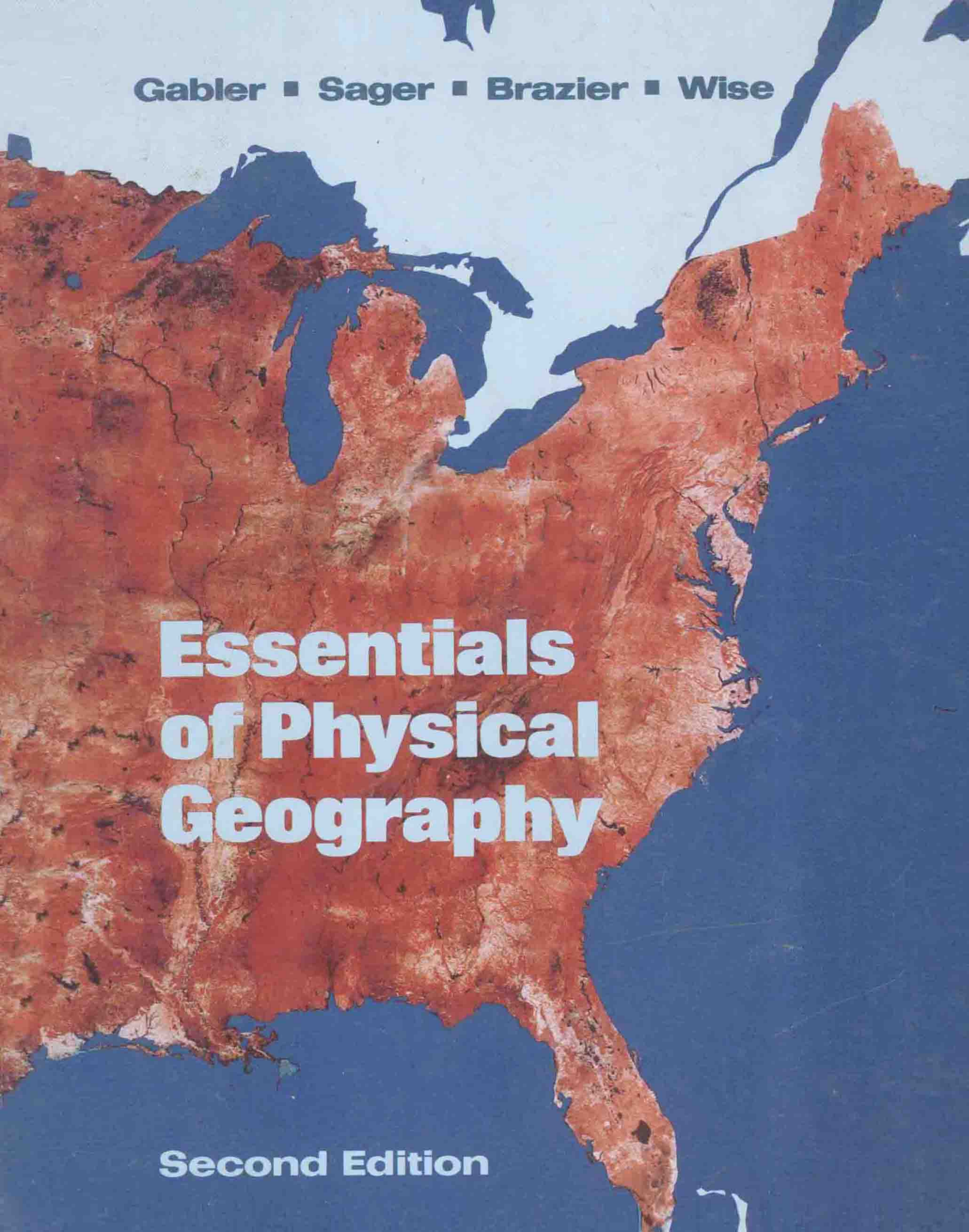
Gabler ▪ Sager ▪ Brazier ▪ Wise



Essentials of Physical Geography

Second Edition

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Robert E. Gabler
Western Illinois University

Sheila Brazier
Golden West College

Robert J. Sager
West Los Angeles College

Daniel L. Wise
Western Illinois University

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Plate 22 is by Marie Tharp, oceanographer, who has been associated with the Lamont-Doherty Geological Observatory since its founding in the late 1940s. During this time she collaborated with the late Dr. Bruce C. Heezen in the study of sea floor topography. The World Ocean Floor Panorama is based upon soundings of continually increased accuracy from many sources during a time of changing concepts of the geology of our earth. This chart is available from Marie Tharp, One Washington Avenue, South Nyack, N.Y. 10960, U.S.A.

