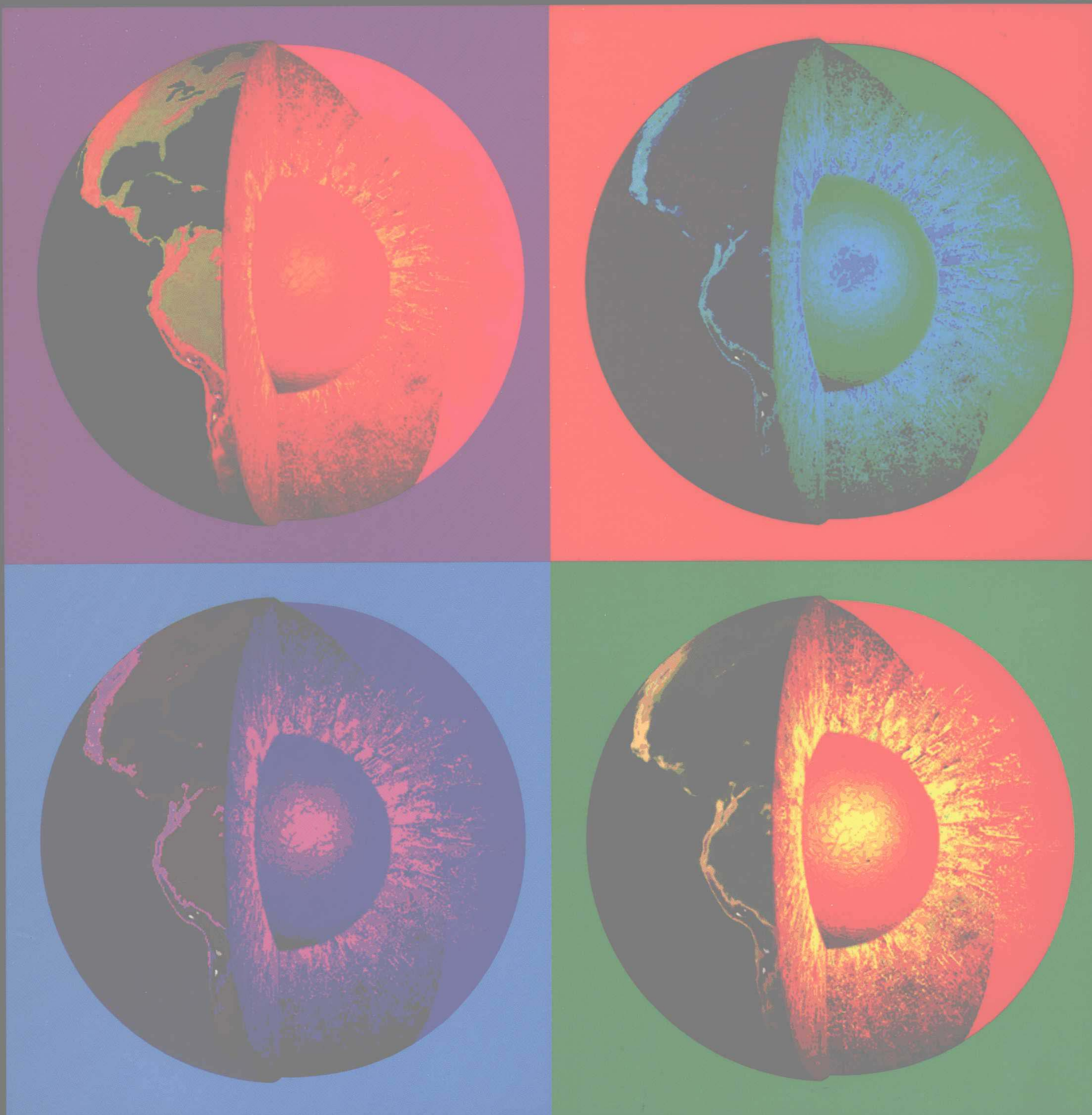
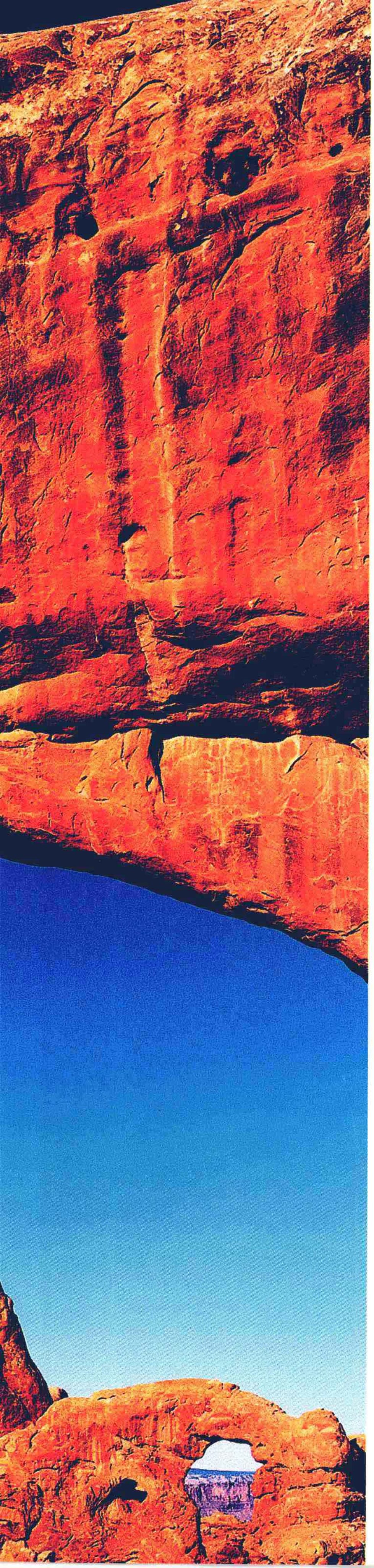
ESSENTIALS OF GEOLOGY



STEPHEN MARSHAK



Essentials of Geology

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W. W. NORTON & COMPANY

NEW YORK LONDON

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Printed in the United States of America.
First Edition.

The text of this book is composed in Stone Serif, with the display set in Frutiger.
Composition by TSI Graphics.
Manufacturing by Courier.

Editor: Jack Repcheck
Director of manufacturing: Diane O'Connor
Photography editors: Ruth Mandel, Neil Ryder Hoos, Sarah Chamberlin, Julia Hines
Project editors: Mary Kelly, Thomas Foley
Layout artists: JoAnn Simony, Roberta Flechner, Cathy Lombardi
Editorial assistant: Julia Hines
Book designer: Joan Greenfield

Library of Congress Cataloging-in-Publication Data

Marshak, Stephen, 1955–
Essentials of geology / Stephen Marshak.
p. cm.
Includes index.

ISBN 0-393-92411-4 (pbk.)

