How do we recognize plate boundaries?

The Earth's lithosphere is made-up of tectonic plates that pull apart, collide, and slide past each other. In this activity, students will use tectonics data in a Web GIS to identify the eastern and western boundaries of the North American plate. They will:

- f. Analyze earthquake epicenter and volcano data to determine the boundaries of the North American Plate.
- g. Analyze the movement of the surrounding plates to determine plate boundary types (divergent, convergent, or transform).

Model the following procedural instructions with your students. It is recommended that you display your computer image to the front of the classroom.





Have students open their Web browser. Go to www.ei.lehigh.edu/learners/tectonics/

Click on: Investigation 2: How do we recognize plate boundaries?

The Web GIS will open to a map focused on the United States with a blue box around the study area.

Step 2: Identify and trace the North American Plate boundary.

We live on the North American Plate, which includes the continent of North America and parts of the Atlantic and Arctic Ocean floors. Tectonic forces cause plates to collide, pull apart, and slide past each other causing earthquakes. In this step, students will use the location of recent (occurred between September, 2008 and September, 2011) earthquake epicenters to trace part of the North American plate boundary.



- a. Direct students to the Map Layers tab in the toolbox menu.
- b. Instruct students to activate the Earthquakes M > 4.0 (9/08-9/11) layer in the Dynamic Layers menu by clicking on the check box.
- c. Different shades of orange circles are displayed on the students' maps. The location of each circle represents the *epicenter* of an earthquake with a magnitude > 4.0 that occurred between September 2008 and September 2011. The epicenter is the point on the Earth's surface vertically above the earthquake *focus*, the position of the fault rupture at depth and starting point of the earthquake.
- d. Students should click on the **Map Legend tab** to view the map legend. The color indicates the *focal depth* of the earthquake. The focal depth is the depth of the fault rupture vertically beneath the surface, the point in the crust where a seismic rupture begins.
- e. Have students click on Hide Tools in the upper right hand corner to hide the toolbox menu. This will enable them to see the entire North America study area in the blue box. Point out to the students that earthquakes appear in some locations and not others. Most earthquakes occur along plate boundaries. Earthquakes that occur on the interior of a continental plate occur along old faults that were formed when the area was once closer to plate boundaries.



f. Students will use the **Draw Tools** to outline the North American plate boundary. This toolbox allows students to draw lines and place labels on their maps.

- g. Instruct students to click on **Show Tools** in the upper right hand corner to show the toolbox menu. Select the **Draw Tools tab** in the toolbox menu.
- h. Show students how to use the **Polyline** tool. Starting at the blue box, trace the path of the densely clustered earthquakes on the Pacific Coast of North America.
 - **i.** First, click on a point at the western edge of the blue box to start drawing a line (see figure above).
 - ii. Next, hold your mouse down while you drag along the cluster of earthquakes.
 - iii. To finish a line, let go of your mouse at the southern edge of the blue box (see figure above).
 - iv. If a mistake is made, clicking vill erase the line segment.

Note: Students should not press the delete button on their keyboard to try to erase the line. This will cause them to leave the Web GIS and lose their work. Also, common keyboard shortcuts to undo and redo actions will not work.

The line on the student's map should look similar to the image below. Lines drawn within the green area are acceptable.



i. The eastern edge of the North American plate is located in the Atlantic Ocean. Click on Hide Tools to hide the toolbox menu. Locate the clusters of earthquakes and use the polyline tool to trace the plate boundary in the North Atlantic Ocean.



The student's map should look similar to this:



The other two plates are located on the eastern boundary of the North American Plate. Show students the line of earthquakes that runs east-west between Europe and Africa. This is another plate boundary that separates these two plates. Instruct students to trace this line of earthquakes with the polyline tool.

The student's map should now look like this:



When students are finished drawing both boundaries, instruct them to click the **Stop Drawing** button in the **Draw Tools tab** to deactivate the drawing tools.

- j. At this point, students should submit their map images for assessment using the Export Map tool.
- First, instruct students to click on the Export Map tab in the toolbox menu. Next, click
 Prepare Map for Export
 This will create an image of the GIS map to be exported to a location on the computer.
- I. Next, follow directions in the toolbox for Macintosh or PC depending upon the computers that are used in your classroom.
- m. Provide specific file naming instructions and a computer or network location for students to save their images to.
- n. When they are finished, students can click **Return to Map Navigation** to return to their maps.

Make sure that students keep their plate boundaries on their map.

Step 3: Identify the plates surrounding the North American Plate.

There are three major plates that border the North American plate. In this step, students will identify these adjacent plates and record the plate names on their investigation sheet.



- a. Have students click on the **Map Layers tab** in the toolbox menu. Hide the toolbox menu so the whole map is visible.
- b. When a location on the GIS map is clicked, a box will appear with that location's plate name. Click on North America, a box that says "**Plate Name**: North American Plate" will appear.

Note: If the tool menu is not hidden and the draw tool is still selected, this will not work. Make sure students are **not** on the **Draw Tools tab**, and have clicked on the **Map Layers tab**.

c. There are three plates surrounding the North America Plate. First, have students find the Pacific Plate, located to the west of the North American plate. Instruct students to click on a point in the Pacific Ocean located near latitude 35° and longitude -132°. **Reminder:** the latitude and longitude of the cursor is displayed on the bottom left corner of your GIS map.

