ACTIVITY 2—PLATE BOUNDARIES AND PLATE INTERACTIONS

Background Information

At the heart of the concept of the theory of plate tectonics is the idea that large segments of Earth's lithosphere (consisting of the crust and the rigid uppermost part of the mantle) move relative to one another. New lithosphere is continuously created at the mid-ocean spreading ridges. This lithosphere consists of a thin layer of ocean crust above and a layer of rigid mantle below. As the lithosphere moves away from its place of origin at the spreading ridge, it becomes thicker, by progressive downward rigidification of underlying mantle asthenosphere as the material cools. Because the Earth is not becoming larger, the addition of surface material in one place must be accompanied by an equal loss of surface material somewhere else on the planet. This is manifested as subduction zones. Also, in certain places two lithospheric plates slide parallel to each other. There are thus three basic kinds of plate boundaries: divergent boundaries at spreading ridges; convergent boundaries at subduction zones and sites of continent–continent collision; and transform boundaries, where plates are sliding past each other.

Divergent boundaries exist where two plates are moving apart. This occurs where convection currents in the mantle rise toward the surface and spread apart. Divergent plate boundaries are characterized by basaltic volcanism, intrusion of gabbro dikes, and shallow-focus earthquakes. As the plates move away from each other, a geographic feature known as a rift valley is produced. They are usually found atop mid-ocean ridges such as the Mid-Atlantic Ridge. Two examples of divergent boundaries on land are the East African Rift Zone and Thingvellir in Iceland.

Convergent boundaries exist where two plates move toward each other. The processes associated with convergent boundaries differ depending upon the nature of the lithosphere involved. Crustal material can be continental (granitic) or oceanic (basaltic). Granitic rock is less dense than basaltic rock and therefore cannot subside into the higher-density mantle. As a result, convergent boundaries can be divided into three subtypes, each of which has characteristic features.

If both of the plates are capped by oceanic crust, one of the plates moves downward under the other plate at some angle, which ranges from rather shallow in the case of fast convergence to almost vertical in the case of slow convergence. This pattern of convergent motion is called subduction. A deep trench is formed on the sea floor at the point where the one plate bends downward under the other. Earthquakes occur along the subducting plate, ranging from shallow-focus earthquakes near the trench to deep-focus earthquakes at depths as great as several hundred kilometers. The earthquakes are the result of stresses within the plates themselves, in response to pushing and pulling of the plate, rather than to slippage between the subducting plate and the enclosing mantle. Also, an arcuate chain of volcanic islands, called a volcanic island arc, develops above the subduction zone by melting of some of the mantle rock overlying the subducting plate, as the subducting plate releases some of its water content. The Aleutian trench and island arc is an excellent example of a modern subduction zone of this kind, which could be called an ocean–ocean subduction zone.

If one plate is capped by oceanic crust and the other is capped by much thicker and less dense continental crust, the downgoing plate is always the one carrying oceanic crust, because it has a higher density. A trench develops just offshore of the continental plate. The pattern of earthquakes is similar to that associated with subduction of an oceanic plate beneath another oceanic plate, but the earthquakes occur beneath the continent and the volcanism forms a chain of volcanic mountains inboard of the margin of the continent. The subduction zone along the west coast of South America is an excellent example of a modern subduction zone of this kind, which could be called an ocean–continent subduction zone.

The final possibility is the convergence of two plates, both of which carry continental crust. Because continental crust is much less dense than the mantle, neither of these plates is subducted. Instead, one is pushed horizontally beneath the other for some distance, until the friction forces along the boundary between the two plates builds up to be greater than the compressive force that is pushing the plates together. The thickening of the lithosphere in this way results in very high land elevations over very large areas. Compressive fault movements of large masses or sheets of continental crust result in the formation of high mountains at the site of the continent–continent collision. Although volcanic activity is not common, earthquakes are common and can occur far from the plate boundary beneath either plate. The outstanding modern example of continent–continent collision is the collision of the Indian Peninsula with the main mass of southern Asia, which has resulted in the Himalayas mountain chain and the Tibetan Plateau. Old mountain belts, such as the Appalachians, are interpreted by geoscientists to have formed from a continent–continent collision earlier in geologic time.

Transform faults exist where two plates slide past each other in parallel but opposite motion. A look at any map of mid-ocean ridges shows that the ridges are offset by numerous transform faults. Movement along transform faults generates frequent earthquakes but usually no volcanic activity. The San Andreas Fault in California is an unusually long transform fault.

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