

The Dynamic Crust

1) *Virtually everything you need to know about the interior of the earth can be found on page 10 of your reference tables. Take the time to become familiar with page 10 and everything on it.*

A) The crust:

- 1) **Oceanic crust** - basalt - thin - high density - young (because new sea floor crust is always being created while old floor is subducted).
- 2) **Continental crust** - granite - thick - low density - very old (because it 'just floats around').

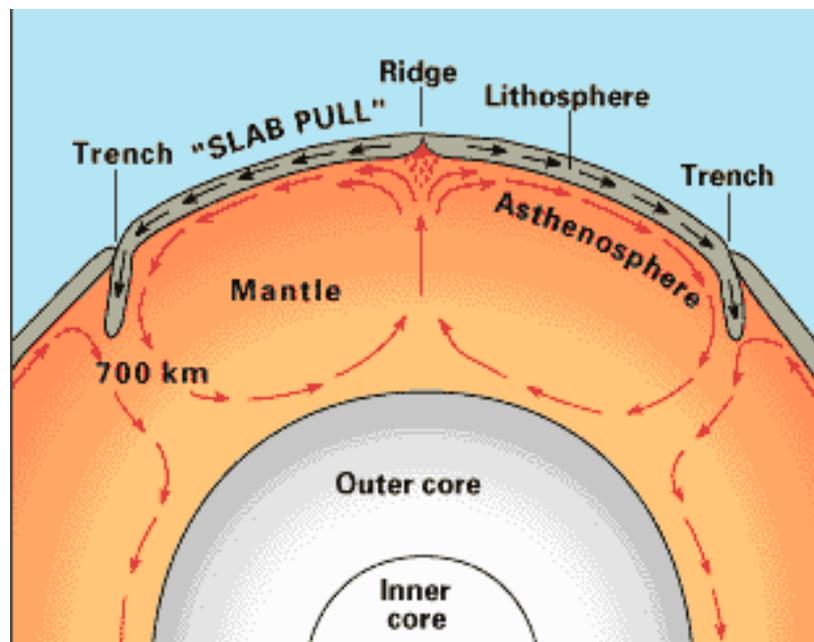
B) The Mantle:

- 1) **MOHO**: The interface (dividing line) between the crust and the rigid mantle beneath.
- 2) **Rigid mantle**: Relatively thin layer of relatively solid rock.
- 3) **Asthenosphere (plastic mantle)**: Layer of relatively flexible (plastic) rock that can (convection currents) flow because it is at or near its melting point.
- 4) **Stiffer mantle**: As the name implies the rock here is less plastic but it can still flow very slowly (convection currents)

IMPORTANT: It is believed that the *force* driving continental drift is convection currents in the mantle.

- 5) **Outer core**: Liquid. Mostly iron and some nickel. Convection currents here are probably responsible for the earth's magnetic field.
- 6) **Inner core**: Solid. High pressure keeps the iron/nickel core from melting.

2) EVIDENCE FOR CRUSTAL MOVEMENT

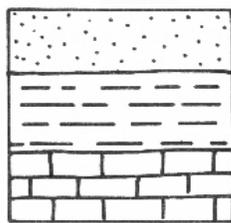


NOTE: Law of Original Horizontality - Sedimentary rock layers are always deposited horizontally as continuous layers. Thus, if a layer is tilted, broken, folded, or otherwise deformed, **it must have moved after it was deposited.**

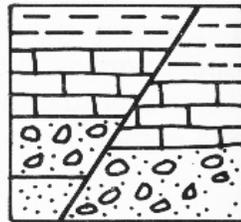
Displacement of rock layers (strata)

- a) Tilting: sedimentary rock layers are tilted (no longer horizontal)
- b) Faulting: sedimentary rock layers are broken - probably by earthquake activity.
- c) Folding: sedimentary rock layers are folded and squeezed by pressure in the crust.
(see diagrams below)
- d) Shallow water marine fossils (clams, scallops, etc) at high elevations in mountains.
This is evidence that the crust has been uplifted.
- e) Shallow water marine fossils in deep marine deposits (geosynclines).
A geosyncline is an unusually thick (thousands of feet) deposit of sedimentary rock that often accumulates at the mouth (delta) of large rivers. If clams are

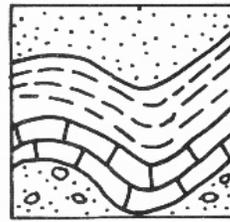
found 5,000 feet below the ocean bottom it is evidence that the crust has subsided (sunk).