Note: The students will not see the red location squares shown above.

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d. Next, students will identify the name of the plates south of the North American plate by clicking different locations on their map where they think there are different plates. Make sure the class understands that earthquake epicenter clusters identify plate boundaries.



e. Have students click on the **Map Layers tab** in the toolbox menu. Then, hide the toolbox menu so they can see the whole map.

f. Instruct students to click different locations south of the North American plate, below the blue study box, where they think there may be a different plate. You may want to model this by clicking a location in the Caribbean Sea. This will pop-up a box that says "Caribbean Plate", and you can show students that earthquakes surround this plate. Have students click until they have identified the 3 different plates: Cocos, Caribbean, and South American. If needed, prompt students to click on South America to view a pop-up a box that says "South American Plate".

Instruct students to answer **Question #4** on their investigation sheet.

Step 4: Revisit the western plate boundary and investigate volcano locations.

Sometimes when plates collide, volcanoes related to subduction occur on the overriding plate. In these locations, the plate boundaries are also identified by the pattern of volcanoes. In this step, students will use the volcanoes data set to identify the eastern boundary of the Juan de Fuca Plate, a plate that is aseismically subducting on the western edge of the North American plate.



- a. Click on the Map Layers tab in the toolbox menu.
- b. Have students activate the **Volcanoes** layer in the Dynamic Layers menu by clicking on the check box. The location of each triangle represents the location of an active volcano.
- c. Students should click on the **Map Legend tab** in the map Table of Contents to view the volcano types in the map legend. The color indicates the type of volcano: cinder cone, composite, or shield.
- d. For this step students should focus on the U.S. Pacific Northwest area. Click on the **Map Navigation Tools tab** in the toolbox menu.
- e. Select **U.S. Pacific Northwest** from the list of bookmark locations. The map will zoom to this area and a new blue study area box will appear.



f. The Juan de Fuca plate is a small plate located on the western edge of the United States. It was once part of a larger plate that has now been mostly subducted beneath the United States. Students should have already drawn the western boundary in Step 4 when tracing the pattern of earthquakes. Because they drew the western plate boundary while zoomed out, it may not line up exactly with the

earthquakes. Instruct students to use the **Polyline** tool to trace a line **to the west of the volcanoes near the coast (See red line on image above).** Make sure the student's line does not extend into the Pacific Ocean. The line should not be located on the coast, but should run parallel to it ~100 km to the east.

g. Have students click the **Stop Drawing** button, then click to another toolbox menu tab. Then, have students click the middle of the plate (latitude 46° and longitude 127°) to learn its name. Their map should now display a newly drawn plate with its name displayed.



Instruct students to answer **Questions #5-6** on their investigation sheets.



h. At this point, students should again submit their map images for assessment using the **Export Map tool**.

to return to their maps.

- Instruct students to first click on the Map Navigation Tools tab in the toolbox menu and select North America from the list of bookmark locations. The Web GIS will zoom out so all the plate boundaries are visible.
- Next, instruct students to click on the Export Map tab in the toolbox menu. Next, click
 Prepare Map for Export
 This will create an image of the GIS map to be exported to a location on the computer.
- k. Follow directions in the toolbox for Macintosh or PC depending upon the computers that are used in your classroom.
- I. Provide specific file naming instructions and a computer or network location for students to save their images to.
- m. When they are finished, students can click Return to Map Navigation

Step 5: Identify the types of plate boundaries.

There are three types of plate boundaries that are defined by the relative plate motion across the plate boundary. In this step, students will identify the plate boundaries they have drawn as: (1) divergent - plates moving apart, (2) convergent - plates moving towards one another, or (3) transform - plates moving parallel to their boundary.



- a. Click on the Map Navigation Tools in the toolbox menu.
- b. Instruct students to select **North America** from the bookmark locations list. This will zoom out so the Web GIS is focused on the entire North America study area.
- c. Click on the Map Layers tab in the toolbox menu.
- d. Have students turn off the Volcanoes and Earthquakes M > 4.0 (9/08-9/11) layers and activate the **North American Plate Motion** layer.
- e. These arrows show how the plates are moving relative to the boundary. Instruct students to click on the Plate Motion Image icon (i) at each arrow pair to view what is occurring at these plate boundaries.
 - Arrows perpendicular to the boundary and pointing towards each other are located at **convergent** boundaries.

- Arrows perpendicular to the boundary and pointing away from each other are located at **divergent** boundaries.
- Arrows parallel to the boundary and pointing in opposite directions are located at **transform** boundaries.

Instruct students to answer **Questions #7-11** on their investigation sheets.

Step 6: Identify the different types of lithosphere

This last step is meant to help students think about the location of plate boundaries more generally, and the types of lithosphere that make up plates. The lithosphere is the layer of the Earth that is broken into plates. It is made-up of the crust and the uppermost part of the mantle. There are two types of lithosphere:

- Oceanic lithosphere, which is associated with oceanic crust and exists beneath ocean basins
- · Continental lithosphere, which is associated with continental crust and exists beneath continents



Instruct students to look at their map. They should examine the relationship between the plate boundaries they traced and the edge of the continents. They should see that the plates are made-up of oceanic and continental lithosphere, and that plate boundaries occur in both oceanic and continental lithosphere. Instruct students to answer **Questions #12** on their investigation sheet.