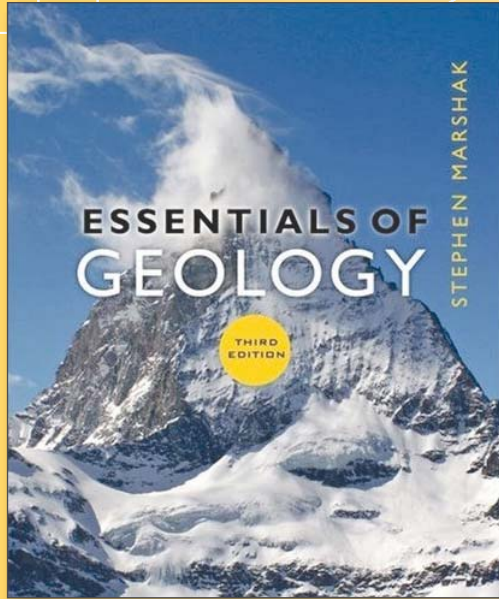


CASE STUDY:

# ESSENTIALS OF GEOLOGY



## MISSION

Update a best-selling geology textbook with an innovative look and feel while maintaining easy-to-follow text for introductory level students.

## THE CHALLENGES


In the case of *Essentials of Geology*, the author was very interested in being involved in all aspects of the process, but he also had an extensive travel schedule. In addition, both he and Norton wanted PG to provide a brand-new book design that would capture student interest while still maintaining pedagogical integrity. It became immediately obvious that the traditional paper-based workflow was not going to work.

## OUR SOLUTION

Precision provided electronic samples at all stages of the project, including web-based document transfer and reviewing tools. This allowed both the author and the publisher to review and weigh in without delays for shipping. We maintained close contact with the author, making it possible to develop and incorporate an elaborate art style that ultimately

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**FIGURE 4.8** Studying rocks in thin section.



Hand specimen of rock. Saw blade. Rock coated by water or diamond dust.

8d Using a special lens, a geologist looks at a thin slice of a rock specimen.

Rock "chip" (hand specimen) of rock. 1 cm. 1 mm.

8b The geologist gives the chip to a glass slide and grinds it down until it is so thin that light can pass through it.

8c The light is polarized, allowing certain colors, different colors, and other features to be seen.

8d With a petrographic microscope, it is possible to view the thin section with light that shines through the specimen from below.

**INTERLUDE 4** Rock Groups

Each individual rock type has a name. Names come from a variety of sources. Some come from the dominant component making up the rock, some from the region where the rock was first discovered or is particularly abundant, some from a root word of Latin origin, and some from a traditional name used by people in an area where the rock is found. All told, there are hundreds of different rock names, though in this book, we will introduce only about thirty.

**A5 STUDYING ROCK**

**Outcrop Observations**

The study of rocks begins by examining a rock in an outcrop. If the outcrop is big enough, such an examination will reveal relationships between the rock and its environment and the rocks around it, and will allow you to detect layering. Geologists carefully record observations about an outcrop, then break off a **hand specimen**, a fist-sized piece, which they can examine more slowly with a hand lens (magnifying glass). Observation with a hand lens enables geologists to identify small-sized or larger mineral grains, and may enable them to describe the texture of the rock.

**Thin-Section Study**

Geologists often must examine rock composition and texture in more detail in order to identify a rock and develop a hypothesis for how it formed. To do this, they take a specimen back to the lab, make a very thin slice (about 0.03 mm thick, the thickness of a human hair) mounted on a glass slide. They study the resulting **thin section** (Fig. 4.8) with a petrographic microscope (Fig. 4.8) with a petrographic microscope. Light comes from the back of the rock as an ordinary microscope in that it illuminates the thin section with transmitted light. This means that the illuminating light beam first passes through a special slide that makes all the light waves in the beam vibrate in the same plane, and then the light passes up through the thin section. When the light looks through the thin section as if it were a window. When illuminated with transmitted polarized light, each type of mineral grain displays a unique suite of colors (Fig. 4.8d). The specific color the observer sees depends on both the identity of the grain and its orientation with respect to the waves of polarized light.

