Supplement: Classroom Activities

Putting down roots in earthquake country

Earthquake education and awareness in Idaho

Idaho Bureau of Homeland Security — Prevent Protect Respond Recover

citizen corps

Idaho Geological Survey — Since 1919, serving the state through geologic research

Department of Education, State of Idaho

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Idaho Seismicity: Where and How Often do Earthquakes Occur in Idaho?

***Putting Down Roots*, p. 2, "Idaho is 'Earthquake Country'"**

Idaho State Standards:

Earth Science 1.2.1, 1.2.3, 1.6, 1.8
8th Mathematics 3.5, 4.3, 5.1.1, 5.3.1, 5.3.2, 5.5.1
9th Mathematics 1.1.2, 1.3.1, 2.2, 2.3, 2.4.1, 3.5.1, 4.3, 4.4, 5.1, 5.2, 5.3, 5.5

Objectives:

Students will:

- Describe the pattern of historical seismicity at magnitude 5 or greater in Idaho.
- Describe the pattern of Quaternary faults in Idaho.
- Describe the relationship of seismicity to faults in Idaho.
- Describe the relation of seismicity to Idaho's geologic provinces.
- Define the concept of the recurrence interval for earthquakes.
- State the recurrence intervals in Idaho for earthquakes with magnitudes of at least 5, 6, or 7.

RATIONALE

This exercise is designed to help students understand where and how often earthquakes are likely to occur in Idaho. This activity will require students to analyze data and describe patterns associated with the data.

FOCUS QUESTION(S):

- Is there a pattern to where and why earthquakes occur in Idaho?
- What is the recurrence interval for earthquakes in Idaho with different magnitudes?

TEACHING CLUES AND CUES

Become familiar with the different maps associated with this activity. A current Quaternary fault map of Idaho can be found at the following USGS web site: http://earthquake.usgs.gov/hazards/qfaults/. Select the static link on the left side bar of the web page – unless you are good working with Google Maps and want to download the KMZ files. The two Google maps you want to download would be the Holocene to Late Pleistocene (younger than 15,000 years) and Late Quaternary (younger than 130,000 years). This map could be projected. The map is interactive and will display the names of the faults when pointed to. Be aware of the color code used; orange for the Holocene faults and yellow for the Quaternary faults.

You might notice that when plotting location of the earthquakes from Table 1 that some do not fall on or near a named fault. There are many unknown faults in Idaho and it is through earthquakes that these faults are identified and studied further.

You may also want to purchase a classroom set of a poster-sized "Geologic Map of Idaho" from the Idaho Geologic Survey at http://www.idahogeology.org/Products/reverselook.asp?switch=pubs&value=Miscellaneous_Maps. Click on "How to Order" at the top of the page. 4 x 6 postcards of the map are also available for purchase.

The Geologic Map of Idaho is colored and has more faults plotted than the Google maps, because it includes faults older than 130,000 years old. It also has details about rock type and geologic age.

*A new geologic map will be coming out in the fall of 2011. It is not known at this time if there will also be an accompanying poster-sized map printed.

MATERIALS:

for teacher

- Teacher Background, pp. 10-11
- Answer Key, pp. 12-14
- *Optional*, Geologic Map of Idaho, Computer with internet capabilities, Projection equipment
- Geologic Time Chart at http://imnh.isu.edu/Exhibits/Online/geo_time/geo_chart.htm

for the students:

- Student worksheet, pp. 3-6
- Maps (Figures 1 & 2), pp. 8-9
- Data table (Table 1), p. 7.

PROCEDURE:

Teacher Preparation

Copy the materials for the students. Decide if the fault map and plotting will be interactive or done on paper. Using available technology, teachers may want to give each student an earthquake latitude and longitude from the list (Table 1) and have them plot its position on the projected map. Teachers may also want students to use a graphing program to plot the data and generate a graph, instead of doing it manually. Both approaches have merit and are dependent on the skills and academic level of the student.

A. Introduction

The general question addressed in this activity concerns where and how often earthquakes occur in Idaho. Using maps and data, the students will explore the answer to this question.

Many earthquakes occur within tectonic plates, instead of at plate boundaries. These intraplate earthquakes are responsible for Idaho's seismicity and are best understood in relation to the geologic and tectonic settings (see the diagrams in Teacher Background, pp. 10-11). In this activity students associate earthquake epicenters with active faults, identify regions of high and low seismic activity, and determine the recurrence intervals for earthquakes of certain magnitudes.

B. Lesson Development

1. Tell students that they will use data to understand where and how often earthquakes are likely to occur in Idaho. They will be using a list of earthquakes with a Richter magnitude of 5 or greater that have occurred in or near Idaho since 1884.

2. Students will describe the patterns associated with earthquakes and the location of faults and geologic provinces of Idaho.

3. Have students look at the two maps. Instruct them to identify the latitude and longitude markings on Figure 1. Figure 1 is a map of faults in Idaho that show evidence of displacement (movement) in the last 15,000 years. Note that if you use the Google map component, you may display other faults that are younger than 130,000 years to mirror the fault map that students have). Students will need to have an understanding of geologic time with reference to Periods and epochs as well as age range values. Reference http://imnh.isu.edu/Exhibits/Online/geo_time/geo_chart.htm for a visual of a geologic time chart. The second map (Figure 2) shows the geologic provinces of Idaho.

4. Using the data table (Table 1), maps (Figs. 1 & 2), and the graph on the student worksheet, answer the questions as they apply to location and recurrence interval. Graph your data and frequency of occurrence.

5. Utilizing the components of this activity, write a summary report explaining where, why, and how often earthquakes are likely to occur in Idaho. Support your report with data from the activity as evidence.

C. Conclusion

Help students to synthesize the information from the activity. Encourage them to use data from the activity to support their written conclusion (using computational values and names for geologic provinces or faults, etc).

Adaptations and Extensions

If teachers or students use the Google Maps KMZ files they may want to add the faults from 1.6Ma

USGS (United States Geological Survey)
http://earthquake.usgs.gov/earthquakes/

The USGS website includes interactive maps of the latest earthquakes nationally and worldwide. In addition, the websit links to two different formats, a live feed (Atom XML) that monitors earthquakes and the Google Earth KML format, that would be useful in the classroom. An application available at https://geohazards.usgs.gov/eqprob/2009/index.php allows students and teachers to look at Probability Mapping for Earthquakes. The necessary zip codes for Idaho can be found at http://www.555us.com/555ID/555id_zipcodes.htm.

Another mapping option found at the USGS site is the Interactive or Static Fault Maps at http://earthquake.usgs.gov/hazards/qfaults/usmap.php. Visit the Earthquakes Hazards Program website at http://earthquake.usgs.gov/hazards/ for additional maps and tools through the "Online Seismic Hazard Analysis Tools."

Student worksheet

Where Do Earthquakes Occur in Idaho?

Name _____ Class _____ Date _____

1. Using the latitude and longitude values provided in Table 1, place a dot on the fault map (Figure 1) for each of the listed earthquakes and write the earthquakes magnitude next to each dot.

2. Using Figure 1, answer the following questions.

   a. How many earthquakes occur on or very near a fault? _____

   b. How many earthquakes occur in area lacking faults? _____

3. Write the number of earthquakes plotted on the map for each of the following regions:

   a. North of 45 degrees north latitude _____

   b. Between 44 degrees and 45 degrees north latitude _____

   c. In southwestern Idaho _____

   d. In southeastern Idaho and northern Utah _____

   e. In western Montana and western Wyoming _____

4. Refer to the Idaho Geologic Provinces map (Figure 2) to answer the following questions.

   a. Which geologic provinces show the greatest seismicity in the last 110 years?

   b. Which geologic provinces show the least seismicity in the last 110 years?

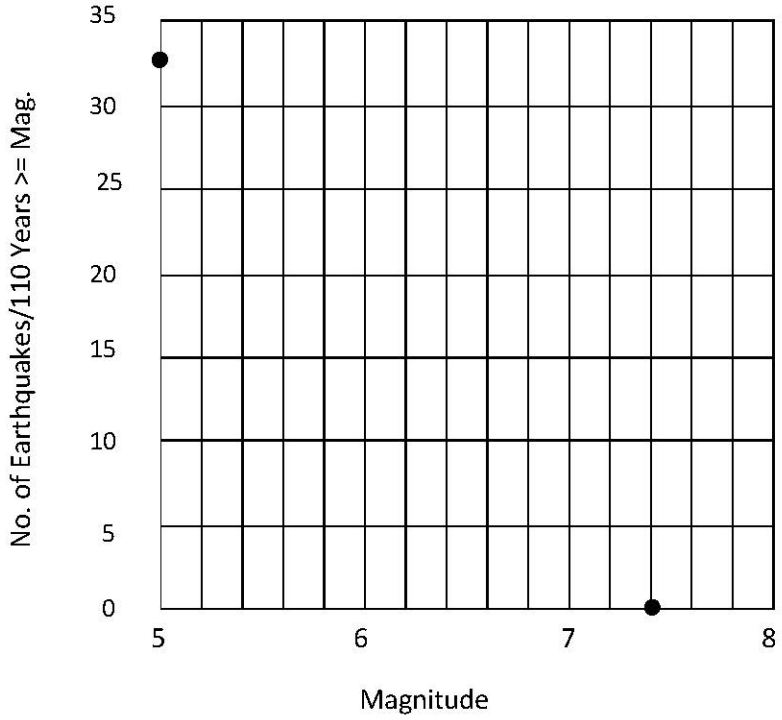
How Often are Earthquakes Likely to Occur in Idaho

1. Next, determine when an earthquake of magnitude 5 or greater is likely to occur in Idaho. Using the data from Table 1, complete the table below by entering in the second column the number of earthquakes having the magnitude listed or greater. The first two and last values have already been entered.

Magnitude	Earthquakes	Magnitude	Earthquakes
5.0	33	6.4	
5.2	27	6.6	
5.4		6.8	
5.6		7.0	
5.8		7.2	
6.0		7.4	0
6.2			

2. Now plot these pairs of values as points of the graph below. The first and last points have already been plotted.

Number of Earthquakes vs. Magnitude



3. Draw a smooth curve that passes through the plotted points or passes very close to them (instead of connecting the points with short, straight line segments).

4. Looking at the graph, how many earthquakes occurred between 1884 and 1994 with a magnitude of 5 or greater?

Answer_____earthquakes

5. Now divide 110 years by the number of earthquakes having a magnitude greater than 5 to find how often an earthquake above magnitude 5 is likely to occur in Idaho. This is called the recurrence interval.

Answer_____years

6. Repeat steps 4 and 5 to find the recurrence interval for an earthquake of magnitude 6 or greater.

Answer_____years

7. Repeat steps 4 and 5 to find the recurrence interval for an earthquake of magnitude 7 or greater.

Answer_____years

8. If the last earthquake with a magnitude of 5 or greater was in 1994, what does the above data say about the probability of a 5.0, 6.0 or 7.0 earthquake occurring?

9. Seismologists at the Idaho Geological Survey have identified the following years in which there was an earthquake with a magnitude of 6 or larger: 1905, 1916, 1934, 1944, 1945, 1959, 1975, 1983, and 1994. Calculate the average (mean) recurrence interval based on this data. How does this average compare to what you calculated above? Are we due or past due for another major shaking event in Idaho?

10. The Idaho Bureau of Homeland Security is responsible for public safety through hazard mitigation activities (any sustained action taken to reduce or eliminate the long term risk to human life and property) of risk from a hazard event.

Seven major risks or hazards that affect Idahoans are: Flooding, Wildfire, Earthquakes, Dam/Levee failure, Severe Weather, Hazardous Materials, and Landslides. Rank these hazards from most (1) funds needed for mitigation to the least (7)? Why did you rank the hazard of earthquakes as you did?

11. Write a summary report that utilizes the components of this activity to explain where, why, and how often earthquakes are likely to occur in Idaho. Support your report with data from the activity as evidence.

Table 1. Historical record of Idaho Earthquakes with magnitudes of 5 or greater.

Year	N. Latitude	W. Longitude	Magnitude
1884	42.00	111.30	6.3
1905	42.90	114.50	5.3
1916	43.70	116.20	5.3
1917	43.00	111.30	5.3
1928	42.10	115.20	5.2
1934	41.50	112.50	6.6
1934	41.80	113.00	5.5
1944	44.50	115.50	6.0
1944	44.25	115.04	6.1
1945	44.70	115.40	6.0
1947	44.75	111.75	6.3
1959	44.83	111.08	7.3
1959	44.90	111.63	6.0
1962	41.80	111.80	5.7
1963	44.30	114.70	5.1
1964	44.80	111.60	5.8
1965	44.90	112.70	5.0
1974	44.56	111.09	5.1
1975	42.06	112.54	6.2
1975	44.75	110.61	6.1
1975	44.80	110.70	5.1
1976	44.80	110.80	5.0
1977	44.85	111.50	5.2
1983	44.05	113.85	6.9
1983	44.23	114.10	5.8
1983	44.10	113.90	5.4
1984	44.40	114.10	5.6
1984	44.50	114.00	5.3
1991	44.50	114.25	5.2
1993	44.40	114.80	5.1
1994	42.70	111.15	5.8
1994	42.70	111.02	5.2
1994	42.56	111.03	5.2

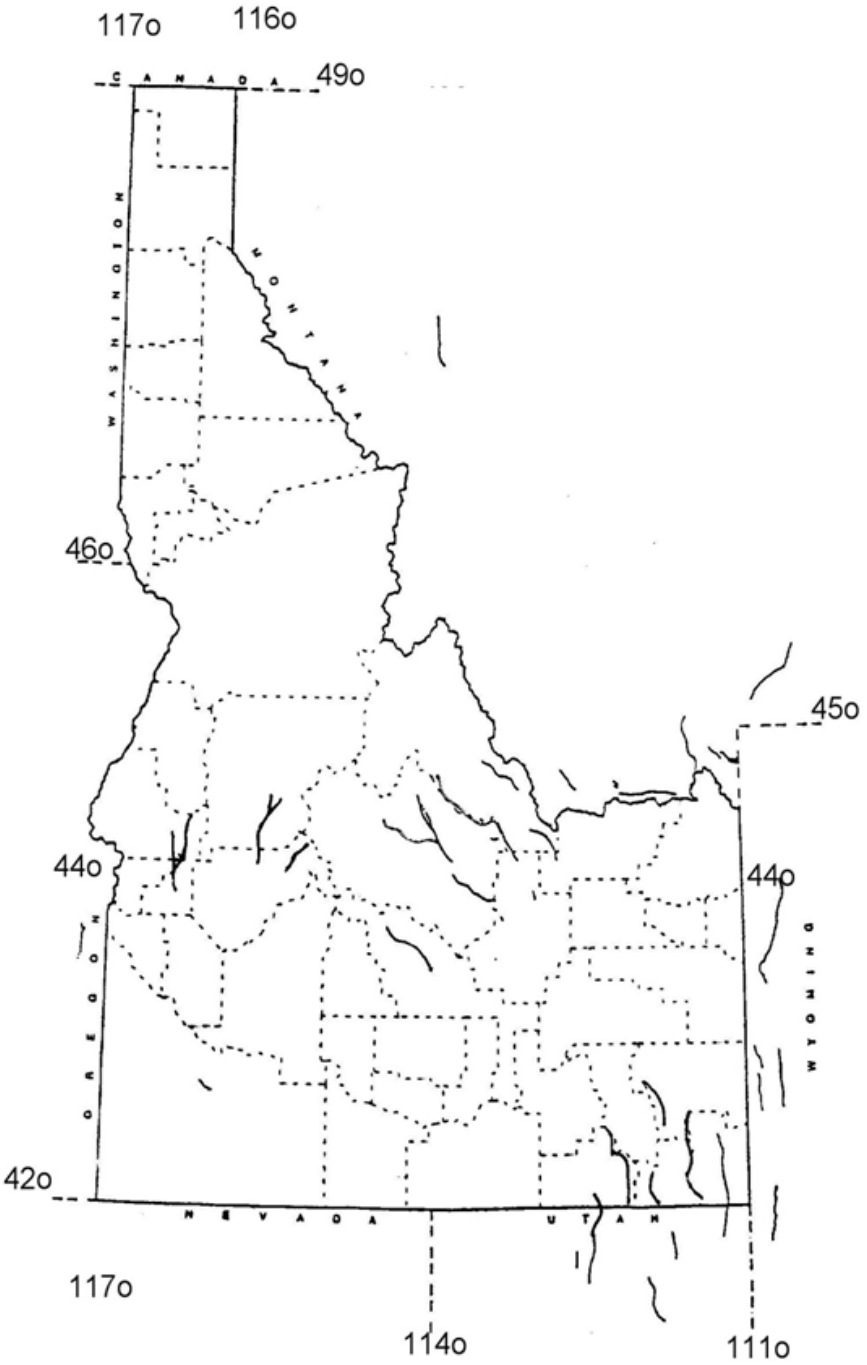


Figure 1. Neotectonic fault map of Idaho (after Hilt, A.P., Breckenridge, R.M., and Sprenke, K.F., 1994, Preliminary Neotectonic Map of Idaho, Idaho Geological Survey, Technical Report 94-1) and worksheet for plotting locations of earthquakes

