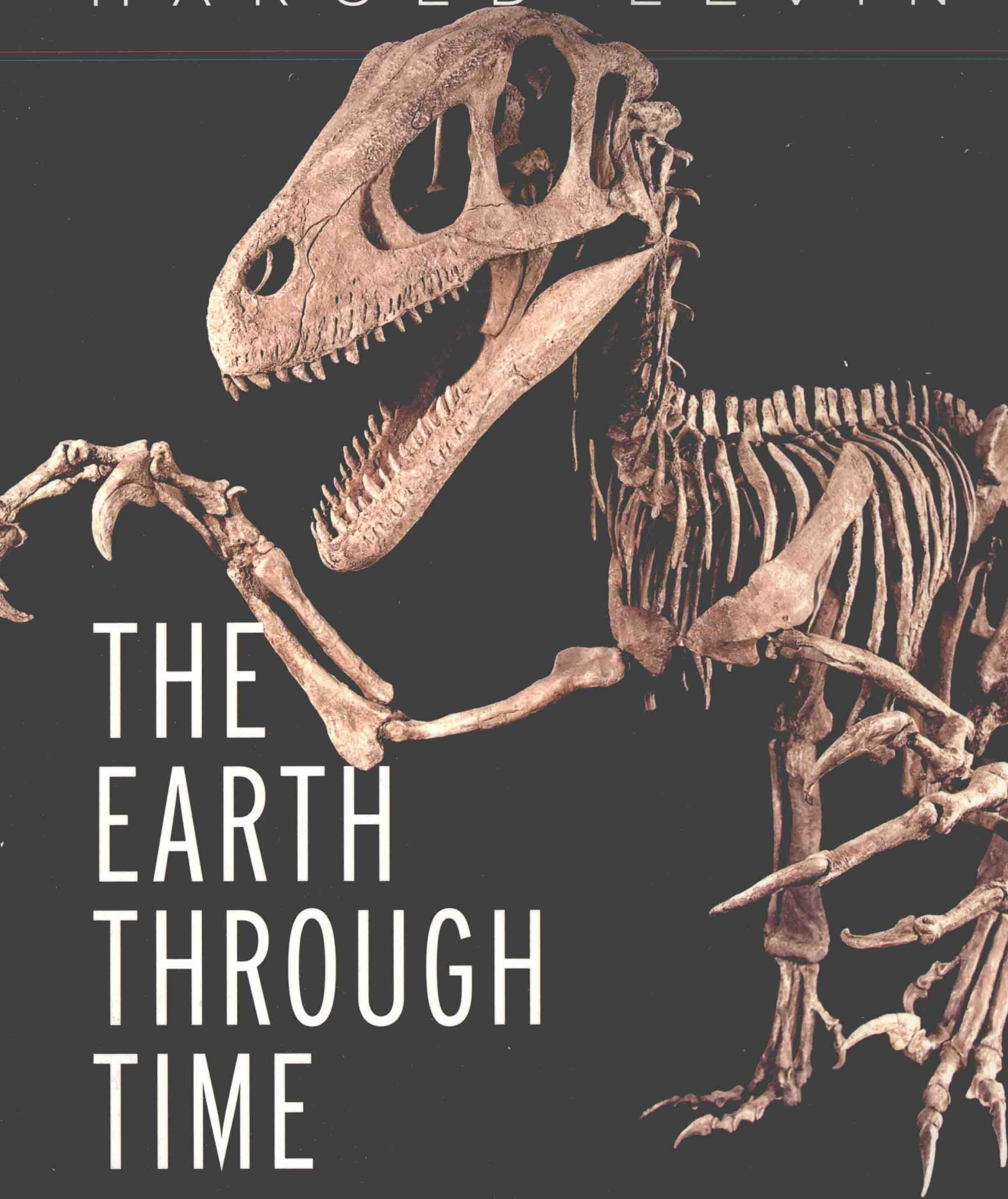


H A R O L D L E V I N



THE EARTH THROUGH TIME

EIGHTH EDITION

E I G H T H E D I T I O N

The Earth Through Time

H A R O L D L . L E V I N

Professor of Geology
Washington University,
St. Louis, Missouri



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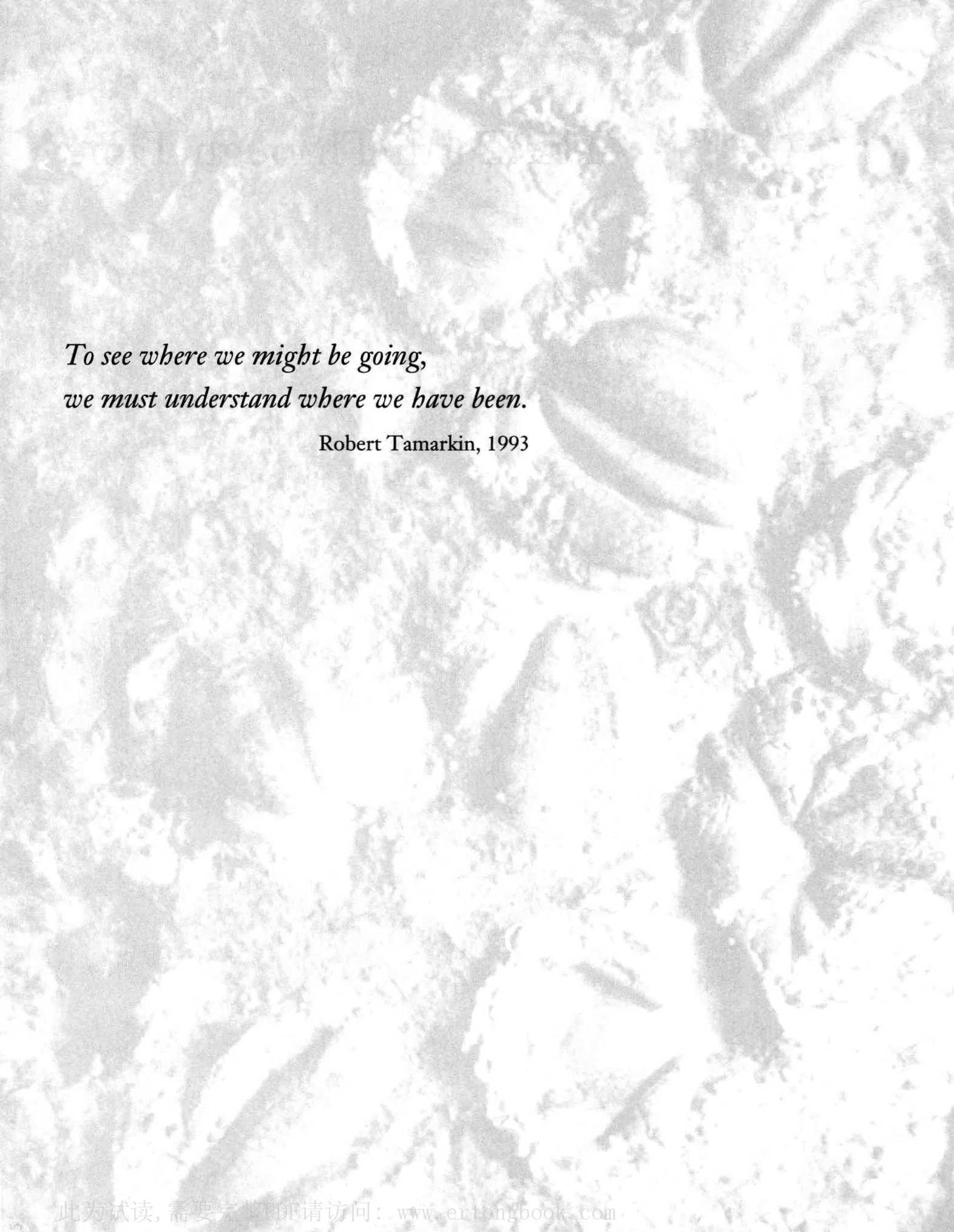
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EIGHTH EDITION

The Earth Through Time



*To see where we might be going,
we must understand where we have been.*

Robert Tamarkin, 1993

This book is dedicated to my wife Kay, who has cheerfully endured my preoccupation with preparing this new edition, and to Noah, Lillie, Eli, Mollie, Natalie, Emily, Caitlyn, Hannah, and Candis. May they have the wisdom to treat the Earth kindly.

