

An aerial photograph of a coastline. On the left, a steep, forested hillside descends to a dark, pebbly beach. To the right, a large, light blue bay or inlet is visible, with a white sandy beach curving along its edge. The water transitions from a pale turquoise near the shore to a deeper blue further out. The sky is a clear, pale blue.

LUE PLANET

ON TO EARTH SYSTEM SCIENCE

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The Blue Planet

An Introduction to Earth System Science



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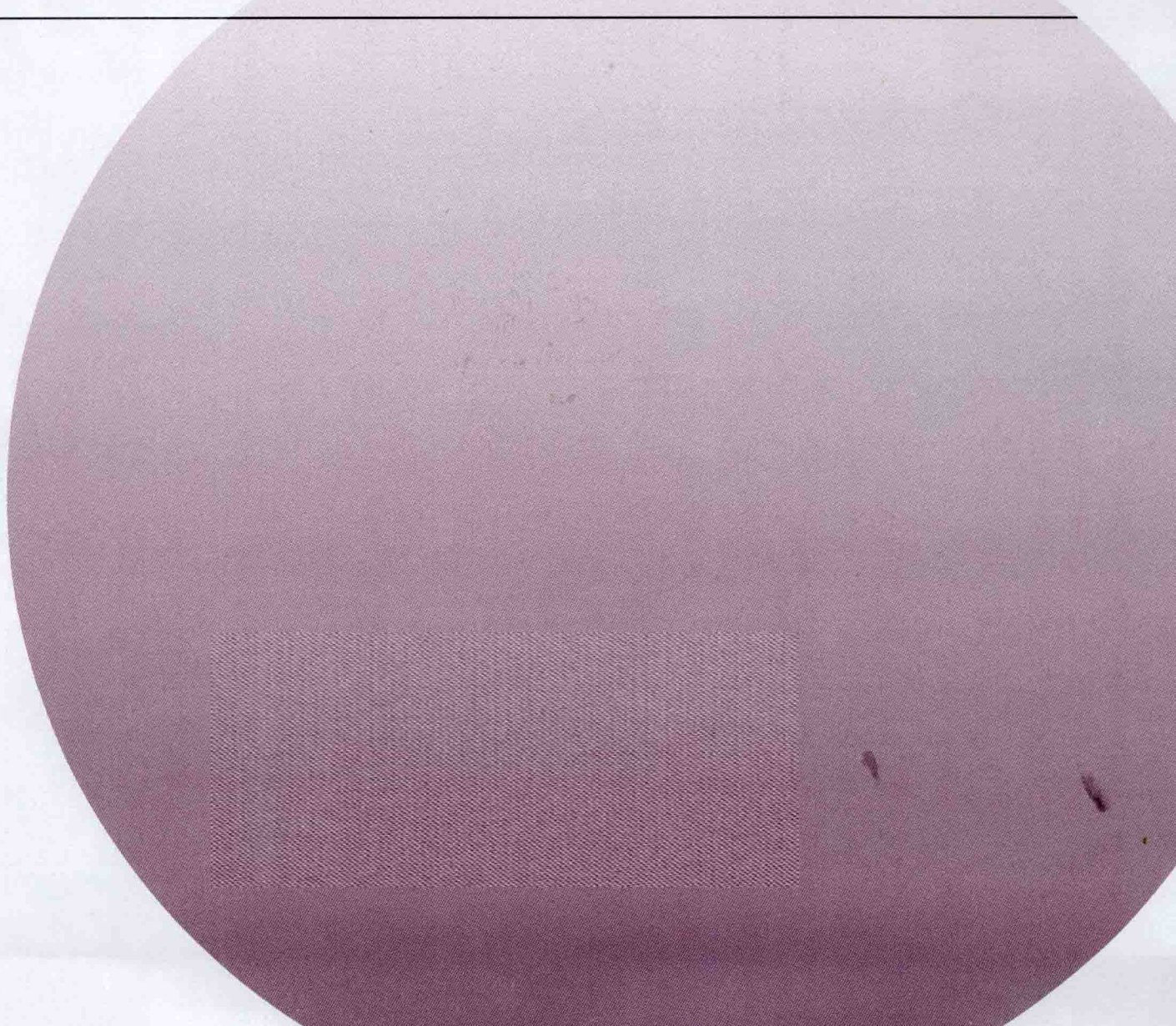
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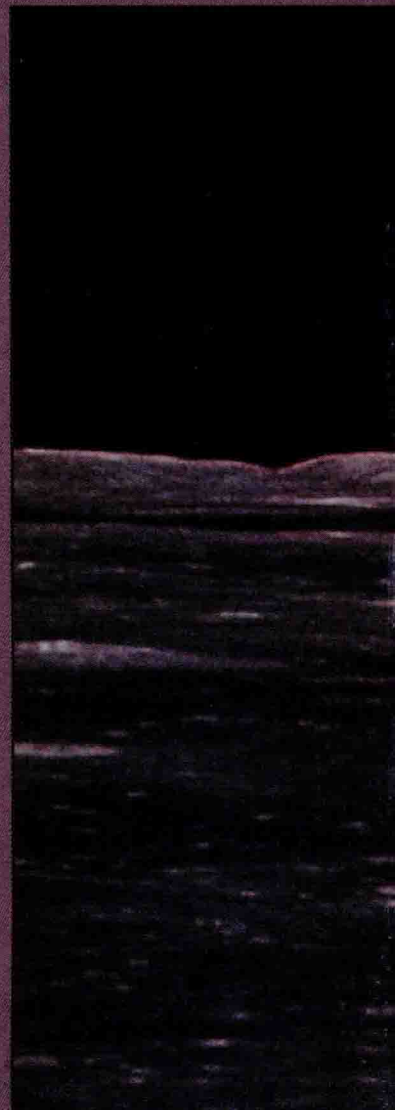