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Preface

If any Americans questioned the importance of physical geography or the relationship of humans to their environment prior to May 18, 1980, all doubts were surely dispelled on that date. It was then that Mount St. Helens exploded with a force that rocked southern Washington, claiming over sixty lives, and affecting tens of thousands of people. Such catastrophes are not uncommon, and as our means of world-wide communication becomes more efficient, we become increasingly aware of how ineffective we are in controlling the forces of nature and how ill-prepared we are to cope with a physical environment that frequently seems to go on a rampage. We must recognize that floods on the Mississippi, tornadoes in Oklahoma, fires and mud slides in California, hurricanes on the Gulf Coast, and earthquakes in Alaska are ordinary events in earth history. Only a knowledge of their origins and a thorough understanding of the events themselves can lessen their impact on individuals and society. The authors of *Essentials of Physical Geography* believe that an introductory physical geography course can provide the explanations necessary to comprehend both ordinary and extraordinary changes in the physical environment.

Physical geography provides a broad view of the earth and its component systems; it identifies physical phenomena and stresses their distribution and relationships. The text provides an introduction to all major aspects of the earth system. It covers a wide range of topics, from atmospheric elements to the earth's interior. It helps to explain the origins, development, significance, and distribution of processes and events that occur within, on, or above the surface of the earth. *Essentials of Physical Geography* contains ideas and information about the earth as a planet and as a human environment. It is a companion piece to any course for which physical geography is a major component. It is designed to provide the broadest possible coverage of the earth's physical patterns and processes. It is written primarily for the individual who is unlikely to study these topics again in depth. Although phenomena as diverse as glaciers, soils, mid-latitude cyclones, and tides are considered, there has been a conscious effort throughout to emphasize interrelationships — to focus on all phenomena, including those associated with humans, as interdependent parts of one integrated earth system.

The authors maintain the point of view that any introductory physical geography text, designed for a general rather than a specialized education, should include the human element, especially the ways in which physical elements and earth systems interact with humans and their activities. The popular Viewpoint essays, which illustrate the close relationship between people and the environment, have been retained and expanded. New Viewpoint essays include such topics as "Solar Energy," "Whither the Wind," "Water and the Quality of Life," "Do Humans Alter Climate?" and "Protecting our Coastal Resources." Students and instructors who have previously used this text or its predecessor, *Introduction To Physical Geography,* will find numerous additions and improvements. A glossary has been added. The number of illustrations has been expanded and many of the original diagrams have been redrafted. There are major additions of four-color maps and photographs, featuring satellite imagery, landform types, vegetation, soil profiles, cloud formations, and landscapes associated with climatic regions. The text has been reorganized and expanded to provide a thorough and comprehensive coverage of the major topics in physical geography. It is written to be both interesting and understandable, yet it has been prepared for courses with limited classroom sessions and students with constantly expanding demands on their time.

Chapter 1 serves as an introduction to the earth as a planet. The earth is examined as an integrated system and the importance of physical geography as a means for understanding the environment is stressed. Chapter 1 also reviews the basic elements of earth-sun relationships and the seasonal fluctuations that occur on earth as a result.

Chapter 2 includes a considerable amount of new material. Explanatory materials useful for laboratory exercises are included, concerning the location systems, maps, and products of remote sensing. Chapter 2 provides information on earth location, the Public Land Survey System, map projections, aerial photography, and satellite imagery.

Because the distributional patterns associated with the atmospheric elements and controls owe so much to the earth-sun relationships introduced in Chapter 1, these elements are examined sequentially in Chapters 3, 4, and 5. The discussion of solar energy and temperature in Chapter 3 leads logically to a discussion of atmospheric pressure and winds in Chapter 4 and atmospheric moisture and precipitation in Chapter 5. The interrelationships of the various atmospheric elements and controls is emphasized and the importance of energy and moisture budgets is stressed.

Chapter 6 examines weather and the events associated with changes in the atmospheric elements. The section on mid-latitude cyclones and local weather has been rewritten to provide realistic examples of weather change. The new material is accompanied by diagrams that illustrate a model situation in the central United States. Students should obtain sufficient background to fully comprehend the daily weather map and better understand the frequently unreliable science of weather prediction.