ABOUT THE AUTHOR



Harold ("Hal") Levin began his career as a petroleum geologist in 1956 after receiving bachelor's and master's degrees from the University of Missouri and a doctorate from Washington University. His fondness for teaching brought him back to Washington University in 1962, where he is currently professor of geology and paleontology in the Department of Earth and Planetary Sciences. His writing

efforts include authorship of seven editions of *The Earth Through Time*; four editions of *Contemporary Physical Geology*; *Essentials of Earth Science*; and co-authorship of *Earth: Past and Present*, as well as eight editions of *Laboratory Studies in Historical Geology*; *Life Through Time*; and, most recently, *Ancient Invertebrates and Their Living Relatives*.

For his courses in physical geology, historical geology, paleontology, sedimentology, and stratigraphy, Hal has received several awards for excellence in teaching. The accompanying photograph was taken during a lecture on life of the Cenozoic Era. The horse skull serves to illustrate changes in the teeth and jaws of grazing animals in response to the spread of prairies and savannahs during the Miocene and subsequent epochs.

The Earth Through Time is an excursion into the Earth's geologic past. The trip began about four and a half billion years ago, approaching the time when our planet had gathered most of its mass from a rotating cloud of dust, gases, and meteorites. From that time to the present, the Earth has undergone constant change. Ocean floors have expanded and moved, continents have broken apart, sea floors have been thrust skyward to form mountain ranges, and once peaceful landscapes have been disrupted by earthquakes and fiery floods of lava. Since about 3 billion years ago, life has existed on this dynamic planetary surface. Fossil remains of ancient life attest to their successes and failures in coping with perpetually changing conditions.

How the Earth and its inhabitants have changed provides a fascinating story. The story alone is sufficient reason for undertaking a study of the Earth's geologic past. Historical geology, however, has value in many other ways as well. As a science, it informs us about the way science works, how discoveries are made, and how to tell the difference between valid and shoddy interpretations. Past events also relate to many problems we face today, including, global warming, environmental pollution, depletion of vital mineral resources, and the adverse effects of loss of animal and plant species. Understanding science, and realizing how each component of our past and present planet interacts with all other components will promote informed decisions about the many environmental issues now being debated in our governing bodies.

Determining the cause of past geologic events is a complex task. As an example, one might infer that the demise of a particular group of ancient animals resulted from cooling of the planet. This leads us to ask *why* cooling occurred. Was it the result of changes in the composition of the atmosphere, changes in the amount of radiation received from the sun, the upheaval of wind-diverting mountain ranges, changes in the Earth's axis of rotation, or shifts in the location of lands and seas? The answers come only after study of the reciprocal actions of all the Earth's systems: the solid Earth, the atmosphere, and the biosphere. This integrated approach applies well both to the solution of contemporary problems and to an understanding of happenings in the remote geologic past. It is an approach embodied in this text.

As in earlier editions, this revision of *Earth Through Time* is designed to meet the requirements of the un-

dergraduate student who has had little or no previous acquaintance with geology. However, for those exploring the possibility of an academic major in geology, the text will provide the initial background needed for advanced courses. Information about geologic materials and processes are included in *Earth Through Time* so that the book can be used either for a single, self-contained first course, or for the second course in a two semester sequence of Physical and Historical Geology.

THE EIGHTH EDITION

The preparation of a new edition provides many opportunities to refashion and improve explanations, to develop better illustrations, and to constructively expand, delete, and reorganize. The greatest effort in this revision has been to make the narrative more lively and engaging, to clearly convey the unique perspective and value of historical geology, and to improve the presentation so as to enhance the student's ability to retain essential concepts.

