Geology 112 – Earthquakes

Activity 1 Worksheet – Introduction to the Course. What is a Fault? What is an Earthquake?

Activity 1 Objectives:

• Introduce student to the topics, requirements and format of the course
• Introduce students to the required learning outcomes of all Area R courses at SJSU
• Describe design of all assignments in this course and how they meet the desired learning outcomes of Area R courses
• Review the greensheet (syllabus), which provides critical information to the successful beginning and completion of the course, including the requirements and due dates of all assignments and assessments of learning
• Introduce students to the frequency of earthquakes, the faults that serve as sources of earthquake, and how slip on the fault results in earthquake (seismic) wave propagation.

Activities in this class take the place of portions of lectures, so students should take comprehensive notes as some of this material will likely be the focus of questions on Unit Exam 1.

The lectures for this activity is divided into four parts, parts 1 through 4, please watch all of the segments (56 minutes of video in all)

1. Introduction to the Course - View Don’s YouTube Video “Activity 1 lecture part 1 of 4” – Introduction in Canvas and follow along in the worksheet. (11 minute-long video)

2. Area R Courses - Required Learning Outcomes, Design and Requirements - View Don’s YouTube Video “Activity 1 lecture part 2 of 4” – Area R in Canvas and follow along in the worksheet. (11 minute-long video)
3. **Review of Greensheet – Course format, assignments, learning assessments and schedule** - View Don’s YouTube Video “Activity 1 lecture part 3 of 4 - Greensheet” in Canvas and follow along in the worksheet. (13 minute-long YouTube video)

If you have any questions on the material covered in the greensheet or the requirements of this course, please post them in Don’s Office discussion in Canvas (http://www.sjsu.edu/at/ec/canvas/)

4. **What is a fault? What is an Earthquake?** - View Don’s YouTube Video “Activity 1 lecture part 4 of 4 – What is a Fault?” in Canvas and follow along in the worksheet. (16 minute-long YouTube video)

1. **Will there be an earthquake today?**

   View Seismic Monitor: http://www.iris.edu/dms/seismon.htm

   Make observations and take notes and answer the question above.

   Go to http://earthquake.usgs.gov/earthquakes/map/

   List three earthquakes, the date time, magnitude, location

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<tr>
<th>Date</th>
<th>Time</th>
<th>Latitude</th>
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   Develop a new question based on your observations
2: What are four types of faults? (Watch animations below, 1 minute in all)

List the four types of faults and describe the nature of movement along the fault (draw pictures of each type of fault with an arrow on the fault plane showing direction of fault slip and label footwall and hanging wall)

3: How are earthquakes generated?

How does the elasticity of the outer earth result in earthquakes? (How does the earth’s crust act like a rubber band?)

Make observations and take notes

View - Elastic Rebound with Trees - http://www.youtube.com/watch?v=-5BqKKutxBs
5. Lastly, post your thought or memory on an earthquake in your Activity #1 Learning Group Discussion in Canvas and reply to the posting of another student.
Activities in this class take the place of lectures, so students should take comprehensive notes as some of this material will likely be the focus of questions on Unit Exam 1.

**What is the due date?** __________________________ (fill-in day, date and time -- see greensheet or information at top of your learning group discussion for this activity in Canvas.

**Objective:** Introduce students to the physics and geology of faults, earthquakes and wave propagation.

**Instructions for required learning group discussion** on last page of the worksheet.

**Slide 2.** Students should discuss any of the questions on Activity #1 (see list on computer presentation slide) – post any questions in Don’s Office or Student Café discussions

List any specific questions here

**Slide 3.** Students should list any questions dealing with Activity #1 (see list on computer slide)?

List any specific questions here and post in Don’s Office or Student Café discussions

**Slides 5 through 9**

What is a fault?

What is a fault trace?

What is the evidence for fault slip?

How is the type of faulting determined?
List the three types of faults discussed in this lecture

**Slides 10 through 12** – What causes faulting?

What is stress?

What is strain?

What are three types of stress?

How does each type of stress relate to a type of faulting?

**Slides 13 through 16** Elastic rebound theory and stick-slip behavior of faults

**Why do faults stick and then slip, so called stick-slip behavior, resulting in an earthquake?**

Describe the behavior of the block as the elastic cord is pulled to the right.

Describe the behavior of the cord, both before the block slides and after it slides.

How does the amount of tension on the cord change from before the block slips to after it slips?

**View Quakecaster** - [http://youtu.be/zlipwGUaFAk](http://youtu.be/zlipwGUaFAk)

What are the key factors that influence slip along a fault and an associated earthquake?
How does the average amount of slip of the block change from two slider blocks, one stacked on the other, to one slider block?

How does the model shown in the video mimic fault slip?

**Slides 18 through 27  Elastic Rebound and the Generation of Seismic Waves**

Describe what you see in the video of the trees?

What is a wave?

What is a body wave?

What is a surface wave?

What are two types of body waves that travel through the Earth?

What is another name for a P wave?

What is the direction of particle motion with respect to the direction of wave propagation in a P wave?

What is another name for a S wave?
What is the direction of particle motion, with respect to the direction of wave propagation, in a S wave?

Required Learning Group Discussion Posting, Review, Answer and Feedback

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• Scoring on required posting will be based on the clarity (ability to communicate in writing) and quality (scientific insight) of the posted questions and the listings of potential answers.
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Activity 3 – Measuring an Earthquake

What is the due date? ________________ (fill-in day, date and time -- see greensheet or information at top of your learning group discussion for this activity in Canvas.

Objective: Address Learning Outcome #1 – Students will understand the methods and limits of scientific investigation by progressing through a problem or question about the earth and environment, in this case, damage caused by seismic waves, then see the design of an experiment to acquire verifiable data that bear on this problem, measuring ground shaking, and begin analysis of these data, identifying arrival times of various seismic waves to later locate earthquakes and determine their magnitude.

Instructions for required learning group discussion on last page of the worksheet.

This lecture is divided into seven parts for a total of 1 hour and 8 minutes of video.

Slides 1 – Introduce Meeting #3 Topic – What is the topic of this meeting?

Slides 2 and 3 – Previous Activities – Did you completed and understand Activities 1 and 2?

Slide 4 – Describe Required Meeting/Activity Postings of 2 multiple-choice questions – do you understand this requirement to work with other students in your learning group?

Slides 5 and 6 – Meeting #3 Learning Objective and Outline of Presentation

Slide 7 – What controls the speed (velocity) of the P and S waves?

Write down the formulas for the P wave and S wave

How does the speed of a P wave compare to the speed of an S wave?

Slides 8 through 12 – Surface Waves

What is a surface wave?
What are two types of surface waves?

What is the direction of particle motion in a Love wave?

What is the direction of particle motion in a Rayleigh wave?

How do surface waves affect ground motion and dame in an earthquake?

Slides 13 – Recap of Seismic Waves

Slide 14 through 16 – Wave Characteristics

What is the crest of a wave?

What is the trough?

What is the amplitude?

What is the wavelength?

What is the period?

What is a wavefront?

Slides 17 through 21 – Detecting Seismic Waves

How do scientists measure seismic waves?

What is a raypath and how does it relate to the wavefront?

What does a seismograph measure?
Describe the components of a seismic station?

What is a seismometer?

What is a seismograph?

What is a seismogram?

How does a seismic station get the data back to a remote computer?

How does a vertical seismograph work?

How does a horizontal seismograph work?

How does a seismogram display the amount of ground motion?

How do seismologists (earthquake geophysicists) analyze seismograms?

**Slide 22 through 24  Earthquakes, Seismic Waves, Shaking and Seismograms**

List in order, from first to last, the order of the seismic waves that arrive at a seismic station from a distant earthquake?

What controls the order of the arrivals of these waves?

How does the ground shake, both the amount and direction, for each of the arriving seismic waves (P, S, and L)?
Slide 25 – What are some of the aspects of an earthquake that scientists want to determine and why?

Slides 26 and 27 – Travel-time Graphs

What are travel-time curves and how are they constructed?

Slide 28 Plot S-P Time Difference on Travel-time Curves

How are travel-time curves used to study earthquakes?

What aspect of an earthquake, relative to the location of the seismic station, is determined from plotting the S-P time on a travel-time graph?

Slides 29 and 30 – What will we do in our next class meeting (#4) and how does it relate to our work on travel-time curves for the S and P waves?

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Due date: see greensheet or information at top of your learning group discussion for this activity in Canvas.

Objective: Address Learning Outcome #3 – Students will apply a scientific approach to a problem of the earth and environment by locating earthquakes and determine their magnitude

Instructions for required learning group discussion on last page of the worksheet.

This lecture is divided into seven parts for a total of 1 hour and 10 minutes of video.

Online Lecture - Part 1- (10 minutes-long)

Slides 1, 2 and 3 – Introduction. Outline and Tasks in this Meeting

Slides 4 through 8– Recap of Last Meeting

Online Lecture Part 2 (9 minutes-long)

Slide 9 – S-P Method for Determining Earthquake Epicenter Location

What will be determined with the S-P methods?

Slide 10 – S-P Time Difference

List the location of the three seismic stations (where the seismometer is located)
What was measured from seismograms at each seismic station?

**Slide 11 – Plot S-P Time Difference on Traveltime Graph**

How is the S-P time difference used to determine from the seismic station to the earthquake epicenter?

**Slide 12 through 16 – Plot Circle with Distance as Radius (Sydney, Tokyo and Vancouver)**

How were the distances from each seismic station used to locate the epicenter?

**Slide 17 – Introduction to Virtual Earthquake Website**

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**Online Lecture – Part 3 (5 minutes-long)**

An example of using Virtual Earthquake to determine location of Kobe, Japan Earthquake

**Online Lecture – Part 4 (6 minutes-long)**

Slide 18- How Big was it?
Slide 19 – Maximum Amplitude

What is meant by the Richter magnitude or simply earthquake magnitude?

What is the key parameter measured at a seismic station that is used to determine the magnitude

Slide 20 – Magnitude (comparing)

What is the nature of the magnitude scale?

How does a magnitude 5 earthquake compare to a magnitude 4 in terms of amount of ground motion and energy released?

Slide 21 – Magnitude of the Earthquake

What is the Nomogram and how is it used to determine the earthquake magnitude?

Online Lecture – Part 5 (4 minutes-long)

An example of using Virtual Earthquake to determine magnitude of Kobe, Japan Earthquake

Online Lecture – Part 6 (11 minutes-long)

Slide 22 – Evolution of Earthquake Magnitude – Write Down and Understand the Equations
How has the definition of magnitude, and how it has been calculated, evolved over time?

What is seismic moment?

How does seismic moment relate to the rupture of a fault during an earthquake?

**Slide 23 – Summary**

What did we discuss in this meeting?

**Online Lecture – Part 7 - [http://youtu.be/HL3KGK5eqaw](http://youtu.be/HL3KGK5eqaw) (6 minutes-long)**

Watch the video – Moment Magnitude Explained – What Happened to Richter scale

What was the problem with the Richter magnitude scale?

What allowed for the Richter magnitude scale to be replaced?

What is the seismic moment?

What are the key parameters used to define the seismic moment?
How is seismic moment used to define earthquake magnitude?

How does the magnitude compare to the amount of energy released in an earthquake?
I. Getting started

1. Enter Google and search on “Virtual Earthquake”
2. Click on Virtual Earthquake – An Introduction, which should be the first website on your list

II. Virtual Earthquake Exercise

1. Read all of the information on this page and make sure that you understand this information as we covers if in Meetings #1 through 4 in the class.

III. Select an Earthquake to Analyze

1. Select an earthquake to examine (use the default - “San Francisco area”)
2. Click on “Submit Choice”

IV. Determining the Epicenter

1. How do you measure the S-P interval?

   Click on View Seismograms

2. Measure the S-P interval for each of the three seismograms and type each into the appropriate box on the webpage (be accurate!)

3. Click on Convert S-P Interval

4. How is the distance from the seismic station to the epicenter location determined?
5. Using the S-P interval for each of the three seismograms and determine the distance to the epicenter and type each into the appropriate box on the webpage (be accurate!)

6. Click on **Find Epicenter**

   How did you do?

   If you did not receive an excellent, then remeasure S-P interval and recalculate distances of the epicenter for each station

7. Where is the epicenter of this earthquake located (give a precise location)?

   Summarize the scientific question that was addressed in this study, the nature of the analysis and the conclusion:

8. If you received an excellent, then move on by clicking on "**Compute Richter Magnitude**"

V. Calculating the Richter Magnitude - How big was it?

   1. What is meant by the strength of an earthquake and why is this a somewhat ambiguous terminology?

   2. What is the Richter magnitude scale? (the initial definition on the webpage is not an accurate one by the way)
3. What measurements are needed to calculate the Richter magnitude and what are they meant to represent (discuss this latter part with your fellow students)?