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Photographed by an Apollo astronaut, Earth, the blue planet, rises over the stark, gray, lunar landscape. The Earth appears to be blue just as the sky seems blue on a bright, sunny day. The cause is the same in both cases, an optical effect of the atmosphere. We know that air is colorless, not blue, but the atmosphere appears to be blue when viewed from a distance, due to scattering of light rays by molecules of gas in the atmosphere. Exactly how the scattering occurs is discussed in Chapter 8.



ABOUT THE AUTHORS

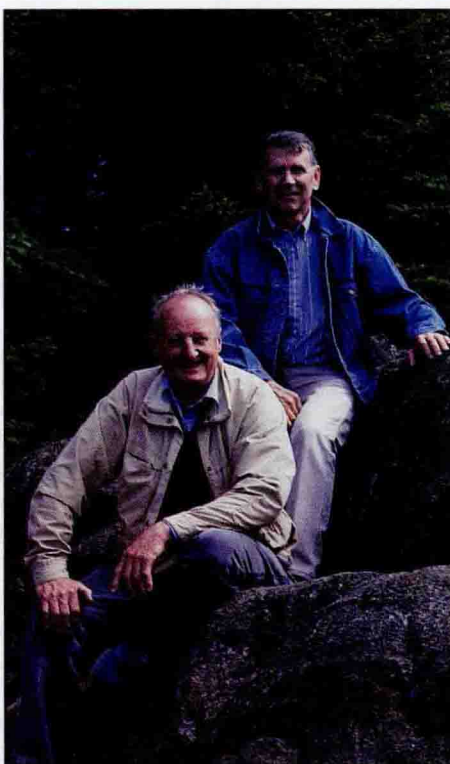
I was born and raised in small country towns in Australia and my early rural experiences did a lot to shape the way I think about the Earth and the way I address problems. I learned to look closely at the world around me, for example, and I saw the giant changes in the landscape as unspoiled bushland was cleared for sheep pastures.

By my twelfth birthday I knew that I wished to be a scientist and the science I fixed my mind on was chemistry. Accordingly, when I entered the University of Adelaide in South Australia in 1946, I selected a course of studies leading to a degree in chemistry. Things never go exactly as planned. Because I had a great-grandfather who had what seemed to me a very mysterious profession, mining engineering, and who had worked at the famous copper mines at Moonta in South Australia, I elected to take a course in geology. My motivation was to find out what had interested my ancestor. What I quickly discovered was my own interest in the subject. I completed my degree in chemistry but I also completed the requirements for graduation in geology.

After experience as a member of an exploration team looking for lead and zinc deposits, and employment as a mining geologist at a tin mine in Tasmania, I entered graduate school at Harvard University. When I emerged 3 1/2 years later with a PhD I returned to Australia and started teaching and research on the origin of mineral deposits, a subject that continues to occupy much of my time and energy. An unexpected offer to become a member of the research staff of the U.S. Geological Survey brought me back to the United States in 1960.

After a number of years in the USGS I moved to the Department of Geology and Geophysics at Yale University and there I have stayed and worked to the present. It was at Yale that I found opportunities to explore the wider aspects of the earth sciences that increasingly occupied my thoughts. For a number of years I was involved in the space program, first the lunar landing experiments and later the unmanned landing experiments on Mars. With Yale colleagues I worked on problems involving oceanography and climatic change, and on such diverse topics as volcanic gases and economic models of resource depletion. Through exposure to such a diverse range of topics I came to understand that everything on the Earth is interconnected and that the way to appreciate how this wonderful planet of ours works is to understand the system by which the disparate parts interact with each other. It was my search for understanding that led to my participation in the preparation of this book about Earth System Science.

B.J.S.



