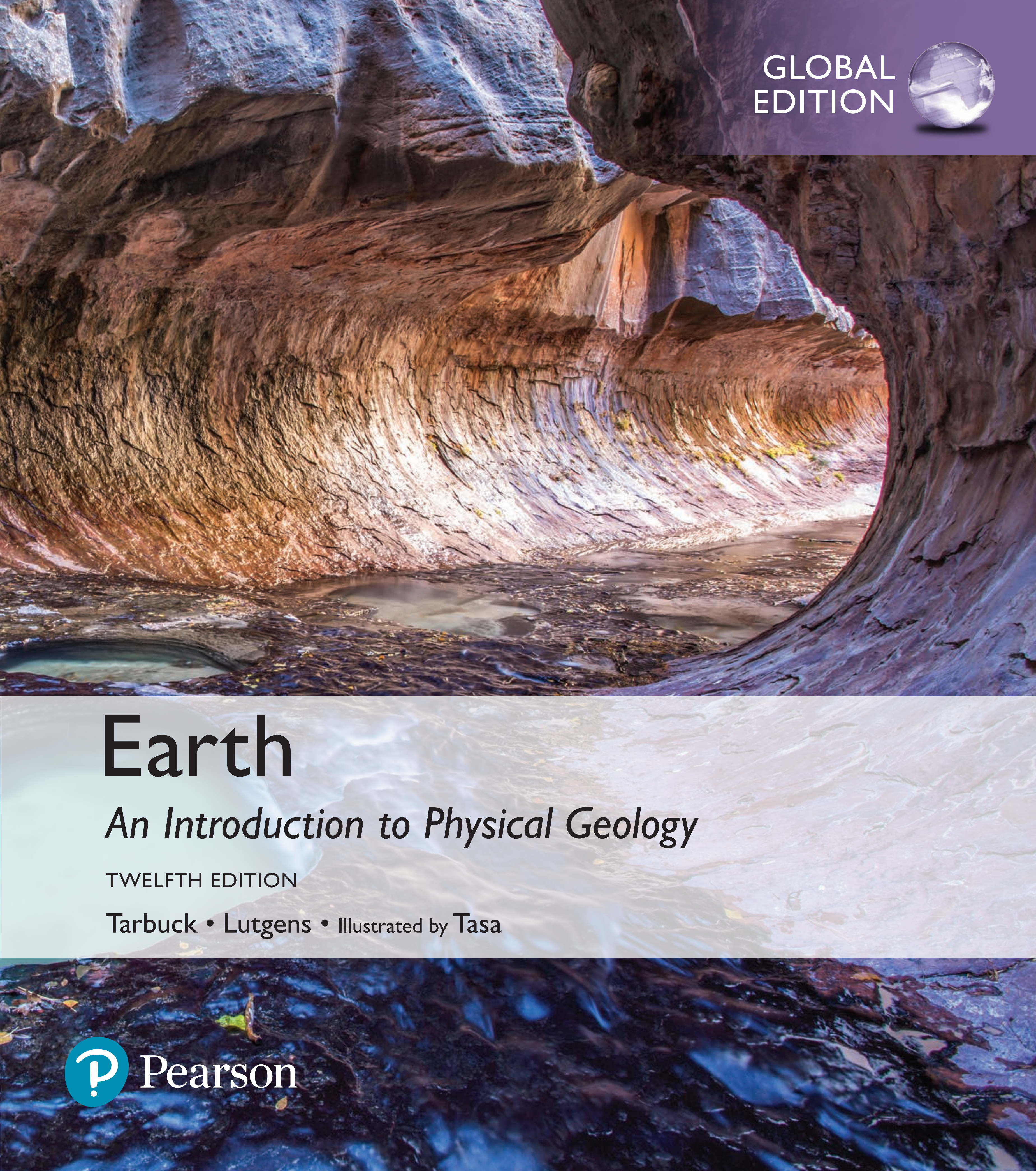

GLOBAL EDITION

# Earth

## *An Introduction to Physical Geology*

TWELFTH EDITION

Tarbuck • Lutgens • Illustrated by Tasa

Pearson

# Earth

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TWELFTH EDITION

GLOBAL EDITION

# Earth

## An Introduction to Physical Geology


EDWARD J. TARBUCK

FREDERICK K. LUTGENS

*Illustrated by*

DENNIS TASA



Pearson

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To Our Grandchildren

Shannon, Amy, Andy, Ali, and Michael

Allison and Lauren

*Each is a bright promise for the future.*

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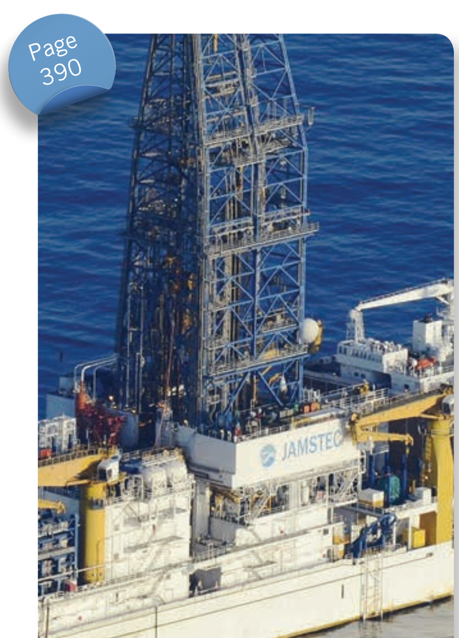

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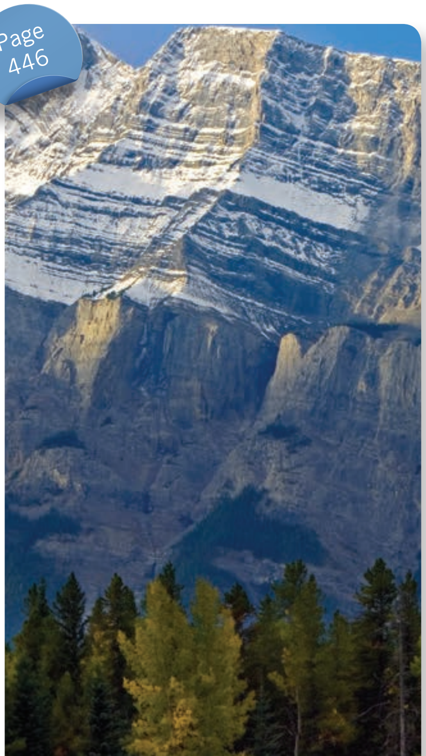




