These pages were modified slightly from SERC to complement the Animation of the Month—Plate Boundaries

Q&A about Plate Tectonics

from SERC (Science Education Resource Center, Carleton College)

Solid Earth Socratic Questions

Sample questions arranged in sequence for Socratic questioning:

1. How big is the Earth? How thick are the layers?
2. What do we know about the interior of the Earth?
3. What is an earthquake? What causes them? Why are some stronger than others?
4. What is a fault? What are the different types of faults? What is the fundamental cause of the different types of faults?
5. What is plate tectonics?
6. What is a tectonic plate?
7. Why is continental crust so much thicker than oceanic crust?
8. When did plate tectonics begin on Earth, and is it still an active process today?
9. What are the different types of plate boundaries and what geological features do they create?
10. What force(s) drives plate tectonics?
11. What are volcanoes? How do they form?

1. How big is the Earth? How thick are the layers?

Earth is about 12,750 kilometers (km) in diameter. This dimension was actually known by the ancient Greeks, but it was not until the turn of the 20th century that scientists determined that our planet is made up of three main layers: crust, mantle, and core. This layered structure can be compared to that of a boiled egg. The crust, the outermost layer, is rigid and very thin compared with the other two. Beneath the oceans, the crust varies little in thickness, generally extending only to about 5 km. The thickness of the crust beneath continents is much more variable but averages about 30 km; under large mountain ranges, such as the Alps or the Sierra Nevada, however, the base of the crust can be as deep as 100 km. Like the shell of an egg, the Earth's crust is brittle and can break.

2. What do we know about the interior of the Earth?

Four and half billion years ago, Earth was formed by the accretion of space debris (asteroids, comets and planetesimals) through impact and agglomeration. The heat energy released by these frequent and steady impact events melted the entire planet, from which it is still cooling today. During this early melt phase, denser materials like iron (Fe) and nickel (Ni) sank into the core of the Earth, while lighter silicate (Si) and oxygen (O) compounds and volatile gases rose toward the surface. The earth is divided into four main layers: the inner core, outer core, mantle, and crust. The core is composed mostly of iron (Fe) and is so hot that the outer core is molten, with about 10% sulfur (S). The inner core is under such extreme pressure that, despite its high temperature, it remains solid. Most of Earth's mass is in the mantle, which is composed of iron (Fe), magnesium (Mg), aluminum (Al), silicon (Si), and oxygen -silicate compounds. At over 1000 degrees C, the mantle is solid but deforms slowly in a plastic manner. The crust is much thinner than any of the other layers, and is composed of the least dense material, mainly calcium (Ca) and sodium (Na) aluminum (Al)-silicate (Si) minerals. Being relatively cold, the crust is rocky and brittle, and it can fracture relatively easily.

3. What is an earthquake? What causes them? Why are some stronger than others?

An earthquake is caused by a sudden slip along a fault. Stresses in the earth's outer layer push the sides of the fault together. Stress builds up and the rocks slips suddenly, releasing energy in waves that travel through the earth's crust and cause the shaking that we feel during an earthquake. An earthquake occurs when plates grind and scrape against each other. Two plates interact in such a fashion in California: the Pacific Plate and the North American Plate. The Pacific Plate consists of most of the Pacific Ocean floor and the California Coast line. The North American Plate comprises most the North American Continent and parts of the Atlantic Ocean floor. The primary boundary between these two plates is the San Andreas Fault, which is more than 650 miles long and extends to depths of at least 10 miles. The Pacific Plate grinds northwestward past the North American Plate at a rate of about five centimeters per year. Parts of the San Andreas Fault system adapt to this movement by constant "creep" resulting in many tiny shocks and a few moderate earth tremors. In other areas where creep is not constant, strain can build up for hundreds of years, producing great earthquakes when it finally releases.

4. What is a fault? What are the different types of faults? What is the fundamental cause of the different types of faults?

