

FIFTH EDITION

EARTH
PORTRAIT *of a* **PLANET**

STEPHEN MARSHAK

EARTH

Portrait of a Planet

FIFTH EDITION





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Portrait of a Planet

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Stephen Marshak
UNIVERSITY OF ILLINOIS



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To Kathy, David, Emma, and Michelle

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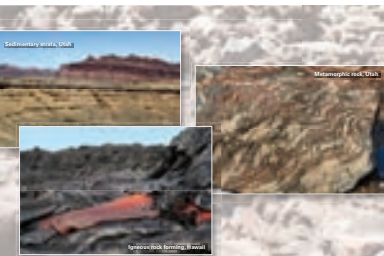
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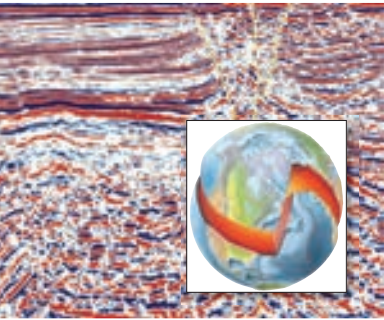
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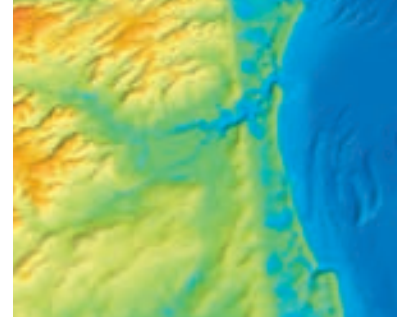
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Narrative Themes

Why do earthquakes, volcanoes, floods, and landslides happen? What causes mountains to rise? How do beautiful landscapes develop? How have climate and life changed through time? When did the Earth form, and by what process? Where do we dig to find valuable metals, and where do we drill to find oil? Does sea level change? Do continents move? The study of geology addresses these important questions and many more. But from the birth of the discipline, in the late 18th century, until the mid-20th century, geologists considered each question largely in isolation, without pondering its relation to the others. This approach changed, beginning in the 1960s, in response to the formulation of two paradigm-shifting ideas that have unified thinking about the Earth and its features. The first idea, called the *theory of plate tectonics*, states that the Earth's outer shell, rather than being static, consists of discrete plates that slowly move, relative to each other, so that the map of our planet continuously changes. Plate interactions cause earthquakes and volcanoes, build mountains, provide gases that make up the atmosphere, and affect the distribution of life on Earth. The second idea, the *Earth System perspective*, emphasizes that our planet's water, land, atmosphere, and living inhabitants are dynamically interconnected, so that materials constantly cycle among various living and nonliving reservoirs on, above, and within the planet. In the context of this idea, we have come to realize that the history of life is intimately linked to the history of the physical Earth, and vice versa.

Earth: Portrait of a Planet, Fifth Edition, is an introduction to the study of our planet that uses the theory of plate tectonics as well as the Earth System perspective throughout, to weave together a number of narrative themes, including:

1. The solid Earth, the oceans, the atmosphere, and life interact in complex ways, yielding a planet that is unique in the Solar System.
2. Most geologic processes involve the interactions of plates, pieces of the outer, relatively rigid shell of the Earth.
3. The Earth is a planet formed, like other planets, from dust and gas. But, in contrast to other planets, the Earth is a dynamic place where new geologic features continue to form and old ones continue to be destroyed.

4. The Earth is very old—indeed, about 4.54 billion years have passed since its birth. 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 produce complex landscapes.
6. Geologic knowledge can help society understand, and perhaps avoid or reduce, the danger of natural hazards, such as earthquakes, volcanoes, landslides, and floods.
7. Energy and mineral resources come from the Earth and are formed by geologic phenomena. Geologic study can help locate these resources and mitigate the consequences of their use.
8. Geology is a science, and the ideas of science come from observation, calculation, and experiment. Thus, people make scientific discoveries, and scientific understanding advances over time.
9. Geology utilizes ideas from physics, chemistry, and biology, so the study of geology provides an excellent means to improve science literacy overall.

These narrative themes serve as the take-home message of the book, a message that students hopefully will remember long after they finish their introductory geology course. In effect, they provide a mental framework on which students can organize and connect ideas, and develop a modern, coherent image of our planet.