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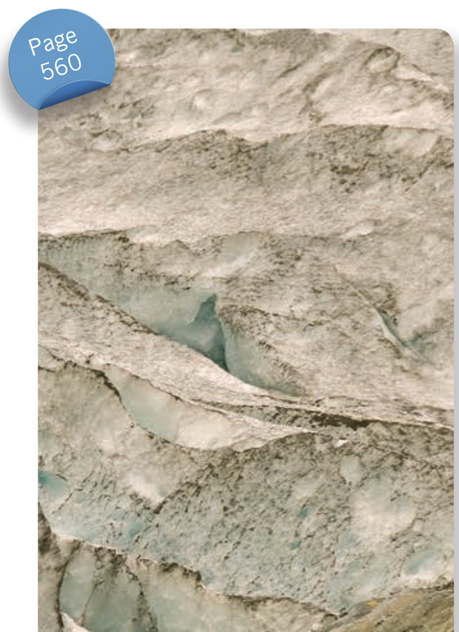
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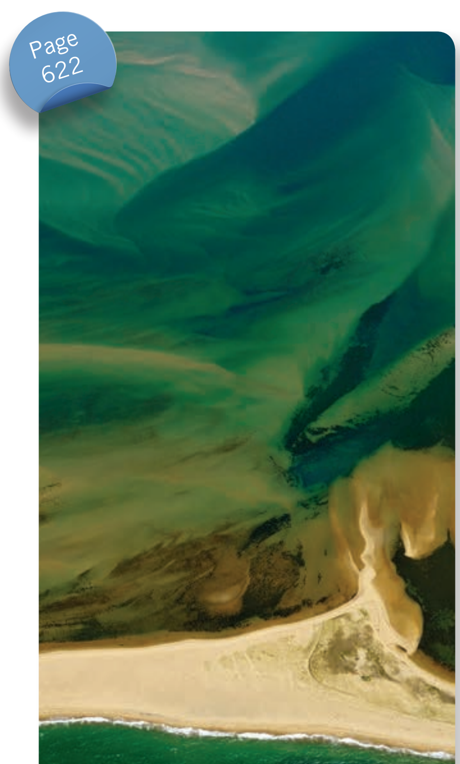
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# SmartFigures

Using a cutting-edge technology called augmented reality, Pearson's BouncePages app launches engaging, interactive videos and animations that bring textbook pages to life. Use your mobile device to scan a SmartFigure identified by the BouncePages icon, and an animation/video/interactive illustrating the SmartFigure's concept launches immediately. No slow websites or hard-to-remember logins required. BouncePages' augmented reality technology transforms textbooks into convenient digital platforms, breathes life into your learning experience, and helps you grasp difficult academic concepts. Learning geology from a textbook will never be the same.

# 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. Knowledge of our physical environment is critical to our well-being and vital to our survival. A basic geology course can help a person gain such an understanding, and can also take advantage of the interest and curiosity many of us have about our planet—its landscapes and the processes that create and alter our physical environment.

This 12th edition of *Earth: An Introduction to Physical Geology*, like its predecessors, is a college-level text that is intended to be a meaningful, nontechnical 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 for a readable and user-friendly text, a book that is a highly usable tool for students learning the basic principles and concepts of geology.

Although many topical issues are examined in the 12th edition of *Earth*, it should be emphasized that the main focus of this new edition remains the same as the focus of earlier editions: to promote student understanding of basic principles. As much as possible, we have attempted to provide the reader with a sense of the observational techniques and reasoning processes that constitute the science of geology.

## New and Important Features

The 12th edition represents an extensive and thorough revision of *Earth* that integrates improved textbook resources with new online features to enhance the learning experience,

- **Significant updating and revision of content.** A basic function of a college science textbook is to present material in a clear, understandable way that is accurate, engaging, and up-to-date. In the long history of this textbook, our number-one goal has always been to keep *Earth* current, relevant, and highly readable for beginning students. To that end, every part of this text has been examined carefully. Many discussions, case studies, examples, and illustrations have been updated and revised.
- **SmartFigures that make *Earth* much more than a traditional textbook.** Through its many editions, an important strength of *Earth* has always been clear, logically organized, and well-illustrated explanations. Now, complementing and reinforcing this strength are a series of SmartFigures. Simply by scanning a SmartFigure with a mobile device and **Pearson's BouncePages Augmented Reality app** (FREE and available for iOS and Android), students can link to hundreds of unique and innovative digital learning opportunities that will increase their insight and understanding of important ideas and concepts. We have also placed short URLs in the caption for every SmartFigure. This will ensure that students who may not have a smart phone, will have the ability to access these videos easily. SmartFigures are truly art that teaches! This 12th edition of *Earth* has more than 200 SmartFigures, of five different types:
  1. **SmartFigure Tutorials.** Each of these 2- to 4-minute tutorials, prepared and narrated by Professor Callan Bentley, is a mini-lesson that examines and explains the concepts illustrated by the figure.
  2. **SmartFigure Mobile Field Trips.** Scattered throughout this new edition are 24 video field trips that explore classic geologic sites from Iceland to Hawaii. On each trip you will accompany geologist-pilot-photographer Michael Collier in the air and on the ground to see and learn about landscapes that relate to discussions in the chapter.
  3. **SmartFigure Condor Videos.** The 10 *Condor* videos take you to sites in the American West. By coupling aerial footage acquired by a quadcopter aircraft with ground-level views, effective narratives, and helpful animations, these videos will engage you in real-life case studies.
  4. **SmartFigure Animations.** Scanning the many figures with this designation brings art to life. These animations and accompanying narrations illustrate and explain many difficult-to-visualize topics and ideas more effectively than static art alone.
  5. **SmartFigure Videos.** Rather than providing a single image to illustrate an idea, these figures include short video clips that help illustrate such diverse subjects as mineral properties and the structure of ice sheets.

  As mentioned, please visit your iOS or Android App Stores to download the FREE Pearson BouncePages App. By scanning one of the two QR codes to the right, you will be taken directly to the BouncePages App.

  Android Store  iTunes App Store

- **Enhanced Modular, learning objective-driven, active learning path.** *Earth* is designed for learning. Every chapter begins with *Focus on Concepts*. Each numbered learning objective corresponds to a major section in the chapter. The statements identify the knowledge and skills students should master by the end of the chapter and help students prioritize key concepts. Within the chapter, each major section concludes with *Concept Checks* that allow students to check their understanding and comprehension of important ideas and terms before moving on to the next section. Two end-of-chapter features complete the learning path. *Concepts in Review* coordinates with the *Focus on Concepts* at the start of the chapter and with the numbered sections within the chapter. It is a concise overview of key ideas, with photos, diagrams, and questions that help students focus on important ideas and test their understanding of key concepts. Chapters conclude with *Give It Some Thought* questions that challenge learners by involving them in activities that require higher-order thinking skills, such as application, analysis, and synthesis of chapter material.

- **An unparalleled visual program.** In addition to more than 100 new, high-quality photos and satellite images, dozens of figures are new or have been redrawn by the gifted and highly respected geoscience illustrator Dennis Tasa. Maps and diagrams are frequently paired with photographs for greater effectiveness. Further, many new and revised figures have additional labels that narrate the process being illustrated and guide students as they examine the figures. *Earth*'s visual program is clear and easy to understand.
- **MasteringGeology.** MasteringGeology delivers engaging, dynamic learning opportunities—focused on course objectives and responsive to each student's progress—that are proven to help students learn course material and understand difficult concepts. Assignable activities in MasteringGeology include SmartFigure (Tutorial, Condor, Animation, Mobile Field Trip, Video) activities, GigaPan activities, Encounter Earth activities using Google Earth, GeoTutor activities, Geoscience Animation activities, GEODe tutorials, and more. MasteringGeology also includes all instructor resources and a robust Study Area with resources for students.

# The Teaching and Learning Package

## MasteringGeology™ with Pearson eText

Used by over 1 million science students, the Mastering platform is the most effective and widely used online tutorial, homework, and assessment system for the sciences. Now available with *Earth*, 12th edition, **MasteringGeology™** offers tools for use before, during, and after class:

- **Before class:** Assign adaptive Dynamic Study Modules and reading assignments from the eText with Reading Quizzes to ensure that students come prepared to class, having done the reading.
- **During class:** Learning Catalytics, a "bring your own device" student engagement, assessment, and classroom intelligence system, allows students to use a smartphone, tablet, or laptop to respond to questions in class. With Learning Catalytics, you can assess students in real-time, using open-ended question formats to uncover student misconceptions and adjust lectures accordingly.
- **After class:** Assign an array of assessment resources such as Mobile Field Trips, Project Condor tutorials, Interactive Simulations, GeoDrone activities, Google Earth Encounter Activities, and much more. Students receive wrong-answer feedback personalized to their answers, which will help them get back on track.

