# Physical Geology 101 Lab
Earthquake Assessment

Introduction & Purpose:

   The purpose of this laboratory exercise is to become successful at applying concepts and techniques of seismology for locating earthquake epicenters, measuring magnitudes, evaluating ground surface stability, measuring active faulting with aerial photography, and assessing seismic hazards.   This lab has five parts: Part I is a 10-question pre-lab that must be completed prior to the start of the lab. Part II is a laboratory earthquake model simulation; Part III is a fault displacement analysis exercise of a segment of an active fault using aerial photography; and Part IV is a computer-Internet virtual courseware interactive activity designed to learn how to measure and assess earthquake epicenter locations and magnitudes. Finally, Part V is a reflection of your learning experience during this lab.
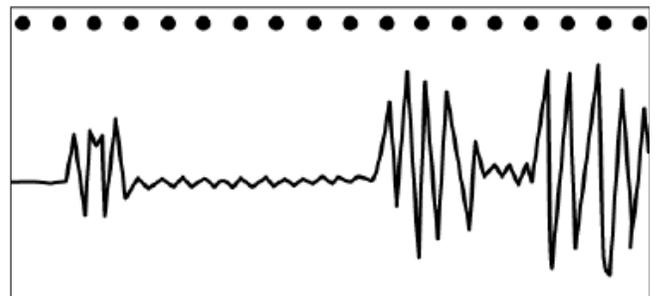
Part I. EARTHQUAKE PRE-LAB ACTIVITY: Answer questions 1 through 10 using the information supplied in your lab manual and in the pre-lab below. Complete Part I prior to the start of the lab.

1. What type of active geologic structures do earthquakes occur along? _____

2. What is the difference between an earthquake's focus and its epicenter?

3. Each increase of 1 on the Richter Scale means an increase of _____ times in the

ground motion and about a _____ times increase in the amount of energy released.

4. The amount of energy released from the focus of an earthquake is called its:
>   a. intensity
>   b. vulnerability
>   c. magnitude

5. Look at the following seismographs and determine the difference in arrival times between the P- and S- waves. Note the dots on the seismogram represent minutes.
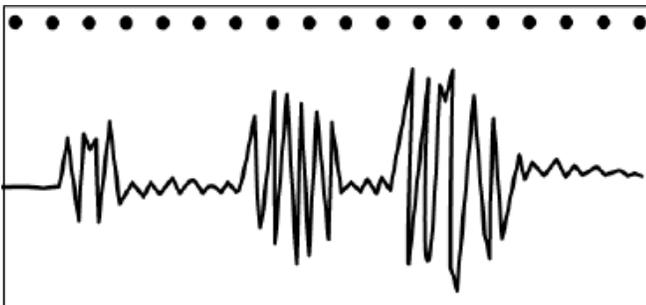
| **Graph A** | **Graph B** |

Graph A: P-S interval is _____ minutes   **Graph B**: P-S interval is _____ minutes

6. Which one of the above seismographs was located closest to the epicenter of this earthquake?   A   B   (Circle your answer)

   How did you determine your answer?

Part II. Locating the Epicenter & Determining Magnitude of an Earthquake

## Locating the Epicenter

Measuring the S-P time interval

There are hundreds of seismic data recording stations throughout the United States and the rest of the world. In order to locate the epicenter of an earthquake, you need to estimate the time interval between the arrival of the P and S waves (the S-P interval) on the seismograms from at least three different stations. You have to measure the interval to the closest second and then use a graph to convert the S-P interval to the epicentral distance. On the sample seismogram at the right the vertical lines are spaced at 2 second intervals. The S-P time interval is about 36 seconds.
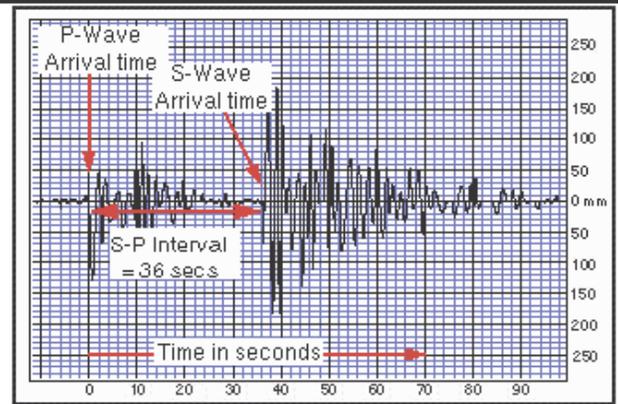
Determining the Earthquake Distance

