CHAPTER 29

Examining the Earth

"These cliff-bound glaciers, seemingly wedged and immovable, are flowing like water and grinding the rocks beneath them. The lakes are lapping their granite shores and wearing them away, and every one of these rills and young rivers is fretting the air into music, and carrying the mountains to the plains."

—John Muir (19th-century naturalist and a founder of the Sierra Club), 1868

Many of us are drawn to the out-of-doors by its timeless tranquility and beauty. We're sure that the mountains we climb this summer will be there next year, too. The tumbling streams that lull us to sleep seem to have flowed forever, and it might be difficult to imagine that the deep valleys and broad plains could ever have been much different from how they are today.

Yet the seeming permanence of terrain is an illusion, as the land is always changing. The quiet, wooded campsites we like so much might once have been at the bottom of an ocean or buried beneath immense expanses of ice. The hills we hike could have been seared by the heat of volcanic blasts or torn apart by earthquakes. Even as we stand on them, granite mountains are slowly rising, or dissolving beneath our feet. Eruption and erosion, creation and decay—the Earth is being continually reshaped, time and again cast anew. It is a relentless, powerful, and fascinating process, and as we explore the world, we are surrounded everywhere by evidence of its complexity and grace.

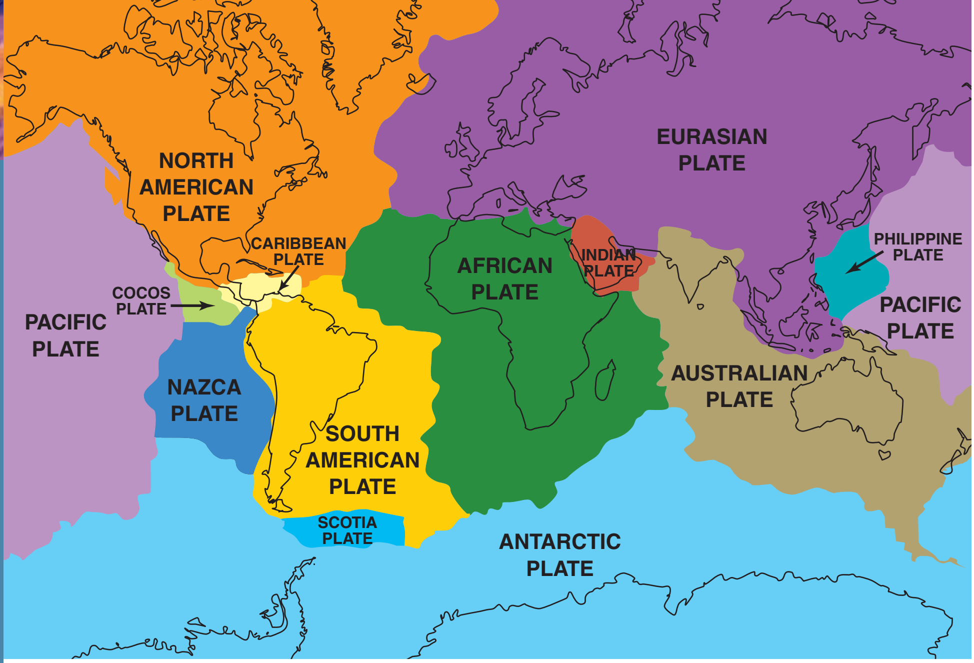


Plate tectonics

Formation of the Earth

Scientists suggest imagining a time-lapse camera photographing the Earth's surface from its beginnings to the present. Even at a rate of one frame exposed every 100 years, the finished film would take weeks to show. Opening scenes of molten rock glowing red gradually give way to those of a globe with its surface dividing into continents and oceans. Mountain ranges heave through the Earth's crust only to diminish. Ice fields flow out from the polar caps, then recede. Seas draw back to reveal vast prairies. Earthquakes and volcanoes abruptly alter the landscape, and the continents drift slowly about the globe. Strange plants and animals flicker into view and then are gone, the dinosaurs perhaps the most recognizable. Humans finally appear on the screen, the history of their civilizations taking only a few seconds at the end of the long film of the Earth's history.

