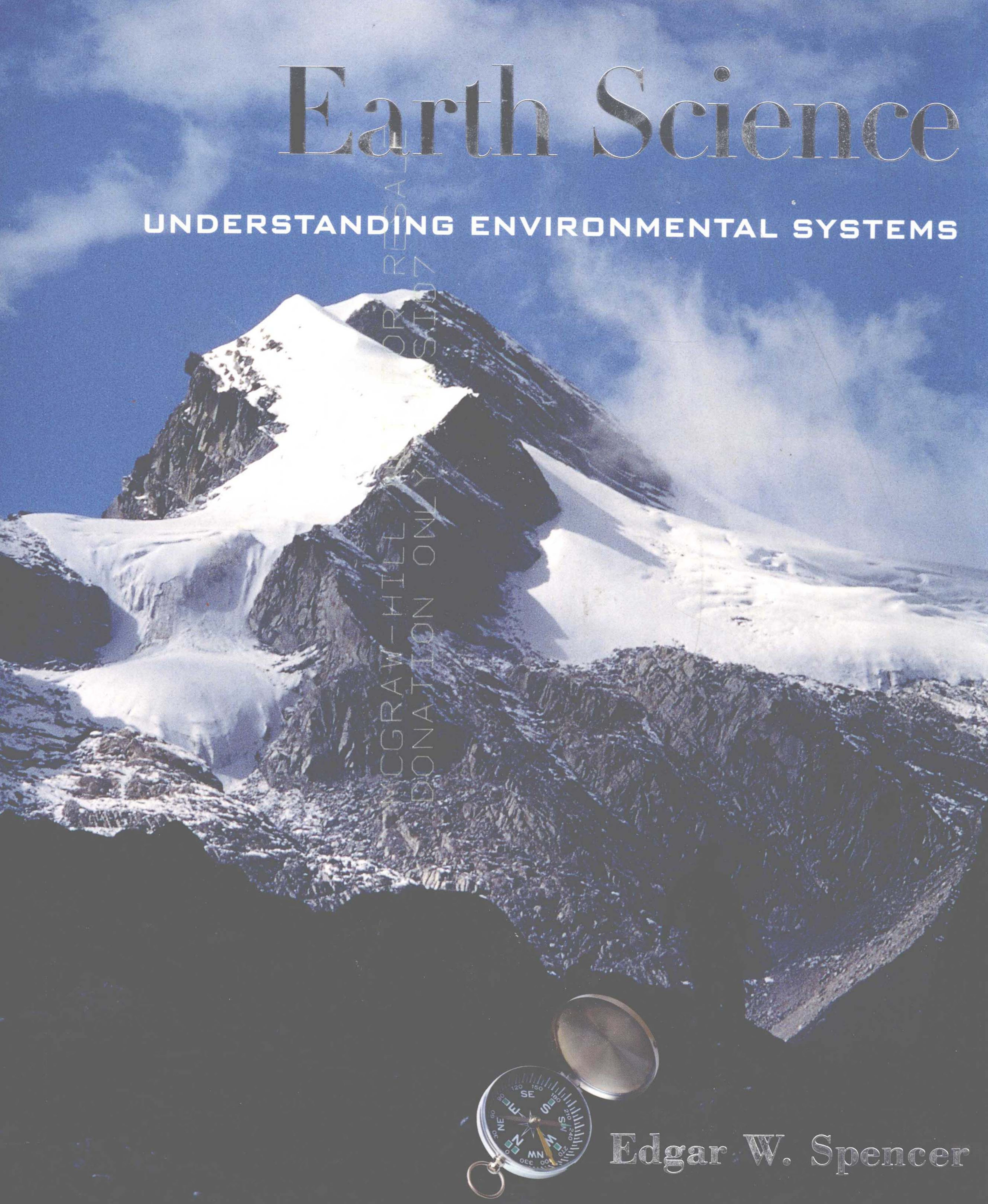
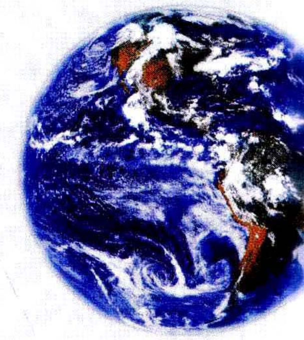
Earth Science

UNDERSTANDING ENVIRONMENTAL SYSTEMS



Edgar W. Spencer



Earth Science

Understanding Environmental Systems

Edgar W. Spencer

Washington and Lee University

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EARTH SCIENCE: UNDERSTANDING ENVIRONMENTAL SYSTEMS

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Preface

As we enter the twenty-first century, the need for a better understanding of Earth and the environment in which we live is increasingly apparent. In almost every community, some look to scientists for leadership in explaining the environmental issues society faces on a day-to-day basis. Ultimately, responsibility for making decisions about environmental issues rests with individual citizens and their representatives, few of whom are trained as scientists. Most of the students who enroll in earth science courses do so to satisfy a general education requirement. For many, this will be their only formal college-level science course. This course may be their only opportunity to learn what science is, how scientists go about examining issues, how scientific ideas evolve over time, and why science has been so successful as a way of looking at the world. In addition to providing broad perspectives on science and the environment, earth science courses also establish links between science, economics, politics, and history. For all these reasons, earth science courses are ideal general education courses.

This book is intended for introductory courses that place emphasis on the systems approach to earth science with special attention to the impact these systems have on the environment. It is appropriate for liberal-arts nonmajors with no previous college science or mathematics. By using a systems approach, students gain a better understanding of Earth as a whole, the relationships among processes acting on and inside Earth, and the connections between physical and biological sciences.

OVERVIEW

The primary goals of this book are to provide the background the general student needs to understand the way Earth works, how knowledge of Earth relates to the environmental issues confronting our society, and how scientists go about examining these issues. The unifying focus used to achieve these goals is the study of the processes that govern the evolution of Earth and control the operation of its environmental systems.