Pedagogical Approach

Educational research demonstrates that students learn best when they actively engage with a combination of narrative text and narrative art. Some students respond more to the words of a textbook, which help to organize information, provide answers to questions, fill in the essential steps that link ideas together, and help a student develop a context for understanding ideas. Some students respond more to narrative art—art designed to tell a story—for visual images help students comprehend and remember processes. And some respond to question-and-answer-based active learning, an approach where

students can, in effect, “practice” their knowledge. *Earth: Portrait of a Planet*, Fifth Edition, provides all three of these learning tools. The text has been crafted to be engaging, the art has been configured to tell a story, the chapters are laid out to help students internalize key principles, and the on-line activities have been designed to both engage students and provide active feedback. As before, the book’s narrative doesn’t just provide a dry statement of facts, but rather, it provides the story behind the story—meaning the reasoning and observation that led to our current understanding, as well as an explanation of the processes that cause a particular geological phenomenon.

Each chapter starts with a list of *Learning Objectives* that frames the most important pedagogical goals for each chapter. *Take-Home Message* panels, which include both a brief summary and a key question, appear at the end of each section to help students solidify key themes before proceeding to the next section. Throughout the chapter, *Did You Ever Wonder?* questions prompt students with real-life questions they may have already thought about—answers to these questions occur in the nearby text. *See for Yourself* panels guide students to key examples of spectacular geologic features, using the power of *Google Earth*TM. They allow students to apply their newly acquired knowledge to the interpretation of real-world examples. Each chapter then concludes with a chapter summary that reinforces understanding and provides a concise study tool at the same time. *Review Questions* at the end of each chapter include two parts: the first addresses basic concepts, as defined by Bloom’s Taxonomy; and the second, labeled *On Further Thought*, stimulates critical thinking opportunities that invite students to think beyond the basics.

To enhance active-learning opportunities, *SmartWork Online Homework* has been specifically developed for *Earth: Portrait of a Planet*, Fifth Edition. In addition to word questions, *SmartWork* also offers students visual drag and drop questions and figure-labeling exercises, all of which come with detailed feedback. *SmartWork* also boasts strong visual features with questions based on videos and vivid animations that display geologic processes.

Organization

The topics covered in this book have been arranged so that students can build their knowledge of geology on a foundation of overarching principles. 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 basic background, students are prepared to delve into plate tectonics theory. Plate tectonics appears early in the book, so that students can relate the content of subsequent chapters to the theory. Knowledge of plate tectonics, for example,

helps students understand the suite of chapters on minerals, rocks, and the rock cycle. Knowledge of plate tectonics and rocks together, in turn, provides a basis for studying volcanoes, earthquakes, and mountains. And with this background, students are prepared to 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 book’s final chapters 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 part concludes with a topic of growing concern in society—global change, particularly climate change.

In addition to numbered chapters, the book contains several *Interludes*. These are, in effect, “mini-chapters” in that they focus on topics that are self-contained but are not broad enough to require an entire chapter. By placing selected topics in interludes, we can keep chapters reasonable in length, and can provide additional flexibility in sequencing topics within a course.

Although the sequence of chapters and interludes was chosen for a reason, this book is designed to be flexible enough for instructors to choose their own strategies for teaching geology. The individual topics are so interrelated that there is not always a single best way to order them. Thus, each chapter is self-contained, reiterating relevant material where necessary. For example, if instructors prefer to introduce minerals and rocks before plate tectonics, they simply need to reorder the reading assignments. A low-cost, loose-leaf version of the book allows instructors to have students purchase only the chapters that they need.

We have used a different approach in highlighting terminology in *Earth: Portrait of a Planet*, Fifth Edition. Terminology, the basic vocabulary of a subject, serves an important purpose in simplifying the discussion of topics. For example, once students understand the formal definition of a mineral, the term can be used again in subsequent discussion without further explanation or redundancy. Too much new vocabulary, however, can be overwhelming. So we have tried to keep the book’s key terms (set in boldface and referenced at the end of each chapter for studying purposes) to a minimum. But, since the field of geology has many important terms, we have also set other, less significant but still useful, terms in italic when first presented, to provide additional visual guidance for students. As in previous editions, we take care not to use vocabulary until it has been completely introduced and defined.

Special Features of this Edition

Earth: Portrait of a Planet, Fifth Edition, contains a number of new or revised features that distinguish it from all competing texts.

The Bear River drains the Uinta Mountains into the Great Salt Lake. Near Corinne, Utah, it meanders over a plain near its mouth, where the stream's longitudinal profile has a very low gradient. Drag each label so that it overlies the appropriate target.

Ancient point bars

Meander neck

Modern point bar

Oxbow lake

Cut bank

Oxbow lake filled with sediment

Dramatic Landscape Created by Meandering of the Bear River, Near Corinne, Utah

What a Geologist Sees

Hint

Check Answer

View Solution

Progress :

Record my Grade

WHAT A GEOLOGIST SEES figures created just for SmartWork.

