Chapter 1 Introduction to Earth Science

Section 1 What Is Earth Science?

Key Concepts

- What is the study of Earth science?
- How did Earth and the solar system form?

Vocabulary

- Earth science
- geology
- oceanography
- meteorology
- astronomy

Overview of Earth Science

Earth science is the name for the group of sciences that deals with Earth and its neighbors in space. Earth science includes many subdivisions of geology such as geochemistry, geophysics, geobiology and paleontology, as well as oceanography, meteorology, and astronomy.

Units 1 through 4 focus on the science of geology, a word that means "study of Earth." Geology is divided into two broad areas—physical geology and historical geology.

Physical geology includes the examination of the materials that make up Earth and the possible explanations for the many processes that shape our planet. Processes below the surface create earthquakes, build mountains, and produce volcanoes. Processes at the surface break rock apart and create different landforms. Erosion by water, wind, and ice results in different landscapes. You will learn that rocks and minerals form in response to Earth's internal and external processes. Understanding the origin of rocks and minerals is an important part of understanding Earth.

In contrast to physical geology, the aim of historical geology is to understand Earth's long history. Historical geology tries to establish a timeline of the vast number of physical and biological changes that have occurred in the past. See Figure 1. We study physical geology before historical geology because we must first understand how Earth works before we try to unravel its past.



Figure 1 Scientists called paleontologists study fossils, which are signs of life in the distant past, to find out how life-forms have changed through time. Posing Questions What questions do you have about this fossil?

Unit 5 is devoted to oceanography. Oceanography integrates the sciences of chemistry, physics, geology, and biology. Oceanographers study the composition and movements of seawater, as well as coastal processes, seafloor topography, and marine life. See Figure 2.



Figure 2 Oceanographers study all aspects of the ocean—the chemistry of its waters, the geology of its seafloor, the physics of its interactions with the atmosphere, and the biology of its organisms.

Unit 6 examines the composition of Earth's atmosphere. The combined effects of Earth's motions and energy from the sun cause the atmosphere to produce different weather conditions. This, in turn, creates the basic pattern of global climates. Meteorology is the study of the atmosphere and the processes that produce weather and climate. Like oceanography, meteorology also involves other branches of science.

Unit 7 demonstrates that understanding Earth requires an understanding of Earth's position in the universe. The science of astronomy, the study of the universe, is useful in probing the origins of our own environment. All objects in space, including Earth, are subject to the same physical laws. Learning about the other members of our solar system and the universe beyond helps us to understand Earth.

Throughout its long existence, Earth has been changing. In fact, it is changing as you read this page and will continue to do so. Sometimes the changes are rapid and violent, such as when tornados, landslides, or volcanic eruptions occur. Many changes, however, take place so gradually that they go unnoticed during a lifetime.

Formation of Earth

Earth is one of nine planets that revolve around the sun. Our solar system has an orderly nature. Scientists understand that Earth and the other planets formed during the same time span and from the same material as the sun. The nebular hypothesis suggests that the bodies of our solar system evolved from an enormous rotating cloud called the solar nebula. It was made up mostly of hydrogen and helium, with a small percentage of heavier elements. Figure 3 on page 4 summarizes some key points of this hypothesis.

High temperatures and weak fields of gravity characterized the inner planets. As a result, the inner planets were not able to hold onto the lighter gases of the nebular cloud. The lightest gases, hydrogen and helium, were whisked away toward the heavier planets by the solar wind. Earth, Mars, and Venus were able to retain some heavier gases including water vapor and carbon dioxide. The materials that formed by outer planets contained high percentages of water, carbon dioxide, ammonia, and methane. The size and frigid temperatures of the outer planets provided the surface gravity to hold these heavier gases.

Layers Form on Earth

Shortly after Earth formed, the decay of radioactive elements, combined with heat released by colliding particles, produced some melting of the interior. This allowed the denser elements, mostly iron and nickel, to sink to Earth's center. The lighter, rocky components floated outward, toward the surface. This sinking and floating is believed to still be occurring, but on a much smaller scale. As a result of this process, Earth's interior is not made of uniform materials. It consists of layers of materials that have different properties.

An important result of this process is that gaseous materials were allowed to escape from Earth's interior, just as gases escape today during volcanic eruptions. In this way, an atmosphere gradually formed along with the ocean. It was composed mainly of gases that were released from within the planet.