It is difficult for students to understand the present condition of Earth unless they are familiar with the processes that cause change. The time frame for these changes may vary from relatively short spans to those that take place slowly over thousands or even millions of years. Thus, the time frame in which natural processes bring about change is an important aspect of Earth systems. Slow processes such as those that cause the gradual shifting of continents, the rise of mountains, the formation of new sea floor, and the evolution of living organisms have set the stage for the present Earth. Although these barely perceptible processes continue, we are more acutely aware of changes produced over short time intervals. These include the development of atmospheric storms that can have great impact in a matter of days or even hours. Waves and currents can transform the coast by eroding some areas while depositing sediment in others, and earthquakes and volcanic eruptions can cause widespread changes in a day and can transform regions as the effects continue to accumulate over thousands of years.

Throughout human history, people have adjusted to natural conditions. Thousands of years ago, our ancestors moved south as glaciers gradually covered the northern latitudes. Subsequently, as the ice margin receded, some groups followed it north, eventually crossing from Siberia to North America where they began the settlement of the Americas. During most of the million of years that humans have inhabited Earth, their numbers were not great. They lacked the capability of modifying Earth's systems and surface significantly. But human population has grown exponentially in the last hundred years, and since the industrial revolution, humans have made significant changes to the environment. Both the size of the human population and our ability to alter Earth's environment have increased dramatically during the last few decades. We have constructed road systems that are long enough to reach the moon; extracted and used a large percentage of the total amount of oil and gas on Earth within a few decades; dug millions of miles of trenches for pipes; and connected oceans by canal works. We have stripped the soil from vast areas; modified drainage basins in ways that cause floods; and disposed of toxic waste using methods that endanger our drinking water. Many scientists think it is likely that humans are changing the climate of Earth, but at present, we do not know how fast those changes may take place or how extreme they may be. The last of the virgin forests are being cut down rapidly, causing thousands of animal and plant species to approach the edge of extinction. We do not know the extent to which our own survival is tied to that of other species or to the overall health of the ecosystem. These will be among the most challenging issues facing the current generation of students. How well they will be able to deal with these as scientists, business managers, teachers, politicians, and citizens will depend on how well they understand the nature of the problems, the interdependence and operation of natural systems.

Can we manage Earth's systems without damaging our own environment? Can we understand and live in harmony with the processes that govern the environment? Can we learn how the different parts of Earth systems are interrelated well enough to predict the consequences of our own actions? These are questions all informed individuals, especially scientists and engineers, must try to answer. These are the subjects this book explores and clarifies by examining the character of the solid earth, the oceans, the atmosphere, biological processes, and the ways they are interrelated.

This book provides a basis for understanding natural systems and identifies many of the problems we face as we try to avoid the difficulties caused by natural processes such as volcanic eruptions, earthquakes, and landslides, as well as those created by our own actions.

FEATURES

1. **Systems Emphasis.** The systems approach emphasizes the relationships among the great variety of processes that affect Earth and its environment. Although the book provides coverage used in earth science courses, emphasis in the first three units is placed on Earth systems, the connections between geology, oceanography, meteorology, and ecology. The physical systems identified by NASA in a book entitled *Earth System Science—A Closer View* are used as a basis for organization of the systems approach. NASA recognizes three major physical systems, the core-mantle, plate tectonic, and physical climate systems. The close relationships between living organisms and the physical environment are treated through examination of biogeochemical cycles.
2. **Major Ecosystems.** Close connections exist between the study of the physical and biological aspects of Earth's environments. These connections are emphasized in this book. Chapter 14 provides an introduction to the land surface and the relationship between terrestrial geology and ecosystems. Similar emphasis is given to marine environments in chapter 8 and to coastal environments in chapter 10.
3. **The Relationship Between Humans and Their Environment.** Not only do natural processes shape the human environment, human activities have become a major influence on natural systems. This theme runs throughout this book, and special attention is given to the relevance of Earth systems for understanding environmental problems.
4. **Flexible Organization.** The interaction of Earth systems is like a web of interrelationships. Some instructors prefer to begin by looking at Earth as a planet and end by examining details of surface processes. Others prefer to cover topics more familiar to students at the start and end with a large-scale picture of Earth's interior. To accommodate various approaches, this book provides flexible organization. After completion of the Introduction in unit one, the instructor can proceed with other units of the book. However, the author thinks that most students will find later chapters easier to understand after they are more familiar with the recycling of Earth materials, the importance of time in the operation of Earth processes, and major features of Earth and its interior.
5. **Chapter Guide.** Each chapter begins with a brief introduction that relates the chapter to other parts of the text. The Chapter Guide summarizes the main objectives of the chapter and indicates how the subject matter of the chapter relates to Earth systems.
6. **Key Words.** Key words are identified in bold-faced print.
7. **Case Histories.** Where appropriate, case histories of events or localities are used to illustrate principles and demonstrate the relevance of the subject matter. Most students find the concepts presented with a case-history approach interesting and easy to understand and to remember because they can associate them with real situations.
8. **Data Banks.** Some tables contain files such as soil and climate types that students need to have readily available for reference as they read the text.
9. **Summary Points.** Summary Points provide a quick review of the most important concepts presented in the chapter.
10. **Review Questions.** Review questions are included to help students evaluate their mastery of basic materials presented in each chapter and to prepare for tests.
11. **Thinking Critically.** Thinking Critically questions encourage the student or a class to go beyond the text materials in exploring the relevance of the subject matter to environmental issues.
12. **Units of Measure.** Both English and SI units of measure are included in the text. Precise conversions are used for measurements that are exact, but approximate and rounded-off conversions are used if exact measurements are unknown.
13. **Appendix.** The appendixes provide supplementary information about several important subjects that some instructors may wish to include in their courses.

Appendix A. Units and Conversions. This appendix contains basic information about units of measure and conversions between English and SI units.