MasteringGeology Student Study Area also provides students with self-study materials like geoscience animations, *GEODe: Earth* activities, *In the News* RSS feeds, Self Study Quizzes, Web Links, Glossary, and Flashcards.

For more information or access to MasteringGeology, please visit www.masteringgeology.com.

## Instructor's Resource Materials (Download Only)

The authors and publisher have been pleased to work with a number of talented people who have produced an excellent supplements package.

**Instructor's Resource Materials (IRM)**

The IRM puts all your lecture resources in one easy-to-reach place:

- *All* of the line art, tables, and photos from the text in .jpg files
- PowerPoint presentations
  - The IRM provides three PowerPoint files for each chapter. Cut down on your preparation time, no matter what your lecture needs, by taking advantage of these components of the PowerPoint files:
- **Exclusive art.** All of the photos, art, and tables from the text, in order, loaded into PowerPoint slides.
- **Lecture outlines.** This set averages 50 slides per chapter and includes customizable lecture outlines with supporting art.

## Instructor Manual (Download Only)

The Instructor Manual has been designed to help seasoned and new professors alike, offering the following for each chapter: an introduction to the chapter, an outline, and learning objectives/Focus on Concepts; teaching strategies; teacher resources; and answers to *Concept Checks*, *Eye on Earth*, and *Give It Some Thought* questions from the textbook.

## TestGen Computerized Test Bank (Download Only)

TestGen is a computerized test generator that lets instructors view and edit Test Bank questions, transfer questions to tests, and print tests in a variety of customized formats. The Test Bank includes more than 2,000 multiple-choice, matching, and essay questions. Questions are correlated to Bloom's Taxonomy, each chapter's learning objectives, the Earth Science Learning Objectives, and the Pearson Science Global Outcomes to help instructors better map the assessments against both broad and specific teaching and learning objectives. The Test Bank is also available in Microsoft Word.

# Acknowledgments

Writing a college textbook requires the talents and cooperation of many people. It is truly a team effort, and the authors are fortunate to be part of an extraordinary team at Pearson Education. In addition to being great people to work with, all of them are committed to producing the best textbooks possible. Special thanks to our geology editor, Andy Dunaway, who invested a great deal of time, energy, and effort in this project. We appreciate his enthusiasm, hard work, and quest for excellence. We also appreciate our conscientious project managers, Crissy Dudonis and Nicole Antonio, whose job it was to keep track of all that was going on—and a lot was going on. As always, our marketing managers, Neena Bali and Mary Salzman, who talk with faculty daily, provide us with helpful advice and many good ideas. The 12th edition of *Earth* was certainly improved by the talents of our developmental editor, Veronica Jurgena. Many thanks. It was the job of the production team, led by Heidi Allgair at Cenveo® Publisher Services, to turn our manuscript into a finished product. The team also included copyeditor Kitty Wilson, compositor Annamarie Boley, proofreader Heather Mann, and photo researcher Kristin Piljay. We think these talented people did great work. All are true professionals, with whom we are very fortunate to be associated.

The authors owe special thanks to three people who were very important contributors to this project:

- Working with Dennis Tasa, who is responsible for all of the text's outstanding illustrations and several of its animations, is always special for us. He has been part of our team for more than 30 years. We not only value his artistic talents, hard work, patience, and imagination but his friendship as well.
- As you read this text, you will see dozens of extraordinary photographs by Michael Collier. Most are aerial shots taken from his nearly 60-year-old Cessna 180. Michael was also responsible for preparing the 24 remarkable Mobile Field Trips that are scattered through the text. Among his many awards is the American Geological Institute Award for Outstanding Contribution to the Public Understanding of Geosciences. We think that Michael's photographs and field trips are the next best thing to being there. We were very fortunate to have had Michael's assistance on *Earth*, 12th edition. Thanks, Michael.
- Callan Bentley has been an important addition to the *Earth* team. Callan is an assistant professor of geology at Northern Virginia Community College in Annandale, where he has been honored many times as an outstanding teacher. He is a frequent contributor to *EARTH* magazine and is author of the popular geology blog *Mountain Beltway*. Callan was responsible for preparing the SmartFigure Tutorials that appear throughout the text. As you take advantage of these outstanding learning aids, you will hear his voice explaining the ideas. We appreciate Callan's contributions to this new edition of *Earth*.

Great thanks also go to our colleagues who prepared in-depth reviews. Their critical comments and thoughtful input helped guide our work and clearly strengthened the text. Special thanks to:

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Last but certainly not least, we gratefully acknowledge the support and encouragement of our wives, Joanne Bannon and Nancy Lutgens. Preparation of this edition of *Earth* would have been far more difficult without their patience and understanding.

**Ed Tarbuck**
**Fred Lutgens**

Pearson would like to thank and acknowledge Supriyo Das, Presidency University, and Julien Moreau, University of Copenhagen, for contributing to the Global Edition, and Prosenjit Ghosh, Indian Institute of Science, Ashima Saikia, University of Delhi, and Vikram Vishal, Indian Institute of Technology, Bombay, for reviewing the Global Edition.

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BouncePages' augmented reality technology transforms textbooks into convenient digital platforms, breathes life into your learning experience, and helps you grasp difficult academic concepts. Learning geology from a textbook will never be the same.

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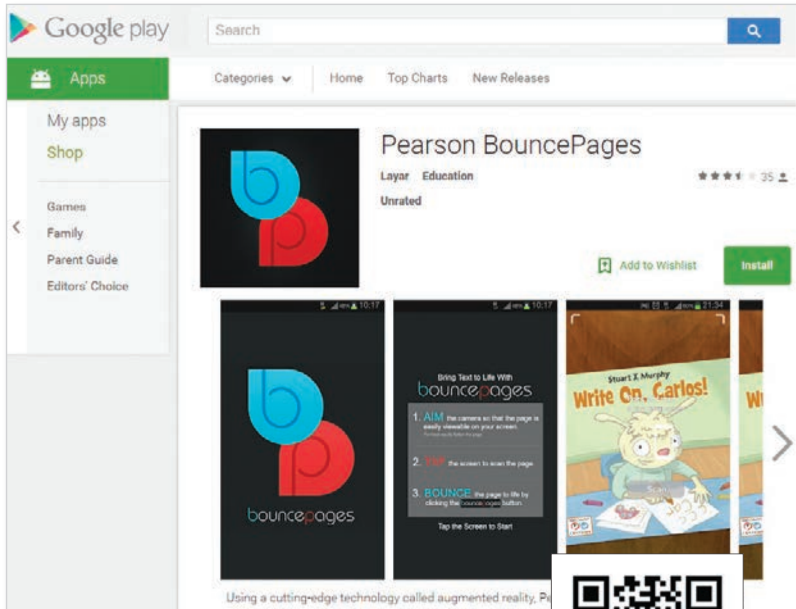


