The Good Earth
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Plate Tectonics

- Earth's lithosphere is divided into a series of major and minor mobile plates.
- Plates move at rates of centimeters per year.
- Plates may be composed of continental and/or oceanic lithosphere.
- The destruction of oceanic lithosphere below oceanic trenches explains the occurrence of earthquakes and volcanoes adjacent to trenches.

Lithospheric Plates

The theory of plate tectonics proposes that the lithosphere is divided into **eight major plates** (North American, South American, Pacific, Nazca, Eurasian, African, Antarctic, and Indian-Australian) and several smaller plates (e.g., Arabian, Scotia, Juan de Fuca) that fit together like the pieces of a jigsaw puzzle (Fig. 15). These plates are mobile, moving in constant, slow motion measured in rates of centimeters per year. The movements of plates over millions of years resulted in the opening and closure of oceans and the formation and disassembly of continents. The theory links Earth's internal processes to the distribution of continents and oceans; it is the big picture view of how the Earth works.

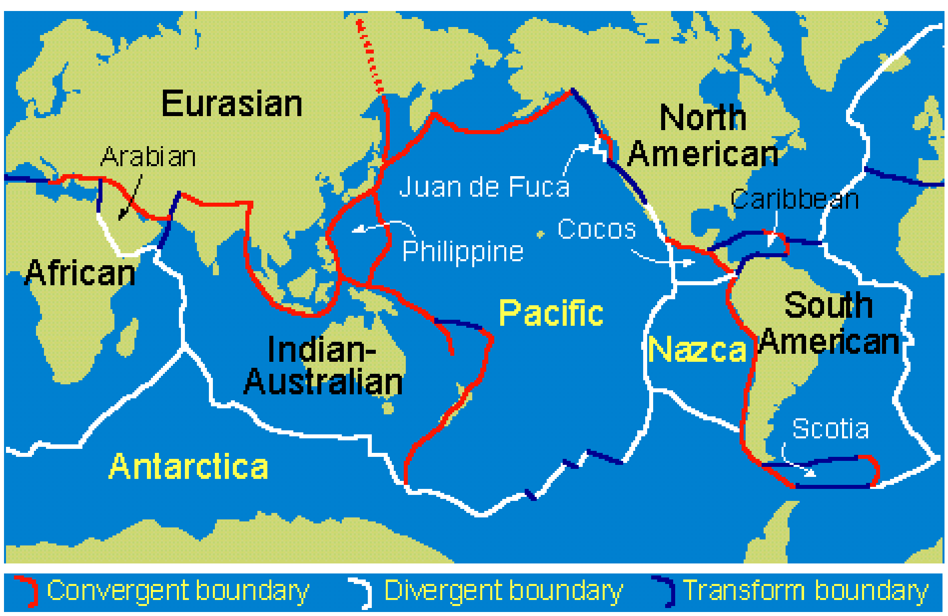


Figure 15. Distribution of tectonic plates with type of plate boundary.

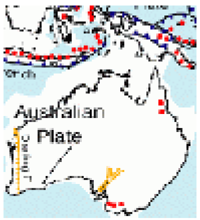
Go to the Web

This Dynamic Earth
A USGS on-line book about plate tectonics by W. J. Kious and R. I. Tilling. See the Understanding plate

Plates are typically composed of both continental and oceanic lithosphere. For example, the South American plate contains the continent of South America and the southwestern Atlantic Ocean. Plate boundaries may occur along continental margins (**active margins**) that are characterized by volcanism and earthquakes. Continental margins that do not mark a plate boundary are known as **passive margins** and are motions section for more on plate motion.

Plate reconstructions
Make your own reconstructions of the position of the continents from 150 million years ago to present at the OSDN (Ocean Drilling Stratigraphic Network) site.

Animations of plate motions
Visit this site at the Museum of Paleontology, University of California, Berkeley, to view a variety of plate animations.