1. Geology. I. Title.

QE28.M3415 2003
550—dc21 2003051197

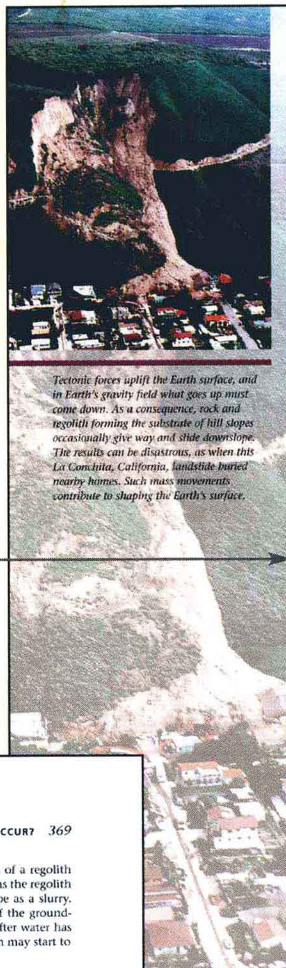
W. W. Norton & Company, Inc., 500 Fifth Avenue, New York, N.Y. 10110
www.wwnorton.com

W. W. Norton & Company Ltd., Castle House, 75/76 Wells Street, London W1T 3QT

1 2 3 4 5 6 7 8 9 0

CHAPTER-OPENING STORY

Most chapters in *Essentials of Geology* begin with a story intended to grab students and propel them into the chapter itself. See, for example, the first page of Chapter 13, "Unsafe Ground," which appears below. What better way to interest students in mass wasting than through recounting the horrific Yungay ice landslide of 1970?



Tectonic forces uplift the Earth surface, and in Earth's gravity field what goes up must come down. As a consequence, rock and regolith forming the substrate of hill slopes occasionally give way and slide downslope. The results can be disastrous, as when this La Conchita, California, landslide buried nearby homes. Such mass movements contribute to shaping the Earth's surface.

CHAPTER 13

Unsafe Ground: Landslides and Other Mass Movements

13.1 INTRODUCTION

It was Sunday, May 31, 1970, a market day, and thousands of people had crammed into the Andean town of Yungay, Peru, to shop. Suddenly they felt the jolt of an earthquake, strong enough to topple some masonry houses. But worse was to come. This earthquake also broke an 800-m-wide ice slab off the end of a glacier at the top of Nevado Huascarán, a nearby 6.6-km-high mountain peak. Gravity instantly pulled the ice slab down the mountain's steep slopes. As it tumbled down over 3.7 km, the ice disintegrated into a chaotic avalanche of chunks traveling at speeds of over 300 km per hour. Near the base of the mountain, most of the avalanche channeled into a valley and thickened into a moving sheet as high as a ten-story building that ripped up rocks and soil along the way. Friction transformed the ice into water, which when mixed with rock and dust created 50 million cubic meters of mud, a slurry viscous enough to carry boulders larger than houses. This mass, sometimes floating on a compressed air cushion that allowed it to pass without disturbing the grass below, traveled over 14.5 km in less than four minutes.

At the mouth of the valley, most of the mass overran the village of Ranrahica and then came to rest, creating a dam that blocked the Santa River. But part of it shot up the sides of the valley and became airborne for several seconds, flying over the ridge bordering Yungay. As the town's inhabitants and visitors stumbled out of earthquake-damaged buildings, they heard a deafening roar and looked up to see the churning mud cloud bursting above the nearby ridge. Moments later, the town was completely buried under several meters of mud and rock. When the dust had settled, only the top of the church and a few palm trees remained visible to show where Yungay once lay (▶Fig. 13.1); 18,000 people are forever entombed beneath the mass. Today, the site is a grassy meadow with a hummocky (irregular and lumpy) surface, spotted by crosses left by mourning relatives.

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13.3 WHY DO MASS MOVEMENTS OCCUR? 369

example, leads to catastrophic mass wasting of the forest's substrate (▶Fig. 13.19).

We've seen that thin films of water create cohesion between grains. Water in larger quantities, though, decreases cohesion, because it fills pore spaces entirely and keeps grains apart (▶Fig. 13.20a, b). Though slightly damp sand makes a better sand castle than dry sand, a slurry of sand and water can't make a castle at all. Thus, the saturation of a regolith with water during a torrential rainstorm weakens the regolith so much that it may begin to move downslope as a slurry. Similarly, if the water table (the top surface of the groundwater layer) rises above a weak glide horizon after water has sunk into the ground, overlying rock or regolith may start to slide over the further weakened glide horizon.

BOX 13.2

THE HUMAN ANGLE

Los Angeles, a Mobile Society

During a year of abundant slumping in southern California, Art Buchwald wrote the following newspaper column.

I came to Los Angeles last week for rest and recreation, only to discover that it had become a rain forest.

I didn't realize how bad it was until I went to dinner at a friend's house. I had the right address, but when I arrived, there was nothing there. I went to a neighboring house where I found a man bailing out his swimming pool.

I beg your pardon, I said. Could you tell me where the Cables live?

"They used to live above us on the hill. Then, about two years ago, their house slid down in the mud, and they lived next door to us. I think it was last Monday, during the storm, that their house slid again, and now they live two streets below us, down there. We were sorry to see them go—they were really nice neighbors."

I thanked him and slid straight down the hill to the new location of the Cables' house. Cable was clearing out the mud from his car. He apologized for not giving me the new address and explained, "Frankly, I didn't know until this morning whether the house would stay here or continue sliding down a few more blocks."

Cable, I said, you and your wife are intelligent people, why do you build your house on the top of a canyon, when you know that during a rainstorm it has a good chance of sliding away?

"We did it for the view. It really was fantastic on a clear night up there. We could sit in our Jacuzzi and see all of Los Angeles, except of course when there were brush fires. Even when our house slid down two years ago, we still had a great sight of the airport. Now I'm not too sure what kind of view we'll have because of the house in front of us, which slid down with ours at the same time."

But why don't you move to safe ground so that you don't have to worry about rainstorms?

"We've thought about it. But once you live high in a canyon, it's hard to move to the plains. Besides, this house is built solid and has about three more good mudslides in it."

Still, it must be kind of hairy to sit in your home during a deluge and wonder where you'll wind up next. Don't you ever have the desire to just settle down in one place?

"It's hard for people who don't live in California to understand how we people out here think. Sure we have floods, and fire and drought, but that's the price you have to pay for living the good life. When Esther and I saw this house, we knew it was a dream come true. It was located right on the tippy top of the hill, way up there. We would wake up in the morning and listen to the birds, and eat breakfast out on the patio and look down on all the smog.

"Then, after the first mudslide, we found ourselves living next to people. It was an entirely different experience. But by that time we were ready for a change. Now we've slid again and we're in a whole new neighborhood. You can't do that if you live on solid ground. Once you move into a house below Sunset Boulevard, you're stuck there for the rest of your life.

"When you live on the side of a hill in Los Angeles, you at least know it's not going to last forever."

Then, in spite of what's happened, you don't plan to move out?

"Are you crazy? You couldn't replace a house like this in L.A. for $500,000."

What happens if it keeps raining and you slide down the hill again?

"It's no problem. Esther and I figure if we slide down too far, we'll just pick up and go back to the top of the hill, and start all over again; that is, if the hill is still there after the earthquake."

SOCIETAL AND ENVIRONMENTAL ISSUES

As inhabitants of the Earth, we interact with geology every day. Our expanding population, our consumption of nonrenewable resources, and the necessity or choice of people to live in geologically dangerous areas (such as beaches frequented by vicious storms) make the treatment of geology and its impact on human society more relevant than ever. *Essentials of Geology* treats these topics both in focused chapters on natural hazards, resources, and global change and in special boxes called "The Human Angle."

