

Not attempting to answer questions on expeditions will result in point deductions on course workbook (**two or more blank answers** will result in a deduction of 5 points; a 10 point deduction will be assessed if **more than five answers** are left blank).

**Objectives:** Learn about the global distribution of earthquakes and volcanoes in both space and time, which is central to our understanding of plate tectonics, the formation of the seafloor, movement of the lithospheric plates, and interactions at the boundaries between plates. The movement of the seafloor, caused by underwater earthquakes poses significant threat to communities along coastal California.

### Information

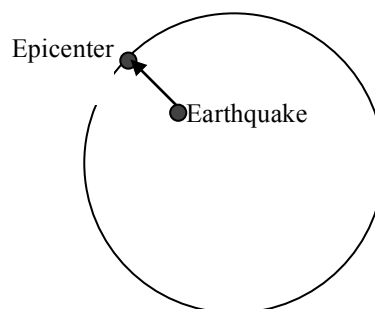
The images of epicenters in this expedition were derived with the computer program SEISMIC/Eruption (version 1.2). The author of the program, Alan Jones (<http://www.geol.binghamton.edu/faculty/jones/>), provides this software for free -- it is pretty cool.

**Important terms and concepts for you to understand for mid-term exam are underlined and contained in the questions and maps.**

## 1. Introduction



The screens that follow will show the distribution of the surface locations of earthquakes, or **epicenters**. We will see that most of these earthquakes are located under the sea or along the coasts -- corresponding to the location of plate boundaries.

Earthquakes occur within the Earth down to a depth of 670 kilometers, in other words in the crust or upper mantle.... in fact, **only in the lithosphere**. The diagram below shows how the location of the earthquakes within the earth is projected upwards, towards the Earth surface, to determine the location of the epicenter.



## 2. Global Distribution

A map of the world's topography will be displayed on the screen.

- Take note of the symbols for the various sizes of earthquakes (along left margin of graphic -- larger magnitude - larger dot size), 
- The depths of earthquakes, below the surface of the Earth, are given by the color of the dot ,
- Locations of volcanoes are shown by triangles 
  - The large number of earthquakes, more than 50,000 since 1960 with magnitudes greater than 5, and volcanoes are testaments to the dynamic nature of the Earth

**Are the earthquakes distributed randomly about the earth's surface or do they occur in specific regions?**

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Earthquakes can only occur in "strong rock" where stresses (forces) can build up to the point to cause the material to fracture, thereby sending seismic waves through the Earth....and strong rock only is found in the rigid lithosphere...deeper in the Earth the temperatures are too high allowing the rocks to flow rather than fracture.

## 3. Earthquakes and Plate Boundaries

You now see the boundaries between the major plates of lithosphere that compose the outer rigid shell of the earth. The plates are composed of the crust and the upper 50 kilometers or so of the mantle. This outer shell is on average between 80 to 100 kilometers thick beneath the oceans, but is much thinner at the mid-ocean ridge where the oceanic lithosphere and sea floor of the abyssal plains are created by sea floor spreading. The lithosphere under the continents (continental lithosphere) is much thicker than under the oceans, reaching a thickness of 125 kilometers to 200 kilometers, although its base is poorly defined by seismological analyses beneath many continents.

**How does the distribution of earthquake epicenters compare to the locations of the boundaries between the plates?**

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Why is this the case?

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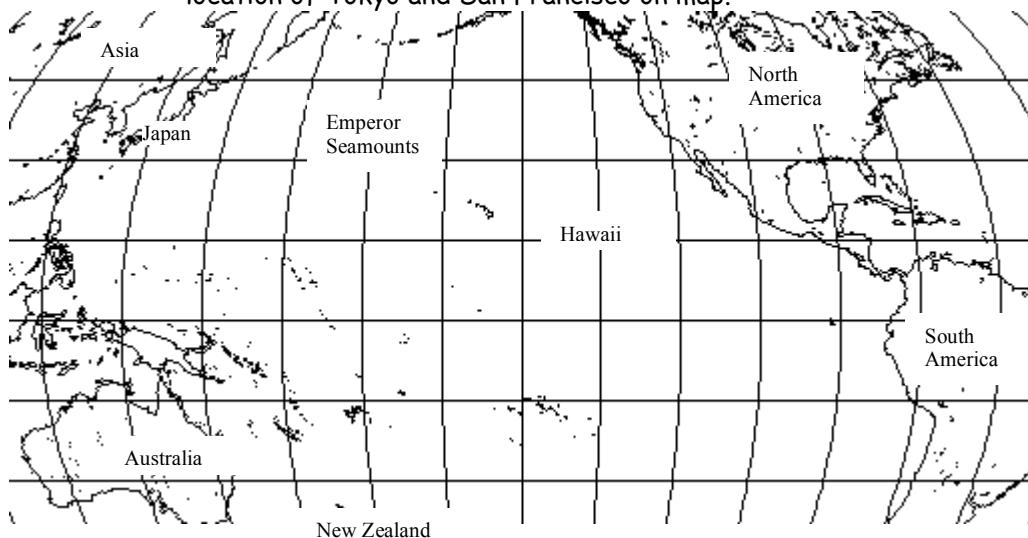
The distribution of many mountain ranges, both on land and offshore, follows the distribution of modern and ancient plate boundaries. Clearly the plate boundaries mark sites of plate deformation and upheaval.