**Key Terms**

bedding (p. 87)  
bedrock (p. 86)  
metre  
sandstone (p. 86)  
clastic (p. 86)  
sediment (p. 86)  
sandstone (p. 87)  
hand specimen (p. 87)  
igneous rock (p. 87)  
sediment (p. 86)  
sandstone (p. 86)

**ADDITIONAL VIEW**

The light provides blocks of sedimentary rock that are visible beneath the ground surface.

## Pages of Earth's Past: Sedimentary Rocks

**SEDPuzzle**

Why do the walls of the Grand Canyon display spectacular layers of different sedimentary rock? Why do some layers form vertical cliffs while others do not?

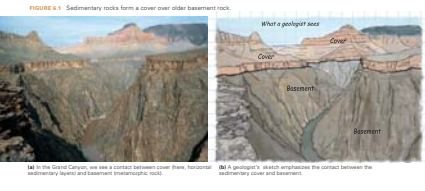
**6.1 INTRODUCTION**

On an isolated, windswept drilling platform in the North Sea off the coast of Scotland, a group of geologists study a multimillion-dollar drill-core plan to penetrate the sea floor and see what lies beneath. The North Sea formed as a consequence of rifting some of millions of years ago. During rifting, what was once dry land between Great Britain and continental Europe slowly sank to its geologic position, "sub-sided." Rivers carried sediments from the surrounding land into the embayments North Sea, and these sediments collected in layers. At certain stages in the process, salts precipitated from seawater, and the shells of sea creatures settled and collected on the sea floor. As the drilling begins, a geologist stationed on the deck of the platform examines the material flushed out of the long-lengthed drill hole by high-pressure water. At first, drilling brings up soft mud and loose sand, silt, pebbles, and shell fragments. But as the hole goes deeper, the material coming up holds together in soft but coherent clumps. Eventually, when the hole has entered layers that were far closer to a kilometer below the sea floor, the drilling fluid flushes out clumps and chunks of solid rock. When the geologist studies these fragments, she finds that they consist of grains of sand or silt cemented together, tightly packed clay that is harder than pottery, masses of shell fragments, or solid aggregates of salt crystals. The geologist has observed the transition of loose sediment into solid layers of sedimentary rock as burial depth progressively increases.

**TAKE-HOME MESSAGE**

By the end of this chapter, you should understand the various processes that produce sedimentary rocks, be able to describe and classify such rocks, and be able to recognize the clues they contain about the past history of the Earth.

**FIGURE 6.1** Sedimentary rocks form a cover over older basement rock.



8a At the Grand Canyon, we see a contact between cover rock, horizontal sedimentary layers, and the basement rock.

8b A geologist's sketch emphasizes the contact between the sedimentary cover and basement.



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**3.2 WHAT IS A MINERAL?**

In this chapter, we begin by presenting the geologic definition of a mineral, then look at how minerals form and at the main characteristics that enable us to identify them. Finally, we see the basic schemes that geologists use to classify minerals. This chapter assumes that you understand the fundamental concepts of matter and energy, especially the nature of atoms, molecules, and chemical bonds. If you are rusty on these topics, please review the Appendix. We summarize basic terms from chemistry in Box 3.1, for convenience.

**TAKE-HOME MESSAGE**

When you finish this chapter, you should understand what minerals are, how they form, and how they are classified. You should also know how to identify a mineral, and recognize the difference between gems and ordinary mineral specimens.

**FIGURE 3.1** The nature of crystalline and noncrystalline materials.

**3.2** What is a Mineral?

The action of geologic processes on organic materials? Is it a mineral. Examples include the crystals that grow in ancient deposits of oil. The atoms in a mineral are arranged in a regular, repeating pattern. This is the crystalline structure. In contrast, the atoms in a noncrystalline material are arranged in a disordered, irregular pattern. This is the amorphous structure.

