What Information Do Paleobotanists Use to Study Ancient Climates?

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National Academic Standards:
Science
Science as Inquiry
- Abilities necessary to do scientific inquiry
- Understandings about scientific inquiry

Earth and Space Science
- Structure of the Earth system

Objective:
The student will be able to:
1. Distinguish the structural differences that are used for pollen classification.
2. Analyze pollen sample analogs to replicate the way that scientists gather paleo-data.
3. Interpret pollen sample analogs to replicate how scientists determine past climates.

Grade Level: 8-10

Subjects: Science

Key Concepts: Past climates, vegetation changes, scientific investigation.

Materials:
1. Pollen Images: Pictures of several types of pollen. (*Note to Teacher:* An excellent example of different pollen types is found in the October 1984 issue of National Geographic on p. 492-493.)
2. One large graduated cylinder (1000 mL at least) for the "sediment" column.
3. Five different types of "sediment" (any rice, sand, vermiculite, kitty litter, etc. that can be layered to show five distinct layers. You will need enough for the sediment column and the corresponding "samples").
4. Small, re-sealable plastic bags.
5. Pie tins (one for each sediment sample).
6. Nine different colors of paper for making "dots" (hole-punched) to serve as pollen analogs.
7. Table 1: Paper dot key for samples.
8. Table 2: Pollen color/climate key.
9. Chart 1: original study data (for extensions)
10. Student Worksheet (copy for students).

Terms:

Pollen grain: The microgametophyte of seed plants; each plant species has pollen grains with a shape unique to that species.

Paleobotanists: Scientists who study vegetation of the past.

Palynologists: Scientists who study pollen.

Sediment: Is made up of organic (e.g., dead algae, dead fish, pollen) and mineral (e.g., soil erosion deposited from streams) materials that blanket the bottom of lakes, riverbeds, or oceans.

Background:

Evidence found in the geologic and plant fossil records indicates that the Earth's climate has been very different from today's in the distant past. There have, however, also been substantial climatic fluctuations within the last several centuries, too recently for the changes to be reflected in the fossil record. These more recent changes are important to understanding potential future climate change, and so scientists have developed methods to study the climate of the recent past. Although accurate human-recorded weather records cover only the last few decades, paleoclimatologists and paleobotanists have found ways of identifying the kinds of plants that grew in a given area in the past, and can infer from the plants what kind of climate must have prevailed at the time. Because plants are generally distributed across the landscape based on temperature and precipitation patterns, as these climatic factors changed, plant communities also changed. Knowing the conditions the plants preferred, scientists can make general, qualitative conclusions about the past climate.

One way paleobotanists can map plant distribution over time is by studying the pollen left in lake sediments by wind-pollinated plants that once grew in the lake's vicinity. Sediment in the bottom of lakes is ideal for determining pollen changes over time because sediments tend to be laid down in annual layers (much like trees grow annual rings). Each layer traps the pollen that sank into the lake, or was carried into it by stream flow that year. To look at the "pollen history" of the lake, scientists collected long cores of the lake sediment. Scientists obtain these samples with long tubes that are approximately 5 centimeters (cm) in diameter. A series of casings hold the hole open as the drilling proceeds. The cores can be 10 meters (m) long or longer, depending on how old the lake is and how much sediment has been deposited.

The core that is removed is sampled every 10-20 cm and washed in solutions of very strong, corrosive chemicals such as potassium hydroxide, hydrochloric acid, and hydrogen fluoride. This harsh process removes the organic and mineral particles in the sample, except for the pollen, which is composed of some of the most chemically resistant organic compounds in nature. Microscope slides are made of the remaining pollen and are examined to count and identify the pollen grains. Because every plant species has a distinctive pollen morphology (called sculpturing), botanists can identify from which plant the pollen came.

Through pollen analysis, botanists can estimate the species composition of a lake area by comparing the relative amount of pollen each species contributes to the whole pollen sample. Carbon-14 dating of the lake sediment cores gives an approximate age of the sample.

Palynologists can infer the climate of the layer being studied by relating it to the current climatic preferences of the same plants. For example, a sediment layer with large amounts of birch pollen can be inferred to have been deposited during a cool, wet climatic period, because those are the current conditions to which this species is adapted.