Section 2 A View of Earth

Key Concepts

- What are the four major spheres into which Earth is divided?
- What defines the three main parts of the solid Earth?
- Which model explains the position of continents and the occurrence of volcanoes and earthquakes?

Vocabulary

- hydrosphere
- atmosphere
- geosphere
- biosphere
- core
- mantle
- crust

Earth's Major Spheres

The view of Earth shown in Figure 5B should help you see why the physical environment is traditionally divided into three major spheres: the water portion of our planet, the hydrosphere; Earth's gaseous envelope, the atmosphere; and the geosphere.



Figure 5 A View that greeted the Apollo 8 astronauts as their spacecraft emerged from behind th Moon. B Africa and Arabia are prominent in this image of Earth taken from Apollo 17. The tan areas are desert regions. The bands of clouds over central Africa are associated with rainforests. Antarctica, which is covered by glacial ice, is visible at the south pole. The dark blue oceans and white swirling clouds remind us of the importance of oceans and the atmosphere.

Our environment is characterized by the continuous interactions of air and rock, rock and water, and water and air. The biosphere, which is made up of all the life-forms on Earth, interacts with all three of these physical spheres. Earth can be thought of as consisting of four major spheres: the hydrosphere, atmosphere, geosphere, and biosphere.

Hydrosphere

Water is what makes Earth unique. All of the water on Earth makes up the hydrosphere. Continually on the move, water evaporates from the oceans to the atmosphere, falls back to Earth as rain, and runs back to the ocean. The oceans account for approximately 97 percent of the water on Earth. The remaining 3 percent is fresh water and is present in groundwater, streams, lakes, and glaciers.

Although these freshwater sources make up a small fraction of the total amount of water on Earth, they are quite important. Streams, glaciers, and groundwater are responsible for sustaining life and creating many of Earth's varied landforms.

Atmosphere

A life-sustaining, thin, gaseous envelope called the atmosphere surrounds Earth. It reaches beyond 100 kilometers above Earth, yet 90 percent occurs within just 16 kilometers of Earth's surface. This thin blanket of air is an

important part of Earth. It provides the air that we breathe. It protects us from the sun's intense heat and dangerous radiation. The energy exchanges that continually occur between space, the atmosphere, and Earth's surface produce weather and climate.

If Earth had no atmosphere, life on our planet as we know it could not exist. Many of the processes and interactions that make the surface such a dynamic place would not occur. For example, without weathering and erosion, the face of our planet might more closely resemble the moon.

Geosphere

Lying beneath both the atmosphere and the ocean is the geosphere. Because the geosphere is not uniform, it is divided into three main parts based on differences in composition—the core, the mantle, and the crust. Figure 6A shows the dense or heavy inner sphere that is the core; the less dense mantle; and the lighter, thin crust. The crust is not uniform in thickness. It is thinnest beneath the oceans and thickest beneath the continents. Figure 6B shows that the crust and uppermost mantle make up a rigid outer layer called the lithosphere. Beneath the lithosphere, the rocks become partially molten, or melted. They are able to slowly flow because of the uneven distribution of heat deep within Earth. This region is called the asthenosphere. Beneath the asthenosphere, the rock becomes more dense. This region of Earth is called the lower mantle.



Figure 6 A On this diagram, the inner core, outer core, and mantle are drawn to scale but the thickness of the crust is exaggerated by about 5 times. B There are two types of crust—oceanic and continental. The lithosphere is made up of the crust and upper mantle. Below the lithosphere are the asthenosphere and the lower mantle.

Biosphere

The biosphere includes all life on Earth. It is concentrated in a zone that extends from the ocean floor upward for several kilometers into the atmosphere. Plants and animals depend on the physical environment for life. However, organisms do more than just respond to their physical environment. Through countless interactions, organisms help maintain and alter their physical environment. Without life, the makeup and nature of the solid Earth, hydrosphere, and atmosphere would be very different.

Plate Tectonics

You have read that Earth is a dynamic planet. If we could go back in time a billion years or more, we would find a planet with a surface that was dramatically different from what it is today. Such prominent features as the Grand Canyon, the Rocky Mountains, and the Appalachian Mountains did not exist. We would find that the continents had different shapes and were located in different positions from those of today.

