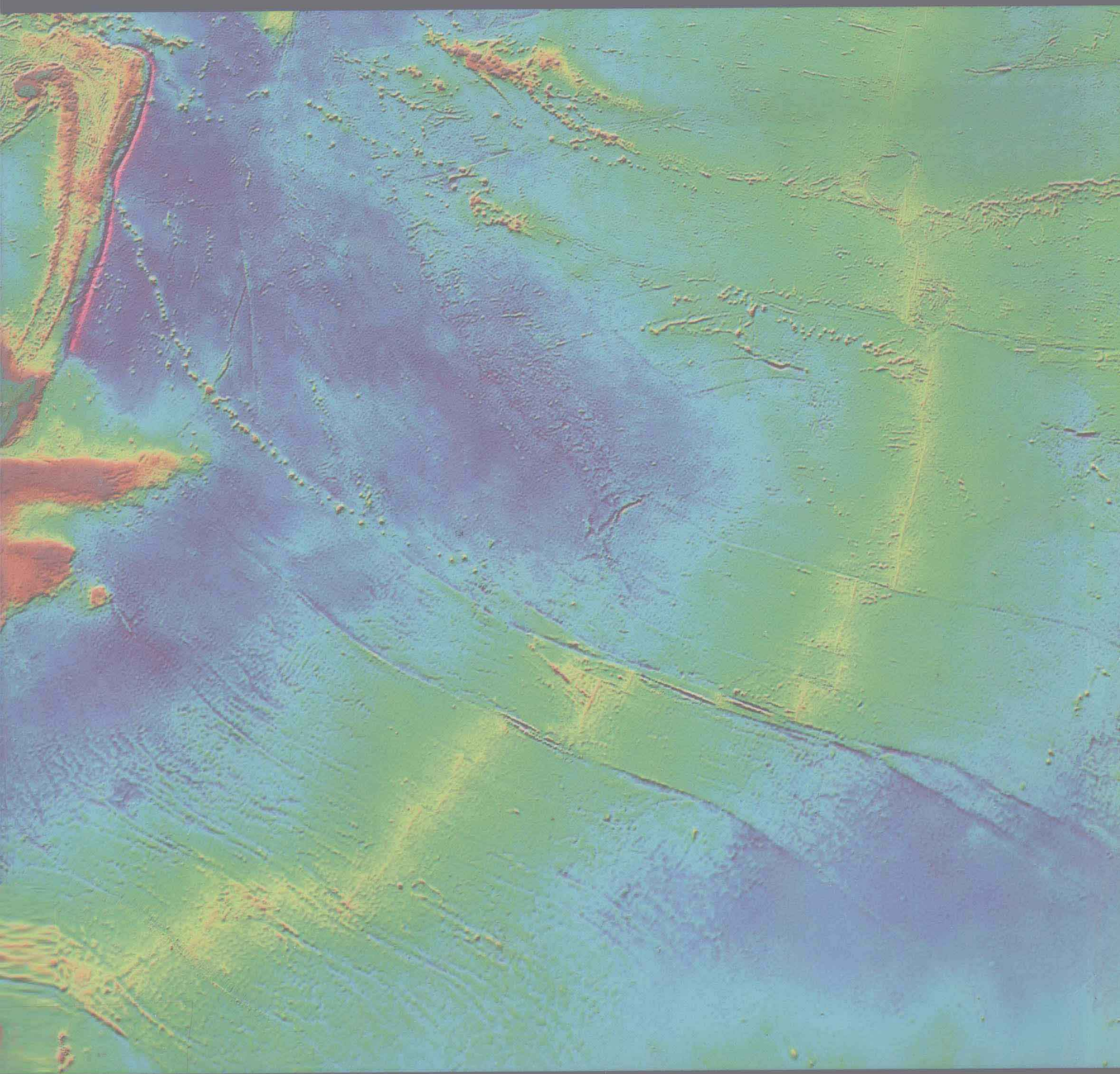
