

*Objectives:*

* To identify geologic structures and activities that occur at the three different type of plate boundaries.
* To name the lithospheric plates and identify the different types of plate boundaries found in the Pacific Northwest, off the west coast of the United States.
* To understand how and why earthquake depth and magnitude vary with the type of plate boundary and associated plate motion.
* To use data and knowledge of processes at mid-ocean ridges to make predictions of future seismic and eruption events.
* To interpret maps, analyze graphs, and apply knowledge gained from a set of data to make predictions and support those predictions with a rationale.

Recall from Lab 2 that the edges of the plates, where one plate meets another plate, are called plate boundaries. Plate boundaries where plates move away from each other are known as **divergent plate boundaries**. Mid-Ocean Ridges form at divergent plate boundaries as new ocean floor is formed and moves away from the ridge in a process known as seafloor spreading. Small transform faults form along ridges that result in shallow, small earthquakes. Plate boundaries where plates move toward each other are known as **convergent plate boundaries**. If there is ocean floor on the edge of one converging plate and continental crust on the edge of the other plate, this oceanic to continental convergence will result in the ocean floor being subducted under the continent. **Subduction zones** are characterized by deep ocean trenches and volcanic islands and result in deep, large earthquakes as the subducting plate grinds down towards the earth’s interior. Plate boundaries where plates slide past each other are known as **transform plate boundaries.** Large magnitude but shallow earthquakes occur at these transform boundaries as the plate grind past each other, lock up and release.

*Exercise 1: Plate Boundary Features:*

Go to the [Plate Boundary Features - Exploration](https://datalab.marine.rutgers.edu/explorations/geology/activity1.php?level=exploration)

(<https://datalab.marine.rutgers.edu/explorations/geology/activity1.php?level=exploration>) activity to use earthquake data (magnitude) from 2010 to 2017 to try to identify any patterns or features along plate boundaries. When the site loads, you will be viewing a map of the Pacific Northwest- the Pacific Ocean off the coast of Washington and Oregon.

Practice interacting with the graphs. You can interact with the data by:

* Selecting a different part of the time series to explore the data in ways that interest you by moving the highlighted section of the bottom graph to the right or left.
* Zooming in and out of the data to look at different time scales that interest you by changing the width of the highlighted section of the bottom graph (it loads with all of the data highlighted).
* Zooming in and out of the map to see more or less of the area of the ocean the earthquakes occurred.

1. Answer the following questions about the graphs:
   1. What variable appears on the x-axis? What is the range of that variable?

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* 1. What variable appears on the y-axis? What is the range of that variable?

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* 1. What do the colors of the circles shown on the graph represent?

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* 1. What do the size of the circles on the map represent? \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
  2. Is there a pattern to the location of the earthquakes or do they seem to occur in random locations? If you see a pattern, describe the pattern.

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* 1. Why do you think this pattern exists? Think in terms of plate tectonics and predict what features would be found in this section of the ocean. Explain your hypothesis:

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1. Be sure you are at the appropriate level of zoom on the map so that the box with the data takes up most of the center of the map, but the entire box is visible on the map. Adjust the zoom using the + and – buttons on the top left of the map if necessary. Print the “Labeled Map of the Pacific Northwest Plates” (pg 9) and hold it up to the computer monitor and line up the printed map with the map on your screen (Hint: pay attention to the island at the top of the map and the coastline). Hopefully you can still see the picture on your computer monitor through the printed map; if not, just use the printed map as a reference by comparing it to what you see on your screen.
   1. Look at the map of the Plate boundaries on the print-out and list the four plates that are found in the region shown on your map (HINT: one is not listed on the map but you should know it- think about what continent you see)

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* 1. Fill-in the blank: At the Juan de Fuca Ridge, the \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ plate and the \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_plate are moving \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ each other.

Fill-in the blank: At the Gorda Ridge, the \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ plate and the \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_plate are moving \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ each other.

What type of plate boundaries are these ridges? \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

* 1. How are the two plates moving relative to each other along the portion of the Blanco fracture zone between the two ridges?

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What type of plate boundary is this? \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

* 1. How are the two plates moving relative to each other along the portion of the Mendocino fracture zone between the Gorda Ridge and the subduction zone along the coastline?

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What type of plate boundary is this? \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

What is the name of this fault, which extends on land down through Southern California?

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* 1. Along which type of plate boundary do most of the earthquakes occur?

