Overview: How do we know there are different tectonic plates? Which way(s) are the plates moving? How are earthquakes and volcanoes involved? In this activity you will use a web-based mapping tool, EarthScope Voyager Jr., to explore earthquakes and volcanoes in the western United States and study the motion of the Earth’s crust using high-precision GPS data.

Materials:
Computer with Internet access OR the map packet provided by your teacher
Transparency film
Dry erase pens of different colors

Part 1: Prepare your map for study

Starting at www.unavco.org

1. Click on Map Tools under the Education and Outreach section.
2. Click on EarthScope Voyager Jr. - The direct link is: http://jules.unavco.org/VoyagerJr/EarthScope
   A map of North America will load in several seconds
3. Orient yourself to the tool.

- Selecting a base map provides your base layer.
- Clicking here turns legend on/off (hint: you will need to use this).
- Clicking here makes changes to your map.

4. Zoom into the Western United States.

- Clicking the map twice to zoom into Western United States.
- Selecting a plate velocity adds observed or modeled velocity vectors in the chosen frame of reference.
- Clicking one or more features adds them on top of your base map.
- Clicking on the teal buttons takes you to a help page.
5. Check that the map view matches the map below. The base map should be Face of the Earth & Relief.

6. Under the Add feature(s) menu, scroll down the list and select Political, Lat/Long.
7. Click the Make changes button. In a few seconds, the map will reload with political boundaries, latitude and longitude lines, and major cities.

Part 2: Compare earthquake and volcano locations

Earthquake Expert go to page 4.
Volcano Expert go to page 5.
Earthquake expert:
1. Scroll down the Add features menu to Earthquakes. Hold the Ctrl key down (on a PC; on a Mac, hold the Command key down) and select Earthquakes. The feature Political, Lat/Long should stay highlighted.
2. Click Make changes once. In a few seconds, the map will reload with the locations of earthquakes displayed as dots.
3. On your own, study the map and answer the questions below:

   **Earthquake Data Questions:** Examine the earthquake data plotted on the map and notice where earthquakes are located as well as where they are not located.

   A. How are earthquakes distributed? If there is a pattern, how would you describe it? Where are there no earthquakes? Are they located near the edges of the continents, mid-continent, in the ocean?

   B. At what depth(s) do the earthquakes occur? (hint: look at the legend)

   Go to Map your data on Page 6 when finished.
Volcano expert:
1. Scroll down the Add features menu (hold the Apple key down on Macs) and select Volcanoes. Political, Lat/Long should stay highlighted.
2. Click Make changes once. In a few seconds, the map will reload with the locations of volcanoes displayed in red.
3. Study the map and fill out the questions below:

**Volcano Map Questions:** Examine the volcano data plotted on the map and notice where volcanoes are located as well as and where they are not located.

A. How are volcanoes distributed? Where are there no volcanoes? Are they located near the edges of the continents, mid-continent, in the ocean?

B. If there is a pattern, how would you describe it?

Go to Map your data on Page 6 when finished.
Part 2 (continued)
4. Map your data
Using a marker or colored pencil, sketch the general locations of the majority of the volcanoes/earthquakes on this map. You do not need to make individual symbols. Lines or shading of the correct color in the general areas will be sufficient.

Get together with your teammate and compare your findings. Sketch on your map the locations of the earthquakes and volcanoes from your partner's map. Compare your data.

A. What geographic features (mountains, plains, valleys, etc) are frequently found in a region where there are only earthquakes?
B. What geographic features are frequently found in a region where there are only volcanoes?

C. In which regions do you find earthquakes and volcanoes near each other? Describe the geographic features of these regions.

D. Summarize the relationships you discovered. Are the features you looked at (earthquakes and volcanoes) more commonly found together or separate?

E. What explanation can you provide for the observed relationships?

Part 3: Examine GPS Vector Data
Return to the EarthScope Voyager Jr. tool and work on your own.
1. Under Add Features menu, click Political, Lat/Long and then click on Make Changes. This removes the earthquakes and/or volcanoes icons.
2. Under the Add velocities menu, select N. America and Obs (for observed data). Click Make changes once. In a few seconds, the map will reload with plate motion vectors (arrows) in purple.

