Student Name: ______________________________ **Grade:** ______

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 FUNDAMENTALS

Directions: Answer questions 1 through 6 using the information supplied in your lab manual and in the pre-lab below. Complete Part I prior to the start of the lab during the pre-lab orientation lecture.

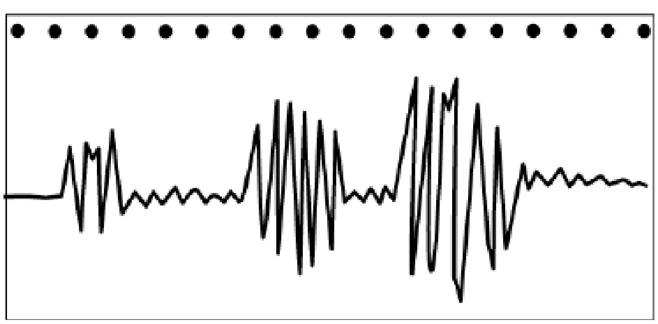
1. What type of active geologic structures do earthquakes occur along? ________________________

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

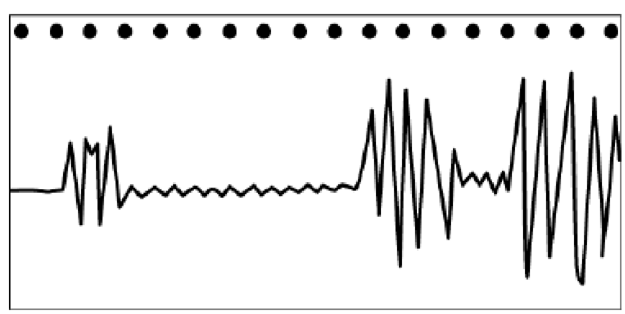
3. Each increase of 1 on the Richter Scale means an increase of _________________times in the ground motion and about a ___________ times increase in the amount of energy released.

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)

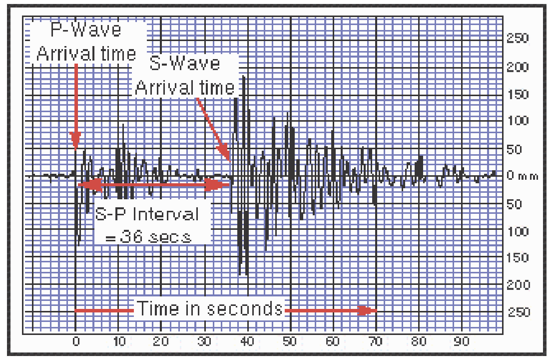
7. How did you determine your answer in question 6? ____

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

Locating the Epicenter

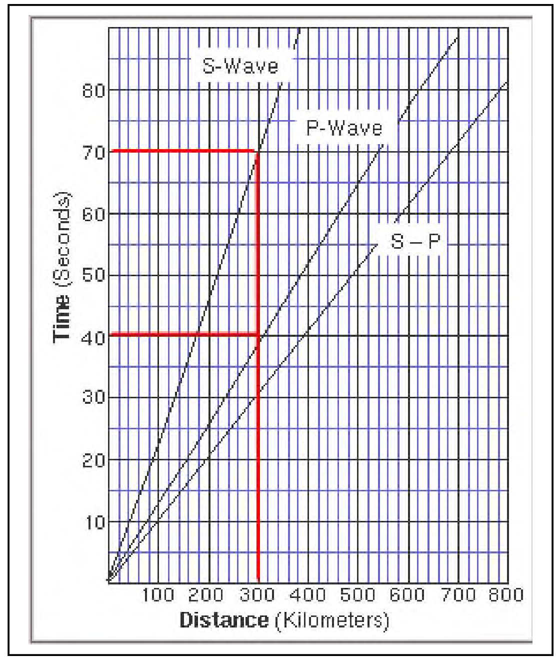
Measuring the S-P time interval

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 must measure the interval to the closest second and then use a graph to convert the S-P interval to the distance to the epicenter. 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.

