Chapter 1

Rocks for Jocks (and Everybody Else)

In This Chapter

- Discovering the scientific study of earth
- Learning that rocks transform through the rock cycle
- Uncovering plate tectonics theory
- Recognizing surface processes
- Delving into earth's history

Geology and earth sciences seem to have a reputation for being easy subjects, or at least the least difficult of the science courses offered in high school and college. Perhaps that's because the items observed and studied in geology —rocks — can be held in your hand and seen without a microscope or telescope.

Geology is the study of the earth, what it's made of, and how it came to look the way it does. Studying geology means studying all the other sciences, at least a little bit. Aspects of chemistry, physics, biology, and astronomy (just to name a few) are the foundation for understanding earth's geologic system, both the processes and the results.

Exploring geology is not just for folks who want to avoid the heavy calculations of physics or the intense labs of chemistry. Geology is for everyone. Geology is the science of the planet you live on — the world you live in — and that is reason enough to want to know more about it.

Finding Your Inner Scientist

You are already a scientist. Maybe you didn't realize this, but just by looking around and asking questions you behave just like a scientist. Sure, scientists call their approach of asking and answering questions the *scientific method,* but what you do every day is the very same thing, without the fancy name. In

Chapter 2, I present the scientific method in detail. Here, I offer a quick overview of what it entails.

Making observations every day

Observations are simply information collected through your five senses. You could not move through the world without collecting information from your senses and making decisions based on that information.

Consider a simple example: Standing at a crosswalk, you look both ways to determine if a car is coming and if the approaching car is going slow enough for you to safely cross the street before it arrives. You have made an observation, collected information, and based a decision on that information — just like a scientist!

Jumping to conclusions

You constantly use your collected observations to draw conclusions about things. The more information you collect (the more observations you make), the more solid your conclusion will be. The same process occurs in scientific exploration. Scientists gather information through observations, develop an educated guess (called a *hypothesis*) about how something works, and then seek to test their educated guess through a series of experiments.

No scientist wants to jump to a false conclusion! Good science is based on many observations and is well-tested through repeated experiments. The most important scientific discoveries are usually based on the educated guesses, experiments, and continued questioning of a large number of scientists.

Focusing on Rock Formation and Transformation

As I explore in detail in Part II of this book, the foundation of geology is the examination and study of rocks. Rocks are, literally, the building blocks of the earth and its features (such as mountains, valleys, and volcanoes). The materials that make up rocks both inside and on the surface of the earth are constantly shifting from one form to another. This cycle and the processes of rock formation and change can be traced through observable characteristics of rocks found on earth's surface today.

Understanding how rocks form

Characteristics of rocks such as shape, color, and location tell a story of how and where the rocks formed. A large part of geologic knowledge is built on understanding the processes and conditions of rock formation. For example, some rocks form under intense heat and pressure, deep within the earth. Other rocks form at the bottom of the ocean after years of accumulation and compaction. The three basic rock types, which I discuss in detail in Chapter 7, are:

- **Igneous:** Igneous rocks form as liquid rock material, called *magma* or *lava,* cools. Igneous rocks are most commonly associated with volcanoes.
- **Sedimentary:** Most sedimentary rocks form by the compaction of sediment particles that have settled to the bottom of a body of water, such as an ocean or lake. (There are also chemical sedimentary rocks, which are not formed this way. I describe these in Chapter 7 as well.)
- **Metamorphic:** Metamorphic rocks are the result of a sedimentary, igneous, or other metamorphic rock being crushed under intense amounts of pressure or subjected to high amounts of heat (but not enough to melt it) that change its mineral composition.

Each rock exhibits characteristics that result from the specific process and environmental conditions (such as temperature) of its formation. In this way, each rock provides clues to events that happened in earth's past. Understanding the past helps us to understand the present and, perhaps, the future.

Tumbling through the rock cycle

The sequence of events that change a rock from one kind into another are organized into the rock cycle. It is a cycle because there is no real beginning or end. All the different types of rocks and the various earth processes that occur are included in the rock cycle. This cycle explains how materials are moved around and recycled into different forms on the earth's surface (and just below it). When you have a firm grasp on the rock cycle, you understand that every rock on earth's surface is just in a different phase of transformation, and the same materials may one day be a very different rock!