STATE-OF-THE-ART ILLUSTRATIONS

One of Stephen Marshak's goals in *Essentials of Geology* was to develop art that conveys the dynamic way geologic processes work. Marshak worked directly with a team of top artists to create figures that are clear and simple enough for students to understand but realistic enough to provide a reference framework. These spectacular 3-D illustrations are accompanied by photographs to help students visualize real geology. All of the illustrations and most of the photographs are available to instructors as PowerPoint slides on the Norton Media Library CD-ROM that accompanies the text.

418 **CHAPTER 15: RESTLESS REALM**

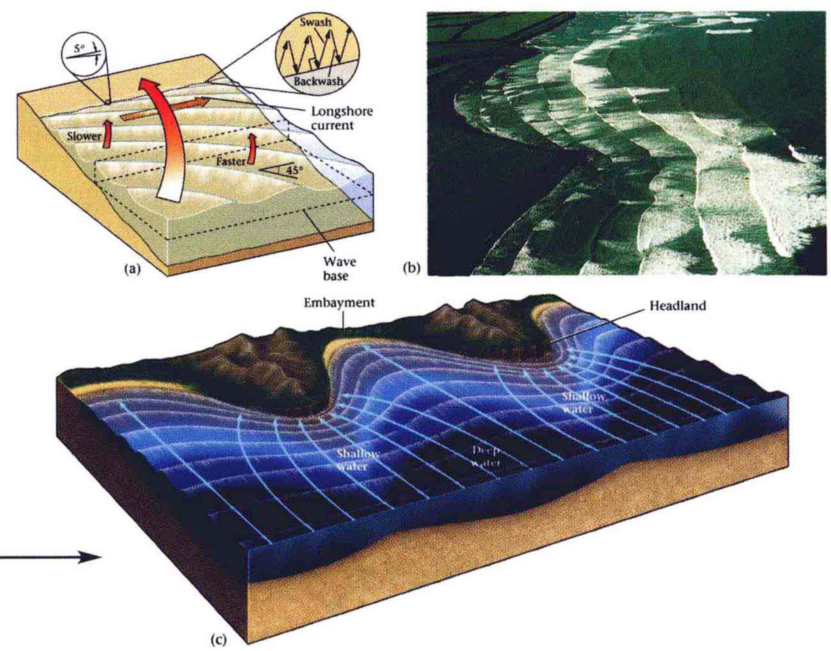


FIGURE 15.16 (a) Wave refraction occurs when waves approach the shore at an angle. The part of the wave that touches bottom first slows down, then the rest of the wave catches up. As a result, the wave bends so that it's nearly parallel with the shore. However, because the wave hits the shore at an angle, water moving parallel to the shore creates a longshore current. (b) Wave refraction on a beach. (c) Like a lens, wave refraction focuses wave energy on a headland, so erosion occurs; and it disperses wave energy in embayments, so deposition occurs.

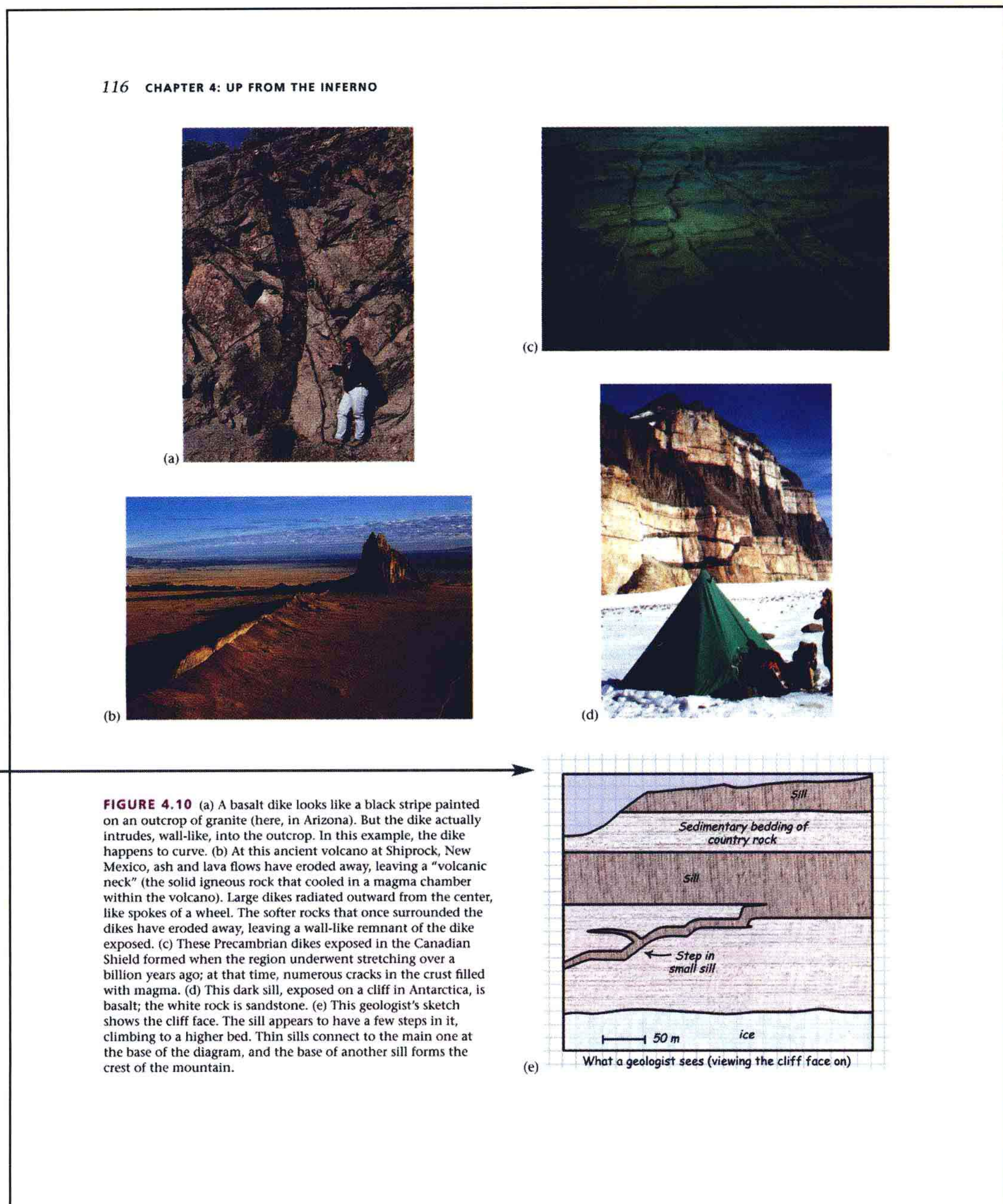
shells. And beaches derived by the recent erosion of basalt may have black sand, made of tiny basalt grains.

A **beach profile,** a cross section drawn perpendicular to the shore, illustrates the shape of a beach (Fig. 15.15). Starting from the sea and moving landward, a beach consists of a **foreshore zone,** or **intertidal zone,** across which the tide rises and falls. The **beach face,** a steeper, concave part of the foreshore zone, forms where the swash of the waves actively scours the sand. The **backshore zone** extends from a small step, or escarpment, cut by high-tide swash to the front of the dunes or cliffs that lie farther inshore. The backshore zone includes one or more **berms,** horizontal to landward-sloping terraces that received sediment during a storm.

