



TARBUCK
—
LUTGENS

EARTH

AN
INTRODUCTION
TO PHYSICAL
GEOLOGY

Ninth Edition



NINTH EDITION

EARTH

An Introduction to Physical Geology

Edward J. Tarbuck
Frederick K. Lutgens

Illustrated by
Dennis Tasa



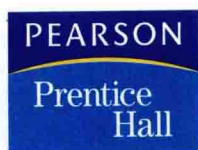
Upper Saddle River, NJ 07458

Library of Congress Cataloging-in-Publication Data

Tarbuck, Edward J.
Earth : an introduction to physical geology / Edward J. Tarbuck, Frederick K. Lutgens ;
illustrated by Dennis Tasa.—9th ed.
p. cm.
Includes index.
ISBN 0-13-156684-9
1. Physical geology—Textbooks. I. Lutgens, Frederick K. II Title.
QE28.2.T37 2008
551—dc22

Publisher, Geosciences: *Daniel Kaveney*
Editor in Chief, Science: *Nichole Folchetti*
Executive Managing Editor: *Kathleen Schiaparelli*
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Composition: *Pine Tree Composition*
Cover Photo: *Hiker in Antelope Canyon, near Paige, Arizona*
(*Galen Rowell/Mountain Light*)
Title Page Photo: *Delicate Arch in Arches National Park, Utah*
(*David Muench/Muench Photography, Inc.*)



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Printed in the United States of America

10 9 8 7 6 5 4 3 2 1

ISBN 0-13-156684-9

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Pearson Education Australia Pty., Limited, Sydney
Pearson Education Singapore, Pte. Ltd
Pearson Education North Asia Ltd., Hong Kong
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GEODE: Earth CD-ROM

Edward J. Tarback and Frederick K. Lutgens

Illustrated by Dennis Tasa

ISBN-13: 978-0-13-156692-7 ISBN-10: 0-13-156692-X

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If your display is larger than 800 x 600 pixels, there will be a black border around the 800 x 600 display window.

Note for NT users: If you cannot hear the narration audio, verify that you have installed the latest version of your computer's sound drivers.

Mac

GEODE: Earth has no installation or setup program.

To start the GEODE: Earth program simply insert "GEODE Earth" CD-ROM into your CD-ROM drive and double-click the icon for your operating system of choice ("GEODE Earth for OS X" or "GEODE Earth for OS 8.6 to 9.2").

If your display is larger than 800 x 600 pixels, there will be a black border around the 800 x 600 display window.

System Requirements:

Windows

Operating System: Windows 98, ME, 2000, NT version 4 or later, XP

Processor: In addition to the processor required by your OS, this application requires at least a Pentium II 200 MHz processor.

RAM: In addition to the RAM required by your OS, this application requires at least an additional 32 Meg RAM.

Required hardware: CD drive, speakers, and a printer is required to print student scores.

Monitor resolution: 800 x 600 pixels; millions of colors

Required third-party software: QuickTime(TM) (version 5.0.2 or later)

A newer version of QuickTime may be available from the QuickTime website: <http://www.apple.com/quicktime/download>

This CD-ROM is intended for standalone use only. It is not for use on a network.

Mac

Operating System: MAC OS X (10.1 or later) and MAC OS 8.6 to 9.2

Processor: In addition to the processor required by your OS, this application requires at least a PowerPC running at 180 Mhz (a G3 is recommended for OS 8.6 to 9.2 and a G3 is required for OS X).

RAM: In addition to the RAM required by your OS, this application requires at least an additional 32 Meg RAM (128 Megs RAM for OS X).

Required hardware: CD drive, speakers, and a printer is required to print student scores.

Monitor resolution: 800 x 600 pixels; millions of colors

Required third-party software: QuickTime™ (version 5.0.2 or later)

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EARTH

*To our wives, Joanne and Nancy,
for their support and patience.*

Preface

Earth is a very small part of a vast universe, but it is our home. It provides the resources that support our modern society and the ingredients necessary to maintain life. Therefore, knowledge of our planet is critical to our well-being and, indeed, vital to our survival. The science of geology contributes greatly to our understanding of planet Earth.

Media reports frequently remind us of the geological forces at work on our planet. News stories graphically portray the violent force of a volcanic eruption, the devastation generated by a strong earthquake, and the large numbers left homeless by landslides and flooding. Such events, and many others as well, are destructive to life and property, and we must learn to deal with them. Moreover, we also face many basic environmental issues that have a significant geological component. Examples include groundwater contamination, soil erosion, and the many impacts of extracting energy and mineral resources. To understand these issues and try to find solutions to the problems related to them requires an awareness of how science is done and the scientific principles that influence our planet, its rocks, mountains, atmosphere, and oceans.

