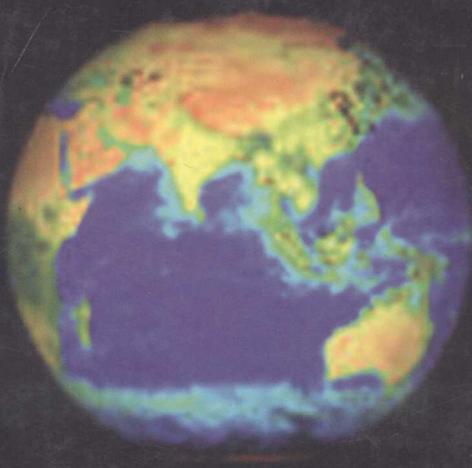


Third Edition

earth

Portrait of a Planet

Stephen Marshak





Earth

Portrait of a Planet

Third Edition

STEPHEN MARSHAK

University of Illinois



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EARTH: PORTRAIT OF A PLANET

Third Edition



DEDICATION

*To Kathy, David, and Emma, who helped in this
endeavor in many ways over many years*

Imagine a desert canyon at dawn. Stark cliffs of red rock descend like a staircase down to the gravelly bed of a dry stream on the canyon floor. Mice patter among dry shrubs and cactus. Suddenly, the sound of a hammer cracking rock rises from below. Some hours later, a sweating geologist—a scientist who studies the Earth—scales back up the cliffs, carrying a backpack filled with heavy rock samples that he will eventually take to a lab. Why? By closely examining natural exposures of rocks and sediments in the field (such as those in the canyon just described), as well as by studying samples in a laboratory, analyzing satellite imagery, and developing complex computer models, geologists can answer a number of profound and fascinating questions about the character and history of our planet: How do rocks form? What do fossils tell us about the evolution of life? Why do earthquakes shake the ground and why do volcanoes erupt? What causes mountains to rise? Has the map of the Earth always looked the same? Does climate change through time? How do landforms develop? Where do we dig or drill to find valuable resources? What kinds of chemical interactions occur among land, air, water, and life? How did the Earth originate? Does our planet resemble others? The modern science of geology (or geoscience), the study of the Earth, addresses these questions and more. Indeed, a look at almost any natural feature leads to a new question, and new questions drive new research. Thus, geology remains as exciting a field of study today as it was when the discipline originated in the eighteenth century.

Before the mid-twentieth century, geologists considered each of the above questions as a separate issue, unrelated to the others. But since 1960, two paradigm-shifting advances have unified thinking about the Earth and its features. The first, *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 relative to each other, 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 advance establishes the concept that our planet is a complex system—*the Earth System*—in which water, land, air, and living inhabitants are dynamically interconnected in ways that allow materials to cycle constantly among various living and nonliving reservoirs. With the Earth System concept in mind, geologists now real-

ize that the history of life links intimately to the physical history of our planet.

Earth: Portrait of a Planet is an introductory geoscience textbook that weaves the theory of plate tectonics and the concept of Earth System science into its narrative from the first page to the last. The book strives to create a modern, coherent image—a portrait—of the very special sphere on which we all live. As such, the book helps students understand the origin of the Earth and its internal structure, the nature of plate movement, the diversity of Earth's landscapes, the character of materials that make up the Earth, the distribution of resources, the structure of the air and water that surround our planet, the evolution of continents during the Earth's long history, and the nature of global change through time. The story of our planet, needless to say, is interesting in its own right. But knowledge of this story has practical applications as well. Students reading *Earth: Portrait of a Planet* and studying this book's multitude of drawings and photos will gain insight that can help address practical and political issues too. Is it safe to build a house on a floodplain or beach? How seriously should we take an earthquake prediction? Is global warming for real, and if so, should we worry about its impacts? Which candidate has a more realistic energy and environmental policy? Should your town sell permits to a corporation that wants to extract huge amounts of water from the ground beneath the town? The list of such issues seems endless.