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* 1. Explain why earthquakes occur here:

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* 1. Click the button that says “1 year” underneath the graph to automatically select one year of data. Slide the highlighted section of the graph to the right and left and look at the map as you do this, what was the depth (shallow or deep) of most earthquakes that occur along the ridges? \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

What was the relative magnitude (small or large) of most of the earthquakes along the ridges? \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Try to explain why earthquakes at ridges have this depth and magnitude (Hint: Think about the thickness of the crust in these areas and how the plates are moving): \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

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* 1. Slide the highlighted section of the graph to the right and left again and look at the map as you do this, what was the depth (shallow or deep) of most earthquakes that occur along the transform faults? \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

What was the relative magnitude (small or large) of most of the earthquakes along the ridges? \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Try to explain why earthquakes at ridges have this depth and magnitude (Hint: Think about the thickness of the crust in these areas and how the plates are moving): \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

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* 1. Look at the entire graph, when did the largest magnitude earthquake occur?

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Move the highlighted section of the graph to the right or left to place the left side highlighted window on the time period when the largest magnitude earthquake occurred. Click the button that says “1 month” underneath the graph to automatically select one month of data to focus in on the exact time. Now look at the map, where did it occur?

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* 1. Click the button that says “1 year” underneath the graph to automatically select one year of data. Slide the highlighted section of the graph to the right and left to find the region where most deep earthquakes occur (remember color represents depth). Look at the map as you do this, where did most deep earthquakes occur? \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Explain why deep earthquakes occur here (HINT: Think about how the plates are moving): \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

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* 1. Zoom in on the Juan de Fuca Ridge by using the + button on the top left of the map. Now set the graph to show 6 months of data and slide the highlighted window across the time left to right. You should notice a set of earthquakes that occur at the center of the ridge at two different times. This is the location of the Axial Seamount, the most active underwater volcano in this region. We will study this seamount next. What years did these earthquakes occur?

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* 1. Explain why active volcanoes are found along ridges (Hint: remember what tectonic process is happening at ridges):

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*Exercise 2: Seamount Eruptions:*

The following lesson plan is modified from one that was featured in the Oceanography article *Using Authentic Data from NSF’s Ocean Observatories Initiative in Undergraduate Teaching: An Invitation* by C. Greengrove et al.

**Axial Seamount Data Exploration Worksheet**

*Developed by Anna Pfeiffer-Herbert, modified by Jean R. Anastasia*

1. Go to the [Seamount Diking-Eruption Event Science: Exploration](https://datalab.marine.rutgers.edu/explorations/geology/activity3.php?level=exploration) page (<https://datalab.marine.rutgers.edu/explorations/geology/activity3.php?level=exploration>) and review the graph of seafloor elevation over time
   1. What is the time range on the x-axis? \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
   2. Which dates does this graph start and end? (Hint: put your cursor on the actual line of the graph and move left to right, the dates will be shown in the upper right corner)

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* 1. What variable appears on the y-axis? What are the units?

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* 1. Describe how seafloor elevation changes over time in this graph?

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* 1. Click the box next to Show Estimated Threshold. What does this line mean? (Hint: read the Data Tips below the graph)

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* 1. Based on the data shown on the graph, what dates were there eruptions at the axial seamount?

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* 1. If you have a mouse, you can click and drag your cursor on the graph to make a prediction for what will happen to seafloor elevation next (if not, trace by eye). In what year do you think the elevation will reach the threshold? \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

What event might happen then? \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

* 1. Go back to question 2k from Exercise 1,the earthquake portion of the lab. What years where their earthquakes around the Axial seamount? How does this relate to the seafloor elevation data in this exercise?

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1. Go to the [Seamount Diking-Eruption Event Science: Application](https://datalab.marine.rutgers.edu/explorations/geology/activity3.php?level=application) page (<https://datalab.marine.rutgers.edu/explorations/geology/activity3.php?level=application>) and review the graph of seafloor elevation over time
   1. What changes or patterns did you observe in changes in seafloor elevation between 1997-2016 at the Axial Seamount?

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* 1. Were these changes or patterns driven by how much time had passed? What is your evidence?

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* 1. Were these changes or patterns driven by how much of a change in the seafloor elevation had occurred? What is your evidence?

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Use your cursor to predict the pattern of seafloor elevation change from December of 2016 forward in time. Based on this prediction, when do you think the next eruption of the axial seamount will occur?

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* 1. Scroll to the bottom of the Data Exploration page and click on the link that takes you to a blog that chronicles past and future[diking-eruption event forecasts at Axial Seamount](https://www.pmel.noaa.gov/eoi/axial_blog.html). Read the most recent post in the blog. What is the current prediction for the next eruption?

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**Labeled Map of the Pacific Northwest Plates**