Brian J. Skinner

Stephen C. Porter

Growing up on the dynamic coast of southern California, I was introduced to geology in action at an early age, an introduction that included being thrown out of bed and across my room by a major earthquake that jolted Santa Barbara in the early 1940s. Although earth science was not part of the curriculum when I attended high school, summers spent trekking in the High Sierra and the Rocky Mountains awakened in me an interest in mountains that gained momentum in college when rock climbing and mountaineering occupied much of my spare time. At Yale, a distinguished faculty introduced me to the science of geology, and after serving aboard a Navy destroyer in the Pacific Fleet, I returned to Yale for graduate study. There I focused on glacial and Quaternary geology under the guidance of Professor Richard F. Flint, for many years a prominent author of Wiley geology textbooks. I had the chance to “prove” myself during three long summers of field work in the Brooks Range of Arctic Alaska where I worked at unraveling the puzzling complexities of a thick section

of intensely deformed sedimentary rocks, without the benefit of plate tectonics to guide the way, and also studied the glacial history of the range.

A faculty position at the University of Washington provided an ideal setting for someone with my interests in glaciers and the ice ages. Within a day’s drive of the campus, our earth science students can be introduced in the field to nearly every topic they will hear or read about in class.

The research on mountain glaciation I began in western North America expanded to include many of the world’s glaciated mountains: the Alps, the Andes, the Himalaya, New Zealand’s Southern Alps, and tropical Mauna Kea on the island of Hawaii. In addition to glacial-geologic studies, my work has also involved analyzing rockfall hazards in the Italian Alps, prehistoric cave sites in northern Spain that served as home to ice-age hunters, and prehistoric eruptions of Cascade and Hawaiian volcanoes. My current research includes collaborative studies with Russian colleagues on mountain glaciation in northeastern Siberia and with Chinese colleagues on the monsoon history of central China and Tibet recorded in deposits of wind-blown dust and ancient soils. Such experiences, together with my duties as editor of *Quaternary Research*, an international interdisciplinary journal on the glacial ages, enable me to keep in touch with other earth scientists throughout the world and help me stay abreast of new advances in a rapidly moving scientific field.

S.C.P.

PREFACE

When historians of the future consider the most important achievements of the 20th century, the chances are that one of the selections will be the development of a holistic view of the Earth. Such a view has come about as a result of the technological and scientific advances that have made it possible to measure the many ways that the different parts of the Earth can interact. For example, how events deep inside the Earth can influence events on the Earth's surface, or how small changes in the water temperature of the ocean can bring about changes in the distribution of land plants and how those changes can lead to the evolution of new plant species.

One of the discoveries that arise from the holistic view of the Earth is that our modern industrial society and our huge population are changing the Earth. We can now measure in real time the innumerable ways by which we humans are changing the global environment as a result of our collective activities.

This book is an introduction to the holistic view of the Earth. It is about the interactions between the different parts of the Earth—the atmosphere, hydrosphere, biosphere, and the solid Earth—and about the balance in the global environment that exists as a result of those interactions. It is a book that presents a new view of the Earth that has come to be called *Earth System Science*.

Purpose of the Book

Earth system science is rapidly changing the way we study and think about the Earth and as a result it is changing the way earth science courses are being taught. We have written this book in order to introduce students to the science of the Earth system.

Courses about the Earth are being taught with increasing frequency. Such courses may have titles such as global change, earth science, biospherics, or even the global environment, but the approach is increasingly that of Earth System Science.

The Book's Organization

The text begins with a discussion of the Earth's place in the solar system and contrasts the Earth's appearance and structure with those of neighboring planetary bodies. A chapter is devoted to the Sun, not only because it is the dominant feature of the solar system, but because it supplies the energy that drives most of the surface processes on our planet and that permits

life to exist. Next, we discuss the solid Earth, the minerals and rocks that comprise it, the nature of processes operating deep within the Earth that are inferred indirectly, and the dynamics of the crust that are explained in terms of a relatively new, comprehensive theory, the theory of plate tectonics. Having explored the solid Earth beneath our feet, we next examine the layers of water and ice that cover much of its surface: the oceans, streams, groundwater, snow, glaciers, sea ice, and frozen ground, and we explore how some of these different agents erode and shape landscapes on which we live. In the third part of the book we explore the atmosphere, weather, and climate, and examine the evidence of past changes in climate on various time scales. Having discussed the aspects of the Earth that have made it a habitable planet, we next look at the diversity and dynamics of plants and animals comprising the biosphere and the evidence of biological evolution through Earth history that is recorded in fossiliferous rocks. In the final section of the book, we look at natural resources that have permitted the development and growth of modern civilization, and ways in which human activities contribute to global changes in our environment.

While we have given careful consideration to the organization of the book we realize that not all instructors will favor the one we have adopted. Therefore, the parts and chapters have been written so that some reorganization of topics is possible without serious loss of continuity. For example, the chapters on the solar system could be assigned toward the end of a course, rather than at the beginning, and the chapters on the biosphere could be shifted, or omitted. Where aspects of astronomy or biology are important in discussion of the solid Earth and its surface environments, they are included there as well.