Narrative Art, *What a Geologist Sees*, and *See for Yourself*

It's difficult to understand many features of the Earth System without being able to see them. To help students visualize these and other features, this book is lavishly illustrated with figures that try to give a realistic context for the particular feature, without overwhelming students with too much extraneous detail. The talented artists who worked on the book have used the latest computer graphics software, resulting in the most sophisticated pedagogical art ever provided by a geoscience text. Many figures have been updated with an eye toward improving the 3-D visualization skills of students. They have also been reconfigured to make them more friendly and intuitive. In addition to the art, the book also boasts over 1,000 stunning photographs from all around the world. Many of the photographs were taken by the author, specifically to illustrate the exact concept under discussion. Where appropriate, photographs are accompanied by annotated sketches named *What*

a Geologist Sees. These figures allow students to see how geologists perceive the world around them and to encourage students to start thinking like geologists.

Throughout the book, drawings and photographs have been integrated into *narrative art*, which has been laid out, labeled, and annotated to tell a story—the figures are drawn to teach! Subcaptions are positioned adjacent to relevant parts of each figure, labels point out key features, and balloons provide important annotation. Subparts are arranged to convey time progression, where relevant. The color schemes of drawings have been tied to those of relevant photos, so that students can easily relate features in the drawings to those in the photos. Further, all the art in this edition has been reworked to achieve a consistent style, using standard colors and textures for similar features across the book.

*Google Earth*TM provides an amazing opportunity for students to visit and tour important geologic sites wherever they occur. Throughout the book, we provide *See for Yourself* panels, which provide coordinates and descriptions of geologic

See for Yourself: Using Google Earth™

Visiting the SFY Field Sites Identified in the Text

There's no better way to appreciate geology than to see it firsthand in the field. The challenge is that the great variety of geologic features that we discuss in this book can't be visited from any one locality. So even if your class takes geology field trips during the semester, you'll at most see examples of just a few geologic settings. Fortunately, *Google Earth*™ makes it possible to fly to spectacular geologic field sites anywhere in the world in a matter of seconds—you can take a virtual field trip electronically. In each chapter in this book, *See for Yourself* panels identify geologic sites that you can explore on your own personal computer (Mac or PC) using *Google Earth*™ software, or on your Apple/Android smartphone or tablet with the appropriate *Google Earth*™ app.

To get started, follow these three simple steps:

- 1 Check to see if *Google Earth*™ is installed on your personal computer, smartphone, or tablet. If not, download the free software from earth.google.com or the app from the Apple or Android app store.
- 2 Each *See for Yourself* panel in the margin of the chapter provides a thumbnail photo of a geologically interesting site, as well as a very brief description of the site. The panel also provides the latitude and longitude of the site.
- 3 Open *Google Earth*™ and enter the coordinates of the site in the search window. As an example, let's find Mt. Fuji, a beautiful volcano in Japan. We note that the coordinates in the *See for Yourself* panel are as follows:

Latitude	35°21'41.78"N
Longitude	138°43'50.74"E

Type these coordinates into the search window of *Google Earth*™ as:

35 21 41.78N, 138 43 50.74E

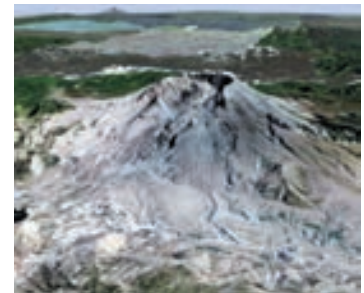
with the degree, minute, and second symbols left blank. When you click enter or return, your device will bring you to the viewpoint right above Mt. Fuji, as illustrated by the following thumbnails.

Google Earth™ contains many built-in and easy-to-use tools that allow you to vary the elevation, tilt, orientation, and position of your viewpoint, so that you can tour around the feature, see it from many different perspectives, and thus develop a three-dimensional sense of the feature. In the case of Mt. Fuji, you'll be able to see its cone-like shape and the

crater at its top. By zooming out to higher elevation, you can instantly perceive the context of the given geologic feature—for example, if you fly up into space above Mt. Fuji, you will see its position relative to the tectonic plate boundaries of the western Pacific. The thumbnail below (on the right) shows the view you'll see of the same location if you tilt your viewing direction and look north.