4. Click on Go to Next Page

5. What is the Richter Nomogram and how is it used to normalize all measured seismogram maximum amplitudes and station distances to the epicenter to a standard?

6. Measure the maximum amplitude of the S wave on each seismogram, shown on the webpage, and type it into the appropriate box for each station.

   Click on Submit to Nomogram

7. Measuring the Earthquake Magnitude
   
   a. Determine the Richter Magnitude at the intersection of the three colored lines drawn from the amplitudes and distance from the three seismic stations.

   b. Type it into the appropriate box on the webpage

   Click on Confirm Magnitude

8. Upon confirmation of the Richter Magnitude, type the appropriate information in the form on the webpage, check the box to email certificate to your instructor and my email (Donald.Reed@sjsu.edu) - make sure that you email a copy to yourself.

   Click on Get Certificate

You are done with this research.
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Activity 5 – Earthquake Epicenter, Seismic Waves and Plate Tectonics

Due date: see greensheet or information at top of your learning group discussion for this activity in Canvas.

Objective: Address Learning Outcome #3 – Students will apply a scientific approach to a problem of the earth and environment by locating earthquakes and analyzing earth structure

Instructions for required learning group discussion on last page of the worksheet.

I. Picking P and S wave arrivals to locate earthquakes with CSUSM FELT Tools at http://www.csusm.edu/cyberteam/resources/FELT_tool.html

1. Enter Google and search on “CSUSM FELT Tools”

2. Click on CSUSM FELT Tools, which should be the first website on your list

3. Flash-Based Earthquake Location Tool – Exercise 1
   a. Read the webpage and then Click on Exercise #1
   b. In this exercise you will be shown how seismologists use data collected from scientific instruments to precisely locate the epicenter of an earthquake. Choose an earthquake from the list and click on Start
   c. Read the text – what is the purpose of this analysis?

Click on Continue

d. Read and understand the meaning of the symbols in the Legend below the map - Epicenter, Station (Current and Visited)

e. You may want to zoom out on the map to allow you to see the locations of more seismic stations

f. Click on a seismic station, read the instructions in the pop-up window compare the S-P interval in the two seismograms and click on the appropriate answer (Closer, Further or About equal).

g. If you have selected the correct answer, a circle of the distance determined from the S-P interval will be plotted on the map around the seismic station, now plotted with a red triangle. Click on Continue
h. Select another **seismic station** and answer the questions in the subsequent pop-up window (One, Two or Three stations – hint: remember your research in Virtual Earthquake).

i. After you have provided the correct answers to the questions following the pick of the second station, another circle, based on the S-P interval will be drawn on the map (notice how two circles can intersect at two points, at most). Which is the location of the epicenter?

j. Click on a **third seismic station**

k. Another circle, representing the distance to the epicenter, based on the S-P interval, from the third station is drawn.

l. Note that the three circles intersect at one point and the Earthquake Epicenter symbol marks this location.

Click on the **epicenter** location to view the latitude and longitude of this location.

You may also click on the various seismic stations on the map to add another circle and each time the seismogram with the picked S and P waves can be viewed in the lower right hand corner of the graphic. You may also to delete and redraw a circle, once again with the associated seismogram displayed on the webpage.

Let's return to our original home page for this activity using the Back command on your browser or do a Google search on "CSUSM FELT Tools"

4. **Flash-Based Earthquake Location Tool – Exercise 2 (A Demo)**

   a. Select **Exercise 2 (A Demo)** – This time you will pick the P and S wave arrivals times yourself (using the Hint circles below each seismogram and (somewhat annoying) audio prompts

   b. Select an earthquake and click on **Start**

   c. Read the instructions carefully. In the next webpage, you will be asked to identify the P- and S-wave arrivals, in order to determine the distance from the station to the earthquake epicenter. Click on **Continue**

On this screen you will attempt to locate the P and S wave fronts.

Slide the time bars to pick the P and S wave arrivals and the P and S times, S-P interval and the distance to the epicenter will be determined for you and displayed below the seismogram. You may want to use the “Hint” for the P and S waves by filling the circles with colors when you have positioned the slider bars accurately. Also, turn on your audio for
instantaneous feedback on your work.

Click on **Submit** after you are satisfied with your picks of the P and S wave arrival times.

d. Do this same analysis for a second station (remember that you can zoom out or in on the map view to see more seismic station locations), drag the P and S wave pick bars, and click on **Submit**

e. Do the same analysis for a third seismic and click on **Submit**

f. You should now see one circle drawn around each of the three seismic stations, and these circle should all intersect at a common location and near that location the Earth Epicenter symbol should appear

g. Drag the Earth Epicenter symbol onto the intersection of the three circles to mark your determination of the epicenter location

h. Hopefully you have done this analysis accurately, so a Congratulations should appear at the top of a blue-colored pop up window.

i. You are to be congratulated on achieving **learning outcome #3 of all Area R courses in which students apply a scientific approach to a problem of the earth and environment**

j. On the next page, write a **summary of your research in 80-100 words that includes**: (1) **scientific question** that was addressed in your study, (2) the **nature of data analysis you completed to address the scientific question**, your **conclusion and its scientific significance**.
You are done with this research.

II. Seismic Waves – model of earthquake wave propagation through the Earth

1. This video represents a screen capture of software that is also available for download for Windows-based computers: (http://bingweb.binghamton.edu/~ajones/#Computer%20Programs)

2. Click on 2011 Tohoku earthquake
   a. Click on Pause
   b. Click on Event Information – Read
c. Click on Information in each window (Seismogram, Earth Surface and Earth Cross-Section)
d. Take notes make sure that you understand the display in each window!

e. Click “Resume” button – you are viewing the seismic wavefronts generated by the earthquake

   Use the slide scale to speed up, slow down, reverse or stop the wave propagation

   Which wave is colored blue?
   Which wave is colored red?
   Which wave is colored yellow?
   Which wave is the fastest?   Which wave is the slowest?

   What is the shape of the wavefront?

   What happens to the wavefronts at the boundaries between the layers in the Earth?

   What is the difference between body waves and surface waves?

   Make sure that you understand the seismograms
III. Plate Tectonics

Slides 8 and 9. Introduction and Interior of Earth

Draw, label and describe the four major chemical layers of the earth

Slides 10 and 11. Evaluate the following two hypotheses:

1. The Earth is a static planet
2. The Earth is a dynamic planet

Cite three lines of scientific evidence that support your favored hypothesis

1.
2.
3.

Slide 12. What is plate tectonics?
Slide 13, 14 and 15. Continental Drift

What was the hypothesis of continental drift?

Describe four lines of evidence used by Wegener and his supporters as evidence of drifting continents

1. 

2. 

3. 

4. 

The Great Debate

What were some of the errors in Wegener’s hypothesis, which lead to its rejection?

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Objective: Address Learning Outcome #1 – Students will understand the methods and limits of scientific investigations of plate tectonics including the motions of the earth’s surface and the resulting earthquakes

- Instructions for required learning group discussion on last page of the worksheet.

Slides 1, 2 and 3 – Introduction, learning outcome, recap of last meeting and reading assignments

Slide 4 – Outline for Today

What will be discussed today?

Slide 5 - Seismic Wave Velocities

How do seismic wave velocities, both P and S, waves, provide evidence of the earth’s internal structure?

Draw, label and describe the four major chemical layers of the earth
How does the earth’s temperature change from the earth’s surface to the inner core?

**Slide 6 – Low Velocity Zone**

How do scientists use seismic wave velocities, both P and S, waves, to provide evidence of the strong and rigid lithosphere lying over a weaker asthenosphere?

**Slide 7 – Physical Layering**

Describe the physical layering of the earth and the characteristics of each layer?

**Slide 8 – Oceanic vs. Continental Lithosphere**

Which chemical layers compose the lithosphere?

Which chemical layer composes the asthenosphere?

Contrast the characteristics and thickness of lithosphere under the oceans with that under the continents?

**Slide 9 – Science Channel Movie**

How did Harry Hess contribute to our understanding the seafloor beneath the oceans and how did he acquire the data, which allowed him to formulate his ideas into a testable hypothesis?

**Slide 10 – Evidence – Mid-Ocean Ridge System**

What evidence for plate tectonic theory came from understanding the shape of the seafloor?
**Slide 11 – Evidence – Rock Sample**

How did oceanographers acquire data on the nature and composition of the rocks on the mid-ocean ridge?

**Slide 12 – Seafloor spreading**

Describe Hess’s hypothesis of seafloor spreading?

**Slide 13 – Oceanic Crust Magnetism**

Describe the patterns of magnetism, contained in the oceanic crust, around the mid-ocean ridges

**Slide 14 – History of the Direction of the Earth’s Magnetic field**

How has the direction of the earth’s magnetic field changed over time?

**Slide 15 – Vine-Matthews Hypothesis of Seafloor Spreading**

Describe the Vine-Matthews Hypothesis (perhaps draw a picture of seafloor spreading)

**Slide 16 – Deep Sea Drilling**

How was the Vine-Matthews hypothesis tested?
Slide 17 - Age of Oceanic Lithosphere

How does the age of the oceanic lithosphere vary with distance away from the center of the mid-ocean ridge?

Slide 18 – Plates of Lithosphere

Describe the plates (their location, movements and some of their names)

Slide 19 – Lithosphere Riding on the Asthenosphere

What are the three types of plate boundaries?

What is mantle convection?

Slides 20 and 21 – Seafloor Spreading and Divergent Plate Boundaries

What is seafloor spreading?

What are the characteristics of divergent plate boundaries?
Slides 22 and 23 – Subduction and Convergent Plate Boundaries

What is subduction?

What are the characteristics of convergent plate boundaries?

Slides 24 and 25 – Transform Plate Boundaries

What are the characteristics of transform plate boundaries?

Slide 26 – Summary

What did we discuss today?

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Geology 112 – Earthquakes  Name _________________________________

Activity 7 – Earthquakes and Plate Tectonics

Due date: see greensheet or information at top of your learning group discussion for this activity in Canvas.

Parts of this exercise were adapted from the Natural Sciences 412D class at SDSU, which is available at http://www.showmegeology.org/seismic-eruption_1.htm)

Objective: (a) Understand about the connection between earthquake characteristics (location, magnitude, depth, timing and frequency) to a number of key relationships to plate tectonics, including plate boundaries, plate motion, and plate structure. Conversely, the earthquakes provide one of the most, if not, the most important supporting evidence for plate tectonic theory.

- Instructions for required learning group discussion on last page of the worksheet.

Students will Seismic Eruption to investigate the distribute of earthquakes worldwide. Seismic-Eruption written by Alan L. Jones at SUNY Binghamton, runs on Windows computers, and is available for free download at:

http://bingweb.binghamton.edu/~ajones/#Seismic-Eruptions

Part 1 - Slides 1, 2 and Canvas Screen - Meeting # 7 Title, Learning Objectives, Class Business and Topic Outline

What is today’s topic?

Do you have any questions on Canvas, material of class format? Post in Don’s Office discussion.

Listen to some general answers to questions from a classroom section about:

(1) where to find assignment information each week,
(2) posting and working in activity learning groups and what becomes of Meeting/Activity multiple-choice questions in Collaborations,
(3) meaning of a free late penalty for the first student to post multiple-choice questions in learning group discussion in each meeting and
(4) navigation in Canvas

Slide 3 - Outline for Activity 7 using Seismic Eruption to Study Earthquakes and Plate Tectonics

Information Screen – Seismic/Eruption - We will watch video segments captured from using the software - Seismic Eruption

1. What does this program do?
2. What are the sources of data?

3. What is shown in Seismic/Eruption?

Part 2 - Title Screen

1. What is meant by topography?

Review of Menus - Most menu options are self explanatory.

Review of Preset Views

Review of Information boxes

World View

Examine the locations and when earthquakes have occurred around the world.

What is the period or length of time of the displayed epicenters?

What is the earthquake magnitude cutoff?

Using the legend in upper right corner, how are the magnitudes and depth of earthquake represented?

Notice the following:

1. Using the time scale bar at the bottom left corner of the video, how many years are represented in this time sequence? ________

2. Examine earthquake and eruption counters, which keep track of the number of quakes and eruptions over time.

3. Once the World View sequence has displayed all of the earthquakes and eruptions up to the present time, how many earthquake epicenters are displayed in this time interval worldwide? ________
4. How many earthquakes on average occur each year over this period?