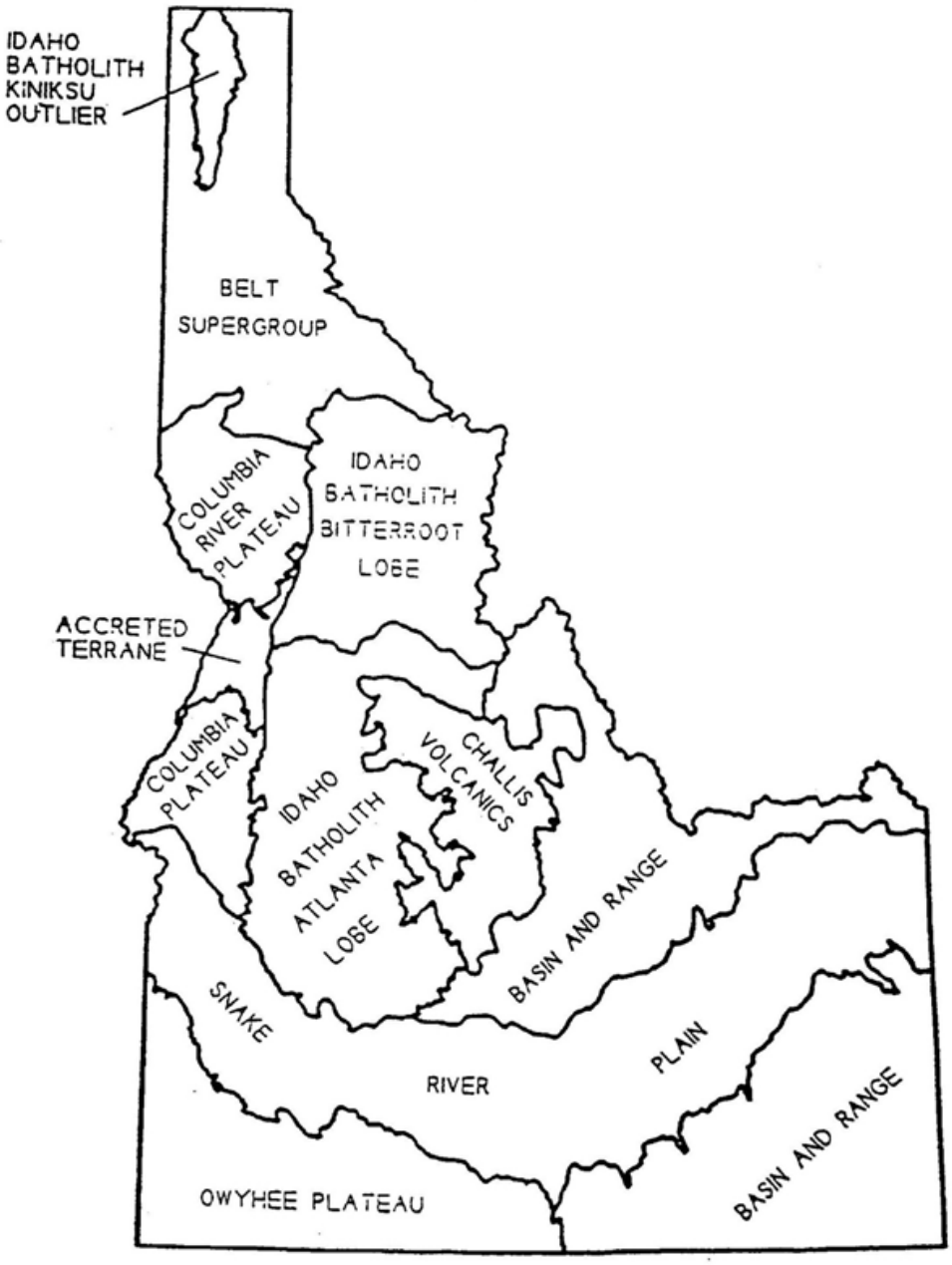


Figure 2. Geologic provinces of Idaho.

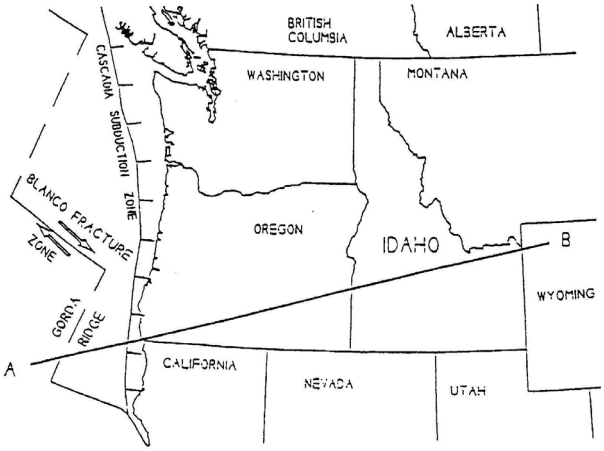
Teacher Background

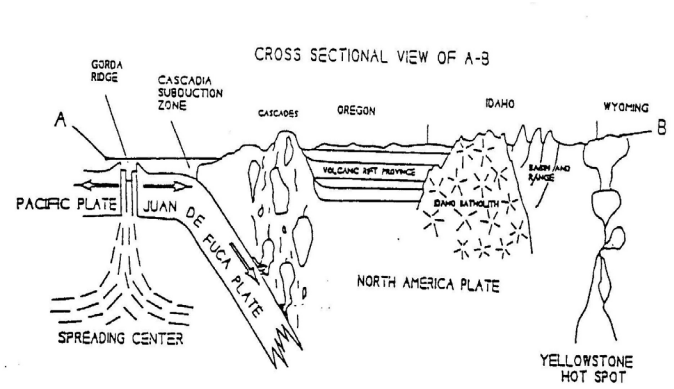
INTRODUCTION

The general question addressed in this activity is "Where and how often do earthquakes occur in Idaho?" Using maps, and data the students will explore the answer to this question.

IDAHO SEISMICITY

Many earthquakes occur within tectonic plates instead of at plate boundaries. These intraplate earthquakes are responsible for Idaho's seismicity and are best understood in relation to the geologic and tectonic settings as shown below.





Idaho's relationship to tectonic plates of the Northwest (after Hilt, A.P., Breckenridge, R.M., and Sprenke, K.F., 1994, Preliminary Neotectonic Map of Idaho, Idaho Geological Survey, Technical Report 94-1). The cross section shows some of the causes of regional uplift and faulting in Idaho.

An exercise designed to help students understand where and how often earthquakes occur in Idaho is included in the activity, *Idaho Seismicity*. In this activity, students associate earthquake epicenters with active faults, identify regions of high and low seismic activity, and determine the recurrence intervals for earthquakes of certain magnitudes.

The activity should be accompanied or preceded by additional teaching media that presents the following concepts and principles.

A. Geologic provinces of Idaho

1. Belt rocks of northern Idaho
2. Accreted terranes of west central Idaho
3. Columbia River basalts of west central Idaho
4. Idaho batholiths of central Idaho
    a. Bitterroot lobe-north
    b. Atlanta lobe-south
5. Owyhee Plateau of southwestern Idaho
6. Snake River Plain of southern Idaho
7. Basin and Range province of southeastern Idaho
8. Challis Volcanics of east central Idaho

B. Intermountain Seismic Belts (*Putting Down Roots in Earthquake Country*, pp. 8-13)

1. Yellowstone Tectonic parabola
2. Intermountain seismic belt (southeastern Idaho)
3. Central Idaho Seismic Zone
4. Western Idaho seismic Zone
5. Lewis and Clark Zone

C. Yellowstone Caldera and Hot Spot

D. Extensional tectonics

1. Possible sources of vertical stress
    a. Mantle plumes
    b. Idaho batholiths isostatic adjustment
2. Resulting strain
    a. Normal Faulting
    b. Reverse Faulting

E. Mathematical skills: plotting x-y coordinates

ANSWER KEY to Idaho Seismicity

WHERE DO EARTHQUAKES OCCUR IN IDAHO?

1. See Figure 3

2. a. 21 (± 3 depending on what students idea of "very close" means)
   b. 12 (± 3 depending on what students idea of "very close" means)

3. a. North of 45 degrees 0
   b. 44 to 45 degrees 21
   c. SW Idaho (114 to 117 degrees) 12
   d. SE Idaho & Utah (111 to 114 degrees) 21
   e. Montana & Wyoming 7

4. Greatest: Atlanta batholiths, Challis Volcanics, Basin & Range
Least: Bitterroot batholiths, Columbia River Plateau, Accreted Terrane, Belt Supergroup, Kaniksu Outlier

HOW OFTEN ARE EARTHQUAKES LIKELY TO OCCUR IN IDAHO?

1. 33, 27, 18, 16, 14, 11, 6, 3, 3, 2, 1, 1, 0

2. See Figure 4

3. See Figure 4

4. 33

5. 110 ÷ 33 earthquakes = 3.3 years per 5.0 earthquakes

6. 10
   110 ÷ 11 earthquakes = 10 years per 6.0 earthquakes

7. 1
   110 ÷ 1 earthquakes = 110 years per 7.0 earthquakes

10. Answers will vary depending on where students live in the state and their life experiences with these hazards. Accept any justifiable answer.

11. Students should address the general location and the proximity to faults of most earthquakes in Idaho, as well as the rock type, geology, and name of the provinces associated with the earthquakes. They should include the probability of earthquakes with a magnitude of 5 or greater as compared to earthquakes of a magnitude 6 or 7.

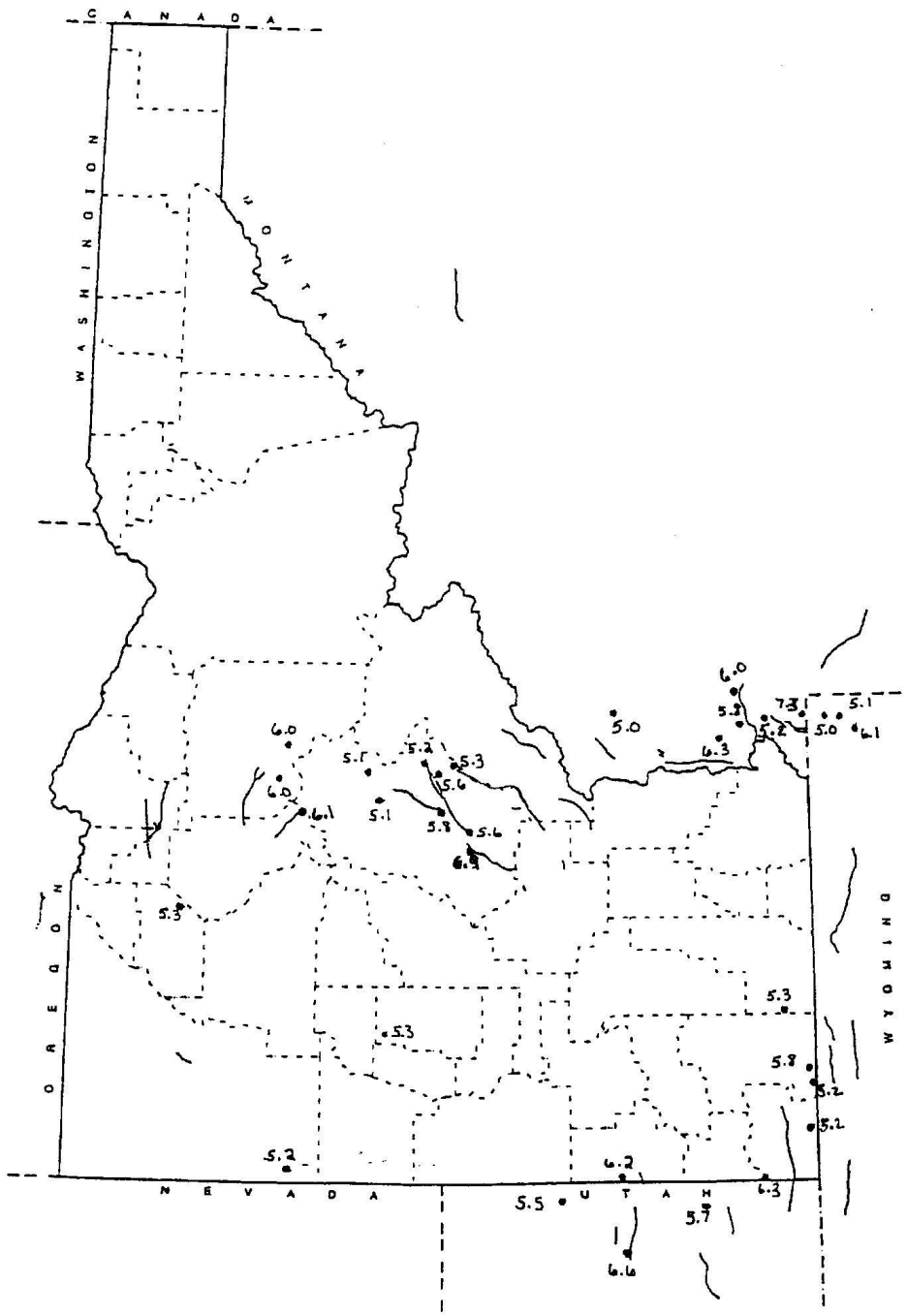


Figure 3. Solution to Idaho Seismicity, Where do Earthquakes occur in Idaho?, problem number 1: Idaho earthquakes with magnitudes of 5 or greater plotted on the neotectonic fault map of Idaho.

Figure 4.

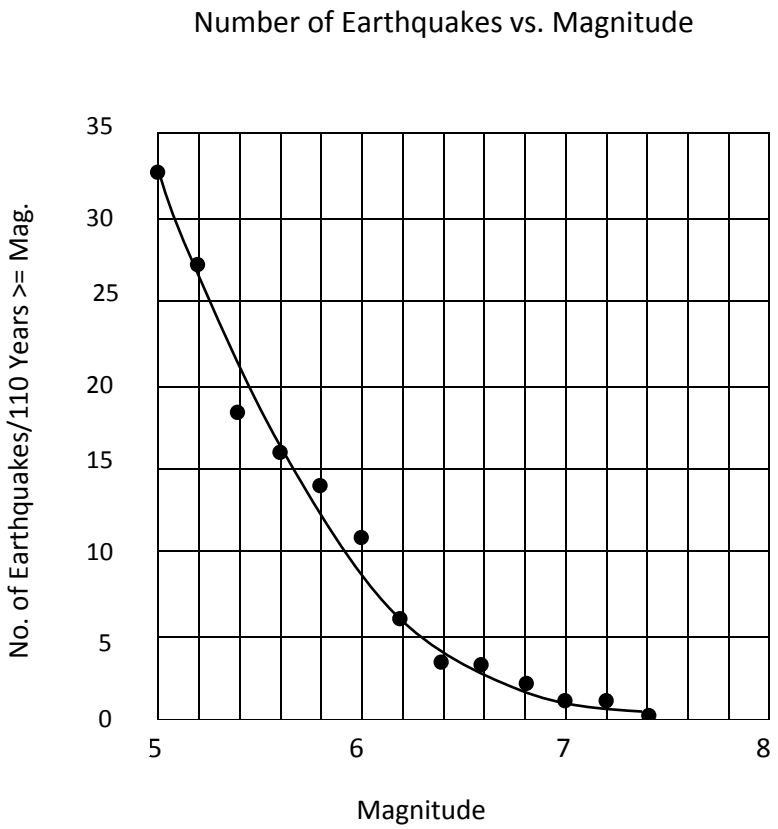


Figure 4. Solution to *Idaho Seismicity, How Often are Earthquakes Likely to Occur in Idaho*, problem numbers 2 and 3.

Earthquake Probability Mapping for Idaho: An Internet Activity

***Putting Down Roots*, pp. 4-13**

Idaho State Standards:

Earth Science 1.2.1, 1.2.2, 1.2.3, 1.6.1, 1.6.2, 1.6.3, 1.6.6, 1.8.1, 5.1.1, 5.2.2
9th Mathematics 5.4, 5.5

Objectives:

Students will:

1. Display and interpret a probability map of an area in Idaho using the USGS 2009 Earthquake Probability Mapping application.
2. Explain how probability changes with a change in time and magnitude.
3. Correlate the probability map with the geologic provinces and seismic zones of Idaho.
4. Compare and interpret probability maps of three locations with the same magnitude and time span.
5. Communicate their findings in a summary report.

RATIONALE

In this activity students will use a computer application from the USGS web site https://geohazards.usgs.gov/eqprob/2009/index.php to display earthquake probability for different locations in Idaho. Students will input Idaho zip codes, a time span, and magnitude to generate a probability map. The web site was designed to display earthquake probabilities that are computed from the source model of the 2008 USGS National Seismic Hazard Mapping Project (NSHMP). The region of model validity is the coterminous (lower 48 states) USA and Alaska. The generated maps will show the probabilities of earthquakes within a radius of 50 km.

FOCUS QUESTION(S):

- Is there a difference between prediction and probability?
- What is the probability of an earthquake occurring within a given location in Idaho?
- How does the probability of an earthquake vary with time and magnitude?
- Which geological provinces in Idaho are most likely to be affected?

TEACHING CLUES AND CUES

Teachers may want to access https://geohazards.usgs.gov/eqprob/2009/documentation.php as background for understanding the finer details of the application.

Teachers may want to use this activity as a homework assignment or as a classroom discussion/presentation. Students should be familiar with Idaho Geologic Provinces as seen on the IGS poster or the black and white image found in the folder of this document. This activity also uses the *Putting Down Roots in Earthquake Country* from the Idaho Bureau of Homeland Security. Using pp. 10-13, students should determine in which seismic zone their towns or cities are located.

The parameters for magnitude and time span could be whatever you, the instructor, choose. However, it has been found that if you change only the magnitude (5.0, 6.0, 7.0) and leave the time span constant (100 years), there will be clearer difference between locations. Control all variables except one to facilitate student analysis. Adjust the time range and magnitude to see how the probability changes for a given location (keep the magnitude within 5.0 and 7.0 and a time span at or above 50 years).

See for yourself how the probability changes for a location with a magnitude of 7.0 and a time span of 100, 1,000, and 10,000 years, or change the magnitude from a 5.0 to 6.0 to 7.0 but keep the time span at 100 years.

