

## 10.6 What Happens at Divergent Boundaries?

AT MID-OCEAN RIDGES, Earth's tectonic plates diverge (move apart). Ridges are the sites of many small to moderate-sized earthquakes and much submarine volcanism. On the continents, divergent motion can split a continent into two pieces, forming a new ocean basin as the pieces move apart.

### A What Happens at Mid-Ocean Ridges?

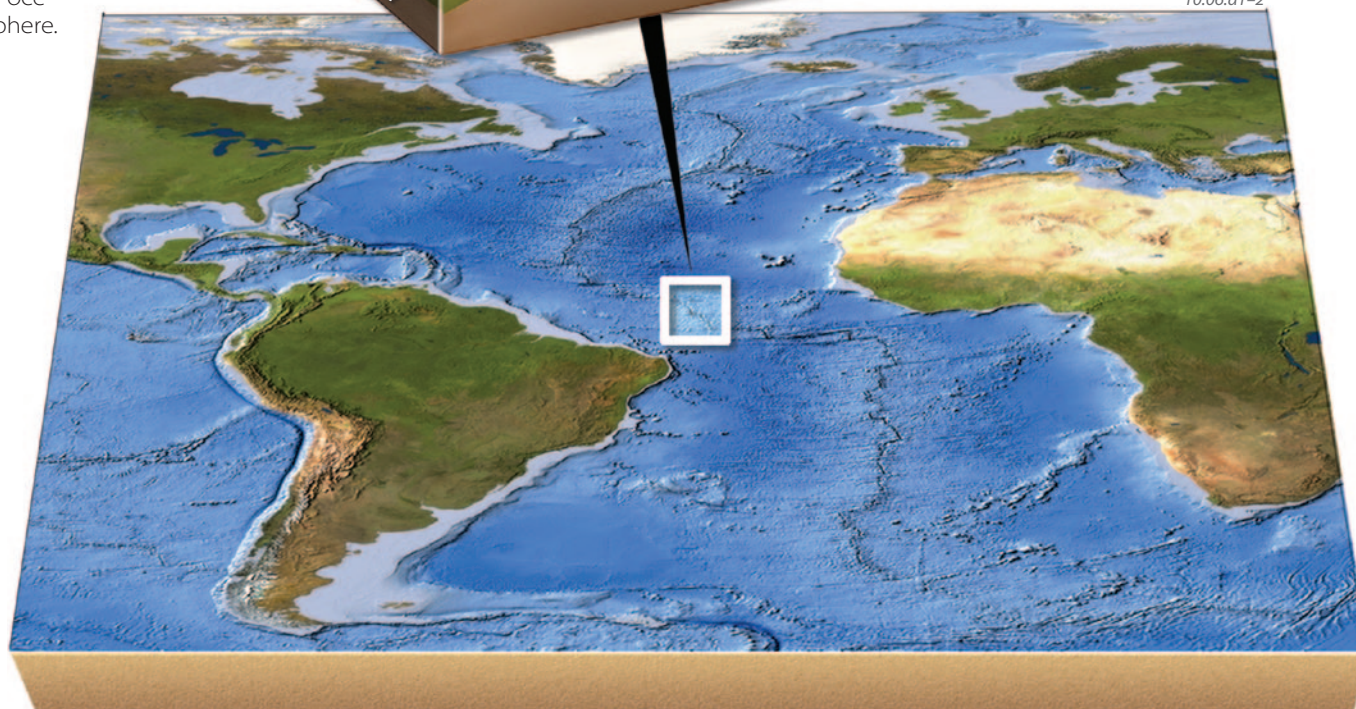
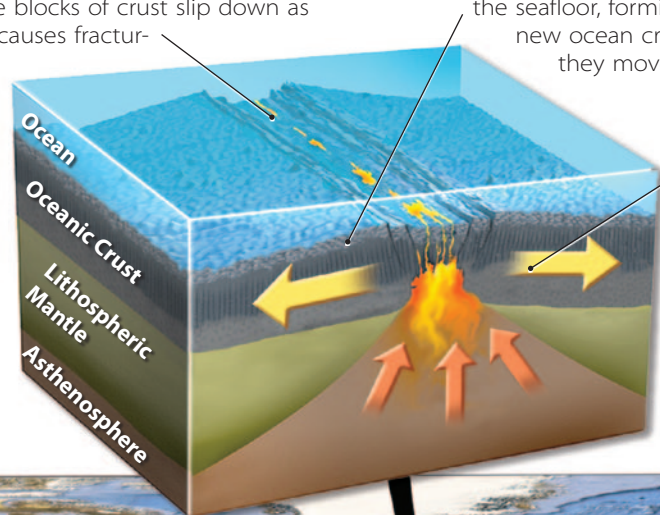
*Mid-ocean ridges* are divergent plate boundaries where new oceanic lithosphere forms as two oceanic plates move apart. These boundaries are also called *spreading centers* because of the way the plates spread apart.