Appendix B. Minerals. This appendix explains how to identify minerals by using their physical properties. It contains a chart of physical properties and composition of common rock-forming minerals and common, economically important minerals.

Appendix C. Rock Identification. This section contains additional details about common rocks.

Appendix D. Topographic and Geologic Maps. This appendix contains a brief explanation of how to read topographic and geologic maps.

Appendix E. Star Charts. Students who enjoy identifying stars will find these star charts and information about locating objects in the sky useful.

Appendix F. The Periodic Table of Elements.

14. **Glossary.** The glossary provides brief definitions of the technical terms used throughout the text.

ORGANIZATION

The organization of this book allows instructors to vary the sequence of coverage. It is organized into four units. Unit three, which covers surficial processes, is subdivided into parts that cover the oceans, the atmosphere, and the land surface.

Unit 1 Major Elements of Earth Systems

The introduction defines science and Earth system science, explains how this field came into existence, and provides basic information that students without previous background in earth science will need in order to understand Earth systems. Unit one contains basic information about Earth, the materials that compose it, the time frame in which the processes cause change on Earth, modern ideas about the origin and place of Earth in the solar system, and the model scientists have developed of Earth's interior. This part encourages students to think of Earth as a planet, its place in time and space, and how processes operating deep inside Earth affect the surface and the human environment. Throughout the text, biogeochemical processes and ecology are emphasized in the discussion of Earth environments.

Unit 2 The Plate Tectonic System

This unit explains the operation of the plate tectonic system and the way movements in the outer parts of Earth cause earthquakes and volcanic activity that have such profound impacts on the surface. The changes in the way Earth scientists think about Earth have been revolutionary. By examining the history of the development of plate tectonic theory, this unit gives students a better understanding of how hypotheses evolve to become widely accepted theories.

Unit 3 Earth's Physical Climate System

This unit includes Earth's surface features and the processes that shape the surface.

Part 1 Oceans and Coasts Chapters 8, 9, and 10 examine the oceans, which cover more than 70% of Earth's surface, the character of the ocean basins, the movement of water in the oceans, and the environments in the oceans. These are important components of systems that interact with the atmosphere and land surface. This part also includes the coastal transition zone between the open oceans and the land surface.

Part 2 The Atmosphere Chapters 11, 12, and 13 begin with a chapter that defines the composition and structure of the atmosphere. This introductory chapter includes discussions of atmospheric pollution, greenhouse gases, global warming, and the ozone hole. It also provides modern coverage of El Niño and its effects on weather.

Part 3 The Land Surface Chapters 14 through 20 examine the terrestrial environment. Terrestrial environments are covered in greater detail than transitional or marine environments because the processes that operate on land environments affect humans more directly. The chapter topics—soil, mass movement, streams, ground water, wind, and ice—resemble those found in conventional Earth Science texts. However, the treatment of these topics emphasizes systems and the relationships of these subjects to the environment. Special attention is given to the hydrologic cycle. Water-supply issues are so widespread and of such great importance that a separate chapter is devoted to this topic.

Unit 4 The Solar System and Its Place in the Universe

Unit four examines the place of Earth in the solar system and as part of the universe. These topics, which are first introduced in chapter 4, are developed more fully in unit four for use in courses that have sufficient time for this coverage.

THE SUPPLEMENTS PACKAGE

Online Learning Center

This website, located at www.mhhe.com/spencer, hosts instructor and student tools. The instructor center is password protected and offers topics for classroom discussions, test questions, an image bank, and PowerPoint lecture outlines. Students will find online quizzing, flashcards, additional readings, study tips, and Internet exercises that will enhance the text material and offer a thorough review of the content.

PowerWeb

Included within the Online Learning Center, PowerWeb provides access to a course-specific website, developed with the help of instructors teaching the course, to provide instructors and students with curriculum-based materials, updated weekly assessments, informative and timely world news, refereed web links, and much more. You'll get daily news updates and have access to 5,900 research sources through the Internet's most thorough search tool, Northern Light. This differs from the Online Learning Center in that it extends the learning experience beyond the core textbook content into other subject areas. PowerWeb is designed to supplement the text content by offering more outside readings, research opportunities, and more.

Digital Content Manager

Free to adopters, this CD-ROM contains illustrations, photos, and lecture outlines that can be imported into PowerPoint, as well as other presentation software, to create your own personalized presentation.

Transparencies

One hundred acetate transparencies of key text illustrations are available to qualified adopters.

Classroom Testing Software

Test questions are also available on McGraw-Hill testing software, for use with Macintosh and IBM PC computers.

ACKNOWLEDGMENTS

It is difficult to emphasize how much this book represents the efforts of many people. I am deeply indebted to my students, colleagues, family, friends, reviewers, and the staff at McGraw-Hill who made the publication of this book possible. In addition to individuals, I am most grateful to the administrators of Washington and Lee University who have provided long-standing support and encouragement of the faculty to pursue their professional interests.

My wife has provided help and supported my work on this book for many years. She and our daughter Shawn prepared many of the illustrations. Our daughter Shannon and her husband Rich Wallace offered suggestions about ways to integrate recent work from fields of environmental studies in the text. Kary Smout, director of the Writing-Across-the-Curriculum program at Washington and Lee University, helped me improve the organization and presentation of ideas throughout the book. Cynthia Abelow, Katherine McAlpine, and Jennifer Strawbridge helped me improve the composition of the manuscript. Kate Metznik, Richard Kilby, Greg Bank, Betty Mitchell, Madelyn Miller, and Linda Davis assisted in editing the manuscript and preparing illustrations. I greatly appreciate the help of the people who assisted me in locating figures, as well as those who granted permission for the use of their illustrations. The reviewers provided constructive criticisms and detailed suggestions for content, organization, depth of treatment, presentation of ideas, and new information. The book has been greatly improved through their efforts. Thomas Arny was especially helpful in reviewing the chapters on astronomy. I appreciate the work of the developmental editor, Lisa Leibold, and the production team, including Rose Koos, Carrie Burger, and Stuart Paterson, who transformed the manuscript into a book.