MATERIALS:

for teacher

- Computer with internet access
- *Optional*: projection equipment
- List of Idaho Zip Codes (see document or access: http://www.555us.com/555ID/555id_zipcodes.htm
- Geologic Map of Idaho (poster size) – Classroom set http://www.idahogeology.org/Products/reverselook.asp?switch=title&value=Geologic_Map_of_Idaho,_color_poster or copies of the black and white image *Idaho Geologic Province* included in the accompanying CD-ROM.
- Highway or atlas maps of Idaho that show location of cities and towns (paper or computer image) http://itd.idaho.gov/maps/
- Copies of the publication *Putting Down Roots in Earthquake Country* from the Idaho Bureau of Homeland Security for each student (see address in Sources for acquiring copies)
- Answer Key, pp. 18-19

for the students: (work in pairs)

- Computer
- Geologic Map of Idaho
- Highway map of Idaho or Atlas
- *Putting Down Roots in Earthquake Country* , pp. 4-13
- Student worksheet/instructions p. 17

PROCEDURE:

Teacher Preparation

Purchase a classroom set of the Idaho Geologic Map poster or print out the black and white "Idaho Geologic Provinces" map found on the accompanying CD-ROM. Print out copies of the student worksheet for the students as well as a list of the Idaho Zip Codes for yourself (also found on the CD-ROM). Decide which zip codes you will use or let students choose. Demonstrate how the students will access and use the application at the USGS web site. Familiarize yourself with the application. Adjust the time range and magnitude to see how the probability changes for a given location. *See Teacher Clues and Cues.*

A. Introduction

Display the Geologic Map of Idaho. Make sure students know how to interpret the map. Each student should receive at least three locations to analyze, preferably one each in the northern, southwestern, and southeastern sections of Idaho. Reinforce the connection between earthquakes and geology. Give students time to find their cities/towns on the highway map or atlas and correlate it to the geologic map. A few, but not all, locations are identified on the geologic map.

B. Lesson Development

1. Provide the students with 3 locations (adjust the number of locations as needed).

2. Using Idaho maps and booklet information, determine where the three towns/cities are located and in which geologic province and seismic zone they are found.

3. Access the application at the USGS web site and input the variables assigned by the instructor.

4. Change the time span and magnitude variables as instructed and analyze the change, if any.

5. Save the map images. Import the images of each location into the summary report.

6. Write a summary of the findings on the probability of an earthquake in the three locations within a specific time span and magnitude. The summary should include a description of how the probability changes as the magnitude **or** time span changes, and an image of each location with the same magnitude and time span. With each location, include the identity of the geologic province and seismic zone in which it is found.

C. Conclusion

Students should see that, as the magnitude increases, the probability of an earthquake occurring over a specific time span will decrease. Different regions of the state will display greater, more obvious changes from one magnitude to the next. Students should see that there is more of a chance for magnitude 5 earthquakes than magnitude 7 earthquakes. However, they will also see that, if they go beyond a 7.4, there will be no data.

Adaptations and Extensions

Students may want to research probability maps of different areas of the United States, including Alaska. Suggest cities located along major rivers, edges of mountain ranges, along coast lines, etc.

Challenge students to see if they can determine the magnitude of the largest probable earthquake in Idaho *(M7.4, due to the types of faults that exist and rock structure in the state).*

Student worksheet

Earthquake Probability Mapping

(An Internet Activity)

Student Instructions:

1. Go the U.S. Geological Survey web site https://geohazards.usgs.gov/eqprob/2009/index.php to access an application that will allow you to compare the probability of an earthquake of a specific magnitude over a specific time period using three Idaho sites.

2. At this web site, you will input the location using three zip codes (given to you by your teacher), rather than the latitude and longitude. Click on the link to "input Zip Code"

3. List the three (3) Towns/cities and their zip codes that you have been assigned:

A. _____

B. _____

C. _____

4. Find the towns on the Idaho Highway Map. Use the Geologic Map of Idaho to determine in which geologic province the towns are located. Use the booklet ***Putting Down Roots in Earthquake Country: Your Handbook for Earthquakes in Idaho*** to determine the Seismic zone in which these towns are located (pp. 8-13).

5. Enter your first location's zip code and a "Time Span" and a "Magnitude" as instructed by your teacher. Click on "Compute Probability."

6. Save the generated image either as a PDF file or an image PNG file on your computer. A PDF file will result in a larger map saved. You will use these images in your summary report.

7. Go back to the map generator page and, without changing the zip code, change either the time span or the magnitude, according to your teacher's instructions. Do not change both. Generate a new map and save. Repeat one more time again changing the Time Span or Magnitude.

8. Enter the zip code of another one of your locations. Repeat steps 4 – 7 for this location.

9. Repeat the process again for your third location.

10. Write a summary report analyzing the probability of an earthquake occurring in your locations. Compare the different sites using the same magnitude and time span. Be sure to include location, geologic province, and seismic zone. Include rock type, if known, and any other relevant information.

11. Cite the resources used at the end of your summary, using appropriate citation methods.

ANSWER KEY (Sample)

The three locations analyzed were Athol, Idaho in the northern Idaho panhandle; Alpha (Cascade) in the west central mountains of Idaho; and the Idaho National Laboratory (INL) near Idaho Falls in southeastern Idaho. The probability parameters for each site were a magnitude of 7.0 within a 100 year time span. Athol, Idaho is located in the Idaho batholiths Kiniksu Outlier province of northern Idaho. This province is composed mainly of granite, intermixed with Belt Super Group metamorphic rock. This province resides within the Lewis and Clark seismic zone. The seismic zone is roughly 30 miles wide and approximately 240 miles long. It extends through northern Idaho to northwestern Montana.

The probability of an earthquake with a magnitude of 7.0 occurring within a 50 kilometer radius during a 100 year time span is basically zero (Figure 1). However, the probability increases as the magnitude (M5.0) decreases (Figure 2). Many of these lower magnitude earthquakes may be associated with rockbursts from mining activity within the 50 km radius. It is interesting to note that the probability increases further east into Montana. As a result, it is likely that the earthquake would be centered in Montana and felt within a 50 km radius, westward into the Idaho panhandle.

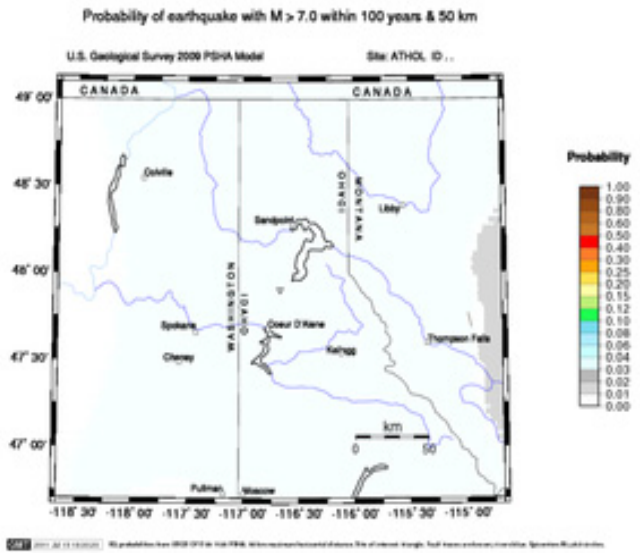


Figure 1

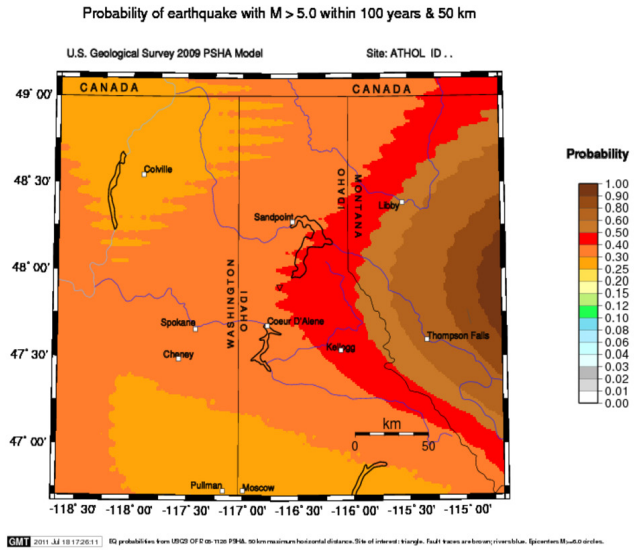


Figure 2

In southern Idaho, the probability of seismic activity varies between the western and eastern part of the state. The two locations compared were the INL (Idaho Nuclear Laboratory) facility outside Idaho Falls and Alpha a small community south of Cascade, ID. For example, between western and eastern Idaho the probability increases moving eastward. Using the same parameters for both locations--a 100 year time span, a 50 km. radius, and a 7.0 magnitude--the two sites were compared. The probability of a 7.0 magnitude earthquake affecting the INL location is higher than an earthquake of the same magnitude affecting Alpha, ID (Figures 3 and 4).

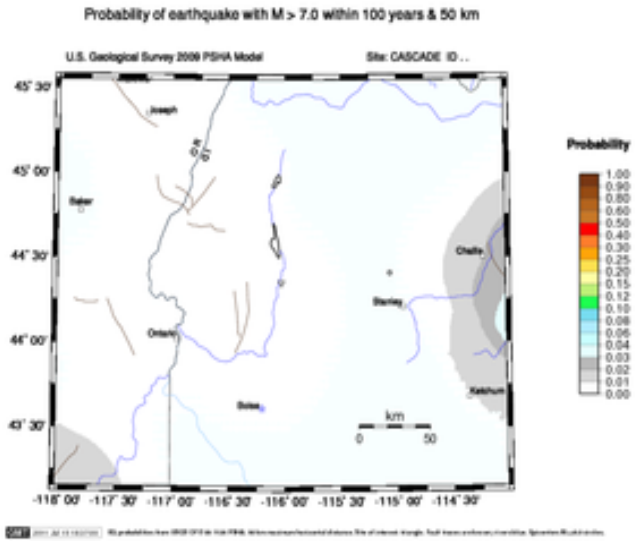


Figure 3

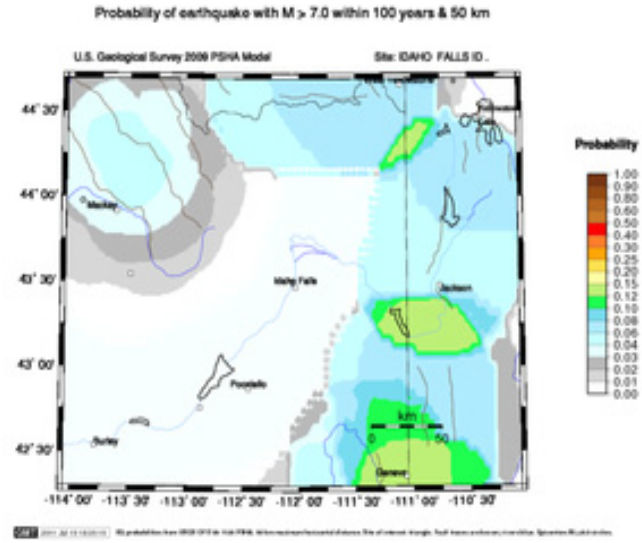


Figure 4

The location of Alpha lies in the Western Seismic Zone and is associated with the Long Valley fault zone. The geologic province in which it resides is the Atlanta Lobe of the Idaho batholith. The INL is located on the Snake River Plain mainly composed of basalt and located south of the Central Idaho Seismic Zone. It sits between two major faults--the Lost River Fault and the Lemhi Fault. According to the Probability maps of the two areas, the INL is 2 times more likely to be affected by a M7.0 earthquake than the area of Alpha, ID over the same 100 year time span. According to the probability maps in Figures 1, 3, & 4, it appears that the southeastern area of Idaho is more likely to have a M7.0 earthquake than the northern and southwestern area of the state.

Idaho Seismic Belt Graphic Organizer

***Putting Down Roots*, pp. 8-13**

Idaho State Standards:

Earth Science 1.2.2, 1.8.1

Objectives:

Students will:

- Design a graphic organizer (concept map, mind map) that will allow them to understand and organize information.
- Use the graphic organizer to interpret maps, write summary reports, and communicate information.

RATIONALE

Graphic organizers are visual representations of knowledge, concepts, thoughts, or ideas. They are sometimes referred to as Concept Maps or Mind Maps and have been used to organize bits of data in easy-to-understand formats, such as charts, tables, graphs and as a way of taking notes. Graphic organizers are used as a way of helping students to organize their thoughts or information. They are known to help relieve learner boredom, enhance recall, provide motivation, create interest, clarify information, and promote understanding (Buzan, 2000). In this activity, students will generate a graphic organizer that will display information about the four Intermountain Seismic Belts in Idaho.

FOCUS QUESTION(S):

- What would be the best way to organize the data presented on pp. 8-13 in the Earthquake booklet?

TEACHING CLUES AND CUES

Putting Down Roots in Earthquake Country has a wealth of information, much of which would be overwhelming to students if not broken down into understandable bits. To accomplish this, atype of graphic organizer can be used. Mind maps are usually done with different colors as a way to take notes. The main idea is placed in the center of the page and then built outward. If this is the first introduction to Mind Mapping, the teacher may want to complete it as a class project, with different groups of students finding the information and then reporting out. The teacher displays or builds the map at the front of the room and the students then copy the information. Allow students to use their designed graphic organizer during a quiz to emphasize its practical use. This technique of note taking will allow students to access the information quickly. Note: Other activities on the accompanying CD-ROM use the information from this section of the booklet.

Various educational graphic organization software programs are available on the market, such as Inspiration®, Kidspiration®, SmartDraw®, etc. If you have access to one of these programs, this may be an appropriate time to incorporate it into the lesson.

MATERIALS:

- *Putting Down Roots in Earthquake Country* booklet for each student
- Paper and colored pencils (4)
- *Optional* - Graphic Organizer Software

PROCEDURE:

Teacher Preparation

Explain to students how mind maps are structured and provide them with the booklet and colored pencils.

A. Introduction

Tell students that they are to design a mind map that displays the information found within pp. 8-13 of the *Putting Down Roots in Earthquake Country* booklet. The key concept is "Seismic Zones in Idaho." For their maps, direct students to find the following information in the publication:

- Name of seismic zones
- Geographic location
- Names of major faults and orientation
- Major Cities or towns (5)
- Water features (rivers, reservoirs, lakes)

B. Lesson Development

1. Describe how and why mind maps are designed.
2. Use a different color of pencil to emphasize the ideas requested.
3. On the chalkboard or whiteboard, list the information that students are to find within the publication

C. Conclusion

Have students place their mind maps in their notebooks to be used for future reference.

A Model of Three Faults

***Putting Down Roots*, pp. 3-4, Idaho and the Intermountain West are Seismically Active**

Idaho State Standards:

Earth Science 1.2.2, 1.3.1, 1.3.3, 4.1.3
8th Mathematics 2.1.1, 2.2.1
9th Mathematics 1.1.1, 2.1, 2.4.1

Objectives:

Students will observe, identify, take measurements, and interpret fault movements on a model of the earth's surface.

RATIONALE

The topographical expression of the earth's surface is the result of geologic processes. These processes result in the formation of mountains, valleys, cliffs, waterfalls, canyons, river beds, etc. Over a long period of time, movements along a fault line contribute to the formation of these geological features. In this activity, the use of a model can help students to vizualize and understand faulting. Models are a three-dimensional configuration of layers, concrete rather than abstract descriptions or diagrams, can be manipulated by the students, and can show the motions of the faults through time.

FOCUS QUESTION(S):

- Can you name a famous fault?
- What happens when giant fractures develop on the Earth and the pieces move relative to one another? Answer: earthquakes occur.
- What type of forces or stress is necessary for movement along a fault? Answer: tension, compression, shearing.

TEACHING CLUES AND CUES

Teachers may want to enlarge (8 ½ x 11) the model before copying. They may also want to have the model enlarged for themselves so that it can be used for classroom demonstration . To create a large model for class demonstrations, have it enlarged onto poster sized paper at an office products store or copy center and glue to foam core or poster board before construction.

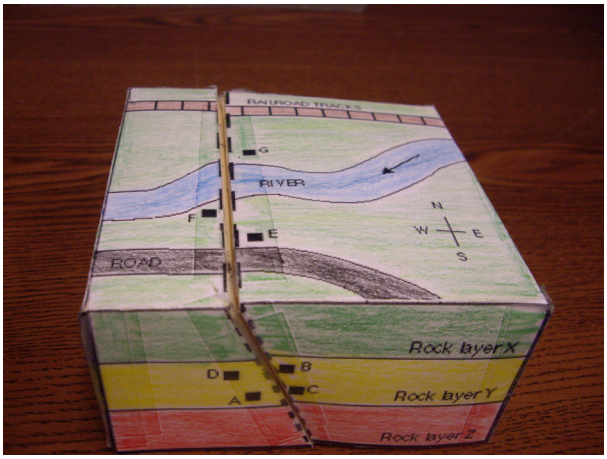
The making of a classroom set of these models is an appropriate use of time. Save the best one from year to year to reuse in the classroom. They can also be used as a manipulative for a quick one-on-one assessment with students.

MATERIALS:
for teacher

- Physiographic map of the world
- Student copies of the Fault Model sheet, p. 23
- Student copies of the student worksheet, pp. 30-33
- Teacher Background, pp. 24-29
- Demonstration model (enlarged or Foam version), p. 23
- Computer and projection system to show videos and/or animations
  Fault models Lecture
  http://www.iris.edu/hq/programs/education_and_outreach/videos#F
  What are the 4 basic classes of faults?
  http://www.iris.edu/hq/programs/education_and_outreach/animations
- Answer Key, pp. 34-35

for the students: (work in pairs)

- Copy of the Fault Model sheet, p. 23
- ½ Manila file folder
- Crayons or colored pencils
- Scissors
- Glue or tape
- Metric ruler
- Copy of the student worksheet, pp. 30-33



PROCEDURE:

Teacher Preparation

Make enough copies of the Fault Model sheet and the student worksheet for the students. Have the student glue their paper model on the ½ sheet of manila file folder before they color and cut. This makes it easier to manipulate and construct.