1. A narrow trough, or *rift*, runs along the axis of most mid-ocean ridges. The rift forms because large blocks of crust slip down as spreading occurs. The movement causes fracturing, resulting in frequent small to moderate-sized earthquakes.

2. As the plates move apart, solid mantle in the asthenosphere rises toward the surface. It partially melts as it rises, because decreasing pressures can no longer confine the rock as a solid. The molten rock (magma) rises along narrow conduits, accumulates in magma chambers beneath the rift, and eventually becomes part of the oceanic lithosphere.

3. Much of the magma solidifies at depth, but some erupts onto the seafloor, forming submarine lava flows. These eruptions create new ocean crust that is incorporated into the oceanic plates as they move apart.

4. Mid-ocean ridges are elevated above the surrounding seafloor because they consist of hotter, less dense materials, including magma. Lower density materials and thin lithosphere means that the plate "floats" higher above the underlying asthenosphere. The elevation of the seafloor decreases away from the ridge because the rock cools and contracts, and because the less dense asthenosphere cools enough to become part of the more dense lithosphere.



10.06.a1-2

### Before You Leave These Pages Be Able To

- ✓ Sketch, label, and explain the features and processes of an oceanic divergent boundary.
- ✓ Sketch and label the characteristics of a continental rift (i.e., a divergent boundary within a continent).
- ✓ Sketch, label, and explain the stages of continental rifting, using East Africa and the Red Sea as examples of stages.

## B What Happens When Divergence Splits a Continent Apart?

Most divergent plate boundaries are beneath oceans, but a divergent boundary may also form within a continent. This process creates a *continental rift*, such as the Great Rift Valley in East Africa. Rifting can lead to seafloor spreading and formation of a new ocean basin, following the progression shown here.

1. The initial stage of continental rifting commonly includes broad uplift of the land surface as mantle-derived magma ascends into and pushes up the crust. The magma heats and can melt parts of the continental crust, producing additional magma. Heating of the crust causes it to expand, which results in further uplift.

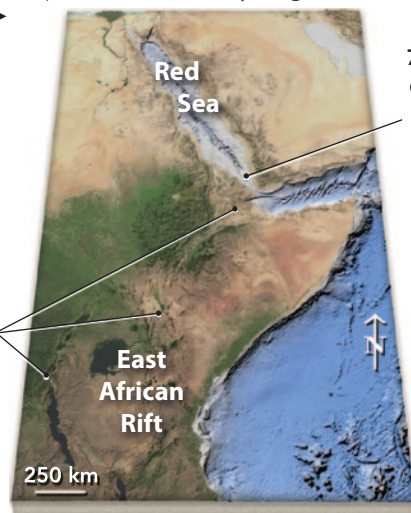
2. Stretching of the crust causes large crustal blocks to drop down along faults, forming a *continental rift*, like in the Great Rift Valley. The down-dropped blocks may form *basins* that can trap sediment and water, resulting in lakes. Deep rifting causes solid mantle material in the asthenosphere to flow upward and partially melt. The resulting magma may solidify beneath the surface or may erupt from volcanoes and long fissures on the surface. The entire crust thins as it is pulled apart, so the central rift becomes lower in elevation over time. The *Rio Grande Rift*, which runs north-south through New Mexico, is another example of a continental rift in its early stages.

3. If rifting continues, the continent splits into two pieces, and a narrow ocean basin forms as seafloor spreading takes place. A modern example of this is the narrow Red Sea, which runs between Africa and the Arabian Peninsula. As the edges of the continents move away from the heat associated with active spreading, the thinned crust cools and drops in elevation, eventually dropping below sea level. The continental margin ceases to be a plate boundary. A continental edge that lacks tectonic activity is called a *passive margin*.