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Meet the Author

Experiences from childhood kindled my interest in nature and eventually led to my career in earth science. I grew up in a small town in southeastern Arkansas and have clear memories of frightening hours watching violent electrical storms during summer months, visiting neighboring towns destroyed by tornadoes, listening to stories about the famous 1927 flood on the Mississippi River, spending many nights camping out as a Boy Scout, fishing on oxbow lakes, and taking float trips down local streams. On a trip west, I was amazed to see the Rocky Mountains rise out of the Great Plains. When I went to college at Washington and Lee University, I knew I wanted to take a course in geology. During that first exposure to the science of the earth, I discovered the scope, application, and fascination of studying earth science. As a senior, I was a field assistant to Dr. Marcellus Stow who was helping prospectors evaluate uranium properties in Montana. We made the Yellowstone Bighorn Research Association camp at Red Lodge our base of operation. There I was introduced to the variety of research interests of geologists from many universities and to the enthusiasm they had for what they were doing. Later I would get to know the YBRA camp well as I studied the structure of the Beartooth Mountains while a graduate student at Columbia University.

During my years at Columbia, I spent a summer on one of the early transatlantic voyages of the R/V Vema. Collecting cores, taking underwater photographs, and making seismic refraction surveys and continuous depth recordings provided a hands-on introduction to oceanography. It was an exciting time at the Lamont Observatory. Evidence that would lead to the development of plate tectonics was being collected and analyzed by an extraordinary group of scientists.

After graduation, I accepted an invitation to join the Washington and Lee faculty where I have had the good fortune of being associated with colleagues who have been enthusiastic teachers, outstanding scientists, and good friends. It has been a special pleasure to work with faculty and students in the Keck Geology Consortium, with members of the Virginia Division of Mineral Resources, and with a number of Washington and Lee alumni college groups. My earlier research continued in Montana, but it gradually shifted to the Central Appalachian Mountains. I've never tired of fieldwork, trying to resolve challenging structural and stratigraphic problems, and making interpretations of complex data. Sabbatical leaves in New Zealand, Australia, Switzerland, Scandinavia, Great Britain, and Greece have provided wonderful opportunities to study geology in many parts of the world. I have especially enjoyed working with students in the field, and in the 1970s developed an introductory course in geology that is centered around work in the field as much as possible. As with many earth science teachers, working closely with undergraduates, following their careers, and sharing their experiences has been richly rewarding.

While a graduate student, I taught at Hunter College and complained to my apartment mate about the content of the textbooks. A few years later, as an editor at T. Y. Crowell, Philip Winsor urged me to write a book. I found that gathering information about a broad range of subjects and looking for new ways to organize and express that information offered a challenging, interesting, and enjoyable way to keep up with the field. Over the years, I have written a number of books, including ones on earth science, structural geology, and, most recently, geologic map interpretation.

Fieldwork in parts of Montana and Virginia that were later designated as wilderness areas is partially responsible for my interest in conservation and the use of geologic information in land use and regional planning. In 1975, I joined a group of individuals who shared an interest in land use planning. We formed a local conservation council that has worked with other organizations and local governments to promote conservation in our community. The insights gained have helped focus my attention on many of the topics discussed in this book.

Professor Spencer was head of the Washington and Lee geology department for over thirty-five years and was named the Ruth Parmly Professor. He is an honorary member of Phi Beta Kappa and the national leadership fraternity Omicron Delta Kappa. He received a National Science Foundation faculty fellowship and research grants from NSF, the American Chemical Society, and the Mellon Foundation. In 1991, he received an Outstanding Faculty Award from the Virginia Council of Higher Education.

The Proven Earth Science *Learning System*

Systems Emphasis

The systems approach emphasizes the relationships among the great variety of processes that affect Earth and its environment. Emphasis in the first three units is placed on Earth systems: the connections between geology, oceanography, meteorology, and ecology.