You can now determine the distance from each seismic recording station to the earthquake's epicenter using the known times of travel of the S and P waves.

Examine the graph of seismic wave travel times (middle graph on this page). There are three curves on the graph: The upper curve shows S wave travel-time graphed versus distance, the center one shows P wave travel time versus distance, and the lower one shows the variation in distance with the difference of the S and P travel times. It takes an S wave approximately 70 seconds to travel 300 kilometers.
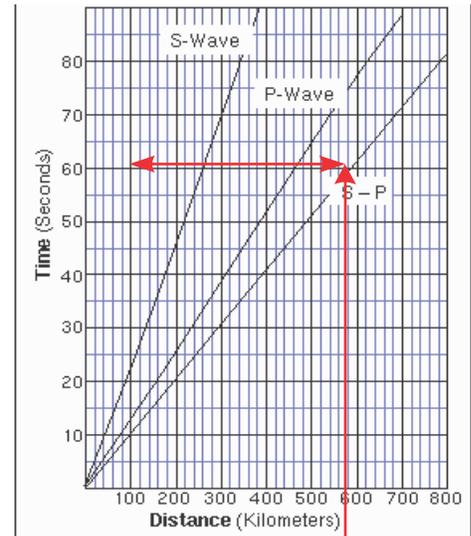
How long does it take the P wave to travel this same distance?

_____

For the rest of this exercise you won't be needing the individual S and P curves, only the S-P curve. Using the example from above, the 36 second S-P interval corresponds to a distance of about 355 km.

To determine the epicentral distance, we need a graph with greater resolution and detail. The bottom graph shows an expanded part of the S-P curve. Use the bottom graph for the exercises.

Finding the Epicenter on a Map

Once you have the epicentral distances, you can draw circles to represent each distance on a map. The radius of each circle corresponds to the epicentral distance for each seismic recording station. Once you have drawn all three circles and located the point where all three intersect, you will have successfully located (triangulated) the epicenter of the earthquake.