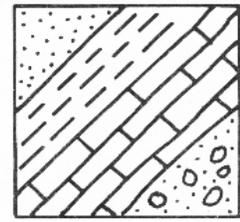
**Original
Horizontality**



Faulting



Folding



Tilting

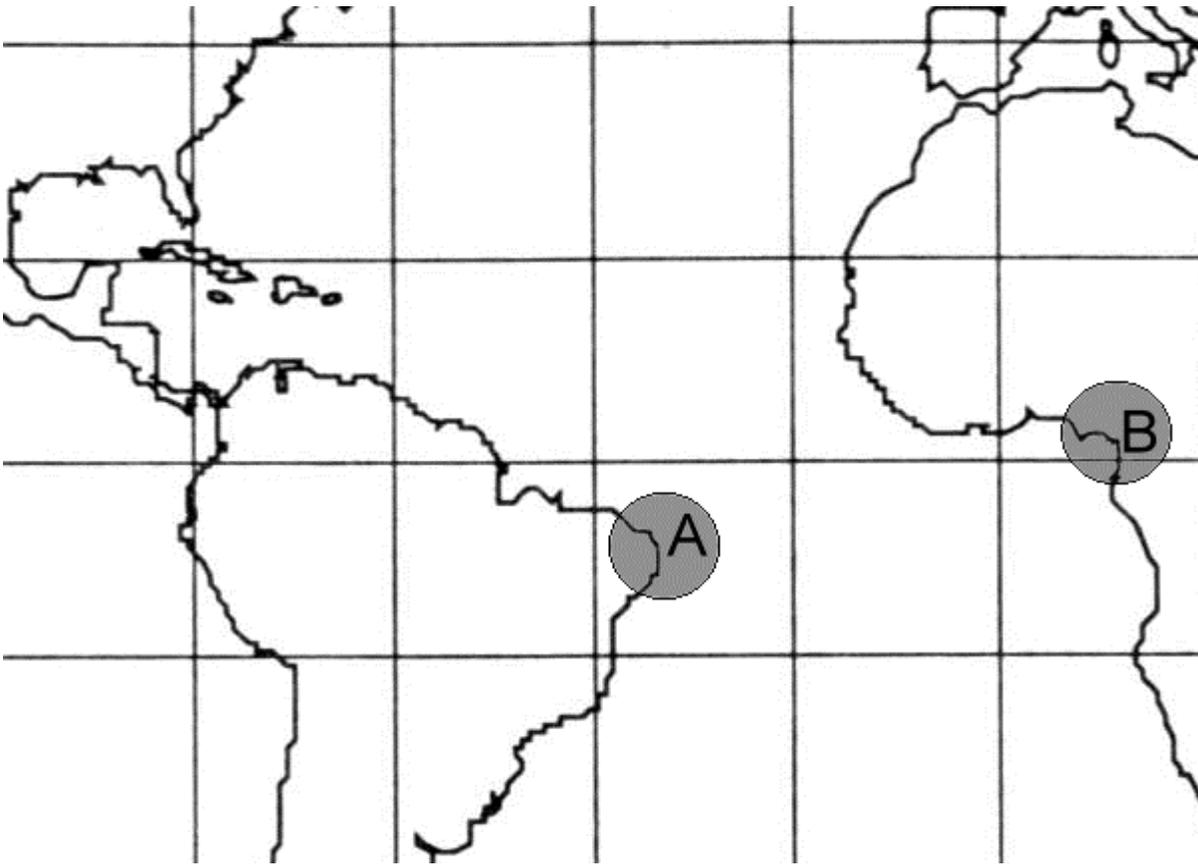
2) CONTINENTAL DRIFT (THEORY OF PLATE TECTONICS):

Theory: The earth's crust is divided into numerous pieces (plates) that are in motion relative to one another. There are 2 types of plates:

- a) Continental plates made of granite. These are low density and are 'floating' on the underlying basaltic plates below. They are very, very old.
- b) Oceanic crust made of basalt. These form the sea floor and underlie the continents. New oceanic crust is continually being produced at mid-ocean ridges (sea floor spreading). Old oceanic crust is continually being destroyed as it is 'subducted' into the mantle and melted. Thus, oceanic crust is not very old.
- c) The force driving the continents is convection currents in the mantle which cause the continents, which are floating on the mantle to drift around.

