Lab 2: Plate tectonics

Plate tectonics is the theory that is used to explain geological phenomena worldwide. For this reason, most of the useful maps that illustrate plate tectonics are world maps, including the two you will use for this lab. Chapter 3 in the text may also be a source of answers for this lab. You may also wish to use web resources.

The Earth's Dynamic Crust map

1. (O) The text classifies all tectonic plate boundaries as either divergent, convergent or transform. Using the definitions of those terms from the text or from the map, categorize each of the interactions shown at the bottom of the “Dynamic Crust” side of the map. “None of these” is also an option.

| Spreading — | Faulting — |
| Subduction — | Accretion — |
| Collision — | Hot Spots — |

2. (O) The text dances around this topic because it has not discussed rock names yet, but the oceanic plates are principally made of a rock called basalt and the continental plates are principally made of a rock called granite.

a. The Arabian plate is most likely made of which rock?

b. The Nazca plate is most likely made of which rock?

c. Give the name of a plate that might be half granite and half basalt.

3. (I) Note that the subduction plate boundaries are always arranged so that the “teeth” of the boundary (see the symbol used for subduction zones on the map) are pointing at the continental plate. What property of the rocks that make up both plates at the boundary might result in the same consistent orientation (in other words, why does the continental plate always subduct the oceanic plate?)?
The Plate Tectonic Map of the Circum-Pacific Basin Region

This is a classic map that summarizes a recent (1985) state of knowledge about plate tectonics in the Pacific Rim (it’s not called the “Ring of Fire” for nothing, you know). Unfortunately, the American Association of Petroleum Geologists (AAPG) no longer prints this, so please be careful (especially folding it and not writing on it)!

4. (O) This map, like the previous one, shows **bathymetry**; darker shading indicates deeper water depths. Find the **East Pacific Rift**. Is this a ridge or a valley in the ocean? Does it ever exceed sea level? Read "Explanations" and determine what kind of **plate boundary** this rift is.

5. (O) What **compass direction** is the Pacific Plate moving near the East Pacific Rift? (I) So would **older** ocean floor be found to the west or to the east?

6. (I) Why does the ocean floor get **deeper** the **further** you are away from the rift? Hint: the weight of the overlying ocean is not relevant, but its temperature is!

7. (O) What do you notice about the **depth** (shallow or deep) and **number** (many or few) of earthquakes which occur near or at rifts, compared to other tectonic boundaries? (I) Why might this be so?
8. Consider the map of the world above (courtesy of the US Geological Survey using infrared spectroscopy from a satellite), which shows the heat flow out of the Earth at various spots. The units of the numbers for the shading given on the map are milliwatts of energy emitted per square meter. (I) Considering your answer to question 6, what tectonic phenomenon is causing the areas with high heat flow on this map? What does your answer suggest about the proximity of molten or at least semi-molten material in these areas?

9. Another way to view where hot material is rising in the asthenosphere is by using seismic (earthquake) wave speeds. The speed of a seismic wave is proportional to the density of the material it is traveling in. In other words, the denser the material, the faster the seismic wave spreads. In other words, seismic waves traveling through hotter (and therefore less dense) material tend to show up at a seismometer later than expected.
a. The lower diagrams (courtesy of Yuancheng Gung and Barbara Romanowicz, 2002, at UC Berkeley) show seismic wave velocities along two lines of cross-section shown (M to N and S to T) through the southern Atlantic Ocean, Africa and the Indian Ocean. The cooler colors represent denser (cooler) rocks and the hotter colors represent less dense (hotter) rocks. (O) What is the evidence for the mid-Atlantic ridge being an area with hot rocks (and would therefore confirm the heat flow map)?

b. (O) The big red tongue of flame in the lower mantle on the M-N cross-section is called the “African Superplume”. Using your textbook or any plate tectonic map that shows this area of the world, find out what (if any) hotspot this superplume directly feeds, or fed. (I) What does this suggest about the likelihood of continental hotspots being directly fueled by core-mantle boundary instabilities that result in superplumes?
10. One of the classic ways in which researchers found evidence for plate tectonics was by looking at the **paleomagnetism** of ocean floor rocks. When the rocks crystallized at the rift, the iron minerals aligned with the prevailing magnetic field at that time, and as the plate spread away from the rift, this magnetic orientation was preserved. Viewed from above by the right equipment, the preserved magnetic grain orientations look like stripes, as shown below.