The ninth edition of *Earth: An Introduction to Physical Geology*, like its predecessors, is a college-level text that is intended to be a meaningful non-technical survey for students taking their first course in geology. In addition to being informative and up-to-date, a major goal of *Earth* is to meet the need of students for a readable and user-friendly text, a book that is a highly usable “tool” for learning the basic principles and concepts of geology.

Basic Organization

Earth is organized to reflect the unifying role that the theory of plate tectonics plays in our understanding of planet Earth. Since the late 1960s scientists have come to realize that Earth’s outer shell is broken into segments called *plates*. Driven by heat from Earth’s interior, these huge slabs gradually move in relation to one another. Where landmasses split apart, new ocean basins are created between diverging continents. Meanwhile, older portions of the seafloor plunge back into Earth’s interior. These movements generate earthquakes, cause volcanoes to form, and lead to the creation of Earth’s major mountain belts.

Chapter 1 presents an introduction to the science of geology, followed by a look at the nature of scientific inquiry, and a discussion of the birth and early evolution of planet Earth. Next, Chapter 2 traces the historical development of the theory of plate tectonics as a way of providing insight into how science and scientists work. This is immediately followed by an overview of the plate tectonics theory. Developing a basic understanding of this model of how Earth

works will aid students as they explore many of the phenomena discussed in the chapters that follow.

With the basic framework of plate tectonics firmly established, we turn to discussions of Earth materials and the related processes of volcanism, metamorphism, and weathering. Along the way, students will clearly see the relationships between these phenomena and the theory of plate tectonics. Next, the fundamental concepts of geologic time are presented in detail. This is followed by an examination of earthquakes, Earth’s internal structure, and the processes that deform rocks.

We revisit plate tectonics again in Chapters 13 and 14. These chapters expand on earlier discussions as we consider the nature of Earth’s ocean basins and mountains. Chapter 13 explores the origin and structure of the ocean floor. Students are asked to examine how the seafloor is generated, why it is continually being destroyed, and what clues it can provide about events that occurred earlier in Earth’s history. Then Chapter 14 considers the role of plate tectonics in the formation of Earth’s major mountain belts. After this examination of Earth’s large-scale features, we examine the geological work of gravity, water, wind, and ice. It is these processes that modify and sculpt Earth’s surface, creating many of its varied landforms.

Following the multichapter examination of Earth’s major surface processes in Chapters 15 through 20, two new chapters focus on global climate change and Earth history. These new additions are described in more detail in the next section of the preface. Finally, *Earth, Ninth Edition* concludes with a chapter on energy and mineral resources followed by a significantly revised chapter on planetary geology.

As in previous editions of this text, we have designed each chapter as a self-contained unit so that material may be taught in a different sequence according to the preference of the instructor or the dictates of the laboratory. Thus, the instructor who wishes to discuss erosional processes prior to earthquakes, plate tectonics, and mountain building may do so without difficulty.

Two New Chapters

Two all-new chapters have been added—Chapter 21, “Global Climate Change” and Chapter 22, “Earth’s Evolution through Geologic Time.” This was done in response to *extensive* pre-revision reviews and surveys that indicated a strong desire among professors to see these topics added. The intent is not to expand the amount of material presented in introductory geology, but to allow for greater instructor flexibility and variety when determining course content.

Chapter 21, “Global Climate Change” provides an excellent opportunity to explore many interrelationships in

the Earth system. The crucial questions of climate change are those of process and response, and cause and effect. What factors cause Earth's climate to change? How does the Earth system respond and on what time scales? This chapter presents an overview that examines both natural variability and climate change related to human activities. Today, climate change is more than just a subject that is of "academic interest." Rather it is a topic that is making headlines. This chapter presents an up-to-date look at a major global environmental issue.

Chapter 22, "Earth's Evolution through Geologic Time" presents a clear, concise summary of Earth history beginning with an engaging introduction entitled "Is Earth Unique?" The chapter includes easy-to-follow discussions on the birth and early evolution of the planet and on the origin of continents, the atmosphere, and oceans. To allow for maximum instructor flexibility, there are separate discussions of Earth's physical history and the evolution of life through geologic time.