EVIDENCE FOR CONTINENTAL DRIFT and SEA FLOOR SPREADING:

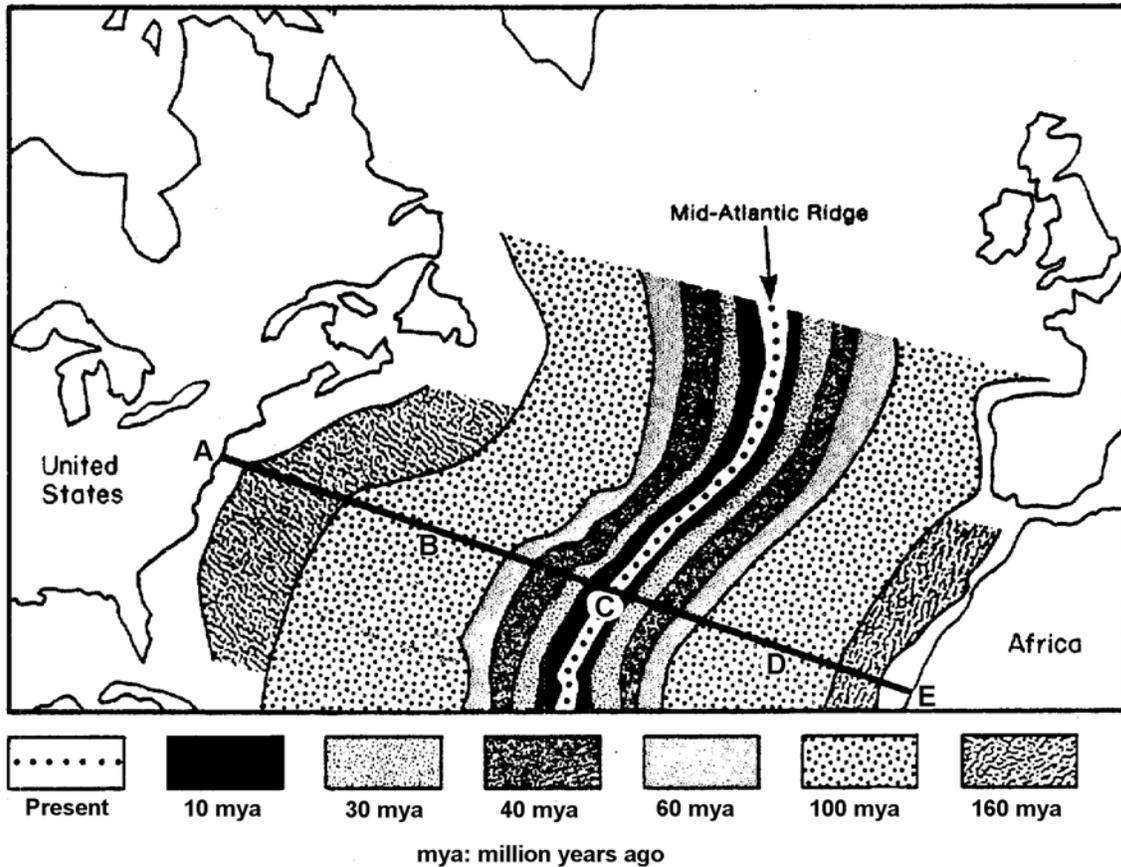
- 1) 'Fit' of the continents: The continents seem to fit together like pieces of a jigsaw puzzle that was together as one piece in the distant past.
- 2) Correlation of rocks from opposite areas of continents (see diagram).
- 3) Correlation of fossils from opposite areas on continents.(see diagram)



If rocks and fossils from area 'A' are the same as rocks and fossils found at area 'B' even though these regions are separated by 2500 miles of ocean, this is powerful evidence that once, in the distant past these two areas were connected and were part of a single landmass.