There are two types of forces affecting Earth's surface. Destructive forces such as weathering and erosion work to wear away high points and flatten out the surface. Constructive forces such as mountain building and volcanism build up the surface by raising the land and depositing new material in the form of lava. These constructive forces depend on Earth's internal heat for their source of energy.

Within the last several decades, a great deal has been learned about the workings of Earth. In fact, this period is called a revolution in our knowledge about Earth. This revolution began in the early part of the twentieth century with the idea that the continents had moved about the face of the Earth. This idea contradicted the accepted view that the continents and ocean basins are stationary features on the face of Earth. Few scientists believed this new idea. More than 50 years passed before enough data were gathered to transform this hypothesis into a widely

accepted theory. The theory that finally emerged, called plate tectonics, provided geologists with a model to explain how earthquakes and volcanic eruptions occur and how continents move.

According to the plate tectonics model, Earth's lithosphere is broken into several individual sections called plates. Figure 7 on page 9 shows their current position. These plates move slowly and continuously across the surface. This motion is driven by the result of an unequal distribution of heat within Earth. Ultimately, this movement of Earth's lithospheric plates generates earthquakes, volcanic activity, and the deformation of large masses of rock into mountains. You will learn more about the powerful effects of plate tectonics in Chapter 9.



Figure 7 Plate Tectonics There are currently 7 major plates recognized and numerous smaller plates. Relating Cause Effect What is the relationship between mountain chains and plate boundaries?

Section 3 Representing Earth's Surface

Key Concepts

- What lines on a globe are used to indicate location?
- What problems do mapmakers face when making maps?
- How do topographic maps differ from other maps?
- Vocabulary
 - latitude
 - longitude
 - topographic map
 - contour line
 - contour interval

Determining Location

Today we use maps and computer programs to help us plan our routes. Long ago, people had to rely on maps that were made using data and information that were collected by travelers and explorers. Today computer technology is available to anyone who wants to use it. Mapmaking has changed a lot throughout recorded history. After Christopher Columbus and others proved that Earth was not flat, mapmakers began to use a global grid to help determine location.

Global Grid

Scientists use two special Earth measurements to describe location. The distance around Earth is measured in degrees. Latitude is the distance north or south of the equator, measured in degrees. Longitude is the distance east or west of the prime meridian, measured in degrees. Earth is 360 degrees in circumference. Lines of latitude are east-west circles around the globe. All points on the circle have the same latitude. The line of latitude around the middle of the globe, at 0 degrees (°), is the equator. Lines of longitude run north and south. The prime meridian is the line of longitude that marks ° of longitude as shown in Figure 8.



• Figure 8 Global Grid

Lines of latitude and longitude form a global grid. This grid allows you to state the absolute location of any place on Earth. For example, Savannah, Georgia, is located at 32° north latitude and 81° west longitude. The equator divides Earth in two. Each half is called a hemisphere. The equator divides Earth into northern and southern hemispheres. The prime meridian and the 180° meridian divide Earth into eastern and western hemispheres.



• Figure 9 Measuring Latitude and Longitude

Globes

As people explored Earth, they collected information about the shapes and sizes of islands, continents, and bodies of water. Mapmakers wanted to present this information accurately. The best way was to put the information on a model, or globe, with the same round shape as Earth itself. By using an accurate shape for Earth, mapmakers could show the continents and oceans of Earth much as they really are. The only difference would be the scale, or relative size.

But there is a problem with globes. Try making a globe large enough to show the streets in your community. The globe might have to be larger than your school building! A globe can't be complete enough to be useful for finding directions and at the same time small enough to be convenient for everyday use.

Maps and Mapping

A map is a flat representation of Earth's surface. But Earth is round. Can all of Earth's features be accurately represented on a flat surface without distorting them? The answer is no. No matter what kind of map is made, some portion of the surface will always look either too small, too big, or out of place. Mapmakers have, however, found ways to limit the distortion of shape, size, distance, and direction.

The Mercator Projection

In 1569, a mapmaker named Gerardus Mercator created a map to help sailors navigate around Earth. On this map, the lines of longitude are parallel, making this grid rectangular, as shown on the map in Figure 10. The map was useful because, although the sizes and distances were distorted, it showed directions accurately. Today, more than 400 years later, many seagoing navigators still use the Mercator projection map.