NARRATIVE THEMES

To understand a subject, students must develop an appreciation of fundamental concepts and by doing so create a mental “peg board” on which to hang and organize observations and ideas. In the case of *Earth: Portrait of a Planet*, these concepts define “narrative themes” that are carried throughout the book, as discussed more fully in the Prelude.

1. The Earth is a complex system in which rock, oceans, air, and life are interconnected. This system is unique in the Solar System.
2. Internal energy (due to the make-up and processes occurring in our planet's interior) drives the motion

of plates, and the interactions among plates, in turn, drive a variety of geologic phenomena, such as the uplift of mountain ranges, the eruption of volcanoes, the vibration of earthquakes, and the drift of continents. But what plate tectonics builds, other Earth phenomena tear down. Specifically, gravity causes materials at the tops of cliffs to slip down to lower elevations. And external energy (provided by the Sun), along with gravity, drives the flow of water, ice, and wind on the Earth's surface—this flow acts like a rasp, capable of eventually grinding away even the highest mountain.

3. The Earth is a planet, formed like other planets from a cloud of dust and gas. Because of its location and history, the Earth differs greatly from its neighbors.
4. Our planet is very old—about 4.57 billion years old. During this time, the map of the planet has changed, surface landscapes have developed and disappeared, and life has evolved.
5. Natural features and processes on Earth can be a hazard—earthquakes, volcanic eruptions, floods, hurricanes, and landslides can devastate societies. But understanding these features can help prevent damage and save lives.
6. Energy and material resources come largely from the Earth. Geologic knowledge can help find them and can help people understand the consequences of using them.
7. Geology ties together ideas from many sciences, and thus the study of geology can increase science literacy in chemistry, physics, and biology.

ORGANIZATION

Topics covered in *Earth: Portrait of a Planet* have been arranged so that students can build their knowledge of geology on a foundation of basic concepts. The book's parts group chapters so that interrelationships among subjects are clear. Part I introduces the Earth from a planetary perspective. It includes a discussion of cosmology and the formation of the Earth and introduces the architecture and composition of our planet, from surface to center. With this background, students are ready to delve into plate tectonics theory. Plate tectonics theory appears early in this book, a departure from traditional textbooks, so that students will be able to relate the contents of all subsequent chapters to this theory. Understanding plate tectonics, for example, helps students to understand the chapters of Part II, which introduce Earth materials (minerals and rocks). A familiarity with plate

tectonics and Earth materials together, in turn, provides a basis for the study of volcanoes, earthquakes, and mountains (Part III). And with this background, students have sufficient preparation to understand the fundamentals of Earth history and the character of natural resources (Parts IV and V).

The final part of this book, Part VI, addresses processes and problems occurring at or near the Earth's surface, from the unstable slopes of hills, down the course of rivers, to the icy walls of glaciers, to the shores of the sea and beyond. This part also includes a summary of atmospheric science and concludes with a topic of growing concern—global change. As we think about the future of the planet, concerns about the warming of the climate and the contamination of the environment loom large.

TEACHING PHILOSOPHY

Students learn best by actively engaging in the learning process, by basing learning on the formulation of questions, and by linking clear explanations to visual images. With these concepts as a foundation, the Third Edition of *Earth: Portrait of a Planet* provides a variety of new active-learning and inquiry-based teaching tools, as well as an even broader array of outstanding illustrations, all couched in a highly readable narrative. Most notably, each chapter provides a Geotour, which uses the magical *Google Earth*[™] to take students to field localities worldwide in order to *see for themselves* what geology looks like, first-hand. Related questions on the book's website allow students to apply their new knowledge to the real world—instantly. This book also helps students to switch into inquiry mode right from the start, by introducing each chapter with a question—a geopuzzle—that prompts students to pursue answers while they read. To encourage students to pause and register the essence of the subject before moving on, each section ends with a take-home message. And in addition to the paper and ink of the book itself, the book's website provides students with access to a variety of resources including 2-D and 3-D animations (to help with visualization of how geologic features evolve over time), practice questions, links to web resources, videos, and even geo-crossword puzzles.

