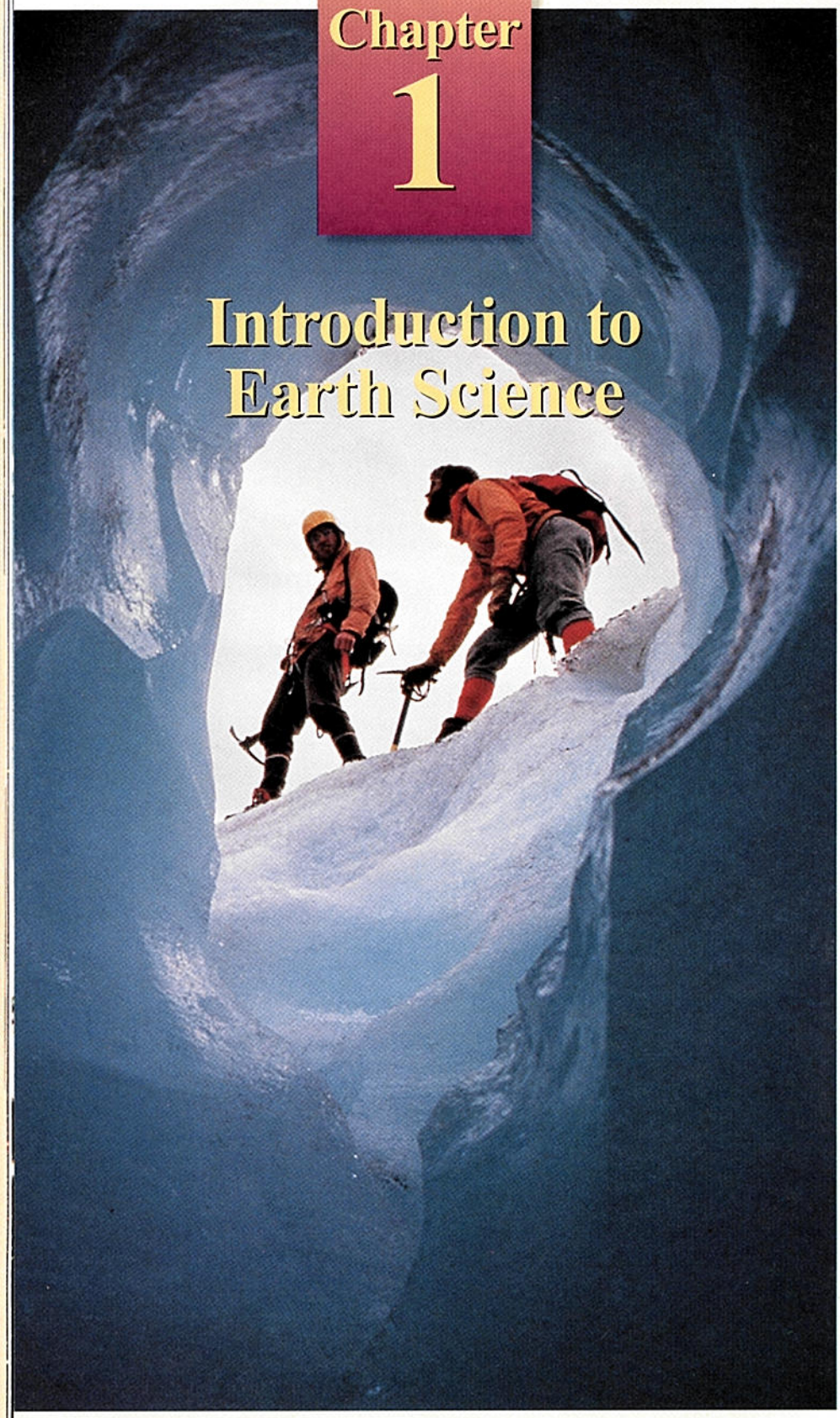
Chapter 1

Introduction to Earth Science



The natural world challenges our understanding with questions about why seasons change, rivers flood, and planets spin through space. Unlocking the secrets of the natural world takes earth scientists to the rainforests of equatorial Africa and to ice caves such as this one in Canada.

This chapter describes the origins of earth science and some of the methods earth scientists use to learn about the world around us.

Chapter Outline

These climbers are poised at the mouth of an ice cave in Canada.