There are two reasons that scientists who study climate change are interested in past climates. First, by examining the pattern of plant changes over time, they can determine how long it took for plant species to migrate into or out of a given area due to natural processes of climate change. This information makes it easier to predict the speed with which plant communities might change in response to human-induced climate change. Second, by determining the kinds of plants that existed in an area when the climate was warmer than at present, the scientists can more accurately predict which plants will be most likely to thrive if the climate warms again.

Doing the Activity:

- Students will examine pictures of pollen grains representing several different species, showing the structural differences that scientists use for identification.
- Students will analyze model soil samples with material mixed in to represent pollen. They will determine the type and amount of the "pollen" in the samples, and the type of vegetation and age of their samples.
- Students will make some conclusions about the likely climate at the time that the pollen was shed.

Procedure:

Part A:
Plants have pollen with unique morphology that can be used to identify them.

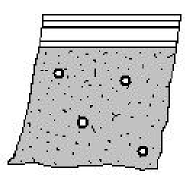
Ask the students to carefully examine the <u>pictures of the different pollen types</u>, noting the structural differences in each type. Discuss those differences, and how scientists can use those to identify the plants from which they were shed.

Part B:
Analysis of pollen data gives evidence of paleoclimate.

Note to teacher: The following exercise was developed based on actual pollen data collected from Devil's Lake in Baraboo, Wisconsin. Other regions may have similar pollen records available. The geology departments of local universities may be able to give you information on locally relevant pollen data that you can adapt to this exercise.

Preparation:

1. Layer the five different kinds of "soil" (rice, sand, fine gravel, kitty litter, vermiculite, perlite, or similar material) into the graduated cylinder so they form five distinct layers. This represents the model sediment core with which the students will work. Label the layers with their respective ages as shown in Figure 1.
2. Choose nine different colors of paper to represent the "pollen" grains. *Note to teacher:* We have suggested colors (Tables 1 and 2); however you can make your own color choices. *To avoid confusion later, make sure you note any color changes on both Tables 1 and 2.*
3. Make the different color pollen grains by using the "dots" from a standard hole punch, using Table 1 as a guide.
4. "Sediment" samples. Prepare one sample for each pair of students. It is important to make certain that all five layers of your sediment core are represented.
5. Fill the re-sealable plastic bags with approximately 100 mL of the same material representing a sediment layer in the core. For example, if you have sand representing Layer 1 in the sediment column, place 100 mL of sand in a plastic bag. If you chose rice for Layer 2, place 100 mL of rice in a second plastic bag and so on, until all 5 layers in the column have corresponding samples. Replicate until you have enough samples to distribute one to each pair of students.
6. Using Table 1 as a guide, mix into each sample bag 25 paper dots to represent the pollen found in that layer.



Activity:

1. Begin by showing the sediment column and discussing the way that sediment is laid down in lakes, how it traps pollen, and how scientists obtain the lake sediment cores.
2. Hand out one sediment sample, a pie tin, and a worksheet to each pair of students. Explain that each sample contains "pollen" from the plants prevalent at the time of deposition. Students should empty the contents of their sample into a pie tin. Their task is to sift through the sample to separate out the pollen from the sediment. Then they will determine from a key (Table 2) what plants are represented and what percentage of the total pollen comes from each species.
3. If more than one pair of students worked on the same sediment layer, ask them to get together and come to a consensus on what plants they've found and the relative abundance of each. The worksheet can be used to keep track of the percentage of plants found in each layer. From the key (Table 2) have them come to a consensus on what the climate must have been like at the time of deposition.
4. Ask each group studying a sediment layer to report their conclusions to the class. Then, as a class, build a consensus on the pattern of climate change represented by this sediment column. Students can complete their worksheets with data provided by students studying different sediment layers.
5. Once a class consensus has been reached, you may wish to share the interpretation of Dr. Louis Maher, the geologist who did the research upon which this exercise is based. His general conclusions are provided in an attached summary.

Note to teacher: Ask the students to carefully replace the pollen in the sample bags. These samples can be used again.