__________ Each day? ______

We will use "Information" button in the lower right of the map window to display information to answer the following questions:

5. Are earthquakes distributed randomly or is there a pattern?

6. Why is there a pattern to distribution of earthquakes?

7. What do earthquakes tell us about the properties of the lithosphere?

8. What do earthquakes tell us about the properties of the plate boundaries?

Part 3 - Pacific Region and Pacific Ocean Group

1. Describe the distribution of earthquake in the Pacific Ocean region?

2. What is the range of depths of these earthquakes?

3. What is the range of magnitudes?
4. **Sendai 2011** - Write down 5 observations/facts about this devastating and tragic earthquake
   a. 
   b. 
   c. 
   d. 
   e. 

**Part 4 - North America Group – Alaska Group – Alaska 1964**

1. What is the depth range of these earthquakes?

2. Which plates are shown in this map?

3. What type of plate boundary is located in this region?

   **Cook Inlet Cross-Section**

4. What do you see?

5. What is the name of this feature?

   **Cook Inlet 3-D**
Summarize your observations of the distribution of earthquakes along a **convergent plate boundary**

**Part 5 - Atlantic Region**

1. Where are the earthquakes located in the Atlantic region?

2. What is the depth range of earthquakes in the Atlantic?

3. What is the range of magnitudes?

4. What is the Mid-Atlantic Ridge?

5. Why are there so few earthquakes located along the rim of the Atlantic Ocean?
Part 6 - North America

1. Compare and contrast the distribution and occurrence of earthquakes along the west and east coasts of North America?

2. Explain the difference in the distribution and occurrence of earthquakes along the west and east coasts of North America?

United States - California Group - California

3. What types of plate boundaries are found along California?
Write a summary of your research, including the scientific question that was addressed in this study, the types of data used to examine this question, the nature of your analysis and the main conclusions of your work.

Required Learning Group Discussion Posting, Review, Answer and Feedback

• After completing this activity, go to your learning group discussion and then post two multiple-choice questions, each with 5 potential answers (a, b, c, d, and e) on the material covered in this meeting; do not highlight the correct answers to your questions.
• Scoring on required posting will be based on the clarity (ability to communicate in writing) and quality (scientific insight) of the posted questions and the listings of potential answers.
• Ambiguous questions or answers, or error in writing quality, will receive point deductions – be clear and precise.
• Do not repeat a question posted previously by another student in your learning group, which will consist of 6-7 students.
• Students will then provide feedback on the clarity and quality of the questions posted by the student immediately above their own posting in their assigned discussion and then answer the questions.
• After your questions have been answered, provide the feedback on the accuracy of the answers and work with your learning group members in Collaborations to compile the top six questions covering the breadth of material in this Activity.
Geology 112 – Earthquakes

Name ____________________________________________

Activity 8 – Aftershocks and Fault Rupture

What is the due date? ______________________ (fill-in day, date and time -- see greensheet or information at top of your learning group discussion for this activity in Canvas.

Objective: Learn about the methods of science, in this case, seismology, to understand the connection between various earthquake characteristics as measured on a seismogram and the nature of fault, depth, location and slip through a case study of the 1989 Loma Prieta earthquake (location, magnitude, depth, rupture area and fault slip)

Instructions for required learning group discussion on last page of the worksheet.

Part 1 - Slides 1 and 2 - Meeting # 8 Title, Learning Objectives, Class Business and Meeting Outline

What is today’s topic?

Ignore error on date of Unit 1 exam in video -- date is correct on downloadable pdf of slide presentation

Slides 3 through 8 – Recap and Activity #7 with Connection to the Types of Plate Boundaries

What information about plate tectonics is derived from the distribution of earthquake epicenters worldwide?

What information about plate tectonics is derived from the distribution of earthquake epicenters around the Pacific Rim?

What information about plate tectonics is derived from the distribution of earthquake epicenters beneath the Atlantic Ocean?
What information about plate tectonics is derived from the distribution of earthquake epicenters along the western and eastern coasts of North America?

**Part 2 - Slides 9 through 11** - California Earthquakes Patterns (Seismicity)

What types of plate boundaries are found along California?

Which plates are in contact at Cape Mendocino and what is this tectonic feature called? Sketch the configuration of plate boundaries, label the names of the plate and the types of plate boundaries.
Slides 12 through 14. Loma Prieta Earthquake and Aftershock Distribution

Where was the epicenter of the 1989 Loma Prieta earthquake?

What was the magnitude of the 1989 Loma Prieta earthquake?

What was the depth of the initial rupture during the 1989 Loma Prieta earthquake?

What does the earthquake distribution around the 1989 earthquake epicenter represent?

What are aftershocks and why do they occur?

How is the length or fault rupture during an earthquake measured?

Slides 15 through 18. Calculating the Depth of an Earthquake

What is the difference between an epicenter and hypocenter (focus)?

How does the pP-P technique determine the depth of an earthquake?
Part 4 - Slides 19 and 20. Fault Rupture

Calculate area of the rupture along the fault(s), which resulted in the 1989 Loma Prieta earthquake from aftershock distribution

Slides 21 and 22. Geometry of Fault Rupture

Calculate the angle between the ground surface and the area of rupture, perpendicular to the San Andreas fault, at the epicenter of the 1989 Loma Prieta earthquake

Slides 23 through 25. Amount of Fault Slip Using Seismic Moment

How is the amount of slip during earthquake calculated from seismic moment?
Part 5 - Slide 26. Type of Fault Calculated from Seismogram, Analysis – Focal Mechanisms

Take notes on the Focal mechanism methodology

Slides 27 through 29. Summary of Key Points of Determining Focal Mechanisms

Slides 30 through 31. Interpreting the Beachballs for Type of Faulting

Draw each beachball diagram and give the type of faulting
Part 6 - Slide 31. 1989 Loma Prieta Earthquake faulting

What was the type of faulting during the 1989 Loma Prieta earthquake as determined from focal mechanisms?

Slide 32. Focal Mechanisms and Plate Boundaries

How are the beachballs, determined for focal mechanisms, used as key evidence for the types of plate boundaries?

Slide 33. Summary

Ignore error on date of Unit I exam in video, date is correctly given in downloadable pdf of slide presentation and in greensheet
Write a summary of your research, including the scientific question that was addressed in this study, the types of data used to examine this question, the nature of your analysis and the main conclusions of your work.

Required Learning Group Discussion Posting, Review, Answer and Feedback

- After completing this activity, go to your learning group discussion and then post two multiple-choice questions, each with 5 potential answers (a, b, c, d, and e) on the material covered in this meeting; do not highlight the correct answers to your questions.
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- After your questions have been answered, provide the feedback on the accuracy of the answers and work with your learning group members in Collaborations to compile the top six questions covering the breadth of material in this Activity.
Geology 112 – Earthquakes

Activity 9 – Energy Released, Frequency of Earthquakes and the Great Earthquakes

What is the due date? ____________________________________ (fill-in day, date and time -- see greensheet or information at top of your learning group discussion for this activity in Canvas.

Objective: Begin to learn in Unit II of the class about some of the largest, and most significant, earthquakes over the past 60 years.

• Instructions for required learning group discussion on last page of the worksheet.

Part 1 - Slides 1 through 3 - Meeting #9 Title, Learning Objectives, Class Business and Meeting Outline

This is the first material covered in Unit #2, Global earthquakes.

Slides 4 through 6 – California Seismicity Rate - Go to FAQ at UC Berkeley Seismological Lab (http://seismo.berkeley.edu/outreach/faq.html)

How many earthquakes occurred in California from 1990 through 2011 of magnitude 1 or greater?

How many earthquakes occurred in California from 1990-2011 of magnitude 1 or greater on average each year?

    on average each month?

    on average each week?

    on average each day?

Using an X-Y graph, plot the average number of earthquakes in California each year, between 1991-2011, versus magnitude of these earthquakes. (You may do this by hand or with a spreadsheet or plotting program like Excel, Numbers, in Google Docs, or free online plotting tools such as Grapher at http://itools.subhashbose.com/maths/Grapher.html)

Slides 7 and 8 - How often do big earthquakes occur?

Go to:

Slides 9 and 10 - Energy Released

Slides 11 and 12

Compare the amount of energy released during a magnitude 7.5 earthquake along the Hayward fault near San Jose and a magnitude 4.5 earthquake in the same region (see http://earthquake.usgs.gov/learn/topics/how_much_bigger.php)

Slides 13 through 18 – The Great Earthquakes

Slides 19 through 20- Search on IRIS Interactive Animations

Click on “Significant Earthquakes 2001-2011”

How would you characterize the distribution of the earthquakes, over the 10 year period as shown on the map?

Next go through each earthquake, 1 through 14, and compile and record the following data for each earthquake: location, date, magnitude, number of deaths, injured, homeless, damage, type of plate boundary in the region of the earthquake, plates along boundary, and type of faulting.
What is the annual rate of mortality from these 14 earthquakes? Post your calculation in your group discussion.

**Required Learning Group Discussion Posting, Review, Answer and Feedback**

- After completing this activity, go to your learning group discussion and then post two multiple-choice questions, each with 5 potential answers (a, b, c, d, and e) on the material covered in this meeting; do not highlight the correct answers to your questions.
- Scoring on required posting will be based on the clarity (ability to communicate in writing) and quality (scientific insight) of the posted questions and the listings of potential answers.
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- Students will then provide feedback on the clarity and quality of the questions posted by the student immediately above their own posting in their assigned discussion and then answer the questions.
- After your questions have been answered, provide the feedback on the accuracy of the answers and work with your learning group members in Collaborations to compile the top six questions covering the breadth of material in this Activity.
Objective: Learn about how science is studying one of the most tragic natural events in recorded human history. Focus your effort on how science is used to study this event.

- Instructions for required learning group discussion on last page of the worksheet.

I. Begin by going into Google Maps, using the satellite view, to locate each of the following countries around the Indian Ocean:

   Indonesia, especially the province of Aceh in northern Sumatra
   Thailand
   Andaman Islands
   Sri Lanka
   India
   Myanmar (Burma)
   Maldives
   Somalia

   Why will knowing the location of these countries contribute to your understanding of this tragic event?

II. View PBS Nova – The Wave that Shook the World (Go to: http://youtu.be/Q5x6a5kAke0

   Transcript at: http://www.pbs.org/wgbh/nova/transcripts/3208_tsunami.html

   01:00 - What was the death toll from this event over how many countries?

   Key questions for you to consider as you view this video:

   How did this event affect the scientific community?

   Why was there little or no warning provided to coastal communities?

   Why did it occur?

   3:00 - When did this earthquake occur?

   4:20 - What seafloor feature was near the epicenter?
5:00 - What type of plate boundary is near the earthquake?
   
   What is the tectonic process called that occurs along this plate boundary?
   
   How long has this process been taking place in this region?
   
   Which plate is sinking beneath western Indonesia?

5:45 – Know the location of the epicenter! Draw it on a map.

   How was the location of the epicenter determined?

5:50 - How long (distance) was the rupture along the fault? (how might have this been determined?)

6:00 - How far was the continental plate thrust out over top the oceanic plate? (how might have this been determined?)

6:25 – How long did the earthquake last?
   
   What was the magnitude?

7:00 - How powerful was this earthquake?

7:20 – Where is the Pacific Tsunami Warning Center located?
   
   What was first detected at the warning center?
   
   What is the purpose of the Pacific Tsunami Warning Center?
8:40 – How does the Pacific Tsunami Warning Center pinpoint the location of earthquake?

What measurements were made along the coast to detect tsunami and transmitted to the Pacific Tsunami Warning Center?

8:50 - What measurements were made in the deep ocean to detect tsunami and transmitted to the Pacific Tsunami Warning Center? Describe the system of data acquisition.

9:40 – What data were recorded in the Indian Ocean and sent to the Pacific Tsunami Warning Center to initiate further study?

What was the form of the initial communication to nations around the Indian Ocean?

10:00 Why didn’t the Pacific Tsunami Warning Center know that a tsunami was generated?

11:00 – Describe how a tsunami was generated by this earthquake?

What was the depth of this earthquake? (how might have this been determined)

11:30 - Why are some areas of the seafloor uplifted and other parts dropped down as a result of the earthquake?

12:20 – How fast is the tsunami traveling (at least in deep water, far from land)?
13:30 - How and why does the tsunami slow down and grow in size as it approaches the coast?

13:50 What happened to the water level along the coast prior to the arrival of the tsunami?

14:00 How did this change at the coast result in the loss of additional lives along these beaches?

14:30 – How is a tsunami different from a typical wave observed at the beach?

15:30 - Besides the water, what else does a tsunami carry as it rushes over the land?

16:00 - How long after the earthquake did the tsunami rush over the coastal communities in Sumatra? Which city was the first to experience the devastating effects?

16:40 - What was the aftermath of the tsunami(s)?

18:20 - How was the height of the wave estimated long after the tsunami was over?

21:45 – After Indonesia, where did the tsunami strike next?
22:00 – How and why did the analysis and subsequent conclusions at Pacific Tsunami Warning Center evolve within the first hour following the detection of the initial earthquake?