Using this method to determine an earthquake's epicenter may not result in an exact point for some earthquakes. Discounting measurement errors, there are a number of factors that affect the speed of earthquake waves. Among other factors, variations in rock types through which the waves travel will change the actual travel times and hence the S-P intervals.
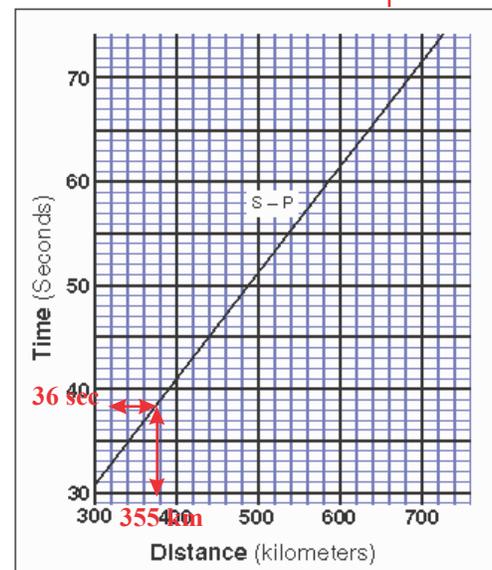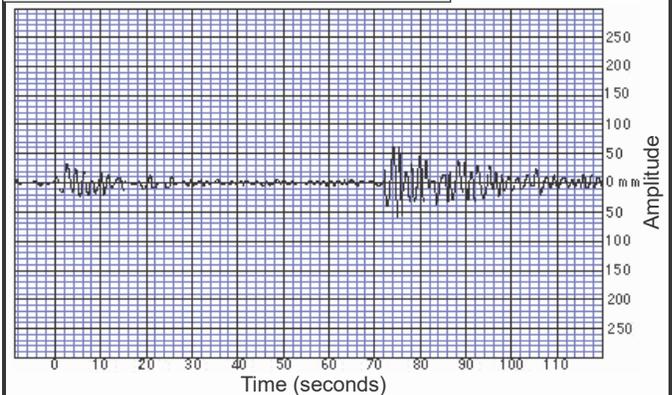
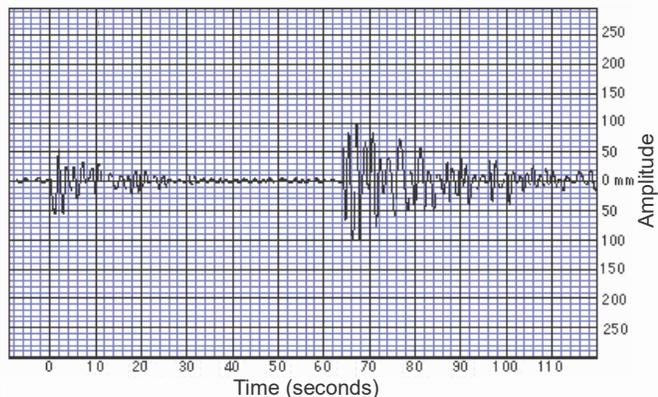# The earthquake seismograms for this exercise are below

Eureka, CA seismograph station

Amplitude — Time (seconds)
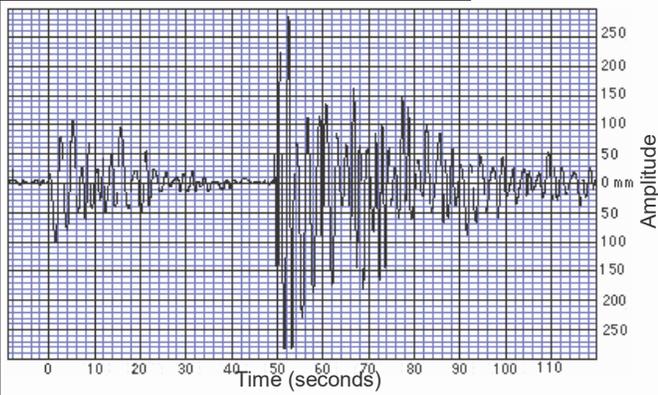
Elko, NV seismograph station

Amplitude — Time (seconds)

Las Vegas, NV seismograph station

Amplitude — Time (seconds)

Which seismogram shows the greatest amplitude?
_____

Using just the amplitude, which seismograph station is probably closest to the epicenter? (assume all three stations are located on bedrock.)
_____

Complete the table below.
Use the seismograph recordings to determine the time interval between the arrival of the P- and S- waves. Next, use these time intervals and the bottom graph on page 1 to determine the distance from the epicenter for each seismograph station.

Station	S-P Time Inteveral	Distance from Epicenter
Eureka, CA	[ ] seconds	[ ] Km
Elko, NV	[ ] seconds	[ ] Km
Las Vegas NV	[ ] seconds	[ ] Km

The last step is drawing circles on the map to the left to represent the distance from the epicenter for each station. The radius of each circle should equal the corresponding distance from the epicenter. To know how large to draw each circle, use the scale on the map.

The location where all three circles overlap (or nearly overlap) is the location where the earthquake occurred.

Where is the epicenter? _____

Determining the Richter Magnitude

Magnitude Explained
So far you have worked on locating the epicenter of an earthquake. The next questions to ask are "How strong was this particular earthquake and how does it compare to other earthquakes?"