A. Introduction

Not all faults are associated with plate boundaries. There is a broad range of faults based on type, linear extension, displacement, age, current or historical activity, and location on continental or oceanic crust. However, they can be categorized according to one of the three basic types of faults--normal, reverse, or strike-slip. The stresses and strains in the earth's upper layers are induced by many causes: thermal expansion and contraction, gravitational forces, solid-earth tidal forces, etc. Faulting is one of the various manners of mechanical adjustment or release of such stress and strain. Normal faults are associated with tensional stress, reverse faults with compressional stress, and strike-slip faults with shearing stress.

B. Lesson Development

1. Glue the model to the ½ sheet of manila file folder to provide stability.

2. Color the model following the key.

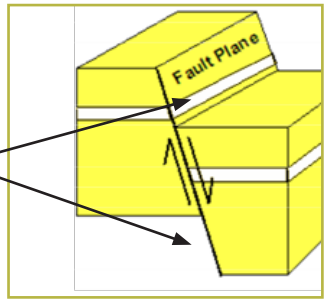
3. Cut out the Fault Model. Fold along solid lines. Use a ruler and edge of scissors to score the lines for a clean, sharp fold.

4. Tape the corners together. This box is a three-dimensional model of the top layers of the Earth's crust.

5. The dashed lines on the model represent a fault. Carefully cut along the dashed lines. You will end up with two pieces.

6. *Optional*--tape the manila-folder paper to the "faces" of the fault planes so students realize they represents rock material and are not merely blank area. Make two rectangles the width and height of the box and tape to the faces after coloring and cutting along the dashed line. This step also helps the two surfaces to slide easily and keeps the model more stable when working with it.

Tape manila file-folder material to these surfaces.



C. Conclusion

Help students to understand that the movements along fault lines result in the formation of surface features. It is not shown on the models but with guidance they may be able to understand how mountains form by repeated uplifting or how the presence of waterfalls may indicate fault movement along a rivers course. Local examples would enhance understanding.

Adaptations and Extensions

1. Have students use their hands to generate the forces necessary for compressional, tensional, and shearing forces. Push their palms together to feel compressional force, lock the fingers and pull to feel the tensional force, and have them place palms together and slide to feel shearing force. These kinesthetic movements further reinforce the motions associated with faulting.

2. Assign groups of students to write a poem, song, rap, etc., that reflect the lesson learned.

3. Ask students to explain the type of faulting associated with Basin and Range faulting. Is the land being compressed or are tensional forces being applied? Where is the energy coming from to generate this movement?

4. Have students compare a relief map to the geologic map of Idaho. Faults are important in mineral and petroleum exploration as they may either seal or act as a barrier to fluid flow (e.g., due to smearing of mud or shale along them), or may be important conduits for the migration of petroleum or mineralizing fluids. Many mineral deposits are fault and fracture controlled (e.g., Idaho's hard rock mining industry such as the Coeur d'Alene Mining District in northern Idaho or Thompson Cyprus Mine of southeastern Idaho). Recognition of faults is also important in hydrogeological studies as fracturing along faults may produce hard-rock aquifers or pathways for geothermal or carbonated water for which Idaho is known (e.g. Boise and Soda Springs).

The following one-page leaflets published by the Idaho Geological Survey support the Adaptations and Extensions section of this activity:

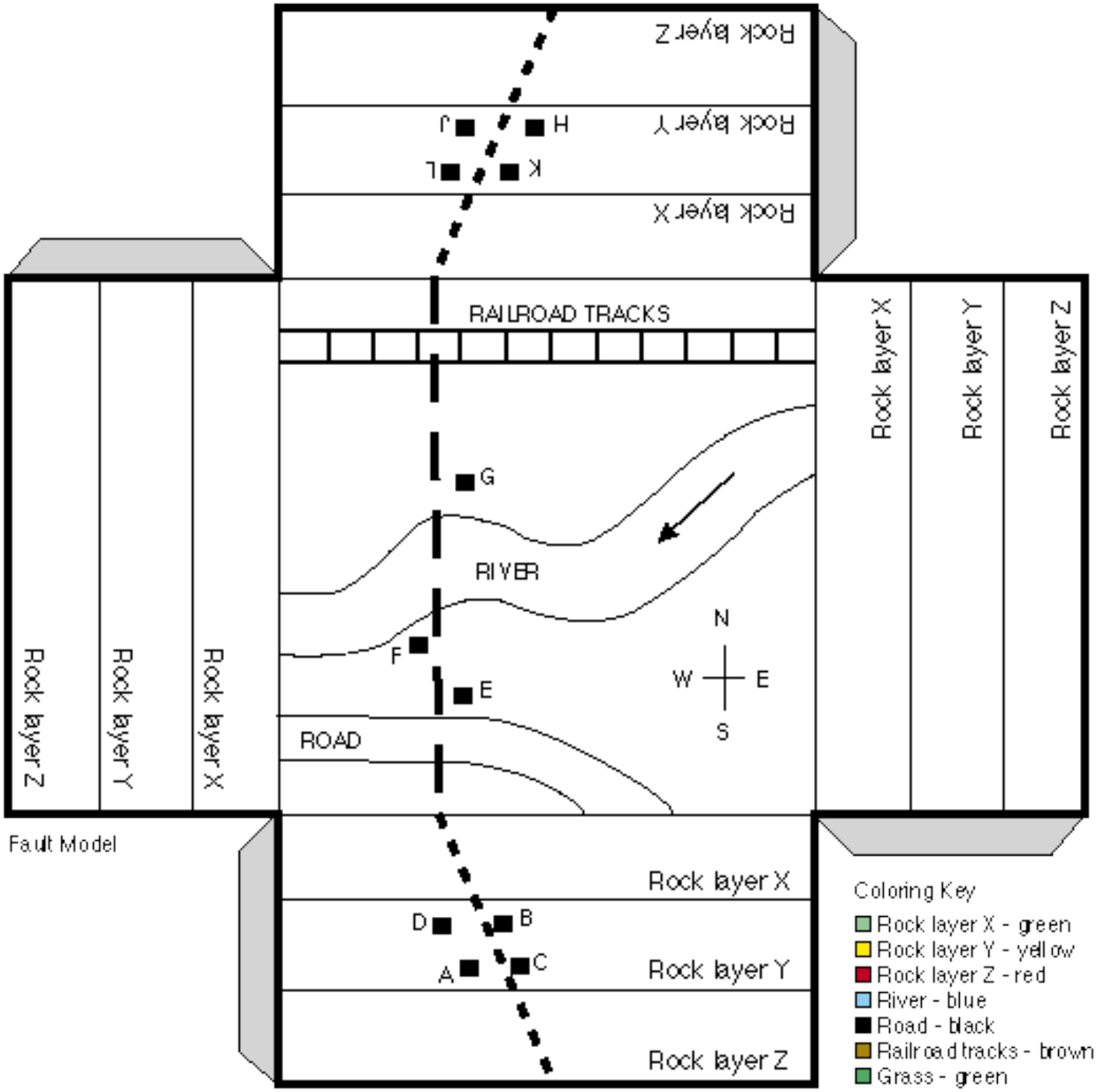
McLeod, J.D. "The Search for Oil and Gas in Idaho," Idaho Geological Survey, GeoNote 21, 1993. http://www.idahogeology.org/PDF/GeoNotes_(G)/geonote_21.pdf

Gillerman, V.S. "Idaho Mining and Geology," Idaho Geological Survey, GeoNote 40, 2001. http://www.idahogeology.org/PDF/GeoNotes_(G)/geonote_40.pdf

Gillerman, V.S. "Rare Earth Elements and Other Critical Metals in Idaho," Idaho Geological Survey, GeoNote 44, 2011. http://www.idahogeology.org/PDF/GeoNotes_(G)/GN44_Rare_Earth_Elements.pdf

Gillerman, V.S., Bennett, E.H. "Idaho Mining and Exploration, 2009," Idaho Geological Survey Staff Report 10-5, June 2010. http://www.idahogeology.org/PDF/Staff_Reports_(S)/2010/Mining_and_Exploration_S-10-5.pdf

Fault Model Pattern



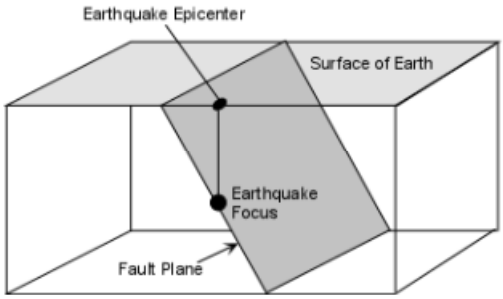
Teacher Background-Types of Faults

The fault models shown here illustrate relatively simple motions and geologic structures. Although these models are accurate representations of real Earth faulting and plate tectonic structures and motions, the spherical shape of the Earth and the complexity of geological features caused by varying rock types and rock properties and geological development over many millions or hundreds of millions of years result in significant complexity and variability of actual fault systems.

Table 1: Faults, Plate Boundaries and Relative Motions

Relative Motion of Layers or Plates	Fault Names	Plate Boundary Descriptions	Related Tectonic and Geologic Features
Extension	Normal	Divergent (extensional, moving apart, spreading, construction - because new lithosphere is generated in the extended zone)	Rifts, grabens, sometimes volcanism, regional uplift but local downdropped fault blocks, shallow earthquakes (Examples: Basin & Range NV, ID, Owen Valley, CA, East African Rift, Mid-ocean Ridge)
Compression	Reverse or Thrust	Convergent (compressional, collision, subduction, moving together, destructive - because one plate is often thrust into the mantle beneath the other plate)	Folded mountain ranges, uplift, reverse faults, volcanic arcs (usually andesitic composite volcanoes), deep ocean trenches, shallow and deep earthquakes in subducted slab (Examples: Himalayan, Alps, Andes and Rocky Mts.)
Translation or horizontal slip	Strike-slip	Transform (horizontal slip, translation)	Linear topographic features, offset stream channels, lakes in eroded fault zone, pull-apart basins and local uplifts along fault bends or "steps" between offset fault segments, oceanic fracture zones, offsets of mid-ocean ridges (Examples: San Andreas, Transform faults of the Ocean,

A **fault** is a fracture or zone of fractures between two blocks of rock. Blocks move relative to each other along the fault plane. This movement may occur rapidly, in the form of an **earthquake** or may occur slowly, in the form of creep. Faults may range in length from a few millimeters to thousands of kilometers. Most faults produce repeated displacements (movement) over geologic time. During an earthquake, the rock on one side of the fault suddenly moves with respect to the other. The fault surface can be **horizontal**, **vertical,** or **oblique** (horizontal and vertical displacement).



Strike-slip Faults

Strike-slip faults develop when rocks are subjected to shear stress. In strike-slip faults, the movement is purely horizontal with no up-and-down displacement. We classify strike-slip faults as either right lateral or left lateral. Imagine yourself standing on one side of a strike-slip fault, so that you are facing the fault. If the block on the other side is displaced to your right, the fault is a right lateral strike-slip fault (Figure 1). If the block on the other side of the fault is displaced to your left, the fault is a left lateral strike-slip fault.

Notice that pure strike-slip faults do not produce fault scarps. There are other tell-tale changes in the landscape that signal strike-slip faulting. The zigzag effect (offset) of the creek channel is the result of movement along the fault (Figure 1). As you might guess, where the two massive blocks on either side of a strike-slip fault grind against each other, rock is weakened. Streams flowing across strike-slip faults are often diverted to flow along this weakened zone.

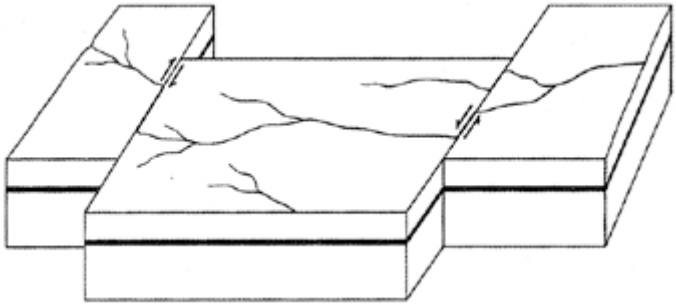


Figure 1. **Right and left lateral** strike-slip faults

Dip-Slip Faults

When distinguishing between the types of dip slip faults, we define the block of rock above the fault plane as the **hanging wall** and the block of rock below the fault plane as the **footwall** block (Figure 2). The terms “hanging wall” and “footwall” are old mining terms. The hanging wall block

was the block of rock where miners would hang their lanterns; the footwall block was where miners would walk. It is easy to determine which side of the fault is the hanging wall if you imagine a miner standing on the fault plane. The hanging wall will be the block above the miner's head; the footwall will be the block below the miner's feet. Strike-slip faults are horizontal and thus do not have hanging walls or footwalls. If rocks break under tensional stress, the hanging wall will move down relative to the footwall and a **normal fault** forms (Figure 2). In this situation, the crust actually extends and lengthens.

When rocks break under compressional stress, the hanging wall moves up relative to the footwall, and a **reverse fault** forms (Figure 3). In a reverse, the crust is shortened. **Thrust faults** (Figure 4) are simply reverse faults in which the angle formed by the fault plane and the surface is quite shallow.

Commonly, the fault plane itself can become grooved and polished as one block of rock scrapes against the other. The scratches on the fault plane surface are called **slikensides**. Slickensides may record the slip orientation of the fault plane, and may even feel smoother in the direct of slip.

There is another relationship between rocks on either side of the fault plane that can be used in distinguishing normal and reverse faults and are seen in Figures 2 and 3. If the rocks are right side up, the normal fault brings down younger rocks over older rocks. Under the same conditions, the reverse fault moves older rocks over younger rocks.

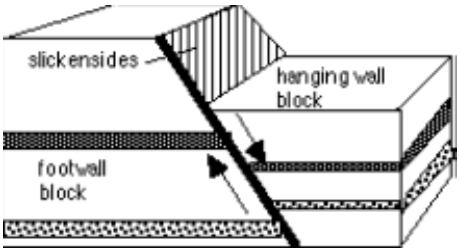


Figure 2. **Normal Fault**

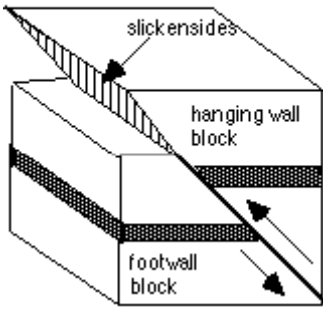


Figure 3. **Reverse Fault**

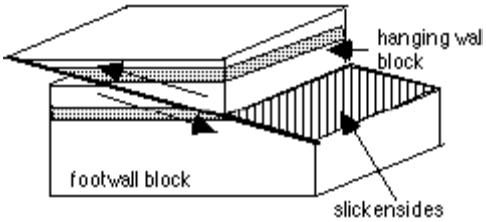


Figure 4. **Thrust Fault**

Teaching About Plate Tectonics and Faulting Using Foam Models

Materials:

- Pre-made foam block models
- Videos > / Fault Models http://www.iris.edu/hq/programs/education_and_outreach/videos#F

OR

- Foam (open cell, foam mattress type) "blocks" shown in Figure 1A
- Felt pens (permanent marker, red and black)
- Manila folders or thin poster board
- Rubber cement
- Closed cell foam ("sleeping bag pads," camping equipment) as shown in Figures 3 and 5
- Pins
- Open cell foam as shown in Figure 3A
- Styrofoam core poster board, 0.6 cm (1/4 in) thick, as shown in Figure 3B
- Razor blade knife
- Metric ruler

Procedures:

Prepare block models as shown in Figure 1A. Cardboard (cut from manila folders or thin poster board) attached to both faces of the fault plane allows the blocks to slip easily along the fault as forces are applied to the blocks.

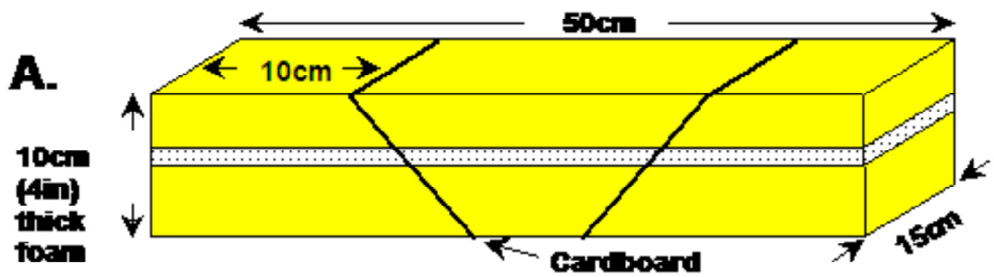
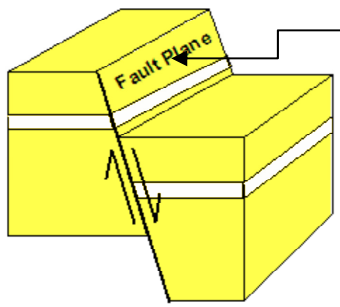


Figure 1A. Foam block model



Glue manila-folder paper to the faces of the fault planes so the blocks slip easily during extension and compression.

1) Normal Faulting (Extension)

Use the block models to demonstrate **normal faulting** as the two outer blocks are moved **apart** (Figure 1B). This procedure is best performed by holding the blocks "in the air" in front of you, supporting the model by the two outer blocks, rather than on a table. Note that as the two outer blocks are moved apart, the inner block drops downward or "subsides." This relationship between extensional motion of geologic layers and downdropped fault blocks (graben or rift valley if the downdropped block is bounded on both sides by normal faults, as in this block model) produces normal faulting. It also represents the extensional motion and resultant rift development associated with divergent plate boundaries (Table 1).

Examples of divergent plate boundaries, where extensional faulting is prominent, are the mid-ocean ridge system in which a narrow rift or graben (downdropped fault block) is commonly observed along the highest part of the ridge and the East African Rift in which extension has been occurring in the continental lithosphere for about 30 million years and the resulting rift system of normal faults is beginning to break apart the continent. In a plate-tectonic related, but not plate boundary environment, the Basin and Range area of the Western United States displays a prominent topographic signature of extensional faulting with many adjacent downdropped fault blocks or grabens and the topographic "high" areas between the grabens are called horsts.

