Name:________________________________

Lab 1: Plate Tectonics
April 2, 2009

Objective: Students will be introduced to the theory of plate tectonics and different styles of plate margins and interactions.

Introduction

The planet can be divided into discrete layers based on material properties, including the inner and outer core, mesosphere, asthenosphere, and lithosphere. The lithosphere (crust and uppermost mantle) behaves rigidly, “floating” on the more plastic asthenosphere. This rigid exterior layer does not form an unbroken shell around the planet but is divided into discrete regions called tectonic plates. The boundaries between these plates do not necessarily correspond with the boundaries of continents: tectonic plates may contain oceanic crust, continental crust, or combinations of oceanic and continental crust. Our understanding of the movements and interactions of these plates – the theory of plate tectonics – provides a framework that helps to explain many of our geologic observations including locations of mountains, volcanoes, earthquakes, different rock types and many others.

Plate Tectonics

Tectonic plates move in different directions and at different speeds, driven by circulation of the underlying material, which in turn is convecting as part of the long-term release of heat from the planet’s interior. Because Earth's size remains constant, as these plates move, they must interact with each other at their margins. There are three possible types of plate margins. First, there are divergent margins, where plates move away from each other and new crustal material is created between them. This new crust, formed by magma rising from the underlying mantle, is generally oceanic-type crust and forms mid-ocean ridges (between oceanic crustal plates) or rift zones (between continental crustal plates). Second, there are convergent margins, where plates come together (or collide). In most cases, this collision forces the more dense plate under the less dense plate in a subduction zone. However, when two continental crustal plates collide, they are both too buoyant to subduct and instead deform, crumpling to form high mountain ranges like the Himalayas. Finally, there are transform margins, where plates slide past each other. These margins are basically large strike slip faults, such as the San Andreas Fault in California.

The direction and speed of plate motion can be characterized in two ways: relative motion and absolute motion. Relative motion measures the velocity of the movement of one plate relative to another moving plate. Rates of relative motion across mid-ocean ridges are often measured using the magnetic reversals recorded in the oceanic crust. Since the ages of these magnetic reversals have been determined by radiometric dating, we can measure the distance between the ridge and a known (dated) magnetic reversal and calculate a rate of spreading. This rate is called a half spreading rate, since it only represents the growth on one side of the ridge, and can be doubled to determine the full spreading rate. Absolute motion measures the velocity of the movement of one plate relative to a fixed, stationary reference point deep in Earth's interior. Absolute motion is often measured using hot spots since they are areas of igneous activity with sources in the deep mantle, below the drifting plates. The location of a hot spot is apparently fixed, perhaps being tied to some sort of feature at the core-mantle boundary, and does not change as plates move above it, so the surface expression of the hot spot is a line of volcanoes that increase in age away from the hot spot. The distance, direction, and age of a volcano with respect to its hot spot allow us to calculate the absolute speed and direction of plate movement.

Part 1. Tectonic Structures

Use the National Geographic Physical Globe to answer the following questions.

1. Study the long mountain chain running North-South along the center of the Atlantic Ocean.

    a. What is this topographic feature?

    b. What type of plate boundary is this?

    c. What type of volcanic rock is produced here?

    d. Note that the main ridge is offset by perpendicular transform faults. Sketch such an offset between two spreading segments and indicate the relative motions of the plates. Where does strike-slip motion occur?

2. Find the Peru-Chile trench.
    a. What type of margin does this indicate?

    b. What continental topographic feature runs parallel to this margin?

    c. Notice the absence of a trench along the Atlantic coast of South America. Explain the reason for this difference, including the difference in volcanic activity along the two coastlines. Is this also true for North America?

3. The Aleutian Islands are an example of island-arc volcanism. Name another group of islands in the Pacific that was formed this way (is adjacent to a trench).

4. What type of margin (convergent, divergent, or transform) is most common around the edge of the Pacific Ocean?

5. In light of your answer to the previous question, is the Pacific Ocean growing wider or narrower from east to west? (Hint: Ask yourself if the Atlantic Ocean is growing wider or narrower from east to west…)

Part 2. Plate Motions

Refer to the "Plate Tectonic Map of the Circum-Pacific Basin Region" for the following questions.

1. Find the section of the East Pacific Rift immediately to the south of the Wilkes Fracture Zone. What is the distance (in km) between the center of the rift axis and the magnetic stripe marked "3"? Using the time scale on the map, what is the approximate age of this stripe in millions of years (Ma)? Calculate the half spreading rate of the ridge in km/Ma, then convert this to cm/yr. Compare this to the spreading rate given on the map.

   Locate the stripe marked "3A" on the other side of the rift. Is the spreading symmetric or asymmetric?

   Don't perform any measurements or calculations, but estimate whether the spreading rate is faster, slower, or the same near the Udintsev Fracture Zone.

2. In which of these two locations is the ocean floor older, 20°N 170°E or 20°S 100°W? Why?

3. Determine the approximate distance from the trench to the volcanic arc for the Cascades. How does it compare with the distance in southern Mexico? How might the dip angles of the two subducting oceanic plates account for this?

4. Notice that the depth of earthquakes in South America increases with distance from the Peru-Chile Trench. Determine the distance from the trench to the deepest earthquakes (blue dots) and the approximate depth of these events. Assuming that these quakes occur at the contact between the top of the subducting oceanic plate and the bottom of the overlying continental plate, what is the dip angle of the oceanic plate?

5. Locate the Hawaiian Islands and the Emperor Seamount Chain. These were formed by a hot spot which is still active.
   a. What feature indicates the present activity of the hotspot?

   b. What is the current absolute direction of motion for the Pacific Plate? How do the Emperor Seamounts indicate that its direction has changed? What was the previous direction?

6. Find the Kammu Seamount at the bend in the Hawaiian –Emperor chain. It is approximately 39 million years old. What is the average absolute velocity of the Pacific Plate for the last 39 Ma? How does this long-term average compare with the current absolute velocity given on the map near Hawaii?