GEOLOGY
***Geo* means "earth"; the suffix *-logy* indicates "a subject of study." *Geology*, then, is the scientific examination of the formation and development of our planet.**

Many geologists studying the development of the planet believe the Earth came into existence as a molten ball composed of various elements. The lighter elements drifted toward the surface of the globe, leaving at the center a dense iron core. A crust formed as the Earth's surface cooled, and even today that crust ranges from about 9 to about 47 miles thick. Temperatures and pressures deep within the Earth are still high enough to keep rock in elastic or plastic form. The great slabs, or *plates,* of the Earth's crust float upon this mantle like so many gigantic islands, drifting, colliding, and overlapping. Known as *plate tectonics,* this slow, remarkable motion can drive mountain ranges skyward.

Plate Tectonics

The major plates of the Earth's crust are named for the areas of land and sea under which they lie. The *North American Plate*, for example, is the underpinning of most of North America and a good share of the Atlantic Ocean. Bordering its western edge is the *Pacific Plate* extending beneath the Pacific Ocean. Other prominent plates are the *Australian, African, South American, Eurasian, Philippine*, and *Antarctic*.

The plates might move only inches a year, but even so slow a migration has far-reaching effects. The motion of adjoining plates takes one of four forms—*separating, sliding, undercutting*, and *colliding*. These motions are caused by convection currents as magma slowly churns deep inside the Earth.

Separating

When two plates pull away from one another, they create a *zone of divergence*. The African Great Rift Valley and the Red Sea are good examples. Occurring primarily under the oceans, zones of divergence allow magma to rise and fill the gaps between the plates.

Sliding

Plates moving parallel to one another can cause earthquakes, especially along the *fault zone* at the edges of the plates, such as occurs in California.

Undercutting

When one plate slides under another plate, it can curve downward, creating a *subduction zone* that is a source of volcanoes, earthquakes, and mountain building, as found in the Ring of Fire surrounding the Pacifc Rim.

Colliding

When one plate slams into another, layers of rock thrust upward can form mountain ranges, such as in the Himalayas, where the Indian Plate is smashing into Asia.

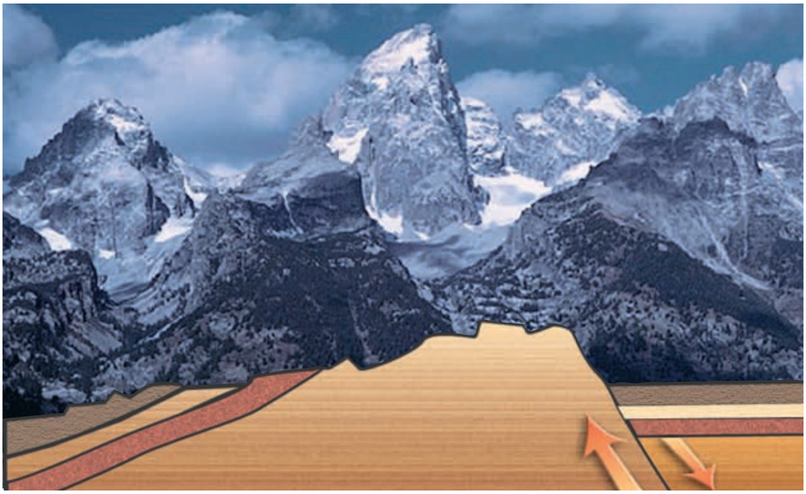
Terrain Formation

The center of the North American Plate, near the Appalachian Mountains, is relatively stable. Far from the active edges of the tectonic plates, the prairie states tend to be flat, often layered with the sediment of ancient oceans that once flowed over them. Farther west, stress in the Earth's crust has created mountain ranges in a variety of ways, primarily through *volcanic activity*, *faults, folds*, and *continental uplifts*.

> Volcanic eruptions occurring in California, Oregon, Washington, and Alaska are caused by pressure and instability as tectonic plates sliding under one another sometimes form cracks in the Earth's crust that allow magma to flow to the surface. The colliding edges of the North American and Pacific plates can be traced along the West Coast of the United States, past British Columbia, and through the Aleutian Islands.