![Diagram of paleomagnetism](image)

a. (O) Find the **magnetic stripe** labeled "3" near the East Pacific Rift south of the Wilkes Fracture Zone. What is the **distance** from the middle of the stripe to the middle of the rift (in kilometers)?

b. (O) How **old** is this magnetic stripe (in millions of years (My))? Hint: look for the magnetic timescale in the "Explanations" section.

c. (I) Divide the answer to part a) by the answer to part b) and you obtain the **speed** of the Pacific Plate in km/My. (Remember that distance/time = speed) Divide this result by 10 to convert the speed into units of centimeters per year (cm/yr).

d. (O) What is the speed of the plate, according to the map (first of all, are the colored or clear arrows the ones you want to look at?)? What are the **units** of speed of the numbers on the map? How does it compare to your number (give a rough percent estimate of how your values differ)?
11. (O) Look for the corresponding magnetic stripe "3" on the other side of the Rift. Is the spreading perfectly symmetric? (I) If not perfectly symmetric, suggest a reason why this is not so.

12. (O) What type of **plate boundary** is the Mendocino Fracture Zone? Hint: look at what happens to the magnetic stripes across the fracture zone. (O) **Draw** a little map of the area which shows the fracture and indicate relative motion with arrows.

13. (O) Does the map show the Mendocino Fracture Zone to be an **active** feature? Give an estimate of the length of time (in My) that it was active. Hint: Look for magnetic stripe lines that meet at the fracture, then determine the difference in age between those stripes!

14. Find the west coast of South America.

   a. (O) What is the long **linear** geographic feature in the ocean near here?

   b. (O) What is the long **linear** geographic feature on the coastal land?

   c. (I) What type of **plate boundary** is this? (convergent, divergent or transform?) How can you tell?
15. (O) Determine the approximate distance from the trench to the volcanic arc for the Cascades (the trench is where the thrust is mapped). Do the same for the Andes in South America.

Cascades: 

Andes:

16. One of the reasons for the difference in distance in the previous question is that the subducting slab must descend to a certain depth before the melting of any rock will occur. Thus, the angle off of horizontal (the dip angle) at which the slab descends is critical in determining the trench-volcanic arc distance. (I) Develop a general rule connecting the trench-volcanic arc distance and the steepness of the dip angle of the subducting slab.

17. Another way to determine where there are hot rocks and where there are cool rocks is to use geodesy, the extremely precise measurement of the Earth’s surface level to determine if a particular area is higher or lower than it ought to be, given the Earth’s rotational and gravitational shape.

a. (O) The Farallon Plate shown in the diagram is the larger plate that the present Juan de Fuca Plate was part of. Is the Farallon Plate (now mostly subducted)
subducting at a steep or shallow angle? Does this confirm or contradict your answer to question 16?

b. (I) Examine the subduction angle of the lower part of the slab of the Farallon Plate. Notice that it is “sinking” nearly vertically toward the core. Suggest a mechanism besides convection that might be moving the Juan de Fuca/Farallon Plate. Hint: The text (page 72) describes two tectonic mechanism hypotheses but does not give them names; the first hypothesis is called “slab pull” and the second is called “plate sliding”.

c. (I) Would you consider the diagram on the previous page evidence for what the text calls “whole mantle convection”?

d. (I) Find the African Superplume in the diagram on the previous page. Note that it rises up and appears to end at a second level of cold rocks under the African Plate. Given the phrase “underplating”, what is happening to the rising hot rocks of the superplume?

18. (O) Trace the magnetic stripes 26 through 32B off the Aleutian Islands. Note that the bend significantly. (I) If these stripes are laid down parallel to spreading ridges and if spreading ridges are linear, why do magnetic stripes “bend”? Hint: Look at the southwestern part of the Cocos Plate for similar current activity.
19. a. (I) Find the **Galapagos Islands** near South America. Did plate tectonics play a role in their origin? If you do not believe so, then what origin do they have?

b. (O) Are they older or younger the further east you go along the islands? (I)
What role did plate tectonics play in this?

c. (I) **Name** the feature nearest us that is similar to the Galapagos feature.

20. a. (O) The fate of the **Cascades**: Off our coast, the __________________ plate is being subducted by the _________________ plate.

b. (O) Assuming that the divergent boundary is more or less stationary, how fast is the North American plate approaching it, in centimeters per year? Hint: should you be looking at the colored or clear arrows now?

c. (O) According to the map, how far (in kilometers) from the trench (thrust) currently is the last part of the **Juan de Fuca Plate** that will be subducted? Convert this number to centimeters. 1 km = 1000 m = 100,000 cm

d. (I) Divide your answer to c) by your answer to b) to obtain the number of years it will take to completely subduct. Math formula: time = distance/speed.

e. (I) What happens to the Cascades after this number of years elapses?
Extra credit metaquestion: Why were some of the questions labeled with an (O) and others labeled with an (I)?