UNIT 2
Atmosphere and Climate

READING

Evidence of Earth's Past

From the hothouse world of the Cretaceous to the icehouse world of the Pleistocene, Earth has kept a record of its climates. To understand the reasons that climate changes, scientists don't just seek snapshots of climate at particular times; they also seek continuous records of climate change over time. Scientists such as those working on the Arctic Coring Expedition are using all types of evidence—from tree rings to bubbles of gas trapped in ice cores—to re-create Earth's climate history. How do they do this? Read on.

Historical Records

Records of climate data collected using instruments such as thermometers go back about 100 years. Before that time, there are anecdotal records of climatic conditions. These records kept by nonscientists of past storms, growing seasons, droughts, heat waves, and other climatic data can be found in ship and farmers' logs, diaries, and newspaper accounts. These various records can be compared to look for common trends in climate conditions. Records such as these can go back hundreds of years. For example, in France and other parts of Europe, records of the first day of the grape harvest have been carefully kept for more than 600 years.

Tree Rings and Corals

For the time before human records were available, one has to look for nature's own records. Have you ever determined the age of a tree by counting the rings on its stump? If you have, you may have noticed that the rings change in width from year to year, as shown in Figure 6.7. The thicker rings formed during good growing years, perhaps years with a good, long growing season or with plentiful rain. Tree rings in recent and preserved wood give scientists important annual and seasonal climate data for the area in which they grew, going back hundreds or thousands of years. The rings can record not only the length of growing seasons and amount of rain but also information about fires, insect infestations, and plant diseases, all of which may be linked to climate. By correlating the oldest rings from living trees with the youngest rings from preserved logs, the tree ring record in some parts of the world goes back more than 10,000 years.

Corals also build their skeletons in concentric rings, using calcium carbonate ($CaCO_3$) extracted from seawater. Ratios of different oxygen isotopes contained within the carbonate are used to determine the temperature of the water in which the coral grew. These corals often live for several centuries and provide a record of sea temperature.

FIGURE 6.7

Annual rings such as those in this tree vary in width depending on the weather conditions during each growing season and can provide a valuable record of historical climate. Times of above average moisture are represented by rings that are wider apart, and narrow rings indicate drier times.

Ice Cores

Glacial ice accumulates gradually from year to year as snow falls—and does not melt—in high latitude areas such as northern Greenland, Canada, and Antarctica. Glacial ice also accumulates in high elevation areas at lower latitudes. Every year, for thousands of years, ice has incorporated samples of the atmosphere in the form of tiny air bubbles in the compacted snow. In the deep central portion of the Antarctic ice sheet, there are layers of ice that date back to over 700,000 years, and the Greenland ice sheet contains a record of past climate going back 100,000 years or more. The bubbles of air trapped in the ice reveal past concentrations of CO_2 and methane in Earth's atmosphere. Ratios of oxygen isotopes within the water molecules of ice provide readings of the temperature at the time the snow fell. The ice also contains windblown dust and salt from the ocean that provide more valuable clues to past climate conditions. An example of an ice core is shown in Figure 6.8

FIGURE 6.8
Ice cores from continents near the poles preserve samples of ancient atmospheres and many other clues to past climate. This core is from the ice sheet on the continent of Greenland. This section of core formed about 16,250 years ago during the last glacial period. The layers result from differences in the size of snow crystals that collected in summer versus winter. The core shown in this photograph represents about 38 years.

Lake and Ocean Sediments

Rivers such as the mighty Mississippi in the midwestern United States carry tons of sand, mud, and gravel to the ocean. When rivers reach the sea, the sediment settles out, layer by layer, and forms deltas. This process happens in lakes as well. Wherever rivers and streams meet a larger body of water, sediment layers accumulate year by year and persist for tens of millions of years.