The topics of climate, vegetation, and soils are introduced and examined in Chapters 7 and 8, prior to the development of climatic regionalization in Chapter 9. The intent is to make the characteristics and relationships of these physical phenomena understandable before their distributions and regional associations are studied.

Chapters 7 through 9 stress the close relationships between discrete elements within the earth system. The subject of climate is introduced in Chapter 7, followed by a general review of vegetation types, their distribution, and their close association with particular climatic conditions. Chapter 8 provides a comprehensive discussion of soils — their composition, characteristics, formation, and intimate ties with both climate and vegetation. Chapter 9 examines the climate, vegetation, and soils of major world regions, illustrating the interconnections between environmental subsystems and the relationship of humans to their environment.

The authors regard methods of classification as an essential element in any science course. Classification of both climate and vegetation is included in Chapter 7, classification of soils appears in Chapter 8, and classification of landforms is introduced in Chapter 10. Climatic classification is a modified version of the Köppen System; vegetation classification is patterned primarily after Küchler; soils are classified utilizing both the USDA Great Soil Groups of 1938 and the Comprehensive Soil Classification System (the 7th Approximation); landform classification is based on the work of Edwin

Hammond. The world distribution of the various classes in each system is stressed and four-color maps have been included in the appropriate chapters to reinforce the presentation.

Chapters 10 through 14 provide a detailed study of the development, appearance, and distribution of the earth's landforms. The discussion follows a traditional approach that stresses a balance in content between process and the physical landscape that is the end product of that process. There are numerous opportunities for students to recognize the close relationship between the earth's landform features and phenomena from the other earth spheres: the atmosphere, biosphere, and hydrosphere. The roles of the internal tectonic processes and the external forces of weathering, mass movement, and the gradational agents are each discussed in separate chapters. Plate tectonism is presented as a broadly inclusive hypothesis, and the ongoing struggle between those forces that tend to disrupt the land surface and those that tend to level it off is emphasized. Landforms are considered as transitory features that are constantly in the process of change, the products of earth systems.

Chapter 15 is another major product of the reorganization involved in the preparation of this second edition. An examination of the global ocean and its increasing significance, as humankind faces an uncertain future with an ever-changing resource base, seems an appropriate conclusion to a physical geography text. An understanding and appreciation of coastal regions and the global ocean are essential to an educated citizenry, as land-based societies turn increasingly toward the sea.

Although the authors accept full responsibility for the organization and content of this text, they wish to express their sincere appreciation to the many colleagues, friends, and professional associates who have generously contributed to the final product. Among those who have provided helpful criticism are: Richard Arvidson, California State University; Evelyn M. Berg, Morton College; L. T. Engelhorn, Grossmont College; Katherine Fuess, California Polytechnic Institute; H. Donald Hays, University of Alabama; Ralph L. Hannon, Santa Ana College; John G. Hehr, University of Arkansas; Richard S. Jarvis, SUNY at Buffalo; Tom McKnight, UCLA; John M. Moravek, SUNY at Plattsburgh; Ray Pfleger, University of Wisconsin at Waukesha; Sten A. Taube, Northern Michigan University; Vernon O. Walton, Essex Community College; Charles L. Zinser, State University of New York at Plattsburgh.

Special thanks also go to Michael Baker, artist and cartographer, who, as a graduate assistant at Western Illinois University, provided valuable assistance in the reconstruction of the illustration program; to Professors Alphons Richert and William Burton, Western Illinois University, whose skill in photography and generosity in sharing their exceptional slide collections should certainly qualify them as honorary physical geographers; to Professor Fred Caspall, Western Illinois University, who developed the new world map projection used in the text and supervised the preparation of the map plates that appear throughout the book; to Diane Zoladz, graduate assistant in International Programs, Western Illinois University, who overnight became an editor and compiler of the illustrations, Glossary, and Index; and to all those others, known and unknown, who have provided helpful criticism, encouragement, and assistance.