Volcanoes

When hot, fluid rock called *magma* finds passage to the surface, it may erupt as a volcano. In some cases an initial eruption can explode with devastating force, as did Mount Saint Helens in the state of Washington, and the flow of magma may continue for a long time, as does that from Mauna Loa on the island of Hawaii. The Cascade Range of the Pacific Northwest is volcanic in origin, and the Hawaiian Islands are the tops of immense volcanoes that, when measured from their bases on the ocean floor, are the tallest mountains on the planet.

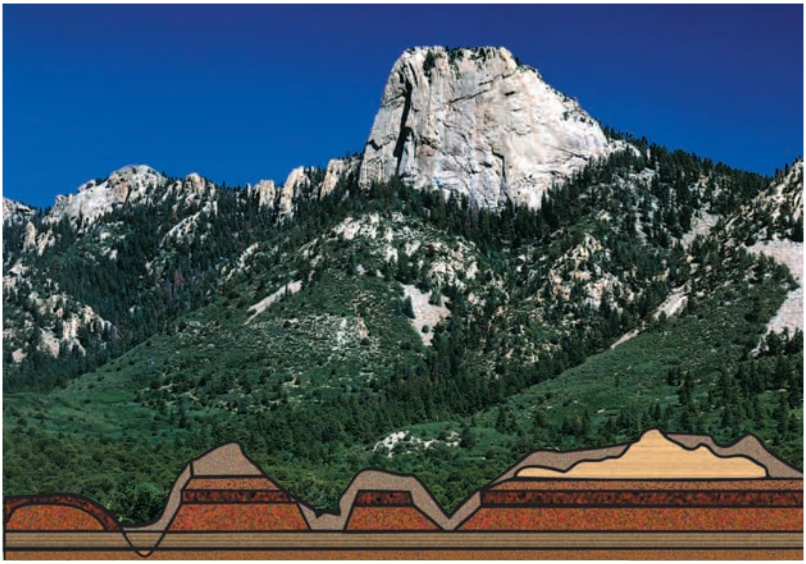


Faults

Pressured by plate movement, the Earth's crust may fracture and shift, creating high walls, zones of broken rock, and disrupted streambeds. Additional plate movement can jumble these terrain features and create the angular shapes of mountain ranges that include the Sierra Nevada and the Tetons.

Folds

Instead of fracturing, a plate of soft, sedimentary rocks may fold. Sections of the Appalachian Mountains were formed this way.

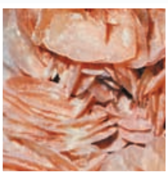


Continental Uplifts

Large sections of the Earth's crust are sometimes forced upward by internal pressures created by plate motion. When that happened in western North America, the towering Rocky Mountains came into being.

Mica

Quartz



Gypsum

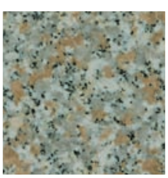
Calcite

Dolomite

Rocks

The elements that make up the Earth (oxygen, silicon, etc.) bind together to form dozens of *minerals* including mica, quartz, gypsum, calcite, dolomite, and feldspar. These are the building blocks of rocks, combining in myriad ways to create the enormous variety you see in the field. Geologists identify the minerals that compose particular rocks by using measurements including hardness, color, and fracturing qualities as the basis of their classifications. A good rock identification book will give you the information you need to do this, too, and you might find that the delights of being a rock hound are as satisfying as being able to identify trees, animals, and cloud formations.

To simplify matters, geologists have divided all rocks into one of three categories, depending on their origins—*igneous*, *sedimentary*, and *metamorphic*. Every rock bears clues of the process that formed it. By deciphering those signs, you can not only learn how certain rocks came into being, but also perhaps better understand the makeup of entire landscapes.