22:45 – What was the next response of the Pacific Tsunami Warning Center?

23:30 - How long after the initial earthquake did it take for the tsunami to reach Thailand?

24:00 - How is the power of a tsunami affected as it nears land and how does this influence the distribution of damage?

28:00 - What happened 15 minutes after the first wave in Thailand?

30:00 – What happens to the seawater brought in by the tsunami over time and how does this contribute to the damage and loss of lives?

31:00 - After Thailand where did the tsunami strike next and how long was this after the first tsunami hit land in Indonesia?

32:00 How far is the affected away from the earthquake epicenter?

34:30 – How was the height of the second wave described by the train passenger?

36:15 – How many lives were lost in Sri Lanka and India?

37:00 - How was the magnitude of the earthquakes updated?
37:30 – Why could the Pacific Tsunami Warning Center not contact coastal communities in advance of the approaching tsunami?

37:45 – What did the Pacific Tsunami Warning Center do next?

38:00 – What was the next area impacted by the tsunami?

39:00 – What was the impact of issuing a tsunami warning to Africa?

39:30 – What was the tsunami weak and small in the Pacific Ocean?

39:50 – Has the region experienced tsunamis before?

40:00 What is the updated magnitude of the earthquake?

40:20 How did the earthquake affect the earth’s rotation as shown by precise scientific studies?

41:00 – How did the earthquakes affect the length of the day?

41:45 – Was the tsunami a one time event?
42:30 – What have scientists requested for the Indian Ocean?

43:45 – What are four causes of tsunamis?

44:15 – How do you decide where to place resources for a warning system?

44:30 – Is there a tsunami threat in the Atlantic Ocean and the east coast of the U.S.?

45:00 - Is there a tsunami threat along the west coast of the U.S.?

46:00 – What is happening in Cascadia off Oregon and Washington?

47:00 – What do scientists not know about an earthquake along Cascadia?

47:15 – What can do we to prepare for future tsunami?

47:30 – Why do scientists know so little about tsunamis?

48:00 – What will scientists and engineers measure in the tsunami model and why?

How will this information be used?

49:45 - What was the reaction of the federal government to this tragic event?
50:00 - Besides installing new technology, what other steps need to be taken?

**Required Learning Group Discussion Posting, Review, Answer and Feedback**

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Activity 11 – 2004 Indian Ocean Tsunami – The Impact on Humans

What is the due date? ___________________________ (fill-in, day, date and time -- see greensheet or information at top of your learning group discussion for this activity in Canvas.

Objective: To allow students to consider the impact of the 2004 Indian Ocean tsunami on global society

• Instructions for required learning group discussion on last page of the worksheet.

  Watch a program on the 2004 Indian Ocean Tsunami, called “Tsunami - Caught On Camera,” which has been divided into 7 segments on YouTube.
  
  Tsunami - Caught On Camera – Part 7 - http://youtu.be/H7BqPEPHnck

The required reading assignments are very important this week – skip them at your own peril on Unit II exam. Make sure that you view all figures and animations.

Required Learning Group Discussion Posting, Review, Answer and Feedback

• After completing this activity, go to your learning group discussion and then post two multiple-choice questions, each with 5 potential answers (a, b, c, d, and e) on the material covered in this meeting; do not highlight the correct answers to your questions.
  Scoring on required posting will be based on the clarity (ability to communicate in writing) and quality (scientific insight) of the posted questions and the listings of potential answers.
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  Students will then provide feedback on the clarity and quality of the questions posted by the student immediately above their own posting in their assigned discussion and then answer the questions.
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Geology 112 – Earthquakes  

Activity 12 - Tsunamis – Past, Present, and Future?

What is the due date? ____________________ (fill-in day, date and time -- see greensheet or information at top of your learning group discussion for this activity in Canvas.

Objectives: Learn about the past tsunamis and the potential for a major tsunami along coastal California.

- Instructions for required learning group discussion on last page of the worksheet.

Slides 1 through 3: What is today’s topic? – What is the objective of this activity?

What is today’s class business?

What will we examine today?

Slides 4 and 5: Which earthquakes and tsunamis will we examine today?

1. __________________________________________

2. __________________________________________

3. __________________________________________

Slides 6 and 7:

What happens to the overriding plate when the plate boundary fault zone on a convergent plate boundary is locked?

________________________________________________________________________________________

________________________________________________________________________________________

________________________________________________________________________________________
How can the deformation of the plates, and accumulation of strain energy, be measured over time above a locked segment of the plate boundary fault along a convergent plate boundary?

What can these measurements tell us about the potential for a great earthquake along a subduction zone?

---

**Slide 8  1964 Great Alaska Earthquake and Tsunami**

We examined the 1964 Good Friday or Great Alaskan Earthquake in a previous activity.

**Question:** In addition to the death and destruction caused in Alaska, this earthquake resulted in the deaths of 12 people as far away as Crescent City in northern California. How?

---

**Slide 9. Path and Timing of 1964 Great Alaska Tsunami and 1960 Chile Tsunami**

What does this graphic show?

The largest earthquake measured this century killed several thousand people in Chile in 1960, 61 people in Hilo, Hawaii, 16 hours later, and more than 200 in Japan less than 24 hours after the earthquake.

Tsunamis have killed hundreds of thousands of people in the past decade. Later in this activity, you will learn about the tragic Indian Ocean tsunami in 2004.
Slide 10. Global Seismographic Network

What is the Global Seismographic Network and what is one benefit of its use?

____________________________________________
____________________________________________
____________________________________________
____________________________________________

Slides 11 through 13. 2004 Indian Ocean Earthquake and Tsunami

Describe the tectonic setting and major features in the region of the 2004 earthquake?

____________________________________________
____________________________________________
____________________________________________
____________________________________________

Slide 14. Seismograms from 2004 Earthquake in Travel-time plot

Slides 15 through 18. Earthquake Information

What is the magnitude? ________________________________

Type of Faulting determined from the focal mechanism? ____________________

Size of rupture area? ________________________________

Size of maximum slip area? ________________________________

Maximum amount of slip area? ________________________________
Slide 19: Tsunami Generation

Examine the tsunami generation animation in great detail – Make 3 observations based on the animation

1. __________________________________________________________
   __________________________________________________________

2. __________________________________________________________
   __________________________________________________________

3. __________________________________________________________
   __________________________________________________________

Slide 20: Tsunami Generation - Factors

List and describe eight factors that can influence the generation of a tsunami

1. __________________________________________________________
   __________________________________________________________

2. __________________________________________________________
   __________________________________________________________

3. __________________________________________________________
   __________________________________________________________

4. __________________________________________________________
   __________________________________________________________

5. __________________________________________________________
   __________________________________________________________

6. __________________________________________________________
   __________________________________________________________

7. __________________________________________________________
   __________________________________________________________

8. __________________________________________________________
   __________________________________________________________
Slides 21 through 22. DART System

“How are scientists studying tsunamis?” by describing and then diagramming at DART buoy system in the Pacific and an individual buoy with a bottom pressure sensor of used to detect tsunamis at sea.

Slides 23 through 24. Coastal Tide Gauge

“How are scientists studying tsunamis using coastal tide gauges?

Slide 25. Two DART records

Describe how DART data are displayed and show the passage of a tsunami?

Slide 26. Tsunami Coming Ashore in Thailand
Slide 27. Tsunami Run Up

Examine the tsunami runup animation in great detail – Make 3 observations based on the animation

1. _____________________________________
   _______________________________________

2. _____________________________________
   _______________________________________

3. _____________________________________
   _______________________________________

What should you do if you are at the beach and shoreline quickly moves out to sea and why?

____________________________________________
____________________________________________
____________________________________________

____________________________________________
____________________________________________
____________________________________________

____________________________________________
____________________________________________
____________________________________________

Slide 28. Tsunami Modeling

Examine the propagation of the 2004 Indian Ocean tsunami through all of the world’s oceans (created by Vasily Titov from NOAA)

A tsunami (seismic sea wave) is generated by movement of the seafloor – this wave travels at frightening speeds. The wavelength (distance between two successive crests) of a tsunami wave is many hundreds of kilometers and can therefore be modeled as a "shallow water" wave.

The approximate speed (S) of a "shallow water" wave is given by the square root of the product of the gravitational acceleration (g), and the water depth (d):

\[ S = (g \times D)^{1/2} \quad \text{where} \quad g = 9.8 \text{ meters per second}^2 \]

Describe how a model of the propagation of a tsunami throughout an ocean basin is generated?

____________________________________________
____________________________________________
____________________________________________

____________________________________________
____________________________________________
____________________________________________

____________________________________________
____________________________________________
____________________________________________
What is an average water depth of the abyssal plain for the Pacific Ocean?
________________________________________________ meters (do a Google search)

Next, calculate the average speed of a tsunami traveling between Alaska and San Francisco? (Leave your calculation in meters per second)

If we were to convert your answer to miles per hour -- it would be over 500 miles per hour as fast as a 747 Jet airliner traveling between San Francisco and Tokyo Japan.

Assume that the distance between the epicenter of the 1964 Alaskan earthquake and San Francisco is approximately 2000 miles, how long after the earthquake did it take for the tsunami to strike San Francisco?

Slide 28. Summary

What did we examine today?

___________________________________________________________________________
___________________________________________________________________________
___________________________________________________________________________
___________________________________________________________________________
Required Learning Group Discussion Posting, Review, Answer and Feedback

- After completing this activity, go to your learning group discussion and then post two multiple-choice questions, each with 5 potential answers (a, b, c, d, and e) on the material covered in this meeting; do not highlight the correct answers to your questions.
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Objective: Learn about the 2011 Tohoko earthquake and tsunami, including the application of science to study this natural and devastating event, and its implications for the coastal areas of the western U.S.

- Instructions for required learning group discussion on last page of the worksheet.

Public Broadcasting Service, Oregon Public Broadcasting, NOVA – Japan’s Killer Quake first aired on March 30, 2011

I. Part 1a (nearly 14 minutes-long) - http://youtu.be/SMgSOYaTI1g

1. Introduction – What is the objective of this NOVA program?

2. Scientific Objectives

   What is Roger Bilham trying to measure?
   a. ___________________________________________________________
   b. __________________________________________________________

3. The earthquake

   Where was the earthquake located? ________________________________

   Which seismic waves caused the major ground shaking, which resulted in extensive damage?
   __________________________________________________________

   Why was the Fukushima reactor still a danger even though it was shutdown?
   __________________________________________________________

   Why were seismologists surprised by the great size of this earthquake?
   __________________________________________________________

   Describe the plate tectonic setting of this earthquake?
How long had energy been building up, and stored in the crust, prior to the earthquake?

How long did the earthquake shaking last in Tokyo? __________________________
What happened to the ground beneath the tourist?

Did Japan’s earthquake warning system work?

What was the magnitude of this earthquake?

Why did the people of Japan know that the earthquake was only the beginning of the threat?

Describe how the upper plate of the subduction zone behaves as the plate boundary fault slips and how this results in a tsunami?

II. Part 1b (14.5 minutes long) -  http://youtu.be/2ob9dl_EknU

4. The tsunami

   How fast does a tsunami travel? ________________________________

   How high is the tsunami in the open ocean? __________________________

   What factor controls the speed of a tsunami? __________________________

   Why does the wave “break” as it approaches the shore?
   ________________________________

   What happens typically happens to the sea near land before the tsunami arrives?

   Why does the tsunami arrive at different coastal locations at different times and with different strengths?

   What is the best early warning system if the earthquake is nearby?

   How does the shape of the land surface influence the spread and advance of the tsunami?
How had one coastal city prepared in advance for a tsunami, given its history of tsunamis in the past?

How high was the tsunami in this city? ________________________________
Why did the tsunami breach the coastal defenses such as the 30 foot-high tsunami walls?

What type of sensors indicated the drop of the land in this region?

What happened at the Fukushima power plant?

What happened to the building debris and displaced automobiles after the tsunami stops advancing landward?

III. Part 2 (25 minutes-long) - http://youtu.be/oPSI0i05OzA

5. Tsunami Across the Pacific

What did the deep ocean sensors show about the tsunami?

What happened in Hawaii?

How did the early warning system work in Hawaii and why?

How important is the tsunami warning system if the earthquake is close by?

Why does the energy of a tsunami decrease as it travels across the Pacific Ocean?

How long after the earthquake did the tsunami take to reach California?

What happened to the height of the tsunami wave in some areas of California and why?

How well did the warning system work in California?
6. Earthquake and Tsunami Damage Back in Japan

Back in Japan, how far did the effects of the tsunami reach inland and how did this occur?

How much did the land sink in the coastal region?

How did the rising water reach even greater heights in some regions?

What was the tsunami composed of, once it reached the urban areas?