Distinguishing Features

Readability

The language of this book is straightforward and written to be understood. Clear, readable discussions with a minimum of technical language are the rule. The frequent headings and subheadings help students follow discussions and identify the important ideas presented in each chapter. In the ninth edition, improved readability was achieved by examining chapter organization and flow, and writing in a more personal style. Large portions of the text were substantially rewritten in an effort to make the material more understandable.

Illustrations and Photographs

Geology is highly visual. Therefore, photographs and artwork are a critical part of an introductory book. *Earth, Ninth Edition*, contains dozens of new high-quality photographs that were carefully selected to aid understanding, add realism, and heighten the interest of the reader.

There has been substantial revision and improvement of the art program. Clearer, easier-to-understand line drawings show greater color and shading contrasts. More figures combine the use of diagrams and/or maps and photos together. Moreover, many new art pieces have additional labels that "narrate" the process being illustrated. The result is an art program that illustrates ideas and concepts more clearly than ever before. As in the eight previous editions, we are grateful to Dennis Tasa, a gifted artist and respected geological illustrator, for his outstanding work.

Focus on Learning

When a chapter has been completed, several useful devices help students review. First, the Summary recaps all of the major points. This is followed by Review Questions that

help students examine their knowledge of significant facts and ideas. Next is a checklist of Key Terms with page references. Learning the language of geology helps students learn the material. This is followed by a reminder to visit MyGeologyPlace, the online study guide for *Earth, Ninth Edition* (<http://www.prenhall.com/tarbuck>). It contains many excellent opportunities for review and exploration. Finally, each chapter closes with two frames from the *GEODE: Earth* CD-ROM to remind the student about this unique and effective learning aid.

Earth as a System

An important occurrence in modern science has been the realization that Earth is a giant multidimensional system. Our planet consists of many separate but interacting parts. A change in any one part can produce changes in any or all of the other parts—often in ways that are neither obvious nor immediately apparent. Although it is not possible to study the entire system at once, it is possible to develop an awareness and appreciation for the concept and for many of the system's important interrelationships. Therefore, beginning with an expanded discussion in Chapter One, the theme of "Earth as a System" recurs at appropriate places throughout the book. It is a thread that "weaves" through the chapters and helps tie them together. Several new and revised special-interest boxes relate to "Earth as a System."

People and the Environment

Because knowledge about our planet and how it works is necessary to our survival and well-being, the treatment of environmental issues has always been an important part of *Earth*. Such discussions serve to illustrate the relevance and application of geological knowledge. With each new edition, this focus has been given greater emphasis. This is certainly the case with the ninth edition. The text integrates a great deal of information about the relationship between people and the natural environment and explores the application of geology to understanding and solving problems that arise from these interactions. In addition to many basic text discussions, more than 20 of the text's special-interest boxes involve the "People and the Environment" theme.

Understanding Earth

As members of a modern society, we are constantly reminded of the benefits derived from science. But what exactly is the nature of scientific inquiry? Developing an understanding of how science is done and how scientists work is another important theme that appears throughout this book, beginning with the section on "The Nature of Scientific Inquiry" in Chapter 1. Students will examine some of the difficulties encountered by scientists as they attempt to acquire reliable data about our planet and some of the ingenious methods that have been developed to overcome these difficulties. Students will also explore many examples of how hypotheses are formulated and tested as well as learn about

the evolution and development of some major scientific theories. Many basic text discussions as well as a number of the special-interest boxes on “Understanding Earth” provide the reader with a sense of the observational techniques and reasoning processes involved in developing scientific knowledge. The emphasis is not just on what scientists know, but how they figured it out.

More About the Ninth Edition

The ninth edition of *Earth* represents a thorough revision. Every part of the book was examined carefully with the dual goals of keeping topics current and improving the clarity of text discussions. In addition to the two new chapters that have already been described, those familiar with previous editions of *Earth* will find many other changes. Here are some examples:

- Chapter 12 “Earth’s Interior” has been *completely* revised and rewritten by Michael Wysession, Earth and Planetary Sciences Department, Washington University. Professor Wysession is not only an expert on geophysics and Earth’s inner structure, but he is also an accomplished geoscience educator. Basic coverage has been expanded to include heat flow and temperature distribution in Earth’s interior, Earth’s gravity, the use of seismic tomography to study Earth’s interior, and a more in-depth treatment of Earth’s magnetic field. The chapter not only has broader, more up-to-date coverage, but explanations of these sometimes complex ideas are written in a more conversational, easier to understand style. The revised chapter is supported with a strong new art program and many new images.
- Chapter 24, “Planetary Geology,” has received a major revision with the assistance of professors Teresa Tarbuck and Mark Watry of Rocky Mountain College. There are new discussions on solar system evolution, lunar history, and the dynamic geologic evolution of Mars. Also included is a new section on dwarf planets (Pluto now has this status) and the latest on the Kuiper Belt and Oort cloud.
- Chapter 5, “Volcanoes and Other Igneous Activity,” includes a revised discussion on the nature of volcanic eruptions, an expanded look at Yellowstone-type calderas and a new section on “Living with Volcanoes.”
- Chapter 7, “Sedimentary Rocks,” has a new introduction that is followed by an all new section on the “Origins of Sedimentary Rocks.”
- Chapter 8, “Metamorphism and Metamorphic Rocks,” has new and revised discussions of “Contact/Thermal Metamorphism” and “Burial Metamorphism” and now concludes with a section on “Interpreting Metamorphic Environments.”
- Chapter 15, “Mass Wasting,” begins with a new section on “Landslides as Natural Disasters” and also has a new case study (Box 15.1) of a deadly event at La Conchita, California.

- Chapter 16, “Running Water,” has been reorganized and almost entirely rewritten so that the discussion of streams progresses in a manner that is clearer and more logical for the beginning student.
- Chapter 18, “Glaciers and Glaciation,” includes a new discussion and art on “Ice Dams and Proglacial Lakes” and a related new box on “Glacial Lake Missoula, Megafloods, and the Channeled Scablands.” An updated and expanded section on “Causes of Glaciation” wraps up the chapter.
- Chapter 20, “Shorelines,” has a new section on “Hurricanes—The Ultimate Coastal Hazard,” that includes a look at the impact of Hurricane Katrina on the Gulf Coast. A new special interest box (Box 20.2) “Examining Hurricane Katrina from Space” accompanies the discussion.
- Chapter 23, “Energy and Mineral Resources,” has a revised and rewritten discussion on “Wind Energy,” and a new box (Box 23.2) on “Maintaining the Flow of Geothermal Energy at The Geysers.”

The Teaching and Learning Package

For the Instructor:

Instructor’s Resource Center (IRC) on DVD The IRC puts all of your lecture resources in one easy-to-reach place:

- All of the line art, tables, and photos from the text in .jpg files (Are illustrations central to your lecture? Check out the Student Lecture Notebook.)
- Animations of dozens of key geological processes
- *Images of Earth* photo gallery
- PowerPoint™ presentations
- *Instructor’s Manual* in Microsoft Word
- *Test Item File* in Microsoft Word
- TestGen EQ test generation and management software

Animations The Prentice Hall Geoscience Animation Library includes over 100 animations illuminating the most difficult-to-visualize topics of physical geology. Created through a unique collaboration among five of Prentice Hall’s leading geoscience authors, these animations represent a most significant leap forward in lecture presentation aids. They are provided both as Flash files and, for your convenience, pre-loaded into PowerPoint™ slides.

PowerPoint™ Presentations Found on the IRC are *three* PowerPoint files for each chapter. Cut down on your preparation time, no matter what your lecture needs:

1. Exclusively Art — All of the photos, art, and tables from the text, in order, loaded into PowerPoint slides.
2. Lecture Outline — Authored by Stan Hatfield of Southwestern Illinois College, this set averages 35

slides per chapter and includes customizable lecture outlines with supporting art.

3. Animations—Each animation preloaded into slides for easy cut-and-paste into your presentation.

All art is modified for projection—labels are enlarged, colors brightened, and contrasts sharpened. The slides are designed for *clear viewing*, even in the largest lecture halls, and *brightness* so you need not dim the lights as much.

Images of Earth Photo Gallery Supplement your personal and text-specific slides with this amazing collection of over 300 geologic photos contributed by Marli Miller (University of Oregon) and other professionals in the field. Photos are grouped by geologic concept and are available on the Instructor's Resource Center.

Transparencies Every table and most of Dennis Tasa's illustrations in *Earth, Ninth Edition* are available on full-color, projection-enhanced transparencies. (Are illustrations central to your lecture? Check out the *Student Lecture Notebook* on the Student Resources Page).

Instructor's Manual with Tests Authored by Stanley Hatfield (Southwestern Illinois College), the *Instructor's Manual* contains: learning objectives, chapter outlines, answers to end-of-chapter questions and suggested, short demonstrations to spice up your lecture. The *Test Item File* incorporates art and averages 75 multiple-choice, true/false, short-answer, and critical-thinking questions per chapter.

