

## ACTIVITY 4— EFFECTS OF PLATE TECTONICS

### Background Information

This is the most comprehensive of the activities in this module. Students will take information from the Earthquakes chapter, the Volcanoes chapter, and the previous activities in the Plate Tectonics chapter and attempt to see how all are related to the theory of plate tectonics. If you are still not familiar with the modern concepts of plate tectonics, this is the time when as good an understanding as possible is needed. You should review the resources listed at the end of this Teacher's Edition and the explanation provided with the USGS map *This Dynamic Planet*.

You can now see why the field of study of plate motion is called plate tectonics. Tectonics comes from the Greek word *tekton*, which means builder. Plate tectonics refers to the building of the features on Earth's surface due to deformation caused by plate movements.

You have learned that in addition to the creation of mountain ranges, trenches, rift valleys, and ridges right at plate boundaries, other features and activities can result from plate movements. For example, there is a clear relationship between volcanoes, earthquakes, and plate boundaries. This is particularly evident around the rim of the Pacific Ocean, where the subduction of oceanic plates around much of the rim results in volcanic arcs and earthquakes.

The presence of a volcanic arc is good evidence for an active plate boundary. Volcanic arcs are supplied by magma that is generated deep in the mantle, above oceanic plates going down subduction zones. In order to melt asthenosphere to create magma, the downgoing plate must go deep enough to be surrounded by mantle rock at sufficiently high temperatures. The upper surface of the downgoing plate is covered with sediments (the cream cheese and cheese spread in **Part 8** of the investigation) that had been deposited on the plate during its long travel from a mid-ocean ridge to the subduction zone, plus additional sediment deposited in the trench from nearby land areas. Much of the sediment is plastered or accreted to the leading edge of the other plate, to build a growing and very complicated mass of sedimentary and metamorphic rock called an accretionary wedge (see below), but some of it is subducted deep down along with the downgoing plate. These sediments contain abundant water, and the rocks of the oceanic crust in the upper part of the downgoing plate also contain water, incorporated into the basaltic lavas in the rift valley of the mid-ocean ridge by the activity of hydrothermal springs, which are typically associated with the volcanism in the rift. At a sufficiently great depth down the subduction zone, much of the water is released and rises up into the overlying hot mantle asthenosphere. This addition of water lowers the melting point of the overlying rock, causing generation of magma by partial melting. The magma is slightly less dense than the solid rock from which it was derived, causing it to rise buoyantly toward the surface. The students observe this in **Part 2** of the investigation. When the magma reaches the surface, a volcano is formed.

A chain of such volcanoes behind a subduction zone forms a volcanic arc. Volcanic arcs are common in the Pacific Ocean along several ocean–ocean subduction zones, and they also extend along the Andes, run the length of Central America, across central Mexico, and run in a chain, known as the Cascades, from northern California to southern British Columbia. These latter volcanoes are associated with small oceanic plates (the Nazca, Cocos, and Juan de Fuca Plates, for example) that are being subducted under the Americas. The Alaskan Peninsula, the Aleutian Islands, the islands of Japan, the Philippines, and the Marianas are other examples of volcanic arcs.

Not all of the magma reaches the surface to form volcanoes; some of it remains below the surface in magma chambers and cools slowly to form massive and complex igneous intrusive bodies, called batholiths. Volcanic arcs thus typically consist of a foundation of intrusive igneous rocks overlain by thick successions of volcanic rocks. The Sierra Nevada, a major mountain range in central California, is thought to be mostly a gigantic and complex batholith that was the root of an ancient volcanic arc. Much later uplift, not associated with the subduction zone that formed the volcanic arc, has raised the batholith to the surface.

Not all volcanoes are associated with subducting plates. Hot spots are narrow plumes of unusually hot, and therefore less dense, mantle rock that is heated in certain places deep in the mantle, presumably at the interface between the mantle and the core. These plumes of rock then rise buoyantly toward the surface, flowing upward through the much broader convection cells of the asthenosphere. As they reach the upper mantle, where melting temperature is less

because the pressure is much less, some of the hot rock melts, and the magma rises to the surface, resulting in hot-spot volcanism.

Hot spots can exist under continents as well as under oceans. The hot spot that has produced the hot springs and the past (and perhaps future!) volcanism at Yellowstone National Park is a good example. One theory suggests that the bulge created by a hot spot initiates the splitting of continents and the creation of rift (or divergent) zones. It is thought that a hot spot lies below, and is responsible for, the Rift Valley of Africa. There is also evidence suggesting that the New Madrid fault, which runs down the Mississippi River Valley, may represent an aborted divergent zone originally created by a series of hot spots. The largest series of earthquakes in the United States outside of Alaska occurred on the New Madrid fault in the early nineteenth century, ringing bells as far away as Philadelphia and causing the Mississippi River to run backwards for a brief time!

Therefore, plate tectonics can even affect areas that are within the heart of a continent. Hot spots tend to stay in one place relative to the deep mantle. As a plate moves relative to the deep mantle, the hot spot shifts its position on the moving plate. The Hawaiian Islands have been formed in just this way. The easternmost island, the “big island” of Hawaii, which has active volcanoes, is the youngest island in the chain, and is in the present position of the hot spot beneath. If you look in an atlas of the Pacific Ocean, you will see that there is a chain of seamounts (underwater mountains) called the Emperor Seamounts, which stretch to the northwest from the western end of the Hawaiian Islands chain. They represent even earlier positions of the hot spot relative to the Pacific Plate.

The dogleg bend in the middle of the chain seems to represent a sudden change in the direction of movement of the Pacific plate long ago.

**Part 8** of the investigation, in which a layer of cream cheese and cheese spread is scraped off the downgoing “plate” in a “subduction zone,” also models the growth of continents along ocean–continent subduction zones. It demonstrates that much of the sediment riding on the downgoing plate is scraped off and accreted onto the leading edge of the continent in the form of an accretionary wedge. Slabs or sheets of the sediment are tucked down into the subduction zone and become attached to the underside

of the accretionary wedge. Much of the metamorphic rock of the continents has been formed in this way, as the sediments are pulled down into regions of high pressure and temperature. Most of California west of the Sierra Nevada has been accreted onto the continent in this way in the past two hundred million years (a short time, geologically).

The *EarthComm* web site, [www.agiweb.org/earthcomm/](http://www.agiweb.org/earthcomm/), contains a variety of links to web sites that will help you to deepen your understanding of content and prepare you to teach this activity. Many of the sites also contain images which can be downloaded and made into overheads for incorporation into class discussions.