What is the importance of the Japan earthquake and tsunami for science, both now and in the future?

What threat did aftershocks pose to already damaged communities?

What happened to the helicopter pad? Describe the features and how did they form?

How are aftershocks triggered?

What happened at the Fukushima power plant?

7. What does 2011 earthquake imply for the seismic risk on other fault zones in the region?

Where had scientists forecasted a major earthquake to occur and how might 2011 earthquake have affected the potential for this earthquake in the future?

What is Dr. Chris Goldfinger’s statement about the effect of the 2011 earthquake on stress in the crust in this region?
What is the threat to Tokyo posed by this future earthquake?

When might this earthquake happen?

What is the recommendation of Dr. Costas Synolakis of the Univ. of Southern California?

What is the recommendation of Dr. Simon Boxall, in terms of what science can provide?

8. What does 2011 earthquake imply for the seismic and tsunami risk along California?

What does the Japan earthquake tell scientists about the potential for a similar event in the Pacific Northwest of the U.S.? Explain.

What would happen if there was a great earthquake (M=9) along the Cascadia subduction zone?

How does the preparation level in Japan compare to that along the western U.S. coast and what does portend for the future?

What does 2011 earthquake imply for the seismic and tsunami risk along California?
Required Learning Group Discussion Posting, Review, Answer and Feedback

- After completing this activity, go to your learning group discussion and then post two multiple-choice questions on how science is studying this earthquake and tsunami, each with 5 potential answers (a, b, c, d, and e) on the material covered in this meeting; do not highlight the correct answers to your questions.
- Scoring on required posting will be based on the clarity (ability to communicate in writing) and quality (scientific insight) of the posted questions and the listings of potential answers.
- Ambiguous questions or answers, or error in writing quality, will receive point deductions – be clear and precise.
- Do not repeat a question posted previously by another student in your learning group, which will consist of 6-7 students.
- Students will then provide feedback on the clarity and quality of the questions posted by the student immediately above their own posting in their assigned discussion and then answer the questions.
- After your questions have been answered, provide the feedback on the accuracy of the answers and work with your learning group members in Collaborations to compile the top six questions covering the breadth of material in this Activity.
Objective: Learn about current scientific research on the materials, state of stress and conditions along convergent plate boundary faults, before and immediately after devastating earthquake and tsunamis

- Remember to answer the questions below and take notes
- Required learning group discussion instructions at the end of this worksheet

Slides 1 through 4 – Introduction to NanTroSEIZE (and maybe JFAST, if time) – Convergent Boundaries and Plate Motion in Region

Slide 5 – Today’s Outline – Ignore Specific Dates
Slides 6 and 7 – One for Four Largest in Past 100 Years

Slides 8 through 11 – Epicenter, Seismogram, Aftershocks, Moment Magnitude and Focal mechanism

Slide 12 – Imaging the Subducting Slab Under Japan – Tomography

Slide 13 – Tectonic Plates and Subduction

Slide 14 – GPS – Fault Slip and Displacement

Slide 15 – Minimum Measured Vertical and Horizontal Movements

Slide 16 – DART Buoy – Measuring the Tsunami

Slide 17 – Tsunami Propagation Forecast

Slides 18 and 19 – Inundation and Coastal Tide Gauges
Slide 20 – NanTroSEIZE and JFAST

Slide 21 – Why NanTroSEIZE?

Slide 22 – Drilling the Tsunami Maker

Why drill in the Nankai Trough?

Slide 23 – Drilling Sites

What is the drilling plan?

Slide 24 – Objectives

What are the objectives?

Slide 25 – NanTroSEIZE 3-D

What took place on this voyage?

Slides 26 and 27 – Scientists and Funding

Who is funding this survey and why?

Slides 28 through 30 – 3-D Surveying

What is 3-D seismic surveying?
Slides 31 through 36 - Life at Sea

What happens at sea?

Slides 37 through 41 – 3-D Data Interpretation

How are the data being interpreted?

Slides 42 through 43 - Drilling

Why is this region being drilled?

What is one of the first results?

Slides 44 through 46

What are some of the next results?

Slide 47 – Right Now!

What is taking place today?

Slide 48 – Summary

What did you discuss today?
Required Learning Group Discussion Assignment (6 points)

- After completing this expedition, go to your learning group discussion and then post two multiple-choice questions on how science is studying the potential for devastating earthquakes and tsunamis around Japan, each with 5 potential answers (a, b, c, d, and e); do not highlight the correct answers to your questions.
- Scoring on required posting will be based on the clarity (ability to communicate in writing) and quality (scientific insight) of the posted questions and the listings of potential answers.
- Ambiguous questions or answers, or error in writing quality, will receive point deductions – be clear and precise.
- Do not repeat a question posted previously by another student in your learning group, which will consist of 6-7 other students.
- Students will then provide feedback on the clarity and quality of the questions posted by the student immediately above their own posting in their assigned discussion and then answer the questions.
- **After the due date**, each student will examine the multiple choice questions in their group, and then select the top question, in their opinion, and post it in the appropriate activity collaboration etherpad in the Collaborations area.
- Do not repeat the posted question of another student in the Collaboration area.
Activity 15 - 1700 Pacific Northwest Earthquake and Orphan Tsunami

What is the due date? ______________________ (fill-in, day, date and time -- see greensheet or information at top of your learning group discussion for this activity in Canvas.

Objective: Learn about the scientific discovery of great earthquakes (M=9 or greater) along the Cascadia subduction zone, and the potential for a future devastating event along northern California, Oregon and Washington on the same scale as the 2004 Indian Ocean earthquake and tsunami or 2011 Japan earthquake.

- Remember to answer the questions below and take notes.
- Required learning group discussion instructions at the end of this worksheet.

- First watch a 2 minute-long newscast about the expectation of a magnitude 9.0 earthquake along northern California, Oregon and Washington, followed by
- a 50 minute-long program from the BBC, the Next Megaquake, divided into five 10 minute-long segments on YouTube. A transcript of the program can be access at http://www.bbc.co.uk/sn/tvradio/programmes/horizon/megaquake_prog_summary.shtml if you need it.
- After the BBC show, view two segments of the NOVA program, Deadliest Earthquakes, one 3 minutes-long and another 8 minutes-long, on the recent scientific studies on understanding the frequency of great earthquakes along the Cascadia subduction zone, using sediment samples from the deep-sea and measurements of tiny, nearly imperceptible “slow-slip” earthquake that may foretell a great earthquake?

I. The Situation - Pacific Northwest Cascadia Subduction 9.0 Earthquake Expected at Anytime

View http://youtu.be/X5eloPKhzAM (2 minutes) -- More than 10,000 people could die when — not if — a monster earthquake and tsunami occur just off the Pacific Northwest coast, researchers told Oregon legislators Thursday.

II. Watch The Next Megaquake (called Cascadian Megaquake 1 of 5 on YouTube):

Segment 1 – 10 minutes long at http://youtu.be/NP8cDXsvH8A

1. Where might a great earthquake strike the United States, close to California, and which cities are at risk?

2. What tectonic process operates along the plate boundary beneath the coast of northern California, Oregon and Washington?

3. Describe the deformation of the lithosphere along a subduction zone, ultimately leading to a great earthquake?
4. How is a tsunami different than a wind-driven wave on the surface of the ocean?

5. How is the seismic activity along Cascadia subduction zone different from many other subduction zones worldwide and how did scientists interpret this characteristic early on?

6. What intriguing evidence first caused scientists, like Brian Atwater, to challenge the prevailing idea at the time about the potential for a great earthquake in this region?

Segment 2 – 10 minutes-long at http://youtu.be/LjDixpGsBf4

7. How did Atwater find the initial evidence of a great earthquake and what was the evidence?

8. What is the evidence for a tsunami following the great earthquake?

9. Explain the Atwater’s hypothesis for a great earthquake based on the observations described in the previous two questions?

10. How was a rough date provided for the hypothesized event?

11. What piece of evidence, recorded in Japan, was used to identify the year of the tsunami?

12. What was the date of the tsunami in Japan and how was this determined?
13. How many tsunamis hit Japan on that January day in 1700?

14. What was unique about the tsunami once it arrived along the shores of Japan?

15. What is the final piece of evidence that linked all of the previous observations, both in Japan and along the coast of the Pacific Northwest, into a coherent theory?

16. What killed the trees in the ghost forest?

17. What data provided evidence for the simultaneous death of the trees?

18. What was the date, year and time of the Cascadia earthquake (along north America)?

19. What were the effects that followed this great earthquake?

Segment 3 – 10 minutes-long at http://youtu.be/3SofGBUfEyw

20. How does the length of fault rupture compare to the size of the earthquake?

   How does the length of the fault rupture of the 2004 (M=9.3) Indian Ocean earthquake compare to that estimated for the Cascadia earthquake in 1700?

21. Will there be another great Cascadia subduction zone earthquake in the future? Why or Why not?

22. What key question remains largely unanswered about the damage to buildings in the future Cascadia earthquake and why?
23. What type of buildings will definitely be at risk and may result in great damage and loss of life?


24. How do geologists learn about frequency of earthquakes in the past?

25. When might the next great earthquake occur along the Cascadia subduction zone?

26. What can we do to limit the damage of the next great earthquake and loss of life?

27. How may the fault rupture begin and evolve over the duration of the earthquake?

28. Why is the tsunami predicted to have a devastating effect on the shores of the Pacific Northwest and maybe somewhat less so in Hawaii, Japan and even southern California?

29. Why is the ground shaking forecasted to be severe at the coast along the Pacific Northwest?

30. How is the state of Washington preparing for this eventual earthquake?

**Segment 5 – 9 minutes-long at [http://youtu.be/W-ANmlaVMUk](http://youtu.be/W-ANmlaVMUk)**

31. How should the public react if within a building when the strong ground shaking begins?

32. What is the major hazard to the public in outside areas and what should people do?

33. What will happen to the unreinforced masonry (URM) buildings?

34. How does the duration of shaking affect the structural integrity of the buildings?
35. How will the shaking affect buildings on higher ground, especially on sloping hillsides?

36. If the tsunami warning system is relatively ineffective along the coast of the Pacific Northwest, what then should people on the coast do if the ground shakes violently?

37. What is the best way for people in coastal regions to prepare now, prior to the eventual tsunami?

This is end of the MegaQuake program.

II. First segment of NOVA program “Deadliest Earthquakes” on the Cascadia megathrust
(Program website with written transcript at: http://www.pbs.org/wgbh/nova/earth/deadliest-earthquakes.html)

Watch this segment on YouTube at http://youtu.be/I9LDXRcaWpw

Fast forward player to the 11:43 time mark to watch the last two minutes of this segment (we will cover other segments of this program later in the course)

38. What type of data is Chris Goldfinger using to study the history of Cascadia megathrust earthquakes and how are these data acquired, and over what period of time?

Move on to watch the first 8 minutes of the next segment of the program at http://youtu.be/o4n3drwryg0

39. Describe the nature of the scientific analysis of the core samples being carried out by Chris Goldfinger and what is he trying to identify?

40. What is the principal conclusion of this research and it’s implications for the probability of great earthquakes along the Cascadia megathrust in the future?

41. What is Ken Creager attempting to measure and how?
42. How often do these silent earthquakes occur and how long do they last?

43. What is the hypothesis or question that Ken Creager is testing with his research?

44. What is the potential implication of this research?

Stop at the 8:00 minute mark of this segment
Required Learning Group Discussion Assignment (6 points)

• After completing this expedition, go to your learning group discussion and then post two multiple-choice questions how scientists are studying the earthquake and tsunami potential of the Cascadia subduction zone, and potential damage, each with 5 potential answers (a, b, c, d, and e); do not highlight the correct answers to your questions.
• Scoring on required posting will be based on the clarity (ability to communicate in writing) and quality (scientific insight) of the posted questions and the listings of potential answers.
• Ambiguous questions or answers, or error in writing quality, will receive point deductions – be clear and precise.
• Do not repeat a question posted previously by another student in your learning group, which will consist of 6-7 other students.
• Students will then provide feedback on the clarity and quality of the questions posted by the student immediately above their own posting in their assigned discussion and then answer the questions
• After the due date, each student will examine the multiple choice questions in their group, and then select the top question, in their opinion, and post it in the appropriate activity collaboration etherpad in the Collaborations area.
• Do not repeat the posted question of another student in the Collaboration area.
Activity 16 – Bay Area Fault Systems and Seismic Hazards

Begin Unit III – Earthquake Hazards in Bay Area

What is the due date? ________________________________ (fill-in day, date and time -- see greensheet or information at top of your learning group discussion for this activity in Canvas.

Objective: Learn about the methods used to identify and study earthquake-capable, or seismogenic, faults in bay area

• Remember to answer the questions below and take notes

• Required learning group discussion instructions at the end of this worksheet

Before we can started, go to http://www.google.com/earth/

Download and install Google Earth on your computer, if you do not have it already.