There are many ways that one could evaluate the relative strength of an earthquake: from the cost of repairs resulting from damage, from the length of rupture of the earthquake fault, from the amount of ground shaking, etc. But determining the strength of an earthquake using these kinds of "estimators" is full of potential problems and subjectivity. For example, the cost of repairs resulting from a strong earthquake in a remote region would be much less than that of a moderate earthquake in a populated area. Furthermore, the degree of damage would depend greatly on the quality of construction. Also, only a few earthquakes produce actual ground ruptures at the surface.

A well-known scale used to compare the strengths of earthquakes involves using the records (the seismograms) of an earthquake's shock waves. The scale, known as the Richter Magnitude Scale, was introduced into the science of seismology in 1935 by Dr. C. F. Richter of the California Institute of Technology in Pasadena. The magnitude of an earthquake is an estimate of the total amount of energy released during fault rupture. The Richter magnitude of an earthquake is a number: about 3 for earthquakes that are strong enough for people to feel and about 8 for the Earth's strongest earthquakes. Although the Richter scale has no upper nor lower limits, earthquakes greater than 9 in Richter magnitude are unlikely. The most sensitive seismographs can record nearby earthquakes with magnitude of about -2 which is the equivalent of stamping your foot on the floor.

The Richter magnitude determination is based on measurements made on seisograms. Two measurements are needed: the S-P time interval and the Maximum Amplitude of the Seismic waves. The illustration at the top right on this page shows how to make the measurement of the S wave's maximum amplitude. The blue horizontal grid lines are spaced at 10 millimeter intervals. In this example the maximum amplitude is about 185 mm.
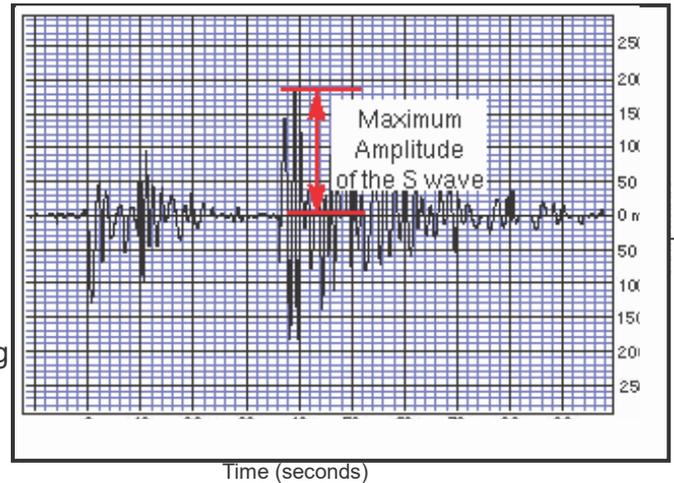
The Richter Nomogram

Although the relationship between Richter magnitude and the measured amplitude and S-P interval is complex, a graphical device (a nomogram) can be used to simplify the process and to estimate magnitude from distance and amplitude. In the diagram to the right, the horizontal dotted line (A) represents the "standard" Richter earthquake. This standard earthquake is 100 km away and produces 1 mm of amplitude on the seismogram. It is assigned a magnitude of 3. Other earthquakes can then be referenced to this standard
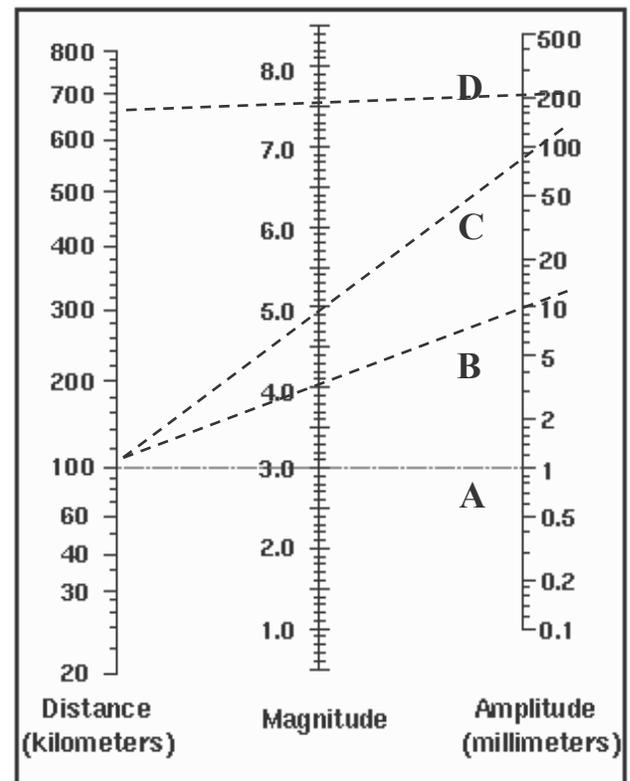
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The Richter Nomogram - continued

