Teaching Activity: Paleoclimatic Evidence and Stable Isotopes

Introduction: The use of *ice cores* to study the chemistry of the past is a development of the past two decades. It has been applied at several areas of Earth where temperatures seldom or never exceed the freezing point of water: Antarctica, Greenland and some mountain glaciers. The technique is to locate an appropriate mass of ice, drill a core in such as way that the sample is retrieved in a minimally contaminated state and return the frozen core to the laboratory for study. The measurement of the species frozen in the ice is made by slicing off a section of the ice corresponding to the desired age period, removing the contaminated external surface, melting the remainder under ultra-clean conditions and analyzing the resulting solution. If gas concentrations are to be measured, the uncontaminated portion of the ice sample is placed in a vacuum chamber and cracked; the gases are then sucked out and analyzed by *gas chromatograph or spectrometric methods.* Ice core techniques are especially useful for species that are relatively unreactive. Species of this type are long lived and well mixed in the atmosphere, so the ice samples provide an approximate average of their global atmospheric concentrations. Atmospheric records in ice do not extend back in time indefinitely, because the lowest layers of ice become so compressed by the weight of the new ice formed above them that they flow under pressure and their individuality and identity are lost. The oldest ice cores drilled and analyzed so far have been dated to nearly 100,000 years in Greenland and about 160,000 years in Antarctica. Cores from both locations are about 2000 m long and 10 cm in diameter. In general, the further back one goes in time, the less accurate the dating becomes. Climate information, particularly temperature and amount of precipitation, can readily be derived from the study of ice cores and $^{18}O/^{16}O$ isotopic analysis.

Objectives:
- To graph ^{18}O and mean annual temperature data;
- To analyze the relationship between the 18O value and the mean annual temperature;
- To trace the steps in ice core acquisition and analysis;

Important Terms: Isotope, ratio, paleoclimatologist, temperature, paleotemperature, evaporation, volume, glaciers, ice core, glacial/ interglacial, gas chromatograph, spectrometer;

Materials: Student Activity Sheet, graph paper, ruler, colored pencils, paper/pencil;

Procedure:
1. Read over and discuss the **Introduction** and the **Data Table** with the class.
   - Review the basic steps taken to retrieve an ice core and the information it contains.
   - Point out the types of information that can be extracted about the past from ice core studies.

2. Explain to students what an isotope is and how it differs from the parent atom.
   - Present examples of different isotopes that they may encounter in their reading. (i.e. $^{14}C/^{13}C/^{12}C$; $^{18}O.^{17}O/^{16}O$)
3. Explain to the class that they will be doing an activity using ^{18}O information and temperatures from different locations within the polar regions.
   - Briefly the discuss the general use of isotopic analysis in studying the atmosphere.
4. Instruct students to answer the appropriate questions in the **Analysis** section.

5. Instruct students to create a graph of the locations on the **Data Table** using their ^{18}O values and mean annual air temperatures (*C).
   - The Y-axis should be labeled: ^{18}O **in** 0/100; measurements units need to be marked off beginning with -50 at the bottom of the axis and proceeding to 0 at the top;
   - The X-axis should be labeled: **Mean Annual Air Temperature (*C)**; measurement units should proceed from -50 on the far left to +30 on the far right;
   - The graph should be given a title: **Stable Isotopes in Precipitation**;
   - A dot should be placed on the grid where the coordinates meet and a line drawn connecting the South Pole with Valentia, using a ruler.

6. Students should then complete the activity by answering the remaining questions in the **Analysis** section.

Completed Graph:

STABLE ISOTOPES IN PRECIPITATION
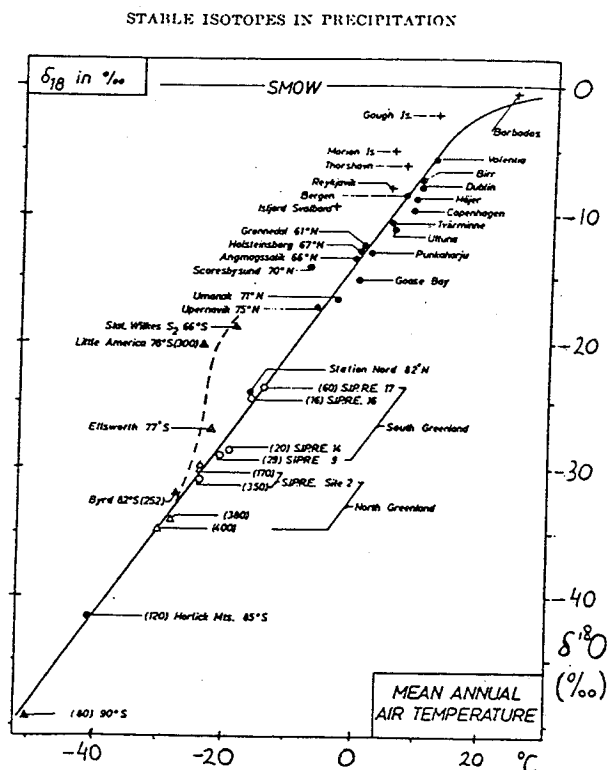
Student Activity Sheet: Paleoclimatic Evidence and Stable Isotopes