I. Introduction to California Earthquakes

1. Tectonic history of Western North America – What do you see?

   First view the big picture at: http://youtu.be/G2_1dqgai10

   What is the range of time in this animation?

   What are the red lines?

   Where are the plate boundaries and which types?

Let’s look in more detail

2. Next View Tectonic history of Western North America Along California – What do you see?

   View history along California at: http://youtu.be/9F8AcDJo2QU

   Which tectonic plates are involved?

   What is the type of plate boundary between the North American and Farallon plates?

   What is the type of plate boundary between the Farallon and Pacific plates?

   When did this plate boundary collide with the plate boundary between the North American and Farallon plates?
What type of plate boundary then formed between the North American and Pacific plates?

Describe the evolution of the plate boundary along California and the formation of the San Andreas fault system between 35 million years ago and today

3. **Open Google Earth - Zoom in on California**

   Describe the topography and physiography of the surface of the earth in California
4. **Analyze Motions of the Earth’s Surface with UNAVCO**


   • Go to the velocity view, to explore GPS velocity vectors. The viewer starts with a zoom on the western United States and shows the overall velocities measure at each GPS station in the PBO network:
   • Select red for Velocities and click on Draw
   • Each vector arrow shows the velocity of a single GPS station installed permanently to the ground. If the Earth moves, the GPS stations record this movement.
   • The GPS vector’s tail is the starting location of the GPS monument
   • The direction the vector points is the direction the GPS station is moving
   • The length of the vector shows how fast the GPS station is moving
   • After viewing GPS motion vectors, zoom in on Bay Area

5. **Current Plate Boundaries Along California**


   Download *Tectonic Plate Boundaries* and view in Google Earth
II. Evidence of Seismogenic or Earthquake-Capable Faults in Bay Area

1. Use Google Earth to Zoom in on the Bay Area

What is the topographic evidence for active faults in bay area?

2. Use Google Earth to examine rock types in bay area

Go to: http://geomaps.wr.usgs.gov/sfgeo/geologic/downloads.html
Download Santa Clara County Geologic map kmz file and open in Google Earth
Toggle the Units and Faults on and off

What is the geologic evidence for active faults in bay area?

3. Use Google Earth to Examine Faults in Bay Area

Download Bay Area Faults kmz file and open in Google Earth
What are the major faults that compose the San Andreas fault system? (list all of them below)

4. Earthquakes of the San Francisco Bay Area


Download Animated Earthquakes kmz file, open with Google Earth and make observations

How do earthquakes compare to fault locations?

5. Real-Time Earthquakes


Download Real-Time Earthquakes kmz file, open with Google Earth and list four observations below:

1. 

2. 

3. 

4. 
Required Learning Group Discussion Assignment (6 points)

- After completing this expedition, go to your learning group discussion and then post two multiple-choice questions on how scientists are studying earthquakes and identifying faults, both of which are used to evaluate the seismic potential in the bay area, each with 5 potential answers (a, b, c, d, and e); do not highlight the correct answers to your questions.
- Scoring on required posting will be based on the clarity (ability to communicate in writing) and quality (scientific insight) of the posted questions and the listings of potential answers.
- Ambiguous questions or answers, or error in writing quality, will receive point deductions – be clear and precise.
- Do not repeat a question posted previously by another student in your learning group, which will consist of 6-7 other students.
- Students will then provide feedback on the clarity and quality of the questions posted by the student immediately above their own posting in their assigned discussion and then answer the questions.
- **After the due date**, each student will examine the multiple choice questions in their group, and then select the top question, in their opinion, and post it in the appropriate activity collaboration etherpad in the Collaborations area.
- Do not repeat the posted question of another student in the Collaboration area.
Geology 112 – Earthquakes

Activity 17 – 1906 San Francisco Earthquake

What is the due date? ____________________________ (fill-in day, date and time -- see greensheet or information at top of your learning group discussion for this activity in Canvas.

Objective: Learn about the 1906 San Francisco Earthquake and the subsequent birth of Earthquake Science (Seismology). Examine how scientists are studying the San Andreas fault in California, including pioneering work following the 1906 earthquake

• Remember to answer the questions below and take notes
• Required learning group discussion instructions at the end of this worksheet

Watch lecture segments as you view these Google Earth files as mentioned in lecture

I. Let's Begin where we left off in the previous activity, using Google Earth

Very important…..

Click on links below to download files, which should then be automatically loaded in Google Earth,

After viewing each file, and answering the questions below associated with that file, then “unclick” that particular file in the “Temporary Places” menu on left side of Google Earth application window.

1. Use Google Earth to Examine Fault Movement in the San Francisco Bay Area


How is GPS used to measure fault slip and stress build up?

The length of each arrow on the map, known as a vector, show the direct and rate of motion of that particular location relative to the rest of North America.

Examine the length and orientation of the arrows (vectors) change from east to west (right to left across the map)

Make a hypothesis to explain this observation? (if you have any questions, then posit in your learning group discussion)
2. Major Historic Ruptures


Describe the relationship of large earthquake ruptures in 1857, 1906 and 1989 along the San Andreas fault system to the locations of bay area fault zones.

3. 1906 Epicenter


Where was the epicenter of the 1906 earthquake?

When did the earthquake take place?

Leave the location of the epicenter in Google Earth as you move on to the next two download (4 and 5).

4. Rupture Length and Slip


The turquoise-colored bars show the amount of slip along the San Andreas fault in feet along the rupture during the 1906 earthquake.

Where was the amount of slip the highest?

Where was the amount of slip the smallest?

How do the regions of greatest and least amount of slip compare to the location of the epicenter?

Make a hypothesis to explain this observation? (if you have any questions, then posit in your learning group discussion)
5. Historic Ruptures


What color on the map is given to fault ruptures before 1906?

What color on the map is given to fault ruptures after 1906?

How does the number of fault ruptures due to major earthquakes before 1906 compare to the number after 1906?

Make a hypothesis to explain this observation? (if you have any questions, then posit in your learning group discussion)
II. Scientific Studies of 1906 San Francisco Earthquake and Future Earthquakes along the San Andreas Fault in California

1. To begin, watch a 3 minute-long Discovery Channel Segment on San Andreas fault at http://youtu.be/ZxPTLmg0ZCw -- take notes

2. View *Shock Waves: One Hundred Years After the 1906 Earthquake* (we will watch this video in two parts, first from 0:00 to 24:45 and then again for part II from 38:00 to 46:26, the two together take 34 minutes) at http://youtu.be/lfnTz7vZyVg

3. Where was the epicenter of 1906 earthquake (answered earlier in this activity but answer again)?

4. (at 5:00 mark) Prior to 1849, who made the earliest records of earthquakes in California and how did these earthquake affect the buildings in the region at this time and why?

5. (at 6:00) What instrumentation was introduced to the bay area in 1887 to measure earthquakes and why?

6. Where was the first instrumental record of strong motion or ground shaking of an earthquake made in California?

7. What event is credited with the birth of earthquake science and what does this says the growth of science?
8. (at 7:00) How did a group of California scientists record information about the 1906 earthquake?

9. (at 8:00) Who chaired the commission that studied the 1906 earthquake and what became of the work?

10. (at 9:00) Why is it important to study the work of previous scientific studies as exemplified by the Lawson report?

11. (at 10:00) What factors influenced the amount of ground shaking at a particular location during the 1906 earthquake (as identified in the Lawson report)?

12. (at 10:00) What type of material below the ground surface produces the greatest amount of ground shaking? And do you have this material beneath where you live?

13. (at 11:00) How have scientists continued to study, at least over the past two decades, the amount of ground shaking and how is this information being used to benefit society? How can you access this information?
14. (at 12:00) How long, in terms of distance, was the fault rupture in 1906? How do we know this?

15. (at 13:00) What is paleoseismology?

16. (at 14:00) How is trenching used in plaeoseismology? What is observed in a trench?

What is the objective of this method of studying earthquakes?

17. (at 17:00) How are scientists monitoring the ground continuously, before during and after earthquakes and why is this information valuable?
18. How are shake maps used by damage response teams with minutes of an earthquake?

19. (at 19:00) How are the shake maps used by the media?

20. (at 21:00) How much movement, on average, takes place between the NA and PA plates each year, along the San Andreas fault system in the bay area?

21. What type of scientific data resulted in the development of elastic rebound theory?

22. (at 22:00) How does the small amount of crustal movement each year along the San Andreas fault result in the rapid movement during fault rupture in an earthquake?

22. (at 23:00) List the segments of the San Andreas fault system in the bay area, from west to east.

23. (24:00) How and where can you find more information on earthquakes?

At 24:45 fast forward to 38:00,
24. (at 38:00) How are earthquakes being studied beneath the ground surface at Parkfield?

25. What is SAFOD (give the full name and describe the methodology being used)?

What are some of the objectives of SAFOD?

Why may SAFOD be important for the understanding and identification of future earthquakes?

26. (at 42:00) In the long-term, how should we best prepare for future earthquakes?

**Required Learning Group Discussion Assignment (6 points)**

- After completing this expedition, go to your learning group discussion and then post two multiple-choice questions on how scientists are studying earthquakes and faults in the bay area, both of which are used to evaluate the potential of earthquakes in the future, each with 5 potential answers (a, b, c, d, and e); do not highlight the correct answers to your questions.
- Scoring on required posting will be based on the clarity (ability to communicate in writing) and quality (scientific insight) of the posted questions and the listings of potential answers.
- Ambiguous questions or answers, or error in writing quality, will receive point deductions – be clear and precise.
- Do not repeat a question posted previously by another student in your learning group, which will consist of 6-7 other students.
- Students will then provide feedback on the clarity and quality of the questions posted by the student immediately above their own posting in their assigned discussion and then answer the questions.
- **Beginning with this activity, do not post in Collaboration Etherpad**
Geology 112 – Earthquakes  Name _________________________________

Activity 18 – The Hayward Fault

What is the due date? ___________________________ (fill-in day, date and time -- see greensheet or information at top of your learning group discussion for this activity in Canvas.

Objective: Students will develop an appreciation of the scientific evidence for the Hayward fault and the hazard it poses to the bay area

- Remember to answer the questions below and take notes
- Required learning group discussion instructions at the end of this worksheet

I. Fast forward to 11:30 mark of “Deadliest Earthquakes On Mother Earth -1- “ on YouTube

at http://youtu.be/SPbLpE5tQ_A and watch for 3 minutes until the end

1. How long is the SAF system? Where is the fault located from end to end?

What type of fault is it?

How many scientists are working to together to understand the San Andreas fault system and earthquakes in southern California?

When was the last lethal earthquake along the fault system in southern California?

Where was the earthquake located? How many people died?

What was it magnitude?
II. Earthquakes: Where the Fault Lies (Part I) (12 minutes-long) (TV Bay Area)

Learn about the Hayward fault segment at [http://youtu.be/nlkOqiUx530](http://youtu.be/nlkOqiUx530)

Watch and take notes on this Emmy Award-winning program as well as answer the question below.

1. How is the San Andreas fault system distributed about the bay area (a sentence or two will suffice and draw a rough map)?

2. What does this distribution of this system of faults imply for the potential for earthquake damage in local communities around the bay area?

3. How is the movement between the Pacific and North American plates taken up in the bay area?

4. Which fault in the bay area is the cause of the greatest concern in the bay area and where is it located?

5. What is the evidence (give several) for Hayward fault in bay area?

6. How much offset or fault slip is predicted when the expected “Big One” ruptures along the Hayward fault?

How is this predicted amount of fault slip estimated (not in video, but covered previously in Unit I this class)?
7. How do scientists predict where the Hayward fault will rupture?

8. When was the last major earthquake along the Hayward fault?

9. What is the recurrence interval for a major earthquake along the Hayward fault (average length of time between major earthquakes) and how is it calculated?

10. How will a major earthquake impact the infrastructure in bay area?

III. Earthquakes: Where the Fault Lies (Part II) (15 minutes-long) (TV Bay Area)

Learn about the Calaveras fault segment at http://youtu.be/p4UcmsMAYRM

11. Describe fault creep and how else if fault slip accommodated if not in fault creep?

12. Which fault runs through Hollister?

13. What is the evidence of the Calaveras fault north of Hollister?

14. How does the average rate of slip on the Calaveras fault compare to other member of the San Andreas Fault system in bay area?

15. How do scientists measure the movements on the fault each year?

16. What is the estimated maximum magnitude of an earthquake along the Calaveras fault?
17. How does the fault influence the shape of the ground in the bay area?

18. Which segment of the San Andreas Fault system is closest to SJSU?

19. What type of fault is the San Andreas fault system?

20. How fast are the plates moving by each other in the bay area?

21. How is the small amount of average movement each year, and therefore energy, stored and then released along the fault?