Note that a 100 km-away earthquake of magnitude 4 would produce 10 mm of amplitude (line B) and a magnitude 5 would produce 100 mm of amplitude (line C) at the same distance. 1, 10 and 100 are all powers of 10 and this is why the Richter Scale is said to be "exponential." A change of one unit in magnitude (say from 4 to 5) increases the maximum amplitude by a factor of 10. The last line drawn, line D, shows the result for an earthquake that produces an amplitude of 150 at a distance of 600 km.

Although only one amplitude measurement is necessary to estimate the magnitude of an earthquake, it is better to use measurements from several seismograph stations. This enables you to determine the magnitude value as an average of several values, thus increasing the likelihood that you are accurate in your estimate.

What is the magnitude of the earthquake? _____

Complete the table below. First, copy the distances from page 2. Then use the seismograph recordings on page 2 to determine the maximum S-wave amplitude for each earthquake.

Station	Distance from Epicenter	S-wave Amplitude
Eureka, CA	[＿＿＿] Km	[＿＿＿] millimeters
Elko, NV	[＿＿＿] Km	[＿＿＿] millimeters
Las Vegas NV	[＿＿＿] Km	[＿＿＿] millimeters

Last, use the amplitude and distance data to draw a line for each seismograph recording on the nomogram below.
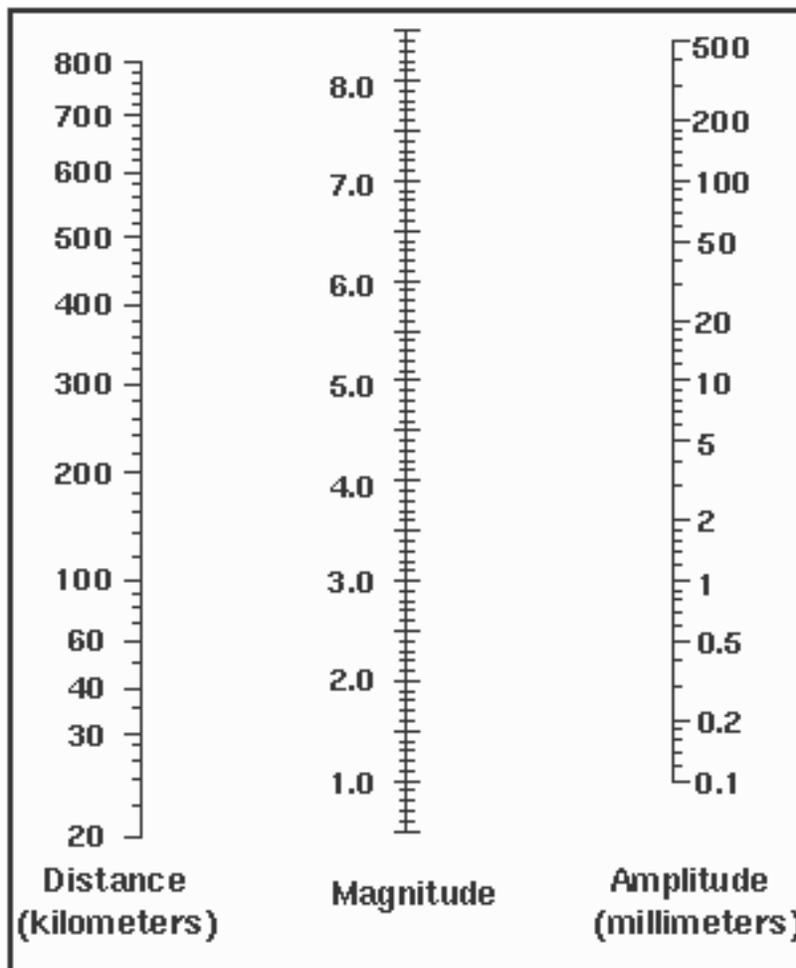
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Distance (kilometers) — Magnitude — Amplitude (millimeters)

