

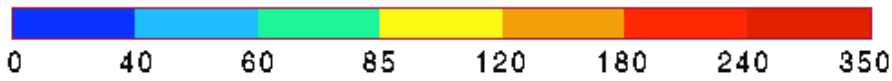
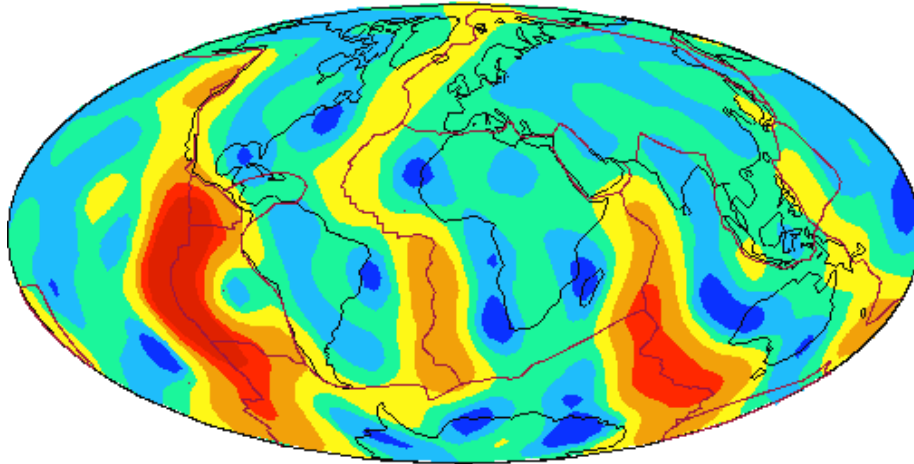
Lab 8: Plate tectonics*The Plate Tectonic Map of the Circum-Pacific Basin Region*

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)! Other sources that might help *conceptually* are the *Physical Earth* map and the *Shaping of a Continent* map, both published by the National Geographic Society. **Please use the numbers off of the AAPG map, though.**

1. a. (O) This map 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.

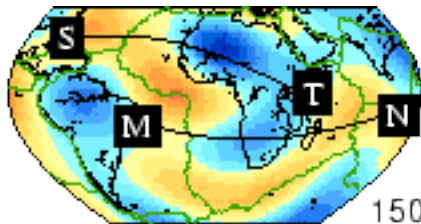
b. (I) What **rock** would you expect to see a lot of here? (Hint: it's oceanic lithosphere material)
2. (O) What **compass direction** is the Pacific Plate moving near the East Pacific Rift? (I) So would **older** ocean floor be found to the west or to the east?
3. (I) Why does the ocean floor get **deeper** the **further** you are away from the rift?
4. a. In fact, the map of the world on the next page (courtesy of the US Geological Survey), which shows the **heat flow** out of the Earth at various spots, should confirm your idea in question 3. The units of the numbers for the shading given on the map are milliwatts per square meter. (I) What kind of **spectroscopy** (in other words, what form of **electromagnetic radiation**) allows this type of information to be obtained?

Heat Flow

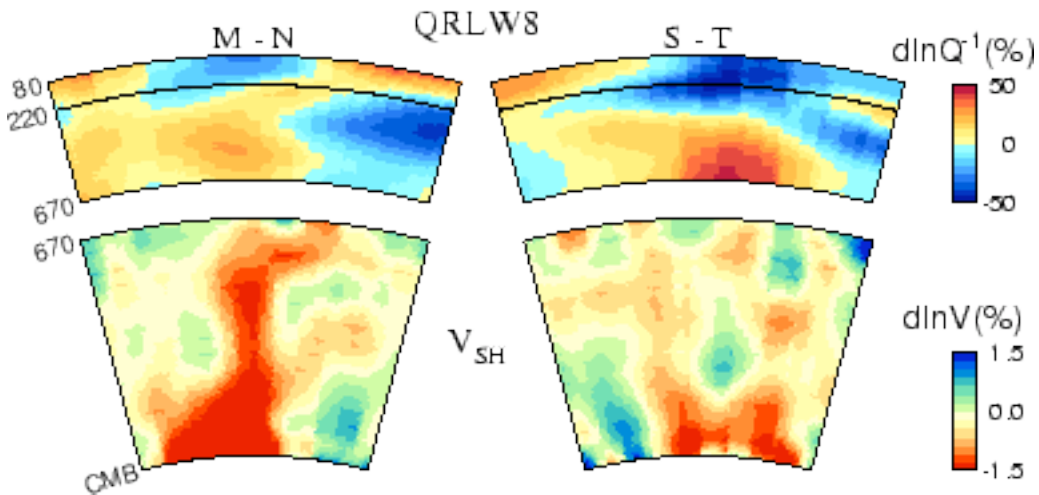


mW m^{-2}

b. (O) Back on the plate tectonic map, what do you notice about the depth and number of earthquakes which occur near or at rifts? (I) Why might this be so?