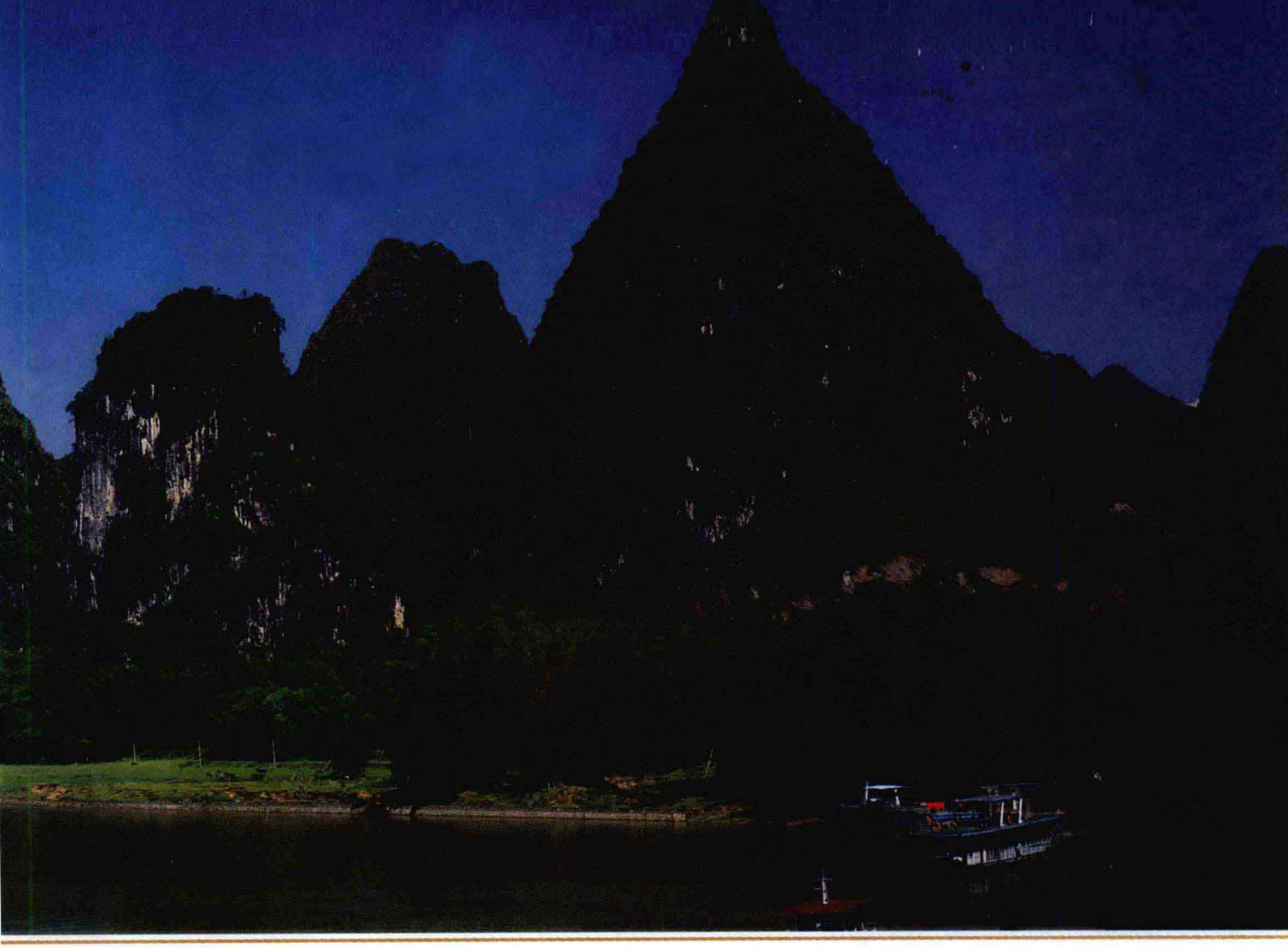
EARTH'S DYNAMIC SYSTEMS

