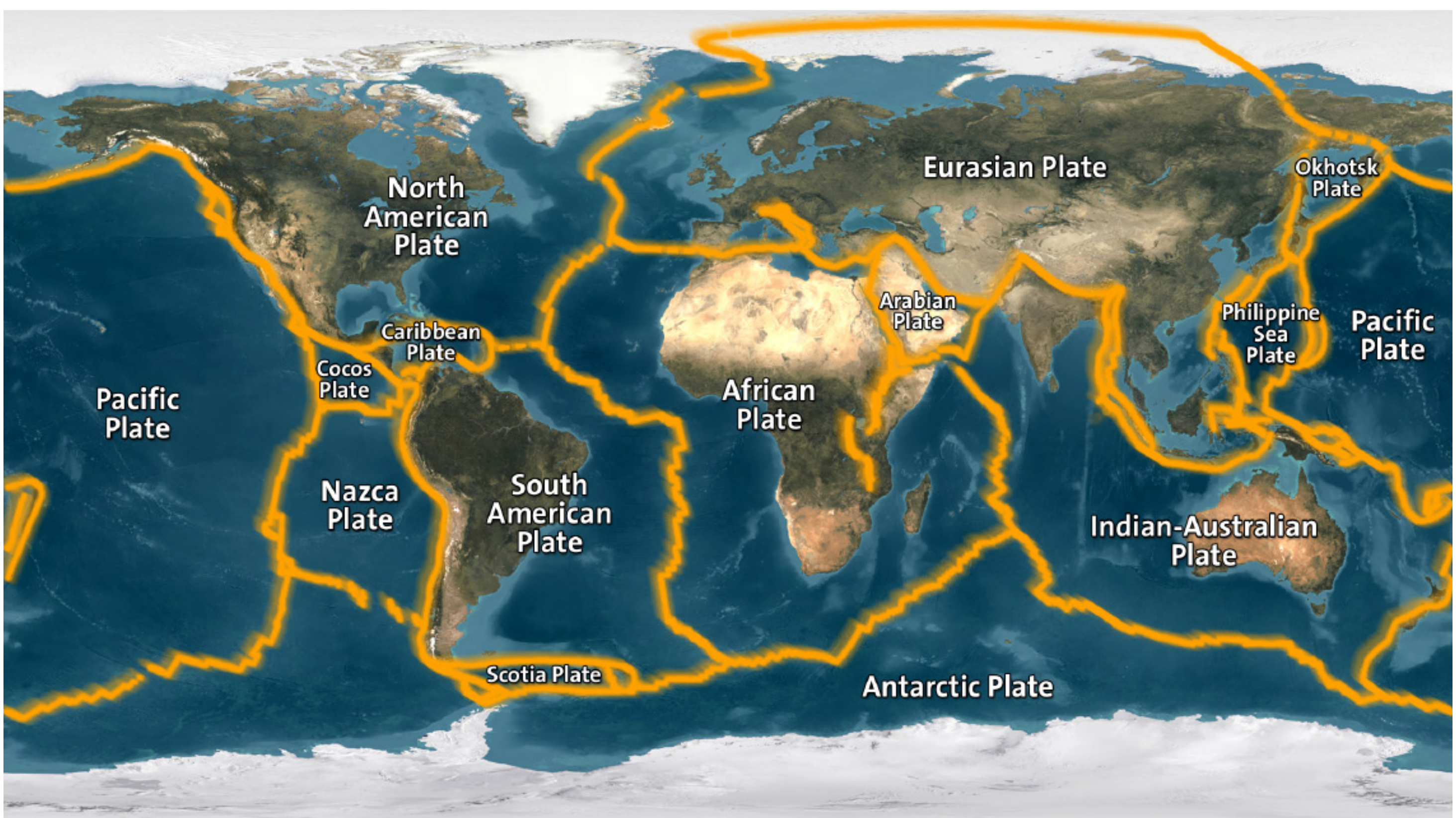
Student Reading

Earth's Dynamic Machine: Basics of Plate Tectonics

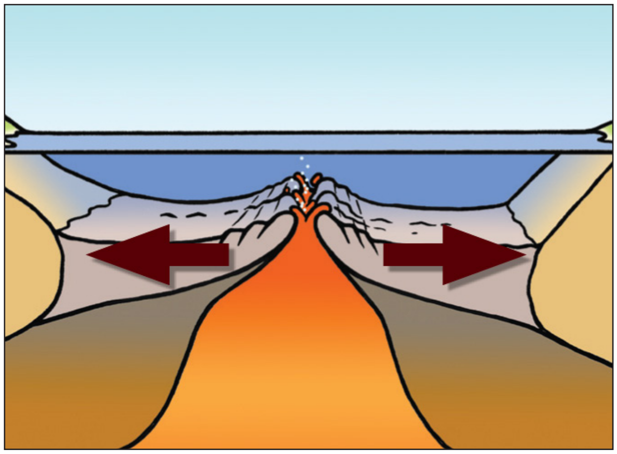
Text adapted from *The Earth Machine: The Science of a Dynamic Planet* by Edmond A. Mathez. Columbia University Press, 2007.

The lithosphere, the rigid, strong outermost shell of Earth, is broken into ten large plates. The mantle below those plates is solid rock. However, over time — and at high temperatures and pressures — the solid rock of the mantle very slowly flows in enormous circular motions called convective currents. These currents cause the plates to move, a process geologists describe with the theory of plate tectonics.

Because of plate tectonics, Earth's surface is in constant motion. Plates separate. They slip past one another. They even collide with each other. Arabia, for instance, pulls away from Africa, opening up the Red Sea. North America creeps away from Europe at about one inch per year — roughly the rate at which a fingernail grows! Large regions of the Pacific seafloor dive beneath the surrounding continents. And as India pushes north into Asia, it creates the world-famous mountain range called the Himalayas.



Plates Moving Apart