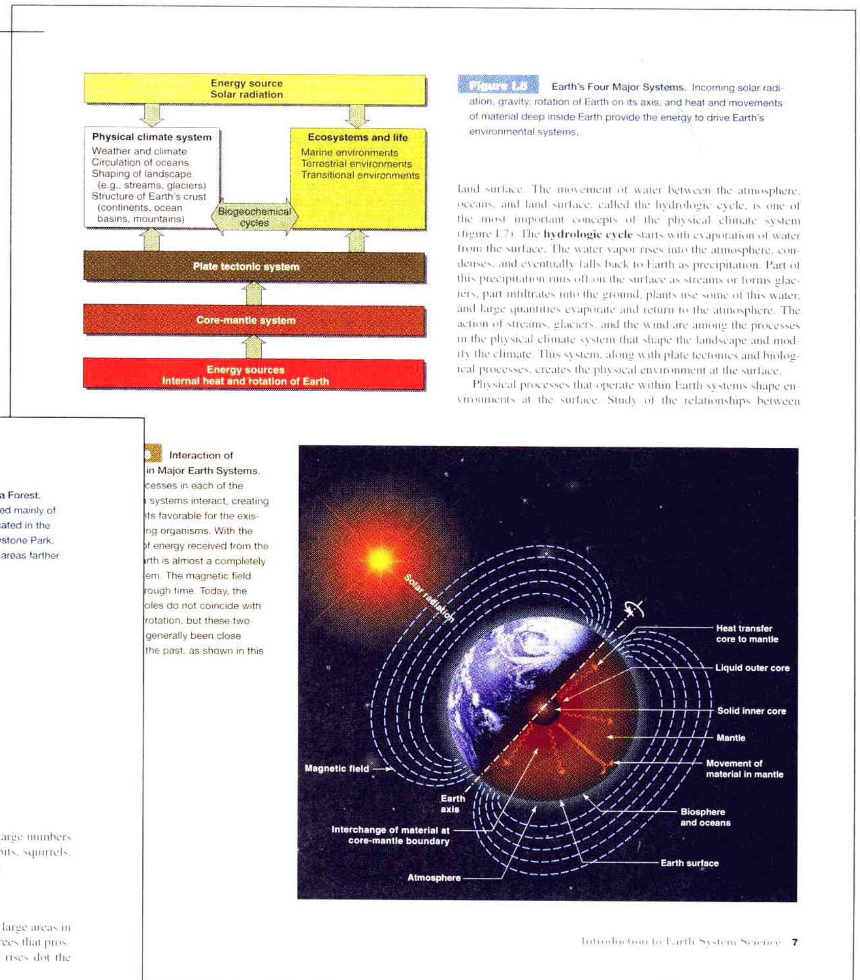

Figure 1.5 Earth's Four Major Systems. Incoming solar radiation, gravity, rotation of Earth on its axis, and heat and movements of material deep inside Earth provide the energy to drive Earth's environmental systems.

land surface. The movement of water between the atmosphere, oceans, and land surface, called the hydrologic cycle, is one of the most important concepts of the physical climate system (figure 1.7). The **hydrologic cycle** starts with evaporation of water from the surface. The water vapor rises into the atmosphere, condenses, and eventually falls back to Earth as precipitation. Part of this precipitation runs off on the surface as streams or forms glaciers, part infiltrates into the ground, plants use some of this water, and large quantities evaporate and return to the atmosphere. The action of streams, glaciers, and the wind are among the processes in the physical climate system that shape the landscape and modify the climate. This system, along with plate tectonics and biological processes, creates the physical environment at the surface.

Physical processes that operate within Earth systems shape environments at the surface. Study of the relationships between

...8 Interaction of ... in Major Earth Systems. ...cesses in each of the ... systems interact, creating ...ts favorable for the exis...ng organisms. With the ...f energy received from the ...rth is almost a completely ...em. The magnetic field ...rough time. Today, the ...oles do not coincide with ...rotation, but these two ... generally been close ... the past, as shown in this

Introduction to Earth System Science 7

Figure 14.9 A Taiga Forest. This taiga forest, composed mainly of spruce and fir trees, is located in the mountains north of Yellowstone Park. Similar forests cover vast areas farther north in Canada.

Boreal (High-Latitude) Forests

South of the tundra, winters are also extremely cold, but they are short compared with arctic winters. Summers vary in length. Some are warm; others are cool and wet. When the ice sheets retreated from these areas, they left a low-lying, poorly drained rocky surface with thin soil. Some evergreen trees prosper under these conditions. Fir, spruce, and pine dominate the forests of northern Canada, northern Europe, and parts of Asia, but in northern Siberia, most of the trees are larches. Ecologists refer to these high-latitude forests as **taiga forests** (figure 14.9). Broadleaf deciduous trees, such as oaks and elms, which are so abundant farther south (figure 14.10), are rare in the taiga forests. The wet, mossy, and boggy ground is an ideal habitat for mosquitoes, and the bogs also make an ideal home for moose, mink, and beavers.

Midlatitude Forests

In the midlatitudes, global atmospheric circulation causes the eastern sides of continents to have cold winters and warm summers, and precipitation is evenly distributed throughout the year. These are ideal conditions for a great variety of deciduous trees, such as oaks, hickory, maples, elms, sweet gums, and conifers. Seasonal changes, especially the loss of leaves in the fall and new growth in the spring, are prominent features of the temperate deciduous forests (figure 14.10). Most of these forests lie south of the areas that were glaciated during the last glacial advance that culminated about 18,000 years ago. Undoubtedly, the advancing ice disrupted similar forests that grew farther north during the last interglacial period.

With the changing seasons, numerous migratory birds come and go as they move from summer habitats in Canada to winter feeding grounds in temperate or tropical climates. These birds as well as other animals help disperse seeds of trees and shrubs that produce their fruit in the autumn and early winter. Large numbers of animal species, including bears, foxes, deer, rabbits, squirrels, skunks, and groundhogs, also populate these forests.

Savannas

The grass-covered plains that define savannas cover large areas in both tropical and temperate regions. Small areas of trees that prosper along rivers and in places where ground water rises dot the

Figure 14.10 A Deciduous Forest. This deciduous forest is in the Blue Ridge Mountains, part of the Central Appalachian Mountains of Virginia and contains a great variety of deciduous trees, including oak, poplar, and maples, as well as some conifers.