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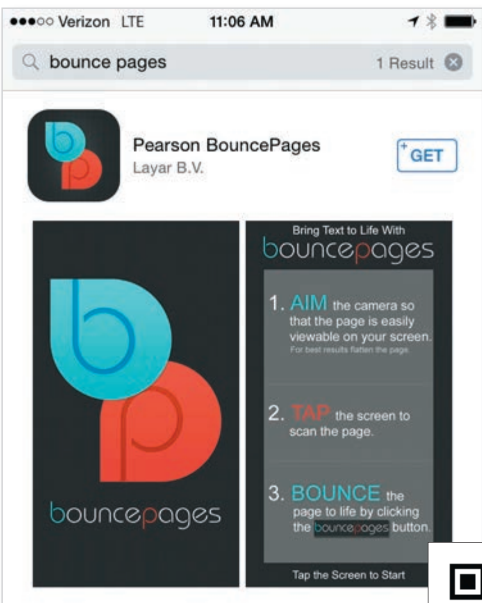
**Download the FREE BP App for iOS**

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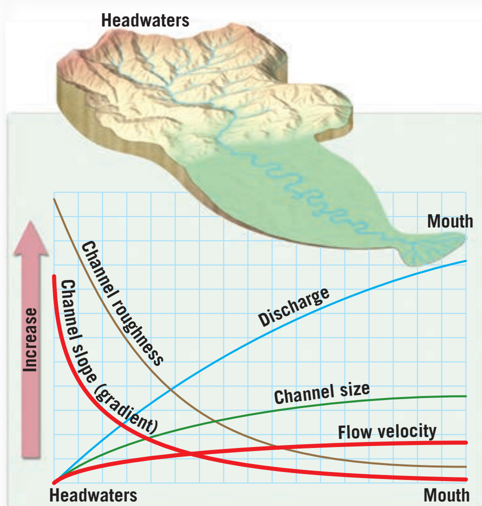
By scanning figures associated with the BouncePages icon, students will be immediately connected to the digital world and will deepen their learning experience with the printed text.




**SmartFigure 16.14**
**Channel changes from head to mouth**
Although the gradient decreases toward the mouth of a stream, increases in discharge and channel size and decreases in roughness more than offset the decrease in slope. Consequently, flow velocity usually increases toward the mouth. (https://goo.gl/6srX2s)

Tutorial

# Bring the Field to YOUR Teaching and Learning Experience

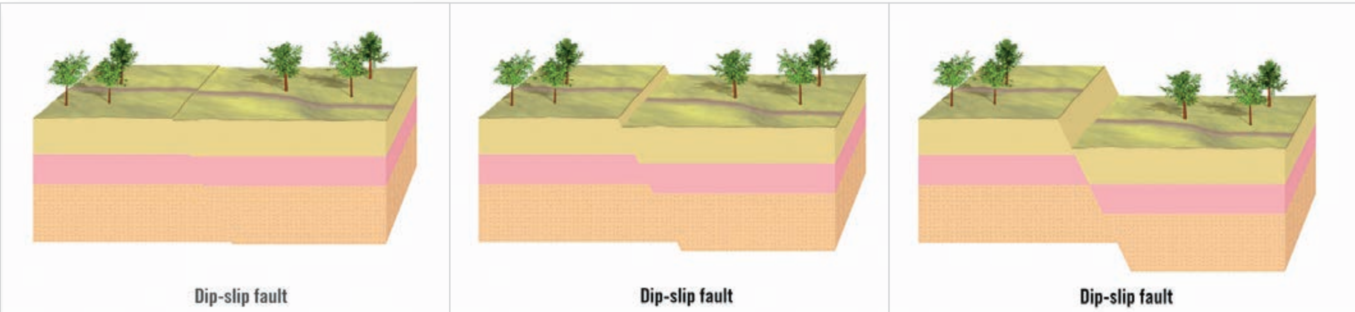

**NEW! SmartFigure: Condor Videos.** Bringing Physical Geology to life for GenEd students, three geologists, using a quadcopter with a GoPro camera mounted to it, have ventured out into the field to film 10 key geologic locations. These process-oriented videos, accessed through BouncePages technology, are designed to bring the field to the classroom or dorm room and enhance the learning experience in our texts.

Condor Video

**NEW! SmartFigure: Mobile Field Trips.** Scattered throughout this new edition of Earth are **24 video field trips**. On each trip, you will accompany geologist-pilot-photographer Michael Collier in the air and on the ground to see and learn about iconic landscapes that relate to discussions in the chapter. These extraordinary field trips are accessed by using the BouncePages app to scan the figure in the chapter—usually one of Michael's outstanding photos.

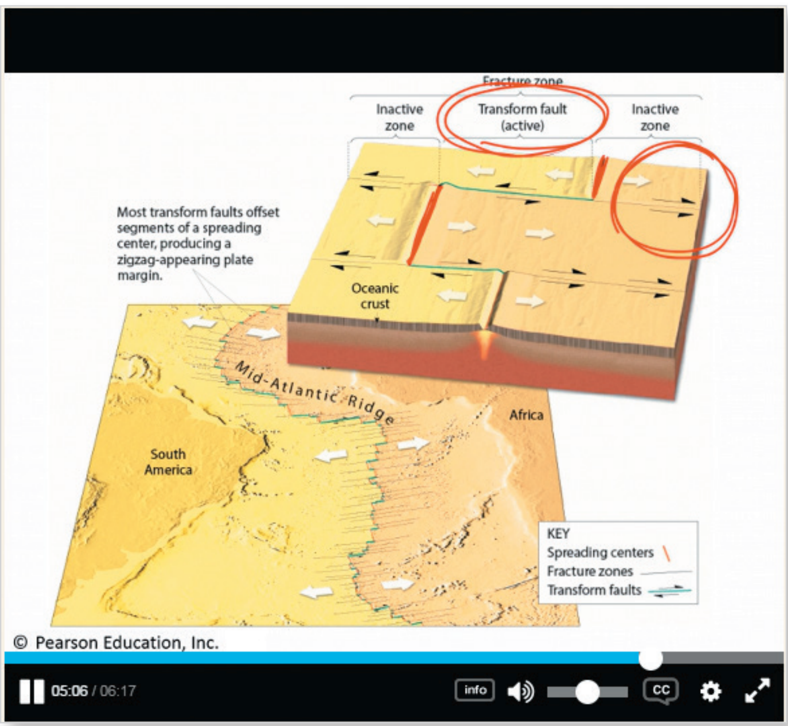
Mobile Field Trip

# Visualize Processes and Tough Topics




**NEW! SmartFigure: Animations** are brief videos, many created by text illustrator Dennis Tasa, that animate a process or concept depicted in the textbook's figures. This technology allows students to view moving figures rather than static art to depict how a geologic process actually changes through time. The videos can be accessed using Pearson's BouncePages app for use on mobile devices, and will also be available via MasteringGeology.

Animation




**SmartFigure: Tutorials** bring key chapter illustrations to life! Found throughout the book, these Tutorials are sophisticated, annotated illustrations that are also narrated videos. They are accessible on mobile devices via scannable BouncePages printed in the text and through the Study Area in MasteringGeology.

Tutorial

Callan Bentley, SmartFigure Tutorial author, is a Chancellor's Commonwealth Professor of Geology at Northern Virginia Community College (NOVA) in Annandale, Virginia. Trained as a structural geologist, Callan teaches introductory level geology at NOVA, including field-based and hybrid courses. Callan writes a popular geology blog called *Mountain Beltway*, contributes cartoons, travel articles, and book reviews to *EARTH* magazine, and is a digital education leader in the two-year college geoscience community.