Mapping Continental Movements

Most of the rock-forming processes of the rock cycle depend on forces of movement, heat, or pressure. For example, building mountains requires pressure exerted in two directions, forcing rocks upward or folding them together. This type of movement and the associated forces of pressure are a result of continental plate movements. The idea that the surface of the earth is separated into different puzzle-like pieces that move around is a relatively new concept in earth sciences, called *plate tectonics theory* (the subject of Part III).

Unifying geology with plate tectonics theory

For many decades, earth scientists studied different parts of the earth without knowing how all the features and processes they examined were tied together. The idea of plate movements came up early in the study of geology, but it took a while for all the persuasive evidence to be collected, as I describe in Chapter 8.

By the middle of the twentieth century, information about the age of sea floor rocks gathered during World War II had provided scientists with the evidence they needed to build a theory of plate tectonics. After they recognized and accepted that new ocean floor was formed along *mid-ocean ridge plate boundaries* (a place on the earth's surface where two crustal plates are moving apart from one another), scientists could explain how continental plates moved around on the earth's surface.

One of the things they realized was that the earth's crustal plates interact in different ways. These interactions are described as plate boundary types and include:

- **Convergent boundaries:** At convergent boundaries, two crustal plates are moving toward one another and come together. Depending on the density of the crustal plates, this collision builds mountains, creates volcanoes, or causes plate *subduction* (meaning one plate goes beneath another).
- **Divergent boundaries:** At divergent plate boundaries, two crustal plates are separating or moving apart from one another. These boundaries are most commonly observed along the sea floor, where the cooling of magma along the boundary creates a mid-ocean ridge, but they may also occur on continents, such as in the African rift valley.
- **Transform boundaries:** At transform boundaries, the two plates are neither colliding nor separating; they are simply sliding alongside one another.

In Chapter 9, I provide the details on the different characteristics of continental plates and how they interact as they move around earth's surface, including the particular geologic features associated with each plate boundary type.

Debating a mechanism for plate movements

While the unifying theory of plate tectonics has been well-accepted by the scientific community, geologists have yet to agree on what, exactly, drives the movement of continental plates.

Three dominant hypotheses explain what drives plate tectonic motion. Each one relies on the *convention* of the mantle — the movement of heated rock materials beneath earth's crust — but each one focuses on a different piece of the cycle:

- **Mantle convection hypothesis:** This hypothesis proposes that heated materials inside the earth move up and down in a circular motion (like the wax in a lava lamp) and the continental plates resting on this material are moved in the direction of the circular motion.
- **Ridge-push hypothesis:** This hypothesis states that the creation of new rock materials along mid-ocean ridges continually pushes oceanic crustal plates upward and outward, so that the far edges are forced into collisions with other plates.
- **Slab-pull hypothesis:** This hypothesis is the opposite of the ridge-push model. It proposes that the heavy, dense outer edges of crustal plates sink into the mantle at plate boundaries and pull the rest of the plate along with them.

And some scientists propose that the movement of crustal plates is due to a combination of all three of these driving mechanisms. Read Chapter 10 and decide what you think is the best explanation for driving plate movements.

Moving Rocks Around on Earth's Surface

On a smaller than global scale, rocks are constantly being moved around on earth's surface. Surface processes in geology include changes due to gravity, water, ice, wind, and waves. These forces sculpt earth's surface, creating landforms and landscapes in ways that are much easier to observe than the more expansive processes of rock formation and tectonic movement. Surface processes are also the geologic processes humans are more likely to encounter in their daily lives.

- **Gravity:** Living on earth you may take gravity for granted, but it is a powerful force for moving rocks and sediment. Landslides, for example, result when gravity wins over friction and pulls materials downward. The result of gravity's pull is *mass wasting,* which I explain in Chapter 11.
- **Water:** The most common surface processes include the movement of rocks and sediment by flowing water in river and stream channels. The water makes its way across earth' surface by removing and depositing sediment, reshaping the landscape as it does. The different ways flowing water shapes the land are described in Chapter 12.
- **Ice:** Similar to flowing water but much more powerful, ice moves rocks and can shape the landscape of an entire continent through glacier movements. The slow-flowing movement of ice and its effect on the landscape are described in Chapter 13.
- **Wind:** The force of wind is most common in dry regions, and you are probably familiar with the landforms it creates, called *dunes.* You may not realize that the speed and direction of wind create many different types of dunes, which I describe in Chapter 14.
- **Waves:** Along the coast, water in the form of waves is responsible for shaping shorelines and creating (or destroying) beaches. In Chapter 15, I describe in detail the various coastal landforms created as waves remove or leave behind sediments.