4. With continuing seafloor spreading, the ocean basin becomes progressively wider, eventually becoming a broad ocean like the modern-day Atlantic Ocean. The Atlantic Ocean basin formed when North and South America rifted away from Europe and Africa, following the sequence shown here. Continental edges on both sides of the Atlantic are currently passive margins. Seafloor spreading continues today along the ridge in the middle of the Atlantic Ocean, so the Americas continue to move away from Europe and Africa.

5. East Africa and adjacent seas illustrate the different stages of continental rifting. Here, a piece of continent has been rifted away from Africa, and another piece is in the early stages of possibly doing the same. ►

6. Early stages of rifting occur along the East African Rift, a long continental rift that begins near the Red Sea and extends into central Africa. The rift is within an elevated (uplifted) region and has several different segments, each featuring a down-dropped rift. Some parts of the rift contain large lakes.

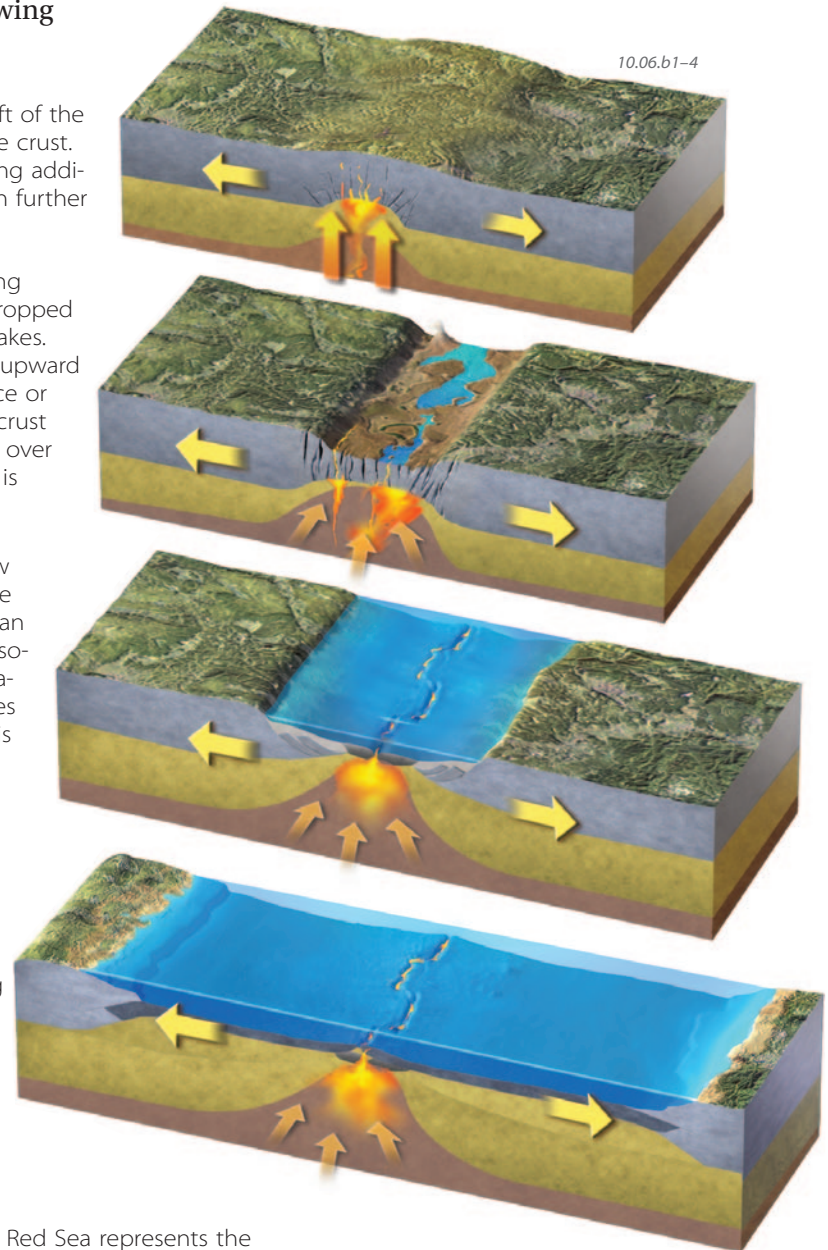


10.06.b5

7. The Red Sea represents the early stages of seafloor spreading. It began forming about 50 million years ago when the Arabian Peninsula rifted away from Africa. The Red Sea continues to spread and slowly grow wider.