<u>Enrichment:</u>

1. Instead of preparing the bags of sediment and having them count pollen grains, have students figure the percentages themselves, using <u>Chart 1</u>. The major periods of change are marked as numbers 1-5, which correspond to Table 1. Substitute the following instructions for activity numbers 2 and 3 (above):
   ? First have the students determine the major "players" for each period. List on the board the plants they've decided are the most populous during those times.
   ? Have the students figure the approximate percentages for each plant they've chosen. Some plants vary considerably in percentage even within a single period – estimate the median percentage for each.
   ? Make sure that the total percentage for each <u>period</u> equals 100! (Use Table 1 to check students' answers.)
   ? After the students have determined relative percentages for each plant, have them use Table 2 to determine climatic conditions and trends during periods 1-5.
   ? Pick up the activity where you left off at #4.
2. Discuss some possible difficulties with obtaining sediment cores. Possible answers: tippy boats, bad weather, having the hole you've been drilling fill before you're done, etc.
3. Discuss some reasons why most lake sediments can only tell you about vegetation hundreds or thousands of years ago (not millions). Possible answers: lakes aren't that long-lived, glaciers, mountain building, etc. will destroy lakes, sediment will eventually fill lakes completely.
4. Provide students with prepared pollen slides, or have students collect and mount their own pollen on slides for examination under a microscope. Ask them to sketch the different pollen types and produce their own identification key to pollen.
5. Discuss some of the complexities associated with using pollen data for climate studies. Possible answers: the amount of pollen produced by each species can vary greatly – lots of pollen doesn't always mean lots of that species; it's not possible to identify most pollen grains to the species level, usually only family and genus; individual species in a genus or family can vary widely in terms of climate preference and adaptability.

<u>What is Chart 1?</u>

Chart 1 organizes the original pollen data collected by Dr. Louis Maher. This data is the source for the information in Table 1.

<u>How to read Chart 1</u>:

Depth corresponds to age - the top layers are youngest. The left side of the Y axis (vertical) shows the depth of the core (in centimeters). The right side of the Y axis shows the age of the core (in years) as indicated by Carbon dating. The margin of error for each date is listed below it.

The X axis (horizontal) shows the percentage of each type of pollen found in each sample (total = 100 percent). The scale beneath each type of pollen (the scientific name for each type is listed along the top) is given in a segment of the range 0-100. Each begins at 0, and the range is only given up to the maximum amount found in the core (for space conservation on the chart).

Toward the right of the chart, notice a box with the letters "AP" and "NAP" on either side. Also note that the percentage on this box includes the complete range of 0 to 100. This box divides the chart into two types of plants: Arboreal (trees) and Non-Arboreal (herbaceous). The box also shows the ratio of Arboreal plants to Non-Arboreal (herbaceous) plants. The horizontal line is drawn for the Arboreal plants, and shows their percentage of the total for that depth/age. The remaining percentage (after the line ends) corresponds to the number of Non-Arboreal plants for that depth/age.

The Paleoclimate of Devils Lake, Baraboo, Wisconsin:

The research site is located in Devils Lake State Park, Sauk County, Wisconsin. (43° 25' N, 89° 44' W).

The lake has been in existence for at least 14,000 radiocarbon years.

Trapped in the sediments are pollen grains from the plants that grew in the general vicinity of the lake at the time the sediments were deposited. By examining the pollen in different layers of sediment from the bottom layer to the top, scientists can reconstruct the vegetation changes that have occurred in the area during the lake's existence. Because they know something about the climatic conditions that the plants needed to survive, scientists can use the vegetation data to reconstruct the past climate in the area for the past 13,000 years.

There were 73 samples taken at Devils Lake, with at least 500 pollen grains per sample – a total of **36,500** pollen grains examined. For comparison, our activity uses only 125 "pollen" grains – dots – to represent the total grains in the sediment column. Each of our "grains" represents approximately 300 pollen grains from the study.

Because the data were charted in century intervals – 130 intervals in all – many layers have been identified by Dr. Louis Maher, a geologist at the University of Wisconsin. For simplicity's sake, we have combined these into five major layers (Chart 1). The age of each layer has been established by radiocarbon dating.