A fault is a fracture or zone of fractures between two blocks of rock. Faults allow the blocks to move relative to each other. This movement may occur rapidly, in the form of an earthquake - or may occur slowly, in the form of creep. Faults may range in length from a few millimeters to thousands of kilometers. Most faults produce repeated displacements over geologic time. During an earthquake, the rock on one side of the fault suddenly slips with respect to the other. The fault surface can be horizontal or vertical or some arbitrary angle in between.

Earth scientists use the angle of the fault with respect to the surface (known as the dip) and the direction of slip along the fault to classify faults. Faults that move along the direction of the dip plane are dip-slip faults and described as either normal or reverse, depending on their motion. Faults that move horizontally are known as strike-slip faults and are classified as either right-lateral or left-lateral. Faults which show both dip-slip and strike-slip motion are known as oblique-slip faults.

5. What is plate tectonics?

"Plate tectonics" is a term that refers to the continual slow movement of rigid oceanic and continental "plates" that comprise the outermost crust of the earth. There relative motion, colliding and slipping past each other, causes earthquakes and volcanoes and has created most of the spectacular landforms around the world.

In the early 1960s, the emergence of the theory of plate tectonics started a revolution in the earth sciences. Since then, scientists have verified and refined this theory, and now have a much better understanding of how our planet has been shaped by plate-tectonic processes. We now know that, directly or indirectly, plate tectonics influences nearly all geologic processes, past and present. Indeed, the notion that the entire Earth's surface is continually shifting has profoundly changed the way we view our world.

In geologic terms, a plate is a large, rigid slab of solid rock. The word tectonics comes from the Greek root "to build." Putting these two words together, we get the term plate tectonics, which refers to how the Earth's surface is built of plates. The theory of plate tectonics states that the Earth's outermost layer is fragmented into a dozen or more large and small plates that are moving relative to one another as they ride atop hotter, more mobile material.

6. What is a tectonic plate?

A tectonic plate (also called lithospheric plate) is a massive, irregularly shaped slab of solid crust (comprised of many rock types and surface features). A tectonic plate can be composed of continental or oceanic lithosphere. Plate size can vary greatly from a few hundred to thousands of kilometers across; the Pacific and Antarctic Plates are among the largest. Plate thickness also varies greatly, ranging from less than 15 km for young oceanic lithosphere to about 200 km or more for ancient continental lithosphere (for example, the interior parts of North and South America).

7. Why is continental crust so much thicker than oceanic?

The answer lies in the composition of the rocks. Continental crust is composed of granitic rocks that are composed of relatively lightweight and less dense minerals such as quartz and feldspar. By contrast, oceanic crust is composed of basaltic rocks, which are much denser and heavier. The variations in plate thickness are nature's way of partly compensating for the imbalance in the weight and density of the two types of crust. Because continental rocks are much lighter, the crust under the continents is much thicker than oceanic crust. Like icebergs, where only the tips of which are visible above water, continents have deep roots to support their elevations.

8. When did plate tectonics begin? is it still an active ?

Tectonic plates probably developed very early in the Earth's 4.5-billion-year history, and they have been drifting about on the surface ever since, like slow-moving bumper cars repeatedly clustering together and then separating. Plates can change over time. Lithosphere can sink under a lighter continental plate. Eventually, the plunging oceanic plate will disappear completely. This process is happening now off the coast of Oregon and Washington. The small Juan de Fuca Plate, a remnant of the formerly much larger oceanic Farallon Plate, will someday be entirely consumed as it continues to sink into a subduction zone beneath the North American Plate.

9. What are the different types of plate boundaries and what geological features do they create?

There are four main types of plate boundaries, convergent, divergent and transformation and zones. Convergent boundaries occur when two or more plates collide, causing the collision zone to rumple and fold, creating high mountain ranges (the Himalayas and the Alps are examples). Subduction zones also occur at convergent plate boundaries where, often, thin and dense oceanic crust plunges beneath thick and light continental crust. Heating of the lithsphere as it descends causes partial melting, which then rises to the surface to form a line of volcanoes parallel to the plate boundary. The Cascade Range of North America and the Andes of South America are examples of volcanic ranges produced by subduction.