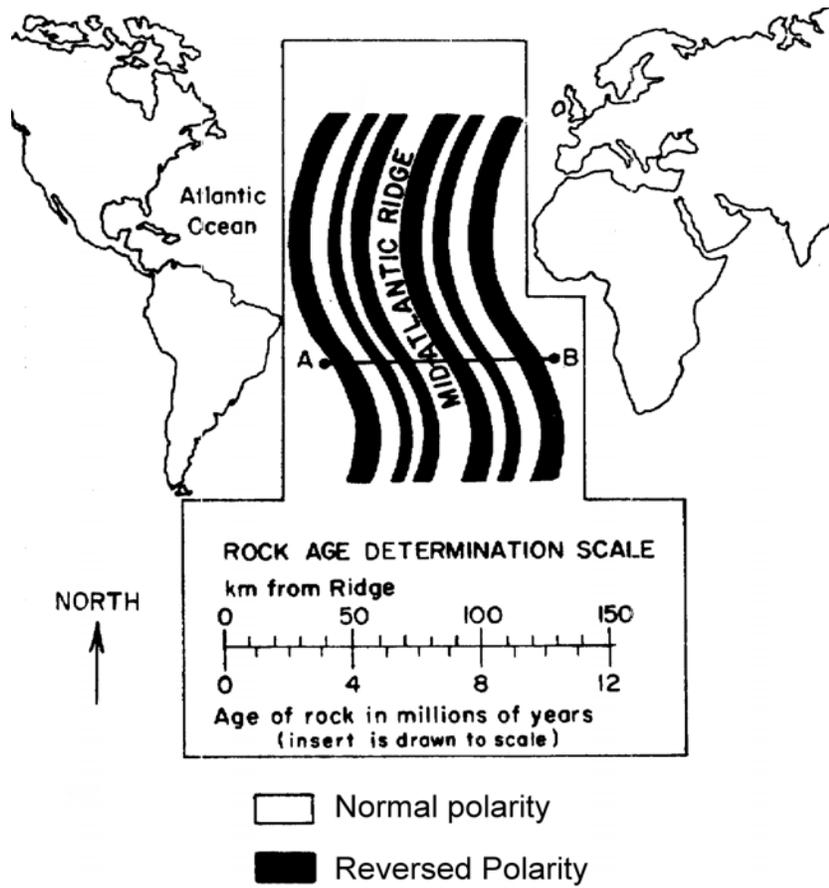
4) Age of the sea floor:

- a) Youngest rock at mid-ocean ridge where new sea floor is created.
- b) Oldest rock is found near continents where old sea floor is subducted and recycled.
- c) Rocks equidistant from the mid-ocean ridge in opposite directions are of the same age.



The rocks at location 'A' and 'E' are the oldest. The rocks at 'B' and 'D' are of the same age because they are equidistant from the ridge in opposite directions.

5) Paleomagnetism: Corresponding bands of “normal” and “reversed” magnetic polarity in the rocks on either side of the mid-ocean ridge.