Figure 10 Mercator Map To make a Mercator map, mapmakers have to carve an image of Earth's surface into slices and then stretch the slices into rectangles. Stretching the slices enlarges parts of the map. The enlargement becomes greater toward the north and south poles. Observing What areas on the map appear larger than they should?

Different Projection Maps for Different Purposes

The best projection is always determined by its intended use. The Robinson projection map is one of the most widely used. Maps that use this projection show most distances, sizes, and shapes accurately. However, even a Robinson projection has distortions, especially in areas around the edges of the map. You can see this in Figure 11. Conic projection maps are made by wrapping a cone of paper around a globe at a particular line of latitude, as shown in Figure 13. Various points and lines are projected onto the paper. There is almost no distortion along the line of latitude that's in contact with the cone, but there can be much distortion in areas away from this latitude. Because accuracy is great over a small area, these maps are used to make road maps and weather maps. Gnonomic projections, as shown in Figure 13, are made by placing a piece of paper on a globe so that it touches a single point on the globe's surface. Various points and lines are then projected onto the paper. Although distances and directions are distorted on these maps, they are useful to sailors and navigators because they show with great accuracy the shortest distance between two points.



Figure 11 Robinson Projection Map Compare this map to the Mercator projection. Comparing And Contrasting How do the shapes in the continents differ between these maps? Are there any other differences?



Figure 12 Conic Projection Map Because there is little distortion over small areas, conic projections are used to make road maps and weather maps.



Figure 13 Gnomonic Projection Map Gnomonic projections allow sailors to accurately determine distance and direction across the oceans.

Topographic Maps

A topographic map, like the one shown in Figure 15, represents Earth's three-dimensional surface in two dimensions. Topographic maps differ from the other maps discussed so far because topographic maps show elevation. Topographical maps show elevation of Earth's surface by means of contour lines. Most also show the presence of bodies of water, roads, government and public buildings, political boundaries, and place names. These maps are important for geologists, hikers, campers and anyone else interested in the threedimensional lay of the land.



• Figure 15 Topographic Map This is a portion of the Holy Cross, Colorado, topographic map. Contour lines are shown in brown.

Contour Lines

The elevation of the land is indicated by using contour lines. Every position along a single contour line is the same elevation. Adjacent contour lines represent a change in elevation. Every fifth line is bold and labeled with

the elevation. It is called an index contour. The contour interval tells you the difference in elevation between adjacent lines. The steepness of an area can be determined by examining a map. Lines that are closer together indicate a steeper slope, while lines farther apart indicate a gentler slope. You can see this relationship on the illustration in Figure 14. Contour lines that form a circle represent a hill. A depression is represented by circular contours that have hachure marks, which are small lines on the circle that point to the center. Contour lines never touch or intersect.



• Figure 14 This illustration shows how contour lines are determined when topographic maps are constructed.

Scale

A map represents a certain amount of area on Earth's surface. So it is necessary to be able to determine distances on the map and relate them to the real world. Suppose you want to build a scale model of a boat that is 20 feet long. If your model is a 1/5-scale model, then it is 4 feet long.

In a similar way, a map is drawn to scale where a certain distance on the map is equal to a certain distance at the surface. Because maps model Earth's surface, the scale must be larger than that of the model boat. Look at the scale on the map in Figure 16. The ratio reads 1:24,000. This means that 1 unit on the map is equal to 24,000 units on the ground. Because the ratio has no units, it may stand for anything. We usually use inches or centimeters for our units. If the 1 stands for 1 centimeter on the map, how many kilometers does the 24,000 stand for on the ground?

Another scale provided on a map is a bar scale. See Figure 15. This allows you to use a ruler to measure the distance on the map and then line the ruler up to the bar to determine the distance represented.

Geologic Maps

It is often desirable to know the type and age of the rocks that are exposed, or crop out, at the surface. This kind of map is shown in Figure 16. A map that shows this information is called a geologic map. Once individual rock formations are identified, and mapped out, their distribution and extent are drawn onto the map. Each rock formation is assigned a color and sometimes a pattern. A key provides the information needed to learn what formations are present on the map. Contour lines are often included to provide a more detailed and useful map.