In this eighth edition, seventeen chapters have been organized under three major divisions. Part I, *Discovering Time and Deciphering Earth's Amazing History*, explains the methods used in reconstructing the Earth's geologic history, introduces contributions made by early geologists to the science, and describes how rocks are dated and then used to construct the geologic time scale. Part II, *Rocks and What They Tell Us About Earth History* describes the nature and origin of Earth materials, and how rocks and fossils can reveal events of the geologic past. In Part III, *History of Planet Earth and Its Inhabitants* we explore the actual history of our planet from its fiery birth to the unfolding of the modern world.

WHAT KINDS OF PEDAGOGY DOES EARTH THROUGH TIME PROVIDE?

Earth Through Time has a variety of features to engage the student and promote learning.

- Technical terms are printed in **boldface** type the first time they are used, and clearly defined, both in the text and in the glossary.
- So that students will know what lies ahead, each chapter begins with a concise list of **Key Chapter Concepts**.

- Each chapter ends with a **Summary** of essential concepts. These provide students with a reality check. If the summary statement is not understood, it is a cue for the student to visit that topic in the chapter again.
- A list of **Key Terms** is provided. If the student does not remember the meaning of a term, it provides another opportunity to check their understanding of concepts developed in the chapter.
- **Questions for Review** allows students to test their understanding of material in a chapter and to further “process” what they have learned.

Caption questions occur beneath many photographs. These questions draw attention to geologic features depicted in the images, and clarify explanations in the text.

- Appendices in *Earth Through Time* include a **Classification of Living Things** that helps students place fossils described in the text in their correct taxonomic position, a **Glossary** containing a list of important terms and their definitions, Physiographic, political and bedrock geology **maps**, the **Periodic Table and Symbols for Chemical Elements**, **Convenient Conversion Factors**, an explanation of **Exponential or Scientific Notation**, a **Table of Rock Symbols**, and a table providing the composition and physical properties of **Common Rock-Forming Silicate Minerals**.
- Most chapters feature one or more boxes. The **Enrichment** boxes discuss some topics of general interest that relate to material in the chapter, and the **National Parks and Monuments** boxes provide an example of a location where the geology discussed can be directly seen.
- To help students correlate events they are reading about in the text to their actual time of occurrence, small time scales containing an age indicator accompany many photographs of rock formations and fossils.

SUPPLEMENTS

The eighth edition of *The Earth Through Time* is accompanied by an extensive set of supporting materials. These include:

A **Student Study Guide** prepared by Harry Wagner of Victoria College. Designed to enhance students’ understanding of the text, the guide includes Chapter Overviews, Learning Objectives for each chapter, Questions for Review, Key Terms, illustrations and maps.

An **Instructor’s Manual and Test Bank** has been prepared by David T. King Jr., of Auburn University. To facilitate use of the text by instructors, the manual

includes chapter outlines, questions that can be incorporated into examinations, and answers to questions in the textbook.

Computerized Test Banks are available in three disk versions: Windows, IBM, and Macintosh.

A set of 100 full-color **Overhead Transparencies** is provided for use in the laboratory or lecture hall, as well as a set of one-hundred 25-mm slides of illustrations and photographs.

Earth Sciences Instructor’s Resource CD-ROM provides numerous images from this and other John Wiley & Sons geology texts.

John Wiley and Sons, Inc. may provide complementary instructional aids and supplementary packages to those adopters qualified under our adoption policy. Please contact your sales representative for more information.

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B R I E F C O N T E N T S

CHAPTER 1

The Science of Historical Geology 1

CHAPTER 2

Early Geologists Tackle History's
Mysteries 11

CHAPTER 3

Time and Geology 27

CHAPTER 4

Rocks and Minerals: Documents that
Record Earth's History 47

CHAPTER 5

The Sedimentary Archives 77

CHAPTER 6

Life on Earth: What Do Fossils Reveal? 117

CHAPTER 7

Plate Tectonics Underlies All Earth
History 162

CHAPTER 8

Earliest Earth: 2,100,000,000 Years of the
Archean Eon 208

CHAPTER 9

The Proterozoic: Dawn of a More Modern
World 243

CHAPTER 10

Early Paleozoic Events 267

CHAPTER 11

Late Paleozoic Events 295

CHAPTER 12

Life of the Paleozoic 327

CHAPTER 13

Mesozoic Events 373

CHAPTER 14

Life of the Mesozoic 405

CHAPTER 15

Cenozoic Events 451

CHAPTER 16

Life of the Cenozoic 487

CHAPTER 17

Human Origins 525

APPENDICES A1

GLOSSARY G1

INDEX I1

CHAPTER 1

The Science of Historical Geology 1

- Why Study Earth History? 2
- Geology Lives in the Present and the Past 2
- A Way To Solve Problems: The Scientific Method 3
- Three Great Themes in Earth History 6
- What Lies Ahead? 8