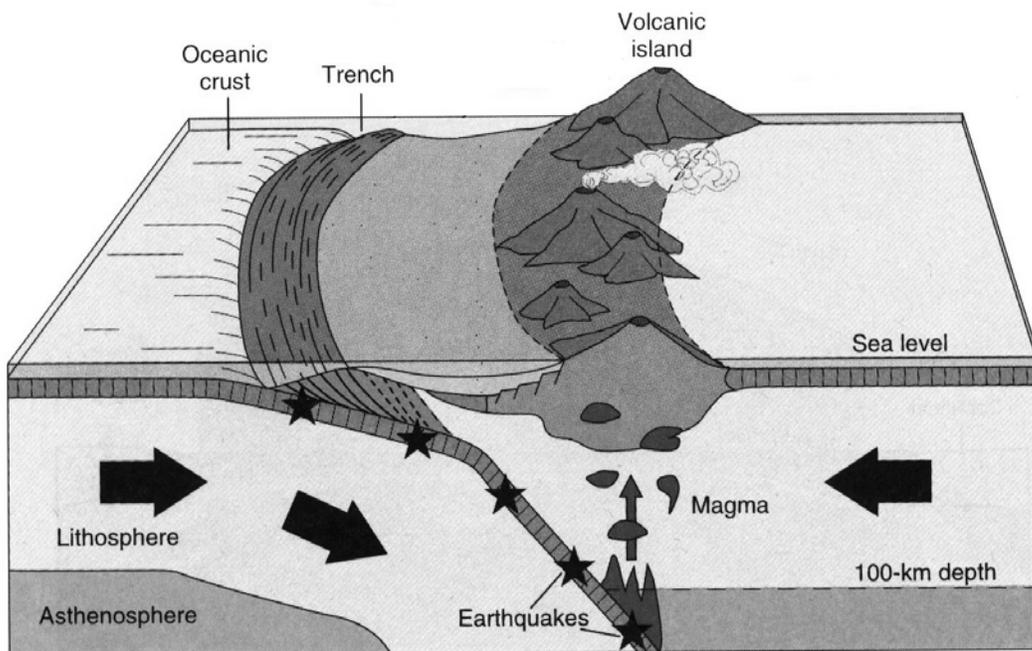
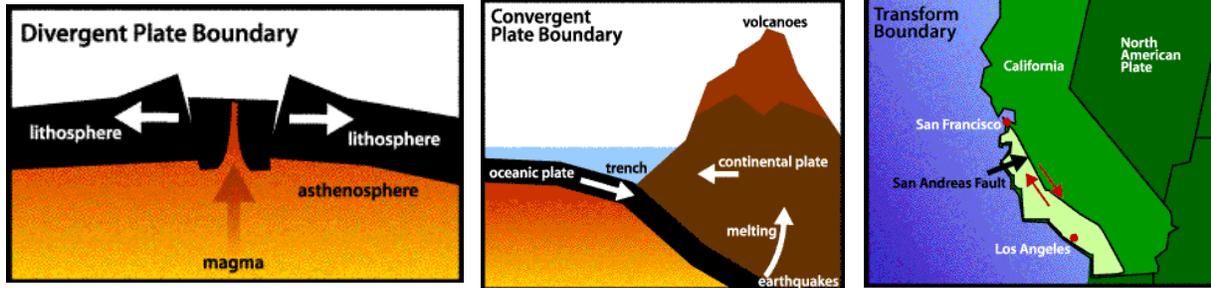
6) Actual laser measurement of the changing distance between continents. Measurements of the distance between North America and Europe made by bouncing laser beams off reflectors left on the moon show that continental drift continues to this day. The continents are moving at the rate of 2 - 3 cm/yr.

Plate Boundaries:

There are several kinds of plate boundaries (places where different plates meet)

- Convergent boundaries: 2 plates come together.
- Divergent boundaries: 2 plates move apart.
- Transform boundary: 2 plates slide past one another.

See map on page 5 of your reference tables.



This diagram shows a convergent boundary where basaltic oceanic crust meets granitic continental crust. Because the oceanic crust is more dense, it is subducted forming a trench. It sinks down under the continent back into the mantle where it melts. The melting magma rises causing volcanos and earthquakes in the region.

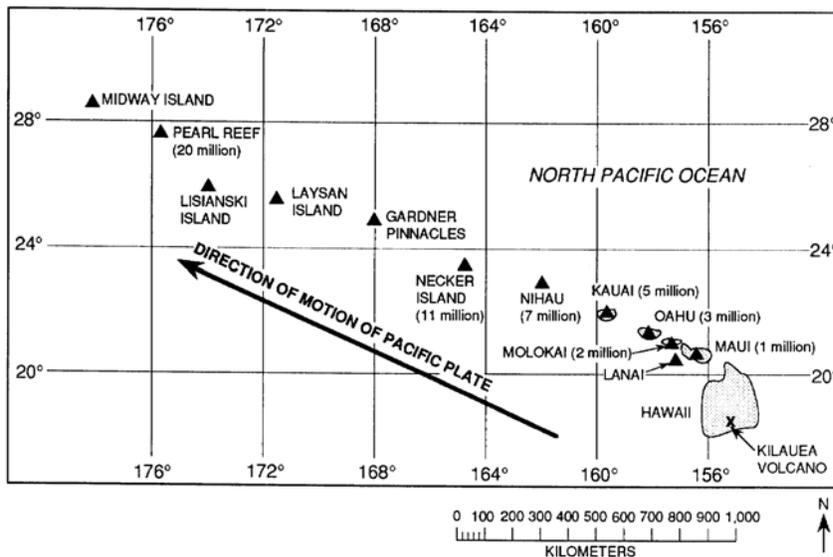
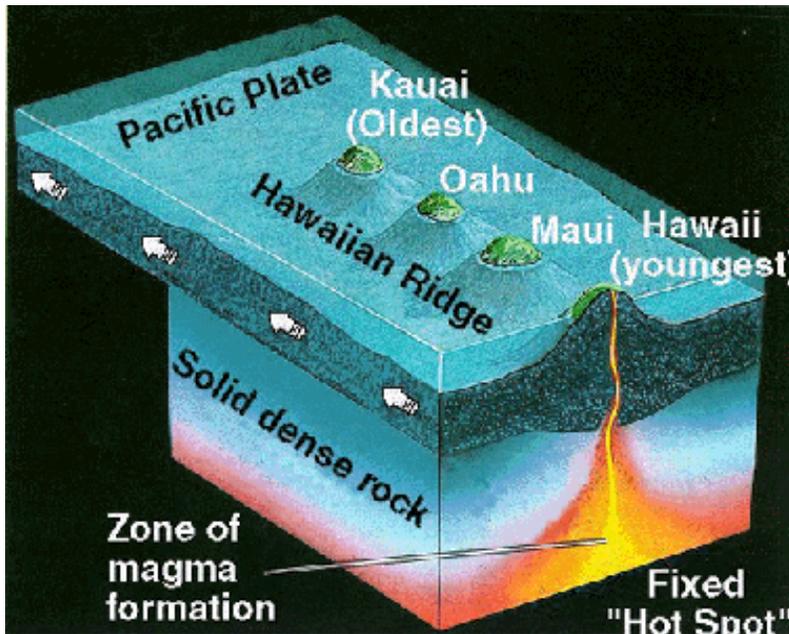
HOT SPOTS:

Hot spots are plumes of rising magma that come from deep within the mantle. These plumes are extremely stable lasting for millions of years and generally staying in one place.

While a plume may stay in one place, pieces of the crust drift over it. As a piece of the crust, oceanic or continental, moves over the hot spot volcanoes erupt and islands may form. As a volcano moves off the hot spot it becomes extinct (no longer erupts) and a new volcano may form on the crustal plate that is now over the rising plume of magma.

This creates island chains such as the Hawaiian and Galapagos islands.

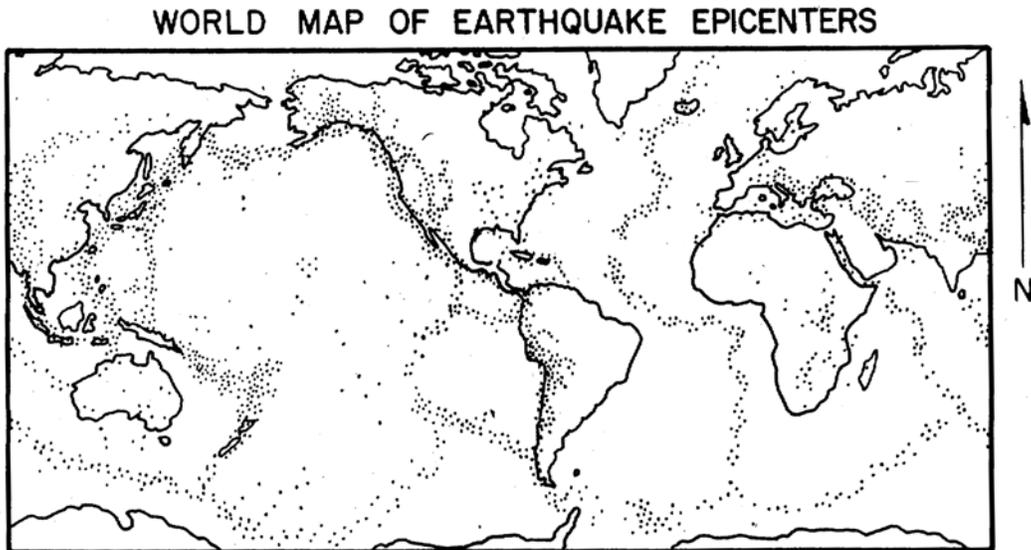
Closer to home, Yellowstone National Park is a collapsed volcano (a caldera) which is sitting over a hot spot. It is likely to erupt again someday.



Note that Kilauea is the youngest volcano and is still erupting because it is still over the 'hot spot'. As you look toward the NW, the islands become older and older. These are extinct volcanos which used to be where Kilauea is today but they have drifted, with the Pacific plate, off the plume.