1.1 What Is Earth Science?

Section Objectives

- **Name the four main branches of earth science.**
- **Discuss the relationship between earth science and ecology.**

Since the beginning of human history, people have observed the world around them and wondered about the forces that shaped that world. As early humans watched a volcano erupt, felt the earth tremble beneath them, or saw the moon darken during an eclipse, they asked why. To explain these natural phenomena, ancient people forged myths and legends, attributing such events to powerful supernatural forces. Angry goddesses hurled fire from volcanoes; giants wrestled underground, causing the earth to shake.

Not until people began to make careful observations and to search for natural causes to natural phenomena did the scientific study of the earth begin. The ancient Chinese, for example, began keeping written records of earthquakes as early as 780 B.C. The ancient Greeks compiled a catalogue of rocks and minerals in the third century B.C. Other ancient people, such as the Mayas in Central America, kept track of the movements of the sun, the moon, and the planets. They used these observations to create accurate calendars.

At first, scientific discoveries were limited to observations made with the unaided eye. Then, in the seventeenth century, the invention of instruments such as the microscope and the telescope extended human observation to previously hidden worlds.

Eventually, people accumulated an organized body of knowledge about the earth, and the field of **earth science** was born. Earth science is the study of the earth and of the universe around it. Earth science, like other modern sciences, is based on the assumption that the causes of natural phenomena can be discovered through careful observation and experimentation.

Branches of Earth Science

As the technology for studying the earth improved, the range of human observation increased dramatically. With the help of special equipment, scientists began to explore the dark ocean depths, the

Figure 1-1. El Caracol, an observatory built by the ancient Mayas of Mexico, is the oldest known observatory in the Americas.

EARTHBEAT

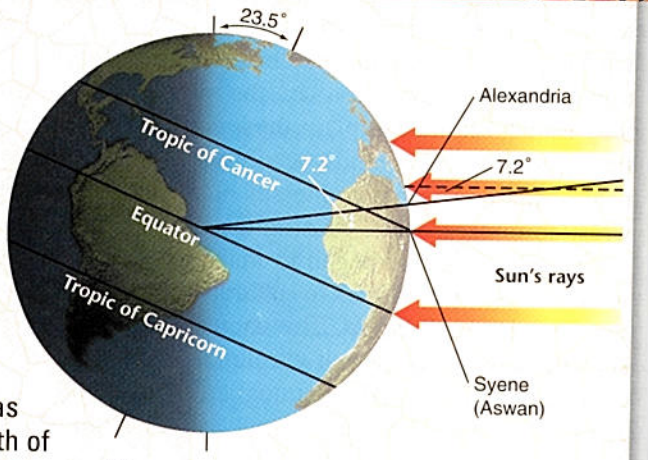
The Earth's Circumference

More than 22 centuries ago, a Greek mathematician named Eratosthenes used careful observations and simple geometry to determine the circumference of, or distance around, the earth.

Eratosthenes read of a well in Syene, Egypt—modern-day Aswan, Egypt—where the sun's rays reached the bottom once each year, at noon on June 21. Furthermore, the sun cast no shadows in Syene at that time. Eratosthenes thought these facts meant that the sun was directly overhead at Syene on June 21. Eratosthenes knew that the sun *did* cast shadows in Alexandria, a city to the north of Syene, on June 21, indicating that the sun's rays were striking that city at an angle.

Eratosthenes determined that the angle of the sun's rays in Alexandria at noon on June 21 was 7.2°. He thought that meant that the distance between the two cities was also 7.2°, or 1/50th of the 360° circumference of the earth. Eratosthenes knew that the distance between Syene and Alexandria was about 5,000 stadia (925 km). By multiplying the known distance between Alexandria and Syene by 50, Eratosthenes calculated the polar circumference of the earth to be 250,000 stadia (46,250 km).

With the aid of modern technology and sophisticated instruments, scientists now calculate the earth's circumference to be about 40,000 km.



This value, which is considered accurate, differs from Eratosthenes' calculation of 46,250 km by only 6,250 km.

Suppose that city A is 3,335 km north of city B and that on June 21 the angle of the sun's rays in city A is 0° while the angle of the rays in city B is 30°. Use Eratosthenes' method to find the earth's circumference.

earth's unknown interior, and the vastness of space. Their discoveries have created an immense body of knowledge about the earth.