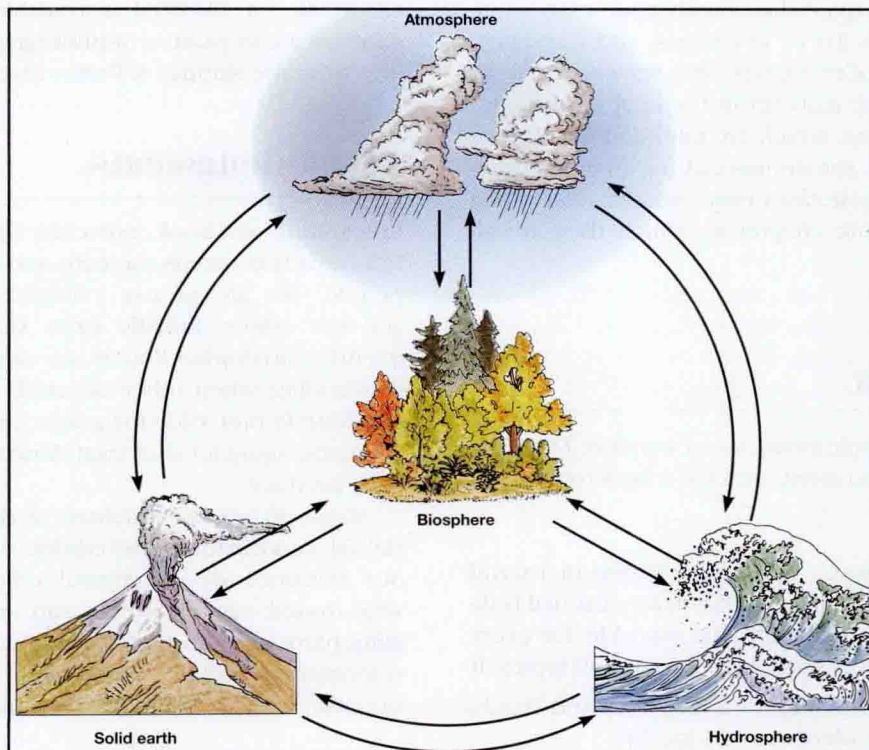
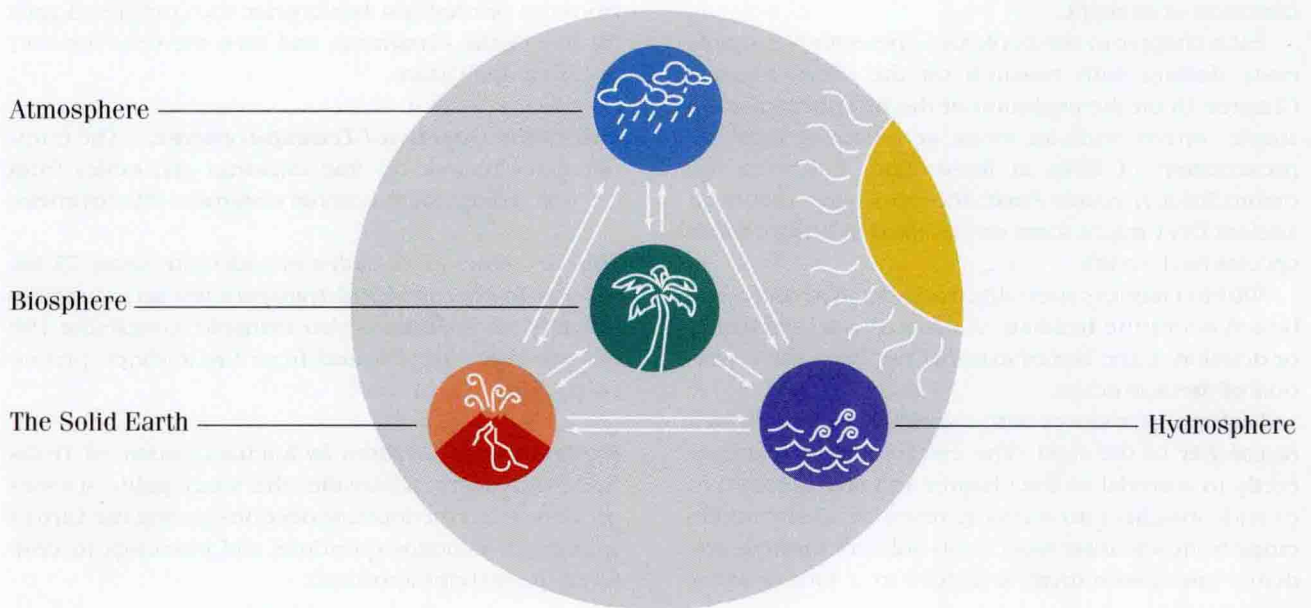
The Artwork

Special attention has been devoted to producing artwork and photographs that illuminate discussions in the text. Because no continent or country holds a monopoly on relevant and interesting examples, we have attempted to provide photographs, maps, and illustrations from around the world to provide a global perspective of Earth System Science. The art program has benefitted from talented artists who have worked closely with the authors to make their illustrations both attractive and scientifically accurate. Two hundred and twelve photographs and line drawings, all in full color, have been selected.