With the advent of smart classrooms, laptop computers, the web, PowerPoint[™], Quicktime[™], and a myriad of pedagogical tools, students enjoy ever-widening opportunities to absorb and understand the subjects they study. But while this boggling array of diverse learning options helps make education fun, it does harbor a risk.

Specifically, students may miss seeing the unifying threads that hold a subject together, and may find themselves longing for a clear, straightforward explanation of a topic. To meet this need, *Earth: Portrait of a Planet* holds to the concept that a well illustrated, well written, and well organized textbook helps provide a framework for understanding a subject. This book, therefore, offers thousands of carefully designed drawings and carefully selected photographs, with annotations to highlight key features. It includes interpretative sketches that help students to understand *what a geologist sees* when looking at a photograph of a landscape or outcrop. And to ensure that the illustrations mean something, this book provides carefully crafted explanations and discussion in an accessible, sequential, narrative form. The book treats each topic with sufficient thoroughness that students should be able to understand a topic by reading the book alone. The approach has stood the test of time—the repeated refrain by previous users of this book is that it is “easy to read” and “makes concepts very understandable.”

SPECIAL FEATURES

Broad Coverage

Earth: Portrait of a Planet provides complete coverage of the topics in traditional Physical Geology or Introductory General Geology courses. But increasingly, first-semester courses in geology incorporate aspects of historical geology and of Earth System science. Therefore, this book also provides chapters that address Earth history, the atmosphere, the oceans, and global change. Finally, to reflect the international flavor of geoscience, the book contains examples and illustrations from around the world.

Flexible Organization

Though the sequence of chapters in *Earth: Portrait of a Planet* was chosen for a reason, it has been structured to be flexible, so that instructors can rearrange chapters to fit their own strategies for teaching. Geology is a nonlinear subject—individual topics are so interrelated that there is not a single best way to order them. Thus, each chapter is largely self-contained, repeating background material where necessary for the sake of completeness. Readers will note that the book includes a Prelude and several Interludes. These treat shorter subjects in a coherent way that would not be possible if they were simply

subsections within a larger chapter. Finally, the book includes two Appendices. The first reviews basic physics and chemistry, and as such can be used as an introduction to minerals, if students lack the necessary science background. The second provides full-page versions of important charts and maps.

A Connection to Societal Issues

Geology's practical applications are addressed in chapters on volcanic eruptions, earthquakes, energy resources, mineral resources, global change, and mass wasting. Here, students learn that natural features can be hazardous, but that with a little thought, danger may be lessened. In addition, where relevant, *Earth: Portrait of a Planet* introduces students to some of the ways in which geologic understanding can be applied to environmental issues. Case studies show how geologists have used their knowledge to solve practical problems.

Boxed Inserts

Throughout the text, boxes expand on specific topics. “The Human Angle” boxes introduce links between geologic phenomena and the human experience. “Science Toolboxes” provide background scientific data. And “The Rest of the Story” boxes give additional interesting, but optional, detail. “Case Studies” boxes provide specific examples of geologic phenomena that impact society.

Superb Artwork

It's hard to understand features of the Earth System without being able to see them. To help students visualize topics, *Earth: Portrait of a Planet* is lavishly illustrated—the book contains over 200 more illustrations than competing texts! The author has worked closely with the artists to develop an illustration style that conveys a realistic context for geologic features without overwhelming students with extraneous detail. The talented artists who worked on the figures have pushed the envelope of modern computer graphics, and the result is the most realistic pedagogical art ever produced for a geoscience text.

In addition to line art, *Earth* features photographs from all continents. Many of the pictures were taken by the author and provide interesting alternatives to the stock images that have appeared for many years in introductory books. Where appropriate, photographs are accompanied by annotated sketches labeled “What a

geologist sees,” which help students see the key geologic features in the photos.

In the past, students would need to go to a museum to see bold, colorful paintings of geologic features. Now, they need only flip through the pages of *Earth: Portrait of a Planet*. Famed British painter Gary Hincks has provided spectacular two-page synoptic paintings that illustrate key concepts introduced in the text and visually emphasize the relationships among components of the Earth System.

