




FOUNDATIONS OF
**EARTH
SCIENCE**

FOURTH EDITION

Lutgens • Tarbuck



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**EARTH
SCIENCE**

FOURTH EDITION

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To our students, who have often been our best teachers.

PREFACE

Foundations of Earth Science, Fourth Edition, like its predecessors, is a college-level text designed for an introductory course in Earth science. It consists of seven units that emphasize broad and up to date coverage of basic topics and principles in geology, oceanography, meteorology, and astronomy. The book is intended to be a meaningful, nontechnical survey for undergraduate students with little background in science. Usually these students are taking an Earth science class to meet a portion of their college's or university's general requirements.

In addition to being informative and up to date, a major goal of *Foundations of Earth Science* is to meet the need of beginning students for a readable and user-friendly text, a book that is a highly usable "tool" for learning basic Earth science principles and concepts.

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 also help students follow discussions and identify the important ideas presented in each chapter. In the fourth edition, improved readability was achieved by examining chapter organization and flow and by writing in a more personal style. Many sections were substantially rewritten in an effort to make the material more understandable.

Focus on Learning To assist student learning, every chapter opens with a series of questions. Each question alerts the reader to an important idea or concept in the chapter. Upon completion of a chapter, four useful devices help students review. First, a helpful summary—*The Chapter in Review*—recaps all of the major points. Next is a checklist of *Key Terms* with page references. Learning the language of Earth science helps students retain the material. This is followed by *Questions for Review*, that helps students examine their knowledge of significant facts and ideas. Each chapter closes with a reminder to visit the Web site for *Foundations of Earth Science 4e* (<http://www.prenhall.com/lutgens>). This valuable tool works as an on-line study guide that gives students

one more opportunity to test their understanding of key concepts, ideas, and terms.

Illustrations and Photographs The Earth sciences are highly visual. Therefore, photographs and artwork are a very important part of an introductory book. *Foundations of Earth Science*, Fourth Edition, contains dozens of new high-quality photographs that were carefully selected to aid understanding, add realism, and heighten the reader's interest.

The illustrations in each new edition of *Foundations of Earth Science* keep getting better and better. In the fourth edition more than 100 pieces of line art are new or redesigned. The new art illustrates ideas and concepts more clearly and realistically than ever before. The art program was carried out by Dennis Tasa, a gifted artist and respected Earth science illustrator.

Focus on Basic Principles and Instructor Flexibility

The main focus of the Fourth Edition remains the same as in the first three—to foster student understanding of basic Earth science principles. With this in mind, we have attempted to provide the reader with a sense of the observational techniques and reasoning processes that characterize the Earth sciences.

Whereas student use of the text is a primary concern, the book's adaptability to the needs and desires of the instructor is equally important. Realizing the broad diversity of Earth science courses in both content and approach, we have continued to use a relatively nonintegrated format to allow maximum flexibility for the instructor. Each of the major units stands alone; hence, they can be taught in any order. A unit can be omitted entirely without appreciable loss of continuity, and portions of some chapters may be interchanged or excluded at the instructor's discretion.

Interactive CD-Rom Each copy of *Foundations of Earth Science*, Fourth Edition, comes with an extremely interactive CD-ROM: *GEODE: Earth Science*. In addition to excellent treatment of topics in geology, the CD-ROM includes broad coverage of the oceans, basic meteorology, and the solar system. *GEODE: Earth Science* includes many tutorials, interactive exercises, animations, and video clips. Every unit in the text has a corresponding unit in *GEODE: Earth Science*. A special *GEODE: Earth Science* icon appears throughout the

book wherever a text discussion has a corresponding *GEODE: Earth Science* activity.

More About the Fourth Edition

The Fourth Edition of *Foundations of Earth Science* 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.

People familiar with previous editions of *Foundations of Earth Science* will notice that the trim size of the fourth edition is larger. The result is a less cluttered appearance and room to expand the size of many of the diagrams and photos.