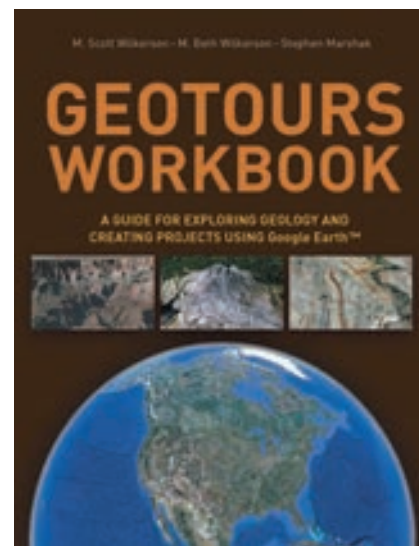
View looking down.



View looking north.

Need More Help? If you're having trouble, please visit wwnorton.com/rd/SeeEarth5. There, you will find a video showing how to download and install *Google Earth*™, additional instructions on how to find the *See for Yourself* sites, links to *Google Earth*™ videos describing basic functions, and links to any hardware and software requirements. Also, notes addressing *Google Earth*™ updates will be available at this site.

We also offer a separate book—the *Geotours Workbook* (ISBN 978-0-393-91891-5), by Scott Wilkerson, Beth Wilkerson, and Stephen Marshak—that identifies additional interesting geologic sites to visit, provides active-learning exercises linked to the sites, and explains how you can create your own virtual field trips.



features that students can visit at the touch of a finger, or the click of a mouse. The adjacent box provides a quick guide for using these panels.

Featured Paintings—*Geology at a Glance*

In addition to individual figures, British artist Gary Hincks has created spectacular two-page annotated paintings for each chapter. These paintings, called *Geology at a Glance*, integrate key concepts introduced in the chapters, visually emphasize the relationships between components of the Earth System, and allow students a way to review a subject . . . at a glance. The Fifth Edition includes a brand-new painting, illustrating the Earth's history, in Chapter 13.

Enhanced Coverage of Current Topics

To ensure that *Earth: Portrait of a Planet*, Fifth Edition, reflects the latest research discoveries and helps students understand geologic events that have been featured in current news, we have updated many topics throughout the book. For example: the energy chapter has been substantially revised to clarify the impact of the switch to unconventional gas and oil reserves; new geophysical data from the EarthScope project have been incorporated into discussions of the Earth's interior; discussions of Earth history incorporate the latest revisions to the geologic time scale; and data from the latest IPCC report contribute to the book's treatment of climate change. *Earth: Portrait of a Planet*, Fifth Edition, also covers the lessons learned from recent natural disasters such as Hurricane Sandy, Typhoon Haiyan, the Washington landslide, and the Tōhoku tsunami.

This book addresses geology's practical applications 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 geologic hazards. And students are encouraged to apply their geologic understanding to environmental issues, where relevant. *Science and Society* features, available through Norton Coursepacks to instructors, further challenge students to use material learned in class to interpret news articles and publicly available geologic data.

Supplementary Materials

SmartWork

The student experience of reading *Earth: Portrait of a Planet*, Fifth Edition, can be enhanced significantly through the use of *SmartWork Online Homework* for Geology. The *SmartWork*

system features visual assignments that provide students with answer-specific feedback. Students get the coaching they need to work through the assignments, while instructors get real-time assessment of student progress with automatic grading and item analysis. Image-based drag-and-drop and labeling questions make use of carefully developed images. Also available are additional *What a Geologist Sees* figures created exclusively for *SmartWork*; additional video, animation, and conceptual questions that challenge students to apply their understanding of important concepts; reading quizzes for each chapter; and *Geotour*-guided inquiry activities using *Google Earth*[™]. Designed to be intuitive and easy to use (for both students and instructors), *SmartWork* makes it a snap to assign, assess, and report on student performance, and to keep the class on track.

Tablet- and Mobile-ready E-book

Earth Portrait of a Planet, Fifth Edition is available in a new format perfect for tablets and other mobile devices. Within the ebook, art expands for a closer look, links send you to geologic locations in *Google Maps*[™], animations and videos link out from each chapter, and pop-up key terms provide a quick review. It's also easy to highlight, take notes, and search the text

The Geotours Workbook

Created by Scott Wilkerson, Beth Wilkerson, and Stephen Marshak, the *Geotours Workbook* provides active-learning opportunities that take students on virtual field trips to see outstanding examples of geology at localities around the world, using *Google Earth*[™]. Arranged by topic, questions in the *Geotours Workbook* have been designed for auto-grading, and are available as worksheets both in print format (these come free with the book and include complete user instructions and advanced instruction), or electronically with automatic grading through *SmartWork* or your campus LMS. The *Geotours Workbook* also provides instructions that will allow instructors or students to make their own geotours. Request a sample copy to preview each worksheet.