In a previous expedition you located nine of the plates, such as the North American, South American, Eurasian, African, Pacific, Indian-Australian, and Antarctic. These are only a few of the major plates in this picture.

#### 4. The Pacific Ring of Fire

***So many earthquakes -- they are everywhere around Pacific Rim***

Draw a rough sketch of the distribution of the epicenters around the Pacific and label the continents on your sketch. Include the location of seamount chain which extends northwest from the Hawaiian Islands, and bends to the north; this string of volcanoes (active on the Big Island and inactive elsewhere) is the Hawaiian-Emperor seamount chain. Draw in location of Tokyo and San Francisco on map.



**Where are the largest magnitude earthquakes located? (Use size of dots)**

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The locations of deep earthquakes in the western and northern Pacific, down to as deep as 670 kilometers within the Earth, lie along the western edge of the Pacific Plate -- from Russia southward to New Zealand.

The depth of these earthquakes, combined with the rapid northwest movement of the Pacific plate (remember problems at end of the expedition on plate motions) provide evidence that the plate is being pulled to the northwest by slabs of lithosphere that sink down subduction zones in the western Pacific. Oceanic lithosphere, because of its high density when it gets old and cold, sinks back into the mantle at subduction zones along convergent plate boundaries.

Thus the Pacific plate is created at mid-ocean ridges along its eastern margin at the East Pacific Rise and Juan de Fuca Ridge, travels to the northwest and ultimately is recycled into the Earth by subduction along its western and northern boundaries.

**For the subduction process to take place how must the density of the lithosphere compare to the density of the asthenosphere?**

\_\_\_\_\_

**How might the density of the oceanic lithosphere change with age? \_\_\_\_\_**

\_\_\_\_\_  
(Hint: consider the effect of temperature on density - remember it floats on the asthenosphere when it is hot and young)

**How deep are the deepest earthquakes around the Pacific? \_\_\_\_\_**

### 5. The Ring of Fire and Convergent Plate Boundaries

The distribution of earthquakes and volcanoes around the Pacific Rim is known as the Ring of Fire and outlines the region of some of the largest earthquakes ever recorded. This ring of earthquakes coincides with a ring of active, explosive volcanoes (triangles), such as Mount Pinatubo (and many others) in the Philippines, the volcanoes in Japan and Alaska, Mount St. Helens, Mount Shasta, and Mount Lassen in the northwest U.S. (including California), and the volcanoes located throughout Mexico, Central and South America.



Mt. Shasta in Northern California

Also, take note of the shallow earthquakes along the East Pacific Rise (the mid-ocean ridge in the eastern Pacific).

## **6. Earthquakes Below the Atlantic Ocean**

The boundary in the middle of the Atlantic Ocean separates the North American and Eurasian plates and lies along an underwater volcanic mountain range called the Mid-Atlantic Ridge. This boundary is composed of north-south oriented divergent boundary segments, which are sites where oceanic lithosphere is created by seafloor spreading, and east-west-trending transform segments marking regions where the plates slide by one another. Transform plate boundaries in ocean basins extend laterally into fracture zones, which are not fault zones, but instead mark the boundaries between oceanic crust and lithosphere of different ages within the same lithospheric plate.