8. The East African Rift is topographically lower than its flanks, but contains numerous active volcanoes (►). Volcanoes are especially common in the *Afar region* of Ethiopia, located where the rift joins the Red Sea. The Afar region is one of the most volcanically active regions on the planet.

10.06.b6 East African Rift, Ethiopia



10.06.b1-4

## 10.7 What Happens at Convergent Boundaries?

**CONVERGENT BOUNDARIES FORM** when two plates move toward each other. Convergence can involve two oceanic plates, an oceanic plate and a continental plate, or two continental plates. Oceanic trenches, island arcs, and Earth's highest mountain belts form at convergent boundaries. Many of Earth's most dangerous volcanoes and largest earthquakes also occur along these boundaries.

### A What Happens When Two Oceanic Plates Converge?

1. Convergence of two oceanic plates forms an *ocean-ocean convergent boundary*. One plate bends and slides beneath the other plate along an inclined zone. The process of one plate sliding beneath another plate is *subduction*, and the zone around the downward-moving plate is a *subduction zone*. Many large earthquakes occur in subduction zones.

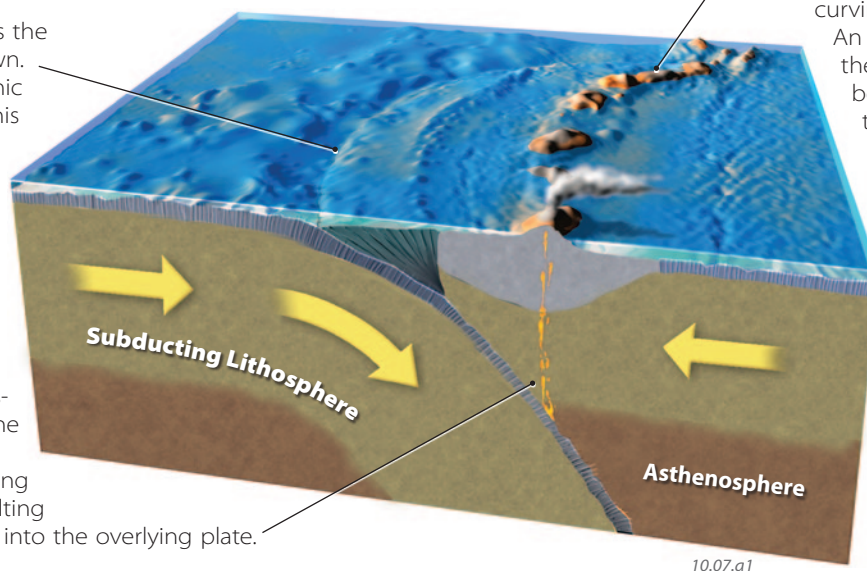
2. An *oceanic trench* forms as the subducting plate moves down. Sediment and slices of oceanic crust collect in the trench. This sheared, scraped-off material generally remains completely submerged, but is exposed in a few islands, like Barbados.

3. As the plate subducts, its temperature increases, releasing water from minerals in the downgoing plate. This water causes melting in the overlying asthenosphere, and the resulting magma is buoyant and rises into the overlying plate.

4. Some magma erupts, initially under the ocean and later as dangerous, explosive volcanoes that rise above the sea. With continued activity, the erupted lava and exploded volcanic fragments construct a curving belt of islands in an *island arc*.

An example is the arc-shaped belt of the Aleutian Islands of Alaska. The area between the island arc and the ocean trench accumulates sediment, most of which comes from volcanic eruptions and from the erosion of volcanic materials in the arc.

5. Magma that solidifies at depth adds to the volume of the crust. Over time, the crust gets thicker and becomes transitional in character between oceanic and continental crust. Volcanic islands join to form more continuous strips of land, as occurred to form the island of Java in Indonesia.