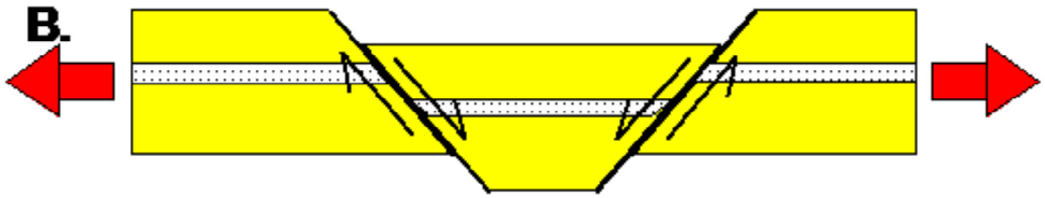


Figure 1B. Normal faulting using the foam model. Red arrows represent extension. Half-arrows along faults show direction of relative motion along the fault plane.

2) Reverse (Thrust) Faulting (Compression)

To demonstrate compressional motion and resulting **reverse** (also called thrust) faults, hold the foam block models as described above and then move the two outer blocks **together** as in Figure 1C. The inner block will be thrust upwards producing reverse faults and an uplifted block. In a plate tectonic setting, such compressional motion is associated with convergent plate boundaries (Table 1) where two lithospheric plates are moving together or colliding (see also section 3 below). Not surprisingly, these convergent zones are associated with mountain ranges (Himalayas, Alps, Andes, etc.).

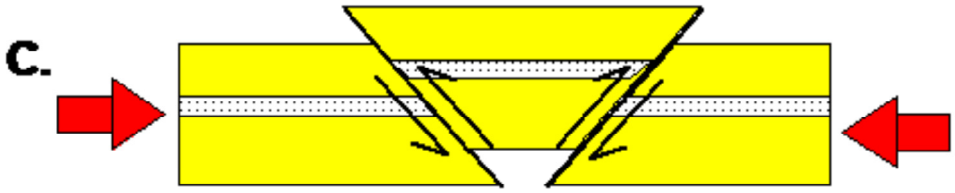
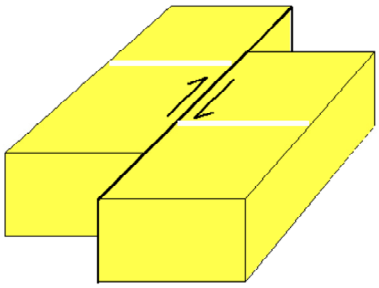


Figure 1C. Reverse faulting using the foam model. Red arrows represent compression. Half-arrows along faults show direction of relative motion along the fault plane.

3) Strike-slip or Horizontal slip fault motion (shear)

Note: This does not require the building of a second model as suggested here. This motion can be modeled by looking at the top of the foam block model used above. Coloring in a feature to be offset such as a road or river shows the lateral offset of strike-slip faulting.



Strike-Slip Fault

To demonstrate horizontal slip or strike-slip fault motion, prepare foam blocks as shown in Figure 1D. Moving the blocks horizontally on a tabletop, as shown in Figure 1E, demonstrates strike-slip or horizontal slip fault motion. This motion along a plate boundary is also called **transform** (Table 1). The San Andreas Fault zone is a system of strike-slip faults that form the transform plate boundary at the western edge of the North American Plate. Transform faults also occur as oceanic fracture zones between segments of the mid-ocean ridge spreading zones

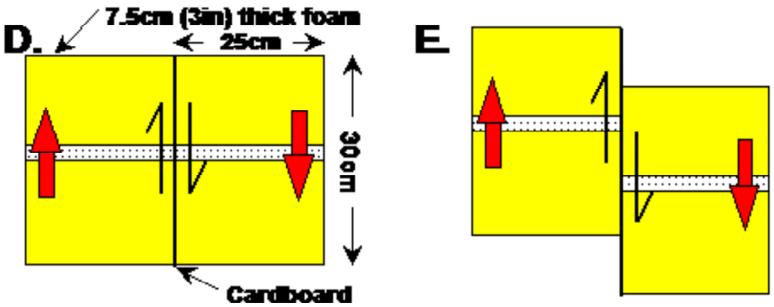


Figure 1D and 1E. Strike-slip faulting using the foam model. Red arrows represent shearing. Half-arrows along faults show direction of relative motion along the fault plane.

Student worksheet

Modeling the Faults

Name_____Date_____

Normal Fault

Locate points A and B on your model. Move point B so that it is next to point A. Observe your model from the side (its cross-section).

Draw the normal fault as represented by the model you have just constructed.

Questions

1. Which way did point B move relative to point A?

2. Place half-arrows on your diagram to show the direction of movement along both sides of the fault line.

3. What happened to rock layers X, Y, and Z?

4. Are the rock layers still continuous?

5. What likely happened to the road? The railroad tracks?

Normal Fault

6. Look at the direction of flow of the river. Describe what you think would likely happen to the rivers pathway?

7. Return your model to its original position. Using a metric ruler measure (mm) across the cross-section from one side to the other. _____mm. Move point B next to point A and again take a measurement (mm). _____mm. Compare the two measurements.

8. Is this type of fault caused by compression, tension, shearing? Explain.

9. Many normal faults are found in Nevada and southeastern Idaho. This is because this location is in a region called the Basin and Range Province where the lithosphere is stretching. Did your model stretch (distance increase) when you moved point B next to point A? Explain

Reverse Fault

Locate points C and D on your model. Move point C next to point D. Observe the cross-section of your model.

Draw the reverse fault as represented by the model you have just constructed.

Questions

1. Which way did point D move relative to point C?

2. What happened to rock layers X, Y, and Z?

3. Are the rock layers still continuous?

4. What likely happened to the river?

Reverse Fault

5. Return your model to its original position. Using a metric ruler measure (mm) across the cross-section from one side to the other. _____mm. Move point C next to point D and again take a measurement (mm). _____mm. Compare the two measurements.

6. Many reverse faults are found in southeastern Idaho. Did your model shorten (distance decrease) when you moved point C next to point D? Explain

7. Is this type of fault caused by compression, tension, shearing? Explain.

8. If the rock material of the uplifted block fell on top of the down dropped block would the relative ages of the rocks be younger rock on top of older or older rock on top of younger? Explain

Strike-Slip Fault

Locate points F and G on your model. Move the pieces of the model so that point F is next to point G.

Draw an **overhead** view of the surface as it looks after movement along the fault

Questions

1. If you were standing at point F and looking across the fault, which way did the block on the opposite side move?

2. What happened to rock layers X, Y, and Z?

3. Are the rock layers still continuous?

4. What likely happened to the river?

5. If the scale used in this model is 1mm = 2m, how many meters did the earth move when the strike-slip fault caused point F to move alongside point G? **(Show you calculations for full credit)**

   (Note that this scale would make an unlikely size for the railroad track!) If there were a sudden horizontal shift of this magnitude it would be about five times the shift that occurred in the 1906 San Andreas Fault as a result of the San Francisco earthquake.

6. Is this type of fault caused by tension, compression, or shearing? Explain

7. Is the strike-slip fault a right or left – lateral movement? Explain

8. Does it make a difference which side of the fault you stand on in naming the right-lateral or left-lateral strike-slip fault? Explain

9. The San Andreas Fault in California is a right-lateral strike-slip fault. Which block is moving to the right? The Pacific block or the North American block?

Strike-slip Fault

Reinforcement and Enrichment

1. Name and describe the type of faults that form in convergent margins. Explain why these types of faults form. Give an example of a convergent margin and use a simple diagram to illustrate your answer.

2. Name and describe the type of faults that form in a divergent boundary. Explain why these types of faults form. Give an example of a divergent boundary and use a simple diagram to illustrate your answer.

3. Name and describe the type of faults that form along a transform boundary. Explain why these types of faults form. Give an example of a transform boundary and use a simple diagram to illustrate your answer.

4. Research and classify three of the faults below. Be sure to cite the source of your information and the internet URL. Go to> http://earthquakes.usgs.gov/hazards/qfaults/ as a starting point. >**Quaternary Faults > Fault Maps – Static** click on **Idaho.** After the map completes loading scroll down to the bottom and click on **Database Search**. Then >**Identifiers > Name** (type in the "name of the fault") and then >**Geographic Characteristics** > **State** select "Idaho" >

   Provide the following information (>**Brief** under the fault name): Location (include map AMS sheet), Length, Age of most recent movement (deformation), Rate or movement (Slip-rate), Type of fault (Normal, Reverse or Thrust, Strike-slip), Seismic Zone or Belt.

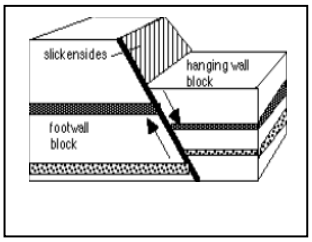
   - Long Valley Fault
   - Cascade Fault
   - Squaw Creek Fault
   - Grand Valley Fault
   - Wasatch Fault
   - Bear Lake Fault
   - Sawtooth Fault
   - Western Snake River Plain Fault
   - Jakes Creek Fault
   - Centennial Fault
   - Council Fault
   - Lemhi Fault
   - Beaverhead Fault

5. Research on which section/s of the Lost River Fault the 1983 Borah Peak earthquake occurred. Identify the names of the segment/s, location, length/s of fault segment/s that moved, and type of fault. What percent of the total Lost River Fault moved during the 1983 Borah earthquake? Go to> http://earthquake.usgs.gov/ at the top of the page select >**Hazards** from the side bar select >**Quaternary Faults** > **Database Search.** Then >**Identifiers > Name** (type in the "name of the fault") and then >**Geographic Characteristics** > **State** select "Idaho".

ANSWER KEY for Student Worksheet
Modeling the Faults

Normal Fault

Draw the normal fault as represented by the model you have just constructed.

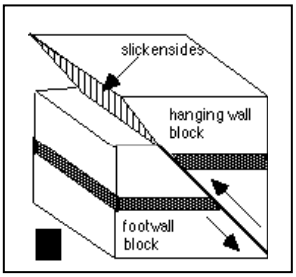


Questions

1. Point B moves closer to point A
2. See the diagram.
3. Rock layers X, Y, and Z get offset by the fault.
4. The rock layers are no longer continuous, they have been broken by the fault.
5. They were offset vertically. During that process they will be potentially broken.
6. The river could possibly be dammed up, until it found a new pathway. A temporary lake my form causing flooding to the area below the fault scarp. The river would follow the fault line until it could eventually reestablish its' route. The old river bed will dry up.
7. Measurement should be greater.
8. This fault is caused by tension. In order for point B to move opposite point A the two blocks needed to be pulled apart so that point B could move down to point A. Normal faults are caused by tensional forces.
9. The distance across the block increased by _x_ mm. The stretching of the lithosphere is caused by horizontal extension (page 3, Putting Down Roots….). The source of this stretching is an upwelling of heat from the mantle associated with the N. American hotspot of Yellowstone.

Reverse Fault

Draw the reverse fault as represented by the model you have just constructed.

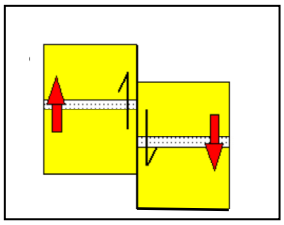


Questions

1. Point D moved closer to point C.
2. Rock layers X, Y, and Z get offset by the fault.
3. The rock layers are no longer continuous, they have been broken by the fault.
4. Perhaps a waterfall could have formed by the rising block.
5. Measurement should be less.
6. The distance became less. In order for point D to move opposite point C the two pieces had to be pushed together so that point D could be uplifted to point C.
7. This fault is caused by compression. Reverse faults are caused by compressional forces.
8. The collapse of the overhang or uplifted block would result in older rocks setting on top of younger rocks. The surface of block D would be covered by the rocks below the surface of block C.

Strike-Slip Fault

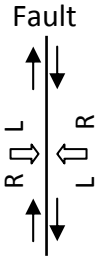
Draw an overhead view of the surface as it looks after movement along the fault.



Questions

1. The block on the opposite side of point F moved to the right.
2. Rock layers X, Y, and Z have not be offset vertically but they have been offset horizontally.
3. The rock layers are still continuous.
4. The rivers has been offset to the right (south). The river will likely follow the fault and reconnect with the old riverbed. This will cause the river to have a sharp 90 degree turn in its course.
5. *(Depending on how much the model has been enlarged will change these numerical values, but the overall ratio will not change.)* Approximately 48 meters
   1mm = 2 m; 24mm x 2 = 48m
6. This type of fault is caused by shearing. The two blocks are moving past one another in a horizontal motion with little vertical motion.
7. The fault is a right lateral strike-slip fault. The east side of the fault moves to the south or toward the right of point F
8. No, it does not matter which side of the fault one is standing on. Imagine yourself standing on one side of a strike-slip fault, so that you are facing the fault. If the block on the **other side** is displaced to your right, the fault is a right lateral strike-slip fault. If you were to step across the fault and then face the fault the block to your right would still be displaced to the right. See Figure 1 below.
9. The Pacific (block) Plate is moving to the right.

Figure 1.



Magnitude and Intensity: How "Hard" Does an Earthquake Shake?

***Putting Down Roots*, pp. 14-15**

Idaho State Standards:

Earth Science 1.2.1-.3, 1.3.1-.3, 1.6.2-.7, 1.8, 5.2
8th Mathematics 2.1, 3.1.1, 3.5.1, 4.3, 5.1.1-.3, 5.2.1, 5.3.1-5.3.2, 5.4.1-.4, 5.5.1-.3
9th Mathematics 1.2, 2.3, 2.4.1, 3.2, 3.5, 3.6, 4.3, 4.4, 5.1, 5.2, 5.4, 5.5

Objectives:

Students will be able to:

1. Explain how the magnitude of an earthquake, like the dropped water bottle, is tied to the physical properties of a fault and how acceleration is related to the intensity of ground motion.
2. Calculate the amount of energy released when a weight (water bottle) is dropped from different heights.
3. Students will be able to explain the information expressed in a three-component seismogram, particularly direction of motion, peak absolute amplitude and accelerations.
4. Explain several factors that contribute to the intensity of shaking at a particular location.
5. Interpret a Shake Map from the USGS.

RATIONALE

This activity describes the differences between an earthquake's magnitude and intensity. Students calculate the energy released during a weight drop (magnitude) and use an accelerometer (iPhone, QCN sensor, or other) to investigate what happens to this energy as the source is moved further and further from the sensor (intensity). Students examine USGS Shake Maps to explore other factors that, in addition to event size and distance from the source to the receiver, affect the intensity (e.g. structures, land composition, etc.).

FOCUS QUESTION(S):

- How hard does the ground shake during an earthquake?
- What does an accelerometer measure? How can it be used to measure an earthquake?
- What is earthquake intensity?
- How is earthquake intensity measured?

TEACHING CLUES AND CUES

Teachers will need to have access to an accelerometer for one of the activities. There are smartphone apps for accelerometers or a sensor can be ordered from Quake Catchers Network. This lesson can be done as a teacher demonstrated lab using one sensor. If more sensors are available, the activity can be done as a student centered lab. If the lab is student centered, it is important to separate each station from other stations to avoid any station's data interfering with another station. A constant weight is needed. Drop a water bottle weighted with sand from a set height. These are inexpensive, are easily weighted, and provide an easy way to create a consistent source throughout the activity.

Activity 2 does not require an accelerometer but uses the shake map from the USGS site and pages 14-15 from the BHS booklet *Putting Down Roots in Earthquake Country*. The shake map needs to be printed in color. You may want to go to the USGS ShakeMap Atlas and download other maps for comparison. The Atlas starts with 2007 earthquakes. A classroom set can be printed and put in protective covers. Students should be shown the three videos listed in the Materials section with the web addresses where they can be found. Have students look for the different types of motions that are displayed by observing the way objects move. These video clips of the house shaking had a peak acceleration of about 1g.

Note: The footage from the first video listed shows a two story house being tested by a simulated earthquake on a shake table at the University of California at San Diego on July 11, 2000. The test examined the effects of severe ground shaking on a structure with strong construction. The goal was to verify that a new house conforming to all building code regulations and specially engineered can escape with little damage from such an earthquake.

Students also need to understand a three-component seismogram. A three-component seismogram will show motion up and down or vertical, horizontal North – South (front to back), and horizontal East – West (side to side). Examples of these seismograms can be found at http://rev.seis.sc.edu/. On the left side of the webpage, select a "Recent Earthquake." On the next screen, select a station from the list below the seismograms. The following screen will show a three component seismogram--Vertical, North – South and East – West (see p. 45 for a sample).

MATERIALS:
for teacher

- Accelerometer and computer (iPhone, QCN sensor USB, or other) QCN sensor purchased ($49.00) from Quake Catchers Network (QCN): (see QCN Sensor folder on the CD-ROM for activities on use of the sensor) http://qcn.stanford.edu/learning/lessons.php
- Download free software for QCN USB sensor at: http://qcn.stanford.edu/downloads/index.php
- Projection equipment

- Download video clips; Kitchen/Office (5.3MB) and child's Bedroom (4.1MB) from http://abag.ca.gov/bayarea/eqmaps/fixit/videos.html
- Download USGS Shake Map of Borah Peak 1983 earthquake from http://earthquake.usgs.gov/earthquakes/shakemap/
- Download video clip of 1995 Kobe, Japan Earthquake (M7.2) http://www.youtube.com/watch?v=0plbf5w0sbA
- Meter stick
- Tape
- Water bottle (filled with sand for weight)
- Data table and graph paper
- Copies of Student worksheet, pp. 39-43

for the students: (work in pairs)

- Student worksheet, pp. 39-43
- Data table and graph paper
- Accelerometer (per group)
- Meter stick
- Water bottle (weighted with sand)
- Lap top computer with downloaded software for QCN USB sensor

PROCEDURE:

Teacher Preparation

1. Set up the QCN accelerometer, so that it is correctly aligned. Place the sensor on the ground and turn until the red line on the compass is lined up with North (indicated by an arrow on the compass). Use the tape provided to secure the sensor in place. Plug the sensor into the USB port of the computer and start the program QCNLive.