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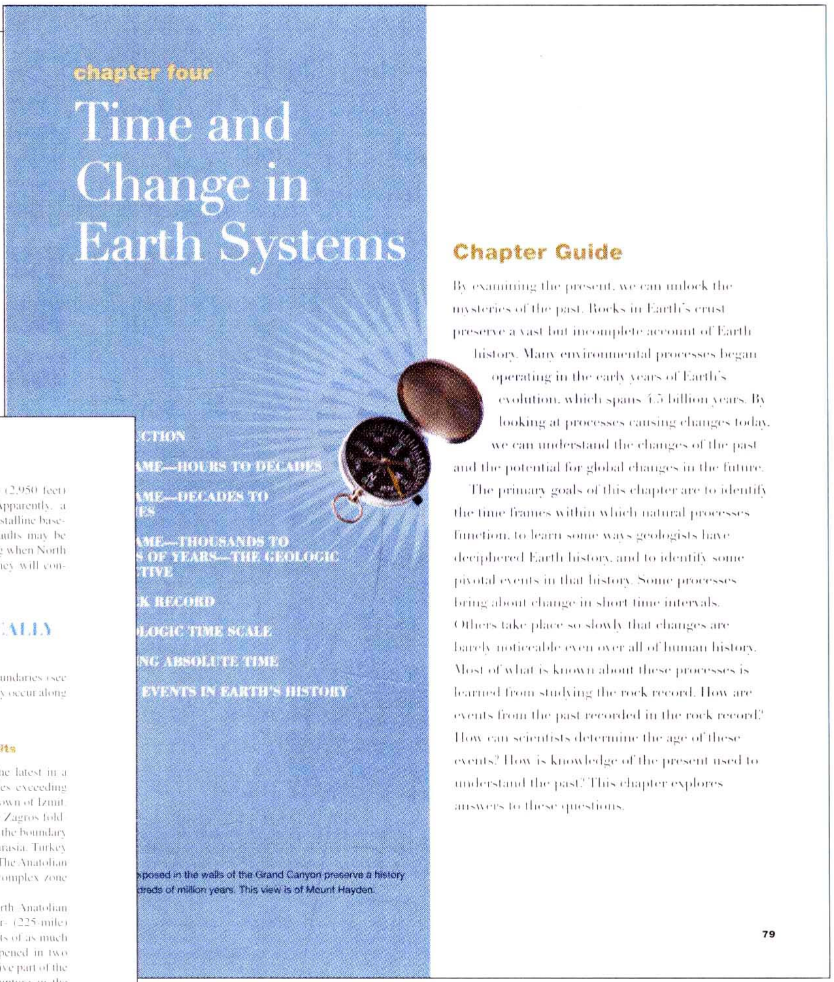
Major Ecosystems

Close connections exist between the study of the physical and biological aspects of Earth's environments. These connections are emphasized in chapters 8, 10, and 14.

Chapter Guide

Each chapter begins with a brief introduction that relates the chapter to other parts of the text. The **Chapter Guide** summarizes the main objectives of the chapter and indicates how the subject matter of the chapter relates to Earth systems.



chapter four

Time and Change in Earth Systems

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...AME—DECADES TO ...ES

...AME—THOUSANDS TO ...S OF YEARS—THE GEOLOGIC ...TIVE

...K RECORD

...LOGIC TIME SCALE

...NG ABSOLUTE TIME

... EVENTS IN EARTH'S HISTORY

...posed in the walls of the Grand Canyon preserve a history ...dreds of million years. This view is of Mount Hayden.

Chapter Guide

By examining the present, we can unlock the mysteries of the past. Rocks in Earth's crust preserve a vast but incomplete account of Earth history. Many environmental processes began operating in the early years of Earth's evolution, which spans 4.5 billion years. By looking at processes causing changes today, we can understand the changes of the past and the potential for global changes in the future.

The primary goals of this chapter are to identify the time frames within which natural processes function, to learn some ways geologists have deciphered Earth history, and to identify some pivotal events in that history. Some processes bring about change in short time intervals. Others take place so slowly that changes are barely noticeable even over all of human history. Most of what is known about these processes is learned from studying the rock record. How are events from the past recorded in the rock record? How can scientists determine the age of these events? How is knowledge of the present used to understand the past? This chapter explores answers to these questions.

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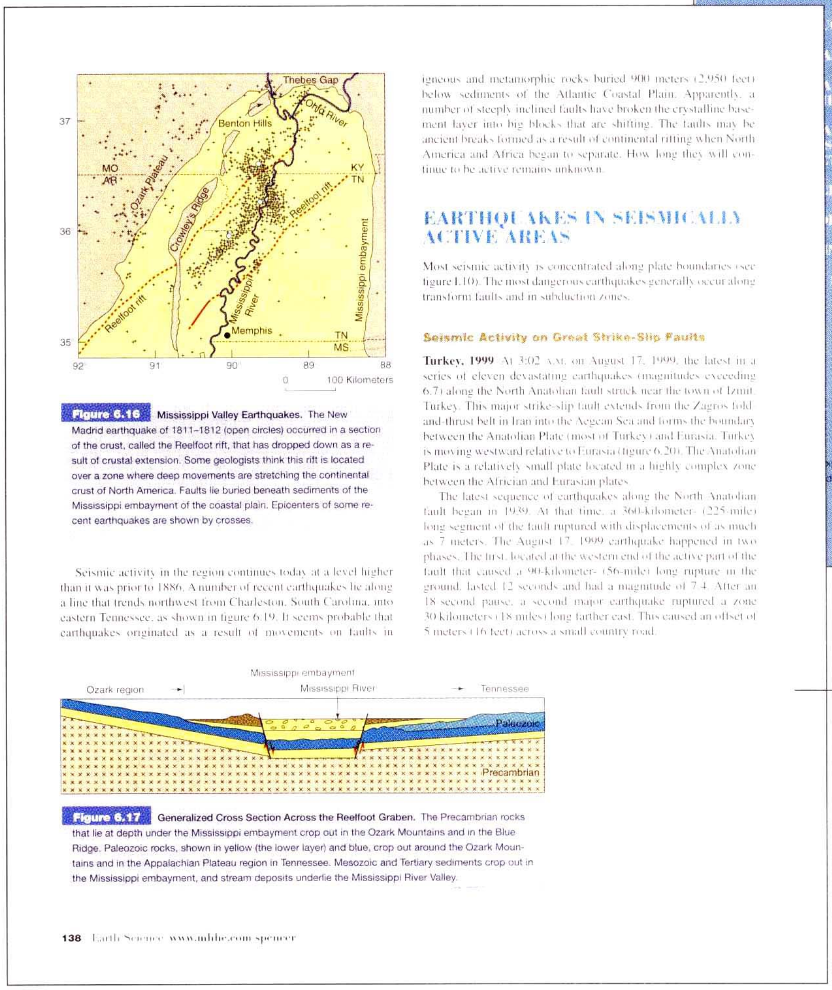

Figure 6.16 Mississippi Valley Earthquakes. The New Madrid earthquake of 1811–1812 (open circles) occurred in a section of the crust, called the Reelfoot rift, that has dropped down as a result of crustal extension. Some geologists think this rift is located over a zone where deep movements are stretching the continental crust of North America. Faults lie buried beneath sediments of the Mississippi embayment of the coastal plain. Epicenters of some recent earthquakes are shown by crosses.