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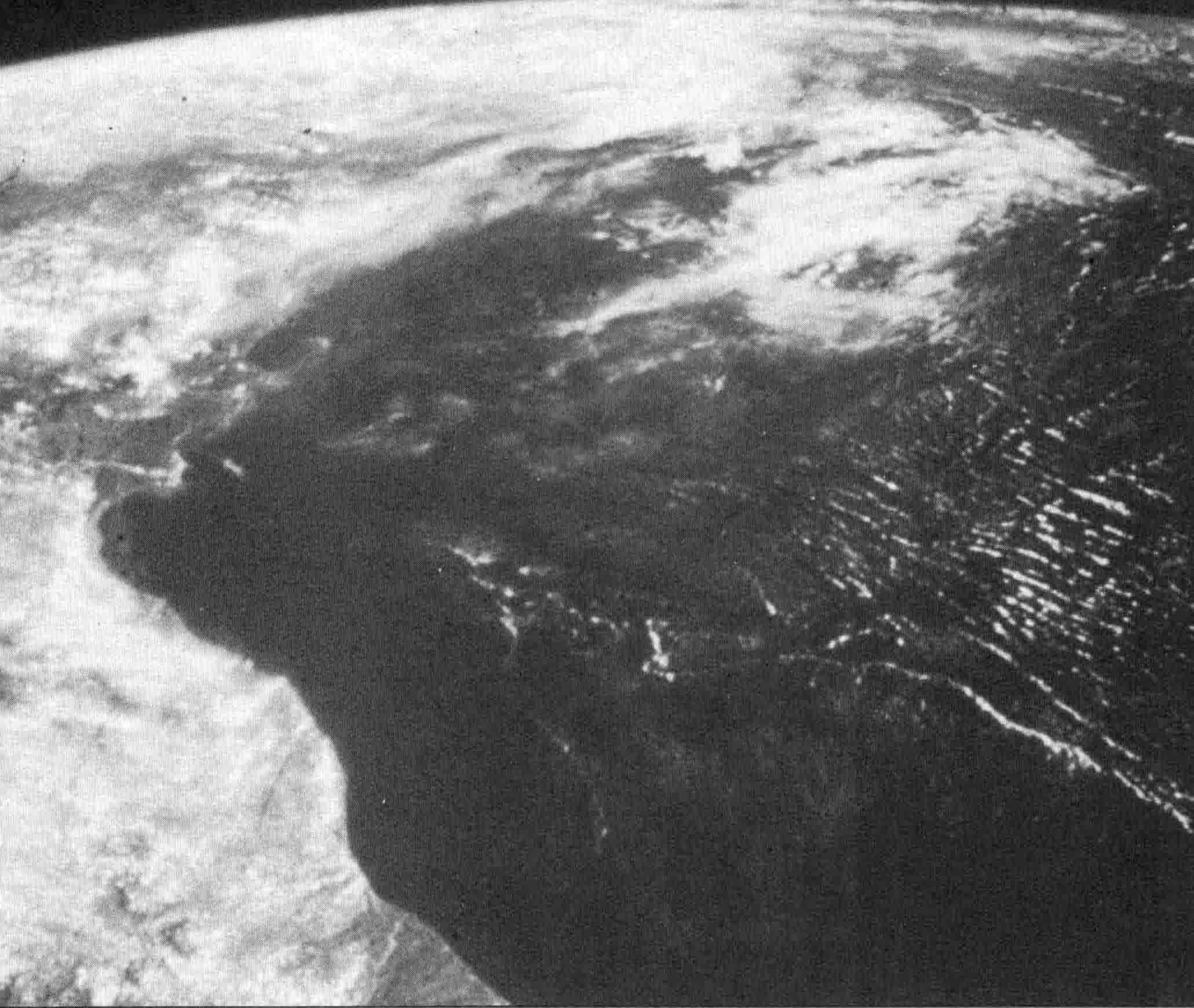


Satellite photo of earth (*NASA, Gemini 11, 1*

Our planet can be compared to a gigantic spaceship. Like the spacecraft used by the astronauts to go to the moon, the earth contains all of the things necessary for us to be able to exist. But our world is also different from vehicles that have been invented or imagined by humans for travel through space. While the Apollo and Skylab spacecraft have hard exteriors and hollow interiors, the earth is a solid ball surrounded by a blanket of air that serves to protect us from the hazards of space, as well as providing us with gases like oxygen that we need in order to survive. While spaceships are designed to have some type of power and steering system so they can be guided, the earth moves through space in ways we cannot control. Our world is also much larger and much more complicated than any spaceship we could hope to construct.