Because one person cannot keep up with the developments in all areas of earth science, most earth scientists today specialize. Currently, earth scientists specialize in one of the following four major areas of study: the solid earth, the oceans, the atmosphere, and the universe beyond the earth. *Career Focus*, a special feature that appears in each unit of this book, offers detailed information about careers in earth science.

Geology

The study of the origin, history, and structure of the solid earth and the processes that shape it is called **geology.** Geology is a broad field that includes many areas of specialization. Some geologists explore the earth's crust in search of new deposits of coal, oil, gas, and

other valuable resources; some geologists study the forces within the earth in order to better understand and forecast earthquakes and volcanic eruptions; and some geologists study fossils to learn more about the earth's past. Units 1, 2, 3, 4, and 5 of this book deal with topics of primary concern to geologists.

Oceanography

Vast oceans cover nearly three-fourths of the earth's surface. The study of the earth's oceans is called **oceanography.** Some oceanographers work on research ships equipped with special instruments for studying the sea. Other oceanographers study waves, tides, and ocean currents. Some oceanographers explore the ocean floor for clues to the earth's history and to locate mineral deposits. Other oceanographers study marine plant and animal life. A discussion of the earth's oceans is presented in Unit 6.

Meteorology

The study of the earth's atmosphere is called **meteorology.** Using satellites, radar, and other modern technology, meteorologists study the variations in atmospheric conditions that produce weather. Many meteorologists work as weather observers, measuring such factors

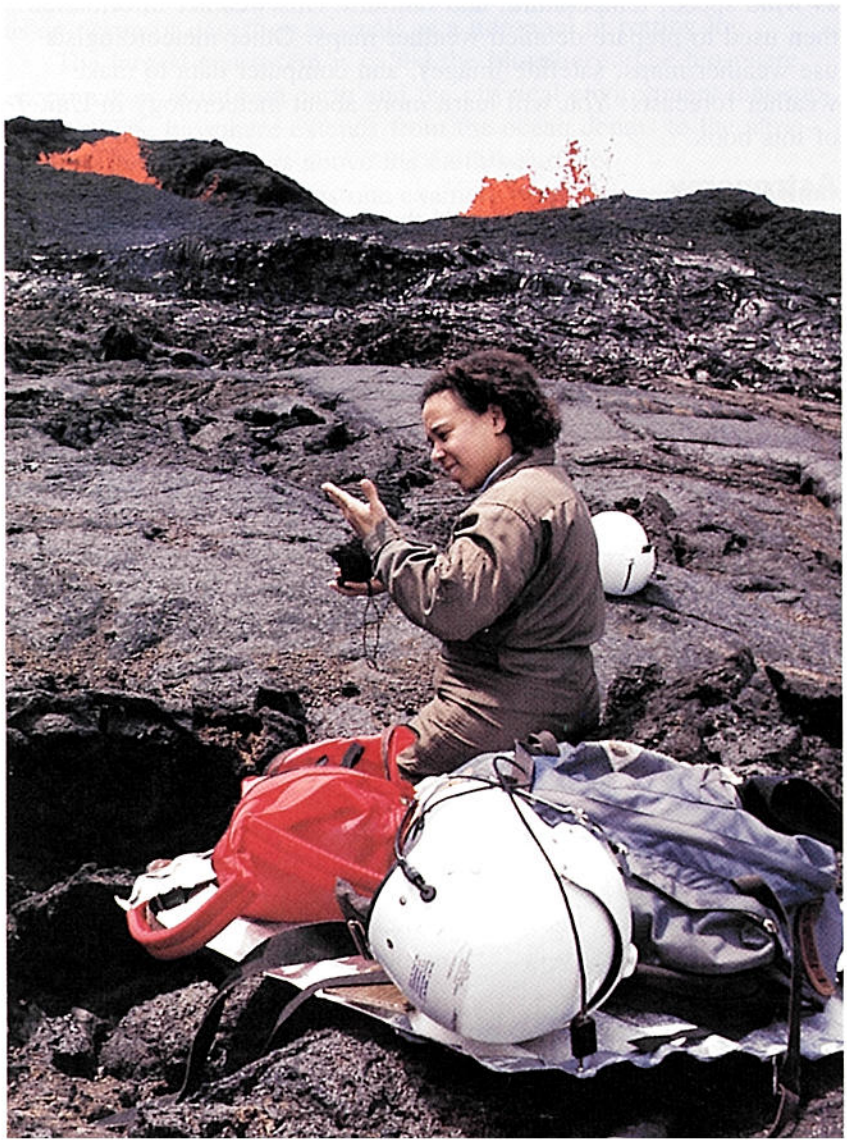


Figure 1–2. A geologist uses special equipment to study erupting volcanoes (left). Oceanographers prepare to enter a submersible to study the ocean floor (above).

