Section Objectives

- **Identify the types of plate collisions that build mountains.**
- **Identify four types of mountains and discuss the forces that shaped them.**

5.3 Mountain Formation

Mount Everest has the highest elevation of any mountain on earth, rising 8 km above sea level. Mount St. Helens became the most newsworthy mountain in the United States after it erupted in 1980.

Despite the fame of these mountains, neither stands alone. Each is part of a **mountain range,** a group of adjacent mountains with the same general shape and structure. Mount Everest is in the Great Himalaya Range, and Mount St. Helens is part of the Cascade Range.

Just as a group of individual mountains make up a range, a group of adjacent mountain ranges make up a **mountain system.** The Great Smoky, the Blue Ridge, the Cumberland, and the Green mountain ranges make up the Appalachian mountain system in the eastern United States.

The largest mountain systems are part of two still larger systems called **mountain belts.** The two major mountain belts on earth, the circum-Pacific belt and the Eurasian-Melanesian belt, are shown in Figure 5–5. The circum-Pacific belt forms a ring around the Pacific Ocean. The Eurasian-Melanesian belt runs from the Pacific islands through Asia and southern Europe and into northwestern Africa.

Plate Tectonics and Mountains

Both the circum-Pacific mountain belt and the Eurasian-Melanesian mountain belt are located along convergent plate boundaries. Scientists think that the location of these two mountain belts is evidence that most mountains were formed when lithospheric plates collided. Some mountains, such as the Appalachians, do not lie along active convergent plate boundaries. However, evidence indicates that these ranges formed where plates collided in the past.

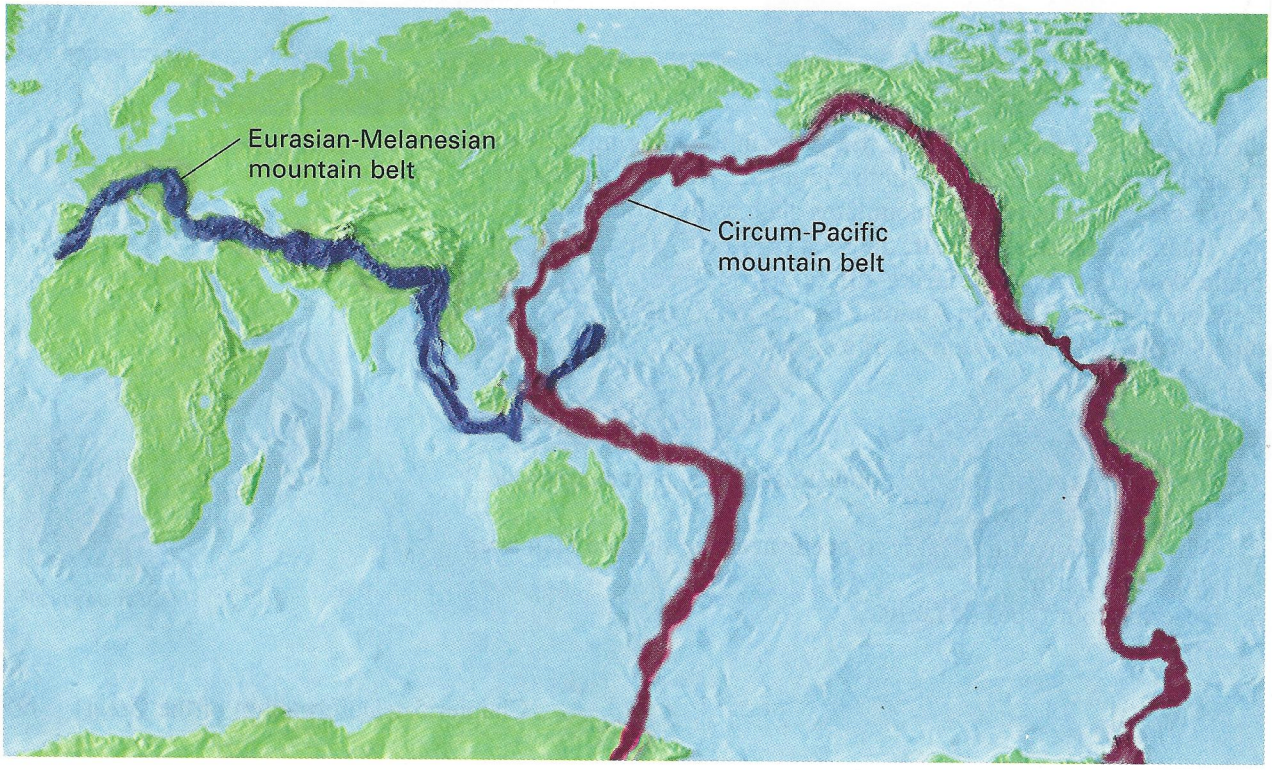


Figure 5–5. Most of the great mountain ranges of the world lie along two mountain belts.