The chief value to humans of either a spaceship or the earth is that of providing a life support system. A *system* is a group of interacting and interdependent units that form an organized whole. If any part of the system changes, there will be alterations in other components. In a **life support system,** all parts act to provide surroundings in which life can exist. If critical parts of that system are changed, living things may no longer be able to survive. For instance, if all the oxygen is used up in a spacecraft, the crew in it will die. Or if there is no way to keep it at the right temperature, its occupants will burn or freeze. If food supplies run out, they will starve. On the earth, there are natural processes that provide a constant oxygen supply, the sun sends a regular flow of heat energy, and there is a continuous cycle of creation of new food supplies for living things.

The earth, then, is a system of components that are vital and necessary for the existence of human beings. As we move toward the last decades of the twentieth century, we have come to realize that important parts of our life support system, which may be called **natural resources,** can be abused, thereby threatening the functioning of the whole system.

We are aware that some of the earth's resources, such as air and water, can be polluted to the point where they could be unusable or even lethal to some lifeforms. By polluting the oceans, we may be killing off some important fish species, although less desirable species might increase in number. We may be using up some other resources, especially those we need for fuel, too rapidly. While we still have enough coal to last several hundred years, we may exhaust our supplies of petroleum by the end of the century. Already, some schools and industries have had to shut down at times in the winter when supplies of fuel were cut off because of shortages.

Humans are learning that there are limits to the amount of space on the earth and that they must use it wisely. In the search for living space, they occasionally construct buildings in places that are not safe, and many places where they live are overcrowded. Also, they sometimes plant crops in areas that are ill suited to agriculture because there is not always enough good farmland to fill their needs.

As we continue to explore space, we are learning more and more about the world in which we live. With the use of cameras and other remote-sensing devices from manned and unmanned spacecraft, scientists can see larger parts of the earth than they could before, and they have come to a fuller realization that there are limits to the support that can be given to mankind by the earth. All citizens of the earth must understand the effects of their actions on the complex earth system. It is to geography and other earth sciences that we look in order to learn the consequences of our activities on the world.

THE EARTH SYSTEM

The earth is a system of interrelated components. All parts of the earth system affect all other parts, and they appear in worldwide patterns that, when examined, demonstrate clear interconnections. Mountains help to determine the distribution of rainfall. The resulting moisture affects the amount and types of vegetation. Vegetation and soils are inextricably linked. Vegetation affects the runoff of water, and the circle is finally complete when stream erosion reduces mountains. In turn, mountains can be born again with changes in the interior of the earth.

Furthermore, the earth system is in a state of **equilibrium** in which there is a balance of energy flow, sometimes referred to as the **heat energy budget.** Over time the earth gives off the same amount of energy as it absorbs, primarily from the sun. If this were not true, if the earth absorbed more energy than it gave off, then the average temperature of the earth would rise. Or, if the earth gave off more energy than it absorbed, the average temperature would decrease. Since the temperature of the earth has remained steady (with variations of a few degrees during the ice ages), we can say that the earth's heat energy budget is balanced.

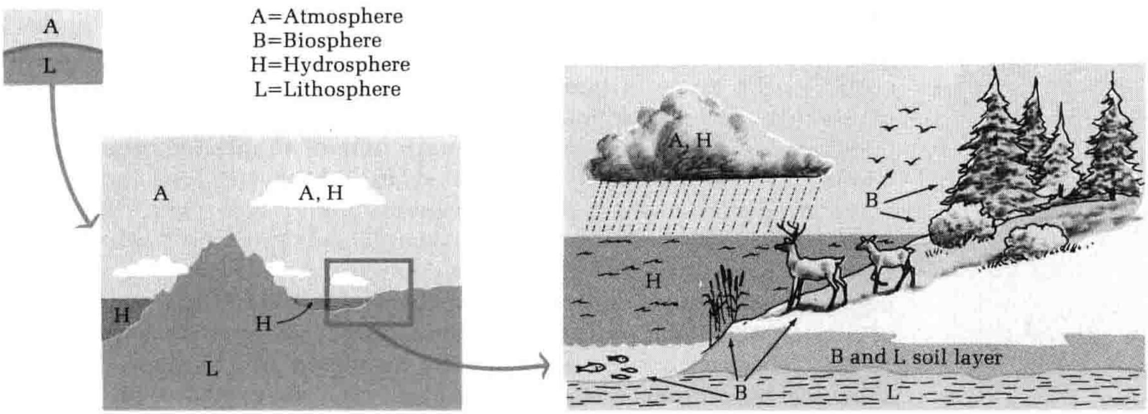
There is a **water budget** that also is balanced for our planet as a whole and that further illustrates the equilibrium of the earth system. The total amount of water on the earth—water stored in oceans, ice, snow, vegetation, animals, soil, lakes, and streams, and in the atmosphere—remains constant, although the amount stored in each location varies from time to time.