THE SYSTEMS APPROACH

The key to understanding the Earth system is an appreciation of the interactions between the spheres. Interactions are emphasized by the four icons shown below, each of which represents a part of the system.

The icons appear throughout the book and help the reader identify sections in the text where interactions are discussed. For example, in the discussion of streams and drainage systems in Chapter 9, the icons for water, air and land are introduced to emphasize the interactions between those three parts of the Earth system.



Features

Each of the six parts in the book opens with a brief essay on a special aspect of the topics covered within the chapters of the part. The intent of the essays is to emphasize that the different parts of the Earth system are interdependent. For example, Part V, *The Dynamics of Life*, opens with an essay on how some migrating birds find their way by using the stars while others employ the magnetic field and still others use the polarization of sunlight.

Each chapter in the book also opens with a topical essay dealing with research on the chapter topic. Chapter 16 on the evolution of the biosphere, for example, opens with an essay on research into the preservation of DNA in fossils and, following the theme from *Jurassic Park*, the possibility that such ancient DNA might some day be used to bring extinct species back to life.

Within chapters specialized and detailed topics are boxed under the heading "A Closer Look". Inclusion or deletion of the boxed material can be at the discretion of the instructor.

Each chapter closes with a guest essay written by a researcher in the field. The essay subjects relate directly to material in the chapter and are intended to provide insights into on-going research. Essay writers range from scientists working in industry through academic and government scientists to a former astronaut.

Finally, each chapter closes with a summary of in-chapter material, a list of key terms, and questions. The questions are of two kinds: first, review questions relate strictly to the material in the chapter; second, discussion questions, which are intended for class or section discussion, sometimes call for a bit of library research, and in most cases raise broader issues than those in the specific chapter to which they are attached.

Supplements

A full range of supplements to accompany *The Blue Planet* is available to assist both the instructor and the student.

Laboratory Manual. Written by Marcia Bjornerud of Miami University, Ohio, the laboratory manual is divided into six modules with labs available for every part of the text, flexibly arranged to cover all topics. It includes many computer-based exercises and hands-on activities that students can do locally.

Instructor's Manual and Test Bank. Written by Barbara Murck, of Toronto University, this guide includes a table of contents, chapter summaries references, and approximately 85 test questions per chapter.

Computerized Test Bank. A computerized test bank is available in both IBM-compatible and Macintosh versions. This easy-to-use test generating program enables instructors to choose test questions from the printed test bank, print the completed tests for use in the classroom, and save the tests for later use on modification.

Full-Color Overhead Transparencies. The transparencies include 75 line drawings and tables from the text, edited for maximum classroom effectiveness.

Slides. One set of slides includes the same 75 images as in the overhead transparency set; a supplementary set of slides is also available, containing 150 images from the text and from the authors' private collections.

Study Guide. Written by Michael Jordan, of Texas A&M University, Kingsville, the study guide stresses processes and the interconnections among the Earth's spheres. It contains questions and exercises to reinforce the systems approach.

CD-ROM. A CD-ROM is available to adoptors and contains a compilation of photographs and line drawings from the Skinner & Porter texts.

Acknowledgments

Preparation of a book, especially the first edition of a full color text, needs the help and expertise of many people. We are greatly indebted to our publisher and our editor, initially Barry Harmon and subsequently Christopher Rogers, for supporting us, for understanding when other demands meant we had to put *Blue Planet* aside for a time, and for maintaining an encouraging level of confidence that we would finally produce.

Above all we are indebted to Brent Peich for his skillful coordination and editing of the Guest Essay our freelance developmental editor, Irene Nunes, who ironed out our syntax and undangled our dangling participles; to Barbara Heaney, our in-house developmental editor, who kept things flowing smoothly and did the thousand things we overlooked.

Many of our professional colleagues have provided a great deal of help and support. Two must be singled out for especial thanks. Bryan Gregor of Wright State University provided valuable help with the chapters on the biosphere and geochemical cycles, and Jill Schneiderman, initially at Pomona College and now at Vassar, read all the galleys, catching many errors in the process and allowing us to concentrate on illustrations and other unfinished business.