Geologists commonly refer to beaches as "rivers of sand," to emphasize that beach sand moves along the coast over time—it is not a permanent substrate. Wave action at the shore moves an active sand layer on the sea floor on a daily basis. Inactive sand, buried below this layer, moves only during severe storms or not at all. Where waves hit the beach at an angle, the swash of each successive wave moves active sand up the beach at an angle to the shoreline, but the backwash moves this sand down the beach parallel to the slope of the shore. This sawtooth motion causes sand to

WHAT A GEOLOGIST SEES

Stephen Marshak has developed a clever device to show students how thoughtful observation can reveal a great deal of information. Using simple drawings, he conveys what a trained geologist sees when viewing a photograph of a landscape. The untrained eye sees only a pretty picture—a geologist sees a page of Earth history.



116 CHAPTER 4: UP FROM THE INFERNO

(a)

(c)

(b)

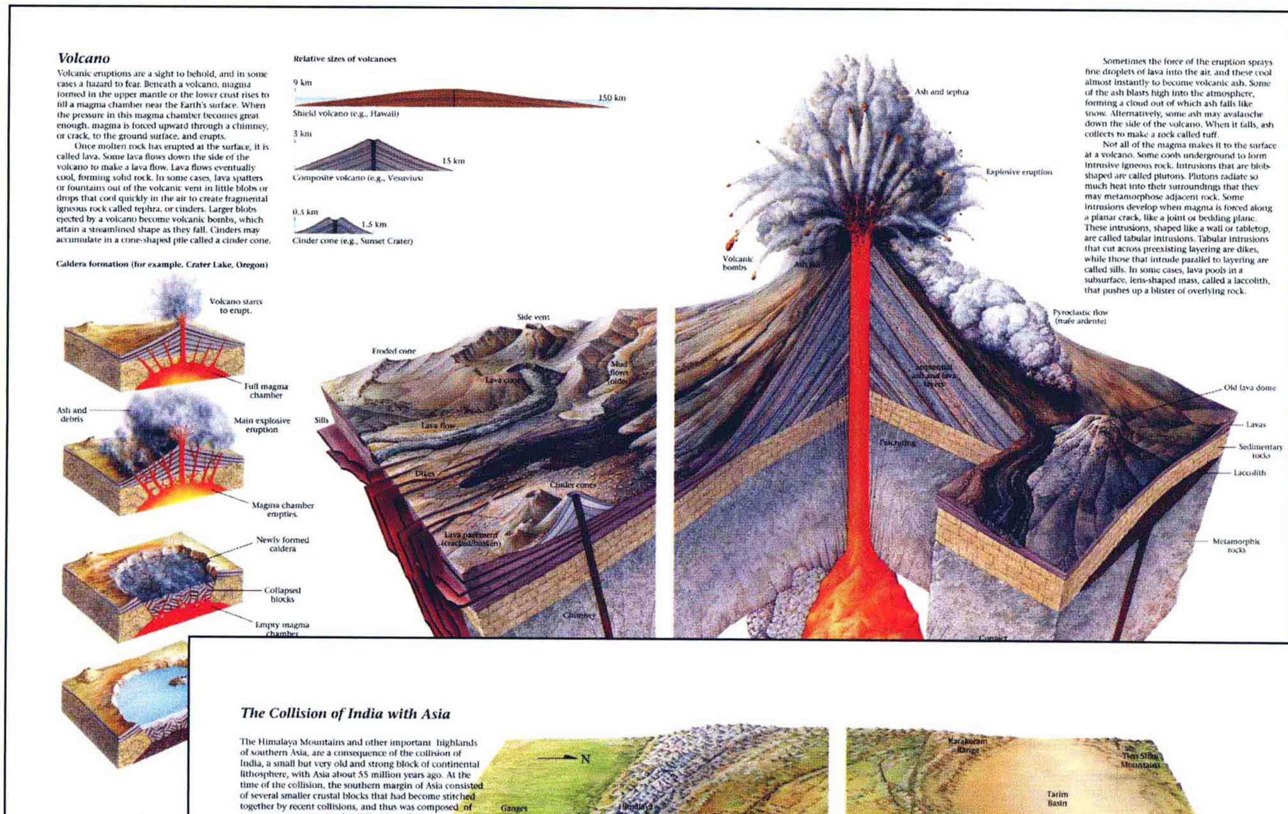
(d)

(e)

FIGURE 4.10 (a) A basalt dike looks like a black stripe painted on an outcrop of granite (here, in Arizona). But the dike actually intrudes, wall-like, into the outcrop. In this example, the dike happens to curve. (b) At this ancient volcano at Shiprock, New Mexico, ash and lava flows have eroded away, leaving a "volcanic neck" (the solid igneous rock that cooled in a magma chamber within the volcano). Large dikes radiated outward from the center, like spokes of a wheel. The softer rocks that once surrounded the dikes have eroded away, leaving a wall-like remnant of the dike exposed. (c) These Precambrian dikes exposed in the Canadian Shield formed when the region underwent stretching over a billion years ago; at that time, numerous cracks in the crust filled with magma. (d) This dark sill, exposed on a cliff in Antarctica, is basalt; the white rock is sandstone. (e) This geologist's sketch shows the cliff face. The sill appears to have a few steps in it, climbing to a higher bed. Thin sills connect to the main one at the base of the diagram, and the base of another sill forms the crest of the mountain.

TWO-PAGE SYNOPTIC PAINTINGS

These comprehensive paintings by the most respected geologic artist in the world—Gary Hincks—are designed to encapsulate a number of topics. Each of the paintings in *Essentials of Geology* is a complete synopsis of a major part of a chapter. By studying them carefully, students can see interconnections among subtopics covered in the chapter.