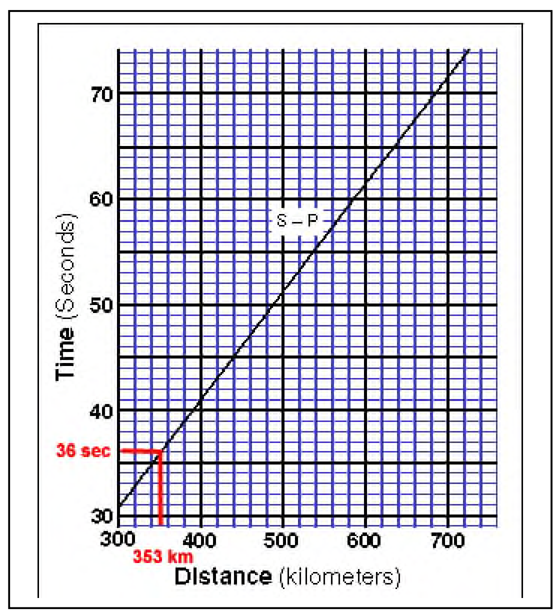


Examine the graph of seismic wave travel times (middle graph on this page). There are three sloped lines on the graph: The steepest-sloped line shows S wave travel-time graphed versus distance. The center one shows P wave travel time versus distance and the lower one shows the variation in distance with the difference of the S and P travel times. It takes an S wave approximately 70 seconds to travel 300 kilometers, whereas it only takes a P-wave 40 seconds to travel 300 km

Question 1: How much faster are P-waves compared to S-waves?

____

For the rest of this exercise, you won't need 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 355 km. To determine the distance to the epicenter, 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 following exercises.



Finding the Epicenter on a Map

Once you have determined the epicentral distances, you can draw circles on the map around each station location 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.

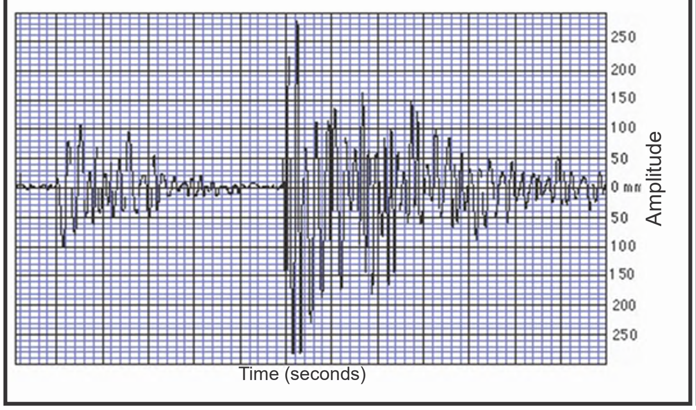
Using this method to determine an earthquake's epicenter may not result in an exact point for some earthquakes. Discounting measurement errors, there are several factors that affect the speed of earthquake waves. Variations in rock type, rock temperature, and lithostatic pressure will affect wave speed, and in turn, will change the actual travel times, and hence the S-P intervals.

Question 2: How far away is the epicenter if the local seismogram's S-P interval is 65 seconds?

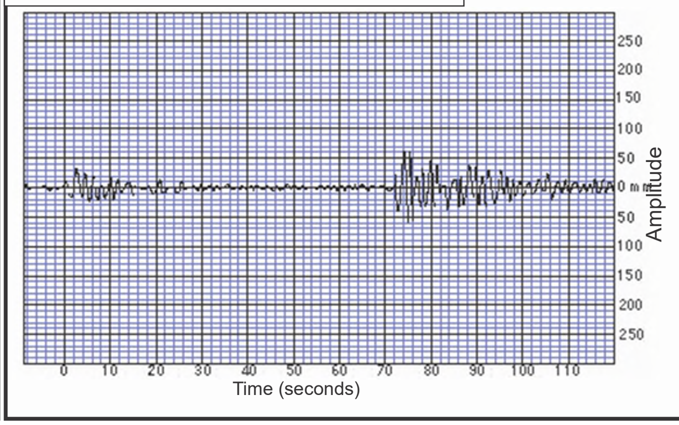
Epicenter is ___________ km's away

The earthquake seismograms for this exercise are posted below:

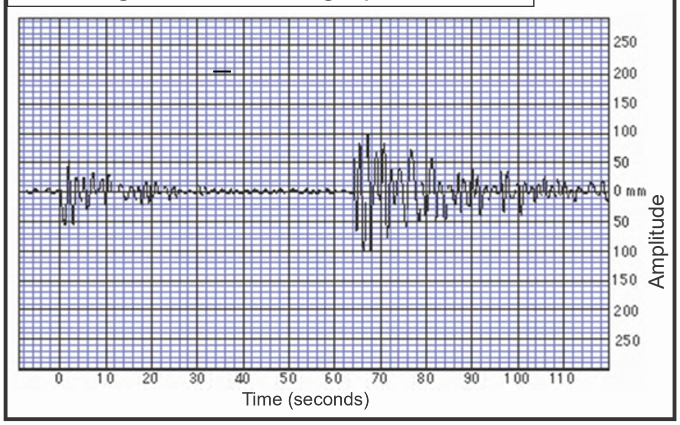
Eureka, CA seismograph station



Elko, NV seismograph station



Las Vegas, NV seismograph station



Question 3. Which seismogram shows the greatest amplitude? ____________________

Question 4. 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:

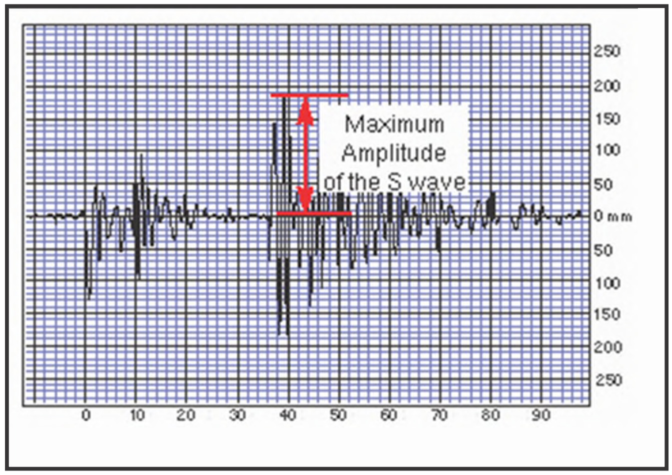
Use the seismograph recordings to determine the time interval between the arrival of the P- and S-waves. Next, use these time intervals and the bottom graph on page 1 to determine the distance from the epicenter for each seismograph station.

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

Finally, draw 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 earthquake's epicenter

Question 5. Where is the epicenter for this earthquake? ______________________________

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?"

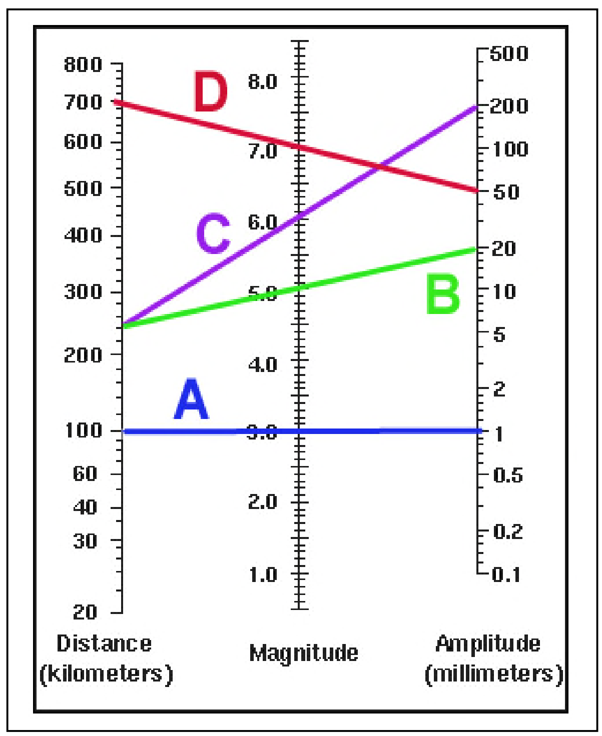
There are many ways that one could evaluate the relative strength of an earthquake: the degree of damage to buildings of various constructions, the length of rupture of the earthquake fault, the amount of ground shaking, etc. But determining the strength of an earthquake using these kinds of "estimators" is full of potential problems and various levels of subjectivity.

A well-known scale - known as the "Richter Scale" - is used to compare the strengths of earthquakes involves using the records (the seismograms) of an earthquake's shock waves. Dr. C. F. Richter of the California Institute of Technology in Pasadena introduced the Richter Magnitude Scale into the science of seismology in 1935. 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 9 for the Earth's strongest earthquakes. Although the Richter scale has neither 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. Note the Richter Scale's accuracy tops out at around 6.8 M on the chart. Another scale - termed "Seismic Moment" - is used for earthquakes larger than 6.8M.

