

Understanding Plate Motions

Scientists now have a fairly good understanding of how the plates move and how such movements relate to earthquake activity. Most movement occurs along narrow zones between plates where the results of plate-tectonic forces are most evident.

There are four types of plate boundaries:

- Divergent boundaries -- where new crust is generated as the plates pull away from each other.
- Convergent boundaries -- where crust is destroyed as one plate dives under another.
- Transform boundaries -- where crust is neither produced nor destroyed as the plates slide horizontally past each other.
- Plate boundary zones -- broad belts in which boundaries are not well defined and the effects of plate interaction are unclear.

Divergent boundaries

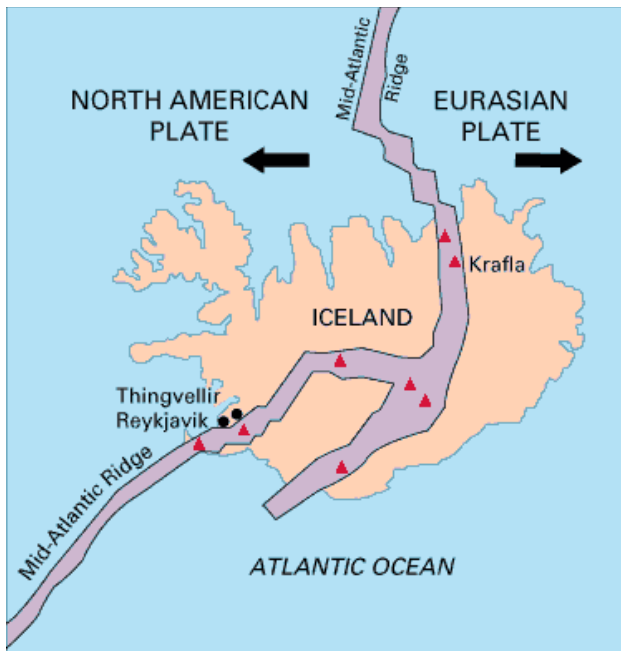
Divergent boundaries occur along spreading centers where plates are moving apart and new crust is created by magma pushing up from the mantle. Picture two giant conveyor belts, facing each other but slowly moving in opposite directions as they transport newly formed oceanic crust away from the ridge crest.

Perhaps the best known of the divergent boundaries is the Mid-Atlantic Ridge. This submerged mountain range, which extends from the Arctic Ocean to beyond the southern tip of Africa, is but one segment of the global mid-ocean ridge system that encircles the Earth. The rate of spreading along the Mid-Atlantic Ridge averages about 2.5 centimeters per year (cm/yr), or 25 km in a million years. This rate may seem slow by human standards, but because this process has been going on for millions of years, it has resulted in plate movement of thousands of kilometers. Seafloor spreading over the past 100 to 200 million years has caused the Atlantic Ocean to grow from a tiny inlet of water between the continents of Europe, Africa, and the Americas into the vast ocean that exists today.



Mid-Atlantic Ridge

The volcanic country of Iceland, which straddles the Mid-Atlantic Ridge, offers scientists a natural laboratory for studying on land the processes also occurring along the submerged parts of a spreading ridge. Iceland is splitting along the spreading center between the North American and Eurasian Plates, as North America moves westward relative to Eurasia.



Map showing the Mid-Atlantic Ridge splitting Iceland and separating the North American and Eurasian Plates. The map also shows Reykjavik, the capital of Iceland, the Thingvellir area, and the locations of some of Iceland's active volcanoes (red triangles), including Krafla.

In East Africa, spreading processes have already torn Saudi Arabia away from the rest of the African continent, forming the Red Sea. This is another example of a Divergent boundary. It is likely this region in East Africa will be the site of the Earth's next major ocean!