**Describe three ways that the earthquakes beneath the Atlantic Ocean differ from that shown beneath the Pacific Ocean?**

1. \_\_\_\_\_
2. \_\_\_\_\_
3. \_\_\_\_\_

**Why are the earthquakes shallow in the middle of the Atlantic and what does this information say about the thickness of the lithosphere at mid-ocean ridges? (remember that earthquakes only occur in the rigid lithosphere)**

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**Why are there few earthquakes along the margins of eastern North American or western European continents?**

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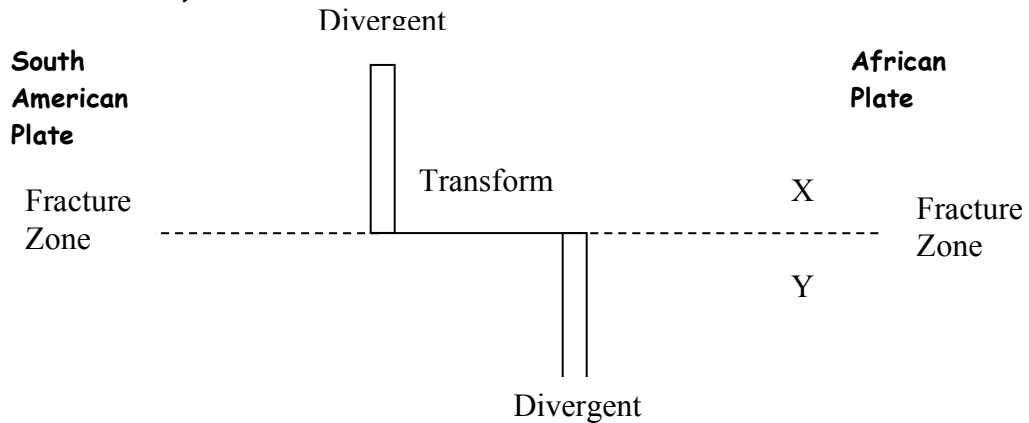
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## 7. Earthquakes and Plate Boundaries Beneath the Atlantic Ocean

Examine the sketch below looking down on two divergent plate boundary segments that are connected by a single east-west trending transform fault.

You are looking down on the seafloor. Note the fracture zones that extend away from the ends of the transform faults.

Put arrows on your diagram showing the direction of plate motion (remember that plates move parallel to transform faults and away from divergent plate boundaries).



Find the X on the north side of the fracture zone on the right side of the diagram and the Y directly across from the X, on the other side of the fracture zone

Which letter lies on the older oceanic crust? \_\_\_\_\_

Which letter lies on the colder oceanic crust? \_\_\_\_\_

Which letter lies on oceanic crust of greater density? \_\_\_\_\_

Which letter lies at a greater water depth along the sea floor? \_\_\_\_\_  
 (Hint: Remember the equation from a previous expedition,  $D=2500 + 350 T^{1/2}$ )

Why are there few, if any, earthquakes located along the fracture zones in the Atlantic?

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### 8. The Great Alaskan (1964 Good Friday) Earthquake

The large magnitude event (9.2) was the largest earthquake recorded in the U.S. during this century, and occurred on Good Friday in 1964. Note the location of the plate boundary, which marks the Aleutian Trench and the gray triangles marking the volcanic arc -- **What type of plate boundary is located here?**

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### 9. A Vertical Slice through a Convergent Plate Boundary

Here you see a vertical slice through the Aleutian subduction zone.

Here you see a vertical slice through the top 200 kilometers of the Earth's surface in Cook Inlet oriented with southeast on the right and northwest on the left. The axes on this plot are in kilometers.

Make a drawing of the earthquake distribution with an outline of the subducting Pacific Plate and the overriding North American plate.

-100                      -50                      0                      50                      +100



Notice the distribution of earthquakes with depth.

The dipping region of earthquakes shown here is called the Wadati-Benioff Zone or just Benioff Zone. These earthquakes show the oceanic lithosphere of the Pacific plate sinking back into the asthenosphere by the subduction process. The shallow earthquakes in the upper right corner are located near the Aleutian Trench, which marks the boundary between the North American and Pacific plates along the sea floor. This type of plate boundary is known as a convergent plate boundary.

### 10. Oooh....Ah!!!! 3-D Look

Now you can see the geometry of the subducting oceanic lithosphere of the Pacific plate in 3-dimensions.

### 11. California Earthquakes and Plate Boundaries

Here we see the distribution of earthquake epicenters along California. The locations of earthquakes along the coast of central and northern California mark the San Andreas fault system, which is a transform plate boundary between the Pacific and North American plates along California between San Diego and San Francisco.