Global tectonic activity map
This map shows plate boundaries, volcanic centers, rates of plate motion. Map created by NASA Goddard Space Flight Center by Paul Lowman, Penny Masuoka, Brian Montgomery, and Jacob Yates

free of volcanism and earthquakes. The Atlantic coastlines of North and South America are examples of passive margins.

Earthquakes and Volcanoes

Scientists had long recognized that volcanoes and earthquakes were present in greatest concentrations around the rim of the Pacific Ocean (**Ring of Fire**). Seismologists Kiyoo Wadati and Hugo Benioff noted that the focal depths of earthquakes became progressively deeper underlying ocean trenches (Fig. 16). Prior to the seafloor spreading hypothesis there was no obvious explanation for the presence of these **Wadati-Benioff zones**. Now it is widely accepted that earthquakes occur as one plate bends and fractures as it descends beneath another into the asthenosphere.

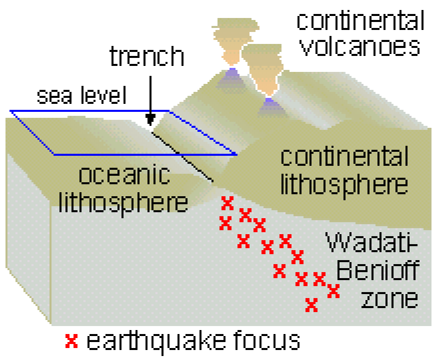


Figure 16. Inclined zone of earthquake foci adjacent to oceanic trench slopes downward under the overriding plate. The distribution of foci define the Wadati-Benioff zone.

The ocean floor was being pulled or pushed into the mantle were it was heated to form magma which in turn generated volcanoes. The destruction of the oceanic lithosphere caused earthquakes down to depths of 700 to 800 km (440-500 miles), explaining the presence of the deepest earthquakes adjacent to oceanic trenches. The term **subduction zone** was coined to refer to locations marked by Wadati-Benioff zones where the oceanic lithosphere is consumed adjacent to a trench.

Plate tectonics theory (Fig. 17) joined continental drift to sea-floor spreading to propose:

- The plate boundaries are mainly represented by oceanic ridges and trenches.
- Interactions at plate boundaries cause volcanic activity and earthquakes.
- The plates are in motion, moving away from ridges and toward trenches.
- Plates descend into the mantle below trenches in subduction zones.
- Plates typically contain both oceanic and continental lithosphere.
- Oceanic lithosphere is continually created and destroyed.
- Continental lithosphere cannot be destroyed but continents can be subdivided and assembled into supercontinents.

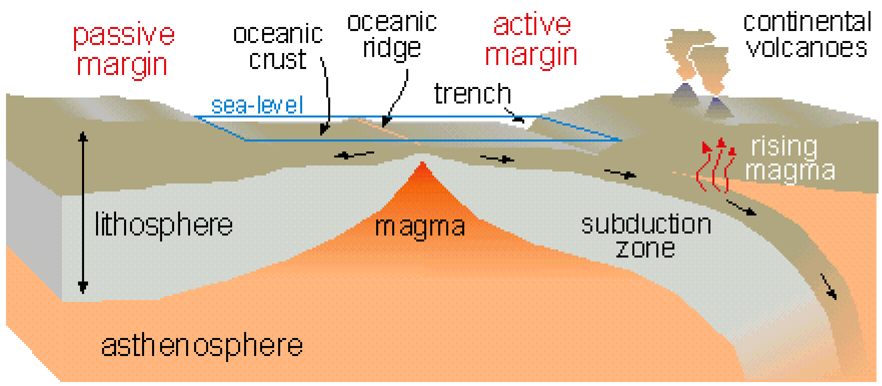


Figure 17. Illustration of the plate tectonic cycle. Oceanic lithosphere created by magma rising from the asthenosphere. Plates move away from the oceanic ridge and descend beneath a trench at the subduction zone.

Think about it . . .

The exercise found **here** asks you to examine maps of the age and topography of the ocean floor and the distribution of earthquakes and volcanoes and identify some common patterns associated with plate margins.