The list of specifics is long. Examples include the following:

- The *Introduction to Earth Science* includes an all new section on “Earth as a System” and expanded treatment of “The Nature of Scientific Inquiry.”
- Chapter 2 contains new identification charts for all three rock groups and substantial new material on igneous and metamorphic rocks.
- Chapter 3 contains an all new discussion on “Controls and Triggers of Mass Wasting.”
- Chapter 5 “Plate Tectonics: A Scientific Theory Unfolds” (formerly “Plate Tectonics: A Unifying Theory”) now places greater emphasis on the historical development of this basic and important theory. In addition, it provides students with even clearer, more up-to-date explanations and illustrations of how Earth works.
- There is much that is new in Chapter 6, including a complete revision and updating of the discussions relating to mountain building.
- Chapter 7 includes new discussions of “Volcanic Structures and Eruptive Styles” and “Igneous Activity and Plate Tectonics.”
- Chapters 9 and 10, which focus on oceanography, have been substantially revised with many new headings, rewritten discussions, and new line art.
- Chapter 11 includes a new discussion on “The Fate of Incoming Solar Radiation” and a substantially revised and updated section on “Global Warming.”
- In Chapter 12 an expanded and revised treatment of atmospheric stability now includes new, easier-to-understand diagrams.
- Chapter 14 includes expanded and updated coverage of severe weather.
- Chapter 15 includes coverage of the recent Mars landers.

Acknowledgments

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

We are grateful to Professors Ken Pinzke and Stan Hatfield at Southwestern Illinois College. In addition to their many helpful suggestions regarding the manuscript, Ken and Stan are responsible for the text's Website, and many of its instructor's resources. They are an important part of our team and valued friends as well.

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

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We also want to acknowledge the team of professionals at Prentice Hall. We sincerely appreciate the company's continuing strong support for excellence and innovation. Special thanks to our executive editor, Patrick Lynch. We value his leadership and appreciate his attention to detail, excellent communication skills, and easygoing style. The production team, led by Ed Thomas, has once again done an outstanding job. All are true professionals with whom we are very fortunate to be associated.

Frederick K. Lutgens

Edward J. Tarbuck

Instructor Resources

Prentice Hall continues to improve the instructor resources in this edition with the goal of saving you time in preparing for your classes.

Instructor's Resource Center (IRC) on CD:

Your "go-to" presentation resource, the IRC contains:

- All of the line art and tables, and select photos from the text as .jpg files (Are illustrations central to your lecture? Check out the *Student Lecture Notebook*.)
- 43 animations of Earth processes (see below)
- *Images of Earth* photo gallery
- Three PowerPoint presentations for each chapter (see below)
- *Instructor's Manual* in Microsoft Word
- *Test Item File* in Microsoft Word

PowerPoints

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 line art and tables and select photos from the text pre-loaded into PowerPoint slides.
2. Lecture Outline—Authored by Stanley Hatfield of Southwestern Illinois College, this set averages 35 slides per chapter and includes customizable lecture outlines with supporting art.
3. Animations—Each animation is pre-loaded into PowerPoint for easy integration into your presentation.

All art is modified for projection—labels are enlarged, colors brightened, contrast sharpened. The slides are designed for *clear viewing*, even in the largest lecture halls, and *brightened* 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 Martin Miller (University of Oregon) and other professionals in the field. The photos are grouped by geologic concept and available on the IRC on CD.

Animations

Found on the IRC, the *Prentice Hall Geoscience Animation Library* includes 43 animations illuminating many difficult-to-visualize Earth science topics. Created through a unique collaboration among five of Prentice Hall's leading geoscience authors, these animations represent the most significant leap forward in lecture presentation aids since the overhead projector. Available on the IRC on CD, each animation is mapped to its corresponding chapter. They are provided as both Flash files and, for your convenience, pre-loaded into PowerPoint slides.

- Earth-Sun Relations
- Convergent Margins
- Foliation
- P & S Waves
- Stream Processes
- Faults
- Transform Faults
- Angular Unconformity and Nonconformity
- Global Warming
- Beach Drift
- Folding
- Seismograph Operations
- Breakup of Pangaea
- Nebular Hypothesis
- Hurricanes
- Oxbow Lake Formation
- Crater Lake
- Igneous Features
- El Niño/La Niña
- Hydrologic Cycle
- Tidal Cycle
- Seafloor Spreading
- Glacial Processes—Ice Budget
- Relative Dating
- Coriolis Effect
- Tectonic Settings and Volcanic Activity
- Glacial Processes—Plucking and Moraines
- Water Phases
- Wave Motion
- Coastal Stabilization—Jetties, Groins, Breakwaters
- Ocean Circulation
- Accretion of Terranes
- Formation of Tornadoes
- Global Atmospheric Circulation Model
- Fronts
- Ozone Depletion
- Atmosphere Energy Balance
- Cyclones & Anticyclones
- Seasonal Pressure and Precipitation Patterns
- Jetstream and Rossby Waves
- Wind Pattern Development
- Mid-Latitude Cyclones
- Atmospheric Stability

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.