It should be noted that an examination of the earth system cannot be complete without studying people and their works as a part of that system (that is, without studying *all geography*). We have *chosen,* however, since this is a text on physical geography, to emphasize the physical components of the system and to discuss people primarily as they interact with the physical components.

Atmosphere—Lithosphere—Biosphere—Hydrosphere

There are four major divisions of our earth system, and the interactions between the components of each of these subsystems create our physical landscape (Fig. 1.1). The **atmosphere** is the blanket of air that envelops the earth. Composed of many gases, its actions create the chang-

Figure 1.1 The four interdependent subsystems of the earth's physical environment.



ing conditions we know as weather and climate. Below the atmosphere is the earth. The earth's landforms—together with its crust, rocks, minerals, and soils—make up the **lithosphere.** And the variations and actions of the lithosphere, the changes in landforms, create a part of the physical landscape that in turn affects the development of the **biosphere.** All living things—people, animals, plants—make up the biosphere. The fourth major subsystem is the **hydrosphere,** which is composed of the waters of the earth.

We can see many interactions between these subsystems. For example, the hydrosphere acts as a supply of water for man and as a home for many types of animal life and vegetation. It affects the lithosphere as countless streams wear down land formations, and it influences the atmosphere through evaporation and condensation and with the effects of ocean temperatures on climate.

Further, there are many instances of overlap between the four subsystems. Soil can be examined as part of the biosphere or the hydrosphere as well as part of the lithosphere. The water stored in plants and animals is part of both the biosphere and the hydrosphere, and water in clouds belongs to the atmosphere as well as the hydrosphere. That we cannot draw definite dividing lines between the subsystems underscores the interrelatedness of the various parts of the earth system. Like an engine or like the human body, the earth is a system that functions only when all its parts work together harmoniously.

Environment—Ecology—Ecosystem

In the last half of the twentieth century people have become more conscious of their environment than ever before. We talk about the environment and worry about ecology. Popular news magazines often devote whole sections to discussions of environmental issues. But what are we really talking about when we use words like *environment? ecology? ecosystem?*

We can define the **environment** as our surroundings; it is made up of all the physical, social, and cultural aspects of our world that affect our growth, our being, and our way of living. Not only man has an environment; so do other animals as well as plants. We can speak of a plant's environment and include in our discussion the soil in which the plant grows, the amount of sunlight and rainfall it receives, the gases that surround it, the range of temperature in the air, and the number of other plants that grow near it and serve to block winds, sunlight, and rain.

Just as man interacts with his environment, so do other animals and plants. The examination of these relationships between organisms, whether animal or plant, and their environments is a science known as **ecology.** Ecological relationships are complex but balanced "webs of life." Disrupting the natural ecology of a community of organisms may have negative results, although this is not always so. The filling in or polluting of coastal marshlands may disrupt the natural ecology of such areas. As a result, fish spawning grounds may be destroyed and the food supply of some marine animals and migratory birds could be greatly depleted.

Ecosystem is a contraction of *ecological system.* That is, an ecosystem is a community of organisms and the relationships of those organisms to their environment. An ecosystem is dynamic in that its various parts are always in flux. For instance, plants grow, rain falls, animals eat, and soil matures, all changing the environment of a particular ecosystem. Since each member of the ecosystem belongs to the environment of every other part of that system, any change in one alters the environment for all others. And as those components react to the alteration, they in turn continue to transform the environment for the others. A change in the atmosphere from conditions of sunshine to those of rain affects plants, soils, and animals. Heavy rain may carry away soils and plant nutrients, so the plants may not be able to grow as well and the animals then may not be able to eat as much. On the other hand, the addition of moisture to the soil may help some of the plants grow, increasing the amount of shade beneath them and thus keeping other plants from growing.