Art Files and PowerPoints

The publisher provides a variety of electronic presentations of art and photographs in the book to enhance the classroom experience. These include:

- *Enhanced Art PowerPoints*—Designed for instant classroom use, these slides utilize photographs and line art from the book in a form that has been optimized for use in the PowerPoint environment. The art has been

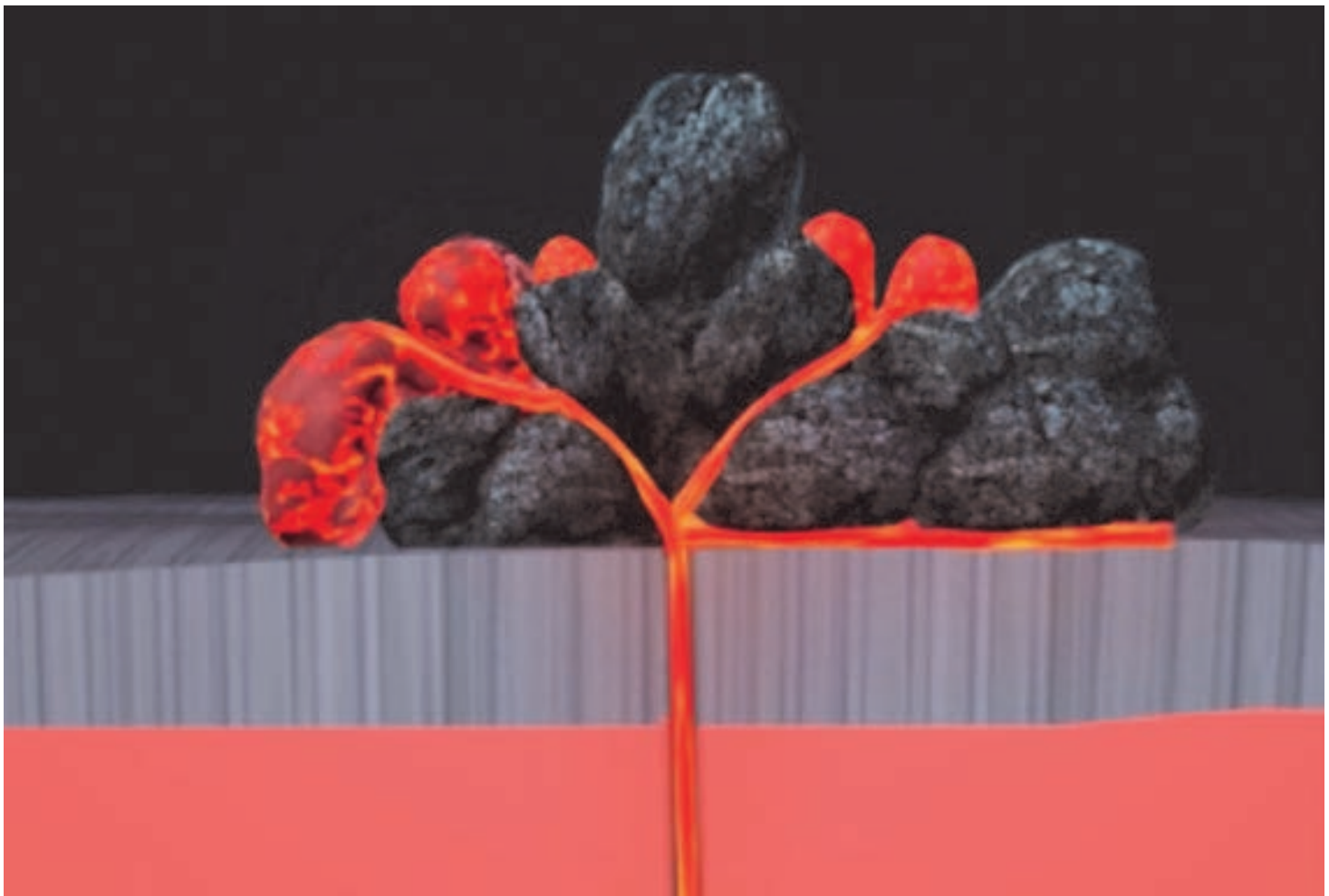
reabeled and resized for projection formats. Enhanced Art PowerPoints also include supplemental photographs. For the Fifth Edition, both enhanced and lecture bullet PowerPoints were revised by Jennifer Sliko of Penn State University, Harrisburg.