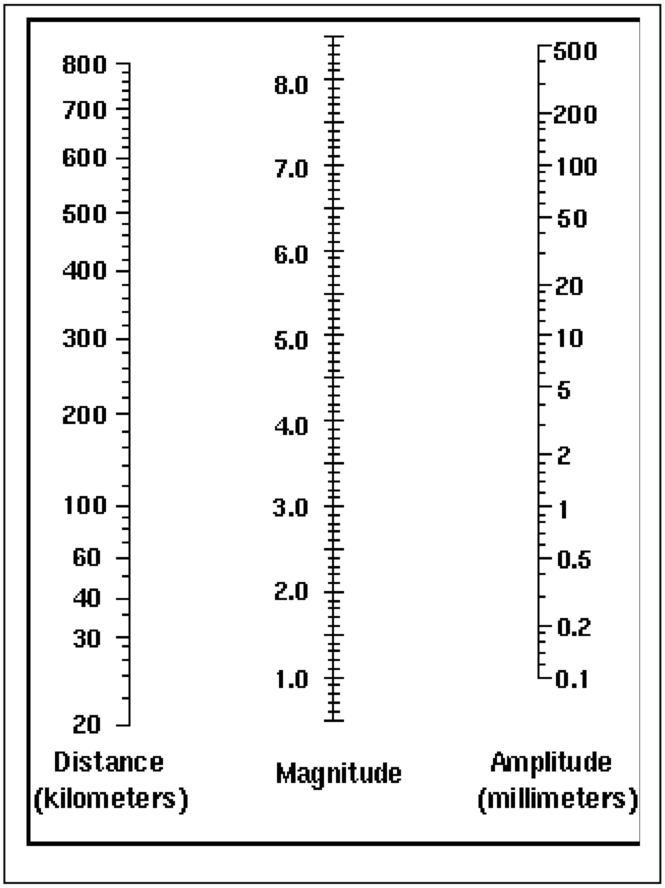
The Richter magnitude determination is based on measurements made on seismograms. Two measurements are needed: the S-P Time Interval value and the Maximum Amplitude value of the S-waves. The illustration at the top right on this page shows how to make the measurement of the S wave's maximum amplitude. 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 blue 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.



Note that an earthquake that is 250 kilometers away with a magnitude of 5 will have a maximum S-wave amplitude of 20 millimeters (line B). Another earthquake with the same distance away (250km), but with a magnitude of 6 will have an amplitude of 200 mm (line C). Lastly, an earthquake that is 700 km away with a magnitude of 7 will have an amplitude of about 50 mm (line D). 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 likelihood that you are accurate in your estimate.



Directions: Complete the table below. First, copy the calculated distances from page 3. Then use the seismograph recordings on page 3 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 to the left. Where the three lines cross is your Richter magnitude for the quake.

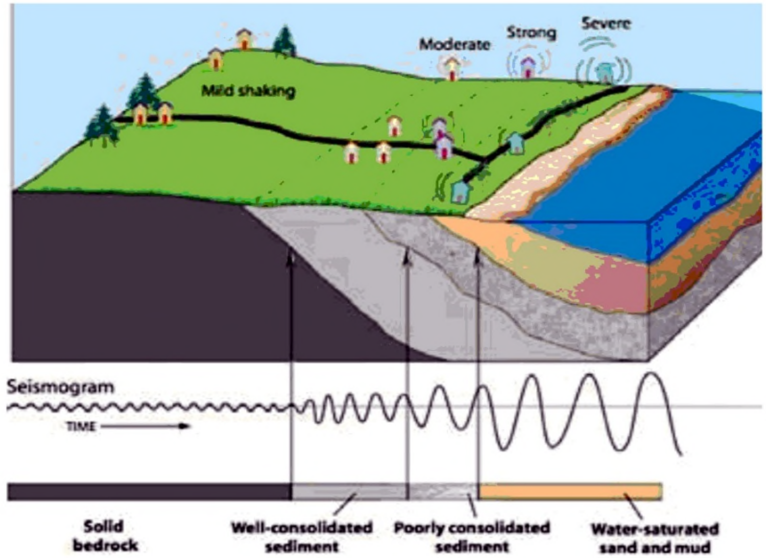
Question 6: What is the magnitude of the earthquake? __________ M