22. Have there been large (M=7) earthquakes in the past in the bay area?

IV. Earthquakes: Where the Fault Lies (Part III) (15 minutes-long) (TV Bay Area)

Learn about the San Andreas fault at http://youtu.be/DDtqbwGwQGE

23. What features make the San Andreas segment of the fault in the bay area?

24. Where was the biggest earthquake in California history?

25. How long has the San Andreas fault been in existence in the Carrizo Plain in central California?

26. What is the state of the stress on the San Andreas fault in the bay area (Santa Cruz Mountains)?

27. How do geologists use historic photographs and maps to study the 1906 earthquake?

28. How much did the ground shift in the 1906 earthquake near San Bruno?
29. What is a sag pond and why has this evidence for the fault been destroyed?

30. Where does the San Andreas fault go offshore near San Francisco?

31. What happened in the Marina District in the 1989 earthquake?

V. Earthquakes: Where the Fault Lies (Part IV) (8 minutes-long) (TV Bay Area)
   Learn about the 1989 Loma Prieta Earthquake at http://youtu.be/RVGMHRHY0To
   32. Describe some of the damage in the 1989 earthquake

33. Compare the size of the next big earthquake predicted for the bay area and the 1989 earthquake

34. What is the point of this television show?

VI. The Hayward Fault: Predictable Peril (Watch the first 7 minutes)
   Go to http://youtu.be/3jtAKPO4iHA

35. When was the Great San Francisco earthquake in the 1800's, where was it and what is the estimated magnitude?

36. Where did the greatest shaking take place?

37. What is the length of the Hayward Fault? How deep does the fault extend into the earth’s crust?
38. What is paleoseismology and how it is used to determine the frequency of earthquakes in this region?

39. How are the dates of previous earthquakes along the Hayward determined?

40. How is the rate of earthquakes on the Hayward fault over the past 2000 years determined what does this imply for the timing of a major earthquake in the future?

41. What is the probability determined by scientists for a major earthquake on one of the faults of the San Andreas system in the bay over the next 30 years?

42. What is believed to be the most dangerous fault in U.S. and why is it considered so dangerous?

43. Why are scientists concerned about a single potential earthquake that ruptures across the Hayward and Calaveras faults, especially for San Jose?

You may stop at 7:00 mark as we will discuss the remainder of this video in Unit IV of the course.
Required Learning Group Discussion Assignment (6 points)

• After completing this expedition, go to your learning group discussion and then post two multiple-choice questions on about the scientific evidence for recent movement along the Hayward fault and the seismic hazard it poses in the bay area, each with 5 potential answers (a, b, c, d, and e); do not highlight the correct answers to your questions.

• Scoring on required posting will be based on the clarity (ability to communicate in writing) and quality (scientific insight) of the posted questions and the listings of potential answers.
• Ambiguous questions or answers, or error in writing quality, will receive point deductions – be clear and precise.
• Do not repeat a question posted previously by another student in your learning group, which will consist of 6-7 other students.
• Students will then provide feedback on the clarity and quality of the questions posted by the student immediately above their own posting in their assigned discussion and then answer the questions
• Beginning with this activity, do not post in Collaboration Etherpad
Activity 19 – Hayward Fault Virtual Tour

**What is the due date?** ____________________________ (fill-in day, date and time -- see greensheet or information at top of your learning group discussion for this activity in Canvas.

**Learning Objective:** Students will achieve learning outcome #3 by applying a scientific approach to problems of the Earth and environment, which in this activity will be acquiring and analyzing evidence of the active movement of the Hayward fault.

I. Students will participate in a virtual tour of the Hayward fault, using Google Earth, to make observations, take notes, pose questions to their peers, make measurements, and examine photographs documenting evidence of recent activity and fault slip along the Hayward fault. Measurements of fault-related features, photographs and drawings should be included in the scientific report, described below.

II. Remember that you are the scientist in this tour, so make observations and measurements, take notes, and collect photographs documenting evidence of recent activity and fault slip along the Hayward fault in both natural and urban settings. Students should analyze this evidence to determine the recent activity along the fault.

Students are encouraged to post questions to their peers in their learning groups to improve the quality of the report to be submitted, which should include measurements of fault-related features, photographs and drawings to document evidence for verification and validity.

III. Before completing the tour, view or read the stories below as background information:


3. Copy and paste the following web address into your browser to read blog: [http://www.gearthblog.com/blog/archives/2006/03/usgs_virtual_to.html](http://www.gearthblog.com/blog/archives/2006/03/usgs_virtual_to.html)


You will need to download and install Google Earth, if you have not already, open it, then open the .kmz file, which you will download from USGS website.

**Make observations and measurement just as if you were viewing this information in person,** first hand, like the students doing a walking or car tour.
Hayward Fault Fieldtrip Report Instructions
150 points (120 points for Content Quality and 30 points for Writing Quality)

Objective: Students will apply a scientific approach to determine the evidence for recent activity of the Hayward fault, which is learning outcome #3 of all Area R courses.

Report Format:

The report should present the scientific basis for the field trip, background information on the Hayward fault and its relationship to the San Andreas fault system in the bay area, describe the activities carried out on the trip, and include a summary of findings and conclusions.

The narrative body of report should be no more than 1000 words-long with doubled-spaced text and written in 11 or 12 point font. (3 pages for parts 3 through 6 listed below)

The report should have the following components:

1. Title and Student Name (at top of first page and not as a title page)
2. Summary: (3-4 sentences) – summarizes entire report
3. Introduction (1/2 page) – establishes context and framework of scientific question to be addressed, including well-defined thesis statement
4. The Hayward Fault (1/2 to 3/4 page) – background information on fault, including tectonic setting, relationship to San Andreas fault system, location and extent, type of faulting, history and depth of seismicity, GPS measurement of fault slip and estimates of earthquake probability. (at least one graphic, better to have 2-3)
5. Field Trip Activities (1 to 1.5 pages) – for example, a listing of at least 5 stops with critical observations and measurements at these stops,
6. Findings and Conclusions (1/2 page) – conclusions of student on activity of Hayward fault based on evidence documented during trip
7. Reference List (should be very brief, 2 to 4 references at most – all could be from our reading assignment – no outside references required)

Any photographs or drawings can be either inserted into text or be at back of report, and numbered, in order and cited within text, for example: (see Photo # 1) or (see Drawing #1).

Parts 2 through 6 of the paper, listed above, must not exceed 1000 words and will be submitted as a rough draft to Criterion ETS for a writing quality examination. The review is automatic and only takes a few minutes after submission.

Use the feedback from this evaluation to make any changes you deem necessary to improve the overall quality and clarity of their report, and then submit the final draft to
Canvas Assignment area, which will then automatically perform an originality check using [www.turnitin.com](http://www.turnitin.com). Students may then view the results from www.turnitin.com to make any modifications and resubmit, if they choose.
Activity 20 – Earthquake Recurrence & Prediction – Science or Pseudoscience?

What is the due date? __________________________ (fill-in day, date and time -- see greensheet or information at top of your learning group discussion for this activity in Canvas.

Learning Objective: Students will achieve learning outcome #2 of all Area R courses at SJSU and that is to be able to distinguish between science and pseudoscience

• Remember to answer the questions below and take notes

• Required learning group discussion instructions at the end of this worksheet

Slides 1 through 4 - Topic, Introduction, Business, Schedule and Outline

Slides 5 and 6 – Activity #20 Posting

Slides 7 through 12 – The San Andreas Fault System in Bay Area

What type of plate boundary is located in bay area?

How do scientists measure movements of the crust in the bay area?

What types of faults can be identified in bay area?

How do scientists study the location and geometry of faults, and faults systems, beneath the earth’s surface?
**Slides 13 and 14 - History of Bay Area Earthquakes**

How has the occurrence of earthquakes, and fault ruptured varied over time, in particular, before and after the 1906 San Francisco earthquake?

**Slide 15 and 16 – Earthquake Prediction**

How is earthquake prediction defined and what are its key characteristics?

**Slides 17 and 18 – Case Study #1 - Earthquake Prediction – Success - China 1975?**

What happened in northeast China in 1975 and why did this result in great optimism for successful earthquake prediction?

**Slide 19 – Case Study #1 - Earthquake Prediction – Not so fast - China 1976?**

What happened in northeast China in 1976 and why did this result call into question the enthusiasm for successful earthquake prediction?
What is a key requirement for valid science-based prediction?

**Slide 20 – Case Study #2 – Back in the U.S. - 1976**

How did the U.S. respond to the events in China in 1975 and 1976?

**Slides 21 through 24 – Parkfield, California Observations**

Describe the basic observations of earthquake occurrence (location and timing) and magnitude of earthquakes along the San Andreas fault in Parkfield, CA?

What is meant by the term, recurrence interval?

What is meant by the term, characteristic earthquake?

**Slides 25 and 26 – Fault Slip Models**

Describe how the observations at Parkfield are placed in the framework of a conceptual model of fault slip over time?
Why are complex observations simplified and placed within a context of a scientific model?

**Slides 28 through 30 – Parkfield Experiment – Testing a Scientific Prediction**

What was the hypothesis put forth by Bakun and Lindh?

How was this scientific research released to the media?

What was the objective of the Parkfield experiment?

**Slide 31– Precursory Strain Before Fault Slip**

What is the idea of precursory strain?
Slides 32 and 33 – Parkfield Experiment – Design and Data Acquisition

What was the design of the Parkfield experiment?

What types of data were to be acquired?

Why were these types of data to be acquired? (What was to be measured and why?)

Slides 34 through 36 – Parkfield Experiment – Findings

What were the findings of the Parkfield Experiment?

Slide 37 – Parkfield Experiment – Interpretation & Conclusions

What conclusions were drawn by USGS scientists from these findings and strategies proposed for future efforts?
Slide 38 – Summary

What did we discuss in this activity?

Homework

I. What is science? List and describe five or six characteristics of science (you probably want to do some research online) – write them below

II. What is pseudoscience? List and briefly describe five characteristics of pseudoscience (you probably want to do some research online) – write them below
III. Go to YouTube and search on earthquake prediction

Find an example of pseudoscience dealing with earthquake prediction.

Why do you consider your example pseudoscience?

IV. Required Learning Group Discussion Assignment (Worth 35 points) - 25 points for scientific accuracy and quality and 10 points for organization, clarity and writing quality).

After completing this activity, post your thoughts on distinguishing science, such as the Parkfield experiment by the U.S.G.S., from pseudoscience based on your earthquake prediction research on YouTube.

Using no more than 300-350 words and provide feedback on the clarity and quality of a posting by another student,
Objective: Students will think critically about the methods and limits of scientific investigation to analyze a recent court decision on communicating the difference between earthquake forecasting and prediction.

- Remember to answer the questions below and take notes
- Required learning group discussion instructions at the end of this worksheet
- Remember to complete the required reading assignments.

Slides 1 through 5 – Title, Class Business, Schedule and Activity #20 Recap

Slide 6 – Outline

Slides 7 through 9 – Parkfield Experiment – Recap Prediction Failure

Slide 10 – Fundamental Questions

Slide 11 – Earthquake Prediction – A science on shaky ground video – take notes!
**Slide 12 – Forecasting Earthquakes**

How is forecasting different from prediction?

What is the methodology used to make forecasts?

**Slide 13 – Geodesy**

How are GPS measurements used in earthquake probability forecasting?

**Slide 14 – Geology**

How are geological measurements used in earthquake probability forecasting?

**Slide 15 – Seismology**

How is seismology used in earthquake probability forecasting?
**Slide 16 – Paleoseismology**

How is paleoseismology used in earthquake probability forecasting?

**Slide 17 – Trenching**

What is trenching and how is it used in paleoseismology?

**Slide 18 – History of fault ruptures**

**Slide 19 - Uniform California Earthquake Rupture Forecast**

Who worked together in making these forecasts?

**Slides 20 and 21 - Uniform California Earthquake Rupture Forecast**

What types of data were used in making these forecasts?

**Slide 22 - Uniform California Earthquake Rupture Forecast**

What is the probability of a magnitude 6.7 or greater earthquake in California over the next 30 years?
What is the probability of a magnitude 6.7 or greater earthquake in northern California over the next 30 years?

What is the probability of a magnitude 6.7 or greater earthquake in southern California over the next 30 years?

What is the probability of a magnitude 6.7 or greater earthquake in Los Angeles area over the next 30 years?

What is the probability of a magnitude 6.7 or greater earthquake in San Francisco area over the next 30 years?

List the probabilities of a magnitude 6.7 or greater earthquake on the individual major faults in California over the next 30 years?