# Improved Geospatial and Data Visualizations

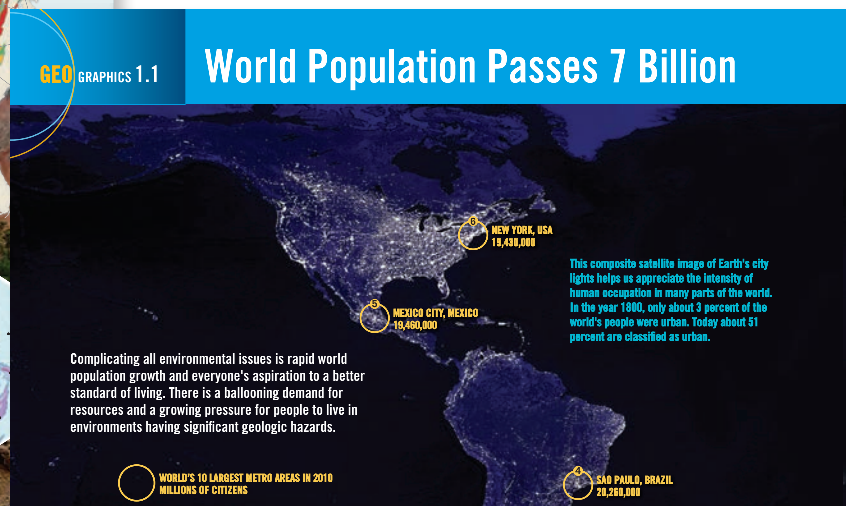
GEOGRAPHICS 15.2

## Landslide Risks: United States and Worldwide

According to the U. S. Geological Survey, each year in the United States, landslides cost nearly $4 billion (2010 dollars) in damage repair and cause between 25 and 50 deaths. All states experience rapid mass-wasting processes, but not all areas have the same landslide potential. What's the risk where you live?



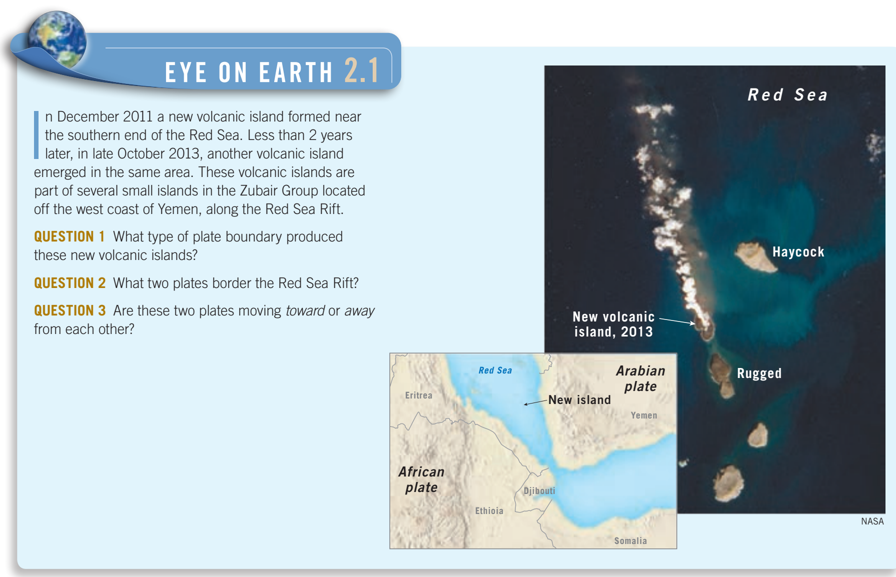
**GEOgraphics** use contemporary, compelling visual representations to illustrate complex concepts, enhancing students' ability to synthesize and recall information and important data.



GEOGRAPHICS 1.1

## World Population Passes 7 Billion





EYE ON EARTH 2.1

In December 2011 a new volcanic island formed near the southern end of the Red Sea. Less than 2 years later, in late October 2013, another volcanic island emerged in the same area. These volcanic islands are part of several small islands in the Zubair Group located off the west coast of Yemen, along the Red Sea Rift.

**QUESTION 1** What type of plate boundary produced these new volcanic islands?

**QUESTION 2** What two plates border the Red Sea Rift?

**QUESTION 3** Are these two plates moving *toward* or *away* from each other?



**Eye on Earth** features engage students in active learning, asking them to perform critical thinking and visual analysis tasks to evaluate data and make predictions.

# Modular Approach Driven by Learning Objectives

The new edition is designed to support a four-part learning path, an innovative structure which facilitates active learning and allows students to focus on important ideas as they pause to assess their progress at frequent intervals.

The chapter-opening **Focus on Concepts** lists the learning objectives for each chapter. Each section of the chapter is tied to a specific learning objective, providing students with a clear learning path to the chapter content.


**Concepts in Review,** a fresh approach to the typical end-of-chapter material, provides students with a structured and highly visual review of each chapter. Consistent with the Focus on Concepts and Concept Checks, the **Concepts in Review** is structured around the section title and the corresponding learning objective for each section.

Each chapter section concludes with **Concept Checks,** a feature that lists questions tied to the section's learning objective, allowing students to monitor their grasp of significant facts and ideas.

**10.5 Concept Checks**

1. Distinguish between the two measurements used to establish the orientation of deformed strata.
2. Briefly describe the method geologists use to infer the orientation of rock structures that lie mainly below Earth's surface.

**10 Concepts in Review** Crustal Deformation

**10.1 What Causes Rock to Deform**

Describe the three types of differential stress and name the type of plate boundary most commonly associated with each.

KEY TERMS deformation, rock structure (geologic structure), stress, confining pressure, differential stress, compressional stress, tensional stress, shear stress, strain

- Rock structures are generated when rocks are deformed by bending or breaking due to differential stress. Crustal deformation produces geologic structures that include folds, faults, joints, foliation, and rock cleavage.
- Stress is the force that drives rock deformation. When stress has the same magnitude in every direction, it is called confining pressure. Alternatively, when the amount of stress coming from one direction is greater in magnitude than the stress coming from another direction, we call it differential stress. There are three main types of differential stress: compressional, tensional, and shear stress.
- Strain is the change in the shape of a rock body caused by stress.

Q Classify the following everyday situations as illustrating confining pressure, compressional stress, tensional stress, or shear stress: (a) a watermelon being run over by a steamroller, (b) a person diving to the bottom of the deep end of a swimming pool, (c) playing a game of tug-of-war, (d) kneading bread dough, and (e) slipping on a banana peel.

**10.2 How Do Rocks Deform?**

Compare and contrast brittle and ductile deformation.

KEY TERMS elastic deformation, brittle deformation, ductile deformation, outcrop

- There are several types of deformation. Elastic deformation is a temporary stretching of the chemical bonds in a rock. When the stress is released, the bonds snap back to their original lengths. When stress is greater than the strength of the bonds, the rock deforms in either a brittle or ductile fashion. Brittle deformation occurs when rocks break into smaller pieces, whereas ductile deformation is a solid-state flow that allows a rock to bend without fracturing.
- The type of deformation (ductile or brittle) that occurs depends mainly on temperature, confining pressure, rock type, and time. In Earth's upper crust where temperatures and pressure are low, rocks tend to exhibit brittle behavior and break or fracture. At depth rocks tend to deform by flowing or bending.
- Igneous rocks tend to be strong and are more likely to deform in a brittle fashion, whereas sedimentary rocks are weaker and usually deform in a ductile fashion.
- The rate at which differential stress is applied also affects how rocks deform. Silly Putty provides a good analogy: If pulled apart quickly, Silly Putty tends to break, whereas if pulled apart slowly, it tends to stretch (ductile flow) without breaking.

Q Examine the accompanying illustration of a collision between two tectonic plates. At which location (A or B) would brittle deformation be more prevalent than ductile deformation?



