska

2002	Bona-Churchill	St Elias Wrangell Range, SE Alaska	61°24’N, 141°42’W	4420	

Polar

1988-1990	Dyer Plateau	Antarctic Peninsula	70°40’S, 64°52’W	2002	
1997	Graham Bell Island	Franz Josef Land, Russian Arctic	80°47’N, 63°32’E	509	

Sequence of Activities:

Power Point slideshow: A Powerpoint presentation of Dr. Thompson's 2006 trip to Tibet (China) to recover ice cores.

Mapping Activity: The students will be given a blank physical map of the world. In a "think, pair, share" activity, small groups will be asked to locate areas where they think researchers would drill for cores. They will then use the information in the Drilling Sites table to plot the longitude and latitude of cores drilled by BPRC researchers.

Group Activity: Each group will prepare a hypothetical sequence of layers (drawn in a rectangle on paper) to illustrate the kinds of information that researchers might obtain from an ice core somewhere in the world. They must be able to explain what each of these layers or visible characteristics would indicate about past conditions. They will draft and refine a short summary of the "history" of their core, which will be inserted into an envelope, rolled, and placed inside the cylinder, for others to read. It is the "key" to the core.

Advanced work: Students can conduct research about the regions where Dr. Thompson's team has drilled for ice and create a "travel brochure" to describe the region and its contribution to understanding of past climate, based on information obtained from ice core analysis.

Higher thinking skills goals for this activity:

Standards:

National or State Education Standards addressed by this activity **

Objectives

The students will be able to:

a) determine the number of years of record for each ice core image;

b) compare the relative amounts of precipitation in the sample core they've been given;

c) distinguish between observations and interpretations, and

c) describe the types of evidence that can be obtained from an ice core

Materials Needed

Computer and projection system (with Powerpoint player)

Printed images of ice core surface (taped to cardboard mailing tubes)

World map or atlas or globe

Internet access or printed copies of ice core summaries (by location)

Large poster paper (easel tablet or butcher paper)

½ sheet of paper (or 5X7" index card) for summary

Small envelopes (1 per group)

Markers and/or crayons

Scissors

Tape or glue

Mailing tubes, paper towel cylinders, or other re-usable cylinders (1 per group)

Source Material:

http://www.newscientist.com/article/dn8369 Longest Ice Core newspaper article from 2005
(from *Science* 25 November 2005: Vol. 310. no. 5752, pp. 1313 – 1317 DOI: 10.1126/science.1120130)

http://www.ncdc.noaa.gov/paleo/icecore/antarctica/vostok/vostok.html Information about the Vostok Ice Core.

(insert world map w/ mountainous regions marked)

Student worksheet:

1) Where do you think Dr. Thompson has found ice layers that are thick enough to warrant drilling a core? Mark areas on the world map where you think thick ice layers are found today.

2) Using the table of Drilling Sites, place a star at the location of Dr. Thompson's ice coring expeditions, and write the year of that expedition on the map, as well.

3) Dr. Thompson's group needs to deliver up to 6 tons of equipment (drilling rig, tents, fuel, tools, food and other supplies) to each location where he chooses to drill. What would be the nearest departure and destination cities in order to get to the drilling site/s that you've chosen?

4) Look at the "mock ice core" that you've been given. Complete the following items with your observations of this "core":

___________ a) Number of light colored layers (These layers represent the snowy season.)

___________ b) Number of dark colored layers (if any) (These layers represent dust or ash or soot, and are more typical of tropical and subtropical cores. Polar cores rarely, if ever, have dark layers.)

c) Number of layers with visible bubbles. Describe the bubbles: _______________________

____

____

___________ d) Do you see an insect or other clearly visible object included in any of the layers?

If so, please describe it, including which layer it is found in: _________________________

____

____

e) Can you tell which end of the core is the top? If so, how? If not, suggest a reason why this is hard to determine. ____

____

Group activity: Plan a hypothetical core, and sketch the layers that would enable your research colleagues (the rest of the class) to determine the age span of the core, the types of events that have happened during the time it was forming, and whether or not it is a tropical or polar core.

(To conserve resources, your "ice core" will be miniaturized to the size of a paper towel cylinder.)

Important Considerations:

1) Decide how many years will be represented in the core.

2) Decide if any volcanic eruptions occurred, and when.

3) Decide the types and sizes of bubbles that might be present in some of the layers.

4) Decide if any trapped organisms might be found in your core.

5) Decide the order of these events.

Group tasks

Quality Assurance
This teammate is responsible for assuring that the ideas represented are reasonable, and that the descriptions are clear and spelled correctly.

Artist
This teammate is responsible for sketching the surface of the core, showing layers that are identifiable as a snow layer, an ice layer, a dust or ash layer (each of which may be shown with or without bubbles and with or without parts of insects or other organisms).

Historian
This teammate is responsible for describing the history that this core provides. S/he will write a paragraph describing the sequence of events that resulted in the core's appearance looking as it does.

Poster Presenter
This teammate will present the visible clues to the history of the core, and the interpretations of the core's history, based on those clues.

Number of layers _______

Observable features:

Bubbles? (shape & size, in which layers?)

Dust or particulate layers? (color, grain size, thickness, which layers?)

Inclusions (insect pieces or other recognizable objects)

Relative thickness of layers:

Evaluation of learning

1) Distribute a diagram of a hypothetical core (Appendix A) and have students describe what they see and what it means (observations v. interpretations).

2) Have students randomly draw a hypothetical core (labeled A-F) from those produced by their classmates. Students complete the description sheet again, and write their own explanation of the sequence of events recorded in the new core. They can check themselves against the original summary that was written on a half sheet of paper and inserted into the cylinder.

3) Create a list of events, and have the students individually sketch a series of layers that would represent that series of events. All layers are described from the top of that core.

   Example: Create a "core" that has 13 years of annual snow records. The fifth year (from the top) has a 1/4" layer of volcanic ash. The lowest 4 layers of ice are about half as thick as the upper 9. The upper 3 layers have long bubbles in them. A mosquito was found among a lot of pollen in layer 7. If the top layer was deposited in 1877, when was the mosquito trapped in the snow. Which is the oldest layer?

4) Advanced students can also conduct research to learn more about the time periods that are represented by Dr. Thompson's cores from different regions of Earth, and the types of interesting things he has learned from studying ice fields in each region.

5) Some students might be interested in learning more about pollen analysis. Pollen are beautiful, and interesting, as seen under the microscope.