Earthquakes
Physical Geology 2018
Adapted from a lab by Jennifer Wenner

This lab is designed to give you experience exploring seismicity associated with different plate boundaries. You will examine seismograms and determine the location of an earthquake’s epicenter using arrival times of P and S waves. You will also relate the types of hazards and depths of earthquakes to the types of plate boundaries with which they are associated.

1. Log into Titan WiFi on the iPad
   a. Select Settings in the lower left
   b. Turn on the WiFi and choose Titan WiFi
   c. Log in using your TitanApps login information
2. Push the Home button to return to the home page
3. Open Safari (bottom menu)
4. Open the IRIS Earthquake Browser (www.iris.edu/ieb/).
5. Select the “Max quakes” dropdown menu (upper right) as 600.
6. Select “Priority” (just below Max Quakes) to read Largest. Select “on” for “Show Plates.”
7. Hit “Apply” and play around with it and familiarize yourself with its features.

California Earthquakes:
1) Zoom into the western US, so that California and Nevada are in the window.
2) Describe the pattern of Earthquakes in California (where do they occur?).

1) WESTERN 3) Examine the pattern of earthquakes in California and just off the coast of Oregon.
   a) What kind of plate boundary is present in Western California that would explain the distribution of earthquakes there?

b) Draw arrows on the map above that shows the sense of motion on the fault that runs the length of California (Pacific plate is moving north relative to North America).
c) What type of fault is this? (normal; reverse; thrust; right-lateral strike slip; left-lateral strike slip)

4) Examine the pattern of earthquakes in Eastern California – along the border with Nevada. Eastern California is dominated by extension (pulling apart) in the upper part of the crust.
   a) Draw arrows in this region showing the type of stress that dominates.
   b) What type of faults would you expect to dominate in this part of the US? (normal; reverse; thrust; strike slip)

Indonesian Earthquakes: Using IRIS Earthquake Browser. Zoom back out and then zoom in so that the island of Sumatra (in Indonesia – south of Malaysia & near Singapore) is visible. Be sure to select “Earliest Available” in the Time Range and “All Values” in the Magnitude Range.

1) What kind of plate boundary is dominant in Sumatra that would explain the distribution of earthquakes there?

2) Describe the pattern of earthquakes in and around Sumatra. As you go northeast and away from the convergent plate boundary, do earthquakes get deeper or shallower? [Feel free to use the 3D viewer.]

3) Draw arrows on the map above showing the sense of motion on the fault (in yellow at right) that affects Sumatra.
4) How might you expect hazards associated with earthquakes in Sumatra to differ from those associated with California earthquakes?

What hazards would be the same?
Iceland Earthquakes: Using IRIS Earthquake Browser. Zoom back out and then zoom in so that Iceland (in the North Atlantic) is centered and visible.

1) Looking at the earthquakes north and south of Iceland, what kind of plate boundary in this area would explain the distribution of earthquakes there?

2) Draw arrows on the map above showing the direction of plate motion that leads to the observed earthquakes.

3) Zooming in on the island of Iceland, adjust the magnitude range to view earthquakes greater than 5.0 (under Magnitude Range, uncheck “All Values” and make the range \(5 \leq \text{mag} \leq 10\)). Where in Iceland are most of quakes over magnitude 5.0 located?

4) Adjust the time range for your earthquakes to find the \(\text{mag} \geq 5.0\) earthquakes since 2014. Do this by unchecking “Earliest Available” and adding “2014-01-01” to the box. (This means “show earthquakes since Jan 1, 2014”). Use the time range to determine which year since 2014 had the most earthquakes \(\geq 5.0\). Which year was it?

5) What do you think happened to produce the earthquakes in Iceland in the year from the previous question? Justify your answer.

6) What is the magnitude of the largest recorded earthquake in Iceland?

7) Based on the 3 locations you investigated, what kind of plate boundary do you think has the greatest earthquake hazard? Which gives the least earthquake hazard for people?
Introduction: Approximately 280,000 people died as a result of the 9.0 magnitude earthquake and ensuing tsunami associated with the 2004 Sumatra Earthquake. The event marked the second-most devastating natural disaster to hit the world in the last century.

In this lab you'll study seismograms from 3 different seismic stations that record the magnitude 9.0 Sumatra earthquake of December 26th, 2004. By comparing the arrival times of the P and S waves on each seismogram, you'll be able to determine the distance from the epicenter to each station. Using those data, you can accurately map the location of the epicenter of the earthquake. Once you've located the epicenter, you'll calculate the position of the tsunami generated by the quake at one hour intervals. From those determinations, you can predict how much time people had before the tsunami crashed onto their shores.