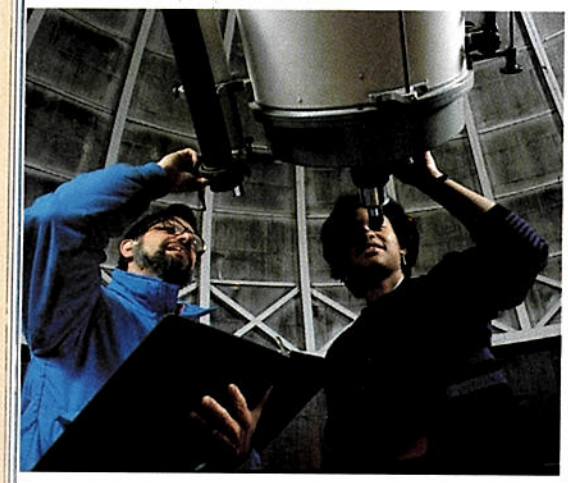


Figure 1–3. Two astronomers use a telescope to observe distant stars (left). A meteorologist uses a computerized system to track storms (right).

as wind speed, temperature, and rainfall. This weather information i then used to prepare detailed weather maps. Other meteorologists use weather maps, satellite images, and computer data to make weather forecasts. You will learn more about meteorology in Unit 7 of this book.

Astronomy

The study of the universe beyond the earth is called **astronomy.** It is one of the oldest branches of earth science. In fact, the ancient Babylonians charted the positions of planets and stars nearly 4,000 years ago. Modern astronomers use earth-based and space-based telescopes and other instruments to study the universe. Space probes, such as *Pioneer, Voyager, Galileo,* and *Ulysses* have also provided much useful data. Unit 8 of this book presents information about the moon, the planets, the sun, the stars, and the universe.

The Importance of Earth Science

Powerful forces are at work on the earth. Volcanoes erupt and earthquakes shake the ground. These events not only shape the earth, but also affect life on the earth. A volcanic eruption may bury a town in ash. An earthquake may produce huge waves that destroy shorelines. By understanding how natural forces shape our environment, earth scientists can better forecast potential disasters and help save lives and property.

Observations made by earth scientists have contributed greatly to our knowledge of the world around us. For example, information gathered by astronomers studying distant galaxies has led to theories about the origins of this solar system. Geologists studying rock layers have found clues to the earth's past environments and to the evolution of life on this planet.

The earth also provides many valuable resources that enrich the quality of people's lives. For example, the fuel that powers a jet, the metal used to make surgical instruments, and the paper and ink in this book all come from the earth. The study of earth science can help people gain access to the earth's resources and teaches them to use those resources wisely.

Ecology

Earth scientists primarily study the **geosphere,** the solid earth; the **hydrosphere,** its water; and the **atmosphere,** the gases surrounding the earth. Other scientists, called biologists, study the living world. An area of science in which biology and earth science are closely linked is called **ecology.** Ecology is the study of the complex relationships between living things and their environment. Most ecologists have backgrounds in either earth science or biology.

Organisms on the earth inhabit many different environments. A community of organisms and the environment they inhabit is called an **ecosystem.** The terms *ecology* and *ecosystem* come from the Greek word *oikos,* meaning "house." Each ecosystem is a physically distinct, self-supporting system. An ecosystem may be as large as an ocean or desert or as small as a tide pool or rotting log.

The largest ecosystem is called the **biosphere.** The biosphere encompasses all life on earth and the physical environment that supports it. The biosphere extends from the ocean depths to the atmosphere a few kilometers above the earth's surface.