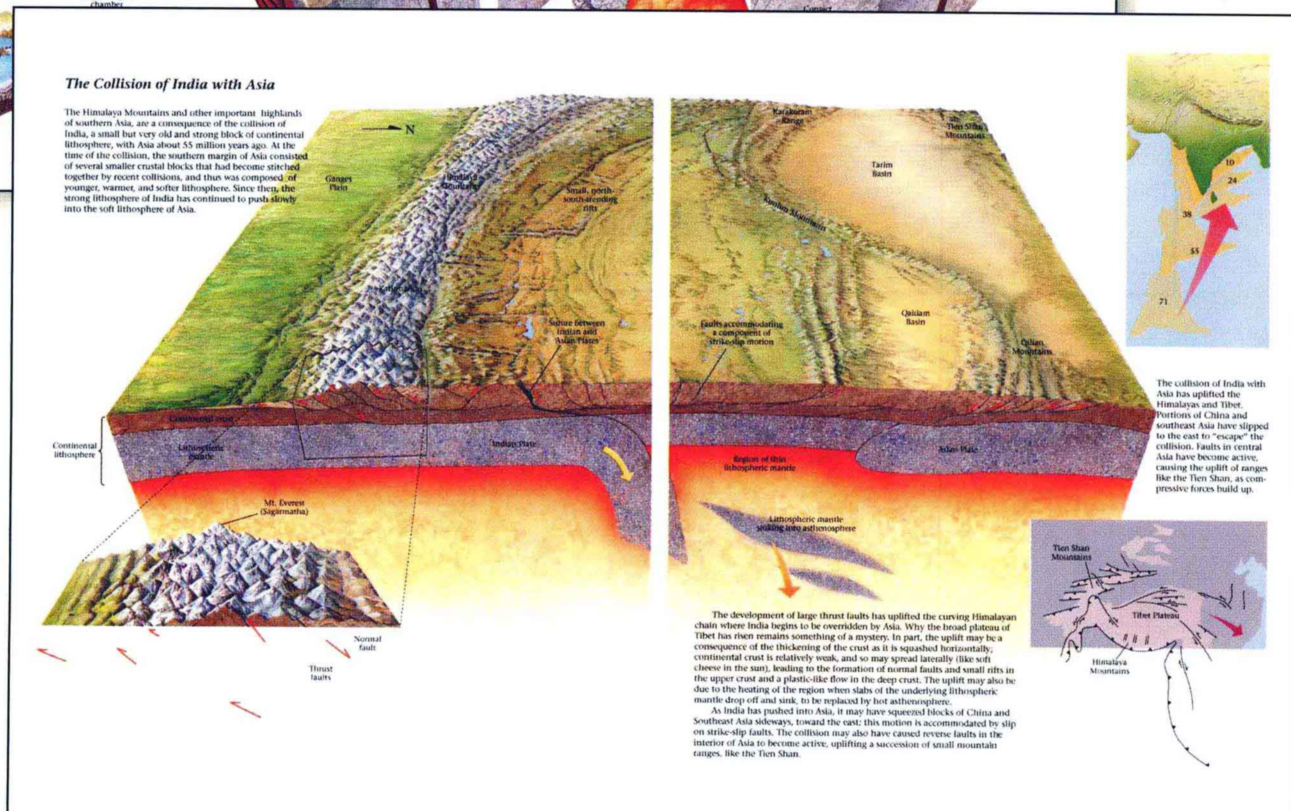
Volcano

Volcanic eruptions are a sight to behold, and in some cases a hazard to fear. Beneath a volcano, magma formed in the upper mantle or the lower crust rises to fill a magma chamber near the Earth's surface. When the pressure in this magma chamber becomes great enough, magma is forced upward through a chimney, or crack, to the ground surface, and erupts.

Once molten rock has erupted at the surface, it is called lava. Some lava flows down the side of the volcano to make a lava flow. Lava flows eventually cool, forming solid rock. In some cases, lava spatters or fountains out of the volcanic vent in little blobs or drops that cool quickly in the air to create fragmental igneous rock called tephra, or cinders. Larger blobs ejected by a volcano become volcanic bombs, which attain a streamlined shape as they fall. Cinders may accumulate in a cone-shaped pile called a cinder cone.

Sometimes the force of the eruption sprays fine droplets of lava into the air, and these cool almost instantly to become volcanic ash. Some of the ash blasts high into the atmosphere, forming a cloud out of which ash falls like snow. Alternatively, some ash may avalanche down the side of the volcano. When it falls, ash collects to make a rock called tuff.

Not all of the magma makes it to the surface at a volcano. Some cools underground to form intrusive igneous rock. Intrusions that are blob-shaped are called plutons. Plutons radiate so much heat into their surroundings that they may metamorphose adjacent rock. Some intrusions develop when magma is forced along a planar crack, like a joint or bedding plane. These intrusions, shaped like a wall or tabletop, are called tabular intrusions. Tabular intrusions that cut across preexisting layering are dikes, while those that intrude parallel to layering are called sills. In some cases, lava pools in a subsurface, lens-shaped mass, called a laccolith, that pushes up a blister of overlying rock.



The Collision of India with Asia

The Himalaya Mountains and other important highlands of southern Asia, are a consequence of the collision of India, a small but very old and strong block of continental lithosphere, with Asia about 55 million years ago. At the time of the collision, the southern margin of Asia consisted of several smaller crustal blocks that had become stitched together by recent collisions, and thus was composed of younger, warmer, and softer lithosphere. Since then, the strong lithosphere of India has continued to push slowly into the soft lithosphere of Asia.

The development of large thrust faults has uplifted the curving Himalayan chain where India begins to be overridden by Asia. Why the broad plateau of Tibet has risen remains something of a mystery. In part, the uplift may be a consequence of the thickening of the crust as it is squashed horizontally; continental crust is relatively weak, and so may spread laterally (like soft cheese in the sun), leading to the formation of normal faults and small rifts in the upper crust and a plastic-like flow in the deep crust. The uplift may also be due to the heating of the region when slabs of the underlying lithospheric mantle drop off and sink, to be replaced by hot asthenosphere.

As India has pushed into Asia, it may have squeezed blocks of China and Southeast Asia sideways, toward the east; this motion is accommodated by slip on strike-slip faults. The collision may also have caused reverse faults in the interior of Asia to become active, uplifting a succession of small mountain ranges, like the Tien Shan.

The collision of India with Asia has uplifted the Himalayas and Tibet. Portions of China and southeast Asia have slipped to the east to "escape" the collision. Faults in central Asia have become active, causing the uplift of ranges like the Tien Shan, as compressive forces build up.

BOXED INSERTS AND SCIENTIFIC APPENDIX

In addition to "The Human Angle" boxes, *Essentials of Geology* features other boxes that enhance the presentation of important topics and issues. Of particular note are the boxes and appendix that provide background information in physics and chemistry to help students that need it.

BOX 15.1

SCIENCE TOOLBOX

The Coriolis Effect

Imagine you are spinning a playground merry-go-round counterclockwise around a vertical axis at a rate of 10 revolutions per minute. The circumference of the outer edge of the merry-go-round is 5 m. Thus, Emma, a child sitting at the outer edge, moves at a velocity of 50 m per minute, whereas David, a child sitting at the center, spins around an axis but moves at zero velocity. If Emma were to try throwing a ball at David by aiming directly along a radius, the ball would veer to the right of the radius and miss David, because the ball is not only moving in the direction parallel to a radius line, but also moving a little in the direction parallel to the edge of the circle. If David were to throw a ball along a radius to Emma, this ball would miss Emma because the revolution of the merry-go-round moves her relative to the ball's trajectory (▶Fig. 15.9a, b).

The rotation of the Earth creates the same phenomenon. Earth spins counterclockwise around its axis, so a cannon shell fired parallel to a line of longitude from the equator to the North Pole veers to the right (east), because as it moves north, it is traveling east faster than the land beneath it (▶Fig. 15.9c). Similarly, a cannon shell fired from the equator to the South Pole veers to the left (east). A cannon shell fired along a line of longitude from the North Pole toward the equator veers to the right (west) because the Earth is moving faster to the east at the equator (▶Fig. 15.9d). German artillerymen learned this lesson during World War I, when shells they aimed at Paris from a distance of 100 km landed about 1 km to the right of their target.

In 1835, a French engineer named Gaspard Gustave de Coriolis (1792–1843) proposed that a similar effect would cause the deflection of winds and currents on the surface of the Earth. Because of this **Coriolis effect**, north-flowing currents in the Northern Hemisphere deflect to the east, while south-flowing currents deflect to the west. The opposite is true in the Southern Hemisphere (▶Fig. 15.9e).