**10.3 Folds: Rock Structures Formed by Ductile Deformation**

List and describe five common folded structures.

KEY TERMS fold, anticline, syncline, dome, basin, monocline

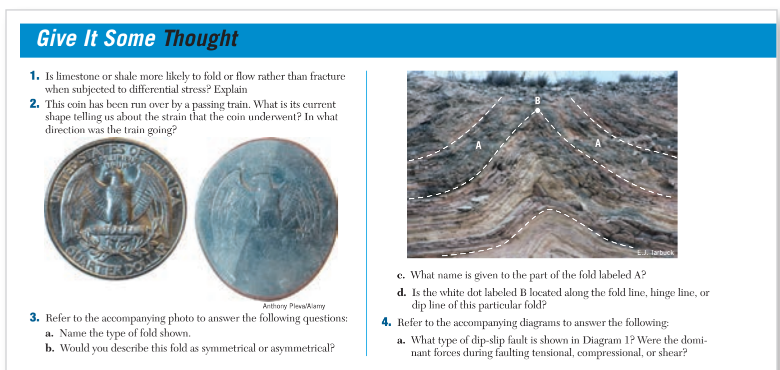
- Folds are wavelike undulations in layered rocks that develop through ductile deformation in rocks undergoing compressional stress.
- Folds may be described in terms of their geometric configuration: If the limbs of a fold dip down from the hinge, the fold has an arch-like structure and is called an anticline. If the limbs of a fold dip upward, the fold has a trough-like structure and is called a syncline. Anticlines and synclines may be symmetrical, asymmetrical, overturned, or recumbent.
- The shape of a fold does not necessarily correlate to the shape of the landscape above it. Rather, surface topography usually reflects patterns of differential weathering.
- A fold is said to plunge when its axis penetrates the ground at an angle. This results in a V-shaped outcrop pattern of the folded layers.
- Domes and basins are large folds that produce nearly circular-shaped outcrop patterns. The overall shape of a dome or basin is like a saucer or a bowl, either right-side-up (basin) or inverted (dome).
- Monoclines are large steplike folds in otherwise horizontal strata that result from subsurface faulting. Imagine a carpet draped over a short staircase to envision how the strata can go from horizontal to tilted and back to horizontal again.

**10.4 Faults and Joints: Structures Formed by Brittle Deformation**

Sketch and briefly describe the relative motion of rock bodies located on opposite sides of normal, reverse, and thrust faults as well as both types of strike-slip faults.

KEY TERMS fault, dip-slip fault, hanging wall block, footwall block, normal fault, fault-block mountain, horst, graben, half-graben, detachment fault, reverse fault, thrust fault, klippe, strike-slip fault, transform fault, oblique-slip fault, megathrust fault, fault scarp, slickenside, joint

- Faults are fractures along which one rock body slides past another.
- The direction of offset on a fault may be determined by comparing the blocks of rock on either side of the fault surface. Faults in which movement is primarily parallel to the dip of the fault surface are called dip-slip faults. Dip-slip faults are classified as normal faults if the hanging wall moves *down* relative to the footwall and as reverse faults if the hanging wall moves *up* relative to the footwall. Large



***Give It Some Thought***

1. Is limestone or shale more likely to fold or flow rather than fracture when subjected to differential stress? Explain
2. This coin has been run over by a passing train. What is its current shape telling us about the strain that the coin underwent? In what direction was the train going?



3. Refer to the accompanying photo to answer the following questions:
   a. Name the type of fold shown.
   b. Would you describe this fold as symmetrical or asymmetrical?
   c. What name is given to the part of the fold labeled A?
   d. Is the white dot labeled B located along the fold line, hinge line, or dip line of this particular fold?
4. Refer to the accompanying diagrams to answer the following:
   a. What type of dip-slip fault is shown in Diagram 1? Were the dominant forces during faulting tensional, compressional, or shear?

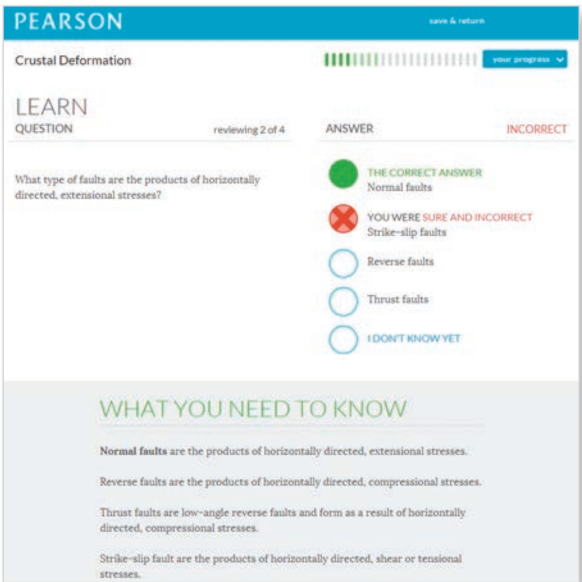
**Give It Some Thought (GIST)** is found at the end of each chapter and consists of questions and problems asking students to analyze, synthesize, and think critically about Geology. GIST questions relate back to the chapter's learning objectives, and can easily be assigned using MasteringGeology.

# Continuous Learning Before, During, and After Class with MasteringGeology™

**MasteringGeology** delivers engaging, dynamic learning opportunities—focusing on course objectives responsive to each student's progress—that are proven to help students learn geology course material and understand challenging concepts.

## Before Class

**Dynamic Study Modules provide students with a preview of what's to come.**



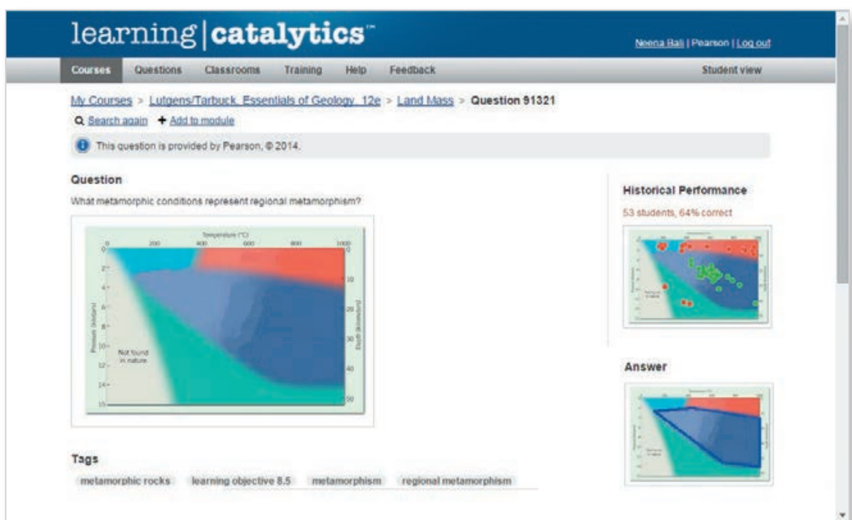

**Dynamic Study Modules** enable students to study effectively on their own in an adaptive format. Students receive an initial set of questions with a unique answer format asking them to indicate their confidence.

Once completed, Dynamic Study Modules include explanations using material taken directly from the text.