Orientation to the vectors on the map
Each arrow represents a data point from a GPS station and is called a velocity vector (or vector). At this time, there are no GPS stations in the ocean, so no vectors are displayed in the ocean for observed data.

The tail of the vector is the location of the GPS station. The vector arrow points in the direction the plate is moving at that GPS station. The length of the vector arrow shows how fast the plate is moving.
Note: Every tectonic plate on Earth is in motion. Scientists compare the motion of one tectonic plate or region relative to another tectonic plate to more easily view the differences in motion. For this activity, we are using a reference frame where the interior of the North American plate is stable and not moving areas. In scientific terms, the vectors displayed on these maps are in the North American Reference Frame.

3. Sketch some of the vector arrows on your map on Page 6; click on the map to zoom in and use the zoom out button to zoom out. Pay special attention to what direction the arrows are pointing (e.g. the direction the ground is moving and the lengths of the vector arrow (velocity). Answer the questions and then join your teammate to discuss your answers and come to a consensus on the answers.

A. What do you notice about the length of the vectors (the velocities) in the Pacific Northwest compared to those in coastal California? What is the scale for the vectors on this map? What direction(s) do the vectors point in the Pacific Northwest and California? What does this indicate?

B. How does the velocity of each GPS station change from the coast to inland California? Why do you think there are many GPS stations (lots of vectors) near the coast of California and not many GPS stations farther inland?

C. What other areas do you notice that have differing velocities? What about differing directions? What do you think is happening in these regions to cause these differences?
Part 4: Put it all together

1. Create a quick reference that to determine the plate boundary from velocity vectors. Sketch in the box what the vectors look like for each plate boundary type from the examples shown in the presentation.

<table>
<thead>
<tr>
<th>Convergent Boundary</th>
<th>Transform Boundary</th>
<th>Divergent Boundary</th>
</tr>
</thead>
</table>

On your own, return to the EarthScope Voyager Jr. tool.

2. Under the Add Velocities area, click on the radio button for model and then click Make Changes. These vectors are modeled from many types of scientific measurements and datasets to create a general vector for each region of a tectonic plate.

3. On your map on Page 6, draw the locations where the vectors are very different from each other (for example places where the vectors are moving in a similar direction but different speeds or where they are moving in different directions.) [Remember to click on the map to zoom in to view the vectors better and use the zoom out button to zoom out.]

4. Collaborate with your teammate to answer the questions below.

A. How do the locations where you drew the vectors compare to the locations of earthquakes and volcanoes you already had marked on your map?

B. Place an overhead transparency or other clear sheet of film over your map and draw with a dry erase marker where you believe the plate boundaries are located. (Blue = convergent boundaries, yellow = transform boundaries, & red = divergent boundaries). (Or use three different colors and make a legend to describe the colors.)

C. Return to EarthScope Voyager, Jr. one more time. On the Features menu, hold the Ctrl key down and select Tectonic Plates and Political, Lat/Long and click Make Changes. Compare these boundaries to your drawing on the transparency.
D. How close do the boundaries in EarthScope Voyager Jr. match the boundaries that you drew? What boundaries were you able to locate? Were there any boundaries that you drew that were not shown in the tool? What additional information would you have needed for you to be able to draw the other boundaries accurately?

E. How would you characterize the width of the plate boundaries on your map? How do they change? Based on your data, which plate boundaries should be shown as a line or a zone? Why?

More questions to think about:
Why does volcanism occur at convergent boundaries but not at transform boundaries?

Relative to the location of the plate boundary, what do you notice about the locations of earthquakes/volcanoes at a subduction zone relative to a transform boundary?

Do you observe a relationship between geographic features and plate boundaries?

Do the patterns that you observed in the Western United States occur worldwide? How would you find the answer?