Seismic activity in the region continues today at a level higher than it was prior to 1886. A number of recent earthquakes lie along a line that trends northwest from Charleston, South Carolina, into eastern Tennessee, as shown in figure 6.19. It seems probable that earthquakes originated as a result of movements on faults in igneous and metamorphic rocks buried 900 meters (2,950 feet) below sediments of the Atlantic Coastal Plain. Apparently, a number of steeply inclined faults have broken the crystalline basement layer into big blocks that are shifting. The faults may be ancient breaks formed as a result of continental rifting when North America and Africa began to separate. How long they will continue to be active remains unknown.

EARTHQUAKES IN SEISMICALLY ACTIVE AREAS

Most seismic activity is concentrated along plate boundaries (see figure 1.10). The most dangerous earthquakes generally occur along transform faults and in subduction zones.

Seismic Activity on Great Strike-Slip Faults

Turkey, 1999 At 3:02 A.M. on August 17, 1999, the latest in a series of eleven devastating earthquakes (magnitudes exceeding 6.7) along the North Anatolian fault struck near the town of Izmit, Turkey. This major strike-slip fault extends from the Zagros fold-and-thrust belt in Iran into the Aegean Sea and forms the boundary between the Anatolian Plate (most of Turkey) and Eurasia. Turkey is moving westward relative to Eurasia (figure 6.20). The Anatolian Plate is a relatively small plate located in a highly complex zone between the Africian and Eurasian plates.

The latest sequence of earthquakes along the North Anatolian fault began in 1939. At that time, a 360-kilometer- (225-mile) long segment of the fault ruptured with displacements of as much as 7 meters. The August 17, 1999 earthquake happened in two phases. The first, located at the western end of the active part of the fault that caused a 90-kilometer- (56-mile) long rupture in the ground, lasted 12 seconds and had a magnitude of 7.4. After an 18 second pause, a second major earthquake ruptured a zone 30 kilometers (18 miles) long farther east. This caused an offset of 5 meters (16 feet) across a small country road.

Figure 6.17 Generalized Cross Section Across the Reelfoot Graben. The Precambrian rocks that lie at depth under the Mississippi embayment crop out in the Ozark Mountains and in the Blue Ridge. Paleozoic rocks, shown in yellow (the lower layer) and blue, crop out around the Ozark Mountains and in the Appalachian Plateau region in Tennessee. Mesozoic and Tertiary sediments crop out in the Mississippi embayment, and stream deposits underlie the Mississippi River Valley.

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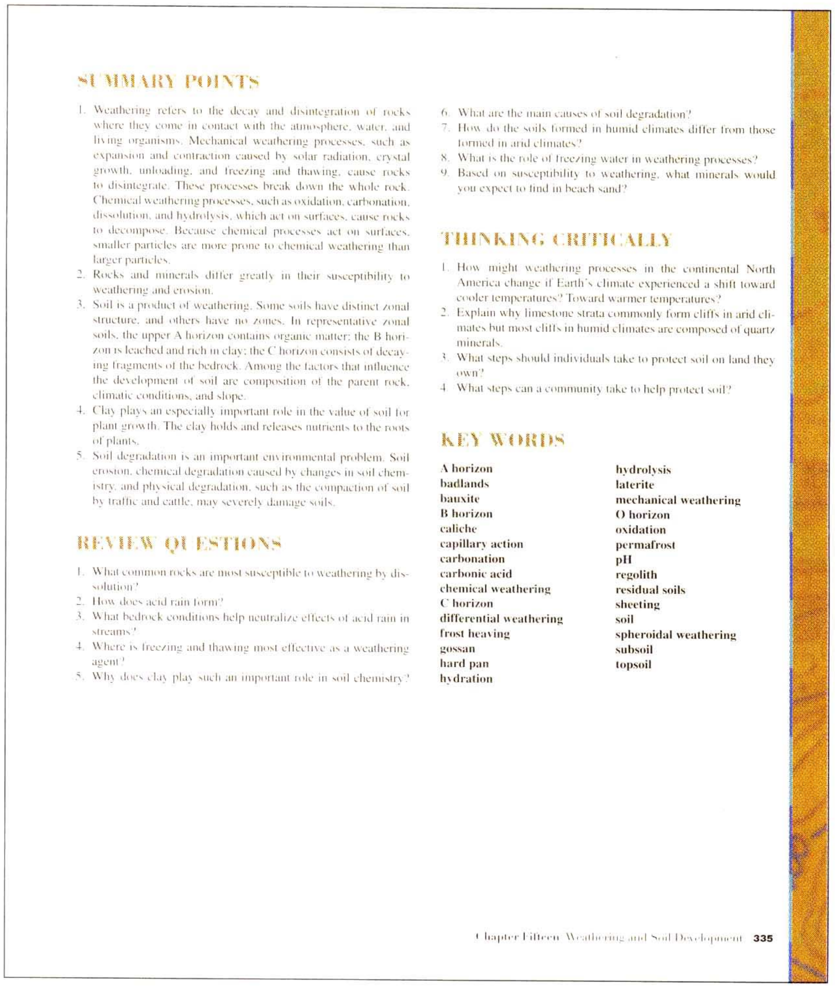
Case Histories

Case Histories of events or localities are used to illustrate principles and demonstrate the relevance of the subject matter. Students will find the concepts presented with a case-history approach not only interesting but also easy to understand because they can associate them with real situations.

End-of-Chapter Material

Each chapter concludes with **Summary Points**, which provide a quick review of the most important concepts; **Review Questions**, intended to help students evaluate their mastery of basic concepts; **Thinking Critically**, which encourages students to go beyond the text materials in exploring the relevance of the subject matter to environmental issues; and **Key Words** which identify important terms and concepts.