- *Lecture Bullet PowerPoints*—These slides include both art and bulleted text for direct use either in lectures or as student handouts.
- *Labeled and Unlabeled Art PowerPoints*—These include all art from the book, formatted as JPEGs, pre-pasted into PowerPoints. We offer one set in which all labeling has been stripped, and one set in which the labeling has been retained.
- *Labeled and Unlabeled Art JPEGs*—We provide a complete file of individual JPEGs for all art and photographs presented in the book.

- *Monthly Update PowerPoints*—W. W. Norton & Company, Inc., offers a monthly update service that provides new PowerPoint slides, with instructor support, covering recent geologic events. Monthly updates are authored by Rich Oches of Bentley University.

New Animations and Videos

Earth: Portrait of a Planet, Fifth Edition, provides a rich collection of animations to illustrate geologic processes all created in a consistent style and with a 3-D perspective. The set includes additional new animations, developed by Alex Glass of Duke University, that allow you to control variables. Further, the new edition comes with a new set of Narrated Figure Videos, in which the author explains core concepts and figures from each chapter. Videos are free, require no special hardware, and are available in coursepacks, with links you can stream to your



ANIMATIONS illustrate geologic processes.

class, or for students to use. In addition, Melissa Hudley of the University of North Carolina–Chapel Hill, Heather Lehto of Angelo State University, and Meghan Lindsey of the University of South Florida developed over 50 videos of geologic processes and topics for our coursepacks and instructor support website. All animations and videos are ready to go and perfect for streaming in the classroom or for online use.

Instructor's Manual and Test Bank

The *Instructor's Manual*, prepared by John Werner of Seminole State College of Florida, is designed to help instructors prepare lectures and exams. It contains detailed *Learning Objectives*, *Chapter Summaries*, and complete answers to the end-of-chapter *Review* and *On Further Thought* questions for every chapter and interlude.

The *Test Bank*, written by Scott Marshall of Appalachian State University, Meredith Denton-Hedrick of Austin Community College, and Heather Lehto of University of South Florida, has been revised not only to correlate to this new Edition, but to provide greater, more rounded assessment than ever before. Expert accuracy checkers Geoffrey Cook of UC San Diego, and Mark Feigenson of Rutgers University have ensured that every question we've included in the *Test Bank* is scientifically reliable and truly tests students' understanding of the most important topics in each chapter, so that the questions can be assigned with confidence.

Instructor's Website—wwnorton.com/instructors

The Instructor's Website provides online access to a rich array of resources: the *Test Bank*, the *Instructor's Manual*, PowerPoints, JPEGs, *Google Earth*™ file of sites from the book, art from the text, animations, new Narrated Figure and additional videos, and LMS-ready content.

Norton Media Library Instructor's DVD-ROM

Supporting the instructor's website, the instructor's DVD offers many of the Fifth Edition's multimedia resources, all structured around the text in a convenient package. Contact your Norton representative to obtain a copy.

Coursepacks

Available at no cost to professors or students, *Norton Coursepacks* bring high-quality Norton digital media into a new or existing online course. *Coursepacks* contain ready-made content

for your campus LMS. For *Earth: Portrait of a Planet*, Fifth Edition, content includes new Narrated Figure Videos keyed to core figures in each chapter, the *Test Bank*, reading quizzes, new visual questions for each chapter, completely revised quiz questions by Cynthia Liutkus-Pierce of Appalachian State University, Geotour questions, animations, streaming video, *vocabulary flashcards*, *Science and Society* features, and links to the ebook.

Student Site—wwnorton.com/rd/SeeEarth5

Free and open for students, the *Student Site* provides Marshak's new Narrated Figure Videos, *vocabulary flashcards*, information on how to best utilize the *Google Earth*™ materials, as well as five new features that were developed by Rick Oches of Bentley University for this edition. The *Student Site* also includes a video designed to help with start-up, as well as a downloadable file of all the *See for Yourself* sites.

Acknowledgments

Many people contributed to the long and complex process of bringing this book from the concept stage to the shelf in the first place, and now to the continuous effort of improving the book to keep it current. Textbooks are, by definition, a work in progress.

First and foremost, I wish to thank my family, who allowed “the book” to become a member of our household, and have also tolerated the overabundance of photo stops on family trips. Production of this book is a partnership with my wife, Kathy. She has carried out the immense task of merging changes completed for *Essentials of Geology*, Fourth Edition, along with changes suggested by reviewers, to produce the initial manuscript for *Earth: Portrait of a Planet*, Fifth Edition. Kathy also edited new text, cross-checked many sets of proofs, and managed the never-ending inflow and outflow of proofs that perpetually occupy our dining-room table. Without her efforts, the updating of *Earth: Portrait of a Planet* through the years would not be possible. Our daughter, Emma, helped develop the concept of narrative art used in the book, provided several photos, served as scale in other photos, and provided invaluable feedback about how the book works. Our son, David, highlighted places where the writing could be improved, helped me to keep the project in perspective, and also served as scale in photographs.