Finding the Epicenter

1. Label the following countries on MAP 1: (Use whatever resources you need)
   - India, Sri Lanka, Somalia, Sumatra (Indonesia), Myanmar, Thailand,

2. Read the time of the P and S waves at each station and place that information in your data table below. Read each arrival time to the nearest second. Note: The first vertical line marks the P-wave arrival and the second vertical line marks the S-wave arrival time.

3. Subtract the P-wave arrival time from the S-wave arrival time (S – P), though there is a more direct way to get that information off the seismogram. Double-check and record your results in DATA TABLE 1.

4. Use the P and S wave travel-time curves to find the distance from each station to the earthquake epicenter. Do this by finding the unique epicenter distance where the difference in the P and S wave travel times is exactly equal to the difference you calculated from the seismogram (NOTE: scales on seismograms are different than on the P-S curve). Record that distance in the last column of the data table.

5. On the “The Great Sumatra Earthquake… (Map 1)” map, use the map scale and your compass to draw circles around each station of a radius equal to the epicenter distances that you just determined using the travel time curves.

6. The intersection of the 3 circles marks the epicenter of the ‘quake. Label it “Epicenter” on your map.

DATA TABLE 1:

<table>
<thead>
<tr>
<th>Seismograph Station</th>
<th>P-wave Arrival</th>
<th>S-wave Arrival</th>
<th>Time Difference (S – P)</th>
<th>Epicenter Distance</th>
</tr>
</thead>
<tbody>
<tr>
<td>PALK</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>DGAR</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>COCO</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Questions/Activities:

1. Which seismic station is located farthest from the epicenter?
   
   a. How could you have determined which was farthest by simply looking the seismograms?
The Great Sumatra Earthquake of 12/26/2004 (Map 1)
SEISMOGRAMS for Part 1
From: https://ida.ucsd.edu

PALK, Pallekele, Sri Lanka: Coordinates: (7.3° N, 80.7° E)

DGAR, Diego Garcia, British Indian Ocean Territory: Coordinates: (7.4° S, 72.5° E)

COCO, Cocos (Keeling) Islands, Australia: Coordinates: (12.2° S, 96.8° E)
(Chart from the New York State Earth Science Reference Tables)
b. Why do you need at least three seismic stations to find the epicenter of the quake?

2. The quake occurred on a tectonic plate boundary. Refer to the global tectonic plate map (Map 2) to answer the following questions:
   a. Between which 2 tectonic plates did this ‘quake occur?
   b. How are the plates moving relative to each other in the area of the ‘quake?
   c. What term describes this kind of plate boundary?

3. The focus of the quake occurred at a depth of about 30 km (18 mi) and about 150 km (90 mi) northeast of the trench (see Map 2).
   a. Explain how this information helps you to determine which plate is being subducted.

Predicting the Arrival of Tsunami Waves

The speed at which a tsunami moves through the ocean is dependent largely on the depth of the ocean. The tsunami generated by this quake moved at an average speed of about 600 kilometers per hour. Though tsunamis travel fast, their wave heights are not very high in the open ocean and are at most only a few feet, but they can have wavelengths over 100 km long (!), so they are often unnoticed as they pass beneath ships at sea. As they approach shallow water near the coast, however, front of the tsunami waves slows down, the trailing portion of the wave “runs into” the front shortening the wavelength, and heights may increase to many meters. (http://vulcan.wr.usgs.gov/Glossary/Tsunami/description_tsunami.html)

Assume the tsunami generated by the Great Sumatra Quake traveled 600 km/hr in the open ocean. On Map 1, draw and label circles around the epicenter showing the distance the tsunami had traveled in 1 hour, 2 hours, 3 hours, and 4 hours.

(You should have four labeled circles surrounding your epicenter representing the position of the leading edge of the tsunami as it traveled through the ocean after the earthquake occurred)

1. Note the number of people killed by the tsunami in the following countries:
   - India: estimated ~18,000
   - Sri Lanka: estimated ~35,000
   - Thailand: estimated~8,000
   - Indonesia: estimated ~170,000
   - Myanmar: estimated ~400
   - Somalia: estimated ~300
2. Using MAP 1 and the tsunami circles that you drew, estimate the amount of time that these countries had before the tsunami crashed onto their shores.

- India ____________________________
- Sri Lanka _________________________
- Thailand __________________________
- Indonesia __________________________
- Myanmar __________________________
- Somalia ___________________________

Why do you suppose Indonesia’s casualty rate was so high?

3. Assume that you live in small town on the coast of Oregon. Examine the region around Oregon on Map 2. What geologic conditions exist in that part of the world that might cause a tsunami?

4. Tsunamis are likely to occur when large earthquakes occur on the seafloor, as happens in the Pacific Ocean. The 2011 Honshu (Japan) earthquake caused a tsunami that devastated parts of coastal Japan, ~30-90 minutes after the quake. Locate Japan on Map 2. Why might a tsunami warning system fail to alert people in a tsunami zone after a major earthquake strikes?