SUMMARY POINTS

1. Weathering refers to the decay and disintegration of rocks where they come in contact with the atmosphere, water, and living organisms. Mechanical weathering processes, such as expansion and contraction caused by solar radiation, crystal growth, unloading, and freezing and thawing, cause rocks to disintegrate. These processes break down the whole rock. Chemical weathering processes, such as oxidation, carbonation, dissolution, and hydrolysis, which act on surfaces, cause rocks to decompose. Because chemical processes act on surfaces, smaller particles are more prone to chemical weathering than larger particles.
2. Rocks and minerals differ greatly in their susceptibility to weathering and erosion.
3. Soil is a product of weathering. Some soils have distinct zonal structure, and others have no zones. In representative zonal soils, the upper A horizon contains organic matter; the B horizon is leached and rich in clay; the C horizon consists of decaying fragments of the bedrock. Among the factors that influence the development of soil are composition of the parent rock, climatic conditions, and slope.
4. Clay plays an especially important role in the value of soil for plant growth. The clay holds and releases nutrients to the roots of plants.
5. Soil degradation is an important environmental problem. Soil erosion, chemical degradation caused by changes in soil chemistry, and physical degradation, such as the compaction of soil by traffic and cattle, may severely damage soils.

REVIEW QUESTIONS

1. What common rocks are most susceptible to weathering by dissolution?
2. How does acid rain form?
3. What bedrock conditions help neutralize effects of acid rain in streams?
4. Where is freezing and thawing most effective as a weathering agent?
5. Why does clay play such an important role in soil chemistry?
6. What are the main causes of soil degradation?
7. How do the soils formed in humid climates differ from those formed in arid climates?
8. What is the role of freezing water in weathering processes?
9. Based on susceptibility to weathering, what minerals would you expect to find in beach sand?

THINKING CRITICALLY

1. How might weathering processes in the continental North America change if Earth's climate experienced a shift toward cooler temperatures? Toward warmer temperatures?
2. Explain why limestone strata commonly form cliffs in arid climates but most cliffs in humid climates are composed of quartz minerals.
3. What steps should individuals take to protect soil on land they own?
4. What steps can a community take to help protect soil?

KEY WORDS

A horizon	**hydrolysis**
badlands	**laterite**
bauxite	**mechanical weathering**
B horizon	**O horizon**
caliche	**oxidation**
capillary action	**permafrost**
carbonation	**pH**
carbonic acid	**regolith**
chemical weathering	**residual soils**
C horizon	**sheeting**
differential weathering	**soil**
frost heaving	**spheroidal weathering**
gossan	**subsoil**
hard pan	**topsoil**
hydration	

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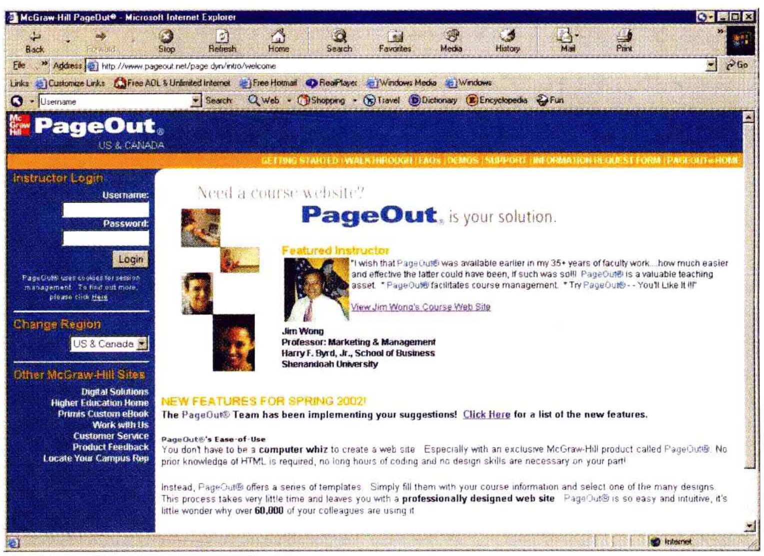

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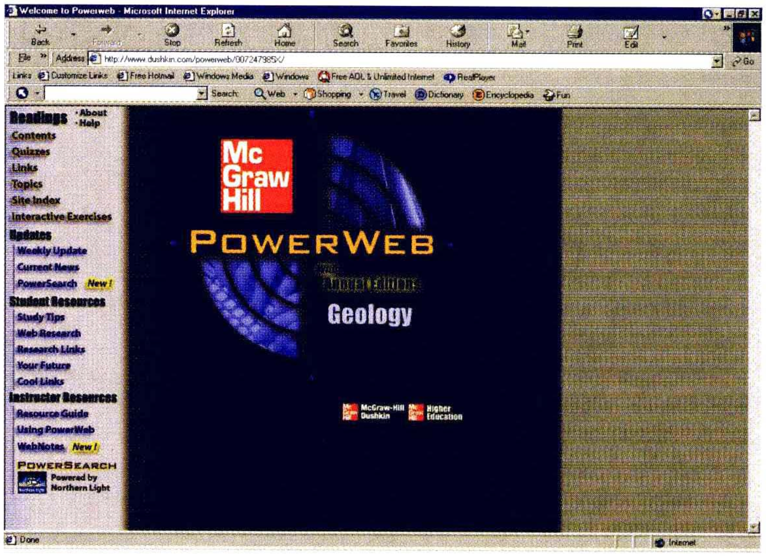

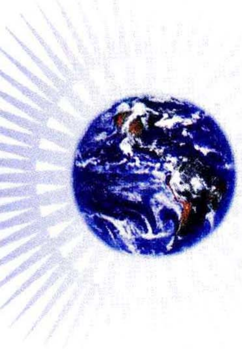

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