Collisions Between Continental and Oceanic Crust

Some mountains form when oceanic crust and continental crust collide at convergent plate boundaries. When the moving plates collide, the oceanic crust is subducted beneath the continental crust. This type of collision produces such large-scale deformation of rock that high mountains are pushed up. In addition, the subducted oceanic crust partially melts, producing the magma that might eventually erupt and form volcanic mountains on the earth's surface. The mountains of the Cascade Range in the Pacific Northwest were formed in this way.

Some mountains at the boundary between oceanic crust and continental crust might have formed by a different process. As the oceanic crust was subducted, pieces of crust called *terranes* were scraped off. According to the suspect terrane theory, they became part of the continental crust. Some of these terranes formed mountains. To learn more about terranes, see Chapter 4.

INVESTIGATE!

To learn more about continental collisions, try the In-Depth Investigation on pages 96–97.

Collisions Between Oceanic Crust and Oceanic Crust

Volcanic mountains sometimes form where two plates with oceanic crust at their edges collide. The oceanic crust of one plate subducts beneath the oceanic crust of the other plate. As the oceanic crust plunges deeper into the mantle, the intense heat melts the crustal material, forming magma. The magma rises and breaks through the oceanic crust. These eruptions form an arc of volcanic mountains on the ocean floor. The Mariana Islands, in the North Pacific Ocean, are the peaks of volcanic mountains that rose above sea level.

Collisions Between Continents

Mountains can also form when two continents collide. The Himalaya Mountains were formed by just such a collision. According to the theory of plate tectonics, India was at one time a separate

Figure 5–6. The Himalayas, shown below, were formed when India collided with Eurasia.

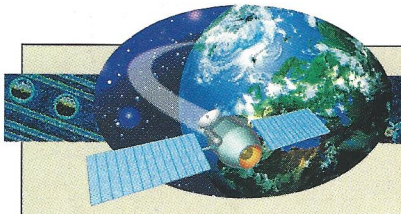
continent riding on the Indian plate, which was moving north toward Eurasia. The oceanic crust of the Indian plate was subducted beneath the Eurasian plate. It continued to move until the continental crust of India collided with the continental crust of Eurasia. This collision produced intense deformation of both continents. As a result, the Himalayas formed and India was connected to the Eurasian continent. Severe earthquakes still occur in the Himalayas. What can you infer about the movement of the Indian plate?

Types of Mountains

Mountains are more than just elevated parts of the earth's crust. They are complicated structures with rock formations that yield evidence of the forces that created them. Scientists classify mountains according to the way in which the crust was deformed and shaped by mountain-building forces.

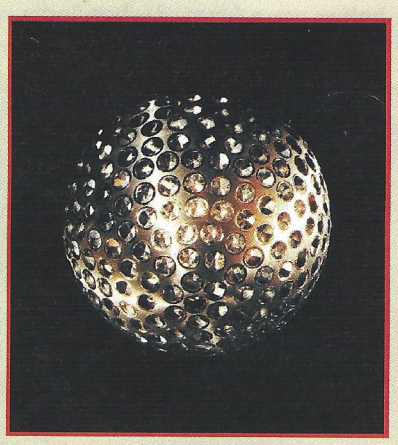
Folded Mountains and Plateaus

The highest mountain ranges in the world are made up of **folded mountains** and are commonly found where continents have collided.



SCIENCE & TECHNOLOGY

Tracking Plate Movements



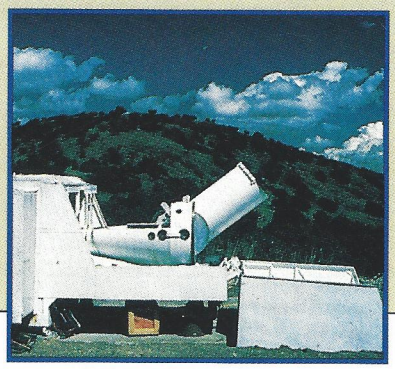
Each *Lageos* sphere has a diameter of 60 cm and a mass of 405 kg. The spheres' high density will allow them to maintain stable orbits for centuries.

In what appears to be a scene right out of a science fiction movie, scientists are firing laser beams at satellites orbiting 6,000 km above the earth. These scientists, however, do not intend to disable the satellites. Instead, they are gathering data on lithospheric plate motion. The scientists will use this information to understand better how plate tectonics shapes the earth's surface.

The target satellites, called *Lageos* (*La*ser *Geo*dynamic *Sat*ellites), resemble huge golf balls. Each *Lageos* sphere is made of aluminum with a brass core and is covered with 426 light retroreflectors called *corner cubes*. A corner cube is a specially designed mirror that reflects light back along exactly the same path by which it came.