Figure 16 Geologic Map The color coding on the map represents some rock formations in Montana. Each color and pattern represents a different type of rock.

Advanced Technology

Advanced technology is used to make maps that are more accurate than ever before. Today's technology provides us with the ability to more precisely analyze Earth's physical properties. Scientists now use satellites and computers to send and receive data. These data are converted into usable forms such as pictures and numerical summaries.

The process of collecting data about Earth from a distance, such as from orbiting satellites, is called remote sensing. Satellites use remote sensing to produce views of Earth that scientists use to study rivers, oceans, fires, pollution, natural resources, and many other topics. How might a scientist use the image shown in Figure 17?



Figure 17 Satellite Image of the Mississippi River Delta Moving sediment (light blue) indicates current patterns. Red shows vegetation.

We can use this technology in our daily lives too. For example, Global Positioning Systems (GPS) can provide maps in our cars to help us reach our destinations. GPS consists of an instrument that receives signals to compute the user's latitude and longitude as well as speed, direction, and elevation. GPS is an important tool for navigation by ships and airplanes. Scientists use GPS to track wildlife, study earthquakes, measure erosion, and many other purposes. Table 1 describes some of the technology that is particularly useful in the study of Earth science.

Table 1 Technology and Earth Science	
Type of Equipment	Capabilities
Weather Satelllites	 These monitor atmospheric temperature and humidity, ground and surface seawater temperature, cloud cover, and water-ice boundaries. They can help locate sources of distress signals. They are able to scan Earth's surface in one 24-hour period.
Navigation Satellites	 These assist ships and submarines to determine their exact location at any time.
Landsat Satellites	 The first Landsat satellite was launched in 1972. Landsat 7 was launched in 1999. They provide data on Earth's landmasses, coastal boundaries, and coral reefs. Pictures taken are transmitted to ground stations around the world. They orbit Earth every 99 minutes and complete 14 orbits per day. Total coverage of Earth is achieved in 16 days.
Global Positioning System (GPS)	 This system combines satellite information with computer technology to provide location information in three dimensions: latitude, longitude, and altitude. A satellite signal is detected by four receivers. The distance from the satellite to the receivers is calculated, and the location is determined using the triangulation method. Two signals are available—Standard Positioning Service for civilians and Precise Positioning Service for military and other authorized personnel.
Very Long Baseline Interferometry (VLBI)	 VLBI utilizes a large network of antennas around the world to receive radio waves from space objects such as quasars. In Earth science, VLBI is used in geodesy, or the measurement of the geosphere. Using the arrival times of radio waves from quasars, the position of radio telescopes on Earth are determined to within millimeters of their position. Small changes in the telescope positions allow scientists to study tectonic plate motions and other movements of Earth's crust with great precision and accuracy.

Section 4 Earth System Science

Key Concepts

- How is Earth a system?
- What is a system?
- Where does the energy come from that powers Earth's systems?
- How do humans affect Earth's systems?
- What makes a resource renewable or nonrenewable?

Vocabulary

• system

As we study Earth, we see that it is a dynamic planet with many separate but interactive parts or spheres. Earth scientists are studying how these spheres are interconnected. This way of looking at Earth is called Earth system science. Its aim is to understand Earth as a system made up of numerous interacting parts, or subsystems. Instead of studying only one branch of science, such as geology, chemistry, or biology, Earth system science tries to put together what we know from our study of all of these branches. Using this type of approach, we hope to eventually understand and solve many of our global environmental problems.

What Is a System?

Most of us hear and use the term system frequently. You might use your city's transportation system to get to school. A news report might inform us of an approaching weather system. We know that Earth is just a small part of the much larger solar system.

A system can be any size group of interacting parts that form a complex whole. Most natural systems are driven by sources of energy that move matter and/or energy from one place to another. A simple analogy is a car's cooling system. It contains a liquid (usually water and antifreeze) that is driven from the engine to the radiator and back again. The role of this system is to transfer the heat generated by combustion in the engine to the radiator, where moving air removes the heat from the system.

This kind of system is called a closed system. Here energy moves freely in and out of the system, but no matter enters or leaves the system. In the case of the car's cooling system, the matter is the liquid. By contrast, most

natural systems are open systems. Here both energy and matter flow into and out of the system. In a river system, for example, the amount of water flowing in the channel can vary a great deal. At one time or place, the river may be fuller than it is at another time or place.