10.07.a1

### B What Happens When an Oceanic Plate and a Continental Plate Converge?

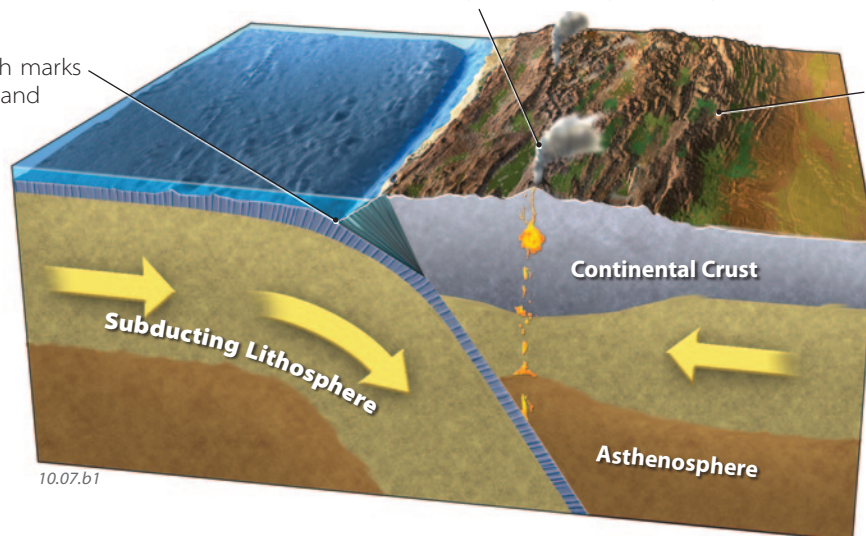
1. The convergence of an oceanic and a continental plate forms an *ocean-continent convergent boundary*. Along this boundary, the denser oceanic plate subducts beneath the more buoyant continental plate.

2. An oceanic trench marks the plate boundary and receives sediment from the adjacent continent. Again, sediment and other material are scraped off the oceanic plate, forming a wedge of highly sheared material near the trench.

3. Volcanoes form on the surface of the overriding continental plate in the same way the volcanoes form in an ocean-ocean convergent boundary. These volcanoes erupt, often violently, producing large amounts of volcanic ash, lava, and mudflows, which pose a hazard for people who live nearby. Examples include large volcanoes of the Andes of South America and the Cascade Range of Washington, Oregon, northern California, and southern British Columbia.

4. Compression associated with the convergent boundary squeezes the crust for hundreds of kilometers into the continent. The crust deforms and thickens, resulting in uplift of the region. Uplift and volcanism may produce a high mountain range, such as the Andes.

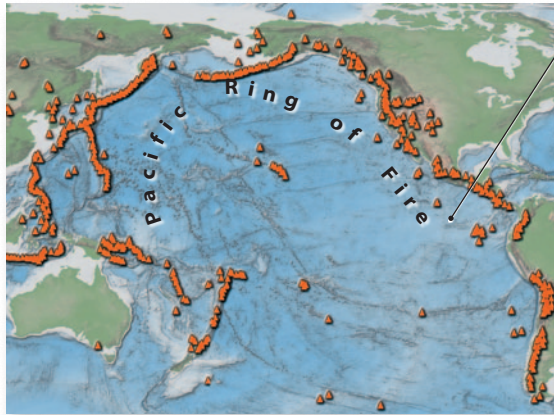
5. Magma forms by melting of the asthenosphere above the subduction zone. It can solidify at depth, rise into the overlying continental crust before solidifying, or reach the surface and cause a volcanic eruption.



10.07.b1

## C What Causes the Pacific Ring of Fire?

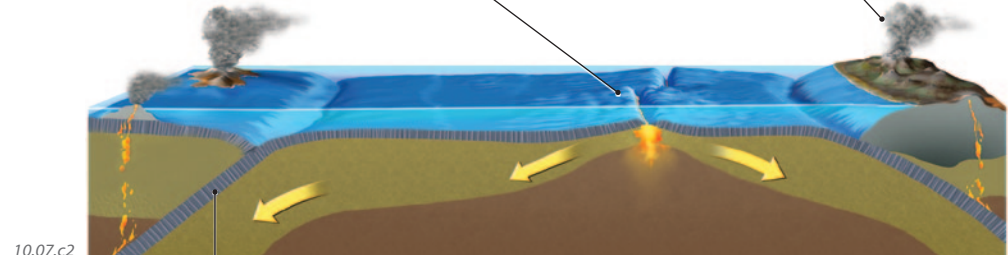
Volcanoes surround the Pacific Ocean, forming the *Pacific Ring of Fire*, as shown in the map below. The volcanoes extend from the southwestern Pacific, through the Philippine Islands, Japan, and Alaska, and then down the western coasts of North and South America. The Ring of Fire results from subduction on both sides of the Pacific Ocean.



10.07.c1

1. In the Pacific, new oceanic lithosphere forms along a mid-ocean ridge, the *East Pacific Rise*. The Pacific plate is west (left) of this boundary and several smaller plates are to the east (right). Once formed, new lithosphere moves away from the ridge as seafloor spreading continues.