**TAKE-HOME MESSAGE**

For a substance to be a mineral, it must first be an element or a compound of elements. It must have a regular arrangement of atoms. It must be a solid. It must have a crystalline structure. It must be inorganic. It must occur in nature, and it must have been formed by geologic processes.

**Box 3.1**

**Some Basic Definitions from Chemistry**

To describe minerals, we need to use several terms from chemistry for a more depth discussion. See the Appendix for a full discussion. Terms are listed in order that permits each successive term to utilize previous terms.

- Element:** a pure substance that cannot be broken into other elements.
- Atom:** the smallest piece of an element that retains the characteristics of the element. An atom consists of a nucleus surrounded by a cloud of orbiting electrons. The nucleus is made up of protons and neutrons bound together in hydrogen, where neutrons contain only one proton and no neutrons. Electrons have a positive charge, the protons have a positive charge, and the neutrons have no charge. The atom that has the same number of electrons as protons is called neutral; if it does not have an equal electrical charge.
- Atomic number:** the number of protons in an atom or an ion of an element.
- Atomic weight:** approximately the number of protons plus neutrons in the atom of an element.
- Ion:** an atom that is not neutral. An ion that has an excess negative charge (because it has more electrons than protons) is an anion, whereas an ion

that has an excess positive charge (because it has more protons than electrons) is a cation. The electrical charge with a subscript. For example,  $Cl^-$  has a single electron (negative charge) missing from its electrons.

- Chemical bond:** an attractive force that holds two or more atoms together. For example, covalent bonds form when atoms share electrons. Ions bond from when a cation and anion bond with opposite charges get close together and attract each other. Atoms with metallic bonds, some of which are metallic bonds, are arranged in a regular, repeating pattern.
- Molecule:** two or more atoms bonded together. The atoms are arranged in a regular, repeating pattern.

**Chemical reaction:** a process that involves the breaking or forming of chemical bonds. Chemical reactions can break molecules apart or create new molecules and/or isolated atoms.

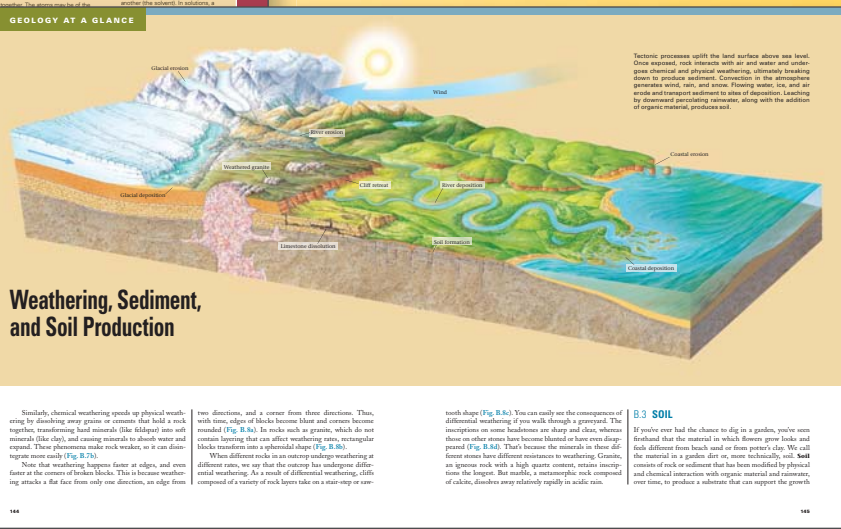
**Mixture:** a combination of two or more elements or compounds that can be separated without a chemical reaction. For example, a natural compound of iron flakes and wax is a mixture. Iron can separate the wax from the iron flakes without destroying either.

**Solution:** a type of mixture in which the solute is the substance dissolved (the solute). In solution, a

“Among the best parts of the book are the illustrations, which are beautiful to look at and supplement the text perfectly . . . reinforcing concepts.”

