Turn in 5 & 6 Key Do Not Remove!! 

# GS 104 Laboratory # 4
# INTRODUCTION TO PLATE TECTONICS

**Introduction**

The Theory of Plate Tectonics has revolutionized the science of Geology in the last 30 years. The theory states that the outer surface of the earth consists of 7 major crustal or lithospheric plates and numerous smaller ones, and these plates move around on a ductile layer referred to as the asthenosphere. The boundaries between the lithospheric plates, which are where they interact with one another, are characterized by distinctive topographic features and catastrophic geologic processes such as earthquakes and volcanism.

**Goals and Objectives**

- Introduce some of the basic ideas of Plate Tectonics
- Study the Plate Tectonic setting of the western United States and parts of the adjacent Pacific Ocean basin
- Describe the relation between earthquakes, volcanoes, and plate boundaries

**Important Terminology**: Complete prior to arriving at your lab section.

**LITHOSPHERE**

**ASTHENOSPHERE**

**DIVERGENT PLATE BOUNDARY**

**CONVERGENT PLATE BOUNDARY**

**TRANSFORM PLATE BOUNDARY**

**Part A – "The Earth's Fractured Surface" Map**

**Examine** the National Geographic map entitled "The Earth's Fractured Surface" and answer the following questions:

1. **Where** do most divergent plate boundaries occur - in oceanic or continental crust? The Red Sea is an exception to this generalization
   (***Note***: the arrows shown on the map [-><-] should be reversed in this region; they should appear like this <- ->).

   Oceanic

2. **What** type of boundary tends to be characterized by numerous volcanoes? Give a specific example.

   Convergent - subduction zone
   West coast of South America

3. **Are** there any areas of active volcanism that do not lie on or near plate boundaries? If so, give an example.

   Yellowstone, Hawaii

4. **What** types of plate boundaries affect the Pacific Northwest? Which plates are involved?

   Transform, Convergent, divergent
   North America Plate
   Juan de Fuca Plate
   Pacific Plate

5. **Why** do geologists often refer to the margins of the Pacific Ocean basin as the "Ring of Fire"? Explain using evidence from the map.

   Margins of Pacific Ocean are surrounded by volcanoes which are associated with subduction zones.

6. Note the distribution of the Hawaiian Islands chain and the Emperor Seamount chain in the Pacific Ocean. The Hawaiian Islands are part of a linear series of volcanic islands and seamounts that extend from Kilauea, which is an active volcano on the island of Hawaii, to beyond Midway Island in the central Pacific. The Emperor Seamount chain is a linear string of submerged volcanic islands.

   a. What is the specific origin of the Hawaiian Islands chain and the Emperor Seamount chain?

   As the Pacific plate moves over a hotspot, it creates a chain of volcanoes.

   b. Are the Hawaiian Islands chain and the Emperor Seamount chain related? Explain your reasoning.

   The Hawain Islands and Emporer Seamount chain are caused by the pacific plate moving over a hotspot. Evidence for the chains being related is their continuous nature and the bend in the Emporer chain as it becomes the Hawaiin chain.

   c. The volcanic rocks on Midway Island are 27 million years old. Determine the rate (in inches/year) and direction of plate motion of the Pacific Plate over the last 27 million years. (Note scale of map: 1 inch = 758 miles; AND Recall: rate = distance/time). Compare your value to the value provided on the map. Think about how fast your fingernails grow. Is the rate of the Pacific Plate motion comparable to how fast your fingernails grow? Explain.

map distance of chain = 2.5 in.

$$\text{rate of motion} = \frac{\text{actual distance}}{\text{time}} = \frac{(2.5\text{ in})\left(\frac{758\text{ mi.}}{\text{in.}}\right)\left(\frac{5280\text{ ft.}}{1\text{ mi.}}\right)\left(\frac{12\text{ in.}}{1\text{ ft}}\right)}{27 \times 10^6\text{ yrs.}} =$$

$$= 4.4' \frac{\text{in}}{\text{yr.}}$$

d. Suiko Seamount, which is not shown on the map but is located approximately beneath the second "R" in the word "EMPEROR", has yielded an age date of 65 million years. Based on the available age data and the distribution of the Hawaiian Islands chain and the Emperor Seamount chain, discuss how the direction of the Pacific Plate movement has changed through time. Is this change in motion consistent with other seamount chains in the Pacific Ocean? Explain.

Between 65 and 27 million years ago, the direction of the Pacific Plate's motion changed from northerly to northwesterly.

7. Study the list of Notable Volcanic Eruptions of the 20th Century.

a. At what type of plate boundary have the vast majority of the volcanic eruptions in the 20th century occurred?

Subduction zones (convergents boundaries)

b. Why was there an eruption in Iceland in 1963? Consider what type of plate boundary this is.

Iceland sits on a divergent boundary with a hotspot underneath. Both the boundary & the hotspot contribute to Icelandic volcanism.

8. Study the list of Notable Earthquakes of the 20th Century. What specific conclusions can you draw about the relationship between the magnitude of a given earthquake and the type of plate boundary where it occurred?

The larger earthquakes occur along subduction zones.

**Part B – "Living on the Edge" Map**

**Examine** the National Geographic map entitled "Living on the Edge" and answer the **following** questions:

1. **Compare** the number of earthquakes along the Cascade Subduction Zone in N. **California**, Oregon, and Washington. Which area has had the largest number of **earthquakes**; which has had the least?