A tropical rain forest is one example of a large ecosystem within the biosphere. Plants in the rain forest use sunlight to produce food through a process known as *photosynthesis*. The plants are then eaten by animals, which are in turn eaten by other animals. When

Figure 1–4. This small tidal pool on the coast of Maine, in Acadia National Park, and the vast ocean are both ecosystems.

Figure 1–5. People try to help the environment by cleaning up the shore after an oil spill (top). Pollution also harms wildlife. Volunteers remove oil from a bird's feathers (bottom).

rain-forest plants and animals die, their bodies are decomposed by microorganisms. The resulting chemicals enter the soil to nourish other plants and animals. Thus, the system is practically self-supporting. What other examples of ecosystems can you name?

Environmental Pollution

Each ecosystem is delicately balanced. When that fragile ecological balance is upset, the survival of the ecosystem, and in some cases the entire biosphere, is threatened. One serious threat to ecosystems today is **pollution,** the contamination of the environment with waste products or impurities.

Some waste products are **biodegradable.** As such, they can be broken down by microorganisms into harmless substances that can then be used by other organisms. Biodegradable waste products pose little threat to the environment, and in many cases they contribute to the well-being of the environment. For example, the chemicals found in such biodegradable wastes as banana peels and eggshells make excellent plant fertilizer.

Many modern waste products, such as most plastics, are not biodegradable. Some ecosystems are threatened by the large quantities of nonbiodegradable wastes. For example, plastic wastes dumped in oceans or lakes can harm the animals there. When particles of plastic are ingested, they clog the digestive tracts of fish, birds, and turtles. Ducks and other birds can starve to death when they become tangled in plastic litter.

Protecting the Environment

Pollution poses serious problems for all living organisms. To help protect the environment from pollution, ecologists often work together with earth scientists in other fields such as meteorology.

For example, in the early 1970's, meteorologists found that the level of ozone, a form of oxygen, in the upper atmosphere was decreasing. This discovery was alarming to ecologists and earth scientists. They knew that ozone helps protect the earth's plant and animal life from the harmful ultraviolet rays of the sun. Further research revealed that the ozone layer was being destroyed by chlorofluorocarbons (CFCs), chemical compounds commonly used as propellants in aerosol sprays. To reduce this threat to the environment, the United States and other countries have agreed to abide by international treaties limiting the production and use of such ozone-depleting chemicals.

Section 1.1 Review

1. What are the four major branches of earth science?
2. Describe the work of meteorologists.
3. What is ecology?
4. Give an example of an ecosystem and explain how it is self-supporting.
5. How might the study of earth science contribute to the survival of the biosphere?

1.2 Paths to Discovery: Scientific Methods

Section Objectives

- **Identify the steps that make up scientific methods.**
- **Explain how the meteorite-impact hypothesis developed.**

Through research, scientists seek to explain natural phenomena and solve mysteries of the earth. Over the years, the scientific community has developed organized, logical approaches to scientific research, called **scientific methods.** Scientific methods are not a set of sequential steps that scientists invariably follow. Rather, they are guides to scientific problem solving.

State the Problem

Scientific inquiry often begins as a result of **observation.** Simply put, observation is using the senses of sight, touch, taste, hearing, and smell to gather information about the world. When you notice thunderclouds forming in the summer sky, that is an observation. So, too, is feeling the cool, smooth surface of polished marble or hearing the roar of rapids around the bend of a river.

Observations often lead to questioning. What causes tornadoes to form? Why is oil found only in certain locations and not in others? What causes a river to change its course? Asking questions like these is one way of stating the problem to be investigated through scientific methods.

One problem that has long puzzled scientists is the extinction of the dinosaurs. For more than 135 million years, these huge reptiles dominated the earth. Then, about 65 million years ago, the dinosaurs and three-fourths of all the other species on the earth died out. Scientists wondered what could have caused such a mass extinction.

Gather Information

To investigate a problem, such as the extinction of the dinosaurs, scientists gather information. An important means of gathering information is **measurement.** Measurement involves the comparison of

Figure 1-6. One means of gathering information is through careful measurement. In this photo, geologists are measuring a crack in the earth's surface caused by an earthquake.

Figure 1–7. Geologists found a clay layer with high-iridium content in Montana.

some aspect of an object or phenomenon with a standard unit, su as a meter, a Celsius degree, or a kilogram. For example, when measure a rock and find that it is 20 cm long, you are comparing length of the rock with a unit of measure—one centimeter. What other units of measure can you name?