## During Class

**Engage Students with Learning Catalytics**

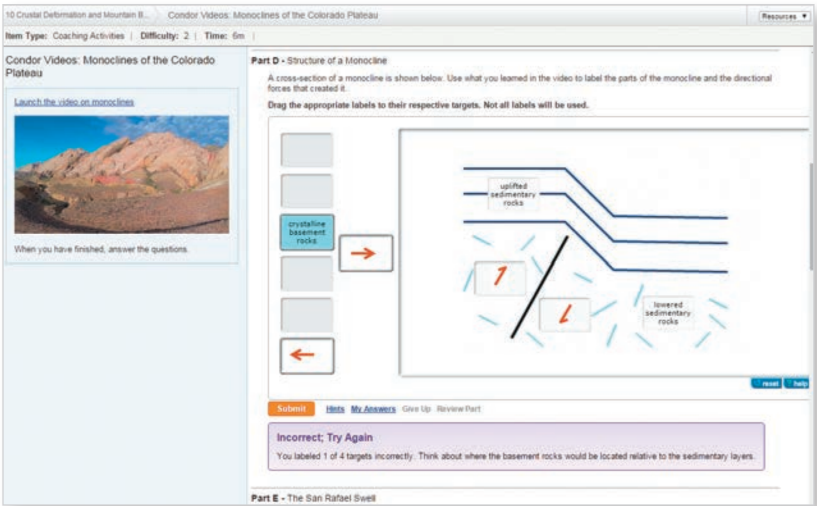
**Learning Catalytics,** a "bring your own device" student engagement, assessment, and classroom intelligence system, allows students to use their smartphone, tablet, or laptop to respond to questions in class.



# MasteringGeology™

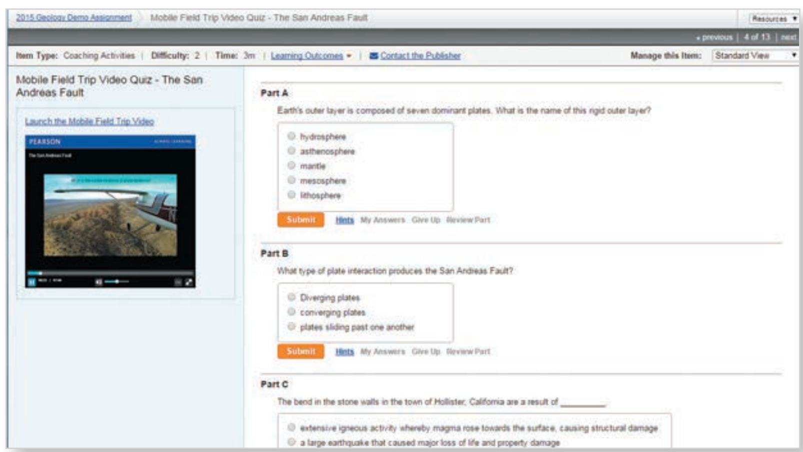
## After Class

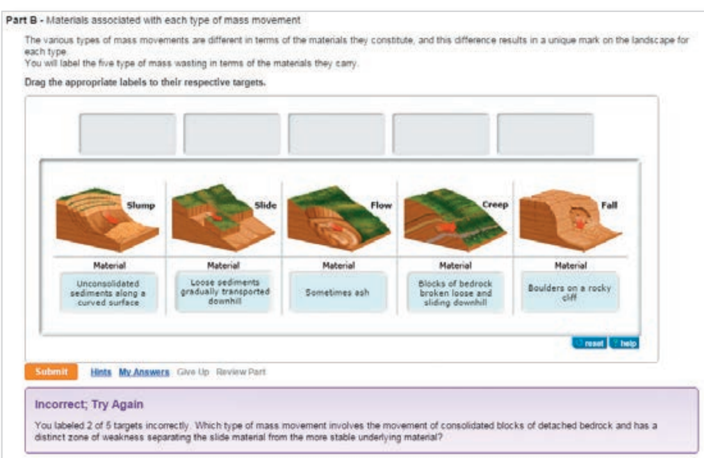
**Easy-to-Assign, Customizeable, and Automatically Graded Assignments**




**NEW! Project Condor Videos** capture stunning footage of the Mountain West region with a quadcopter and a GoPro camera. A series of videos have been created with annotations, sketching, and narration to improve the way students learn about faults and folds, streams, volcanoes, and so much more. In Mastering, these videos are accompanied by questions designed to assess students on the main takeaways from each video.

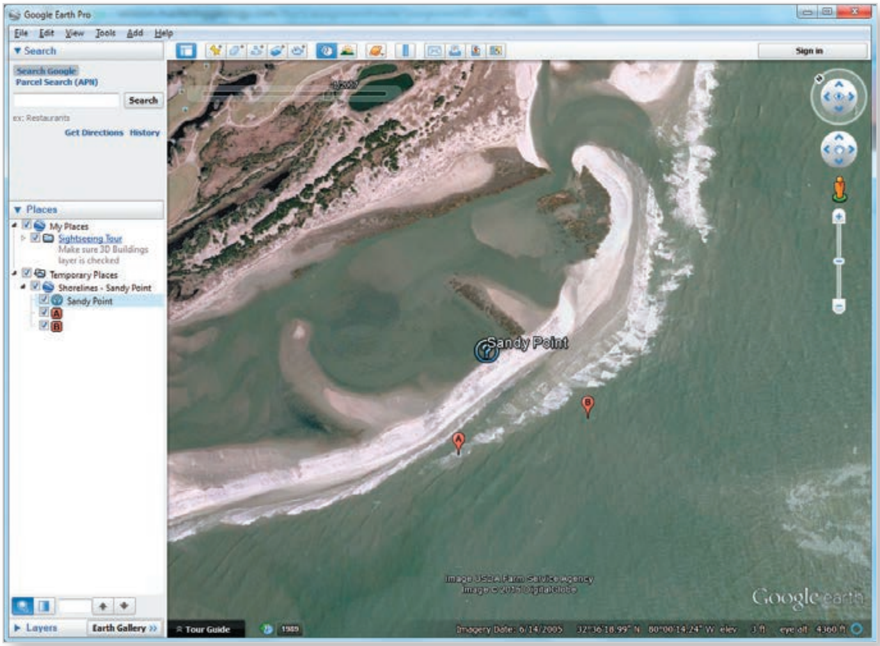
**NEW! 24 Mobile Field Trips** take students to classic geologic locations as they accompany geologist–pilot–photographer–author Michael Collier in the air and on the ground to see and learn about landscapes that relate to concepts in the chapter. In Mastering, these videos will be accompanied by auto-gradable assessments that will track what students have learned.



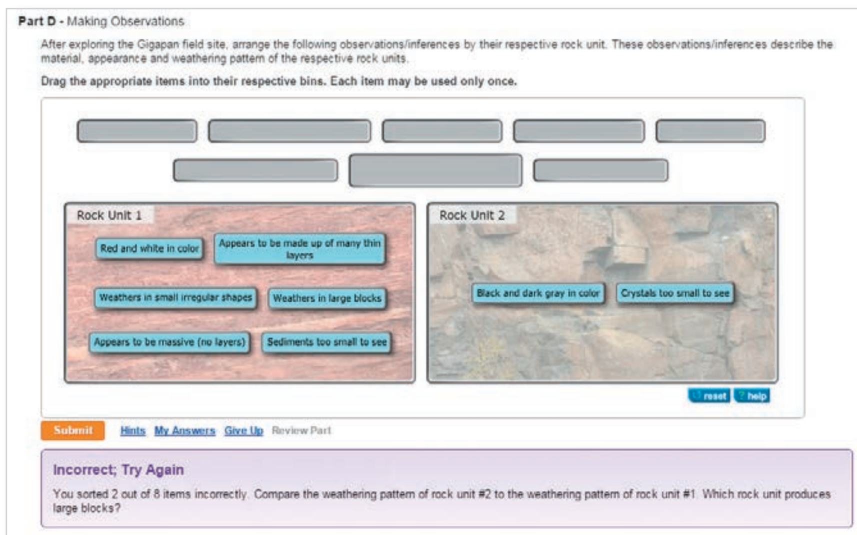

**GeoTutor** coaching activities help students master important geologic concepts with highly visual, kinesthetic activities focused on critical thinking and application of core geoscience concepts.