Part III - Measuring and Analyzing a Virtual Earthquake's Epicenter Location and Magnitude

Part III is a virtual courseware computer activity that will be accessed online over the Internet at the following website links:

http://www.sciencecourseware.com/eec/Earthquake/ or

**http://www.sciencecourseware.com/virtualearthquake/**

These online activities are designed to help you learn the concepts and techniques for measuring and analyzing the location of earthquake epicenters and estimating earthquake magnitudes. I believe that these sets of web-based, interactive exercises nicely compliment the activities in your lab book.
  Before you begin the program, make sure that your computer system has the proper requirements to run the activities. This interactive online program consists of several components: 1) Images of earthquake destruction; 2) Tutorial; 3) Demonstrations; 4) Travel Time activity; and 5) Epicenter and Magnitude Activity. The online components that will be assessed and graded by me only include the Epicenter & Magnitude activities. However, it is very helpful to check out the demonstrations, tutorials, and travel time activity #4 prior to doing activity #5. You must successfully complete these exercises, and a 5-question quiz at the end, in order to receive a passing "certificate". Note that you must save and print out the completion certificate page before you quit the program. **Again, make sure to save and print out the "certificate" when you finish.** Include the certificate with your lab.

Part IV. Modeling Effects of Ground Motion and Liquefaction on Buildings

Introduction: A common cause of damage during earthquakes is the result of liquefaction of the soil. When earthquake vibrations pass through sand or silt, which has a high liquid content, the soil loses the properties of a solid and takes on those of a dense liquid, like quicksand or pudding. The solid strength sand or silt comes from the friction between the grains touching each other. As shaking continues, the pressure of the water between the grains increases until the pore pressure almost equals the external pressure on the soil. At this point the grains spread apart and, after sufficient strength is lost, the sand and water flows. In this portion of the lab, you will simulate ground motion during an earthquake and the affects that different types of shaking substrates have on buildings.
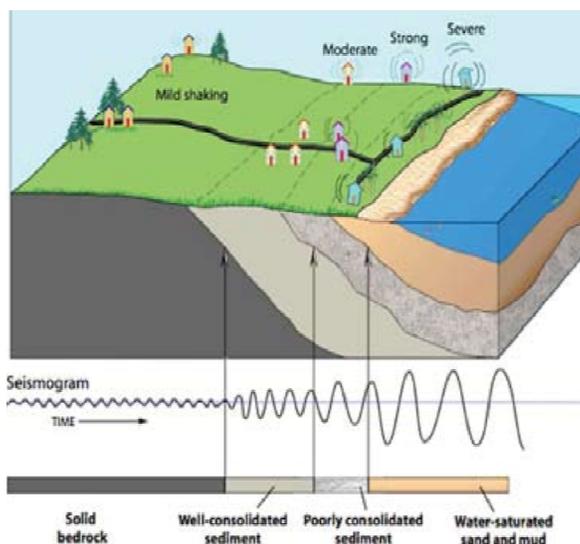
Why does ground shaking from an earthquake change so much with location?
  How seismic waves shake the ground during an earthquake depends on the geologic layering. The figure above shows how an earthquake wave going through solid bedrock has high frequency and low amplitude. When the waves go through weaker material, they oscillate with higher amplitude but lower frequency. Imagine dropping a rock on concrete and recording the vibration compared to dropping a rock on a trampoline or a mattress. Water-saturated sediments are susceptible to liquefaction, which causes sediment to behave like quicksand.