Variations in the thickness and grain size of the sediment layers reflect changes in rainfall or snowmelt on land. The rivers and streams carry the remains of plants, plant pollen, and animals to the ocean, and deposit them along with the sand and mud. Plankton, which live in the ocean water, also settle to the bottom when they die. These include microscopic organisms such as those shown in Figure 6.9 with shells or skeletons made of calcium carbonate, silica, and certain organic materials that are preserved as fossils. Some of these species of plants, animals, and microorganisms are known to live only within certain climate zones and are valuable for chronicling historical climates. In addition, the form, growth rate, and/or isotopic composition of the skeletons of preserved microorganisms can reflect the temperature of the

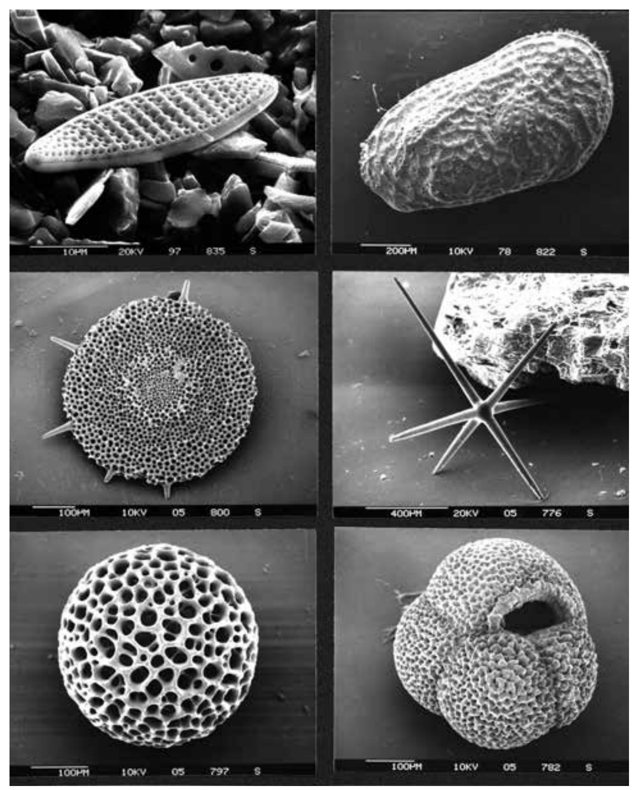

FIGURE 6.9
The skeletons of microscopic plants and animals like these foraminifera settle to the seafloor when they die and are sometimes preserved in the layers of sediments, which accumulate over millions of years. They can provide valuable information about the climate in which they lived. The six skeletons pictured show a startling variety of body types, from spiny to spherical.

water in which the organisms lived and even indicate whether ice sheets were present in high latitude seas. Pollen grains from vegetation characteristic of certain climates may also be preserved in sediment layers in lakes and oceans.

Soil and Bedrock on Land

Evidence preserved in the soil and bedrock that makes up the continents can also be used to reconstruct past climates. For example, continental glaciers that were present in North America and elsewhere during the Pleistocene Ice Age scraped off huge volumes of sand, silt, clay, and even huge boulders, and carried them significant distances. These glacial deposits are still present beneath the regrowth of trees and other vegetation, and geologists recognize them as evidence of a much colder climate. Scientists can also identify in the northern parts of the United States, Europe, and elsewhere certain types of landforms that are characteristic of glaciated areas seen around the world today.

The remnants of the Pleistocene Ice Age haven't been around long enough yet to compress and form into rock. However, sediments deposited on the bottom of the inland sea during the warm and watery Cretaceous period have, in the 100 million years since then, been buried, compacted, cemented, and preserved in sedimentary rock, and then uplifted and exposed by weathering. These rocks contain the fossilized remains of mosasaurs and plesiosaurs as well as other plants and animals that were characteristic of certain climate zones. These fossils help scientists gain an understanding of this prehistoric world. Rocks can be used to look very far back in time: There are some rocks that are billions of years old preserved on land. However, continental rocks are subject to erosion, so scientists must do a great deal of field work and analysis to piece together the bits and pieces that remain.

About the Reading

Write your responses to the following questions in your notebook. Be prepared to discuss your answers with the class.

1. To summarize what you learned from this reading, make a table like Table 6.1. Fill in the information for the climate proxies (evidence of past climate) discussed in the reading.

Table 6.1: Climate Proxy Summary Table

CLIMATE PROXY	TYPE OF INFORMATION	AREA OF EARTH (OCEAN, LAND, HIGH LATITUDE, LOW LATITUDE)	LENGTH OF CLIMATE RECORD
Historical records			
Tree rings			
Coral			
etc.			