2. Click on the "Sensor 2-Dimensional" button (second from the left) to view output from the sensor. Remember you can use the other buttons to zoom in and out in time and to start and stop recording.

3. Practice starting and stopping the sensor's recording.

4. It is important that the water bottle is dropped from the same height throughout the lesson. The magnitude of the earthquake (dropped bottle from same height) does not change.

5. Measure the amplitude of the largest deviation from zero. Zoom in to the seismogram to get an accurate measurement. The amplitude of the wave is the amount of ground shaking referred to as acceleration and a measure of gravity (g).

A. Introduction

Display the geologic map of Idaho. Make sure students know how to interpret the map. Each student should receive at least three locations to analyze, preferably one each in the northern, southwestern, and southeastern sections of Idaho. Reinforce the connection between earthquakes and geology. Give students time to find their cities/towns on the highway map or Atlas and correlate it to the geologic map. A few, but not all, locations are identified on the geologic map.

B. Lesson Development

1. Measure the mass of each of the weighted water bottles.

2. The student worksheet instructions are designed using the QCN sensor and a lap top computer.

3. Students should be able to read a three component seismogram. The teacher background, pp. 44-45, includes a screen capture of a seismogram. Show the Kobe video so that students can observe the arrival of the P, S, and surface waves.

C. Conclusion

Help students to understand that, while the magnitude of the earthquake (weight of bottle) remains the same throughout the lesson, the intensity, or amount of shaking, does change, based on distance from the earthquake.

Ask the following questions:

- How much energy was released when you dropped the water bottle?
- Does the energy change depending on where you drop the bottle horizontally?
- How would the graph look different if we increased the mass, height, or both?
- If the energy did not change, why did the amplitude of the wave change? Where did the energy go as the distance from the sensor increased? Answer: Attenuation.

Adaptations and Extensions

Students may want to research probability maps of different areas of the United States, including Alaska and Hawaii Suggest cities located along major rivers, edges of mountain ranges, along coast lines, etc.

Challenge students to see if they can determine the magnitude of the largest probable earthquake in Idaho *(M7.4, due to the types of faults that exist and rock structure in the state).*

Student worksheet

Magnitude and Intensity Lab
(How Hard does the Ground Shake?)

Name_____ **Date** _____

Introduction

Magnitude: an earthquake's magnitude describes the strength of the earthquake, or how much energy was released during the earthquake. If the earthquake is recorded by several different seismometers at different locations, the seismogram recorded will have different amplitudes. However, the magnitude of the earthquake will not change. Magnitude is measured from seismograms.

Intensity: A measurement of earthquake intensity describes how much ground motion was felt at a specific location. For a single earthquake, the amount of ground motion will be different at different locations. Often, the highest intensity is closest to the earthquake. You do not feel earthquakes that are very far away, but that does not mean they are small! The intensity at your location is just very low. Intensity is measured based on what people felt and what was damaged.

Introductory Questions:

1. How hard does an earthquake shake the ground?

2. Describe what the display of the accelerometer shows. What units does it measure in?

3. What factors might influence the amount of shaking from an earthquake?

Experiment with the accelerometer

Materials:

- Accelerometer with USB cable and software downloaded onto computer
- Tape
- Meter stick
- Data table and graph paper
- Water bottle (weighted)
- Student worksheet

Set-up:

1. Set up the accelerometer so it is correctly aligned. Place the sensor on the ground and turn until the red line on the compass is lined up with North (indicated by an arrow on the compass). Use the tape provided to secure the sensor in place. Plug the sensor into the USB port of the computer, and start the program QCNLive.

2. Click on the "Sensor 2-Dimensional" button (second from the left) to view output from the sensor. Remember you can use the other buttons to zoom in and out in time and to start and stop recording. Practice starting and stopping the sensor's recording. Determine the units of measurement.

3. Practice zooming in and measuring the amplitude of the recording with the greatest deviation from zero.
4. Use a meter stick to determine the height from which the water bottle will be dropped (not over 1 meter). It is important that this height be consistent throughout the lab.
5. Position the water bottle .2m from the sensor.
6. Begin recording with the accelerometer, then drop the bottle.
7. Look at the resulting seismograms generated (it might help to pause the recording in order to look at the graph).
8. Record the absolute value of the largest wave deviation from zero in your data table.
9. Repeat steps #5 through #8 two more times at this same distance.
10. Next move the distance the water bottle will be dropped from the sensor to the next position indicated in the data table.
11. Collect three trials of data at this position.
12. Repeat steps #10 & #11 until the sensor no longer detects the energy from the dropped water bottle.
13. Average the data collected in the three trials to complete the data table.
14. Graph the average amplitude of ground motion (vertical axis) vs. distance between sensor and water bottle dropped (horizontal axis) on the graph provided. Make sure you follow graphing conventions as required.

Examining the data:

1. How much energy is released when the water bottle was dropped? (KE = M*D*g) KE= kinetic energy, M= mass of water bottle, D= distance bottle was dropped, g=acceleration due to gravity ($10 m/s^2$)

2. Does the amount of energy released change depending on its horizontal position (relative to the sensor)?

3. How does the amplitude recorded by the sensor change as the source moves further and further away?

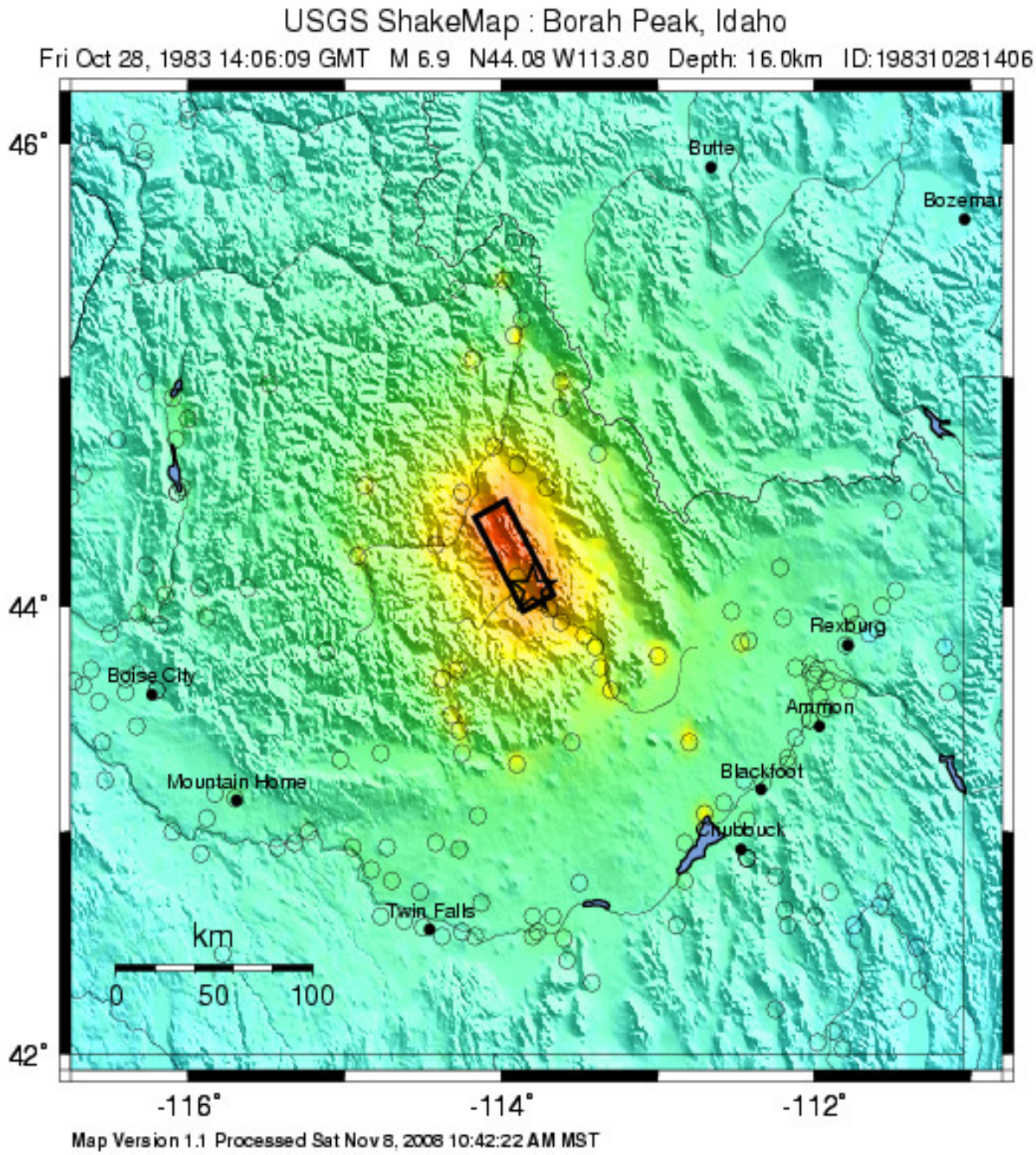
4. How could we modify the experiment to shift the graph upwards or increase the recorded amplitude at each position?

5. When you modify the procedure, as described above, is this equivalent to changing the magnitude of the earthquake or the intensity of the earthquake? Why? (Review the Background Information if you need to.)

6. Drop the same mass from the same height above two different surfaces (e.g. floor and table) with the sensor placed at the same horizontal distance to the source.
   (a) How does the amplitude of the recorded waves compare to each other?

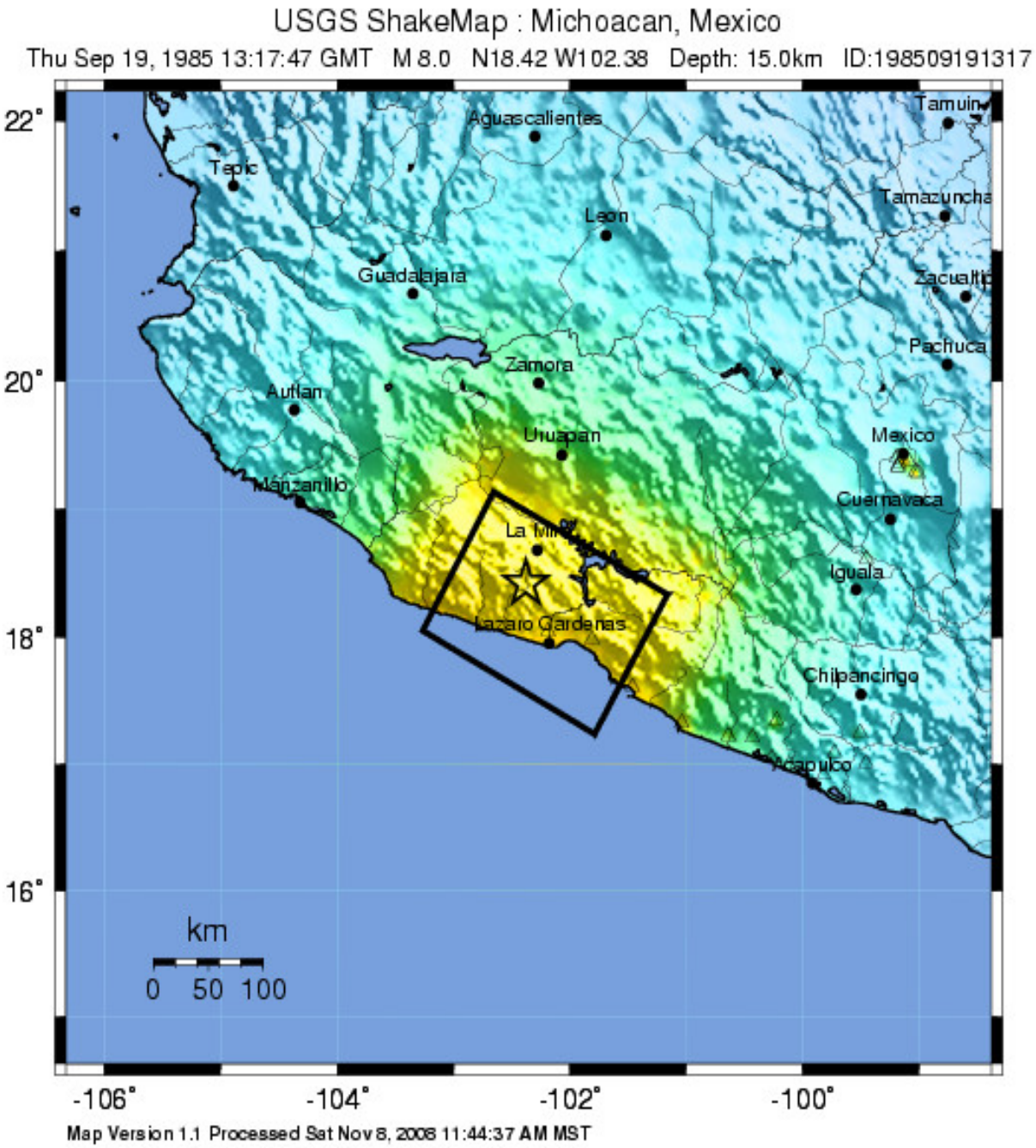
   (b) Examine the Borah Peak ShakeMap below (Figure 1), noting differences in shaking between mountains and valleys near the epicenter. How might your exploration in 6(a) account for this observation?

Figure 1



PERCEIVED SHAKING	Not felt	Weak	Light	Moderate	Strong	Very strong	Severe	Violent	Extreme
POTENTIAL DAMAGE	none	none	none	Very light	Light	Moderate	Moderate/Heavy	Heavy	Very Heavy
PEAK ACC.(%g)	<.17	.17-1.4	1.4-3.9	3.9-9.2	9.2-18	18-34	34-65	65-124	>124
PEAK VEL.(cm/s)	<0.1	0.1-1.1	1.1-3.4	3.4-8.1	8.1-16	16-31	31-60	60-116	>116
INSTRUMENTAL INTENSITY	I	II-III	IV	V	VI	VII	VIII	IX	X+

Figure 2



PERCEIVED SHAKING	Not felt	Weak	Light	Moderate	Strong	Very strong	Severe	Violent	Extreme
POTENTIAL DAMAGE	none	none	none	Very light	Light	Moderate	Moderate/Heavy	Heavy	Very Heavy
PEAK ACC.(%g)	<.17	.17-1.4	1.4-3.9	3.9-9.2	9.2-18	18-34	34-65	65-124	>124
PEAK VEL.(cm/s)	<0.1	0.1-1.1	1.1-3.4	3.4-8.1	8.1-16	16-31	31-60	60-116	>116
INSTRUMENTAL INTENSITY	I	II-III	IV	V	VI	VII	VIII	IX	X+

Data Table

Height of water bottle					
Distance (m)	**Height (m)**	**Trial #1 – Absolute Z axis value**	**Trial #2 – Absolute Z axis value**	**Trial #3 – Absolute Z axis value**	**Average of three trials**
0.2					
0.4					
0.6					
0.8					
1.0					
1.2					
1.4					
1.6					
1.8					
2.0					
2.2					
2.4					
2.6					
2.8					
3.0					

Graph

Modified Mercalli Scale

Measuring Shaking: Intensity is a qualitative measure of the strength of ground shaking at a particular site. Currently in the U.S., the Modified Mercalli Intensity Scale is used (see below). Each earthquake that is large enough to be felt will have a range of intensities. Usually (but not always) the highest intensities are measured near the earthquake epicenter and lower intensities are measured farther away. Roman numerals are used to describe intensities to distinguish them from magnitudes. For example, the magnitude of the Borah Peak earthquake was 6.9. The intensities ranged from IX (violent) close to the epicenter, to V (moderated)at a distance of about 126 miles (203 Km) southwest in Caldwell and a III (weak) at Teton also at a distance of 126 miles, but southeast of the epicenter (USGS).