Transparencies

Simply put: EVERY DENNIS TASA ILLUSTRATION IN *FOUNDATIONS OF EARTH SCIENCE 4E*

IS AVAILABLE ON A FULL-COLOR, PROJECTION-ENHANCED TRANSPARENCY—OVER 240 OHTs—MC IN ALL. (Are illustrations central to your lecture? Check out the *Student Lecture Notebook*.)

For the Laboratory

Applications and Investigations in Earth Science, Fourth Edition (ISBN 0-13-046095-8). Written by Ed Tarbuck, Fred Lutgens, and Ken Pinzke, this full-color laboratory manual contains 22 exercises that provide students with hands-on experiences in geology, oceanography, meteorology, astronomy, and Earth science skills.

Student Resources

The student resources to accompany *Foundations of Earth Science 4e* have been further refined with the goal of focusing the students' efforts and improving their understanding of the concepts of Earth science.

GEODe: Earth Science

Somewhere between a text and a tutor, *GEODe: Earth Science* reinforces key concepts using animations, video, narration, interactive exercises, and practice quizzes. A copy of *GEODe: Earth Science* is automatically included in every copy of the text purchased from Prentice Hall.

**Online Study Guide**

www.prenhall.com/lutgens

A student study tool, the website contains numerous chapter review exercises (from which students get im-

mediate feedback), including a new *Critical Thinking* module that applies and synthesizes concepts. Links to other resources are also included for further study. Professors can utilize the quizzing modules in conjunction with a course management system to assess student progress.

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.

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GEODe: Earth Science

A copy of *GEODe: Earth Science* is packaged with each copy of *FOUNDATIONS OF EARTH SCIENCE*, Fourth Edition—This dynamic learning aid reinforces key concepts by using tutorials, animations, and interactive exercises.

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 - 2. Major Mineral Groups
 - 3. Properties Used to Identify Minerals
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- B. Rock Cycle
- C. Igneous Rocks
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 - 2. Igneous Textures
 - 3. Naming Igneous Rocks
- D. Sedimentary Rocks
 - 1. Introduction
 - 2. Types of Sedimentary Rocks
- E. Metamorphic Rocks
 - 1. Introduction
 - 2. Agents of Metamorphism
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 - 4. Common Metamorphic Rocks

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- B. Running Water
 - 1. Stream Characteristics
- C. Groundwater
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 - 2. Springs and Wells
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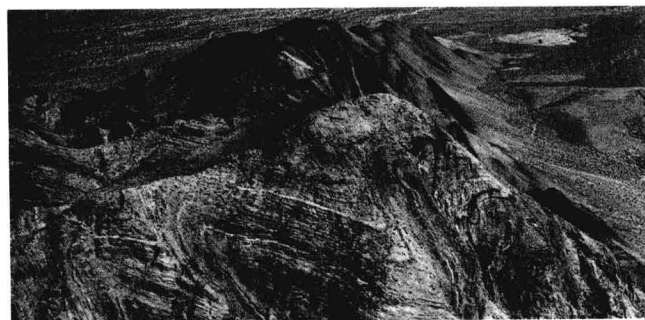
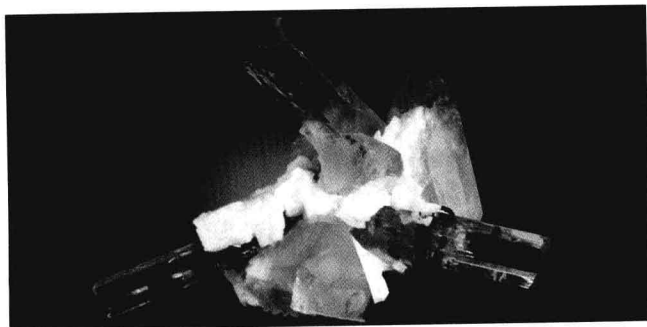
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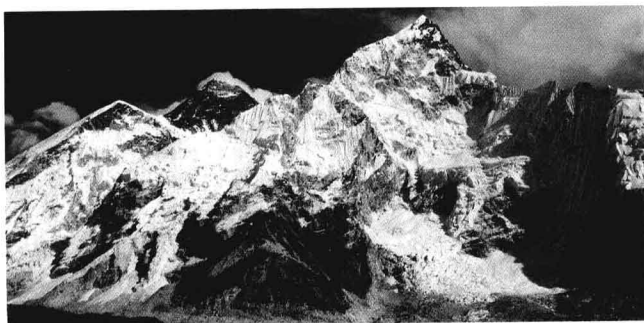
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