Our many colleagues who prepared part or chapter closing essays did so with grace and professional acumen. We are very grateful to them. Besides the essay writers, each of whom is identified by name and photo adjacent to their entry, we are extremely grateful for the guidance and judgment provided by colleagues who discussed this project in encounter groups and who reviewed all or part of the manuscript. They are:

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BRIEF CONTENTS

INTRODUCTION /3



PART ONE
The Earth In Space /20

CHAPTER 1

Fellow Travelers: Earth's Nearest Neighbors /22



CHAPTER 2

The Sun, Giver of Life /45

PART TWO
The Earth Beneath Our Feet /68

CHAPTER 3

Earthquakes and the Earth's Interior /70



CHAPTER 4

Minerals and Rocks /90

CHAPTER 5

The Heat Within: Magmas and Volcanoes /112

CHAPTER 6

The Principles of Plate Tectonics /136

CHAPTER 7

The Earth's Evolving Crust /158

PART THREE **The Earth's Blanket of Water and Ice** /192

CHAPTER 8

The World Ocean /194



CHAPTER 9

Water on the Land: Surface Streams and Groundwater /224

CHAPTER 10

The World of Snow and Ice /250

CHAPTER 11

The Changing Face of the Land /276

PART FOUR **The Earth's Gaseous Envelope** /310

CHAPTER 12

Composition and Structure of the Atmosphere /312



CHAPTER 13

Winds, Weather, and Desert /336

CHAPTER 14

The Earth's Climate System /360

PART FIVE **The Dynamics of Life on Earth** /388

CHAPTER 15

Dynamics of the Global Ecosystem /390



CHAPTER 16

Evolution of the Biosphere /414

PART SIX **Living on the Earth** /442

CHAPTER 17

Resources from the Earth /444



CHAPTER 18

Global Change: A Planet Under Stress /470

Appendices /A-1

Glossary /G-1

Credits /C-1

Index /I-1

CONTENTS

INTRODUCTION

Opening Essay

The Year Without a Summer /3

Earth System Science /4

The Scientific Method /4

The Four Reservoirs of the Earth System /5

Uniformitarianism /7

The Rise of a New Theory /7

Rare Events and the Reconsideration of
Catastrophism /9

The Human Dimension /11

Energy and the Earth System /12

Energy from the Sun /13

Energy from the Earth's Interior /13

A Closer Look: Energy /14

About This Book /16

Guest Essay: William S. Fyfe

Toward Global Responsibility: *Earth Sense* /17

Summary /18

Important Terms to Remember /19

Questions for Review /19

Questions for A Closer Look /19

Questions for Discussion /19

PART ONE

The Earth in Space /20

Part Essay

Venus: An Earthlike Planet /21

CHAPTER 1

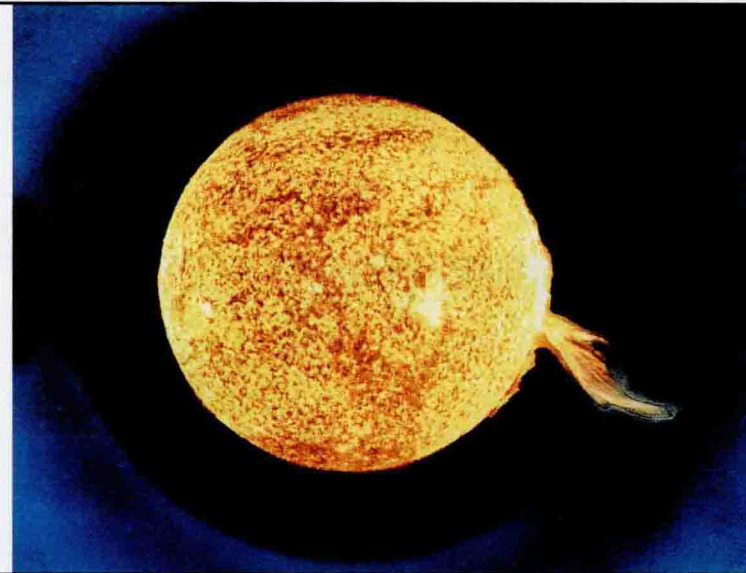
**Fellow Travelers in Space: Earth's
Nearest Neighbors** /22