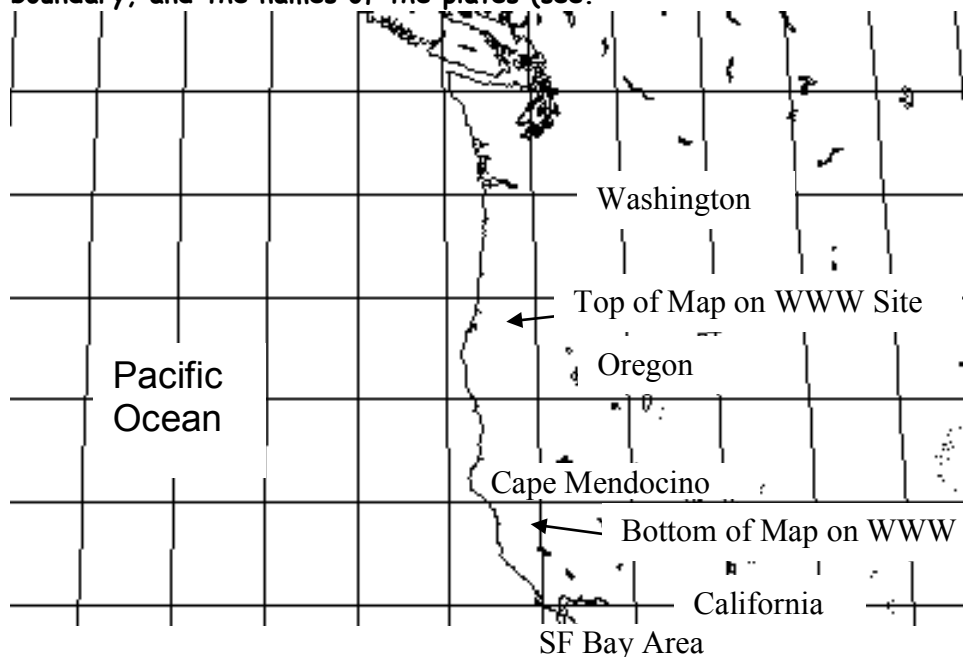
What type of plate boundary lies beneath the ocean only a few miles to the west of San Francisco?

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### 12. Mendocino -- Three Plates in Contact

The high concentration of earthquakes at Cape Mendocino marks the boundary between three plates, the North American plate to the east, Gorda (partially enclosed by the yellow line) lying to the west of Oregon, Washington and northern California, and the Pacific plate to the west of California. The Gorda plate is considered by some people to be the southern part of the Juan de Fuca plate (mentioned in "Commotion beneath the Ocean" expedition).

The intersection of three plates occurs at a point known as a triple junction. **Draw on the diagram on the next page the location of the triple junction, each plate boundary, and the names of the plates (see.**



Notice that there are many earthquakes within the Gorda Plate -- is this deformation consistent with our discussion of rigid plates in plate tectonics?

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Label the types of plate boundaries on the map

Are there many earthquakes along the eastern boundary of the Gorda Plate?

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What type of plate boundary lies here?

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**13. Could It Happen Here?**

What two observations are surprising about the distribution of earthquakes along the plate boundary that is closest to the coasts of Oregon and Washington?

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Read News Article on WWW page - Read "Gigantic Quake Dated to 1700: Japanese scientists pinpoint day and hour too"

**List each piece of evidence in support of this hypothesis:**

1. \_\_\_\_\_

2. \_\_\_\_\_

3. \_\_\_\_\_

4. \_\_\_\_\_

5. \_\_\_\_\_

**14. Are You Prepared for Another 1906?**

How have you prepared for the next major earthquake in bay area?

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**15. 2011 Japan Earthquake - Take Notes on the significance of this earthquake**

a. Where did it occur? \_\_\_\_\_

b. What is the type of plate boundary? \_\_\_\_\_

c. What was the magnitude? \_\_\_\_\_

d. What is the seafloor feature in region? \_\_\_\_\_

e. Have destructive earthquakes in this region before? If so, when?

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**What questions are being addressed by scientists studying this earthquake?**

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**1 minute essay - Summarize what you learned in this expedition - Avoid the "I learned a lot about" syndrome - show some insight**

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**Post Any Questions in "Exped. 9 Shakin - Any Questions" Desire2Learn Discussion**

**In order to receive credit for completing this expedition and gain access to the answer key,**

**Go to Desire2Learn Email and send "Bye Don"**

- **"End Expedition 9" in Subject Line. (VERY IMPORTANT)**
- **Include "Bye Don" in body of email,**
- **Include "Completion Word" (see last page of expedition) and write your name in body of e-mail message**