Interpreting a Long History of Life on Earth

One of the advantages of studying geology is being able to learn what mysteries of the past are hidden in the rocks. Sedimentary rocks, formed layer by layer over long periods of time, tell the story of earth's history: changing climates and environments, as well as the evolution of life from single cells to modern complexity.

Using relative versus absolute dating

Scientists use two approaches to determine the age of rocks and rock layers: relative dating and absolute dating.

Relative dating provides ages of rock layers in relation to one another — for example, stating that one layer is older or younger than another is. The study of rock layers, or *strata,* is called *stratigraphy.* In methods of relative dating, geologists apply *principles of stratigraphy* such as these:

- Rock layers below are generally older than rock layers above.
- All sedimentary rock layers are originally formed in a horizontal position.
- When a different rock is cutting through layers of rock, the cross-cutting rock is younger than the layers it cuts through.

These principles and a few others that I describe in Chapter 16 guide geologists called *stratigraphers* in interpreting the order of rock layers so that they can form a relative order of events in earth's history.

However, sometimes simply knowing that something is older than — or younger than — something else is not enough to answer the question being asked. *Absolute dating* methods use radioactive atoms called *isotopes* to determine the age in numerical years of some rocks and rock layers. Absolute dating methods may determine, for example, that certain rocks are 2.6 million years old. These methods are based on the knowledge, learned from laboratory experiments, that some atoms transform into different atoms at a set rate over time. By measuring these rates of change in a lab, scientists can then measure the amount of the different atoms in a rock and provide a fairly accurate age for its formation.

If the process of obtaining absolute dates from isotopes seems very complex, don't worry: In Chapter 16, I explain in much more detail how absolute dates are calculated and how they are combined with relative dates to construct the *geologic timescale:* a sequence of earth's geological history separated into different spans of time (such as periods, epochs, and eons).

Witnessing evolution in the fossil record

The most fascinating story told in the rock layers is the story of earth's evolution. To *evolve* simply means to change over time. And indeed, the earth has evolved in the 4.5 billion years since it formed.

Both the earth itself and the organisms that live on earth have changed through time. In Chapter 17, I briefly explain the biological understanding of evolution. Much of modern understanding about how species have changed through time is built on evidence from *fossilized* or preserved life forms in the rock layers. Fossilization occurs through different geologic and chemical processes, but all fossils can be described as one of two forms:

- **Body fossils:** Remains of an organism itself, or an imprint, cast, or impression of the organism's body.
- **Trace fossils:** Remains of an organism's activity, such as movement (a footprint) or lifestyle (a burrow) but without any indication of the organism's actual body.

Earth did not always support life. In Chapter 18, I describe the very early earth as a lifeless, hot, atmosphere-free planet in the early years of the solar system's formation. It took billions of years before simple, single-celled organisms appeared, and their origins are still a scientific mystery.

Simple, single-celled life ruled earth for many millions of years before the *Cambrian explosion.* Chapter 19 describes this period of relatively sudden increasing complexity and abundance of life on earth, as well as the millions of years that followed when life was lived almost entirely in the oceans until amphibians emerged on the land.

Chapter 20 delves into the Age of Reptiles, when dinosaurs ruled the earth and reptiles filled the skies and seas. At the end of this period, all the earth's continents were coming together like puzzle pieces to create a supercontinent called *Pangaea.* Evidence for Pangaea is still visible in the coastal outlines of South America and Africa — indicating where they used to be attached as part of the supercontinent.

In relatively recent time, geologically speaking, mammals took over from reptiles to rule the earth. The Cenozoic era (beginning 65.5 million years ago), which we are still experiencing, is the most recent and therefore most detailed portion of earth's history that can be studied in the geologic record (the rocks). All the geologic features of the modern earth, such as the Grand Canyon and the Himalayan Mountains, were formed in this most recent era. In Chapter 21, I describe the evolution of mammal species (including humans) and the geologic changes that occurred to bring us to today.

At various times in the history of earth, many different species have disappeared in what scientists call *mass extinction events.* In Chapter 22, I describe the five most dramatic extinction events in earth's history. I also explain a few of the common hypotheses for mass extinctions, including climate change and asteroid impacts. Finally, I explain how the earth may be experiencing a modern-day mass extinction due to human activity.