CHANGES IN THE THIRD EDITION

The Third Edition of *Earth: Portrait of a Planet* contains a number of major changes and updates. Key changes include:

1. **Geotours:** Each chapter of this book contains a Geotour, which provides the coordinates, a thumbnail photo, and a description of several examples of geologic features that illustrate concepts from the book. By entering the coordinates in *Google Earth™*, the student instantly flies to the site and can view it from any altitude and perspective, in 3-D. Geotours are, in effect, guides that take students around the world to see for themselves what geologic features look like. To ensure ease of use, and to provide an inquiry-based approach to using geotours, the book’s website provides buttons that take students to the sites at the click of a mouse, and questions that prompt active learning.
2. **New Pedagogical Features:** This edition contains three new teaching aids, in addition to Geotours. First, each chapter starts with a *geopuzzle*, a question that prompts students to pursue the concepts contained in the chapter. The answer to the puzzle, provided at the end of the chapter, serves to synthesize the key points of the chapter. Second, every section ends with a *Take-Home Message*, which allows students to pause and take stock of what they’ve learned. Third, a set of questions, under the heading *On Further Thought*, has been added to the end of each chapter, to encourage critical thinking.
3. **Incorporation of New Data and New Events:** Students relate to geology in the news, so every effort has been made to incorporate examples of geologic events that have made global headlines. For example, the Third Edition contains complete coverage of Hurricane Katrina and the Indian Ocean tsunami. Chapters covering rapidly evolving subjects have been revised to incorporate the latest data. For example, the chapter on global

environmental Panel on Climate Change. This book provides the most complete and up-to-date coverage of geoscience available at the introductory level.

4. **New Figures and Photos:** Close to 300 figures and photos have been revised or updated for the Third Edition. At just about every point where a student might be thinking, “What does this look like?” the book has an illustration.

SUPPLEMENTS

Geotours

Earth, Third Edition, is the first textbook to utilize *Google Earth™* to emphasize active student learning. Using *Google Earth*’s spectacular 3-D maps of the planet’s surface, Stephen Marshak has created 23 Geotours that take students on “virtual” geology field trips where they can apply textbook lessons to real-world geologic features. Appearing in the book as two-page spreads in each chapter, Geotours can be incorporated into engaging lectures that work seamlessly with the book. From the free StudySpace student website, students can access the *Google Earth™* Geotours file and Worksheet Activities, developed with Scott Wilkerson of DePauw University. These tools make it easy to use the *Google Earth™* software to explore the locations illustrated in the text, and to assign these explorations as homework or as a quiz.

Earth: Videos of a Planet Instructor’s DVD, Version 3.0

This outstanding lecture resource features 24 short film clips carefully selected from the U.S. Geological Survey archives for use in physical geology lectures. The DVD also includes 10 spectacular 3-D art animations that focus on the geologic processes that are the hardest to understand.

Animations

Students and instructors will have access to over 60 original animations, including 20 animations new to the Third Edition. All have been developed by Stephen Marshak to illustrate dynamic Earth processes. Conveniently accessible from the free StudySpace student website, offline versions of the animations are also available on the Instructor’s CD-ROM, linked from PowerPoint slides and easily enlargeable for classroom display with VCR-like controls that allow instructors to control the pace of the animation during lecture.

Zoomable Art

Explore Gary Hincks's spectacular synoptic paintings in vivid detail using the zoomable art feature. Ideal for lecture use, these figures are included among the resources on the Instructor's CD-ROM.

ebook

Earth, Third Edition, is also available as a value-priced electronic edition—same great book, half the price! Go to nortonbooks.com for more information.