Plate Motions

The rates and directions of plate motions were originally determined by computing the distance of oceanic floor of a known age from the oceanic ridge system. Rates were computed by dividing age (years) by distance (centimeters). Such simple but effective calculations were compared to motion rates determined using the age of volcanic islands formed above mantle **hot spots** (e.g., Hawaii; Fig. 18). Some volcanic islands in the interiors of plates form above fixed plumes of magma rising from the mantle. The locations of these mantle plumes are known as hot spots. The islands form as the plate moves over the magma source, much like a tectonic conveyer belt. Islands are progressively older with increasing distance from the hot spot. The relationship between age and distance yields the rate of plate motion.

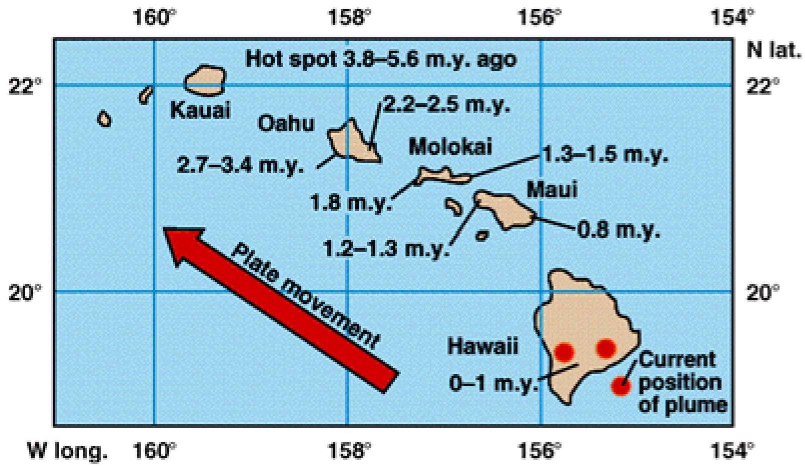


Figure 18. Relative ages and locations of Hawaiian Islands relative to hot spot (mantle plume). Kauai has traveled from the location of the plume to its present site over the last five million years. A submarine volcano, Loihi,

is forming over the current position of the plume.

Today satellite technology is used to determine the current rates of plate motion. Satellites anchored in space can record tiny movements of fixed sites on Earth, thus constraining the motions of plates (Fig. 19). Rates of seafloor spreading range from a little as 1-2 centimeters per year along the oceanic ridge in the northern Atlantic Ocean to more than 15 cm/yr along the East Pacific Rise spreading center. Current seafloor spreading rates are approximately five times higher for the East Pacific Rise than the Mid-Atlantic Ridge. Spreading rates changed through time but consistently higher rates in the Pacific Ocean basin can account for the contrast in size of the Atlantic and Pacific Oceans. The Pacific Ocean floor would be even wider if oceanic crust were not consumed at subduction zones along much of its margin.

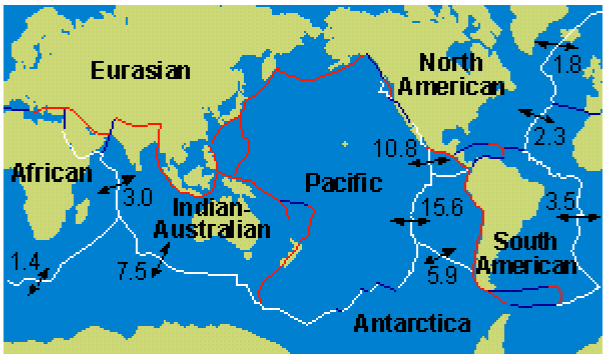


Figure 19. Directions and rates of plate motions (centimeters per year) along oceanic ridge systems. Spreading rates in the Pacific Ocean are nearly five times faster than in the Atlantic. See the global tectonic activity map for more on plate motions.

Think about it . . .

1. Name as many plates as you can on the blank map of the plates found **here**. Identify as many of the features on the associated list as you can.
2. Print the blank map of the world found **here**. Draw the major plate boundaries and label the names of the plates.
3. Examine the idealized plate map **here** and draw a cross section through the map to show the relationship between the featured plates.

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