EARTHQUAKES:

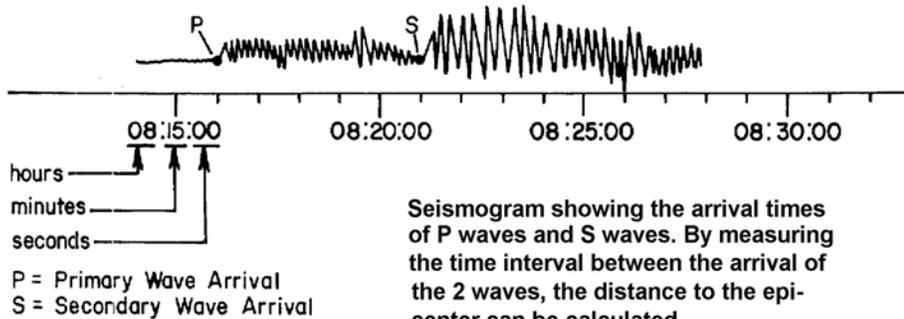
- 1) Earthquakes occur primarily at plate boundaries. They usually occur at shallow depths in the crust in regions where plates come together.
 - a) FOCUS: Point in the earth where the rocks slip causing an earthquake.
 - b) EPICENTER: Point on the surface directly above the focus.



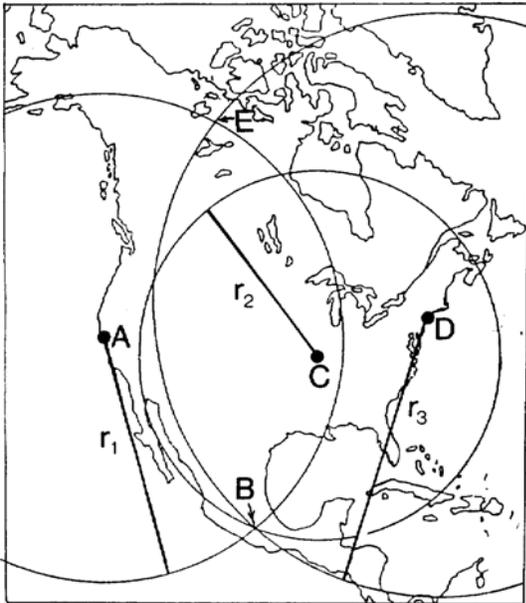
Dots represent earthquake epicenters.

Notice that the locations of earthquakes coincides with the map of plate boundaries on page 5 of your reference tables.

- 2) Earthquakes generate waves which move through the earth:
 - a) P (primary) waves - FAST - move through solids and liquids.
 - b) S (secondary waves - SLOW - do NOT move through liquids.
- 3) Earthquake waves are detected by instruments called seismographs
- 4) Seismographs make paper records of a quake called seismograms (see below)



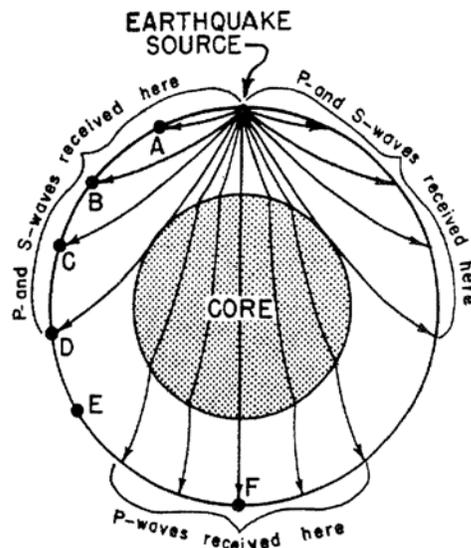
Data from one seismograph can tell you how far you are from an epicenter but it takes data from at least three seismographs to tell you exactly where an earthquake occurred. (see below)



'A' 'C' and 'D' represent the location of seismographs. Each circle shows the distance between the seismograph and the epicenter of an earthquake. The epicenter could be anywhere on a circle. But when three circles from three different seismographs are put together, the point where the circles meet is the location of the epicenter. Here, the epicenter of the earthquake is at location B.