[Historically Active Volcanoes, East Africa](#)



[Oldoinyo Lengai, East African Rift Zone](#)

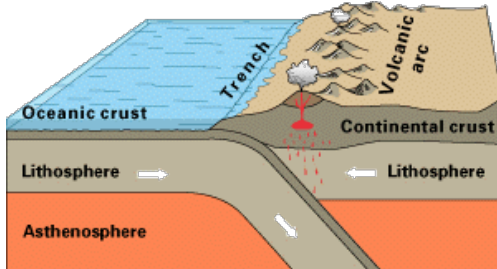
Convergent boundaries

The size of the Earth has not changed significantly during the past 600 million years, and very likely not since shortly after its formation 4.6 billion years ago. The Earth's unchanging size implies that the crust must be destroyed at about the same rate as it is being created. Such destruction (recycling) of crust takes place along convergent boundaries where plates are moving toward each other, and sometimes one plate sinks (is *subducted*) under another. The location where sinking of a plate occurs is called a *subduction zone*.

The type of convergence -- called by some a very slow "collision" -- that takes place between plates depends on the kind and density of lithosphere involved.

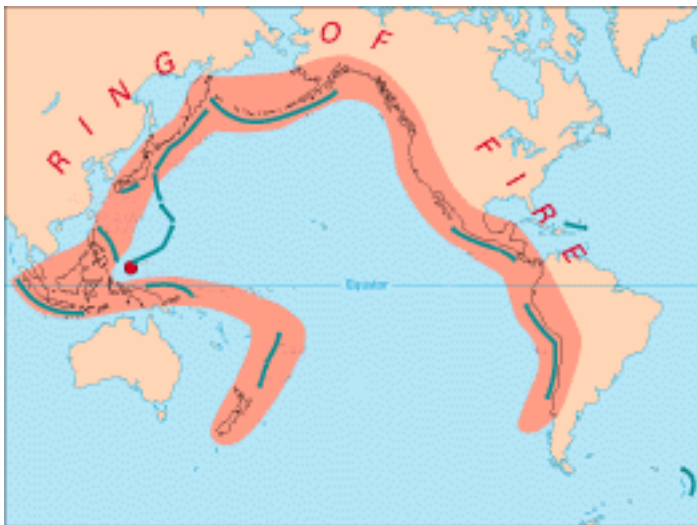
Oceanic-continental convergence

If by magic we could pull a plug and drain the Pacific Ocean, we would see a most amazing sight -- a number of long narrow, curving *trenches* thousands of kilometers long and 8 to 10 km deep cutting into the ocean floor. Trenches are the deepest parts of the ocean floor and are created by subduction.



Oceanic-continental convergence

Off the coast of South America along the Peru-Chile trench, the oceanic Nazca Plate is pushing into and being subducted under the continental part of the South American Plate. In turn, the overriding South American Plate is being lifted up, creating the towering Andes mountains, the backbone of the continent. Strong, destructive earthquakes and the rapid uplift of mountain ranges are common in this region. Even though the Nazca Plate as a whole is sinking smoothly and continuously into the trench, the deepest part of the subducting plate breaks into smaller pieces that become locked in place for long periods of time before suddenly moving to generate large earthquakes. Such earthquakes are often accompanied by uplift of the land by as much as a few meters.

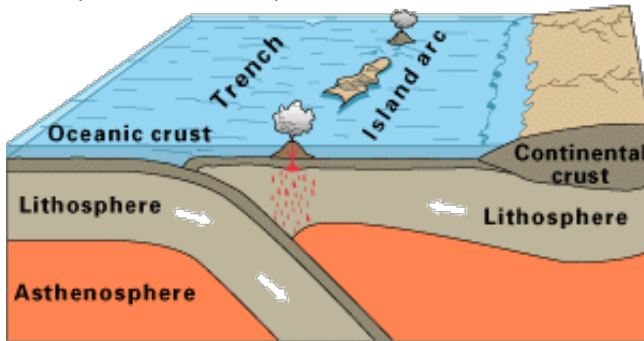


Ring of Fire

Oceanic-continental convergence also sustains many of the Earth's active volcanoes, such as those in the Andes and the Cascade Range in the Pacific Northwest. The eruptive activity is clearly associated with subduction, but scientists vigorously debate the possible sources of magma: Is magma generated by the partial melting of the subducted oceanic slab, or the overlying continental lithosphere, or both?