CHAPTER 2

Early Geologists Tackle History's Mysteries 11

- The Intrigue of Fossils 12
- An Early Scientist Discovers Some Basic Rules 13
- European Researchers Unravel the Succession of Strata 15
- Neptunists and Plutonists Clash 15
- Uniformitarianism: James Hutton Recognizes that the Present is Key to the Past 16
- The Principle of Fossil Succession 18
- The Great Uniformitarianism–Catastrophism Controversy 18
- The Principle of Cross-cutting Relationships 19
- Evolution: How Organisms Change through Time 20
- Earth History in America 22

CHAPTER 3

Time and Geology 27

- Finding the Age of Rocks: Relative versus Actual Time 27
- A Scale of Geologic Time 28
- Actual Geologic Time: Clocks in the Rocks 32
- Radioactivity Provides a Way to Date Rocks 33
- What Occurs When Atoms Decay? 35
- The Principle Radioactive Timekeepers 38

CHAPTER 4

Rocks and Minerals: Documents that Record Earth's History 47

- Minerals as Documents of Earth History 48
- Minerals and Their Properties 48
- Common Minerals that Form Rocks 50

Earth's Three Great Rock Families and How They Formed 55

- Igneous Rocks: "Fire-Formed" 56
- Sedimentary Rocks: Layered Pages of History 65
- Metamorphic Rocks: Changed without Melting 69

CHAPTER 5

The Sedimentary Archives 77

- Tectonic Setting is the Biggest Factor in Sediment Deposition 78
- Environments Where Deposition Occurs 80
- What Rock Color Tells Us 86
- What Rock Texture Tells Us 86
- ENRICHMENT You Are the Geologist 89
- What Sedimentary Structures Tell Us 90
- What Four Sandstone Types Reveal About Tectonic Setting 95
- Limestones and How They Form 98
- Organizing Strata To Solve Problems 98
- Sea-level Change Means Dramatic Environmental Change 102
- Stratigraphy and the Correlating of Rock Bodies 103
- Unconformities: Something is Missing 105
- Depicting the Past 106

GEOLOGY OF NATIONAL PARKS AND MONUMENTS

- Grand Canyon National Park 113

CHAPTER 6

Life on Earth: What Do Fossils Reveal? 117

- Fossils: Surviving Records of Past Life 120
- ENRICHMENT Amber, the Golden Preservative 123
- Figuring Out How Life is Organized 124
- Evolution: Continuous Changes in Life 128
- The Case for Evolution 136
- Fossils and Stratigraphy 139
- Fossils Indicate Past Environments 143
- ENRICHMENT Earbones Through the Ages 144
- How Fossils Indicate Paleogeography 149
- How Fossils Indicate Past Climates 152
- An Overview of the History of life 153
- Life on Other Planets: Are We Alone 156

CHAPTER 7

Plate Tectonics Underlies All Earth History 162

- Earthquake Waves Reveal Earth's Mysterious Interior 162
- Earth's Internal Zones 163
- Earth's Two Types of Crust 167
- Broken, Squeezed, or Stretched Rocks Produce Geologic Structures 168
- Plate Tectonics Theory Ties it All Together 171
- Drifting Continents 174
- Evidence for Continental Drift 175
- Paleomagnetism: Ancient Magnetism Locked into Rocks 178
- Today's Plate Tectonics Theory 181
- What Happens at Plate Margins? 187
- What Drives Plate Tectonics? 189
- Verifying Plate Tectonics Theory 191
- Thermal Plumes, Hotspots, and Hawaii 196
- ENRICHMENT** Rates of Plates 197
- Exotic Terranes 199
- GEOLOGY OF NATIONAL PARKS AND MONUMENTS**
- Hawaii Volcanoes National Park 200