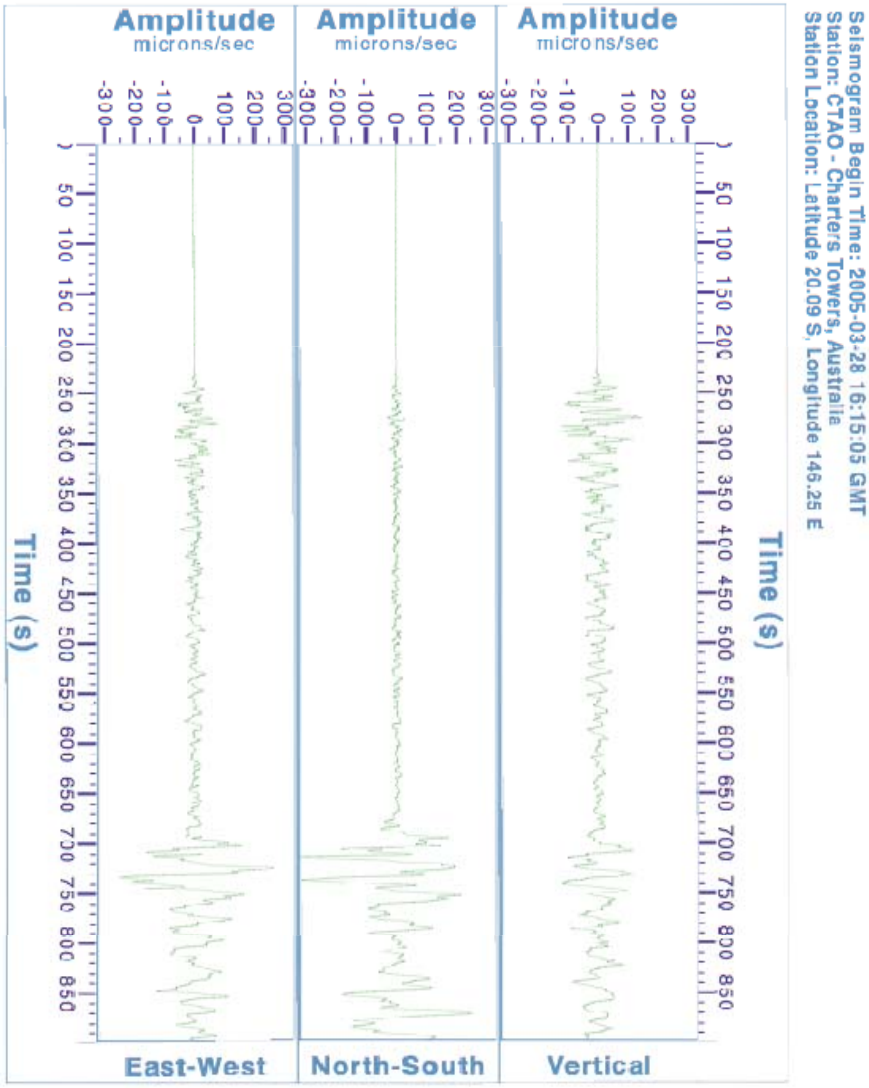
Modified Mercalli Intensity	Acceleration (g)	Description of Intensity Level
I	<0.0017	Not felt except by a very few under especially favorable circumstances.
II	0.0017	Felt only by a few persons at rest, especially on upper floors of buildings. Delicately suspended objects may swing.
III	0.014	Felt quite noticeably by persons indoors, especially on upper floors of buildings. Many people do not recognize it as an earthquake. Standing motor cars may rock slightly. Vibration similar to the passing of a truck. Duration estimated.
IV	0.014 – 0.039	Felt indoors by many, outdoors by few during the day. At night, some awakened. Dishes, windows, doors disturbed; walls make cracking sound. Sensation like heavy truck striking building. Standing motor cars rocked noticeably.
V	0.039 – 0.092	Felt by nearly everyone; many awakened. Some dishes, windows broken. Unstable objects overturned. Pendulum clocks may stop.
VI	0.092 – 0.18	Felt by all; many frightened. Some heavy furniture moved; a few instances of fallen plaster. Damage slight.
VII	0.18 – 0.34	Damage negligible in building of good design and construction; slight to moderate in well-built ordinary structures; considerable damage in poorly built or badly designed structures; some chimneys broken. Noticed by persons driving motorcars.
VIII	0.34 – 0.65	Damage slight in specially designed structures; considerable in ordinary substantial buildings with partial collapse. Damage great in poorly built structures. Fall of chimneys, factory stacks, columns, monuments, walls. Heavy furniture overturned.
IX	0.65 – 1.24	Damage considerable in specially designed structures; well-designed frame structures thrown out of plumb. Damage great in substantial buildings, with partial collapse. Buildings shifted off foundations.
X	> 1.24	Some well-built wooden structures destroyed; most masonry and frame structures destroyed with foundations. Rails bent.
XI	> 1.24	Few, if any (masonry) structures remain standing. Bridges destroyed. Rails bent greatly.
XII	> 1.24	Damage total. Lines of sight and level distorted. Objects thrown into the air.

Adapted from Richter, C 1958, and Wald et al, 1999

Teacher Resource- Three Component Seismogram

Sample Three-Component Seismogram – 3/28/05 N. Sumatra M 8.7

To connect the seismograms that students have studied to actual earthquake ground motion, re-show the 1995 Kobe earthquake (7.2M) video clip "Earthquake in Kobe, Japan," found at http://www.youtube.com/watch?v=0plbf5w0sbA and challenge students to identify the arrivals of the different seismic waves in the video.



Challenge Answer: At about 1 second into the video clip, "Earthquake in Kobe, Japan," a man who was lying down suddenly sits up, so that his head appears in the bottom center of the screen. He likely was awakened by the P wave. At approximately 4 seconds into the video clip, the first horizontal motion begins. This motion is likely the S wave, either combined with or closely followed by the arrival of surface waves.

Activity #1

What is a Seismometer?
Elementary School Level

Objective
Students will learn that a seismometer detects 3 components of motion and that a seismogram is the record of an earthquake.

Background
Prior to this activity, students should be introduced to the basics of earthquakes. Curriculum for this can be found at http://www.redcross.org/disaster/masters/
This curriculum is designed for k-2, 3-5, and 6-8 grade levels. Other good activities can be found at http://www.dlese.org/ or http://web.ics.purdue.edu/~braile/.

Materials
QCN Demo installed on laptop
LCD projector or monitor
internet access to view video
slinky

Activity
1. Begin with the computer on a level surface.

2. Let students observe the seismic sensor for a few minutes. Encourage them to jump up and down or bang on the table with a fist or drop books.

3. Have students explain what they observe on the screen. What does each graph mean? What is the horizontal axis and the vertical axis? (You may want to avoid using x and y since the directions of the sensor are described by x, y, and z). Where on the graph is the time now? Why does the picture move to the left? Any ideas about the Earthquake Significance graph? What about the trigger line? Let students wonder about the Earthquake Significance for now.

4. Begin to lead students to think about what the purpose of the software is. What do you think this program is designed for? Why? The purpose of the Quake Catcher Network is to detect earthquakes and record the seismic activity on many internet-connected computers to rapidly detect earthquake activity.

5. Ask students if they have ever felt an earthquake. Ask for a few descriptions of what they felt. Use their experiences to introduce the Earthquake Simulation. Explain to the students that they are going to pretend that an earthquake occurs. Read the Earthquake Simulation Script three times.
   Round 1. move in any direction
   Round 2. move up and down only
   Round 3. move side to side only

After wrapping up the Earthquake Simulation, show video clips of a real earthquake. Video from the 2001 Earthquake in Seattle, WA was captured by serveral security cameras and can be see at http://www.classzone.com/books/earth_science/terc/content/visualizations/es1005/es1005page01.cfm?chapter_no=visualization or several on Youtube.com.

Earthquake Simulation Script

Imagine that you hear low, rumbling sounds. The noise is getting louder and louder, for just a few seconds. Then you feel a large shake. It's as if you were thrown out of bed, or a truck just hit the side of a building.

The floor or ground is moving beneath you. You move up and down and side to side, shaking and moving every which way. The building is creaking. The trees are swaying. Books fall from the shelves, lights swing, windows may break. Imagine what it feels like as all this chaos is going on. You try to get under your desk to protect yourself from falling and flying objects.

Then it stops. It is quiet. The ground is no longer moving. Everything is a mess.

Ask students how if felt. If they were scared, say that it is ok to feel that way. This is what happens during earthquakes. We build buildings today to withstand earthquakes. Also, we study them to understand how they occur. And with the QCN, we are trying to develop an early warning system for when earthquakes occur for safety reasons.

What direction did they move as the earthquake was occurring? Up and down? Side to side? Was the first jump the biggest and did they get smaller over time?

Repeat with all students going up and down. Then all students going side to side. Make these much shorter than the first.

Earthquake Review

Earthquakes happen because of a sudden slip on a fault in the earth's surface where the rock on one side moves up, down, or sideways relative to the other side. An earthquake is felt as a sudden, rapid shaking on the surface of the earth. This shaking can last a few seconds or even a few minutes. The motion causes waves that move through Earth.

Earthquakes are detected with instruments that measure and record the seismic waves. In general, seismologists now use seismometers and digital recorders, rather than the older seismographs (drum of paper spinning with a needle) which are only used for show on TV when there is a big earthquake because the TV channels like to show them. The record or graph is called a seismogram.

6. There are a few kinds of waves generated by earthquakes. A good way to explain P- and S- waves is with a slinky. Have two students sit opposite each other with a slinky pulled taught across the floor between them. When one student pushes their end of the slinky toward the other, it creates a wave like a P wave. When the student pushes the end of the slinky to the right or left, it creates a wave like an S wave.

7. Demonstrate how different motions of the computer are recorded by the sensor. Move the computer in the different directions as shown in the figure. X is the motion from left to right (east to west). Y is the direction from front to back (north to south) and z is the motion up and down (vertical component). Earthquake Significance is a calculated value based on the X, Y, and Z over the last minute. It helps distinguish noise from a real earthquake signal.

Explanation for the Teacher: One way to think about the different directions is to imagine a boat floating at the surface of the ocean. It moves with the ocean waves, up and down, and side to side. The pitch of the boat is the angle from bow to stern (front to back), measured here as the Y component. The roll of the boat is the angle from port to starboard (left to right), measured here as the X component. The sensor measures angular rotation which is a bit more complex than just measuring a linear distance, which is how the vertical component Z is measured.

8. Bring groups of students up to the computer to experience the changing of the measured motion as they move the computer. This gives each student a chance to experience this 3 component system of the motion themselves.

9. While the other students are at their desks, have them write a letter to a friend describing what they felt during the earthquake simulation. Rotate all the students through the experience of moving the computer.

10. Ask students what they learned from their experience with moving the computer. How are the records similar for the computer and the letter that they wrote? What is the EQ Significance? How does that change? What sources of error are there in the classroom? (doors slamming, table shaking, etc)

11. Describe the Quake Catcher Network and how the computer will always be running the program in the background to detect earthquakes. Discuss EQ Significance graph.

Explanation for the Teacher: Earthquake Significance

The Earthquake Significance is a calculated value based on the last 60 seconds to detect significant signals. It helps detect strong new vibrations measured by the laptop's sensor. If EQ Sig is above some level, the laptop informs the QCN server that it has detected a new vibration. It sends the time, amplitudes (x, y, and z) and the EQ Sig. If many laptops tell the server there is a strong shaking all at once, we know it is an earthquake. The QCN server evaluates triggers from 100s to 1000s of laptops. If the QCN server suddenly receives more triggers than expected from a particular area, we know there is an earthquake. If only a few laptops produce triggers in an area, we know that it is probably people bumping their laptops. If successful, it may be possible for anyone participating to learn of a large earthquake before they feel it and take safety precautions.

Activity #1-HS

What is a Seismometer?
High School Level

Objective
Students will learn that a seismometer detects 3 components of motion and that a seismogram is the record of an earthquake.

Background
Prior to this activity, students should be introduced to the basics of earthquakes. Curriculum for this can be found at http://www.redcross.org/disaster/masters/
This curriculum is designed for 9-12 grade levels. Other good activities can be found at http://www.dlese.org/ or http://web.ics.purdue.edu/~braile/.

Materials
QCN Demo installed on laptop
LCD projector or monitor
internet access to view video
slinky

Activity
1. Begin with the computer on a level surface.

2. Let students observe the seismic sensor for a few minutes. Encourage them to jump up and down or bang on the table with a fist or drop books.

3. Have students explain what they observe on the screen. What does each graph mean? What is the horizontal axis and the vertical axis? (You may want to avoid using x and y since the directions of the sensor are described by x, y, and z). Where on the graph is the time now? Why does the picture move to the left? Any ideas about the Earthquake Significance graph? What about the trigger line? Let students wonder about the Earthquake Significance for now.

4. Begin to lead students to think about what the purpose of the software is. What do you think this program is designed for? Why? The purpose of the Quake Catcher Network is to detect earthquakes and record the seismic activity on many internet-connected computers to rapidly detect earthquake activity.

5. Review earthquake basics with students. Show video clips of a real earthquake. Video from the 2001 Earthquake in Seattle, WA was captured by serveral security cameras and can be see at http://www.classzone.com/books/earth_science/terc/content/visualizations/es1005/es1005page01.cfm?chapter_no=visualization or several on Youtube.com.

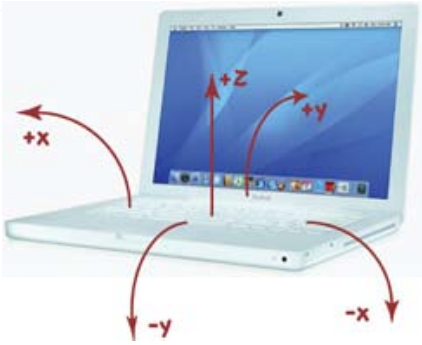
Earthquake Review

Earthquakes happen because of a sudden slip on a fault in the earth's surface where the rock on one side moves up, down, or sideways relative to the other side. An earthquake is felt as a sudden, rapid shaking on the surface of earth. This shaking can last a few seconds or even a few minutes. The motion causes waves that moves through Earth. The first waves are compressional waves, also known as primary or P waves, travel fastest, at speeds between 1.5 and 8 kilometers per second in the Earth's crust. Shear waves, also known as secondary or S waves, travel more slowly, usually at 60% to 70% of the speed of P waves.

Earthquakes are detected with instruments that measure and record the seismic waves. In general, seismologists now use seismometers and digital recorders, rather than the older seismographs (drum of paper spinning with a needle) which are only used for show on TV when there is a big earthquake because the TV channels like to show them. The record or graph is called a seismogram.

6. There are a few kinds of waves generated by earthquakes. A good way to explain P- and S- waves is with a slinky. Have two students sit opposite each other with a slinky pulled taught across the floor between them. When one student pushes their end of the slinky toward the other, it creates a wave like a P wave. When the student pushes the end of the slinky to the right or left, it creates a wave like an S wave.

7. Demonstrate how different motions of the computer are recorded by the sensor. Move the computer in the different directions as shown in the figure. X is the motion from left to right (east to west). Y is the direction from front to back (north to south) and z is the motion up and down (vertical component). Earthquake Significance is a calculated value based on the X, Y, and Z over the last minute. It helps distinguish noise from a real earthquake signal.



Explanation for the Teacher

One way to think about the different directions is to imagine a boat floating at the surface of the ocean. It moves with the ocean waves, up and down, and side to side. The pitch of the boat is the angle from bow to stern (front to back), measured here as the Y component. The roll of the boat is the angle from port to starboard (left to right), measured here as the X component. The sensor measures angular rotation which is a bit more complex than just measuring a linear distance, which is how the vertical component Z is measured.

8. Pass out the Siesmogram Worksheet to all students. Remind students that the first waves are compressional waves, also known as primary or P waves, which travel fastest. Shear waves, also known as secondary or S waves, travel more slowly, usually at 60% to 70% of the speed of P waves.

9. Bring groups of students up to the computer to experience the changing of the measured motion as they move the computer. This gives each student a chance to experience this 3 component system of the motion themselves. Challenge each group to figure out what the EQ Significance and triggers are.

10. Ask students what they learned from their experience with moving the computer. How are the records similar for the computer and the Tonga siesmogram? What is the EQ Significance? How does that change? What sources of error are there in the classroom? (doors slamming, table shaking, etc)

11. Describe the Quake Catcher Network and how the computer will always be running the program in the background to detect earthquakes. Discuss EQ Significance graph.

Explanation for the Teacher: Earthquake Significance

The Earthquake Significance is a calculated value based on the last 60 seconds to detect significant signals. It helps detect strong new vibrations measured by the laptop's sensor. If EQ Sig is above some level, the laptop informs the QCN server that it has detected a new vibration. It sends the time, amplitudes (x, y, and z) and the EQ Sig. If many laptops tell the server there is a strong shaking all at once, we know it is an earthquake. The QCN server evaluates triggers from 100s to 1000s of laptops. If the QCN server suddenly receives more triggers than expected from a particular area, we know there is an earthquake. If only a few laptops produce triggers in an area, we know that it is probably people bumping their laptops. If successful, it may be possible for anyone participating to learn of a large earthquake before they feel it and take safety precautions.