2. Oceanic lithosphere of the Pacific plate and smaller plates subducts beneath the Americas, forming oceanic trenches on the seafloor and volcanoes on the overriding, mostly continental, plates.



10.07.c2

3. Subduction of oceanic lithosphere also occurs to the west, beneath Japan and island arcs of the western Pacific.

4. More oceanic plate is subducted than is produced along the East Pacific Rise, so the width of the Pacific Ocean is shrinking with time.

## D What Happens When Two Continents Collide?

Two continental masses may converge along a *continent-continent convergent boundary*. This type of boundary is commonly called a *continental collision*, and it produces huge mountain ranges, like the Himalaya and Mount Everest in the photograph below.

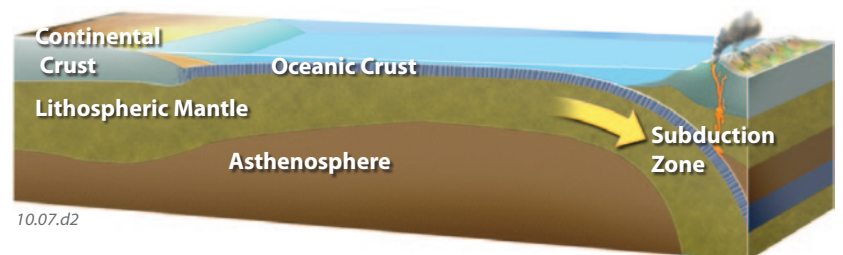


10.07.d1 Mount Everest

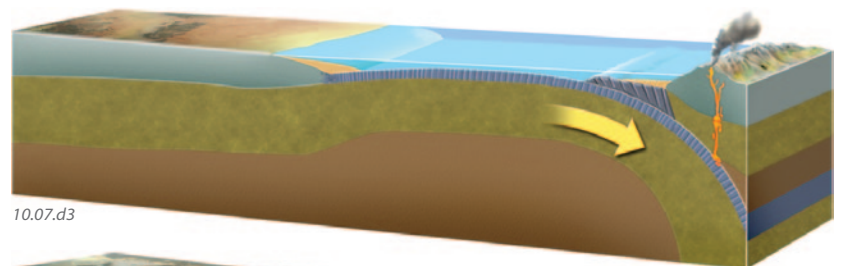
The large plate in the figure to the right is partly oceanic and partly continental. The oceanic part is being subducted to the right, under another continent at a convergent boundary.

As the oceanic part of the plate continues to subduct, the two continents approach each other. Magmatic activity occurs in the overriding plate above the subduction zone. The edge of the approaching continent has no such activity because it is not at a plate boundary, yet.

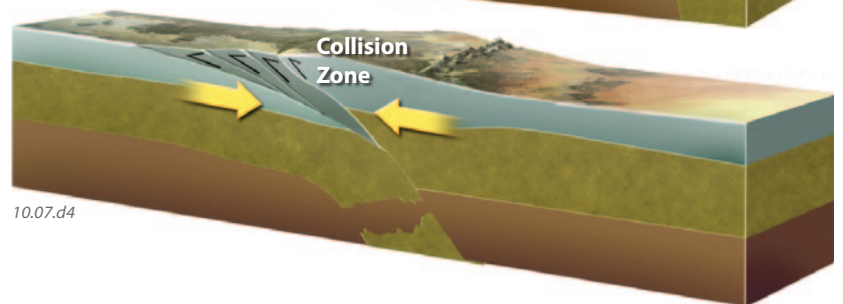
When the converging continent arrives at the subduction zone, it may partially slide under the other continent or simply clog the subduction zone as the two continents collide. Because the two continents are thick and have the same density, neither can be easily subducted beneath the other and into the asthenosphere. Along the boundary, faults slice up the continental crust, stacking one slice on top of another. Continental collisions form enormous mountain belts and high plateaus, such as the Himalaya and Tibetan Plateau of southern Asia. The Himalaya and Tibetan Plateau are still forming today, rising at a rate of about 5 mm/year, as the continental crust of India collides with the southern edge of the Eurasian plate.



10.07.d2



10.07.d3



10.07.d4

### Before You Leave This Page Be Able To

- ✓ Sketch, label, and explain the features and processes associated with ocean-ocean and ocean-continent convergent boundaries.
- ✓ Sketch, label, and explain the steps leading to a continental collision (continent-continent convergent boundary).