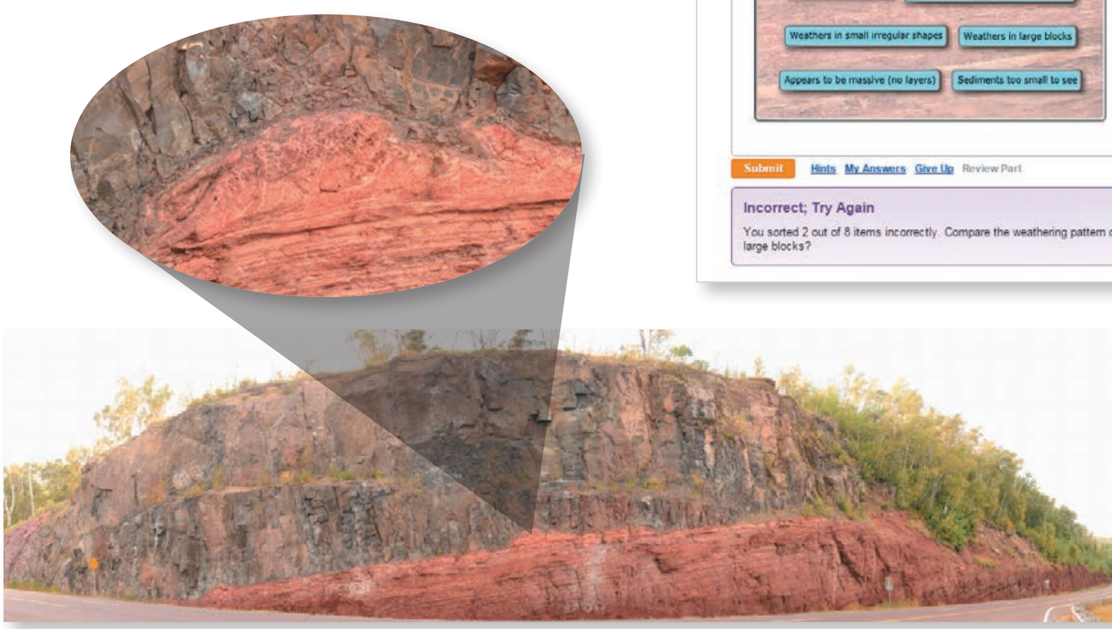
# MasteringGeology™




**Encounter Activities** provide rich, interactive explorations of geology and earth science concepts using the dynamic features of Google Earth™ to visualize and explore earth's physical landscape. Dynamic assessment includes questions related to core geology concepts. All explorations include corresponding Google Earth KMZ media files, and questions include hints and specific wrong-answer feedback to help coach students towards mastery of the concepts while improving students geospatial skills.

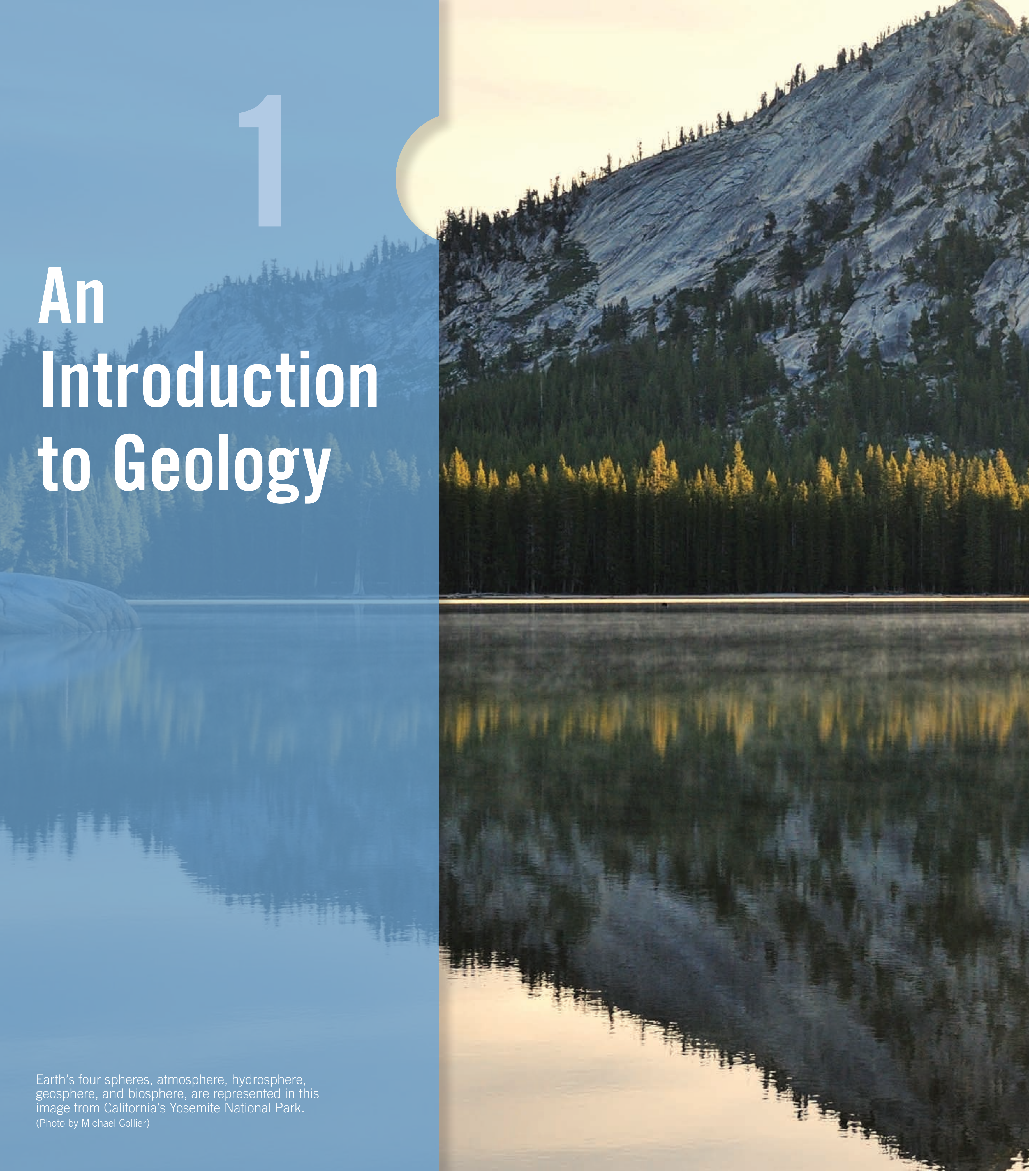
**NEW! GigaPan Activities** allow students to take advantage of a virtual field experience with high-resolution picture technology that has been developed by Carnegie Mellon University in conjunction with NASA.



**Additional MasteringGeology assignments available:**

- SmartFigures
- Interactive Animations
- Give It Some Thought Activities
- Reading Quizzes
- MapMaster Interactive Maps



# 1 An Introduction to Geology

Earth's four spheres, atmosphere, hydrosphere, geosphere, and biosphere, are represented in this image from California's Yosemite National Park.
(Photo by Michael Collier)