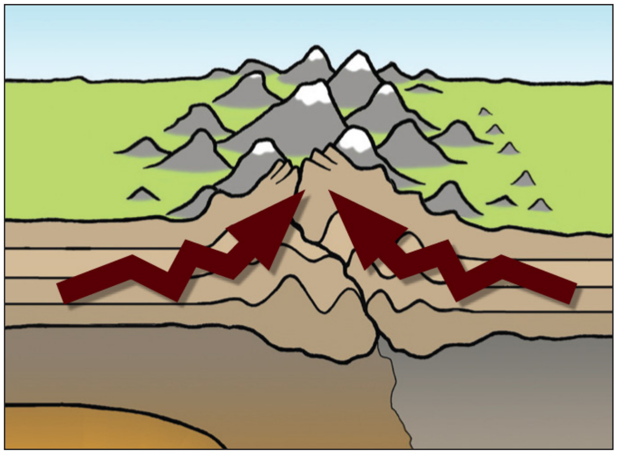
Where plates separate, or diverge, ocean basins are created. 85% of Earth's volcanic eruptions occur along *divergent boundaries*. Many small earthquakes happen along these boundaries at shallow depths (less than 6 miles). As the plates move apart, magma rises from the mantle to fill the empty space. In this way, the plates grow as they separate. By this process, entire ocean basins re-form about every 200 million years.

Most divergent plate boundaries run through the world's oceans. In the Atlantic, the boundary divides the ocean basin almost exactly in half. This boundary is called a *mid-ocean ridge*. This term means that there is a range of volcanic mountains running through the bottom of the Atlantic Ocean. This range is part of a worldwide system of such ranges. Together, they form a system of mountain ranges 50,000 miles long.

The lithosphere near the mid-ocean ridges is thin and warm. As the lithosphere moves away from the mid-ocean ridge, it cools and becomes denser. Then it sinks. That means the depth of the ocean is greater farther from a mid-ocean ridge. Mid-ocean ridges are chains of volcanoes sitting on broad rises with vast and deep oceanic plains on both sides.