FOR INSTRUCTORS:

1. Norton Media Library Instructor's CD-ROM

This instructor CD-ROM offers a wealth of easy-to-use multimedia resources, all structured around the text and designed for use in lecture presentations, including:

- editable PowerPoint lecture outlines for each chapter by Ron Parker of Earlham College
- links, from PowerPoint, to the *Google Earth*TM Geotours file. These shortcuts make it easy to “fly to” relevant geologic localities identified in the textbook
- all of the art and most of the photographs from the text
- zoomable art versions of Gary Hincks's spectacular synoptic paintings from the text
- additional photographs from Stephen Marshak's own archives
- over sixty animations unique to *Earth: Portrait of a Planet*, Third Edition
- multiple-choice GeoQuiz Clicker Questions for each chapter

2. Norton Resource Library Instructor's Website

www.wwnorton.com/nrl

Maintained as a service to our adopters, this password-protected instructor website offers book-specific materials for use in class or within WebCT, Blackboard, or course websites. Resources include:

- editable PowerPoint lecture outlines by Ron Parker of Earlham College
- over sixty animations unique to *Earth: Portrait of a Planet*, Third Edition
- multiple-choice GeoQuiz Clicker Questions for each chapter
- Test Bank questions in *ExamView*[®] Assessment Suite, WebCT, and BlackBoard-ready formats.

- JPEG versions of all drawn art in the textbook
- instructor's manual and test bank in PDF format

3. Instructor's Manual and Test Bank

Prepared by John Werner of Seminole Community College, Terry Engelder of Pennsylvania State University, and Stephen Marshak, this manual offers useful material to help instructors as they prepare their lectures and includes over 1,200 multiple-choice and true-false test questions. The test bank is available in printed form and electronically in *ExamView*[®] Assessment Suite, WebCT, and Blackboard-ready formats.

4. Transparencies

Approximately 200 figures from the text are available as color acetates.

5. Supplemental Slide Set

This collection of 35mm slides supplements the photographs in the text with additional images from Stephen Marshak's own photo archives. These images are also available as PowerPoint slides on the Norton Media Library CD-ROM.

FOR STUDENTS:

1. StudySpace Student Website

www.wwnorton.com/studyspace

Developed specifically for *Earth: Portrait of a Planet*, Third Edition, and free and open for students, StudySpace provides a wealth of materials to help students organize, learn, and connect the concepts they are learning.

- **Study Plans** highlight the learning tools built into each chapter of the textbook and its associated media resources.
- **Guides to Reading** prepared by Rita Leafgren of the University of Northern Colorado provide an overview of the major ideas introduced in each chapter.
- **GeoTours** with direct links to *Google Earth*TM locations and worksheet Activities that can be printed out for self study or assigned as homework or quizzes.
- **Diagnostic Quizzes** for each chapter, prepared by Rita Leafgren of the University of Northern Colorado, help students identify which parts of the text they need to review further and give them instant feedback on right and wrong answers.
- **Animations** developed for *Earth*, Third Edition.
- **FlashCards** that help students review key terms in each chapter.

- **Feature Articles** by Stephen Marshak that comment on particular topics of interest.
- **Geology in the News** featuring newsfeeds to the most geology news, updated regularly.
- **Ebook** direct links that allow students using the ebook to go directly to the relevant sections mentioned in the Study Plan.
- **Norton Gradebook** that allows students to submit [email] their Diagnostic Quiz results and Geotours Worksheets directly to instructors' gradebook.

ACKNOWLEDGMENTS

I am very grateful for the assistance of many people in bringing this book from the concept stage to the shelf in the first place, and for helping to provide the momentum needed to make the Third Edition take shape. First and foremost, I wish to thank my family. My wife, Kathy, has helped throughout in the overwhelming task of keeping track of text and figures and of handling mailings. In addition, she helped edit text, read proofs, shuttle artwork, and provide invaluable advice. My daughter, Emma, helped locate and scan photos, and my son, David, helped me keep the project in perspective and highlighted places where the writing could be improved. During the initial development of the First Edition, I greatly benefited from discussions with Philip Sandberg, and during later stages in the development of the First Edition, Donald Prothero contributed text, editorial comments, and end-of-chapter material.