Introduction. The use of *ice cores* to study the chemistry of the past is a development of the past two decades. It has been applied at several areas of Earth where temperatures seldom or never exceed the freezing point of water: Antarctica, Greenland and some mountain glaciers. The technique is to locate an appropriate mass of ice, drill a core in such as way that the sample is retrieved in a minimally contaminated state and return the frozen core to the laboratory for study. The measurement of the species frozen in the ice is made by slicing off a section of the ice corresponding to the desired age period, removing the contaminated external surface, melting the remainder under ultra-clean conditions and analyzing the resulting solution. If gas concentrations are to be measured, the uncontaminated portion of the ice sample is placed in a vacuum chamber and cracked; the gases are then sucked out and analyzed by *gas chromatograph or spectrometric methods.* Ice core techniques are especially useful for species that are relatively unreactive. Species of this type are long lived and well mixed in the atmosphere, so the ice samples provide an approximate average of their global atmospheric concentrations. Atmospheric records in ice do not extend back in time indefinitely, because the lowest layers of ice become so compressed by the weight of the new ice formed above them that they flow under pressure and their individuality and identity are lost. The oldest ice cores drilled and analyzed so far have been dated to nearly 100,000 years in Greenland and about 160,000 years in Antarctica. Cores from both locations are about 2000 m long and 10 cm in diameter. In general, the further back one goes in time, the less accurate the dating becomes. Climate information, particularly temperature and amount of precipitation, can readily be derived from the study of ice cores and $^{18}O/^{16}O$ isotopic analysis.

Objectives:
- To graph ^{18}O and mean annual temperature data;
- To analyze the relationship between the 18O value and the mean annual temperature;
- To trace the steps in ice core acquisition and analysis;

Procedure:
1. Read over and discuss the **Introduction** and the **Data Table** with your teacher.

- Take notes on the basic steps taken to retrieve an ice core and the information it contains.

2. Be sure that you understand completely what an isotope is and how it differs from the parent atom.

3. Answer the appropriate questions in the **Analysis** section.

4. Create a graph of the locations on the **Data Table** using their ^{18}O value and mean annual air temperature (*C).

- The Y-axis should be labeled: ^{18}O in 0/100; measurements units need to be marked off beginning with -50 at the bottom of the axis and proceeding to 0 at the top;
- The X-axis should be labeled: **Mean Annual Air Temperature (*C)**; measurement units should proceed from -50 on the far left to +30 on the far right;
- The graph should be given a title: **Stable Isotopes in Precipitation;**
- Place a dot on the grid where the coordinate meet and draw a line connecting the South Pole with Valentia, using a ruler.

5. Complete the activity by completing the remaining questions in the **Analysis** section.

Data Table: Stable Isotopes in Precipitation
(W. Dansgaard, Tellus Vol.16.1964)

LOCATION	Air Temp. in *C	^{18}O 0/100
South Pole (90*S)	-52	-50
Horlick Mountains (85* S)	-41	-41
North Greenland (Site 400)	-30	-35
North Greenland (Site 380)	-30	-34
Sipre Site 2	-25	-31
Sipre Site 3	-24	-30
Sipre Site 9	-21	-29
Sipre Site 14	-20	-28
Upernavik (75*N)	-9	-17
Umanak (71*N)	-8	-16
Goose Bay	0	-15
Angmagssalik (66*N)	-1	-14
Holsteinborg (67*N)	0	-13
Punkaharju	+1	-13
Grannedel (61*N)	0	-12
Ultuna	+2.5	-11
Tvarminne	+3	-10.5
Copenhagen	+9	-10
Hoger	+9	-9
Dublin	+9	-9.5
Bergen	+8	-9
Reykavik	+6	-9
Birr	+9	-8
Thorshavn	+8	-7
Marion Island	+6	-5
Valentia	+9	-5.5
Gough Island	+9	-3
Barbados	+15	-1
Ellsworth (77* S)	-18	-27
Little America (78* S)	-23	-20

Analysis

1. In what way are ice cores useful for studying the Earth's past chemistry?

_____

_____

2. List or illustrate the steps in ice core acquisition and analysis. _____

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_____

3. What are the 2 analysis methods used to study the gases found in ice cores?

_____

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4. Why can't ice core analysis extend back indefinitely in time? _____

_____

_____

_____

5. What are the two oldest ice cores drilled to date? _____

_____

6. What happens to the accuracy of ice core data as you go farther back in time?

_____

_____

_____

7. What element and its isotopes are used to derive past temperature and precipitation amounts? _____

8. On the graph you created, what information was given on the Y-axis? _____
_____On the X-axis ?_____

9. What type of line was formed by the points you plotted? _____
Was it perfectly straight? _____

10. As the amount of $\delta^{18}O$ increased, what did you notice about the temperature?

_____

11. In areas where there were very high amounts of $\delta^{18}O$, what did you notice about temperature? _____

_____

12. What can be said about the amount of $\delta^{18}O$ when the temperatures increased?

_____

13. What relationship do you see between $\delta^{18}O$ and temperatures from your graph?

_____

_____

14. During a cold period, like an ice age, water vapor containing the lighter ^{16}O is evaporated more than water containing ^{18}O. The ocean water will become "enriched" in ^{18}O? Explain why this would happen. _____

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_____

_____

15. How could $^{18}O/^{16}O$ help scientists plot the occurrence of warm and cold periods in Earth history? Explain. _____

_____

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_____

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