Most - Northern California

Least - Oregon

2. **In comparison** to other subduction zones worldwide (see the "The Earth's Fractured **Surface**" map, e.g., along S. America, and the Aleutian and Kuril Trenches), suggest **two possible** reasons why the Cascade Subduction Zone has an overall lack of **earthquake** activity.

The Juan de Fuca plate is much smaller than other subducting plates (i.e. Nazca plate). This places the divergent edge of plate much closer to the subduction zone & reduces the length of the Cascadia subduction zone.

3. **Read** the information on the map indicating that a large earthquake occurred in the **geologic** past along offshore Oregon. Are any of your reasons above consistent with **this** evidence? Explain.

Having the divergent boundary close to the subduction zone in Cascadia results in the subduction of a young, hot, buoyant plate compared to the old, cold, dense plate subducting in South America. This makes the Juan de Fuca plate harder to subduct & could result in locking along the plate boundary.

4. **Read** the information on the map about several of the Cascade volcanoes. Would you **consider** the Cascades to be active volcanoes? Explain.

Many Cascade volcanoes have had eruptions in the last few hundred years, and many exhibit earthquake activity indicating that the volcanoes continue to be active.

5. **Locate** Long Valley Caldera in eastern California, and suggest a reason why there have **been** such a large number of earthquakes in this region. (***Hint***: Note that Mt. St. Helens **shows** a similar cluster of earthquakes).

The earthquake beneath Long Valley Caldera are due to magma movement and indicate that the area is still volcanically active.

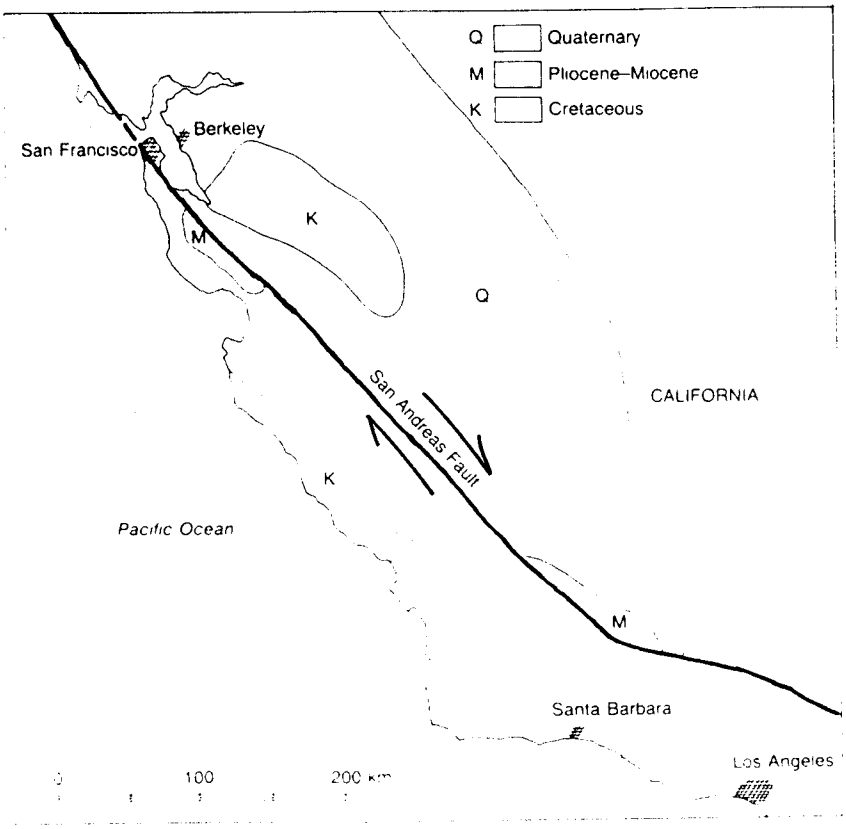


**Figure 1:** Generalized geologic map of southern California showing the San Andreas Fault.

**Part C – Studying the San Andreas Fault, California**

**Study Figure** 1 on the previous page and answer the following questions.

1. **Put** arrows along opposite sides of Figure 1 to show the relative sense of movement **along** the San Andreas Fault. What kind of plate boundary is the San Andreas Fault?

   Transform

2. **It is** possible to estimate the average annual rate of movement along the San Andreas **Fault** by recognizing rocks older than the fault that have been offset by the fault. Note **that** Pliocene-Miocene (M) rocks have been cut and offset by the fault. These rocks **have** been dated as being 25 million years old. What is the average annual rate of fault **movement** in centimeters per year (cm/yr)? Show all your work.

$$\text{rate} = \frac{(325\ \text{km})\left(\frac{1000\ \text{m}}{\text{km}}\right)\left(\frac{100\ \text{cm}}{1\ \text{m}}\right)}{25\ \text{million years}} = 1.3\ \frac{\text{cm}}{\text{yr}}$$

3. **The** average yearly rate of movement on the San Andreas Fault is very small. Does this **mean** that the residents of southern California have nothing to worry about from this **fault**? Explain.

   No. The fault may be locked resulting in slow rate of movement, but also resulting in a build up of stress that will later be released in a large earthquake.

4. **An** average movement of about 5 meters along the San Andreas Fault was associated **with** the 1906 San Francisco earthquake. Assuming that all displacement along the **fault** was produced by Earth motions of this magnitude, how often must such **earthquakes** have occurred in order to account for the total displacement? Show all **your** work.

$$\begin{pmatrix}\text{recurrence}\\ \text{interval}\\ (\text{time between}\\ \text{plates}\end{pmatrix} = \frac{5\ \text{m}}{0.013\ \frac{\text{m}}{\text{yr}}} = 385\ \text{yrs.}$$