Eighth Edition



W. Kenneth Hamblin • Eric H. Christiansen



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EIGHTH EDITION

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PREFACE

A multitude of recent developments in Earth science have given us an increased awareness of how our planet is continually changing, and reminded us of how fragile it is. Earth is a finite sphere with limited resources, so it is impossible for the population to grow indefinitely. We may find more oil, gas, and coal by improved detection methods, yet nature requires more than a million years to concentrate the oil now consumed in only 12 months. We have created nuclear waste, yet are unsure how to safely dispose of it. What can we do about the fact that rivers today transport more agricultural and industrial waste than natural sediment? Is greenhouse heating real? Eventually, we must understand Earth as a system with its interdependent and interconnected components and how they operate.

There are two major pathways for the flow of energy and matter on the planet: (1) the hydrologic system—the circulation of water over Earth's surface, and (2) the tectonic system—the movement of material powered by heat from Earth's interior. Most of the geologic processes occur at plate boundaries, and involve volcanism, earthquakes, mountain-building, and the evolution of continents and ocean basins. Everything discussed is related to these unifying themes.

The eighth edition of *Earth's Dynamic Systems* introduces these systems and will help students to understand and participate in the solutions to some of the problems outlined above. It is written for students taking their first college course in physical geology at both two- and four-year schools.

New To This Edition

This edition was significantly reorganized and revised to make it a more effective learning tool.

1. Most importantly, we revised the organization of about one-half of the book. In the latter part of the book, we have focused on plate interactions, with separate chapters on divergent, transform, and convergent boundaries as well as mantle plumes. Thus, we have adopted the same philosophy used in the discussion of the hydrologic system where we present the subsystems chapter by chapter.
2. Other new chapters include a chapter on geologic systems, which briefly overviews the hydrologic and tectonic systems. We have added a new chapter on the interactions between the ocean and atmosphere, the foundations of Earth's hydrologic system and global climate. Another new chapter focuses on Earth's resources and how they are generated by the hydrologic and tectonic systems.
3. We have tried to provide a new perspective in visualizing geology by using panoramic photographs of the landscape. Many were taken specifically for this edition. Panoramic photographs begin each chapter, and by briefly discussing what we see, we present to the student a geological perspective of Earth's landscapes. The panoramas could stand alone as a visual summary of physical geology.
4. All chapters were updated and checked for accuracy. We have refined chapters on igneous rocks, metamorphic rocks, geologic time, weathering, glaciers, seismicity, landscape evolution, and planetary geology.

5. Special attention was focused on improving the illustrations (over 50% are new or revised) so that the student can more fully experience the excitement and satisfaction of visualizing geology. We have traveled over much of North America and many other parts of the world—China, Tibet, Oman, Indian Ocean—to take photographs specifically for this edition.
6. We have used new digital topographic maps to enhance the book. The release of new data on seafloor and continental topography by various defense and other government agencies has opened a new window through which we can see the continents and the seafloor in more accurate and detailed fashion than ever before. These colored shaded relief maps are a visual and intellectual feast for those who carefully study them.

In spite of the new organization, we have retained all of the subjects of the classical physical geology course and expect that instructors will be able to adapt this book to their various needs.

The real test of any textbook is how well it helps the student learn. We welcome opinions from students and instructors who have used this book. Please address your comments, criticisms, and suggestions to:

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The artists who contributed to this and previous editions of *Earth's Dynamic Systems* deserve special recognition. William L. Chesser executed the drawings for the first edition. Many of his fine illustrations reappear

here. Robert Pack, Dale Claflin, and Russell McMullin prepared new figures for subsequent editions, many of which are included in this revision. The artists at Barney McKay Design Group prepared numerous new illustrations for this edition.

The staff at Prentice Hall played a critical role in the development of this edition. We are grateful for the assistance of Fred Schroyer, Tim Flem, and Yvonne Gerin at various stages in the project. We are especially indebted to our editor, Robert McConnin, for his advice and supervision.

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W.K.H.
E.H.C.