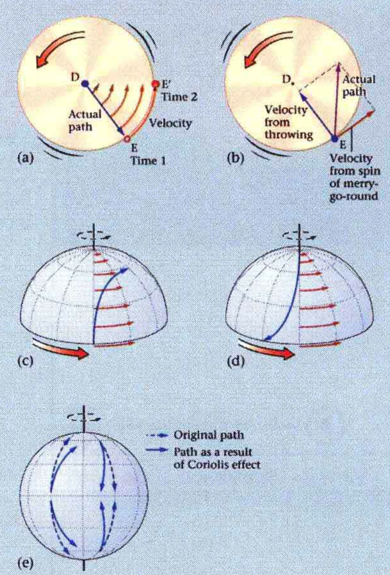
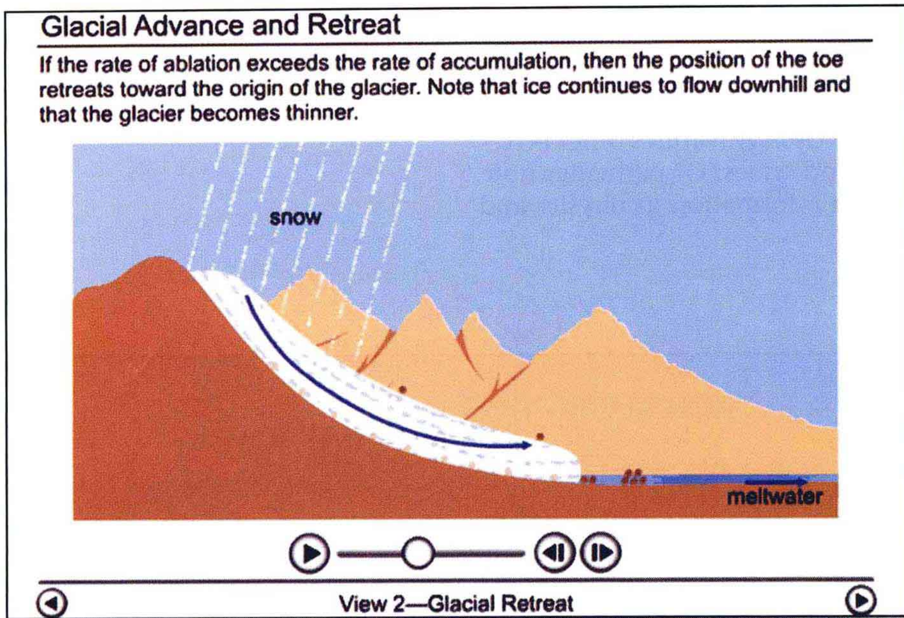
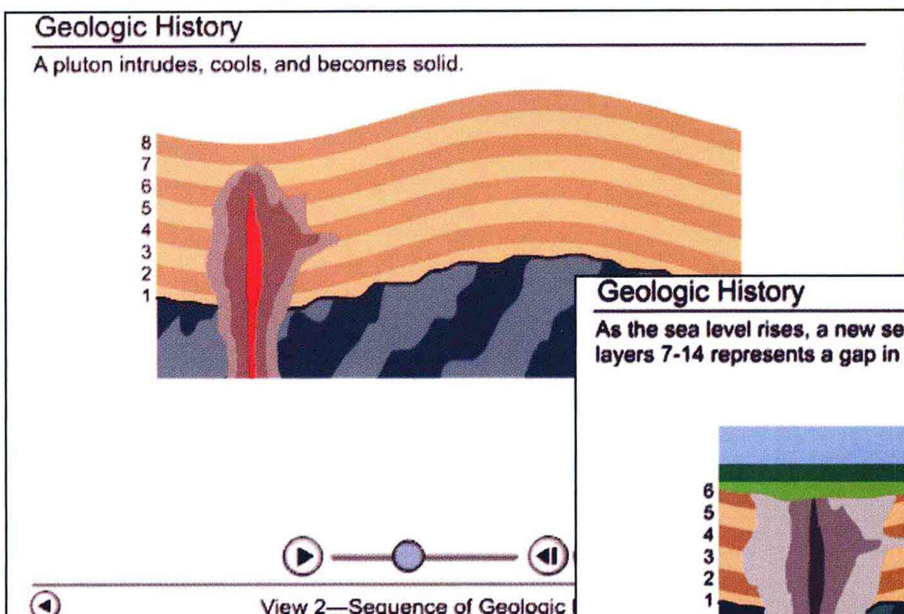
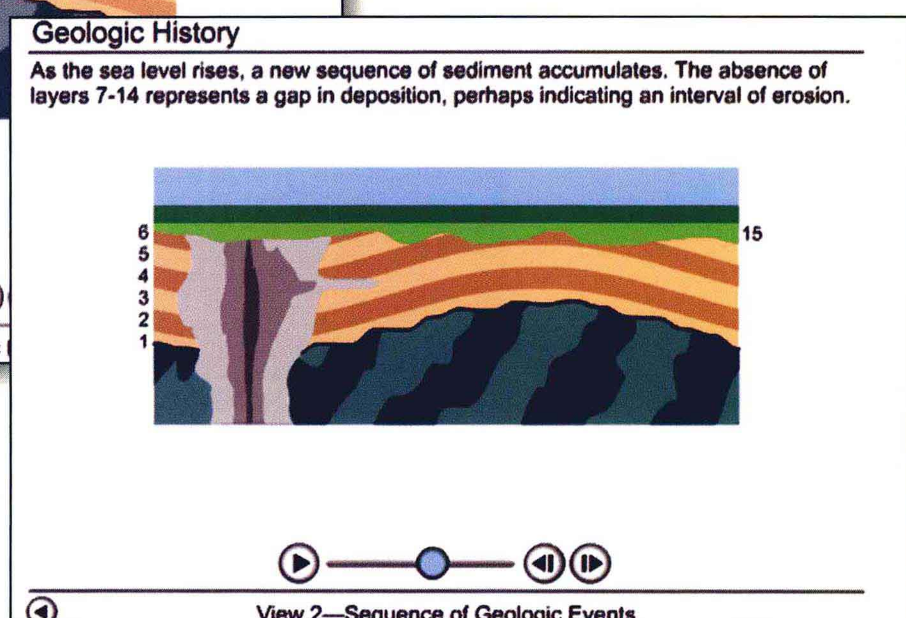


FIGURE 15.9 The Coriolis effect. (a, b) The velocity of a point on the rim of this spinning merry-go-round is greater than the velocity at the center. A ball thrown from the center (D) to an observer at point E would follow a straight line, but while the ball is in the air, the catcher on the rim moves from point E to point E'. Relative to the surface of the merry-go-round, the ball looks like it follows a curved path—but remember, the ball goes straight, it's the surface that moves underneath the ball. A ball aimed from the rim to the center won't go straight to the center, because it moves parallel to the rim at the point of departure. Again, since the merry-go-round is moving under the ball, the ball appears to follow a curved path with respect to the surface of the merry-go-round. (c, d) The same phenomenon happens on Earth. A projectile shot from the equator to the pole in the Northern Hemisphere is deflected to the east, while a projectile shot from the pole to the equator is deflected to the west. (e) Thus, on the Earth, north-flowing currents in the Northern Hemisphere are deflected eastward, and south-flowing currents are deflected westward, while the opposite is true in the Southern Hemisphere.