CHAPTER 8

Earliest Earth: 2,100,000,000 Years of the Archean Eon 208

- Earth in Context: A Little Astronomy 208
- ENRICHMENT** The Origin of the Universe 213
- A Solar System Tour, from Center to Fringe 214
- Following Accretion, Earth Differentiates 219
- The Primitive Atmosphere—Virtually No Oxygen 222
- The Primitive Ocean and the Hydrologic Cycle 224
- Origin of Precambrian “Basement” Rocks 224
- The Origin of Life 230
- GEOLOGY OF NATIONAL PARKS AND MONUMENTS**
- Voyageurs National Park 238
- In Retrospect 239

CHAPTER 9

The Proterozoic: Dawn of a More Modern World 243

- Highlights of the Paleoproterozoic (2.5 to 1.6 billion years ago) 245
- ENRICHMENT** The 18.2-Hour Proterozoic Day 247
- Highlights of the Mesoproterozoic (1.6 to 1.0 billion years ago) 249

- ENRICHMENT** BIF: Civilization's Indispensable Treasure 250

- Highlights of the Neoproterozoic (1.0 to 542 million years ago) 251
- Proterozoic Rocks South of the Canadian Shield 253
- ENRICHMENT** Heliotropic Stromatolites 254
- Proterozoic Life 255

CHAPTER 10

Early Paleozoic Events 267

- Dance of the Continent 269
- Some Regions Tranquil, Others Active 269
- Identifying the Base of the Cambrian 273
- Early Paleozoic Events 273
- Cratonic Sequences: The Seas Come in, the Seas Go Out 274
- The Sauk and Tippecanoe Sequences 275
- Way Out West: Events in the Cordillera 278
- Deposition in the Far North 281
- Dynamic Events in the Past 281

GEOLOGY OF NATIONAL PARKS AND MONUMENTS

- Jasper National Park 282
- ENRICHMENT** A Colossal Ordovician Ash Fall: Was it a Killer? 284
- The Caledonian Orogenic Belt 288
- ENRICHMENT** The Big Freeze in North Africa 290
- Aspects of Early Paleozoic Climate 290

CHAPTER 11

Late Paleozoic Events 295

- Epicontinental Sea on the Craton 298
- Unrest in the West 303
- To the East, a Clash of Continents 306
- ENRICHMENT** The Wealth of Reefs 309
- Sedimentation and Orogeny in the West 316
- Europe During the Late Proterozoic 319
- Gondwana During the Late Paleozoic 320
- Climates of the Late Paleozoic 320
- Mineral Productions of the Late Paleozoic 321
- GEOLOGY OF NATIONAL PARKS AND MONUMENTS**
- Acadia National Park 322

CHAPTER 12

Life of the Paleozoic 327

- Animals with Shells Proliferate—and so does Preservation 329
- The Cambrian Explosion of Life: Amazing Fossil Sites in Canada and China 330

Continuing Diversification: Each Creature Found Its Ecological Niche	333
Protistans: Creatures of a Single Cell	334
Marine Invertebrates Populate the Seas	335
ENRICHMENT The Eyes of Trilobites	349
Advent of the Vertebrates	353
The Rise of Fishes	354
Conodonts: Valuable but Enigmatic Fossils	359
Advent of Tetrapods	360
Plants of the Paleozoic	363
Mass Extinctions	366

CHAPTER 13

Mesozoic Events 3 7 3

The Breakup of Pangea	374
The Mesozoic in Eastern North America	375
The Mesozoic in Western North America	378
GEOLOGY OF NATIONAL PARKS AND MONUMENTS	
Zion National Park	382
ENRICHMENT Did Seafloor Spreading Cause Cretaceous Epicontinental Seas?	388
GEOLOGY OF NATIONAL PARKS AND MONUMENTS	
Grand Staircase-Escalante National Monument	394
The Tethys Sea in Europe	396
ENRICHMENT Chunneling Through the Cretaceous	399
Gondwana Events	399

