

## Plate Tectonics

Earth's outer shell, the **lithosphere**, long thought to be a continuous, unbroken, crust is actually a fluid mosaic of many irregular rigid segments, or plates. Comprised primarily of cool, solid rock 20 to 60 km thick, these enormous blocks of Earth's crust vary in size and shape, and have definite borders that cut through continents and oceans alike. **Oceanic crust** is much thinner (about 5 km) and denser than **continental** or terrestrial crust.

There are nine large plates and a number of smaller plates. While most plates are comprised of both continental and oceanic crust, the giant Pacific Plate is almost entirely oceanic, and the tiny Turkish-Aegean Plate is entirely land. Of the nine major plates, six are named for the continents embedded in them: **the North American, South American, Eurasian, African, Indo-Australian, and Antarctic**. The other three are oceanic plates: **the Pacific, Nazca, and Cocos**. The relative small size of the numerous other plates neither diminishes their significance, nor their impact on the surface activity of the planet. The tiny **Juan de Fuca Plate**, for example, sandwiched between the Pacific and North American Plate near the state of Washington, and is largely responsible for the frequent tremors and periodic volcanic eruptions in that region of the country.

### How Plates Move

Powered by forces originating in Earth's radioactive, solid iron inner core, these tectonic plates move at varying speeds and in different directions atop a layer of much hotter, softer, more malleable rock called the **asthenosphere**. Because of the high temperatures and immense pressures found here, the uppermost part of the asthenosphere is deformed and flows almost plastically just beneath the Earth's surface. This characteristic of the asthenosphere to flow allows the plates to inch along on their endless journeys around the surface of the earth, moving no faster than human fingernails grow.

One idea that might explain the ability of the asthenosphere to flow is the idea of **convection currents**. When mantle rocks near the radioactive core are heated, they become less dense than the cooler, upper mantle rocks. These warmer rocks rise while the cooler rocks sink, creating slow, vertical currents within the mantle (these convection currents move mantle rocks only a few centimeters a year). This movement of warmer and cooler mantle rocks, in turn, creates pockets of circulation within the mantle called **convection cells**. The circulation of these convection cells could very well be the driving force behind the movement of tectonic plates over the asthenosphere.

### Plate Boundaries

There are 3 primary types of Tectonic Plate boundaries: Divergent boundaries; Convergent boundaries; and Transform boundaries. As the giant plates move, diverging [pulling apart] or converging [coming together] along their borders, tremendous energies are unleashed resulting in tremors that transform Earth's surface. While all the plates appear to be moving at different relative speeds and independently of each other, the whole jigsaw puzzle of plates is interconnected. No single plate can move without affecting others, and the activity of one can influence another thousands of miles away. For example, as the Atlantic Ocean grows wider with the spreading of the African Plate away from the South American Plate, the Pacific sea floor is being consumed in deep subduction trenches over ten thousand miles away.

**Iceland** offers scientists a natural laboratory for studying - on land - the processes that occur along submerged parts of a divergent boundary. Iceland is splitting along the **Mid-Atlantic Ridge** - a **divergent boundary** between the North American and Eurasian Plates. As North America moves westward and Eurasia eastward, new crust is created on both sides of the diverging boundary. While the creation of new crust adds mass to Iceland on both sides of the boundary forming new ocean floor crust in a process commonly known as sea-floor spreading, it also creates a rift along the boundary. Iceland will inevitably break apart into two separate land masses at some point in the future, as the Atlantic waters eventually rush in to fill the widening and deepening space between.

**Convergent Boundaries:** Here crust is destroyed and recycled back into the interior of the Earth as one plate dives under another. These are known as **Subduction Zones** - mountains and volcanoes are often found where plates converge. There are 3 types of convergent boundaries: Oceanic-Continental Convergence; Oceanic-Oceanic Convergence; and Continental-Continental Convergence.