Since human beings first walked the earth, they have been part of the ecosystem. However, with the advanced technology of the twentieth century people today have a greater ability than ever before to alter the world's natural ecosystems. The Aswan High Dam provides a classic example of the effects of human technology on the ecosystem. Built on the Nile River to provide a reservoir of water for the irrigation of arid lands, the Aswan High Dam had unexpected results because it disturbed the natural ecosystem. Because of the dam, silt was no longer carried downstream. Lands below Aswan have always been enriched by the deposit of these silts when the Nile overflowed its banks each spring, but now more and more fertilizers have to be applied because of a lack of silt. In fact, Egypt, once a land with rich soils along the Nile, has become a large importer of fertilizers. Fish nutrients are also being blocked by the dam, and this has resulted in a decrease in the fish catch of the eastern Mediterranean Sea. Furthermore, the water below the dam moves at a faster rate than before because it does not carry as much silt and other materials, and it now threatens buildings and piers constructed along its banks and may even undermine the banks themselves. The changes and problems that the Aswan High Dam has created in the ecosystem of the Nile delta should serve as a useful lesson. It is during the planning stages of activities that alter the environment such as building a dam or a freeway or changing the course of a river that the geographer's view of the whole system and his sensitivity to its components can be of service.

Pollution

When examining our effect upon our environment, we cannot ignore the problem of **pollution.** But what exactly is pollution? First, there are many varieties, including air pollution, water pollution, noise pollution, and solid waste pollution. As we think about air pollution, can we say that one car in the middle of the desert or alone on a New Hampshire mountain road pollutes the atmosphere? Or would emptying the dregs of our beer into the Mississippi alone constitute polluting those waters? No, since pollution does not occur simply because of the addition of foreign material to a system like the atmosphere or the hydrosphere.

Pollution does occur, however, when more foreign material is put into a system than the system can tolerate. On a smoggy day in Los Angeles more pollutants get blown, pushed, and exhausted into the air than can be handled (Fig. 1.2). Pollution is the accumulation, to an intolerable level, of undesirable elements in any one of the diverse aspects of the physical environment. In the strictest sense, there is natural pollution (lime, iron, or sulphur in water supplies, smoke from forest fires, or dust from the eruption of volcanoes). But in our current usage, pollution is considered to be the product of man and goes beyond the natural elements to include those wastes in the water, air, or other aspects of the environment for which man is responsible.

Man always leaves evidence of his presence, but this evidence becomes too much and is considered pollution when it creates a problem—that is, when it significantly alters the natural environment or when it threatens normal growth and reproduction—for the normal functioning of all lifeforms, including man.

PHYSICAL GEOGRAPHY AND THE ENVIRONMENT

Geography examines, describes, and explains the earth—its variation from time to time and place to place. Geography is often called the "spatial

Figure 1.2 The smog of Los Angeles was once regarded as a peculiar, but relatively harmless, local phenomenon. Now it is recognized as a real hazard to life. Moreover, many cities in the United States and other countries of the world now admit to equally severe, if not worse, problems of atmospheric pollution. *(Environmental Protection Agency)*

science" because it includes the recognition, analysis, and explanation of likenesses and differences, or of variations in phenomena as they are distributed on the earth's surface (through *earth* space). The word *geography* comes from two Greek roots. *Geo* refers to the earth, and *graphy* means picture or writing.

Geography is both a physical and a social science. In its concern with the natural environment, geography is very much a physical science. Yet geography also examines man's two-way relationship with the earth and is thus a social science as well.

Human geography is the study of man's activities and the results of those activities. The human geographer studies such subjects as population distribution, cities and urbanization, natural resource utilization, industrial location, and transportation networks. When a geographical study concentrates primarily on the physical and human features of a specific region, such as Canada or the Middle East, we call this **regional geography.**

Physical geography encompasses the study of the natural aspects of man's environment. That is, physical geographers look at the atmospheric elements that affect the surface of the earth and that together make up weather and climate. They examine the variations in soil and in natural vegetation. The varieties of water bodies on earth, their movements, effects, and other characteristics are subjects of physical geography, as are the landforms of the earth, their formation, and modification. Yet although physical geographers emphasize the elements that make up our physical environment, they cannot ignore the effect of people on those elements.

Learning about our environment and the processes that govern it is a major function of physical geography. The knowledge learned can be of help to us in analyzing problems such as whether we should continue to build nuclear power plants, allow offshore oil development, or permit SST aircraft to land in and/or fly over the United States. Closer to home, there are smaller problems that the principles and processes of physical geography can help us to analyze. For example, should you plant your new lawn before or after the spring rains? What sort of effects can be expected from a proposed shopping center? Will it make your home more or less valuable and livable? What are the advantages and disadvantages of a particular home site? What hazards—flooding, landslide, earthquake—might your house be subject to? What can you do to minimize the potential damage to your house from a natural disaster?