Opening Essay

The Jewel of the Solar System /23

Astronomy and the

Scientific Revolution /24



Ideas from Antiquity /24

The Challenge by Copernicus /24

Kepler and the New Astronomy /24

Newton and Galileo /28

A Closer Look: Testing Newton's Law of Gravitation /29

The Solar System /29

The Birth of the Solar System /30

A Closer Look: Time and the Calendar /32

Evolution of the Planets /34

The Terrestrial Planets /35

Layers of Different Composition /35

Layers of Different Rock Strength /36

Layers of Different Physical State /36
Comparison of the Terrestrial Planets /36

The Jovian Planets /38

Guest Essay: Harrison H. Schmitt
The First Stepping Stone in Space /40

Summary /41

Important Terms to Remember /42

Questions for Review /42

Questions for a Closer Look /42

Questions for Discussion /42

Update: Flotsam in Space /42

CHAPTER 2

The Sun, Giver of Life /44

Opening Essay

How Many Suns in the Universe? /45

**The Life-Giving Properties
of the Sun /45**

The Sun's Vital Statistics /46
Size /46

Apparent Motion /46

Energy Output /47

Source of the Sun's Energy /49

**A Closer Look: Electromagnetic
Radiation /50**

Structure of the Sun /51

The Solar Spectrum /53

The Active Sun /55

Sunspots /56

Changes in Luminosity /57

Other Suns /57

Star Color and Luminosity /57

A Closer Look: Telescopes /60

Hertzsprung-Russell Diagrams /62

Stellar Evolution /62

Profile: Maria Mitchell

Barbara L. Welther

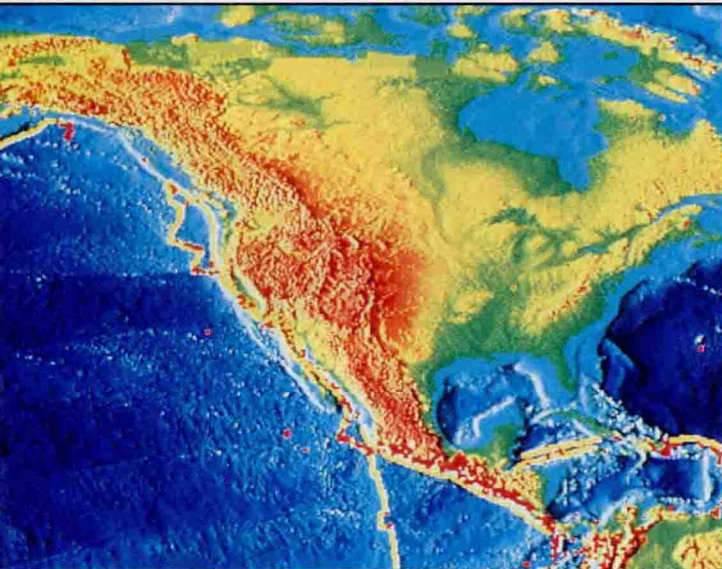
Summary /66

Important Terms to Remember /66

Questions for Review /66

Questions for A Closer Look /67

Questions for Discussion /67



PART TWO

**The Earth
Beneath Our Feet /68**

Part Essay

The Way the Earth Works /69

CHAPTER 3

**Earthquakes and
the Earth's Interior /70**

Opening Essay

**Bad News and Good
about Earthquakes /71**

Earthquakes /71

Origin of Earthquakes /72

Seismic Waves /73

- Location of the Epicenter /77
- A Closer Look: Earthquake Magnitudes** /78
- Earthquake Risk** /79
 - Earthquake Disasters /79
 - Earthquake Damage /81
- Earthquake Prediction** /82
- Gravity Anomalies and Isostasy** /83
 - Gravity Anomalies /83
 - Isostasy /84
- Guest Essay: Jeffrey Park**
Rethinking Earthquake Prediction
- Summary** /87
- Important Terms to Remember** /88
- Questions for Review** /88
 - Questions for A Closer Look /89
- Questions for Discussion** /89

CHAPTER 4

Minerals and Rocks /90

Opening Essay

Minerals: A Linchpin of Society /91

Minerals and Their Chemistry /92

- Elements and Atoms /92
- Common Minerals /94

A Closer Look: Identifying Minerals /98

Rocks /103

- Features of Rocks /103

The Rock Cycle /105

Uniformitarianism and the Rate of the Rock Cycle /107

Guest Essay: Jill S. Schneiderman
Asbestos: To Understand the Science Is to Understand the Politics /108

Summary /109

Important Terms to Remember /110

Questions for Review /110

- Questions for A Closer Look /110

Questions for Discussion /110

CHAPTER 5

The Heat Within:

Magma and Volcanoes /112

Opening Essay

Violent Eruptions /113

Properties of Magma /114

Composition /114

Viscosity /115

Temperature /115

Eruption of Magma /116

Nonexplosive Eruptions /116

Explosive Eruptions /117

Types of Volcanoes /120

Volcanic Hazards /123

After an Eruption /124

Intrusion of Magma /125

The Origin of Magmas and Igneous Rocks /126

A Closer Look: Naming

Igneous Rocks /128

Fractional Melting and Magma Types /130

Guest Essay: Kathleen Crane

Lake Baikal, One of the World's Underwater Wonders /132

Summary /133

Important Terms to Remember /134

Questions for Review /134

- Questions for A Closer Look /134

Questions for Discussion /135

CHAPTER 6

The Principles of Plate Tectonics /136

Do We Drift or Don't We?