Model 1

Procedures/Directions: Obtain a small plastic or paper cup. Fill it three-quarters full with dry sand (sediment). Place several coins in the sediment so they resemble vertical walls of buildings constructed on a substrate of uncompacted sediment. This is Model 1. **Observe what happens to Model 1 when you simulate an earthquake by lightly tapping the cup on counter while you also rotate it counter clockwise. Answer all questions with complete sentences for full credit.**

Questions:

1. What happened to the vertically positioned coins in the uncompacted sediment of **Model 1** when you simulated and earthquake?

_____

_____

2. Why does this happen? _____

_____

Model 2

Procedures/Directions: Remove the coins from model one, and add a small bit of water to the sedimentin the cup so that it is moist (but not soupy). Press down on the sediment in thecup so that it is well compacted, and then place the coins into this compactedsediment just as you placed them in Model 1 earlier. Simulate an earthquake asyou did for Model 1, and then answer questions 2 & 3.

Questions:

1. What happened to the vertically positioned coins in the compacted sediment of **Model 2** when you simulated an earthquake?

_____

_____

2. Based in your experimental **Models 1 and 2**, which kind of Earth material is more hazardous to build on in an earthquake-prone regions: compacted sediment or uncompacted sediment? (Justify your answer by citing the evidence from your experimental models.)

_____

_____

3. Consider the moist compacted sediment in Model 2. Do you think this material would become more hazardous to build on, or less hazardous to build on, if it became totally saturated with water during the rainy season?

To find out and justify your answer, set up, run and observe **Model 3** next.

Model 3

Procedures/Directions: Remove the coins from model two, and add more water to the compacted sediment in the cup so that it is gets a thin layer of water on top of the sediments. Pour off any excess water so that there is no pooling of water on top of the sediment in thec up. Then place the coins into this water-saturated, compacted sediment just as you placed them in Models 1 and 2 earlier. Simulate an earthquake as you did for Models 1 and 2, and then answer questions 1, 2 and 3 below.

Questions:

1. What happened to the vertically positioned coins in the compacted sediment that is saturated with water when you simulated an earthquake?

_____

_____

2. What will the effects of liquefaction will be on buildings?

_____

_____

3. Where would liquefaction be likely to occur?

_____

_____

Write a statement (100-150 words) that summarizes how water in a sandy substrate beneath a home can be beneficial or hazardous. Justify your reasoning with the reference to your experimental models.

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Part V - Measuring and Analyzing Displacement on an Active Fault Using Aerial Photography

Part V is designed to familiarize you with how geologists investigate the movement of an active fault by examining aerial photographs and determining the following about the fault: 1) position and extent of the fault, 3) notable offset markers, 4) apparent direction of offset, and 5) amount of offset. This activity comes out of your lab manual under the earthquake chapter. Locate the aerial photograph of the San Andreas fault in the vicinity of Wallace Creek.

Question 1: What's the orientation of the San Andreas Fault in this aerial image? North-south?; east-west?

Answer : _____

Question 2: What is the length of the San Andreas Fault in this aerial image?

Answer : _____ kilometers

Question 3: What is the apparent lateral offset movement of Wallace Creek across the San Andreas Fault in this aerial image? Right-lateral or left-lateral?

Answer : _____

Question 4: What is the amount of apparent lateral offset movement of Wallace Creek across the San Andreas Fault in this aerial image? In kilometers

Answer : _____ kilometers

Question 5: What is the relationship of Dry Creek to Wallace Creek in relation to ancient movement of the San Andreas Fault over time? Think about multiple large rupture offsets over time.

Answer : _____

Part VI - Earthquake Laboratory Reflection

Directions: Write a reflection (minimum 120 words in length) about your experience in doing the earthquake lab today. Include the following: 1) What was the purpose of the lab?; 2) What did you learn during this laboratory?; 3) What did you find interesting? 4) What were the problems and challenges you encountered; and 5) Your opinion on how this lab was designed – good or bad.

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