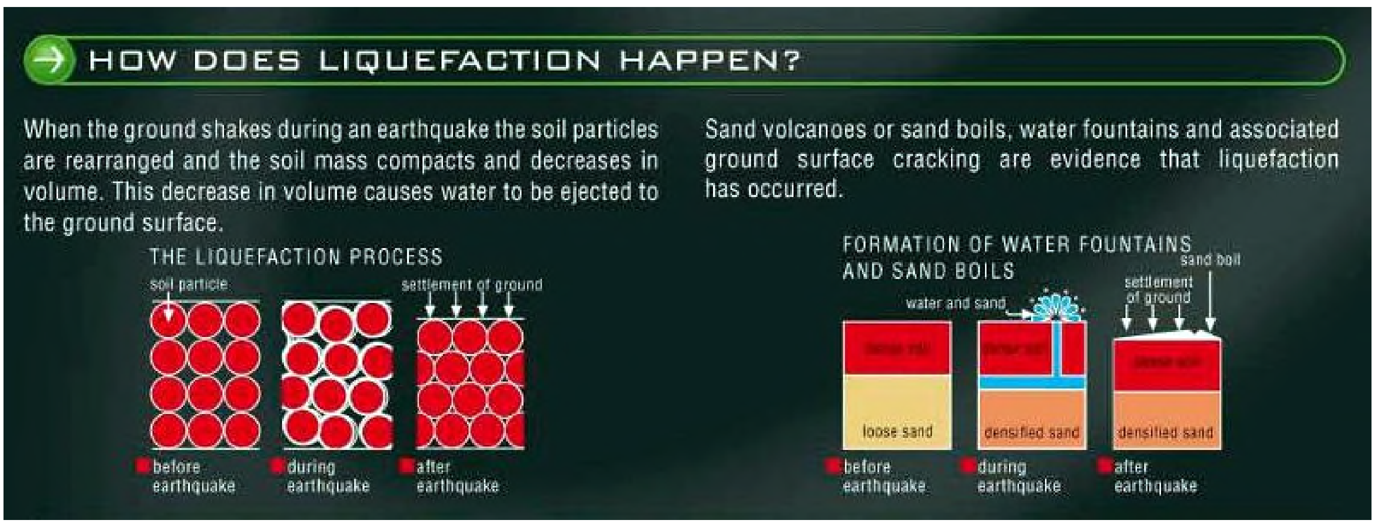
Part III. Modeling Effects of Ground Motion and Liquefaction on Buildings

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 type of geology beneath the surface – rock type and structure. The figure below shows how an earthquake wave going through solid bedrock has high frequency and low amplitude. In contrast, when the waves go through weaker (lower density/porous) 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, unconsolidated sediments are susceptible to ***liquefaction***, which causes sediment to behave like quicksand. Liquefaction typically commonly occurs in regions of unconsolidated sediments that are near bodies of water or where the groundwater table is very close to the surface.





<u>Model 1</u>- Simulating the Shaking of Uncompacted Dry Sediment

Procedures/Directions: Obtain a small plastic or paper cup. Fill it three-quarters full of 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 counterclockwise. 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 the earthquake by shaking and tapping the cup on the table top?

____

____

2. Why did the coins do what they did? ____

____

<u>Model 2</u> - Simulating the Shaking of Well-Compacted/Cemented Sediment or Solid Bedrock

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

____

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

____

____

3. Consider the moist compacted sediment in **Model 2** (simulating consolidated substrate). 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 to Question 3 above, set up and run **Model 3** next and see what happens.

Model 3 -- Simulating the Shaking of Uncompacted Water-Saturated Sediment

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 the cup. 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 uncompacted sediment that is saturated with water when you simulated an earthquake? Did liquefaction occur?