2. Each of the climate proxies discussed in the reading yields information about climate in a particular area of Earth—land or sea, tropical, temperate, or arctic areas. Why would it be important to have data from all these different areas?
3. Some climate records, such as tree rings, give more detailed and continuous information about past climate, but only date back hundreds or thousands of years. Other climate records, such as those in continental rocks, go back much farther but are less complete or detailed. How might scientists use each of these types of information to learn about how Earth's climate system works?

ACTIVITY 2
Using Climate Proxies

Setting the Stage: Using Forams as Clues to Ocean Temperature

As you learned in the reading *Evidence of Earth's Past,* scientists are able to use various clues preserved in ocean sediment to learn about Earth's climate history. The microscopic foraminifera *Neogloboquadrina pachyderma* (*N. pachyderma)* serves as a particularly useful indicator of ocean temperature. These foraminifera (Figure 6.10) are found in two forms. When the ocean water is relatively warm, this organism tends to grow into a right-coiling form. When the water is relatively cold, *N. pachyderma* grows into a left-coiling form. When these organisms die, they settle to the ocean bottom and their skeletons are incorporated into the accumulating layers of sediment, preserving a record of the ocean temperature at the time each organism was alive.

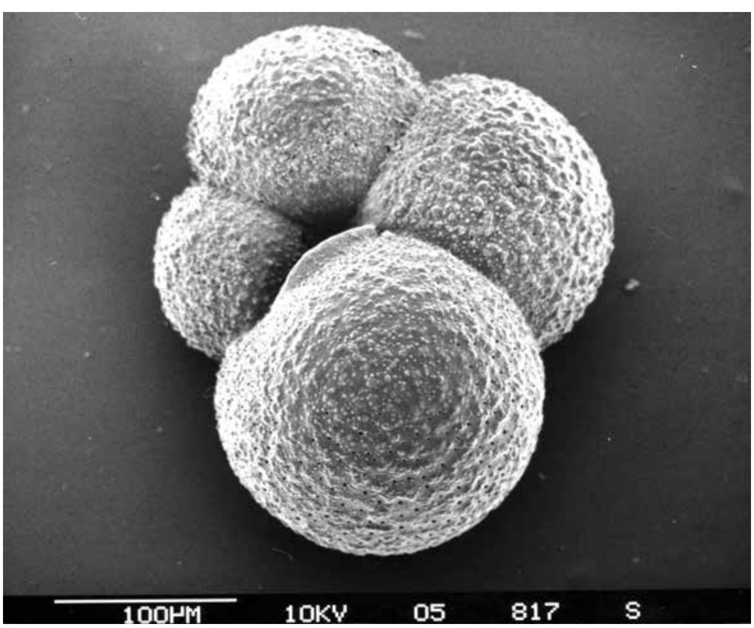

FIGURE 6.10
Neogloboquadrina pachyderma *is a microscopic organism that provides valuable clues about past ocean temperature.*

Scientists study the record preserved in the sediment layers by drilling into the ocean bottom using a variety of coring devices. They obtain undisturbed sediment cores using hollow tubes, such as the one shown in Figure 6.11. The sediment cores are then brought to the surface and analyzed. The age of the layers is determined using radioisotopic dating techniques, and each layer is carefully studied.

In this activity, you will simulate counting and analyzing the number of right-coiling versus left-coiling *N. pachyderma* in the layers of a sediment core. You will use these data to determine past ocean temperatures.