TO THE STUDENT

OUR APPROACH TO WRITING

One of the most difficult problems you face as a student in beginning a course in a new subject is to identify fundamental facts and concepts and separate them from supportive material. This problem is often expressed by the question, "What do I need to learn?" We have attempted to overcome this problem by presenting the material in each chapter in a manner that will help you recognize immediately the essential concepts.

Outline of Major Concepts. To help you focus on the key points of each chapter, we have identified them at the beginning of each chapter under the title Major Concepts.

Thesis Statements. We have rewritten every major section of each chapter trying to state the main ideas in a brief statement. The thesis statement of each topic is in bold type and separated from the body of the text by horizontal lines.

Guiding Questions. Experience has shown that the most successful students are those who read with a specific purpose—those who read to answer a question. Consequently, we have developed guiding questions that are presented in the margins next to the appropriate text material. The questions are intended to guide you in your study, stimulate curiosity, and help focus attention on important concepts.

Illustrations. You will find that careful study of the figures and captions is one of the most useful methods of reviewing the content of the chapter.

Key Terms. Important terms are printed in bold type. In the Key Terms section that appears at the end of each chapter, the terms are listed alphabetically, with the number of the page on which each appears. These terms are also defined in the glossary at the end of the book.

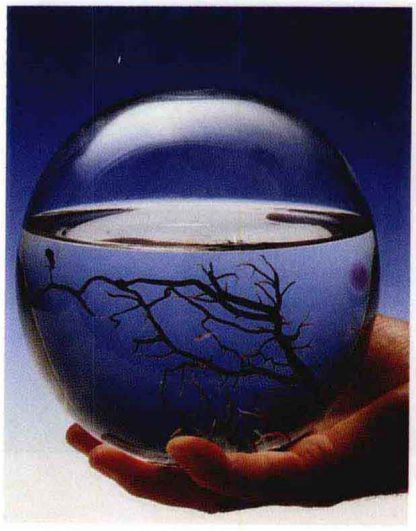
Review Questions. These discussion questions are intended to reinforce the main concepts and stimulate further investigation by pointing out some of the intriguing questions on which scientists are working.

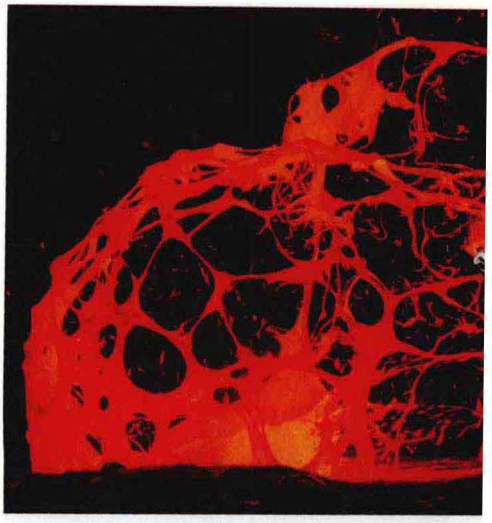
Additional Readings. A reading list at the end of each chapter includes both periodicals and books to direct those who would like to learn more about the topic.

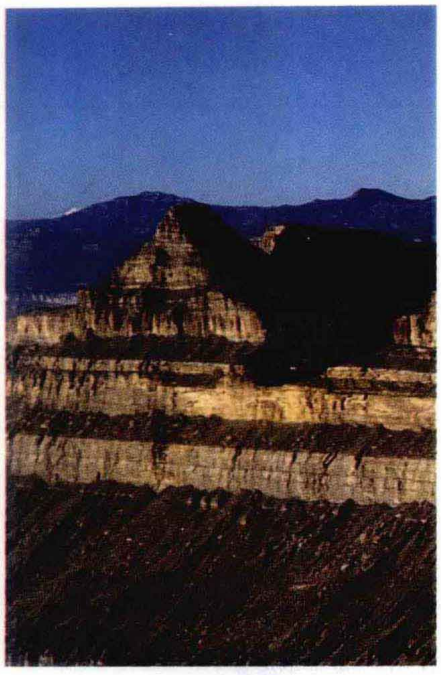
World Wide Web Resources. A list of several Internet addresses is given at the end of each chapter to help you utilize this vast new source of information. We have chosen those sites that reinforce the discussions in each chapter in novel ways with animations, movies, unique illustrations, or timely data.