____

____

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

____

____

3. Where would liquefaction most likely occur in San Diego?

____

____

Earthquake Model Simulations Reflection: Write a statement (paragraph) 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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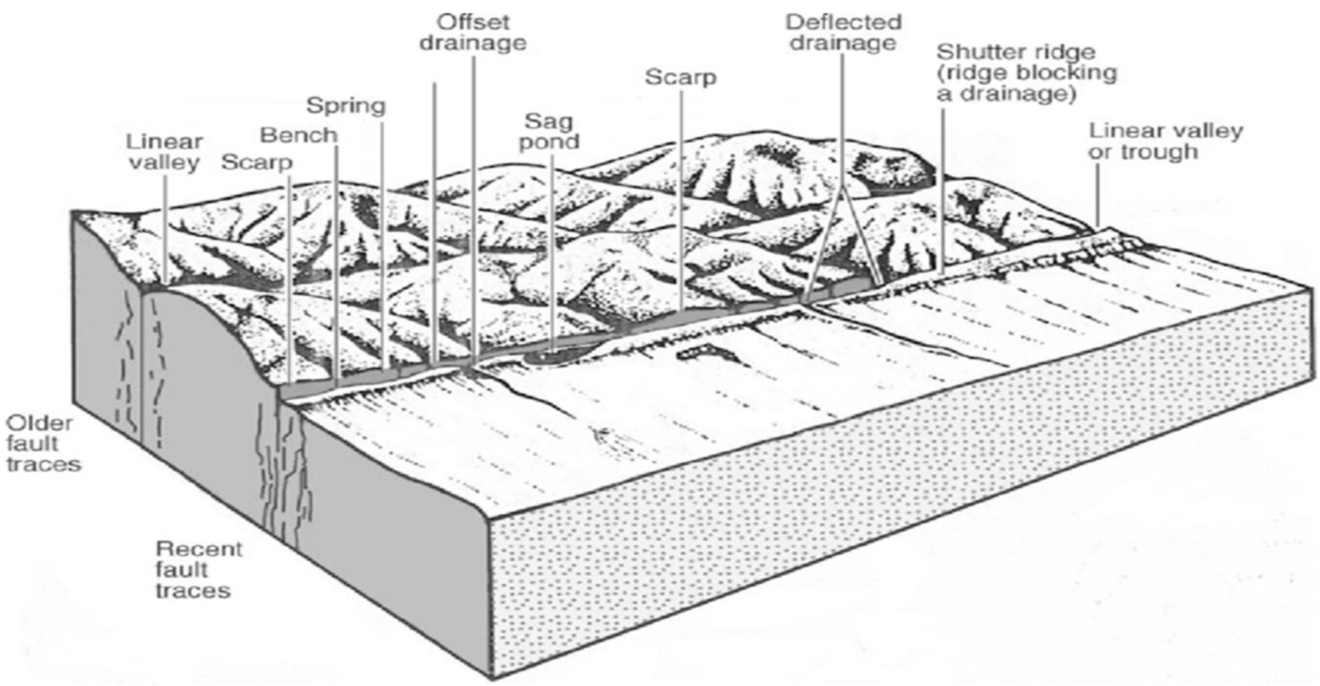
Part IV - Measuring and Analyzing Displacement on an Active Fault Using Aerial Photography

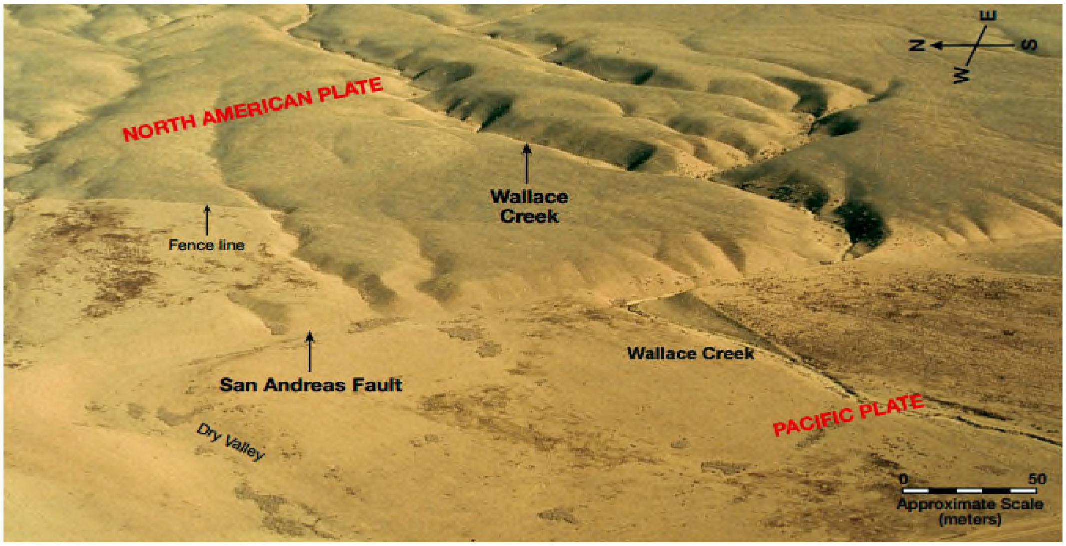
Geologists investigate the movement of an active fault by analyzing aerial photographs of a fault, combined with in-the-field mapping of the fault zone region. From maps and field work, geologists can determine the following about the fault: **1)** position and extent of the fault, **2)** notable offset markers, **3)** apparent direction of offset, and **4)** amount of offset. Unique fault-related landforms develop along an active strike slip fault like the San Andreas Fault, in response to lateral fault movement and the stresses applied to the crust along the fault line. The following image illustrates a number of these features.