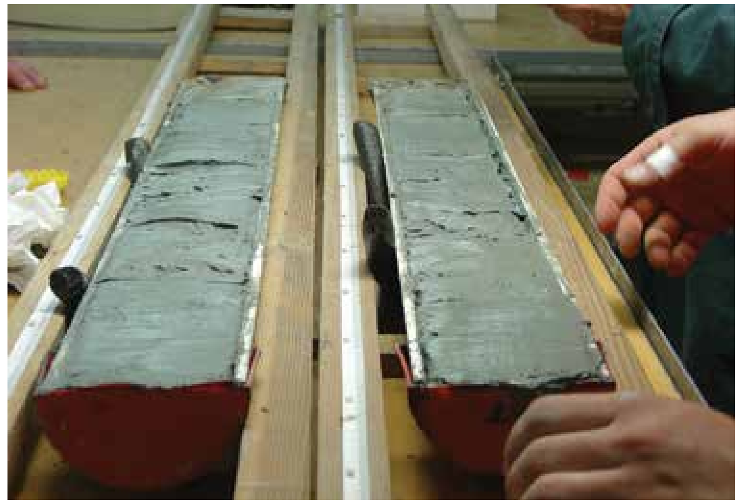

FIGURE 6.11
This sediment core from the ocean floor near New Zealand contains microscopic organisms, such as foraminifera, that can be used to determine past ocean temperatures. The core halves have been swiped with a spatula so that sedimentary features in the core can be seen.

Procedure

Record all observations and answers in your notebook as you work.

1. Carefully pour the contents of your core onto your desk or lab bench, being careful not to lose any pieces (this could cause errors in your measurements). Notice that there are three different fossil foraminifera (forams) as shown in Figure 6.12 below: left-coiling *N. pachyderma*, right-coiling *N. pachyderma*, and *Globigerinoides sacculifer (G. sacculifer)*:[3]

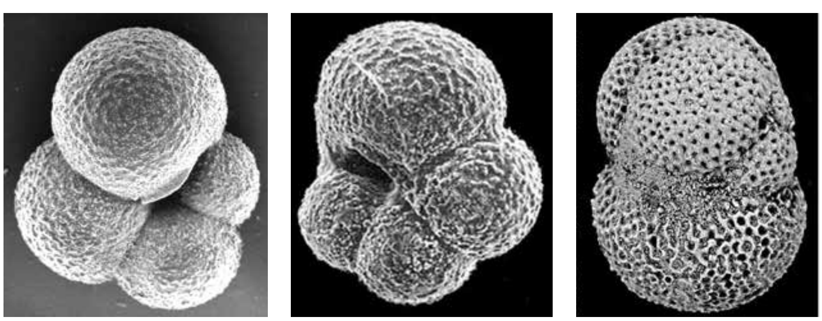

FIGURE 6.12
(left to right) left-coiling N. pachyderma, *right-coiling* N. pachyderma, *non-coiling* G. sacculifer

2. Count and record the number of each of the different types of forams found in your sediment core.
3. Note the age of your core sample (printed on your core tube) then record the number of right-coiling and left-coiling *N. pachyderma* in the row of the class chart that corresponds to the age of your core.
4. Make a table in your notebook similar to Table 6.2. Copy the class data into it.

Materials

FOR EACH TEAM OF STUDENTS

- "sediment core" containing "forams"
- tray
- calculator

FOR EACH STUDENT

- ruler (optional)
- graph paper

5. For each time period in the chart, calculate the total number of *N. Pachyderma* and the percent of right-coiling *N. Pachyderma*. Record your results in Table 6.2.

Table 6.2

AGE (years ago)	RIGHT-COILING *N. PACHYDERMA*	LEFT-COILING *N. PACHYDERMA*	TOTAL NUMBER OF *N. PACHYDERMA*	% RIGHT COILING (WARM WATER)
0				
30,000				
60,000				
90,000				
120,000				
150,000				
180,000				
210,000				

6. Create a labeled line graph that shows the percent of right-coiling organisms versus time.
7. Since a higher percentage of right-coiling *N. Pachyderma* corresponds to warmer temperatures, label the warm and cool periods on your graph.
8. Write answers to the Analysis questions and be prepared to discuss them with the class.

Analysis

With your group, complete the following questions and record your answers in your notebook. Be prepared to share your answers with the rest of the class.

1. Describe your results:
   a. During what time periods was the ocean water relatively warm according to the simulated foraminifera data?
   b. During what time periods was the ocean water relatively cold according to the simulated foraminifera data?
2. Relate the ocean-water temperature recorded in these sediment samples to past global climate. What does it tell you? What does it not tell you about global climate at the time these layers formed?
3. Aside from the fact that you didn't use real organisms, describe your initial ideas about how this activity might be similar to and different from the real processes scientists follow to analyze sediment cores.

Now that you have a better idea of how scientists study past climate, you will look at what they've learned about what has caused climate to change in the past. The first mechanism you'll study is change in Earth's orbit.