150 km

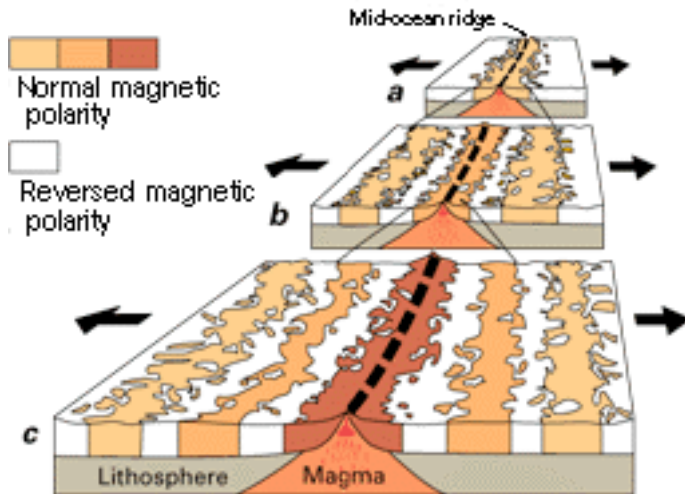


5. Another way to view where hot material is rising in the asthenosphere is by using **seismic wave speeds**. Recall from the previous exercise that the speed of a seismic wave is proportional to the density of the material it is traveling in. In other words, the denser the material, the faster the seismic wave spreads. In other other words, seismic waves traveling through hotter (and therefore less dense) material tend to show up at a seismometer later than expected.

a. (O) The diagrams on the lower half of the previous page (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. Is there **evidence** for the mid-Atlantic ridge being an area with hot rocks (and would therefore confirm the heat flow map)? **Circle** these confirming areas on the cross-sections.

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?

6. 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.



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)?

7. (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.

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

9. a. (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.

b. (O) Name the currently active feature of this plate boundary type *closer* to us than the Mendocino Fracture Zone. (I) What **larger active feature** might this currently active area become part of, perhaps in three million years?

10. Find the west coast of South America.

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

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

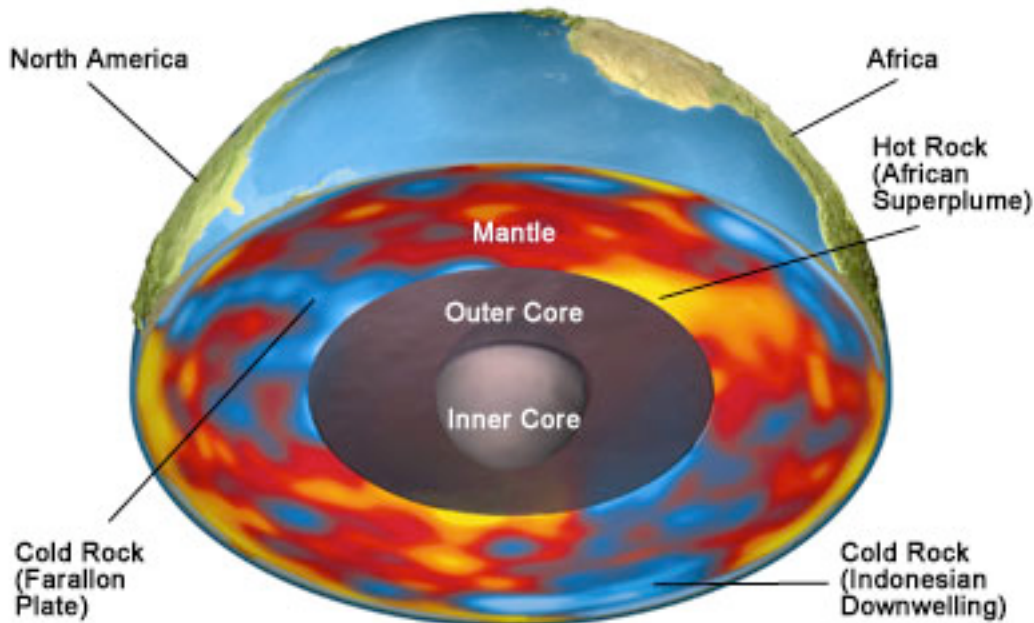
c. (I) What type of **plate boundary** is this?

d. (I) What is the most likely **volcanic rock** to be found in the mountains here (Hint: think of the name of the mountains)?

11. (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. (I) Why are these distances different?

12. (I) Develop a general rule connecting the trench-volcanic arc distance and the steepness of the **dip angle** of the subducting slab.

13. (O) What happens to the **depth** of **earthquakes** as you go further inland? Hint: see "Explanations" for a depth chart and earthquake symbols. Are the deepest earthquakes further to the east in the Cascades or in the Andes? Does this confirm your rule in question 12?



Space-based geodetic observations provide detailed information for understanding deformation of the tectonic plates and the fluid behavior of the mantle below. Image courtesy of David Fierstein.

14. 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 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 12?

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.

15. (I) Find the **African Superplume** in the diagram above. 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?

16. (I) In the previous diagram, note that the layer of cold rocks directly under the African Plate has an area in its middle where it is quite thin and/or warmer. This is the southern extension of the **East Africa Rift**. Suggest what the underplate does to the viability (continued existence) of the East Africa Rift.

17. a. Find the plate boundary along the **Aleutian Islands**, and the plate boundary off **Tonga Island** in the south Pacific. (I) Which has the more steeply subducting slab and how can you tell?

b. (I) Why are there no volcanoes west of 175° E longitude on the Aleutian Islands?

18. 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) How fast is this convergence occurring 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: $\text{time} = \text{distance} / \text{speed}$.

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)?