CHAPTER 14

Life of the Mesozoic 4 0 5

Climate Controls It All	407
Mesozoic Invertebrates	409
Mesozoic Vertebrates	415
Dinosaurs: "Terrifying Lizards"	417
ENRICHMENT Can We Bring Back the Dinosaurs?	424
GEOLOGY OF NATIONAL PARKS AND MONUMENTS	
Dinosaur National Monument	426
Dinosaurs: Cold-Blooded, Warm-Blooded, or Both?	429
Dinosaur Parenting	430
The Flying Archosaurs	431
A Return to the Sea	433
The Rise of Birds	437
The Mammalian Vanguard	437
Sea Plants and Phytoplankton	439
Land Plants	441
Late Cretaceous Catastrophe	443
ENRICHMENT Is There a Bolide in Our Future?	446

CHAPTER 15

Cenozoic Events 4 5 1

The Tectonics-Climate Connection	452
Stability and Erosion along the North American Eastern Margin	454
Gulf Coast: Transgressing and Regressing Sea	455
Tectonics and Erosion in the Rockies	455
ENRICHMENT Oil Shale	459
Creating the Basin and Range Province	460
GEOLOGY OF NATIONAL PARKS AND MONUMENTS	
Badlands National Park	461
Colorado Plateau Uplift	464
Columbia Plateau and Cascades Volcanism	464
ENRICHMENT Hellish Conditions in the Basin and Range Province	464
Sierra Nevada and California	467
The New West Coast Tectonics	467
Meanwhile, Drama Overseas . . .	470
Big Freeze: The Pleistocene Ice Age	473
Why Did Earth's Surface Cool	480
Cenozoic Climates	483

CHAPTER 16

Life of the Cenozoic 4 8 7

Grasslands Expand, Mammals Respond	489
Plankton	490
Marine Invertebrates	492
Vertebrates	496
Mammals	499
Monotremes	501
Marsupials	501
Placental Animals	504
ENRICHMENT How the Elephant Got Its Trunk	517
Demise of the Pleistocene Giants	521

CHAPTER 17

Human Origins 5 2 5

Primates	526
Modern Primates	527
The Prosimian Vanguard	528
The Early Anthropoids	529
The Australopithecine Stage and the Emergence of Hominids	532
The <i>Homo Erectus</i> Stage	537
ENRICHMENT Being Upright: Good News, Bad News	538
Final Stages of Human Evolution	538
ENRICHMENT Neandertal Ritual	540

Humans Arrive in the Americas 543

Population Growth 544

APPENDIX A

Classification of Living Things A1

APPENDIX B

Physiographic Provinces of the
United States A6

APPENDIX C

World Political Map A7

APPENDIX D

Periodic Table and Symbols for Chemical
Elements A9

APPENDIX E

Convenient Conversion Factors A12

APPENDIX F

Exponential or Scientific Notation A13

APPENDIX G

Rock Symbols A13

APPENDIX H

Bedrock Geology A14

APPENDIX I

Common Rock-Forming Silicate Minerals A15

GLOSSARY G1

INDEX I1

The Science of Historical Geology

*To see where we might be going,
we must understand where we have been.*

—Robert Tamarkin, 1993

OUTLINE

- ▶ PART I—DISCOVERING TIME AND DECIPHERING EARTH'S AMAZING HISTORY
- ▶ WHY STUDY EARTH HISTORY?
- ▶ GEOLOGY LIVES IN THE PRESENT AND THE PAST
- ▶ A WAY TO SOLVE PROBLEMS: THE SCIENTIFIC METHOD
- ▶ THREE GREAT THEMES IN EARTH HISTORY
- ▶ WHAT LIES AHEAD?
- ▶ SUMMARY
- ▶ KEY TERMS
- ▶ QUESTIONS FOR REVIEW AND DISCUSSION
- ▶ WEB SITES

Key Chapter Concepts

- The study of events in the Earth's past can often be used to predict future events.
- The Earth and its inhabitants have undergone continuous change during the past 4.6 billion (4,600,000,000) years.
- Physical geology examines the structure, composition, and processes that affect the Earth today. Historical geology considers all past events on Earth.
- The scientific method is a way to find answers to questions and solve problems. It involves collection of information through observation and experimentation, formulation of tentative answers, and validation by testing.
- The three most pervasive themes in the history of Earth are the immensity of geologic time, plate tectonics, and organic evolution.