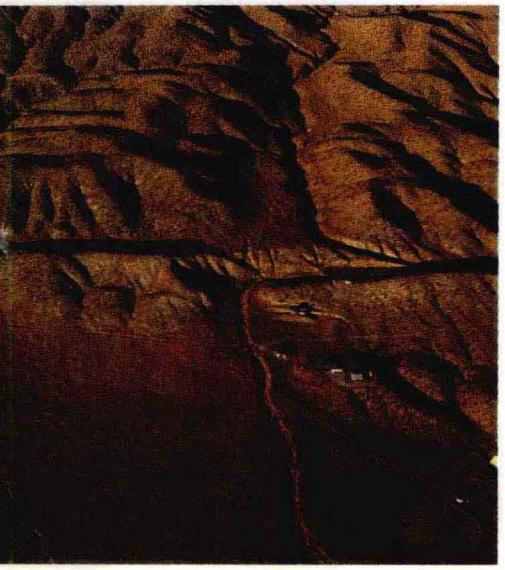
Illustrated Glossary. At the end of the book there is an illustrated glossary defining approximately 800 important geologic terms. Many of the terms are accompanied by an illustration, which will help in visualizing the definition and meaning of the term.

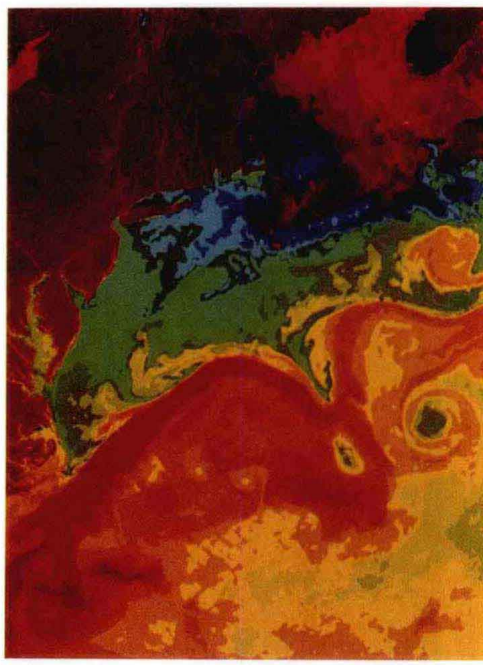