That Was the Question /137

The Solid Earth and Plate Tectonics /138

Magnetism and the Revival of the

Continental Drift Hypothesis /138

Magnetism in Rocks /138

Apparent Polar Wandering /139

Seafloor Spreading /140

Plate Tectonics /142

Plate Motions /142

A Closer Look: Plate Speeds /144

Plate Margins /147

Plate Tectonics and the External

Structure of the Earth /147

Divergent Margins /148

Convergent Margins /149

Transform Fault Margins /152

Cause of Plate Tectonics /153

Movement of the Lithosphere /154

Guest Essay: Charles Drake

Harry Hess and Global Tectonics /155

Summary /156

Important Terms to Remember /156

Questions for Review /157

Questions for A Closer Look /157

Questions for Discussion /157

CHAPTER 7

The Earth's Evolving Crust /158

**Tectonics, Erosion, and
the Rock Record** /159

Sedimentary Strata /160

Stratigraphy /160

Breaks in the Stratigraphic Record /161

Stratigraphic Correlation /162

The Geologic Column /163

**A Closer Look: Radioactivity and
the Measurement of Absolute
Time** /164

Sediment and Sedimentary Rock /167

Clastic Sediment and Clastic Sedimentary
Rock /167

Chemical Sediment and Chemical Sedimentary
Rock /169

Metamorphism: New Rocks from Old /170

The Limits of Metamorphism /171

Controlling Factors in Metamorphism /171

Metamorphic Mineral Assemblages /173

Kinds of Metamorphism /173

**A Closer Look: Kinds of
Metamorphic Rock** /175

Metamorphic Facies /177

Plate Tectonics and Metamorphism /177

**Plate Tectonics, Continental Crust, and
Mountain Building** /179

Regional Structures of Continents /179

Continental Margins /180

Mountain Building /184

Guest Essay: Paul D. Lowman
**Plate Tectonics and Continental Drift:
A Skeptic's View** /187

Summary /189

Important Terms to Remember /190

Questions for Review /190

Questions for A Closer Look /191

Questions for Discussion /191



PART THREE

**The Earth's Blanket of
Water and Ice** /192

Part Essay
Water and the Hydrologic Cycle /193

CHAPTER 8
The World Ocean /194

Polynesian Navigators /195

The Oceans /196

Ocean Geography /197

Depth and Volume of the Oceans /197

Age and Origin of the Oceans /198

The Salty Sea /199

Ocean Salinity /199

Salinity of Surface Waters /200

Minerals from the Sea /201

Temperature and Heat Capacity of the Ocean /201**Vertical Stratification of the Ocean /202****Ocean Circulation /203**

Surface Currents of the Open Ocean /203

Ekman Transport /205

Upwelling and Downwelling /206

A Closer Look: Understanding**El Niño /207**

Geostrophic Flow /209

Major Water Masses /209

The Global Ocean Conveyor System /211

Ocean Waves /212

Wave Motion /213

Wave Base /213

Wave Refraction and Longshore Currents /215

Seismic Sea Waves /216

Ocean Tides /216

Tide-Raising Force /216

Tidal Bulges /217

Tidal Power /218

Changing Sea Level /219

Submergence /219

Emergence /219

Relative Movements of Land and Sea /220

Guest Essay: Victoria Kaharl**Where the Sun Never Rises. Seeing Is Believing /221****Summary /222****Important Terms to Remember /222****Questions for Review /223**

Questions for A Closer Look /223

Questions for Discussion /224**CHAPTER 9****Water on the Land: Surface Streams and Groundwater /224****Tampering with the Nile /225****Streams and Drainage Systems /226**

Stream Channels /227

Dynamics of Streamflow /227

The Stream's Load /231

Floods /234

Drainage Systems /235

Groundwater /236

The Water Table /236

Movement of Groundwater /237

Recharge and Discharge Areas /238

Wells /239

Aquifers /240

Chemistry of Groundwater /241

Water and People /242

Human Impact on Rivers /242

Human Impact on Groundwater /243

Guest Essay: W. R. Osterkamp
River Aesthetics—A Janus Perspective /246**Summary /247****Important Terms to Remember /248****Questions for Review /249****Questions for Discussion /249****CHAPTER 10****The World of Snow and Ice /250****Glacial Water for Arid Lands /251****The Earth's Cover of Snow and Ice /251****Snow and the Snowline /252**

Annual Snow Cycle /252

The Snowline /252

Glaciers /254

How Glaciers Form /256

Distribution of Glaciers /257

Warm and Cold Glaciers /257

Why Glaciers Change Size /259

How Glaciers Move /260

Rapid Changes in Glacier Size /262

A Closer Look: Earthquakes, Rockfalls, and Glacier Mass Balance /264

Glaciers As Environmental Archives /265

Sea Ice /265

How Sea Ice Forms /265

Sea-Ice Distribution and Zonation /266

Sea-Ice Motion /266

Sea Ice in the Earth System /268

Periglacial Landscapes and Permafrost /268

Permafrost /269

Living with Permafrost /271

Guest Essay: Lonnie Thompson
Ice Core Archives: The Keys to Our Future Are Frozen in Our Past /272**Summary /273****Important Terms to Remember /274****Questions for Review /274**

Questions for A Closer Look /274

Questions for Discussion /275