When scientists at a laser station, such as the one shown below, fire a pulse of light at a *Lageos* sphere, the corner cubes reflect the light directly back to the station. The scientists record the time it takes for the light to reach the satellite and return. Then they determine the exact

International cooperation has played a crucial role in maintaining more than 35 laser stations worldwide.



In folded mountains, tectonic movements have squeezed rock layers together like an accordion. Parts of the Alps, the Himalayas, the Appalachians, and Russia's Ural Mountains consist of very large and complex folds. These long mountain chains also show evidence of faulting.

The same forces that form folded mountains also uplift **plateaus.** Plateaus are large areas of flat-topped rocks high above sea level. Most plateaus are formed when thick, horizontal layers of rock are slowly uplifted. The area is pushed up gently enough so that the layers remain flat rather than faulting and folding as do mountains. Most plateaus are found next to mountain ranges. For example, the Tibetan Plateau is next to the Himalayan Mountains, and the Colorado Plateau is next to the Rockies. A number of plateaus also were formed when layers of molten rock hardened and piled up on the earth's surface.

Figure 5–7. The Canadian Rockies are a dramatic example of folded mountains.

Fault-Block Mountains and Grabens

Some mountains have been formed by faults where parts of the earth's crust have been broken into large blocks. These blocks were then lifted above the surrounding crust. Faulting tilted the blocks,

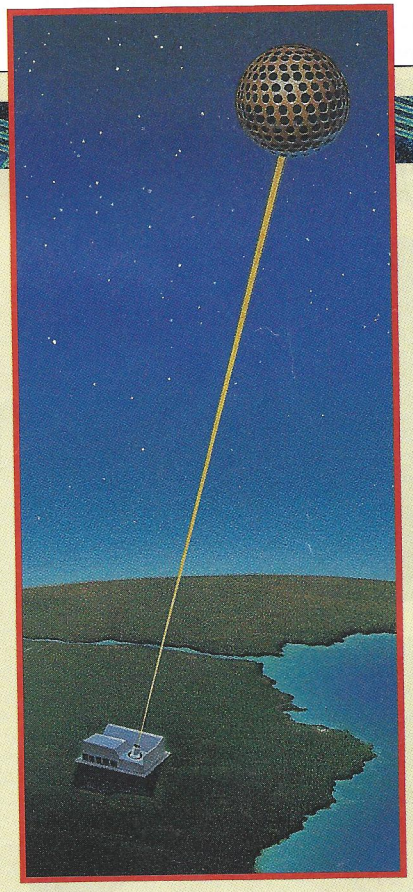
location of the sphere at the time they fired their laser. The scientists use this information to calculate the speed at which the laser station is drifting, as well as its direction. Because the station rests on a lithospheric plate, the scientists are essentially calculating the speed and direction of movement of the plate.

Scientists are interested in the *Lageos* data for several reasons. Knowing which way the earth's plates are moving enables scientists to model the future geography of the earth. The data could also help scientists predict geological activity caused by plate interactions. Scientists may find ways of using the *Lageos* data to study minute changes in the earth's gravity field, in the rotation of the earth, and in isostatic adjustments.

Message in a Bottle

In 1992, astronauts aboard the space shuttle *Columbia* deployed a *Lageos* sphere that contains a message intended for explorers from other planets. Inside *Lageos II* are two stainless steel plates etched with identical messages. Each plate contains a picture of the *Lageos* sphere, a binary code representing the numbers one through ten, and sketches of the earth. The sketches depict the earth's continents as they might have looked 268 million years ago, as they look now, and as they might look 8.5 million years in the future.

What are some specific predictions scientists might make when they know the direction and speed of plate movements?



▲ Each laser station is equipped with a receiving telescope capable of detecting individual photons

creating **fault-block mountains,** as shown in Figure 5–8. The Sierra Nevada range of California is an example of fault-block mountains. The desert regions of Nevada, Arizona, western Utah, southern Oregon, northern New Mexico, and southeastern California are broken up by fault-block mountains. These mountains form nearly parallel ranges that average 80 km in length.

The same type of faulting that forms fault-block mountains also forms long, narrow valleys called **grabens.** Grabens develop when steep faults break the crust into blocks and a block slips downward relative to the surrounding blocks. Death Valley in California is a graben.