Divergent plate boundaries occur where earth's crust splits and moves apart, creating a rift valley. Rift valleys can occur in continental and oceanic crust. Examples of divergent plate boundaries are the Great Rift Valley of East Africa (continental) and the mid-Atlantic ridge (oceanic), where new crust is generated as the plates pull away from each other.

Transformation boundaries occur when plates slide past each other, creating major fault zones. The San Andreas fault is an example of a transformational plate boundary. Crust is neither produced nor destroyed as the plates slide horizontally past each other.

Plate boundary zones are broad belts in which boundaries are not well defined and the effects of plate interaction are unclear. One of these zones marks the Mediterranean-Alpine region between the Eurasian and African Plates, within which several smaller fragments of plates (microplates) have been recognized. Because plate-boundary zones involve at least two large plates and one or more microplates caught up between them, they tend to have complicated geological structures and earthquake patterns.

10. What force(s) drives plate tectonics?

From geophysical evidence and laboratory experiments, scientists generally agree that the plate-driving force is the slow movement of hot, softened mantle that lies below the rigid plates. This idea was first considered by Arthur Holmes in the 1930s. Holmes speculated that the circular motion of the mantle carried the continents along in much the same way as a conveyor belt. Both the Earth's surface and its interior are in motion. Below the lithospheric plates, at some depth the mantle is partially molten and can flow, albeit slowly, in response to steady forces applied for long periods of time. Just as a solid metal like steel can be softened and take different shapes when exposed to heat and pressure, so too can solid rock in the mantle when subjected to heat and pressure in the Earth's interior over millions of years.

The mobile rock beneath the rigid plates is believed to be moving in a circular manner somewhat like a pot of thick soup when heated to boiling. The heated soup rises to the surface, spreads and begins to cool, and then sinks back to the bottom of the pot where it is reheated and rises again. This cycle is repeated over and over to generate what scientists call a convection cell or convective flow. While convective flow can be observed easily in a pot of boiling soup, the idea of such a process stirring up the Earth's interior is much more difficult to grasp. While we know that convective motion in the Earth is much, much slower than that of boiling soup, many unanswered questions remain: How many convection cells exist? Where and how do they originate? What is their structure?

Convection cannot take place without a source of heat. Heat within the Earth comes from two main sources: radioactive decay and residual heat. The radioactive decay of naturally occurring elements -- most notably uranium, thorium, and potassium -- releases energy in the form of heat, which slowly migrates toward the Earth's surface. Residual heat is gravitational energy left over from the formation of the Earth -- 4.6 billion years ago -- by the "falling together" and compression of cosmic debris. How and why the escape of interior heat becomes concentrated in certain regions to form convection cells remains a mystery.

11. What are volcanoes? How do they form?

Volcanoes are built by the accumulation of their own eruptive products, primarily lava and ash. A volcano commonly has the form of a conical hill or mountain built around a vent that connects with reservoirs of molten rock below the surface of the Earth. The term volcano also refers to the opening or vent through which the molten rock and associated gases are expelled.

As with earthquakes, volcanic activity is linked to plate-tectonic processes. Many of the world's active above-sea volcanoes are located near convergent plate boundaries where subduction is occurring, particularly around the Pacific basin. However, much more volcanism -- producing about three quarters of all lava erupted on Earth -- takes place unseen beneath the ocean, mostly along the oceanic spreading centers (divergent plate boundaries), such as the Mid-Atlantic Ridge and the East Pacific Rise.

Subduction-zone volcanoes like Mount St. Helens (in Washington State) and Mount Pinatubo (Luzon, Philippines), are called composite cones and typically erupt with explosive force, because the magma is too stiff to allow easy escape of volcanic gases. As a consequence, tremendous internal pressures mount as the trapped gases expand during ascent, before the pent-up pressure is suddenly released in a violent eruption. Such an explosive process can be compared to putting your thumb over an opened bottle of a carbonated drink, shaking it vigorously, and then quickly removing the thumb. The shaking action separates the gases from the liquid to form bubbles, increasing the internal pressure. Quick release of the thumb allows the gases and liquid to gush out with explosive speed and force.