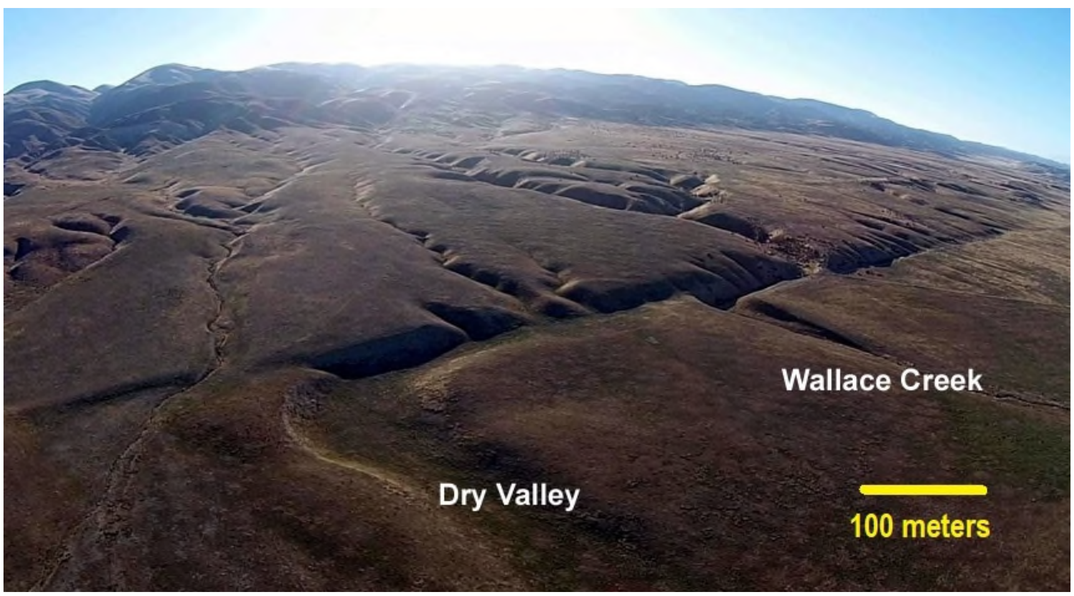


Many of the above fault-related landforms can be seen in the following aerial photo images of a segment of the San Andreas fault found in the three aerial photographs of the San Andreas Fault of Central California in the vicinity of Wallace Creek on the next page. Study those images for the next exercise.

Finding the Fault Line Exercise:

Directions: Examine the various landforms found along the fault line, including stream offset and scarps. Trace the fault line in each of the three images below with your pencil or pen, Answer the following questions below.





Question 1: How many kilometers long is this segment of San Andreas Fault (first aerial image)?

Answer : _______________ kilometers

Question 2: What direction does the San Andreas Fault run? (check first image with compass direction symbol)

Answer : Circle one: N-S NE-SW E-W NW-SE

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 meters

Answer : ______________ meters

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

Answer : ____

Question 6: List the different types of fault-related landform features that you observe along the San Andreas Fault in the Wallace Creek area. Use the illustration on the previous page. Name at least three.

Answer : 1) __________________ 2) _____________________ 3) _____________________

Part V - Earthquake Laboratory Reflection

Directions: Write a 3-point reflection of the lab activity, explaining its purpose, the methods used, the results obtained, and a brief personal reflection of what you enjoyed and learned about doing this earthquake lab (*3 points possible*). Answer the following 3-point question reflection set.

1) *What was the purpose of this lab? What did you discover and learn during this lab?*

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____

____

2) *What did you enjoy most about this lab? Also, what was challenging or thought-provoking?*

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3) *What are your constructive comments about the design and execution of this lab? What's good? What's bad? Offer suggestions for making the lab better.*

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