ANIMATIONS

Geology is all about dynamic processes, and that dynamic quality is difficult to present on the printed page. Modern computer technology and graphics now allow for the creation of animations that demonstrate the movements and interactions that define geology. Stephen Marshak has worked with talented animators to create 31 animations to accompany *Essentials of Geology*, the goal of which is to allow students to visualize these often-hidden processes. The art in these is intentionally simple, so that during the course of the animation, students can easily follow the key elements. These animations are included on the instructor's CD-ROM, student CD-ROM, and student Web site (see pp. xiv–xv for a complete list and description of supplements for students and instructors).

DEDICATION

To Kathy, David, and Emma, who helped in (and put up with!) this endeavor in so many ways over the years it resided in our home

The modern science of geology (or geoscience), the study of the Earth, began in the late eighteenth century. So in comparison with other sciences, geology is a young subject. But over the past two centuries, thousands of geologists have provided answers to a wide range of questions: Why do earthquakes and volcanoes happen? What causes mountains to rise? How do Earth's varied landscapes develop and change through time? How has the climate changed through time? When did our planet form, and by what process? Where do we dig to find valuable ore, and where do we drill to find oil? Indeed, a look at almost any natural feature leads to a new question, and new questions fuel the need for new research. Thus, geoscience remains an active and exciting field today.

Before the mid-twentieth century, geoscientists studied each of the questions listed above on its own, without considering its relation to other issues. But since 1960, there have been two "paradigm-shifting" ideas that have unified thinking about the Earth and its features. The first idea, called the theory of plate tectonics, shows that the Earth's outer shell, rather than being static, consists of discrete plates that constantly move very slowly, so that the map of our planet constantly changes. We now understand that plate interactions cause earthquakes and volcanoes, build mountains, provide gases for the atmosphere, and affect the distribution of life on Earth. The second idea, called the concept of Earth systems science, emphasizes that the planet's water, land, atmosphere, and living inhabitants are dynamically interconnected. Earth materials constantly cycle among various living and nonliving reservoirs on, above, and within the planet, and the history of life is intimately linked to the history of the physical Earth.

Essentials of Geology is an introduction to geology that weaves the theory of plate tectonics and the concept of Earth systems science into its narrative from the beginning, and thus strives to create a modern, coherent image of our planet.

NARRATIVE THEMES

To develop a complete understanding of the Earth, students must go beyond vocabulary and be aware of fundamental concepts, or narrative themes, that explain how the Earth works. These themes provide a peg-board on which to hang observations and ideas, and allow students to make connections between them. Several narrative themes (discussed more fully in the Prelude) are emphasized throughout the text:

1. The Earth is a complex system in which the solid Earth, the oceans, the atmosphere, and life are interconnected to yield a planet unique in the solar system.
2. Most geological processes can be understood in the context of plate tectonics theory.
3. The Earth is a planet, formed like other planets from dust and gas, but a constantly changing one.
4. The Earth is very old—about 4.6 billion years old. During this time, the map of the planet and its surface features have changed, and life has evolved.
5. Internal processes (driven by Earth's internal heat) and external processes (driven by heat from the Sun) interact at the Earth's surface to create our landscapes.
6. Natural hazards—earthquakes, volcanoes, landslides, floods—and processes such as the depletion of oil and gas reserves are of vital interest to us all.
7. Physical features of the Earth are linked to life processes.
8. Science comes from observation, and people make scientific discoveries.
9. The study of geology can increase science literacy.

ORGANIZATION

The topics covered in this book have been arranged so that students can build their knowledge of geology on a foundation of basic concepts. Thus, the book starts with cosmology and the formation of the Earth, and then introduces the architecture of our planet, from surface to center. With this background, we can delve into plate tectonics theory. Plate tectonics appears early, a departure from standard practice in introductory geology texts, so that students can relate all subsequent chapters to this concept. Knowing about plate tectonics, for example, helps students understand the next suite of chapters on minerals, rocks, and the rock cycle. A knowledge of plate tectonics and rocks together then provides a basis for learning about volcanoes, earthquakes, and mountains. And with this background, we can see how the map of the Earth has changed through the vast expanse of geologic time, and how energy and mineral resources have developed.

The final chapters of the book address processes and problems occurring at or near the Earth's surface, from the unstable slopes of hills, down the course of rivers, to the shores of the sea and beyond. This section concludes with a topic of growing concern in society—global change, particularly climate change.

SPECIAL FEATURES

Broad Application

Essentials of Geology provides concise coverage of topics used in an introductory geology course. It has been shortened, relative to its progenitor (*Earth: Portrait of a Planet*), by removal of topics less frequently covered in an introductory geology course, and by simplification of the treatment of the remaining topics.

Flexible Organization

Though the sequence of chapters was chosen for a reason, this book is designed to be flexible enough for instructors to choose their own strategies for teaching geology. Thus, each chapter is largely self-contained, reiterating relevant material or at least referring to other chapters where certain topics can be reviewed. This apparent redundancy in some parts of the text is intentional, for geology is a nonlinear subject: the individual topics are so interrelated that there is not always a single best way to order them.

Societal Issues

Geology's practical applications are addressed in several chapters. Students will learn about such topics as energy resources, mineral resources, global change, and mass wasting. Further, chapters on earthquakes, volcanoes, and landscapes highlight geological hazards. And students are encouraged to apply their geological understanding to environmental issues, where relevant.

Boxed Inserts

Throughout the text, boxes expand on specific topics by giving further scientific background, additional detail, or related information that's just plain interesting.

Detailed Illustrations

It's hard to understand features of the Earth system without being able to see them. To help students visualize topics, this book is lavishly illustrated, with figures that attempt to give a realistic context for a geologic feature without overwhelming students with extraneous detail. The talented artists who worked on the book have "pushed the envelope" of modern computer graphics, and the result is the most realistic pedagogical art ever provided by a geoscience text.

Photographs from around the world have been assembled for this book. Where appropriate, they are accompanied by annotated sketches labeled "What a geologist sees," to help students discover what the photos show.

Featured Paintings

In addition to individual figures, British painter Gary Hincks has provided spectacular two-page spreads for most chapters. These paintings illustrate key concepts introduced in the chapters and visually emphasize the relationships between components of the Earth system.

SUPPLEMENTS

For Instructors

1. *Norton Media Library with PowerPoint Slides*
Included on this CD-ROM (dual platform) are approximately 100 photographs, 300 state-of-the-art illustrations from the text, and 31 unique and dynamic Flash animations. Developed by Stephen Marshak in collaboration with Precision Graphics, and by Declan DePaor, these animations illustrate key geologic principles that are difficult to convey through static images. Some examples:

- Transform faulting
- Plate boundaries
- Hot-spot volcanoes
- Subduction
- Rifting
- Mineral growth
- The formation of oceanic crust
- The formation of cross beds
- Transgression and regression
- Types of faults
- Seismic-wave motion
- How a seismograph works
- Types of unconformity
- Folding
- Geologic history
- Oil formation and trapping
- The evolution of a meandering stream
- Glacial advance and retreat
- Milankovitch cycles

Designed for lecture display or student use, these animations can be enlarged to full-screen view, and feature VCR-like controls that allow you to pause, fast-forward, or rewind for more effective use in the classroom.

2. *Overhead Transparency Set*
The text illustrations are featured in a full set of transparency acetates.

3. *Test-Item File*
Prepared by Stephen Marshak, Terry Engelder of Pennsylvania State University, and John Werner of Seminole Community College, Florida, this test bank contains over 1,200 multiple-choice and true-false test questions. It is available in printed form or in Norton TestMaker (MicroTest III), a flexible electronic testing system for IBM-compatible or Macintosh computers. The computerized test-item file includes approximately 700 additional multiple-choice and true-false questions from the Study Guide.