Feldspar

Igneous Rock

Igneous rock forms from cooling molten rock. When magma stays beneath the Earth's surface, it cools slowly, forming crystals. The slower the cooling process, the larger the crystals. Magma thrown up by a volcano is an *extrusive* igneous rock, meaning it cools on the Earth's surface. Since it cools quickly, the crystals are very small—you might need a magnifying glass to see them. Obsidian, for example, is magma that cooled so rapidly it became a kind of glass that can be black, green, gray, or even red in color. Basalt is another extrusive igneous rock. Granite, on the other hand, is an *intrusive* igneous rock, meaning it cooled slowly under the surface of the Earth. The crystals in granite are large and very easy to see and identify.

Igneous rock

Sedimentary Rock

Sedimentary rock forms as eroded particles settle out of the water in which they have been transported. Layers of sediment piling on top of one another become compacted, and moisture percolating through the sediment may deposit calcium carbonate, silica, or iron oxide, which binds the particles. Limestone is among the most common sedimentary rocks, often composed of the skeletal remains of ancient plants and animals. Grains of sand can become sandstone. Pebbles and larger stones can become cemented together to form layers of *conglomerates,* while shale primarily is composed of silt and clay particles. With a sharp eye you often can find tiny, beautifully preserved fossils in sedimentary rock.

Sedimentary rock

Metamorphic Rock

Igneous and sedimentary rocks are sometimes heated enough or put under enough pressure for their minerals to take on new forms. The rocks that result are said to be *metamorphic*. For instance, shale can metamorphose into slate, and limestone into marble. Granite might change into banded gneiss. Under tremendous pressure, graphite can be transformed into diamonds.

Metamorphic rock

Soils

Soil is so familiar to us we seldom give it a second thought. "As common as dirt," goes an old saying, but there is nothing common about soil. It is an ecosystem composed of a complicated combination of mineral matter (a mix of silt, sand, and clay), water, air, and organic material (plant roots, bacteria, fungi, nematodes, protozoa, arthropods, earthworms, etc.).

Decomposing organic matter breaks down into phosphorus, nitrogen, sulfur, and other compounds that vegetation must have in order to thrive. As plants and animals die, their decomposition refreshes the organic material of the soil, making possible one of the environment's most important energy cycles.

Those who study soil classify samples according to a variety of measurements:

- *Composition*—the ratio of sand, silt, and clay
- *Water-holding capacity*—the ability of a soil sample to absorb moisture
- *Biotic contents*—the amount and kind of organic material found in a sample

Another useful measurement for identifying a particular soil is its color, classified by its hue (degrees of red, yellow, green, blue, and purple), darkness or lightness, and strength of color (known as *chroma*). In general, darker soils contain more organic matter, and thus are more fertile, than soils of lighter color. Darker soils also are less likely to erode.

Erosion

Coupled with the creative forces of plate tectonics is the relentless power of erosion. Without erosion, the Earth's mountains would be extremely high. There would be no streambeds, no canyons, and little soil. Without erosion, life as we know it could not exist.

The primary agents of erosion are water, chemicals, ice, gravity, and wind. Moisture seeping into rock fissures expands as it freezes, gradually breaking stone apart. The rocks of talus and scree slopes on mountainsides probably were shattered by frost. Chemicals carried by water can dissolve rock or eat away the crystals that hold it together, allowing it to crumble into particles. Limestone is especially susceptible to chemical weathering, as evidenced by old limestone tombstones whose eroded letters have become almost unreadable, and by the formation of sinkholes and caves.

Rain washes away bits of loosened stone that will act as abrasives as they are carried along. Trickles of water combine to form rivulets, rivulets unite into streams, and streams join into rivers, all patiently cutting channels into the Earth. The steeper the grade of the land, the faster and more erosive

River deltas and weathered rock are both results of erosion.

the movement of the water and the sediment in it. When the grade lessens and streams lose momentum, particles suspended in the water settle to the bottoms of lakes or help create deltas at the mouths of rivers. Floodplains are formed by the deposition of sediment during flooding.

Glaciers are among the most spectacular agents of erosion. A glacier is a long-lasting body of ice formed when yearly accumulations of snow exceed the amounts that melt. The weight of new snow compresses that below it, eventually turning it into ice. As more snow falls on the upper reaches of a glacier, it pushes the ice field downhill in a motion much like that of a very slow river.