CONTENTS

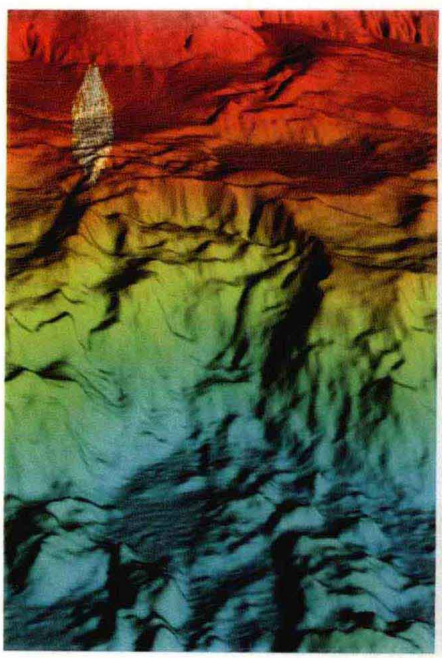


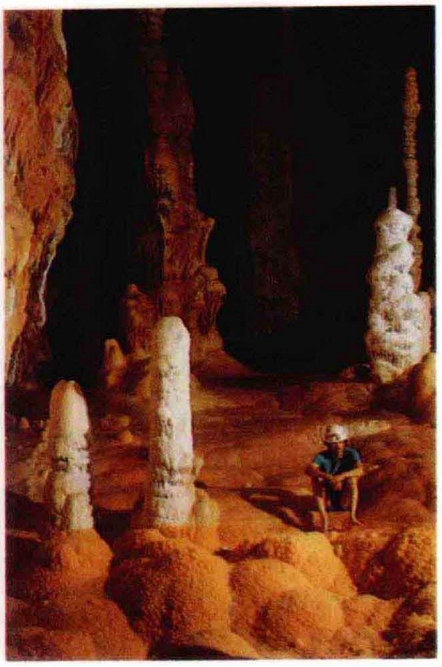


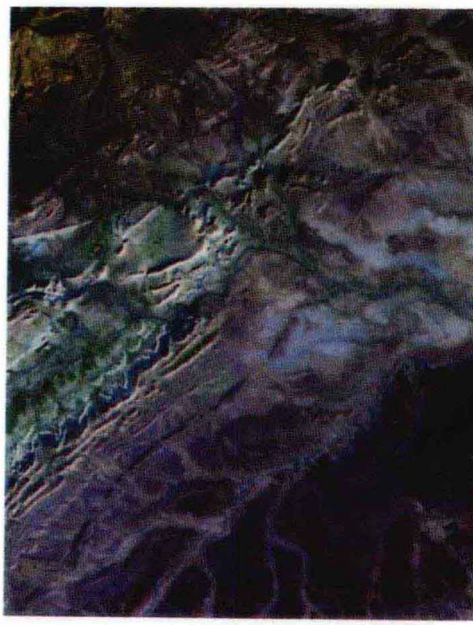


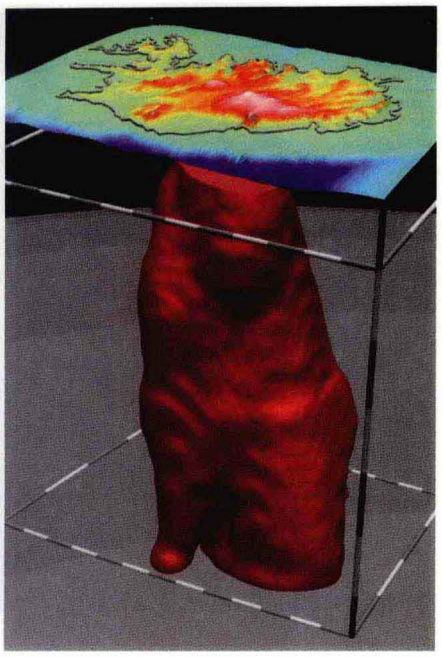


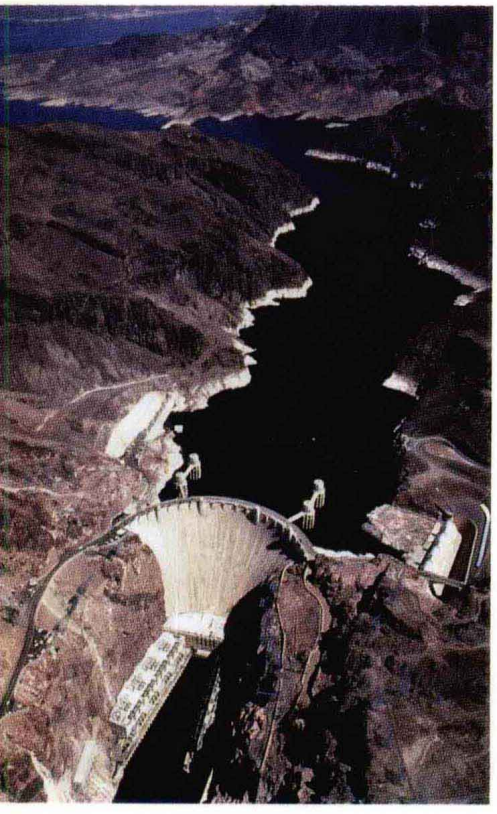












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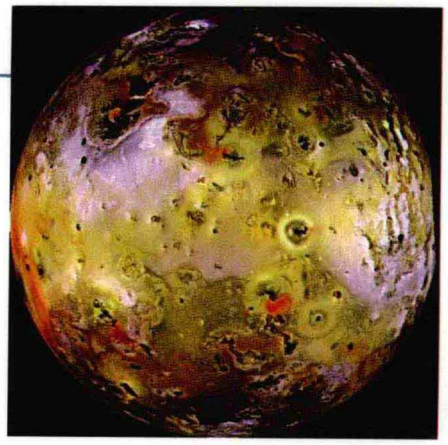