Accuracy is important in scientific measurements. Inaccurate measurements can lead to an incorrect conclusion. Scientists ofte use special tools such as micrometers and calipers to help them make precise measurements.

In the case of the dinosaurs, scientists examined the fossil re for clues to what happened 65 million years ago. They studied rc layers throughout the world that date from the time when the din saurs disappeared. The scientists discovered that in certain locatic these layers contain iridium, a substance that is uncommon in ear rocks, but common in meteorites. Scientists then measured the amount of iridium in the rock layers. They found that the rock la in these particular locations contained nearly 160 times the amou of iridium normally found in earth rocks. The scientists searched an explanation that would relate the iridium measurements to the disappearance of the dinosaurs.

SCIENCE & TECHNOLOGY

The Internet

Do you want to go for a spin on the information highway? Do you want to venture into cyberspace and "surf the Net"? Then take a trek on the Internet, a powerful information system that brings the electronic frontier to your doorstep.

The Internet began as an experimental computer network created by the United States Department of Defense during the Cold War. Its purpose was to safeguard scientific and military research in the event of a nuclear attack. If one or two computing centers were lost, the remaining sites in the network would continue to process and communicat vital data.

Today the backbone of t Internet consists of more tha 2 million host computers in about 60 countries worldwic At least 20 million computer users access these Internet computers using ordinary tel phone lines. Once connectec they are able to send and retrieve information around t world with just a few keystro or mouse clicks.

Access to so much inform tion makes the Internet an exciting place for scientific research. From on-line photo graphs of earthquake damag to space shuttle experiments displayed in real time, the information on the Internet is

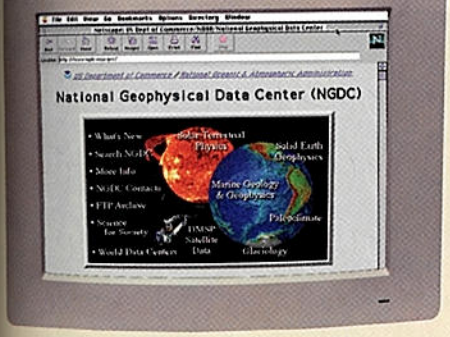
Form a Hypothesis

Once a problem has been stated and information gathered, a scientist may propose a **hypothesis,** (HIE-POTH-uh-sus, pl. hypotheses), a possible explanation or solution to the problem. A hypothesis is based on facts, which are often established through observation.

For example, the scientists who discovered the iridium-laden rock layers proposed the meteorite-impact hypothesis to explain the extinction of the dinosaurs. This hypothesis states that about 65 million years ago, a giant meteorite crashed into the earth. The impact of the collision raised enough dust to block the sun's rays for many years. The earth probably became colder, plant life began to die, and many animal species, including the dinosaurs, became extinct. As the dust settled over the earth, it formed a layer of iridium-laden rock.

Test the Hypothesis

Once a hypothesis has been proposed, it should be tested. A hypothesis will not be accepted by the scientific community unless there is evidence to support it.



This Web page is home to the National Geophysical Data Center (www.ngdc.noaa.gov).

extremely current. Much of this information is difficult or impossible to find elsewhere.

The Internet also makes scientific collaboration easier than ever before. For the cost of an Internet subscription, anyone can quickly share research with an international audience. Various discussion groups and electronic message (e-mail) services help scientists stay informed about new discoveries and make valuable contacts with other professionals in their field.

The best way to get to know the Internet is to explore it firsthand. One popular vehicle for doing this is the World Wide Web, which combines text with graphics such as video clips or photographs. The Web enables users to travel the Internet by simply clicking on highlighted text or icons.

For the new user, there is on-line help available as well as numerous books and magazines about the Internet. Throughout this textbook, you will find Web addresses directing you to Web sites known as home pages. These home pages relate to specific earth science topics and contain links to other useful Web sites.

How might the Internet enhance scientific methods?

On-line information about the Internet and the World Wide Web is available at many sites, including the University of Maryland at **www.cs.umd.edu** and Pacific Lutheran University at **www.plu.edu.** Please note that the standard **http://** prefix has been omitted from all Web addresses in this textbook.