TestGen EQ Use this electronic version of the *Test Item File* to build and customize your tests. Create multiple versions, add or edit questions, add illustrations—your customization needs are easily addressed by this powerful software.

Blackboard and WebCT Already have your own website set up? We will provide a *Test Item File* in Blackboard or WebCT formats for importation. Additional course resources are available on the IRC and are available for use, with permission.

For the Student:

GEODE: Earth Somewhere between a text and a tutor, *GEODE: Earth* reinforces key concepts using animations, video, narration, interactive exercises, and practice quizzes. The quizzes are randomly generated and the results can be printed, making *GEODE: Earth* a great, easy-to-grade homework assignment. A copy of *GEODE: Earth* is automatically included in every copy of the text purchased from Prentice Hall.

Student Lecture Notebook All of the line art from the text and transparency set are reproduced in this full color notebook, with space for notes. Students can now fully focus on the lecture and not be distracted by attempting to replicate figures. Each page is three-hole punched for easy integration with other course materials.

MyGeologyPlace www.prenhall.com/tarbuck This website has been designed to provide students with all the tools needed for online study and review. A self-quiz is available for each key concept within a chapter, and hints and feedback are provided for guidance. Links to other resources are also included for further study. An access code for MyGeologyPlace is bound into the front of every new copy of this textbook.

Acknowledgments

Writing a college textbook requires the talents and cooperation of many individuals. Working with Dennis Tasa, who is responsible for all of the text's outstanding illustrations and much of the developmental work of *GEODE: Earth*, is always special for us. We not only value his outstanding artistic talents and imagination but his friendship.

We were privileged to have Michael Wyssession of Washington University collaborate on the revision of Chapter 12, "Earth's Interior." His expertise, insights, and writing skills greatly improved this chapter. We also appreciate the assistance of Teresa Tarbuck and Mark Watry of Rocky Mountain College in updating and revising Chapter 24, "Planetary Geology."

Our sincere appreciation goes to those colleagues who prepared in-depth reviews. Their critical comments and thoughtful input helped guide our work and clearly strengthened the text. Special thanks to

Jessica Barone, *Monroe Community College*

Sam Boggs, Jr., *University of Oregon*

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We also want to acknowledge the team of professionals at Prentice Hall. We sincerely appreciate the company's continuing strong commitment to excellence and innovation. Thanks to our former Executive Editor, Patrick Lynch, who

guided this project through the critical planning and review stages and to Dan Kaveney, Publisher for Geosciences, who saw *Earth, Ninth Edition* through the remaining stages of development and design. We truly value the leadership of both men and appreciate their genuine interest in what we do.

The production team, led by Ed Thomas, has once again done an outstanding job. The strong visual impact of *Earth, Ninth Edition* benefited greatly from the work of photo researcher Yvonne Gerin and image permission coordinator, Debbie Hewitson. Thanks also to Marcia Youngman for her excellent copyediting skills and to proofreader Alison Lorber. All are true professionals with whom we are very fortunate to be associated.

Ed Tarbuck

Fred Lutgens

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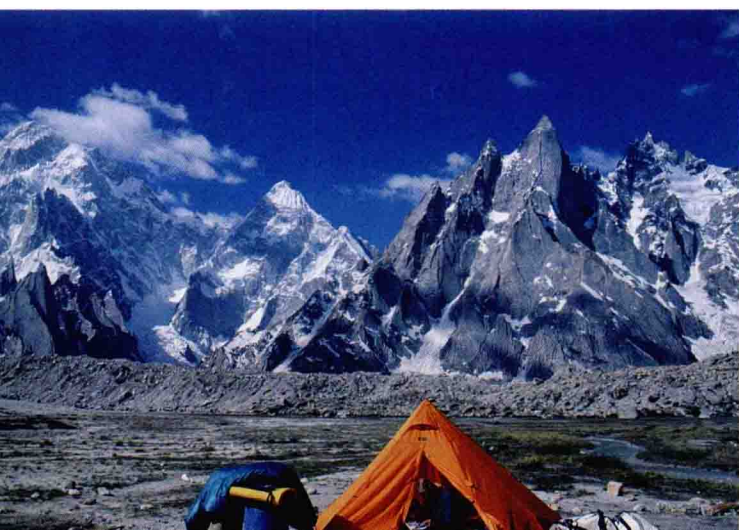
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