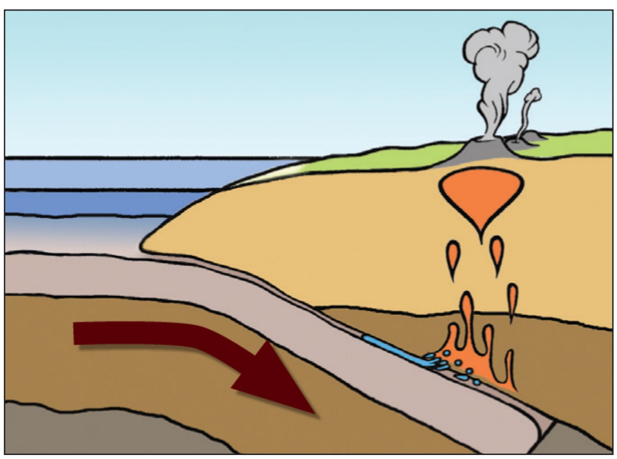
Divergent boundaries are not always in the middle of ocean basins, however. In a few places, divergent boundaries run right through continents. In those places, the lithosphere stretches and thins. This causes rifts to form in the overlying continental crust. Basaltic magma intrudes into the thinned lithosphere. It then erupts onto the continent, and may melt portions of the continental crust to form other lava types. When such rifts develop long enough, an ocean begins to form. The Red Sea is one such rift. It may eventually grow as large as the Atlantic Ocean!

Plates Coming Together



Where plates collide, or converge, a variety of landforms are created. Such structures include mountains, volcanic island arcs and deep-sea trenches. Convergent plate boundaries produce large and small earthquakes. They build great, explosive volcanoes as well. Exactly what happens at a convergent plate boundary depends on what collides with what.

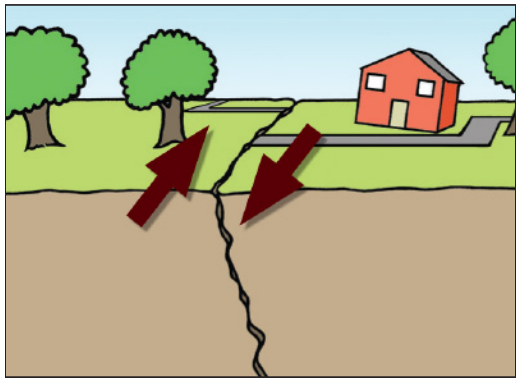
Most plate convergence occurs between oceanic and continental plates. When this happens, the colder and denser oceanic plate sinks below the continental plate into the mantle. That process is known as *subduction*. The boundary where it occurs is called a subduction zone.



The subducted plate becomes heated by the mantle, and it loses water, producing an aqueous rich fluid. The fluid moves upward and infiltrates the overlying mantle. This causes the mantle to partially melt, producing a magma that rises up through the mantle and crust to feed volcanoes on the surface. This process usually produces volcanic mountain chains on the overlying continental plate, such as the Andes. If two oceanic plates converge then the older, colder plate sinks beneath the younger, warmer plate and an arc of islands, like the Aleutians off the coast of Alaska forms on the overlying oceanic plate. Deep-sea trenches are created along convergent margins. That is where the oceanic lithosphere bends into the subduction zone. Trenches are the deepest parts of the ocean. Some have depths in excess of 36,000 feet.

A different type of convergent boundary occurs where two continents collide. In this case subduction does not occur, because both continents have crust with a similar density. Neither is forced down into the mantle. Instead, a mountain range forms as one continent overrides the other. This forms an unusually high and thick crust. The Himalayas are the best example of this type of convergent plate boundary. Behind these mountains, the crust of the Tibetan Plateau can be nearly 50 miles thick.

Plates Sliding By



Where plates slip past each other, they form long furrows in the lithosphere called transform boundaries. These boundaries are typically hundreds to thousands of miles long. At transform boundaries, crust is not created, nor does it disappear. The plates on either side of the fault may be moving in opposite directions. Or they could be moving in the same direction, but at different speeds.

Many people have heard of the San Andreas Fault in California. Or perhaps they know about the Anatolian Fault that runs through northern Turkey. Both of these transform faults are among the most active earthquake zones on Earth, and both have been struck by devastating earthquakes.

Where transform faults bend, one of two different structures will form. A pull-apart basin may grow. This type of long, narrow depression collects sediment or fills with water. The Dead Sea between Jordan and Israel is one such basin. On the other hand, plate motion may cause blocks of crust to jam together, creating ridges and folds called transverse ridges. A good example of this is the Transverse Ranges in California, to the north of Los Angeles. There, a bend in the San Andreas Fault causes the crust to wrinkle.

What Plate Tectonics Tells Us

The theory of plate tectonics teaches us a lot about Earth. It describes how the mantle and crust of Earth interact with each other. It makes clear why mountains, ocean basins or continents form where they do. It also explains why volcanoes and earthquakes so often appear on plate boundaries.