The publisher, W. W. Norton & Company, has been incredibly supportive of my work and has been very generous in their investment in this project. Steve Mosberg signed the First Edition, and Rick Mixter put the book on track. Jack Repcheck bulldozed aside numerous obstacles and brought the First Edition to completion. He has continued to be a fountain of sage advice and an understanding friend throughout the development of the Second and Third Editions. Jack has provided numerous innovative ideas that have strengthened the book and brought it to the attention of the geologic community. Under Jack's guidance, this book has been able to reach a worldwide audience.

April Lange has expertly coordinated development of the ancillary materials. She has not only managed their development, but also introduced innovative approaches and wrote part of the material. Her contributions have set a standard of excellence. JoAnn Simony did a superb job of managing production of the First Edition and of doing the page makeup. Thom Foley and Chris Granville have expertly and efficiently handled the task of manag-

ing production for this Third Edition. They have calmly handled all the back and forth involved in developing a book and in keeping it on schedule. Susan Gaustad did an outstanding job of copy editing the First Edition. This tradition continued through the efforts of Alice Vigliani on the Second Edition and Barbara Curialle on the Third Edition. Kelly Mitchell has taken over and greatly modernized photo research for the Third Edition and has done a great job. Michelle Riley has been invaluable in obtaining permissions and maintaining the credit list for the photos, and Mik Awake, editorial assistant, was a great help in tying up any and all loose ends.

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It has been great fun to interact with Gary Hincks, who painted the incredible two-page spreads, in part using his own designs and geologic insights. Some of Gary's paintings appeared in *Earth Story* (BBC Worldwide, 1998) and were based on illustrations jointly conceived by Simon Lamb and Felicity Maxwell, working with Gary. Others were developed specifically for *Earth: Portrait of a Planet*. Some of the chapter quotes were found in *Language of the Earth*, compiled by F. T. Rhodes and R. O. Stone (Pergamon, 1981).

As this book has evolved, I have benefited greatly from input by expert reviewers for specific chapters, by general reviewers of the entire book, and by comments from faculty and students who have used the earlier editions and were kind enough to contact me by e-mail. The list of people whose comments were incorporated includes:

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I apologize if anyone was inadvertently not included on the list.

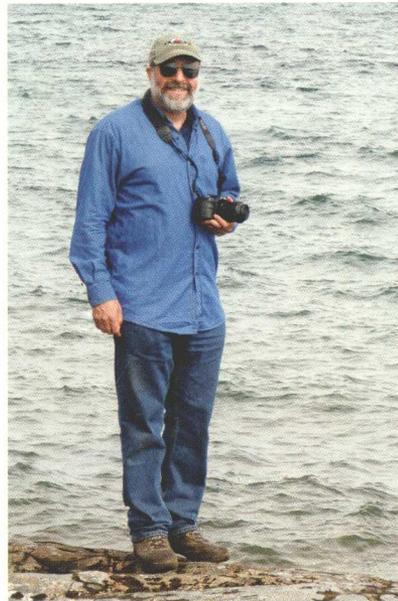
ABOUT THE AUTHOR

Professor Stephen Marshak is the 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. Steve's research interests lie in the fields of structural geology and tectonics. Over the years, he has explored geology in the field on several continents. Since 1983 Steve has been on the faculty of the University of Illinois, where he teaches courses in introductory geology, structural geology, tectonics, and field geology and has won the university's highest teaching awards. In addition to research papers and *Earth: Portrait of a Planet*, Steve has authored or co-authored *Essentials of Geology*, *Earth Structure: An Introduction to Structural Geology and Tectonics*, and *Basic Methods of Structural Geology*.

THANKS!

I am very grateful to the faculty who selected the earlier editions of this book for use in their classes and to the students who engaged so energetically with it. I continue to welcome your comments and can be reached at: smarshak@uiuc.edu.

Stephen Marshak



*To see the world in a grain of sand
and heaven in a wild flower.
To hold infinity in the palm of the hand
and eternity in an hour.*

—William Blake (British poet, 1757–1827)

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