### **Oceanic-Continental Convergence**

When an oceanic plate pushes into and subducts under a continental plate, the overriding continental plate is lifted up and a mountain range is created. Even though the oceanic plate as a whole sinks smoothly and continuously into the subduction trench, the deepest part of the subducting plate breaks into smaller pieces. These smaller pieces become locked in place for long periods of time before moving suddenly and generating large earthquakes. Such earthquakes are often accompanied by uplift of the land by as much as a few meters.

### **Oceanic-Oceanic Convergence**

When two oceanic plates converge one is usually subducted under the other and in the process a deep oceanic trench is formed. The Marianas Trench, for example, is a deep trench created as the result of the Philippine Plate subducting under the Pacific Plate. Oceanic-oceanic plate convergence also results in the formation of undersea volcanoes. Over millions of years, however, the erupted lava and volcanic debris pile up on the ocean floor until a submarine volcano rises above sea level to form an island volcano. Such volcanoes are typically strung out in chains called island arcs.

### **Continental-Continental Convergence**

When two continents meet head-on, neither is subducted because the continental rocks are relatively light and, like two colliding icebergs, resist downward motion. Instead, the crust tends to buckle and be pushed upward or sideways. The collision of India into Asia 50 million years ago caused the Eurasian Plate to crumple up and override the Indian Plate. After the collision, the slow continuous convergence of the two plates over millions of years pushed up the Himalayas and the Tibetan Plateau to their present heights. Most of this growth occurred during the past 10 million years.

**Transform-Fault Boundaries:** Transform-Fault Boundaries are where two plates are sliding horizontally past one another. These are also known as transform boundaries or more commonly as faults.

*Task: Describe the pictures in a separate file.*

## A Changing Earth

As eons pass, continents and other land masses collide, break apart, and drift across the planet on the fiery mantle beneath, opening and closing oceans along the way. Subsequently, their relative position to the equator, the poles, and each other changes over long periods of time. For instance, Africa's Sahara Desert once lay at the South Pole while the equator ran diagonally across North America.

Scientists hypothesize that North and South America must have been 6,000 miles apart 450 million years ago. Yet, 250 million years later, they lay locked together as part of Pangaea, the great supercontinent. Then a great rift developed between them and today's Atlantic Ocean began to open. The plates don't move very quickly. But consider this: Two inches per year - a typical speed - adds up to 30 miles in one million years. It took only 150 million years for a slight fracture in an ancient continent to turn into today's Atlantic Ocean.

While the Atlantic Ocean opened, the Pacific began to shrink. The Americas slid west while the huge Eurasian plate and Australia drifted east along with India, which broke away from southern Africa to begin its long journey north. Some 20 million years later India collided with southern Eurasia, thrusting up their crustal borders, marking the birth of the majestic Himalayan mountain range. And long ago Ireland and northern Scotland were part of North America, attached to Newfoundland, while part of Florida lay in Africa.

All of the evidence suggests that 225 million years ago all of the land masses of earth were locked together as a great supercontinent called **Pangaea**, a Greek word meaning 'all lands'. **Panthalassa**, Greek for 'all seas', was the name given to the resulting world ocean. Pangaea first broke into two large land masses called **Laurasia** and **Gondwana**. The equator serves as the dividing line between them.

The Himalayan Mountains were formed when India and Asia collided and part of India subducted under Asia in the Cenozoic Era about 65 million years ago.

Eventually, tectonic forces caused the break-up of Pangaea, leading to the current, albeit temporary, arrangement of oceans, continents, and other land masses.

Scientists believe that the Earth's crust has been undergoing these transformations for most of its 4.6 billion year history. Two hundred million years from now a new Pangaea will be formed when all lands again converge. Then, inevitably, another break-up will ensue as our restless planet continues to reform and reshape itself.

### Tasks

1. *Substitute the underlined word without changing the meaning of the sentence.*

Eventually, tectonic forces caused the break-up of Pangaea, leading to the current, albeit temporary, arrangement of oceans, continents, and other land masses.

2. *Describe the pictures in a separate file.*

Adapted from <http://www.platetectonics.com>, Věra Hranáčová

Graphics courtesy of USGS.org