I am very grateful to all of the staff of W. W. Norton & Company for their incredible efforts during the development

of my books over the past two decades. It has been a privilege to work with an employee-owned company that is willing to collaborate so closely with its authors. In particular, I would like to thank Eric Svendsen, the geology editor at Norton, who continues to inject new enthusiasm and ideas into the project. His skill in editing, ability to “oversee many moving parts,” and his friendly reminders of deadlines, have led this book to completion. Thom Foley, the book’s senior project editor, continues to do an amazing job of guiding the book through production. He somehow keeps track of all the drafts, all the changes, and all the figures for a lengthy and complicated manuscript, while remaining incredibly calm. It’s thanks to Thom that everything somehow manages to get done, and that mistakes are few and far between. Meredith Leo has done wonders as the marketing manager for the book, by helping to determine how to meet the needs of adopters worldwide. And as always, I would like to thank Jack Repcheck, who served as the geology editor for the first three editions of the book, before passing the baton to Eric for the Fourth and Fifth Editions. Jack suggested many of the original innovations that strengthened the book, and his instincts about what works in textbook publishing brought the book to the attention of a wider geological community than I ever thought possible. He remains an understanding friend and a fountain of sage advice.

Moving *Earth: Portrait of a Planet* from concept to completion involves a large team of professionals. Stan Maddock, Megan Stewart, Kristina Seymour, Stacy McDade, Eric Bramer, and the other artists and production staff at Precision Graphics in Champaign, Illinois, as always have created beauty and enhanced pedagogy with the line art that they have rendered and the page layout that they’ve created. I also wish to thank Jeff Mellander, founder and recently retired President of Precision Graphics, for his support in our interactions with his company over these many years. Stephanie Romeo and Jane Miller at Norton did a fantastic job with the Herculean task of finding, organizing, and crediting photographs, and Leah Scott creatively developed a clean and friendly page design. Trish Marx’s efforts on the previous edition brought the management of the photo collection into the 21st century and has greatly streamlined the selection process. I am also grateful to Robin Kimball, Rob Bellinger, Cailin Barrett Bressack, Victoria Reuter, Kim Yi, Danielle Belfiore, Leah Clark, and Kristin Sheerin for their innovative approach to ancillary and e-media development and for overseeing the development of *Smart-Work*. Thanks also go to Kristian Sanford and Mateus Teixeira for their work on the Tablet and Mobile e-book, and to Ben Reynolds, who coordinated the back-and-forth between the publisher and various vendors and suppliers. Susan Gausstad, the outstanding developmental editor of the First Edition, helped to set the tone of the book and to weed out errors

that otherwise might burden a new edition and Sunny Hwang now provides expert help crafting the text. Chris Thillen has kept that tradition going with her skillful copy editing of this Fifth Edition. And Editorial Assistants Lindsey Thomas and Rachel Goodman provided consistent editorial support and trouble-shooting throughout the process of making this book.

The five editions of this book and its cousin, *Essentials of Geology*, 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 book and were kind enough to contact me or the publisher with suggestions and corrections. Additional accuracy checking for the Fifth Edition was supplied by Andy Bobyarchick of UNC Charlotte, and Heather Lehto of Angelo State University. We gratefully acknowledge the contributions of the reviewers listed below, who have provided invaluable input into this and past editions. I apologize if I’ve inadvertently left anyone off the list.

- Jack C. Allen, Bucknell University
- David W. Anderson, San Jose State University
- Martin Appold, University of Missouri-Columbia
- Philip Astwood, University of South Carolina
- Eric Baer, Highline University
- Victor Baker, University of Arizona
- Julie Baldwin, University of Montana
- Miriam Barquero-Molina, University of Missouri
- Sandra Barr, Acadia University
- Keith Bell, Carleton University
- Mary Lou Bevier, University of British Columbia
- Jim Black, Tarrant County College
- Daniel Blake, University of Illinois
- Andy Bobyarchick, University of North Carolina—Charlotte
- Ted Bornhorst, Michigan Technological University
- Michael Bradley, Eastern Michigan University
- Mike Branney, University of Leicester, UK
- Sam Browning, Massachusetts Institute of Technology
- Bill Buhay, University of Winnipeg
- Rachel Burks, Towson University
- Peter Burns, University of Notre Dame
- Katherine Cashman, University of Oregon
- Cinzia Cervato, Iowa State University
- George S. Clark, University of Manitoba
- Kevin Cole, Grand Valley State University
- Patrick M. Colgan, Northeastern University
- Peter Copeland, University of Houston
- John W. Creasy, Bates College
- Norbert Cygan, Chevron Oil, retired
- Michael Dalman, Blinn College