Earth as a System

The Earth system is powered by energy from two sources. One source is the sun, which drives external processes that occur in the atmosphere, hydrosphere, and at Earth's surface. Weather and climate, ocean circulation, and erosional processes are driven by energy from the sun. Earth's interior is the second source of energy. There is heat that remains from the time Earth formed. There is also heat continuously generated by the decay of radioactive elements. These sources power the internal processes that produce volcanoes, earthquakes, and mountains.

The parts of the Earth system are linked so that a change in one part can produce changes in any or all of the other parts. For example, when a volcano erupts, lava may flow out at the surface and block a nearby valley. This new obstruction influences the region's drainage system by creating a lake or causing streams to change course. Volcanic ash and gases that can be discharged during an eruption might be blown high into the atmosphere and influence the amount of solar energy that can reach Earth's surface. The result could be a drop in air temperatures over the entire hemisphere.

Over time, soil will develop on the lava or ash-covered surface and, as shown in Figure 18, plants and animals will reestablish themselves. This soil will reflect the interactions among many parts of the Earth system—the original volcanic material, the type and rate of weathering, and the impact of biological activity. Of course, there would also be significant changes in the biosphere. Some organisms and their habitats would be eliminated by the lava and ash, while new settings for life, such as the lake, would be created. The potential climate change could also have an effect on some life-forms.



Figure 18 When Mount St. Helens erupted in May 1980, the area shown here was buried by a volcanic mudflow. Now, plants are reestablished and new soil is forming.

The Earth system is characterized by processes that occur over areas that range in size from millimeters to thousands of kilometers. Time scales for Earth's processes range from milliseconds to billions of years. Despite this great range in distance and time, many processes are connected. A change in one component can influence the entire system.

Humans are also part of the Earth system. Our actions produce changes in all of the other parts of the Earth system. When we burn gasoline and coal, build breakwaters along a shoreline, dispose of our wastes, and clear the land, we cause other parts of the Earth system to respond, often in unforeseen ways. Throughout this book, you will learn about many of Earth's subsystems, such as the hydrologic (water) system, the tectonic (mountainbuilding) system, and the climate system. Remember that these components and we humans are all part of the complex interacting whole we call the Earth system.

People and the Environment

Environment refers to everything that surrounds and influences an organism. Some of these things are biological and social. Others are nonliving such as water, air, soil and rock as well as conditions such as temperature,

humidity, and sunlight. These nonliving factors make up our physical environment. Because studying the Earth sciences leads to an understanding of the physical environment, most of Earth science can be characterized as environmental science.

Today the term environmental science is usually used for things that focus on the relationships between people and the natural environment. For example, we can dramatically influence natural processes. A river flooding is natural, but the size and frequency of flooding can be changed by human activities such as clearing forests, building cities, and constructing dams. Unfortunately, natural systems do not always adjust to artificial changes in ways we can anticipate. An alteration to the environment that was intended to benefit society may have the opposite effect, as shown in Figure 19.



Figure 19 The benefit that was intended by the construction of the Aswan Dam in Egypt was not achieved. Drawing Conclusions How might the flooding here have been avoided?

Resources

Resources are an important focus of the Earth sciences. They include water and soil, metallic and nonmetallic minerals, and energy. Together they form the foundation of modern civilization. The Earth sciences deal not only with the formation and occurrence of these vital resources but also with maintaining supplies and the environmental impact of their mining and use.

Resources are commonly divided into two broad categories—renewable resources and nonrenewable resources. Renewable resources can be replenished over relatively short time spans. Common examples are plants and animals for food, natural fibers for clothing, and forest products for lumber and paper. Energy from flowing water, wind, and the sun are also considered renewable resources.

Important metals such as iron, aluminum, and copper plus our most important fuels of oil, natural gas, and coal are classified as nonrenewable resources. Although these and other resources continue to form, the processes that create them are so slow that it takes millions of years for significant deposits to accumulate. Earth contains limited quantities of these materials. Although some nonrenewable resources, such as aluminum, can be used over and over again, others, such as oil, cannot. When the present supplies are exhausted, there will be no more.