Oceanic-oceanic convergence

As with oceanic-continental convergence, when two oceanic plates converge, one is usually subducted under the other, and in the process a trench is formed. The Marianas Trench (paralleling the Mariana Islands), for example, marks where the fast-moving Pacific Plate converges against the slower moving Philippine Plate. The Challenger Deep, at the southern end of the Marianas Trench, plunges deeper into the Earth's interior (nearly 11,000 m) than Mount Everest, the world's tallest mountain, rises above sea level (about 8,854 m).

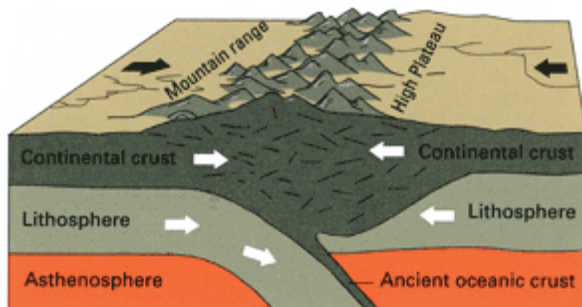


Oceanic-oceanic convergence

Subduction processes in oceanic-oceanic plate convergence also result in the formation of volcanoes. The descending plate also provides a source of stress as the two plates interact, leading to frequent moderate to strong earthquakes.

Continental-continental convergence

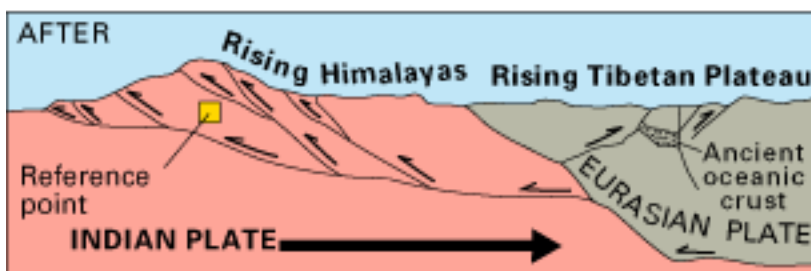
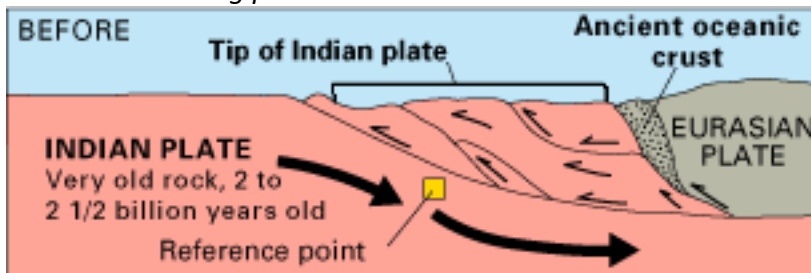
The Himalayan mountain range dramatically demonstrates one of the most visible and spectacular consequences of plate tectonics. When two continents meet head-on, neither is subducted because the continental rocks are relatively light and, like two colliding icebergs, resist downward motion. Instead, the crust tends to buckle and be pushed upward or sideways. The collision of India into Asia 50 million years ago caused the Indian and Eurasian Plates to crumple up along the collision zone.