- Peter DeCelles, University of Arizona
- Carlos Dengo, ExxonMobil Exploration Company
- Meredith Denton-Hedrick, Austin Community College—Cypress Creek
- John Dewey, University of California, Davis
- Charles Dimmick, Central Connecticut State University
- Robert T. Dodd, Stony Brook University
- Missy Eppes, University of North Carolina, Charlotte
- Eric Essene, University of Michigan
- James E. Evans, Bowling Green State University
- Susan Everett, University of Michigan, Dearborn
- Dori Farthing, State University of New York, Geneseo
- Mark Feigenson, Rutgers University
- Grant Ferguson, St. Francis Xavier University
- Eric Ferré, Southern Illinois University
- Leon Follmer, Illinois Geological Survey
- Nels Forman, University of North Dakota
- Bruce Fouke, University of Illinois
- David Furbish, Vanderbilt University
- Steve Gao, University of Missouri
- Grant Garvin, John Hopkins University
- Christopher Geiss, Trinity College, Connecticut
- Bryan Gibbs, Richland Community College
- Gayle Gleason, State University of New York, Cortland
- Cyrena Goodrich, Kingsborough Community College
- William D. Gosnold, University of North Dakota
- Lisa Greer, William & Mary College
- Steve Guggenheim, University of Illinois, Chicago
- Henry Halls, University of Toronto, Mississauga
- Bryce M. Hand, Syracuse University
- Anders Hellstrom, Stockholm University
- Tom Henyey, University of South Carolina
- Bruce Herbert, Texas A & M University
- James Hinthorne, University of Texas, Pan American
- Paul Hoffman, Harvard University
- Curtis Hollabaugh, University of West Georgia
- Bernie Housen, Western Washington University
- Mary Hubbard, Kansas State University
- Paul Hudak, University of North Texas
- Melissa Hudley, University of North Carolina, Chapel Hill
- Warren Huff, University of Cincinnati
- Neal Iverson, Iowa State University
- Charles Jones, University of Pittsburgh
- Donna M. Jurdy, Northwestern University
- Thomas Juster, University of Southern Florida
- H. Karlsson, Texas Tech
- Daniel Karner, Sonoma State University
- Dennis Kent, Lamont Doherty/Rutgers
- Charles Kerton, Iowa State University
- Susan Kieffer, University of Illinois
- Jeffrey Knott, California State University, Fullerton
- Ulrich Kruse, University of Illinois
- Robert S. Kuhlman, Montgomery County Community College
- Lee Kump, Pennsylvania State University
- David R. Lageson, Montana State University
- Robert Lawrence, Oregon State University
- Heather Lehto, Angelo State University
- Scott Lockert, Bluefield Holdings
- Leland Timothy Long, Georgia Tech
- Craig Lundstrom, University of Illinois
- John A. Madsen, University of Delaware
- Jerry Magloughlin, Colorado State University
- Scott Marshall, Appalachian State University
- Jennifer McGuire, Texas A&M University
- Judy McIlrath, University of South Florida
- Paul Meijer, Utrecht University, Netherlands
- Jamie Dustin Mitchem, California University of Pennsylvania
- Alan Mix, Oregon State University
- Otto Muller, Alfred University
- Kristen Myshrall, University of Connecticut
- Kathy Nagy, University of Illinois, Chicago
- Pamela Nelson, Glendale Community College
- Robert Nowack, Purdue University
- Charlie Onasch, Bowling Green State University
- David Osleger, University of California, Davis
- Bill Patterson, University of Saskatchewan
- Eric Peterson, Illinois State University
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- Stephen Piercey, Laurentian University
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- David Sparks, Texas A&M University
- Angela Speck, University of Missouri
- Larry Standlee, University of Texas—Arlington
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- Seth Stein, Northwestern University
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- Michael Stewart, University of Illinois
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- Basil Tikoff, University of Wisconsin
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- Stacey Verardo, George Mason University
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- John Werner, Seminole State College of Florida
- Alan Whittington, University of Missouri
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Stephen Marshak

It was during my enchanted days of travel that the idea came to me which, through the years, has come into my thoughts again and again and always happily—the idea that geology is the music of the Earth.

—Hans Cloos (German geologist, 1885–1951)