Stresses upon glacial ice cause fractures called *crevasses* that can be hundreds of feet deep. When a glacier pushes its way down a steep valley or over a cliff, it creates an *icefall,* a chaotic tangle of frozen walls and pillars known as *seracs* that can topple without warning. If a glacier reaches the ocean, as do many in Alaska and Antarctica, great chunks of ice shear away and drop into the sea. Called *calving,* this glacial activity is a primary source of icebergs.

As a glacier moves across the land, gravel and rocks trapped beneath the weight of the ice scour the surfaces over which they travel. Glaciers can reshape the sharp, V-shaped canyons cut by streams into broad U-shaped valleys. Melting glaciers can leave behind *moraines*—distinctive ridges of rock, boulders, cobbles, and sand they might have pushed along for many miles.

Erratics are boulders carried along by glaciers and deposited in a new location.

Scientists believe that when the climate of the Earth cooled, continental glaciers crept down from the Arctic to cover much of North America. When the weather warmed and the glaciers retreated, they left behind thick deposits of soil and, here and there, solitary boulders known as *glacial erratics*. Much of the rich American prairie was formed by *loess,* windblown soil deposits in glaciated areas. Alpine glaciers continue to cloak the summits and high basins of many mountain ranges in Canada and the United States.

The power of erosion is astonishing. Over the eons it has carved the Grand Canyon, worn down the Appalachian Mountains, and helped shape every landscape you've ever hiked. In fact, you'll find the effects of erosion everywhere you look, but it must be seen in perspective. Erosion plays an essential role in the creation of the soil in which forests, grasslands, and crops can take root, but it has an insatiable appetite. Poor management and abuse of natural resources can allow erosion to take away soil far more quickly than it can be formed.

For more on the effects of erosion and ways to avoid its negative effects, see the section titled "Leaving No Trace." For ways to repair landscapes harmed by erosion, see the chapter titled "Being Good Stewards of Our Resources."

Wisely Using Our Resources

Our Earth has countless resources, including minerals, water, forests, wildlife, oil, and open land, to name a few of them. Minerals are extracted for making metals used in construction, factories, heavy equipment, and automobiles. Water is used for human consumption, crop irrigation, manufacturing, hydroelectric power, and recreation. Oil is used to heat and light our homes and offices, as well as for powering machinery and automobiles. Forest lumber is used to construct buildings, homes, and furniture. Land is used for housing and business development; for raising crops, grazing cattle, building highways, and recreation; and for preserving species of plants and animals.

Human beings have many needs and wants. We are responsible for determining how and for what we will use our resources—decisions that have enormous consequences for our daily lives. We can set aside a river for recreation, or we can build a hydroelectric dam that will generate electricity to light hundreds of thousands of homes—but that same dam also might affect the fish habitat of the river. The consequences of our action or inaction need careful consideration based on all of our needs and wants so that we do not act rashly or do something we might come to regret. Alternative uses of resources need to be carefully researched to achieve a solution that serves the most people and the most significant needs. When you learn about a controversy regarding the environment, take time to educate yourself about each of the alternatives and listen to other people's perspectives before reaching a conclusion. There are no easy answers.

As members of the BSA, we have pledged ourselves to be thrifty. As residents of the planet and consumers of its resources, we must be leaders in doing our part to care for the Earth.

We can pitch in and do plenty of good work repairing environmental damage near our homes, in Scout camps, and in parks and forests we enjoy using. We can recycle. We can be smart about what we purchase and what we consume. We can stay informed and become involved in the political processes that lead to many decisions about how the people of our communities, states, and nation will use and protect natural resources.

Other chapters of the *Fieldbook* have emphasized the importance of practicing Leave No Trace principles during outdoor adventures. The chapter titled "Being Good Stewards of Our Resources" suggests many hands-on projects that can make a real difference in the quality of the environment. With hard work, we can protect the places where we camp and hike. With enthusiasm, patience, and dedication, we can extend our efforts to care for all of the Earth.