Continental-continental convergence

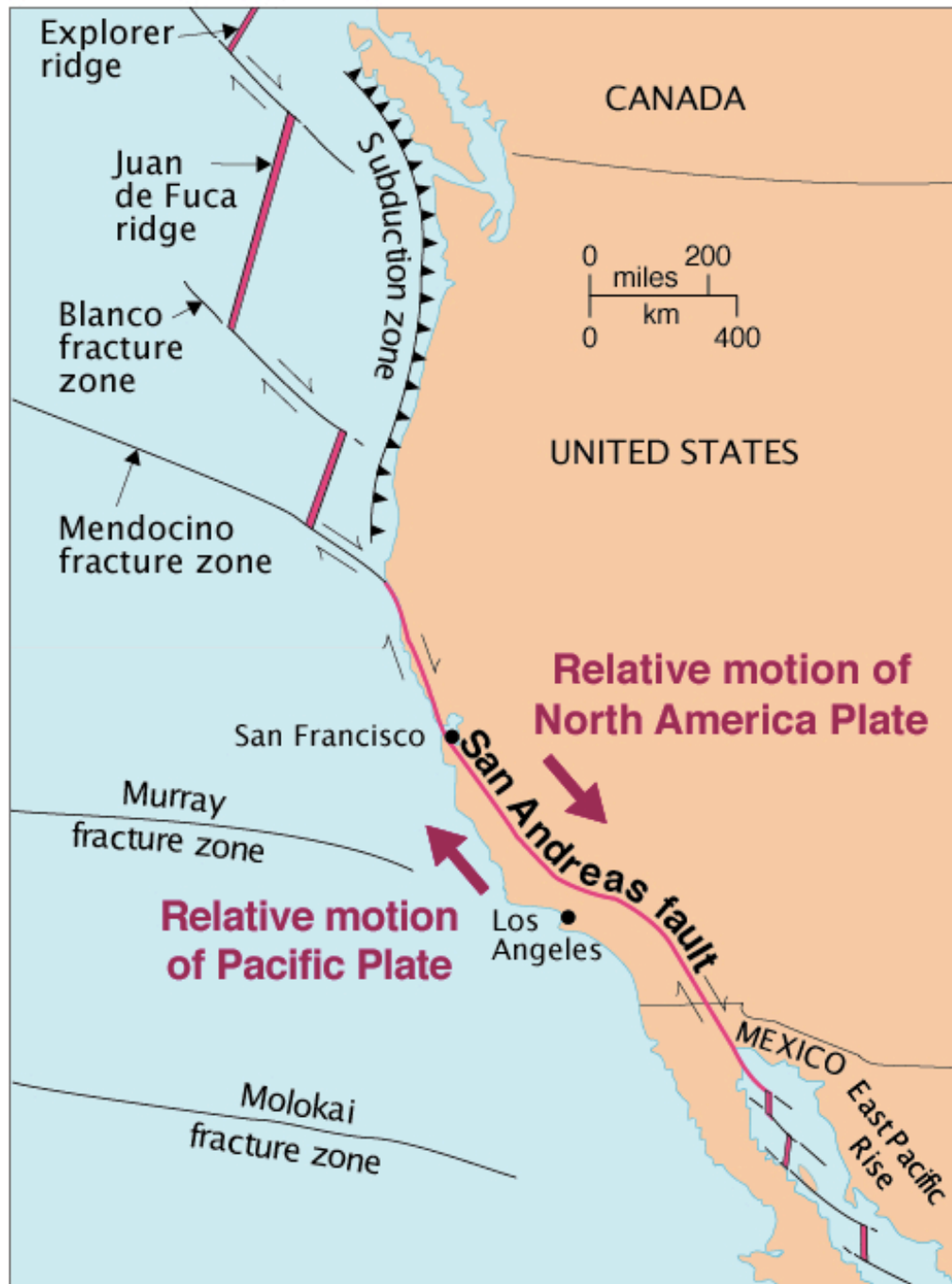


Above: The collision between the Indian and Eurasian plates has pushed up the Himalayas and the Tibetan Plateau. Below: Cartoon cross sections showing the meeting of these two plates before and after their collision. The reference points (small squares) show the amount of uplift of an imaginary point in the Earth's crust during this mountain-building process.



Transform boundaries

The zone between two plates sliding horizontally past one another is called a *transform-fault boundary*, or simply a *transform boundary*. Most transform faults are found on the ocean floor. They commonly offset the active spreading ridges, producing zig-zag plate margins, and are generally defined by shallow earthquakes. However, a few occur on land, for example the San Andreas fault zone in California. This transform fault connects the East Pacific Rise, a divergent boundary to the south, with the South Gorda -- Juan de Fuca -- Explorer Ridge, another divergent boundary to the north.



The Blanco, Mendocino, Murray, and Molokai fracture zones are some of the many fracture zones (transform faults) that scar the ocean floor and offset ridges (see text).

The San Andreas is one of the few transform faults exposed on land.

The San Andreas fault zone, which is about 1,300 km long and in places tens of kilometers wide, slices through two thirds of the length of California. Along it, the Pacific Plate has been grinding horizontally past the North American Plate for 10 million years, at an average rate of about 5 cm/yr. Land on the west side of the fault zone (on the Pacific Plate) is moving in a northwesterly direction relative to the land on the east side of the fault zone (on the North American Plate).