- 6) Sometimes a seismograph may receive only P waves from an earthquake or perhaps no waves at all.
- If only P waves are received it is because the S waves were absorbed by the liquid outer core of the earth (remember, S waves cannot pass through liquids).
 - If no waves are received, it is because the seismograph is in a '*shadow zone*' for that particular quake:

A shadow zone is caused by the bending of earthquake waves as they move from one layer to another. Sometimes they are bent around a particular seismic station which would then receive no waves from that earthquake. See diagram'



How To Use The Earthquake Travel Time Chart (Reference Tables - Page 11)

1) Note:

- a) Distance (bottom axis) is in thousands of kilometers and that each thousand is divided into 5 smaller boxes so that each smaller box is 200 km.
- b) Travel time (vertical axis) is in minutes and each minute is divided into 3 smaller boxes so that each smaller box is 20 seconds.

2) Below are **ALL** the facts about a particular earthquake. Each problem will give you **SOME** of the facts and ask you to find **ONE** of the other facts.

FACTS:

- a) Time of quake: **1:20:40 PM** (20 minutes and 40 seconds after 1 PM)
- b) Distance from epicenter to seismic station: **5200 km**
- c) P wave travel time from epicenter to station: **8:40** (8 minutes and 40 seconds)
- d) S wave travel time from epicenter to station: **15:20** (15 minutes and 20 seconds)
- e) Difference in P - S wave arrival times: **6:40** (6 minutes and 40 seconds)
This is the time interval between when P waves arrived and when S waves arrived. The time between D and E or B and C on the chart.
- f) Time P waves arrived at the station: **1:29:20 PM** (The P waves would arrive 8 min. and 40 sec. after they started out. They started at 1:20:40 so just add 8:40 to their start time. But remember that you are adding seconds so 80 seconds = 1 minute and 20 seconds.)
- g) Time S waves arrived at the station: **1:36:00 PM** (The S waves arrived 15 min. and 20 seconds after they started which was 1:20:40. So add 1:20:40 and 15:20)

3) The problems:

- q1) How long will it take P waves to travel 5200 km?
 - a1) Find 5200 km on the bottom line (A). Go up to the P wave line (B). Go left to the vertical axis (D) and read the time: **8:40**

- q2) It takes P waves 8 minutes and 40 seconds to travel from the epicenter of an earthquake to a seismic station. How long will it take S waves to travel to the same station?
 - a2) Find 8:40 on the vertical axis (D). Go to the P wave line (B). Go straight up to the S wave line (C). Go left and read the time (E) **15:20**

- q3) If a seismic station is 5200 km from the epicenter of an earthquake, how long after P waves arrive will the S waves arrive?
 - a3) Find 5200 km on the bottom axis (A). Go up to the P wave line (B). Count the time interval between (B) and (C): **6:40**

- q4) A seismic station is 5200 km from the epicenter of an earthquake. The earthquake occurs at 1:20:40 PM. At what time will P waves arrive at the seismic station?
- a4) Find 5200 km on the bottom axis (A). Go up to the P wave line (B). Go left and read the time on the vertical axis (D). The time you should read is 8:40. This is how long the P waves must travel to reach the station. If they started out at 1:20:40 then you must add the travel time to this value:

$$\begin{array}{r}
 1:20:40 \\
 + \quad 8:40 \\
 \hline
 \underline{1:29:20}
 \end{array}$$

Remember that when adding seconds, each 60 seconds is a minute. 80 seconds is one minute and 20 seconds.

- q5) P waves arrive at a seismic station at 1:29:20 PM. S waves from the same earthquake arrive at 1:36:00 PM. How far is the seismic station from the epicenter of the earthquake?
- a5) First we must find the ***difference*** in arrival times between P and S waves.

$$\begin{array}{r}
 1:36:00 \\
 - 1:29:20 \\
 \hline
 6:40 = \text{the difference.}
 \end{array}$$

Now find the place on the graph where the space between the P and S lines is 6 minutes and 40 seconds*. This is exactly between B and C. Follow the line from C to B straight down and read the distance: **5200 km**

Helpful hint. To quickly find the place where the difference between the P and S lines is 6:40, do this: Take a blank sheet of paper and place one edge on the vertical axis (time). Mark off two points on the paper: 0 and 6:40. Now slide the paper keeping the 0 mark on the P line. Keep the edge of the paper straight. When the 6:40 mark is exactly on the S line look straight down the edge of the paper. It should be on the 5200 km mark.

Earthquake P-wave and S-wave Travel Time