Finally, not only is physical geography a source of useful knowledge, it is also first and foremost a visual science. Even if you forget every fact discussed in the following pages, you will have been shown new ways to look at, to see, even to evaluate the world around you. Just as you see a painting differently after an art course, even though you have no idea who painted it, so, too, will you look at sunsets, waves, storms, prairies, and mountains with a different, more informed eye. You will see greater variety in the landscape, not because there is any more there, but because your eye will have been trained to see it differently.

THE EARTH AS A PLANET

The color television shots of the earth from the Apollo spacecrafts on their lunar missions gave us some unforgettable views of our planet. The cameras showed the earth as a sphere of blue oceans, green and brown landmasses, and swirls of white clouds. One astronaut has described the earth as it appears to one who has traveled close to the moon:

> The earth looked so tiny in the heavens that there were times during the *Apollo 8* mission when I had trouble finding it. If you can imagine yourself in a darkened room with only one clearly visible object, a small blue-green sphere about the size of a Christmas tree ornament, then you can begin to grasp what the earth looks like from space. I think that all of us subconsciously think that the earth is flat or at least almost infinite. Let me assure you that, rather than a massive giant, it should be thought of as the fragile Christmas tree ball which we should handle with considerable care.
>
> *This Island Earth*, edited by Oran W. Nicks, NASA, SP-250, 1970

Size and Shape of the Earth

For most of his history man has pondered the size and shape of the world in which he lives. Though it was not until the 1960s that man was able to travel deep enough into space to see the shape of the earth, ancient Greeks as early as Pythagoras in 540 B.C. theorized that the earth was a sphere. However, it was not until about 200 B.C. that a philosopher named Eratosthenes made a fairly accurate estimate of the circumference of the earth. He accomplished this by measuring the shadows cast by vertical poles at noon in two different cities in Egypt; his estimate was within a hundred miles of the earth's actual circumference. The accuracy of Eratosthenes' calculation is all the more amazing if we imagine ourselves trying to estimate the shape and size of our planet without the benefit of today's maps, globes, or navigational devices. What kind of description could we provide of the earth, its landforms and oceans, its shape and dimensions, if we knew nothing but what we can see around us? What things can you think of, for example, that might prove the earth is a sphere?

The apparent boundary line between the sky and the earth is called the **horizon.** If you hold a basketball to represent the earth in front of you with the sky as a background, you can see a similar boundary line, which is curved no matter which way you turn the ball. If you were far enough from the earth's surface, the horizon would similarly appear to be curved as indicated in Fig. 1.3.

There are many aspects of our world that are related to the curvature of the earth. For example, the curvature affects the intensity and duration of solar radiation received at different locations on the earth. Differences in temperature from place to place and currents in the oceans and atmosphere are also related to the earth's near sphericity. Further, man determines time by a system based on the earth as a sphere. He has devised a full system of direction and location by means of a grid based on the shape

Figure 1.3 A satellite view of an entire hemisphere all the way from the Pacific at the left to the Mediterranean at the right. The spherical shape of the earth can be clearly seen. EROS Data Center)

of the globe, and part of his navigation system is based on the earth's spherical shape.

For most purposes the earth can be considered a perfect sphere. However, due to **centrifugal force** the area near the earth's equator actually bulges out somewhat, and the two poles are accordingly flattened slightly. So instead of a perfect shape, the earth is more properly an **ellipsoid of rotation.** (Centrifugal force tends to cause matter to move away from the center of rotation of a body.)

The earth's deviation from a perfect sphere is exceedingly minor. Nevertheless, these irregularities do affect navigation, mapping, and distance accuracies. People working in the areas of navigation, surveying, aeronautics, and cartography must include in their calculations the deviations of the earth's shape from true sphericity. Scientists have been able to identify the extent of such deviations from measurements of variations in gravitational pull acting on satellites. They have found that the diameter of the earth at the equator is 7927 miles / 12,758 km, while from pole to pole it is 7900 miles / 12,715 km. On a globe with a diameter of 12 inches this difference of 27 miles would be $^{4}/_{100}$ of an inch, a deviation of about $^{1}/_{3}$ of 1 percent and not noticeable to the naked eye.

Other deviations from the earth's true sphericity are caused by its