4. *Instructor's Resource Manual*
This manual, prepared by John Werner, contains useful material to assist instructors as they prepare their lectures.

For Students

1. *Essentials of Geology* Website
This resource features interactive animations of dynamic processes, with an emphasis on plate tectonics, geologic hazards, and Earth systems science concepts. Overviews, key terms and definitions, crossword puzzles, and multiple-choice quizzes test students' understanding of chapter content. Biweekly *Earth Science News* updates from *Newswise.com* and specially commissioned articles help them to apply their knowledge and further highlight the relevancy and inherent interest of geologic concepts.

2. *Essentials of Geology* CD-ROM
Selected contents from the student website are also available on a free CD-ROM packaged with every copy of the text.

3. *Study Guide*
Written by Rita Leafgren of the University of Northern Colorado, this thorough review provides summaries and study advice for each chapter, recall and matching exercises, short-answer questions, figure-labeling exercises, and practice tests.

ACKNOWLEDGMENTS

I am very grateful for the assistance of many people in bringing this book from the concept stage to the shelf. First and foremost, I wish to thank my family. My wife Kathy helped throughout in the overwhelming task of keeping track of text and figures. In addition, she edited text, copied drafts, checked proofs, and provided invaluable advice. My daughter Emma spent many nights helping to organize figures, and my son David helped me keep the project in perspective. During the early stages, I benefited greatly from discussions with Philip Sandberg, who contributed ideas that helped establish the organization and tone of the book. Donald Prothero assisted at a later stage by contributing text and editorial comments, and providing some of the end-of-chapter questions and suggested readings. I also wish to thank Fernando Alkmim, who helped me figure out the best way to explain some of the complex topics in the book.

The publisher, W. W. Norton, has been incredibly supportive and generous in their investment in this project. I am particularly grateful to the editorial staff. Jack Repcheck, the editor, has been a constant source of ideas and encouragement. Susan Gaustad and Mary Kelly have been outstanding copy editors, who have come up with wonderful suggestions for wordings. April Lange and Julia Hines expertly coordinated the development of ancillaries, particularly the CD-ROM. Ruth Mandel and, later, Neil Hoos, Sarah Chamberlin, and most recently Julia Hines have been outstanding photo researchers, incorporating my own photographs and locating spectacular photos from contributors. Diane O'Connor, Thom Foley, and Marian Johnson ably managed the Herculean task of overseeing production for the book. Steve Mosberg and Rick Mixter helped get the book started and their participation is greatly appreciated.

The illustrations have involved many artists. Precision Graphics, of Champaign, Illinois, has done a phenomenal job of producing overwhelming volumes of high-quality figures on short notice. Joanne Bales of PG has been particularly helpful in working out the details of figure design with me and in coordinating the artists who worked on the book. Stan Maddock helped create the style of the figures, and produced a great many of them. George Kelvin drew a number of the figures in the earlier chapters. And Gary Hincks has produced the incredible two-page spreads, in part using his own designs and geological insight. Some of Gary's paintings appeared earlier in *Earth Story,* BBC Worldwide, 1998. This artwork is closely based on illustrations jointly conceived by Simon Lamb and Felicity Maxwell, working with Gary.

I also much appreciate insightful reviews or discussions of the manuscript by the following geologists. The careful comments by Barbara Tewksbury were particularly valuable.

Jack C. Allen, Bucknell University
David W. Andersen, San Jose State University
Philip Astwood, University of South Carolina
Keith Bell, Carleton University
Mary Lou Bevier, University of British Columbia
George S. Clark, University of Manitoba
Patrick M. Colgan, Northeastern University
John W. Creasy, Bates College
Robert T. Dodd, State University of New York at Stony Brook
James E. Evans, Bowling Green State University
William D. Gosnold, University of North Dakota
Bryce M. Hand, Syracuse University
Donna M. Jurdy, Northwestern University
Robert Lawrence, Oregon State University
John A. Madsen, University of Delaware
Charlie Onasch, Bowling Green State University
Lisa M. Pratt, Indiana University
Bob Reynolds, Central Oregon Community College
Kevin G. Stewart, University of North Carolina at Chapel Hill
Barbara Tewksbury, Hamilton College
Thomas M. Tharp, Purdue University
Kathryn Thorbjarnarson, San Diego State University
Robert T. Todd, SUNY Stony Brook
Jon Tso, Radford University
William E. Sanford, Colorado State University
Alan Whittington, University of Missouri
Lorraine W. Wolf, Auburn University
Christopher J. Woltemade, Shippensburg University

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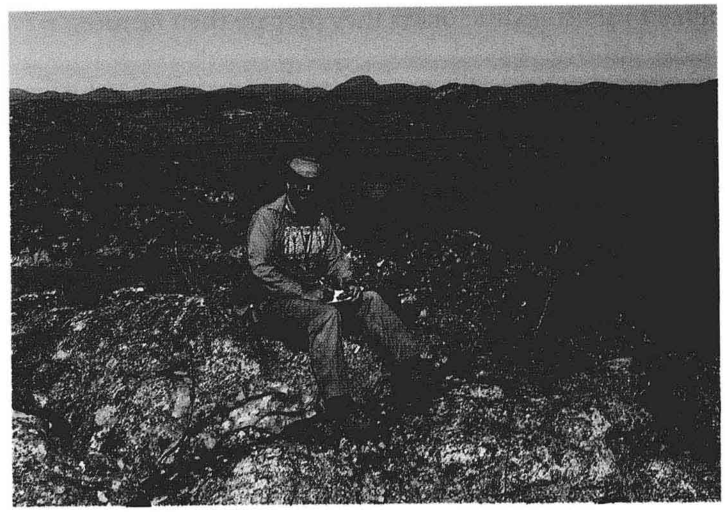

Stephen Marshak is currently professor and head of the Department of Geology at the University of Illinois, Urbana-Champaign. He holds an A.B. from Cornell University, an M.S. from the University of Arizona, and a Ph.D. from Columbia University (Lamont-Doherty Earth Observatory). Steve's research interests lie in the fields of structural geology and tectonics. He has served as chair of the Division of Structural Geology and Tectonics of the Geological Society of America, and as a member of the National Science Foundation Panel for Tectonics. Over the years, he has had the opportunity to explore geology in the field on several continents. Recently, his work has focused on understanding the development of mountain belts, particularly in the ancient crust of Brazil (the accompanying photograph was taken in Serra do Espinhaço in eastern Brazil). Steve has been on the faculty of the University of Illinois since 1983, teaching courses in introductory geology, structural geology, tectonics, field geology, and petroleum geology, and has won the university's highest teaching award. In addition to authoring *Earth: Portrait of a Planet,* he shares authorship on two other books: *Basic Methods of Structural Geology* and *Earth Structure: An Introduction to Structural Geology and Tectonics.* He has also published numerous research articles.

THANKS!

I greatly appreciate your selection of this book as your entrée into the science of geology. This is a first edition, and as such can certainly benefit from input by users. I welcome your comments, especially if you find text or figures that are in error or not clear. Please contact me at: smarshak@uiuc.edu.

Stephen Marshak

ESSENTIALS OF GEOLOGY

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