Volcanic Mountains

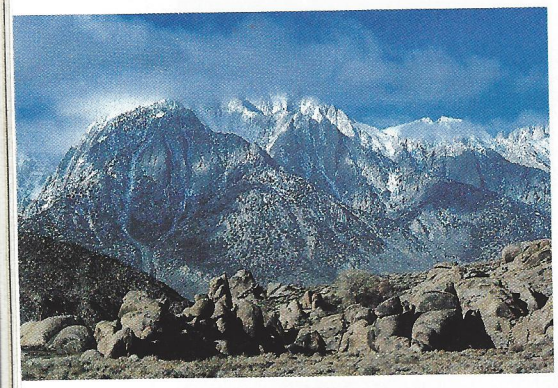
Mountains that form when molten rock erupts onto the earth's surface are called **volcanic mountains.** They may develop on land or on the ocean floor. The Cascade Range of Washington, Oregon, and northern California is composed of volcanic mountains. Some of the largest volcanic mountains are found along divergent plate boundaries, which form the mid-ocean ridges. These mid-ocean ridges are actually huge volcanic mountain chains that run through the centers of the Atlantic, eastern Pacific, and Indian oceans. The peaks of the highest mountains sometimes rise above sea level to form volcanic islands, such as Iceland and the Azores.

Other large volcanic mountains are formed on the ocean floor over *hot spots*. Hot spots are pockets of magma beneath the earth's crust that erupt onto the surface. The Hawaiian Islands are the tips of high volcanic mountains that were formed over a hot spot on the seafloor. The main island of Hawaii is actually a mountain that reaches almost 9 km above the ocean floor, with a base that is more than 160 km wide. Almost 4 km of this mountain is above sea level.

Dome Mountains

An unusual type of mountain is formed when molten rock rises through the crust and pushes up the rock layers above it. The result is a circular dome on the earth's surface. The molten rock that

Figure 5–8. In addition to folded mountains, there are fault-block mountains such as the Sierra Nevadas (top), volcanic mountains such as Mount Hood and Mount Adams (below, left), and dome mountains such as the Solitario Uplift in southwest Texas (below, right).

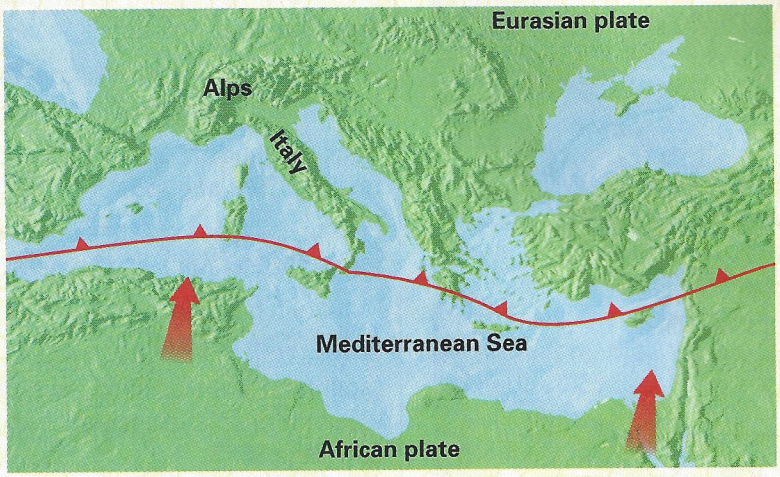


EARTHBEAT

The Disappearing Mediterranean

Two interesting regions in the world are the Alps and the Mediterranean Sea. The Alps, considered to be among the earth's most beautiful mountains, have become a vast natural playground for skiers, hikers, and climbers. The Mediterranean plays host to travelers from around the world who wish to sample its diverse cultures, balmy climate, and famous beach resorts. More important, the people who live nearby depend on the sea for their economic well-being.

The same natural forces that produced the Alps are slowly swallowing up the Mediterranean. The Alps were formed, and are still being shaped, by the collision of two lithospheric plates. Italy, part of which rides on the African plate, collided sometime in the past with Eurasia. The collision formed the Alps, but it did not stop the movement of the African plate. The northern oceanic crust of the African plate, which is actually the sea floor of the Mediterranean, is still subducting beneath the continental crust of Eurasia. As more oceanic crust subducts, the Mediterranean Sea will become smaller. Italy, which continues to be pushed into Eurasia, will eventually cease to exist as we know it. When the northern coast of the African continent finally collides with Eurasia, the Mediterranean Sea will become just a memory, a photograph, perhaps, in some history book.



What do you think will happen to the Alps as the African plate continues to push northward?

pushed up the rock layers eventually cools and forms hardened rock. When the pushed-up rock layers are worn away over time, the hardened rock is exposed. This rock wears away in places, leaving separate high peaks, or **dome mountains.** The Black Hills of South Dakota, and the Adirondack Mountains of New York State are dome mountains.

Section 5.3 Review

1. Describe the types of lithospheric plate collisions that build mountains.
2. Name the four types of mountains and explain how each is formed.
3. Explain how plateaus are formed.
4. How do volcanic mountains grow?