Population

Figure 20 shows that the population of Earth is growing rapidly. Although it took until the beginning of the nineteenth century for the population to reach 1 billion, just 130 years were needed for the population to double to 2 billion. Between 1930 and 1975, the figure doubled again to 4 billion, and by about 2010, as many as 7 billion people may inhabit Earth. Clearly, as population grows, so does the demand for resources. However, the rate of mineral and energy resource usage has increased more rapidly than the overall growth of the population.



Figure 20 Growth of World Population

How long will the remaining supplies of basic resources last? How long can we sustain the rising standard of living in today's industrialized countries and still provide for the growing needs of developing regions? How much environmental deterioration are we willing to accept to obtain basic resources? Can alternatives be found? If we are to cope with the increasing demand on resources and a growing world population, it is important that we have some understanding of our present and potential resources.

Environmental Problems

In addition to the search for mineral and energy resources, the Earth sciences must also deal with environmental problems. Some of these problems are local, some are regional, and still others are global. Humans can cause problems, such as the one shown in Figure 21. Significant threats to the environment include air pollution, acid rain, ozone depletion, and global warming. The loss of fertile soils to erosion, the disposal of toxic wastes, and the contamination and depletion of water resources are also of considerable concern. The list continues to grow.



Figure 21 Air pollution in the Chinese city of Guangzhou. Air quality problems affect many cities. Interpreting Photographs What may have contributed to this air pollution problem?

People must cope with the many natural hazards that exist such as the one shown in Figure 22. Earthquakes, landslides, floods, hurricanes, and drought are some of the many risks. Of course, environmental hazards are simply natural processes. They become hazards only when people try to live where these processes occur.



Figure 22 The damage here was caused by a landslide that was triggered by an earthquake. It is clear that as world population continues to grow, pressures on the environment will increase as well. Therefore, an understanding of Earth is essential for the location and recovery of basic resources. It is also essential for dealing with the human impact on the environment and minimizing the effects of natural hazards. Knowledge about Earth and how it works is necessary to our survival and well being. Earth is the only suitable habitat we have, and its resources are limited.

Section 5 What Is Scientific Inquiry?

Key Concepts

- What is a hypothesis?
- What is a theory?

Vocabulary

- hypothesis
- theory

All science is based on two assumptions. First, the natural world behaves in a consistent and predictable manner. Second, through careful, systematic study, we can understand and explain the natural world's behavior. We can use this knowledge to make predictions about what should or should not be expected. For example, by knowing how oil deposits form, geologists are able to predict the most likely sites for exploration. The development of new scientific knowledge involves some basic steps. First, scientists collect data through

observation and measurement. These data are essential to science and serve as the starting point for the development of scientific theories.

Hypothesis

Once data have been gathered, scientists try to explain how or why things happen in the manner observed. Scientists do this by stating a possible explanation called a scientific hypothesis. Sometimes more than one hypothesis is developed to explain a given set of observations. Just because a hypothesis is stated doesn't mean that it is correct or that the scientific community will automatically accept it.

Before a hypothesis can become an accepted part of scientific knowledge, it must be tested and analyzed. If a hypothesis can't be tested, it is not scientifically useful, no matter how interesting it might seem. Hypotheses that fail rigorous testing are discarded. The history of science is filled with discarded hypotheses. One of the best known is the Earth-centered model of the universe. This hypothesis was based on the apparent movement of the sun, moon, and stars around Earth. As the mathematician Jacob Bronowski stated, "Science is a great many things, but in the end they all return to this: Science is the acceptance of what works and the rejection of what does not."

Theory

When a hypothesis has survived extensive testing and when competing hypotheses have been eliminated, a hypothesis may become a scientific theory. A scientific theory is well tested and widely accepted by the scientific community and best explains certain observable facts. For example, the theory of plate tectonics provides the

framework for understanding the origin of continents and ocean basins, plus the occurrence of mountains, earthquakes, and volcanoes.

Scientific Methods

The process of gathering facts through observations and formulating scientific hypotheses and theories is called the scientific method. There is no set path that scientists must follow in order to gain scientific knowledge. However, many scientific investigations involve the following steps: (1) the collection of scientific facts through observation and measurement, (2) the development of one or more working hypotheses or models to explain these facts, (3) development of observations and experiments to test the hypotheses, and (4) the acceptance, modification, or rejection of the hypothesis based on extensive testing.