Which faults, one in northern California and the other in southern California, have elevated near-term probabilities of a major earthquake?
Slide 27 – Probability in Bay Area

List the probabilities of a magnitude 6.7 or greater earthquake in the bay area over the next 30 years?

Slide 28 – Probability on Bay Area Faults

List the probabilities of a magnitude 6.7 or greater earthquake on each major bay area fault over the next 30 years?

Slide 29 – Important Science

Slide 30 – 2009 L’Aquila Earthquake

What was observed prior to the 2009 L’Aquila Earthquake?

Slide 31 – Italy Seismic Hazard Map

How much of Italy has a high seismic hazard?

Slide 32 – Foreshocks and Aftershocks

Describe the sequence of foreshocks and aftershock associated with the 2009 L’Aquila Earthquake?

Slide 33 – Italian Scientists on Trial

Describe the situation
Slide 34 – Blue Ribbon Panel

What was the finding of a panel of international earthquake scientists on the current of ability of precursory evidence to make a reliable earthquake prediction?

Slides 35-38 – Activity #21 Assignment

Slide 39 – Summary

Share your thoughts on earthquake prediction and forecasting in your learning group discussion (worth 5 points)
I. This activity serves as the starting point for the *Earthquake Forecasting Discussion (worth 40 points)*

1. Let’s begin by examining the data on the 2009 L’Aquila earthquake.

   There is a reading/video resource list given on the Activity #21 webpage in Canvas. You may also Google on 2009 L’Aquila earthquake”

2. Provide a scientific description of the 2009 L’Aquila Earthquake, including each of the following:

   Date: Time: Location (epicenter):

   Main Geographic Feature(s) in Region:

   Moment Magnitude: Depth:

   Type of Faulting and how determined:

   Plate Tectonic Setting:

   History of Earthquakes in Region:

   Historical Seismic Risk in Region:

   Impact of Earthquake on Human Population and Society:
3. List the Evidence from Precursors prior to the Main Shock

4. What was the Role of Scientists in Assessing Hazard Prior to the Earthquake?

5. What is meant by a probabilistic forecast of risk or hazard?

6. How was the seismic risk (mis)communicated to the public?
7. Describe Indictments Against the Scientists?

8. If you were judge in this case, what would be your decision and why? (Give supporting evidence)

Required Learning Group Discussion Assignment (Worth 40 points) - 30 points for scientific accuracy and quality and 10 points for organization, clarity and writing quality).

- After completing this activity, students will first share their thoughts on the current limits of science in predicting or forecasting earthquakes through a critical analysis of the court case, which followed the 2009 L’Aquila earthquake in Italy, and the conviction of earthquake scientists for manslaughter.
- The analysis should be approximately 300-350 words in length, no longer, and include a summary of the scientific information on the earthquake and the events leading up to the earthquake as well as the trial that followed.
Activity 22 – Seismic Hazards to Home, School and Workplace

Unit IV Personal Preparedness Plan

Preparing for Final Exam

What is the due date? See greensheet or information at top of your learning group discussion for this activity in Canvas.

Learning Objective: Students will identify the seismic hazard or risk to home, university and workplace; and therefore address learning outcome #3, which is to have students apply a scientific approach to problems of the earth and environment.

Students will incorporate the information from this analysis into their earthquake preparedness plan, which will be due at the final exam.

I. Bay Area Faults – http://quake.abag.ca.gov/

   Go to the Interactive Fault Rupture Map at http://quake.abag.ca.gov/faults/

   1. How far is your house from the Hayward fault?

   2. How far is your house from the San Andreas fault:

   3. How far is your home from the nearest major bay area fault and what is the distance?

II. Earthquake (Ground) Shaking

   What is the Modified Mercalli Intensity Scale? (http://quake.abag.ca.gov/shaking/mmi/)

   Go to Earthquake Interactive Shaking Potential Map at:

   http://quake.abag.ca.gov/shaking/tp://quake.abag.ca.gov/faults/

   1. What is the potential for earthquake shaking at your house?

   2. What is the potential for earthquake shaking at your university?
3. What is the potential for earthquake shaking at your work?

4. Go back to Static Maps for Future Earthquake Scenarios – by city or region; analyze your home location for an earthquake on the two closest major faults?

5. Go back to Static Maps for Future Earthquake Scenarios – by city or region; analyze SJSU for an earthquake on the two closest major faults?

III. Liquefaction

Go to the Interactive Liquefaction Susceptibility Map at (http://quake.abag.ca.gov/liquefaction/)

1. What is the potential for liquefaction at your house?

2. What is the potential for liquefaction at your university?

3. What is the potential for liquefaction at your work?

IV. Watch the following video:

V. Other Resources for this Information

1. Students can always use a Google or another search engine to locate and access other websites that contain the same information as the ABAG site.

2. My Hazards - California Emergency Management Agency
   http://myhazards.CALEMA.ca.gov/


5. California Geological Survey -
   http://www.conservation.ca.gov/cgs/geologic_hazards/earthquakes/Pages/index.aspx#Faults

There is no posting requirement for this activity, however, the results of your seismic hazard analysis will be used as a critical part of the final exam.
Activity 23 – Seismic Hazard Zones and Beginning Your Preparedness Plan

What is the due date? ________________ see greensheet or information at top of your learning group discussion for this activity in Canvas.

Learning Objective: Students will identify the seismic hazard or risk to home, university and workplace; and therefore address learning outcome #3, which is to have students apply a scientific approach to problems of the earth and environment.

Continue where we left off last time, the seismic hazard analysis to your selected location …..

I. Examine the Potential for Earthquake Shaking-Induced Landslides

Click on the Interactive Earthquake Induced Landslide Hazard Map link near the bottom of webpage at (http://quake.abag.ca.gov/earthquakes/)

The areas in green are susceptible to landslides during an earthquake.

1. Is your home in or near a region that is susceptible to landslides during an earthquake (green area).

II. Seismic Hazard Zone Map – go to http://myhazards.calema.ca.gov

Let’s put it all together………

To find out what natural hazards exist in your area, do the following:

Enter a street address and a city or town name into the search window

Write the output provided by this search, which you will find in the upper left portion of the webpage below “Earthquake Hazard

YOU ARE IN OR NEAR THE FOLLOWING:” – see example for the Fremont Community Center below and on next page.
This information comes from the Seismic Hazard Zonation maps and should form the nucleus of a paragraph in the Seismic Hazard Assessment section of your earthquake preparedness plan. You will combine this information with your work in Activity 22 on earthquake probabilities, fault locations, fault rupture potential, intensity of ground shaking and liquefaction potential near your location and some data on significant earthquakes, (e.g., date, location and magnitude).

Your earthquake preparedness plan should also have the Earthquake Hazard map, on the right side of the webpage page, with a full and complete legend, in the Seismic Hazard Assessment section, see example on the next page. Make sure you describe this map in your text in your plan.

III. Take the Structural Safety Quiz for Your Home

Go to http://www.abag.ca.gov/bayarea/eqmaps/fixit/quiz/

What is your score? __________
IV. Are You Prepared? Each of the Videos Touches on a Different Aspect of Preparedness

View *The Big One - Earthquake Preparedness* (2 minutes) - [http://youtu.be/e-3RYR41Shs](http://youtu.be/e-3RYR41Shs)

View *Earthquake Preparedness Now* (5 minutes) - [http://youtu.be/cYrFXgx0xi8](http://youtu.be/cYrFXgx0xi8)

View *Preparing for an Earthquake* (3 minutes) - [http://youtu.be/hd1bhDGFxKw](http://youtu/be/hd1bhDGFxKw)


Read and browse down the webpage and stop at:

**What Should I Do?—Follow the Seven Steps to Earthquake Safety**

List the *Seven Steps to Earthquake Safety* given in *Putting Down Roots in Earthquake Country*

1. _______________________________________________________________________
2. _______________________________________________________________________
3. _______________________________________________________________________
4. _______________________________________________________________________
5. _______________________________________________________________________
6. _______________________________________________________________________
7. _______________________________________________________________________

Do you understand each of these steps

Continue reading your way down the web

VI. Scroll Down the WebPage to the section “ Your Life Could Change Unexpectedly in the Next Quake….”

In order to establish a context for the assignment associated with the final exam in this class, review the webpage for information on each of the following questions in the space provided.

1. **Where will your family be during the magnitude 7 earthquake on the Hayward fault next week?**
2. *Will you have medical services after the earthquake?*

3. *Will you be able to get home after the earthquake?*

4. *Will you be able to stay in your home after the earthquake?*

5. *Can you live without the services you rely on for three days (72 hours)?*

6. *How will your job be affected or the progress towards a degree at SJSU if SJSU is closed for all of finals week?*

7. *Will you have money, food, and medicine to survive for 96 hours? (Many ATMs will be down due to blackout and markets will only accept cash, generally in small bills)*

8. *Will you be able to recover financially from the earthquake?*

9. *Will your insurance cover your losses?*

10. *Do you or your parents own a small business, if so, does the business have a recovery plan?*

11. *What will the Government do for you?*

VIII. “What Should I Do?— *Follow the Seven Steps to Earthquake Safety*”

1. Read the introduction to this section (everything above “You’ve learned your earthquake hazards, now follow these seven steps. . . BEFORE A QUAKE:)

2. Read about each step in “Putting Down Roots” in Earthquake Country.
IX. Required Learning Group Discussion

Post one sentence in your learning group discussion about whether or not you are adequately prepared for the next major earthquake.

Then, in the same posting, list the number of steps of the 7 step plan that you have currently completed and which ones.
Activity 24 – Compilation and Initiation of Earthquake Safety Plan

Relax – this is easy!

I. What is the due date? _____________, see greensheet or information at top of your learning group discussion for this activity in Canvas.

II. Objective: Develop an earthquake safety plan

III. Completed so far .............

At this point each student should have:

1. Acquired all of the information necessary to undertake a seismic hazard analysis of the location of your earthquake safety plan in Activity #22,
2. Fully understand the meaning and significance of the Seven Step Plan for earthquake preparedness as outlined in required reading assignments and brief videos in Activity #23,
3. Completed the structural-safety analysis quiz for the selected location for their earthquake preparedness plan in Activity #23,

These were all part of activities 22 and 23, both of which should be completed at this point.

Have you completed each of the items listed above? ________________

IV. Today’s Work Plan (Part I):

1. At this point, review each step of the 7 step safety plan.

2. Write down these items for each step that are relevant to your particular living space

3. Think of any and all modifications you may need to make to personalize or customize the steps to satisfy the requirements for your own personal preparedness plan and list them in the Part V below and on next page.

V. Personalize Modifications Required for Each Step

Step #1:

Step #2:
Step #3:

Step #4:

Step #5:

Step #6:

Step #7:

V. **Compile Rough Draft**

1. Review the required format for the final exam report. The report should no exceed 1000 words (3 pages double-spaced)

2. Write a rough draft of the seismic hazard analysis for your living space using a maximum of 350 words, which includes:
   - a description the San Andreas fault system and the members of this system that are closest to your living space.
   - Discuss the probabilities of a major earthquake on each fault near your living area over the next 30 years.
   - Next move on to your analysis of each seismic hazard in your area and the level of threat each poses to your safety.
   - Then review the structural integrity of your living space as determined in a previous activity in this class.
   - Given this information, discuss the importance of developing an earth preparedness safety plan for your living space

3. Go through each step of the 7 seven step plan and summarize the objective of the step and a self-assessment of your current level of preparedness in one paragraph per step. Each paragraph should be no more 70 words.
4. Finally, write a basic plan with a timetable for your implementation of your preparedness safety plan. Use less than 100 words.

VI. Submit Rough Draft to Criterium

Submit the rough draft, which does not exceed 1000 words, to Criterion for a grammar and composition review.
I. **Objective:** Perform a task required of all scientists and that is to verify the work on other scientists for validity, which is called peer review.

II. **Today’s Work Plan:**

1. You should have already submitted the rough draft of your Earthquake Preparedness Safety Plan to Criterion in activity #24, now submit text for review by another student in your learning group.

2. Here are some key questions to consider in preparing your final draft to be submitted to Canvas as your final exam:
   
   a. Does the paper have a title and your name at top of first page?

   b. Is the clarity and writing quality at the appropriate level for a graduating senior at SJSU?

   c. Does the introduction present information of the threat of earthquakes and faults in bay area and a thorough seismic hazard analysis of your selected location

   d. Is each step paragraph complete with an introductory statement and self-assessment of your current status of preparedness?

   e. Is the implementation plan sound and realistic with a timetable for completion?

**Post your rough draft** of the earthquake preparedness plan in your Activity #25 learning group discussion.

**Read and review the draft of another student** and give constructive feedback to improve the overall quality of their work

**After reviewing the work of another student, and receiving a review of your work,** then make any revisions that you deem necessary and submit your final draft to Assignment Area of Canvas by the due date given in course schedule.