—Kenneth A. Ballew, on Amazon.com

**Weathering, Sediment, and Soil Production**



Similarly, chemical weathering speeds up physical weathering by dissolving away grains or crystals that hold a rock together, transforming hard minerals (like feldspar) into soft minerals (like clay) and causing minerals to absorb water and expand. Thus the phenomenon makes rocks wet, or it can disintegrate more easily (Fig. B.7b).

Now that weathering happens faster at edges, and even faster at the corners of blocks. This is because weathering strikes a face from only one direction, an edge from two directions, and a corner from three directions. Thus, with time, edges of blocks become blunter and corners become rounded (Fig. B.8a). In rocks such as granite, which do not contain layers that can affect weathering rates, rectangular blocks transform into a spherical shape (Fig. B.8b).

When different rocks in an outcrop undergo weathering at different rates, we say that the outcrop has undergone differential weathering. As a result of differential weathering, cliffs steepen at a face from only one direction, an edge from two directions, and a corner from three directions. Thus, with time, edges of blocks become blunter and corners become rounded (Fig. B.8a). In rocks such as granite, which do not contain layers that can affect weathering rates, rectangular blocks transform into a spherical shape (Fig. B.8b).

**B.3 SOIL**

If you've ever had the chance to dig in a garden, you've seen firsthand that the material in which flowers grow looks and feels different from beach sand or from potting soil. We call this material a garden dirt or, more technically, soil. Soil consists of rock or sediment that has been modified by physical and chemical interaction with organic material and, conversely, over time, to produce a substrate that can support the growth

**10.7 How Do We Determine Numerical Age?**

**FIGURE 10.10** Life evolution in the context of the geologic column. The Earth formed at the beginning of the Hadean Eon.

of vegetation in this region, you can easily see bedrock exposures on the walls of cliffs and canyons, and some of these exposures are so beautiful that they have become national parks. The oldest sedimentary rock of the region crops out at the base of the Grand Canyon, whereas the youngest form the cliffs of Cedar Breaks and Bryce Canyon (see Geotour 10 on p. GT-22).

Walking through these parks is thus like walking through time—each rock layer gives an indication of the climate and topography of the region in the past (see *Geology at a Glance*, pp. 290–291).

For example, when the Proterozoic metamorphic and igneous rocks exposed in the inner gorge of the Grand Canyon first formed, the region was a high mountain range, perhaps as dramatic as the Himalayas today. When the fossiliferous beds of the Kaibab Limestone at the rim of the canyon first developed, the region was a Bahama-like carbonate reef and platform, bathed in a warm, shallow sea. And when the rocks making up the towering red cliffs of sandstone in Zion Canyon were deposited, the region was a Sahara-like desert, blanketed with huge sand dunes.

**TAKE-HOME MESSAGE**

Correlation of stratigraphic sequences from around the world allowed production of a chart, the geologic column, that represents the entirety of Earth's history. The column, developed using only relative age relations, is subdivided into eons, periods, and epochs.

**10.7 HOW DO WE DETERMINE NUMERICAL AGE?**

Geologists since the days of Hutton could determine the relative ages of geologic events, but they had no way to specify numerical ages. Thus, they could not define a time line for Earth's history or determine the duration of events. This situation changed with the discovery of radioactivity. Simply put, radioactive elements decay at a constant rate that can be measured in the lab

demonstrates that educational illustrations can also be beautiful. Face-to-face meetings with the book team and the author happened as often as they could, sometimes even on the lead artist's front porch! Finally, by having all aspects of production under one roof—from development of sketches through the book layout to final composition—we were able to accommodate the author's travel schedule and desire for hands-on involvement, ensure that all elements of the book maintained a consistent look and feel, and still get the book published on a reasonable schedule.

**THE FINAL RESULTS**

- *Essentials of Geology* has become a geology essential
- Winner of the Crystal Book Award, 58th Annual Book and Media show, 4-color college textbook
- Continued relationship with author and publisher based on this book