understanding of Earth. It also permitted us to land on the Moon, map the surface of Mars, and survey the diverse landscapes of the moons of Jupiter, Saturn, Uranus, and Neptune. Every object in the solar system contains part of a record of planetary origin and evolution that helps us understand our own planet.

We also have seen the deep ocean floor, mapping its topography and structure and gaining insight into its origin and history. We now know that oceanic crust is completely different from continental crust.

We also have peered into Earth's depths using indirect methods of seismic tomography and discovered how its interior is churning slowly and how it affects processes at the surface.

With these recent perspectives of our planet, we must expand the scope of our study. We now must include not only the classical geologic topics (minerals, rocks, rivers, and such) but also an all-encompassing view of how Earth operates as a constantly changing dynamic system. In this chapter, we compare and contrast Earth with other planets. We describe the major features of continents and ocean basins and view Earth's internal structure—all features that make planet Earth unique in the solar system.

Photograph courtesy of NASA.

Major Concepts

1. A comparison of Earth with other inner planets provides insight into the distinguishing characteristics of our planet and what makes it unique.
2. Earth's atmosphere is a thin shell of gas surrounding the planet. It is a fluid, in constant motion. Other planets have atmospheres, but Earth's is unique because it is 78% nitrogen and 21% oxygen.
3. The hydrosphere is another feature that makes Earth unique. Water moves in a great, endless cycle from the ocean to the atmosphere, over the land surface, and back to the sea again.
4. The biosphere exists because of water. Although it is small compared with other layers of Earth, it is a major geologic force operating at the surface.
5. Continents and ocean basins are the largest-scale surface features of Earth.
6. The continents consist of three major components: (a) ancient shields, (b) stable platforms, and (c) belts of folded mountains. Each reveals the mobility of Earth's crust.
7. The ocean floor contains several major structural and topographic divisions: (a) the oceanic ridge, (b) the vast abyssal floor, (c) trenches, (d) seamounts, and (e) continental margins.
8. Earth is a differentiated planet, with its materials segregated into layers according to density. The internal layers classified by composition are (a) crust, (b) mantle, and (c) core. The major internal layers classified by physical properties are (a) lithosphere, (b) asthenosphere, (c) mesosphere, (d) outer core, and (e) inner core. Material within each of these units is in motion, making Earth a changing, dynamic planet.

INTRODUCTION TO GEOLOGY

Geology is the science of Earth. It concerns all of Earth: its origin, its history, its materials, its processes, and the dynamics of how it changes.

Geology is an incredibly fascinating subject. It is concerned with such diverse phenomena as volcanoes and glaciers, rivers and beaches, earthquakes, and even the history of life. Geology is a study about what happened in the past and what is happening now—a study that increases our understanding of nature and our place in it.

Yet, geology does much more than satisfy intellectual curiosity. We are at a point in human history when Earth scientists have a responsibility to help solve some of society's most pressing problems. These include finding sites for safe disposal of radioactive waste and toxic chemicals, determining responsible land use for an expanding population, and providing safe, plentiful water supplies. Geology is being called upon to guide civil engineers in planning buildings, highways, dams, harbors, and canals. Geology helps us recognize how devastation caused by natural hazards such as landslides, earthquakes, floods, and beach erosion can be avoided or mitigated. Another driving force in our attempt to understand Earth is the discovery of natural resources. All Earth materials, including water, soils, minerals, fossil fuels, and building materials, are "geologic" and are discovered, exploited, and managed with the aid of geologic science.