Layer #1: 13,000 – 11,000 years before present (ybp):
Climatic warming is causing continental glaciers to recede. In the region of what is now Devils Lake, the glacier retreats and advances several times between 12,000 – 13,000 ybp. Glacial lake Wisconsin forms about 14,000 – 15,000 ybp, when the Green Bay Ice Lobe dams the Wisconsin River at the Baraboo bluffs, covering most of present-day Adams and Juneau counties, and parts of present-day Monroe, Sauk, and Wood counties. The climate is cold and wet, and the landscape resembles a tundra. Few trees, mainly the hardiest species, are present, due to the recent glacial advances. The hardiest species, spruce and ash, are the only tree types found in abundance. Herbaceous species (grasses, sedges, and sages) are flourishing, fulfilling their role as disturbance indicators.

Layer #2: 11,000 – 9,500 ybp:
The post-glacial warming continues. The climate is warmer than before, but still cool and wet. The forest begins to develop. Mesic species and oak trees, all moisture-loving, are thriving. Several species of trees have begun to carve out niches in the new areas opened by the glaciers to colonization. The presence of herbaceous species, especially ragweed, may represent periods of drought within a larger wet period.

Layer #3: 9,500 – 5,200 ybp:
The ice is gone, the climate continues to warm, and moisture levels remain high. Several smaller glacial lakes are formed. The forest continues to expand. Mesic species and oak trees dominate the scene, while the numbers of pine trees remain steady. The presence of herbaceous species, especially ragweed, may represent periods of drought within a larger wet period.

Layer #4: 5,200 – 170 ybp:
The warming continues, with some drying. Oak trees dominate the scene and the mesic species have been markedly reduced. Some hardy species, ash and birch, are present in small percentages. Later in this period, Native American influence seems to play a role in the number of hickory and walnut trees – a good food source. herbaceous species, especially ragweed, may indicate periods of drought or controlled prairie fires.

Layer #5: 170 ybp - present:
Warm, humid summers and cold, dry winters characterize the current climate. The plants occurring during this period show a heavy influence from European settlers. Oak remains the dominant tree species, with the cold-loving birch and the hardy pine also contributing to the temperate forest. Deforestation due to logging and farming has allowed ragweed and other herbaceous species to claim a sizable chunk of the pollen record, indicating plenty of large open space. However, some grass pollen may be large quantities of wild rice pollen, which can skew the record.

Note: You might have noticed that some species from the original data were left out of the climate analysis. This is because those species are not strong climate indicators for the Devils Lake area. The following list provides an explanation:

? *Alnus* (Alder): Never shows up in significant quantities in the sample; small populations of this plant are not strong climate indicators for this area.

? *Tilia* (Basswood): Never shows up in significant quantities in the sample; small populations of this plant are not strong climate indicators for this area.

? *Carya* (Hickory) and *Juglans* (Walnut): These trees have little impact on other species, and seem to indicate no major climate changes; also, may have been encouraged as a food source by Native Americans.

? *Chenopod* (Pigweed): Never shows up in significant quantities in the sample. When it is present, pigweed often indicates an environmental disturbance. Since the other grasses also indicate a disturbance, this is not significant enough for inclusion.

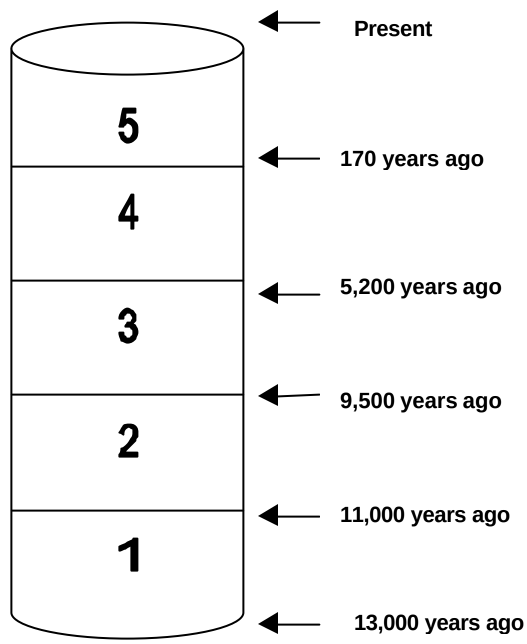


Figure 1. Model Sediment Column

References:

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