Welcome to the amazing history of our planet! Here you will discover many astonishing events of the past and learn how we came to understand them. You will learn the intriguing story of how life developed on Earth and how an extraordinary species evolved that is the only one capable of reading books like this: *us*.

Our planet formed about 4.6 billion years ago. Since that time, it has circled the sun like a small spacecraft observing a rather average star. Between about 300,000 and 150,000 years ago, a species of primate we call *Homo sapiens* (Latin: *wise human*) evolved on Earth. Unlike earlier animals, these creatures with oversized brains and nimble fingers asked questions about themselves and their surroundings. Their questioning has continued to the present day: *How did Earth form? Why do earthquakes occur? What lies beneath the land and below the ocean floor?*

Even ancient people sought answers to these questions. In frail wooden ships, they probed the limits of the known world, fearing that they might tumble from its edge or be consumed by dragons. Their descendants came to know the planet as an imperfect sphere, and they began to examine every obscure recess of its

surface. In harsher regions, exploration proceeded slowly. It has been only within the last 100 years that humans have penetrated the deep interior of Antarctica. Today, except for a few areas of great cold or dense tropical forest, the continents are well charted. New frontiers for exploration now lie beneath the ocean and outward into space.

WHY STUDY EARTH HISTORY?

Earth's spectacular history deserves to be closely examined, for it permits us to see the future. Events of the past will happen again. We owe it to ourselves and to our home planet to look carefully at those events and attempt to understand them.

From the time of its origin to the present day, Earth has undergone continuous modification. Continents have been flooded by vast inland seas. They also have ponderously drifted across the face of the globe and slowly collided with other landmasses to form lofty mountain ranges (Fig. 1-1). Massive glaciers have buried vast tracts of forest and prairie. Earth has witnessed recurrent earthquakes, rampant volcanism, catastrophic impacts of meteorites and asteroids, and major changes in the chemistry of the ocean and atmosphere. Along with these physical changes, life on Earth has also undergone change—sometimes slow, but occasionally swift and deadly.

All of these events of the geologic past have relevance to our lives today. By discovering why they occur, we can better predict the future. For example, we are carefully examining climatic trends of the past so we can better understand today's climatic changes. With knowledge of Earth's history, we can plan ahead. We can avoid further damage to this planetary haven in space that is our home. Aside from these concerns, an

important reason to study Earth history is simply to better understand our favorite and unique planet and its amazing forms of life.

GEOLOGY LIVES IN THE PRESENT AND THE PAST

For convenience, we divide the body of knowledge called geology into physical geology and historical geology. **Physical geology** studies Earth's materials (rocks and minerals) and the varied processes that occur both on the surface and deep in the interior. **Historical geology** addresses Earth's origin and evolution, changes in the distribution of lands and seas, the growth and reduction of mountains, and the succession of animals and plants through time. Historical geologists examine planetary materials and structures to discover how they came to exist. They observe the tangible *results* of past events and work backward in time to discover the *causes* of those events.

Geology primarily studies Earth, but its view has broadened to include other planets. This increase in scope is appropriate, because geologic knowledge is employed in interpreting the images of the surfaces of other planets and their moons, in estimating the power of volcanoes on Venus, and in identifying rocks and minerals from Earth's moon.

Geologists identify the minerals in meteorites (Fig. 1-2) to discover how Earth formed. With sophisticated instruments, they scrutinize images of planets or interpret data transmitted by space probes and planetary exploration rovers (Fig. 1-3). Still others busily unravel the structure of mountain ranges, attempt to predict hazards like earthquakes and volcanic eruptions (Fig. 1-4), or study the behavior of glaciers, streams, or underground water.



FIGURE 1-1 The magnificent Canadian Rocky Mountains viewed from Malign Lake, British Columbia. These mountains were initially raised over 80 million years ago. Their present appearance results from further uplift and erosional sculpting during subsequent geologic periods down to the present day.