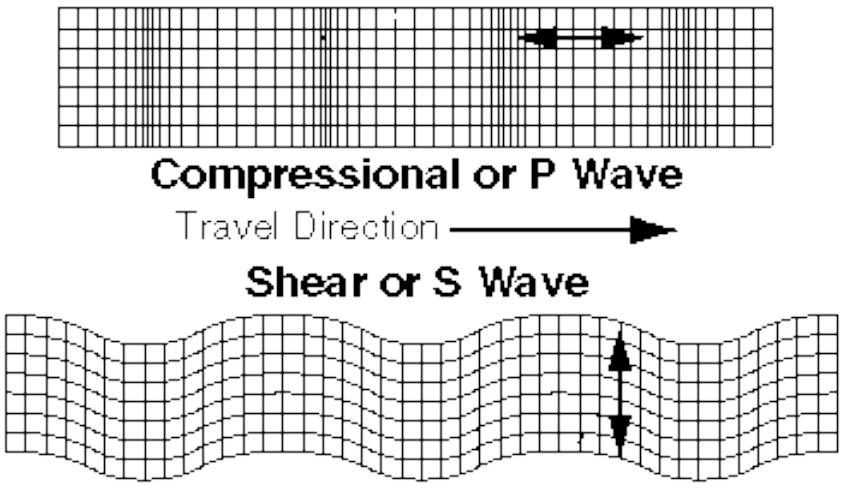
Seismogram Worksheet

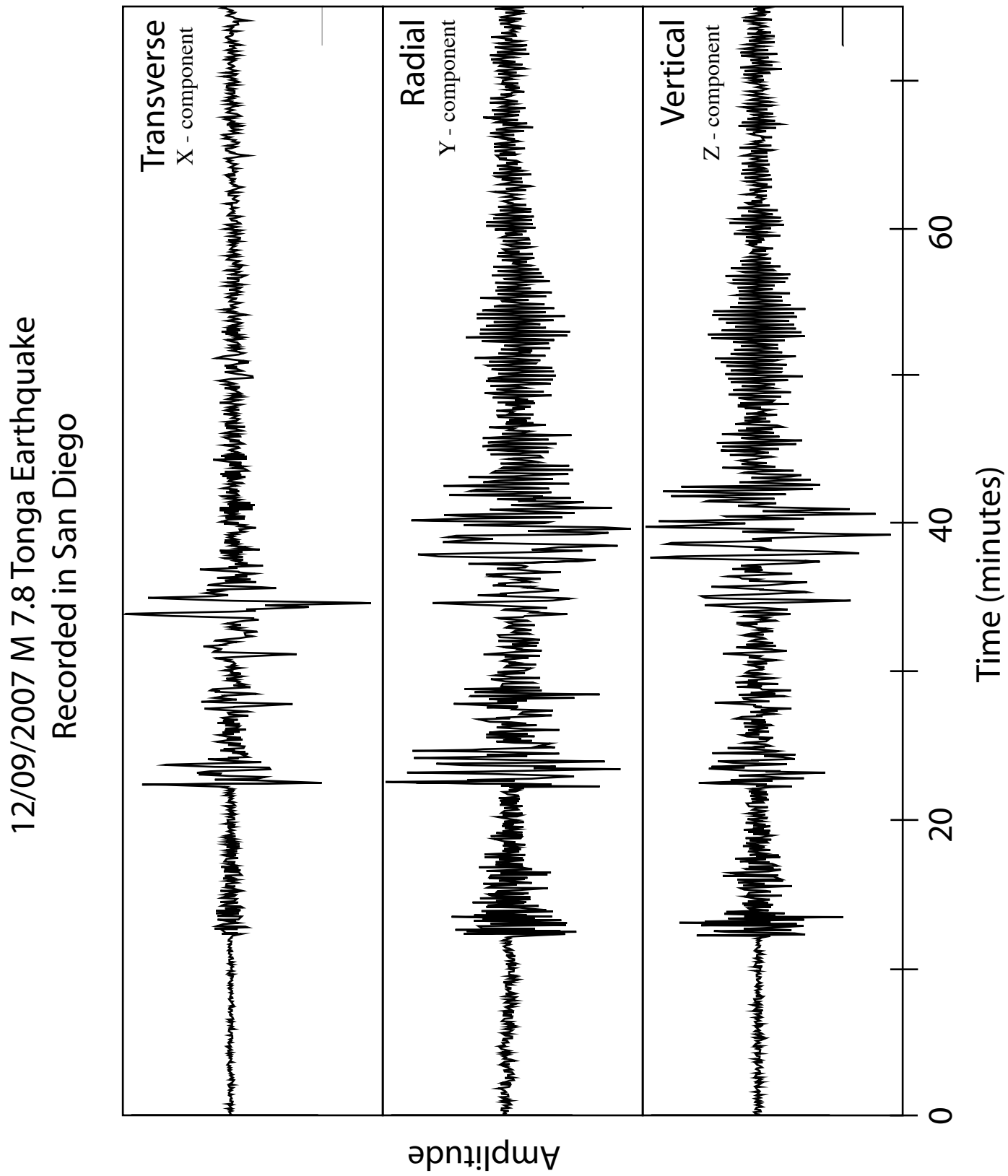
1. Examine the seismogram. When and where did this earthquake occur?

2. Find the beginning of the record where the time is zero. When did the first wave of the earthquake reach this station?
   Label this with a P on each of the 3 components of motion.

3. The first wave is called the P wave, P for primary.
   a. Which direction of motion has the largest disturbance by the P wave?
   b. P waves are compressional waves. Using the diagram of the slinky below, which direction does the slinky move when the P wave goes by?

4. The second wave is called the S wave.
   a. Label the S wave on the seismogram.
   b. Which direction of motion has the largest disturbance by the S wave?
   c. S waves are shear waves. Using the diagram of the slinky, which direction does the slinky move when the S wave goes by?




12/09/2007 M 7.8 Tonga Earthquake
Recorded in San Diego
Transverse
X - component
Radial
Y - component
Vertical
Z - component
Amplitude
0
20
40
60
Time (minutes)

Seismogram Worksheet Teacher Answers

Answers in bolded italics.

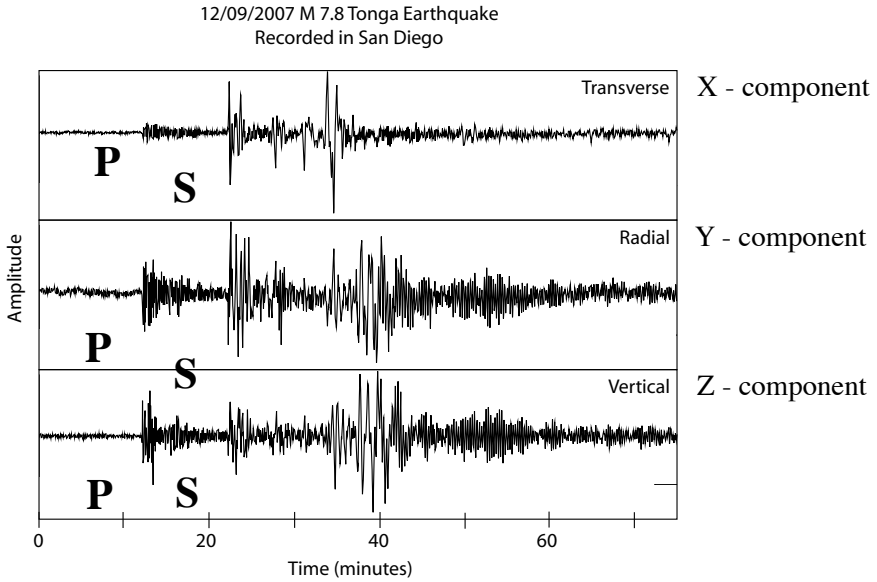
1. Examine the seismogram. When and where did this earthquake occur?
in Tonga on December 9, 2007. This was recorded in San Diego.

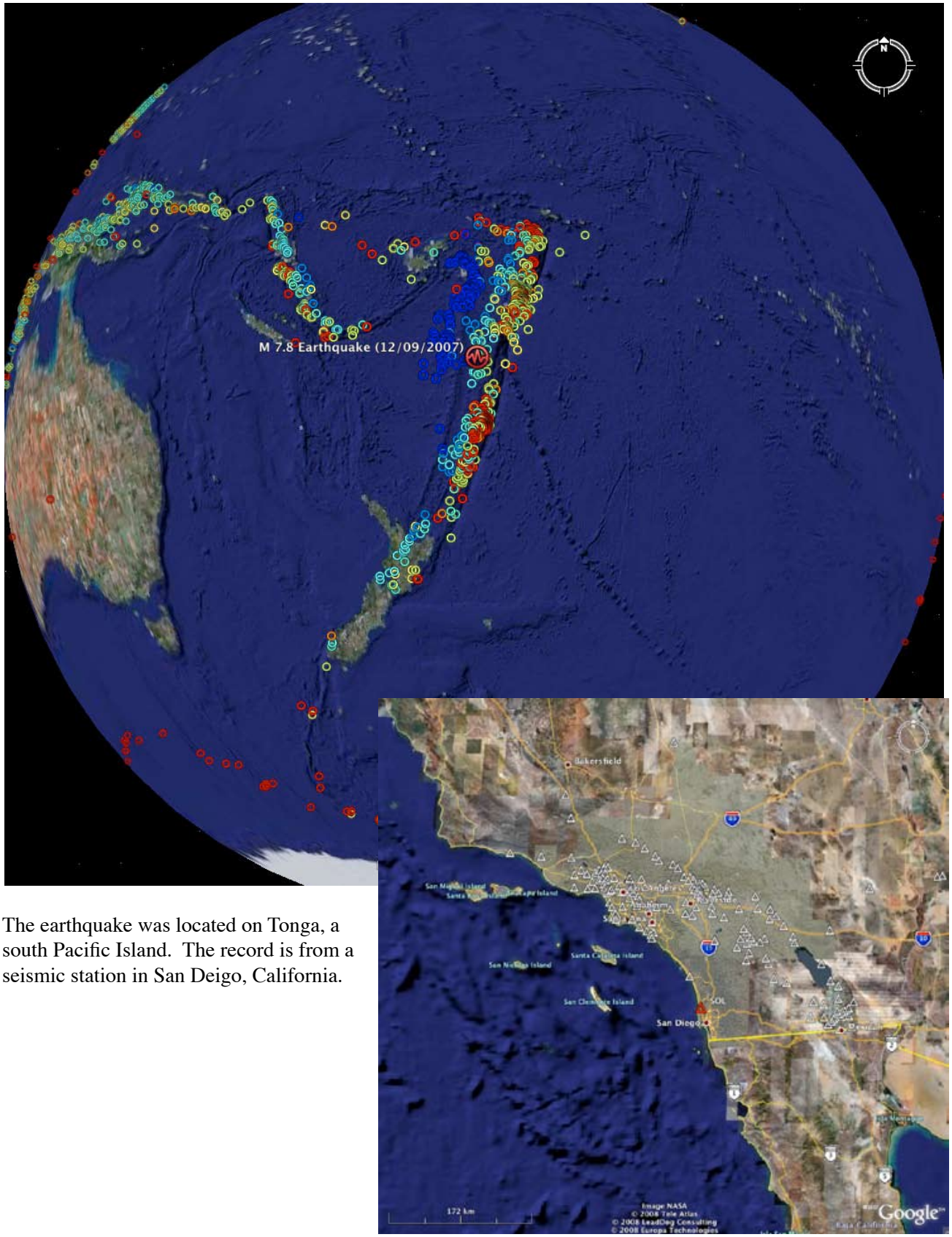
2. Find the beginning of the record where the time is zero. When did the first wave of the earthquake reach this station? ***9 minutes from the start***
   Label this with a P on each of the 3 components of motion.

3. The first wave is called the P wave, P for primary.
   a. Which direction of motion has the largest disturbance by the P wave? ***Z, although Y is pretty close***
   b. P waves are compressional waves. Using the diagram of the slinky below, which direction does the slinky move when the P wave goes by? ***left to right***

4. The second wave is called the S wave.
   a. Label the S wave on the seismogram.
   b. Which direction of motion has the largest disturbance by the S wave? ***X and Y***
   c. S waves are shear waves. Using the diagram of the slinky, which direction does the slinky move when the S wave goes by? ***up and down***

Slinky image from http://www.seismo.unr.edu/ftp/pub/louie/class/100/seismic-waves.html





The earthquake was located on Tonga, a south Pacific Island. The record is from a seismic station in San Deigo, California.

Using USGS ShakeMaps to Understand Intensity

***Putting Down Roots*, pp. 14 - 18**

Idaho State Standards:

8th/9th Earth Science 1.2.1-.3, 1.3.1-.3, 1.6.2-.7, 1.8, 5.2
8th Mathematics 2.1, 3.1.1, 3.5.1, 4.3, 5.1.1-.3, 5.2.1, 5.3.1-5.3.2, 5.4.1-.4, 5.5.1-.3
9th Mathematics 1.2, 2.3, 2.4.1, 3.2, 3.5, 3.6, 4.3, 4.4, 5.1, 5.2, 5.4, 5.5

Objectives:

Students will be able to:

1. Interpret a ShakeMap from the USGS website http://earthquake.usgs.gov/earthquakes/shakemap
2. Understand the relationship between acceleration of gravity and intensity (ground shaking).

RATIONALE

In this activity, students examine ShakeMaps generated from the USGS website. ShakeMaps allow students to explore other factors besides event size and the distance from the source to the receiver that can affect the intensity (e.g. structures, land composition, etc.).

FOCUS QUESTION(S):

- How hard does the ground shake during an earthquake?
- How is ground shaking quantified?
- How is intensity displayed on a map?

TEACHING CLUES AND CUES

This activity does not require the technology and materials of the previous activity. However, it does allow the students to interpret ShakeMaps and develop an understanding of intensity. It is important that students understand that when an earthquake occurs, the ground shakes and this shaking is measured as acceleration. This acceleration is converted to a value expressed as % of gravity (%g). The greater the %g, the greater the intensity as described on the Modified Mercalli Scale.

ShakeMaps display this change by color variations. It is important to note that earthquake waves do not always propagate outward like ripples on a pond. Variations in surface composition or geologic structural changes affect the amount of shaking the ground will display at the surface during an earthquake. Show the video of the 1995 Kobe, Japan Earthquake (M7.2) to students as an anticipatory hook to the activity. Ask "how hard did the ground shake? How could this be displayed on a map? Can you tell from the video when the ground was moving fast or slow?"

MATERIALS:

for teacher

- Computer and projection equipment to show video and/or ShakeMaps
- Copies of the ShakeMaps that will be used in the activity, pp. 61 - 62
- Teacher answer key, pp. 63 - 64
- Copy of the Modified Mercalli Scale, p. 44
- Download video clip of the 1995 Kobe, Japan Earthquake (M7.2) called "Earthquake in Kobe, Japan" at http://www.youtube.com/watch?v=0plbf5w0sbA

for the students: (work in pairs)

- Copies of the ShakeMaps, pp. 61 - 62
- Student Worksheet, pp. 58 - 60
- Copy of the Modified Mercalli Scale with Acceleration Values, p. 44

PROCEDURE:

Teacher Preparation

1. Make copies as needed for the activity.
2. Access the 1995 Kobe, Japan video.
3. Become familiar with the ShakeMaps in order to answer student questions.
4. Access the ShakeMaps to be displayed.

A. Introduction

When an earthquake occurs, the ground shakes. The soil at the surface responds to that shaking, as does anything on the soil. The video of an office building during the 1995 Kobe, Japan earthquake (M7.2) illustrates how violently the ground can shake. The amount of ground shaking and what happens to structures on the surface is referred to as intensity. It can be measured, usually by visual inspection of the damage. The scale used to determine the intensity is called the Modified Mercalli Scale.

B. Lesson Development

1. Present the video "Earthquake in Kobe, Japan." Ask students to determine when they think the earthquake is shaking the least and the hardest. Show the video a couple of times.
2. Distribute copies of the student worksheet, the ShakeMaps, and the Modified Mercalli Scale with Acceleration Values.
3. Discuss the concept of %acceleration from gravity. Compare the acceleration concept to the Modified Mercalli scale and to the video.
4. Display the Mount Borah ShakeMap from the 1983 earthquake. Discuss the map's features and information.

5. Allow students to work independently to answer the questions on the worksheet.

C. Conclusion

Help students to understand that the magnitude of the earthquake does not change, but the intensity does. Intensity is a measure of the amount of ground shaking which may result in damage to structures on the surface during an earthquake. Intensity decreases or increases based on magnitude, distance, soil type, and subsoil geology. Intensity can be measured as a value of % of gravity. Under normal conditions, the value of surface acceleration, at rest, has a value of 0%g. During an earthquake, the land can accelerate (move) in reference to normal conditions. The greater the %g, the more the ground is moving and may be compared to damage noted on the Modified Mercalli scale.

Additional Activities / Labs

Use the following link to access other activities about intensity. http://www.teachingboxes.org/earthquakes/lessons/lesson5_activity2.jsp

This link is to the DLESE teaching box site. In the left margin there are more activities to access. Further instructions and resources accompany Lesson 5: A whole Lot of Shakin' Goin' On! Please note that these lessons focus on California and the Oakland/ San Francisco Area.

DYFI (Did You Feel It?)

You may want to introduce your students to the USGS site "Did You Feel It?" http://earthquake.usgs.gov/earthquakes/dyfi/

There is also a link from the IGS (Idaho Geological Survey) site that connects you to the USGS dyfi page http://www.idahogeology.org/ > Geologic Hazards> earthquakes> Did You Feel It?

Student worksheet

Using USGS ShakeMaps to Understand Intensity

Name_____ **Date**_____

Intensity is a qualitative measure of the strength of ground shaking at a particular site. The Modified Mercalli Intensity Scale is the scale currently used in the United States (see p. 15 of *Putting Down Roots in Earthquake Country: Your Handbook for Earthquakes in Idaho*). Each earthquake large enough to be felt will have a range of intensities. Usually—but not always—the highest intensities are measured near the earthquake's epicenter, while lower intensities occur farther away.

Roman numerals are used to describe intensities in order to distinguish them from magnitudes. For example, the magnitude of the Borah Peak earthquake was 6.9. The intensities ranged from IX (violent) close to the epicenter, to V (moderated) at a distance of about 126 miles (203 Km) southwest in Caldwell, Idaho, and a III (weak) in Teton, Idaho, also at a distance of 126 miles (203 Km), but southeast of the epicenter (USGS).

An instrument used to measure ground shaking is called an accelerometer. This instrument can quantify the amount of shaking or ground motion during an earthquake. This value is a measurement expressed as % of gravity (%g). Normal gravity is zero and any value greater than zero indicates the amount of acceleration. When you step on the accelerator in a car or apply the brakes, the car moves faster or slower. When the car's movement changes from one speed to another, it is accelerating (faster) or decelerating (slower). This change from one speed, or velocity, to another is called acceleration. During an earthquake when the ground is shaking, it also experiences acceleration. The **peak acceleration** is the largest acceleration recorded by a particular station during an earthquake. (USGS)

The USGS ShakeMaps for the 1983 Borah Peak earthquake (Map 1) and the 1985 Michoacan, Mexico earthquake display the intensities recorded during these earthquakes in the surrounding area. Use the map and *Putting Down Roots* to answer the following questions.

1. What information does this map show us?

2. Even though it is not described on the map, what do you think the star represents?

3. Relative to the earthquake, name and describe the location where the strongest shaking took place?

4. What does an accelerometer measure? Why would this measurement be important for earthquake mitigation?

5. What was the highest and lowest probable range of acceleration for the 1983 Borah Peak earthquake? What about the Mercalli value?

6. How would you expect shaking to vary in the region around the earthquake?

7. Where would you expect to find the most damage from an earthquake? Why?

8. If you did not have an accelerometer to measure the shaking in an earthquake, how else could you describe and quantify the shaking at different distances from an earthquake?

9. Based on acceleration estimates, what sort of damage was likely to have occurred?

10. Compare and contrast this map to the map shown on p. 15 of *Putting Down Roots in Earthquake Country*. How are they alike and how are they different?

11. If distance is a factor that affects intensity, why isn't the shaking around an area consistent and spherical? (Refer to the map on p. 15)

12. According to the map, list the states that felt the earthquake with a Mercalli intensity of III.

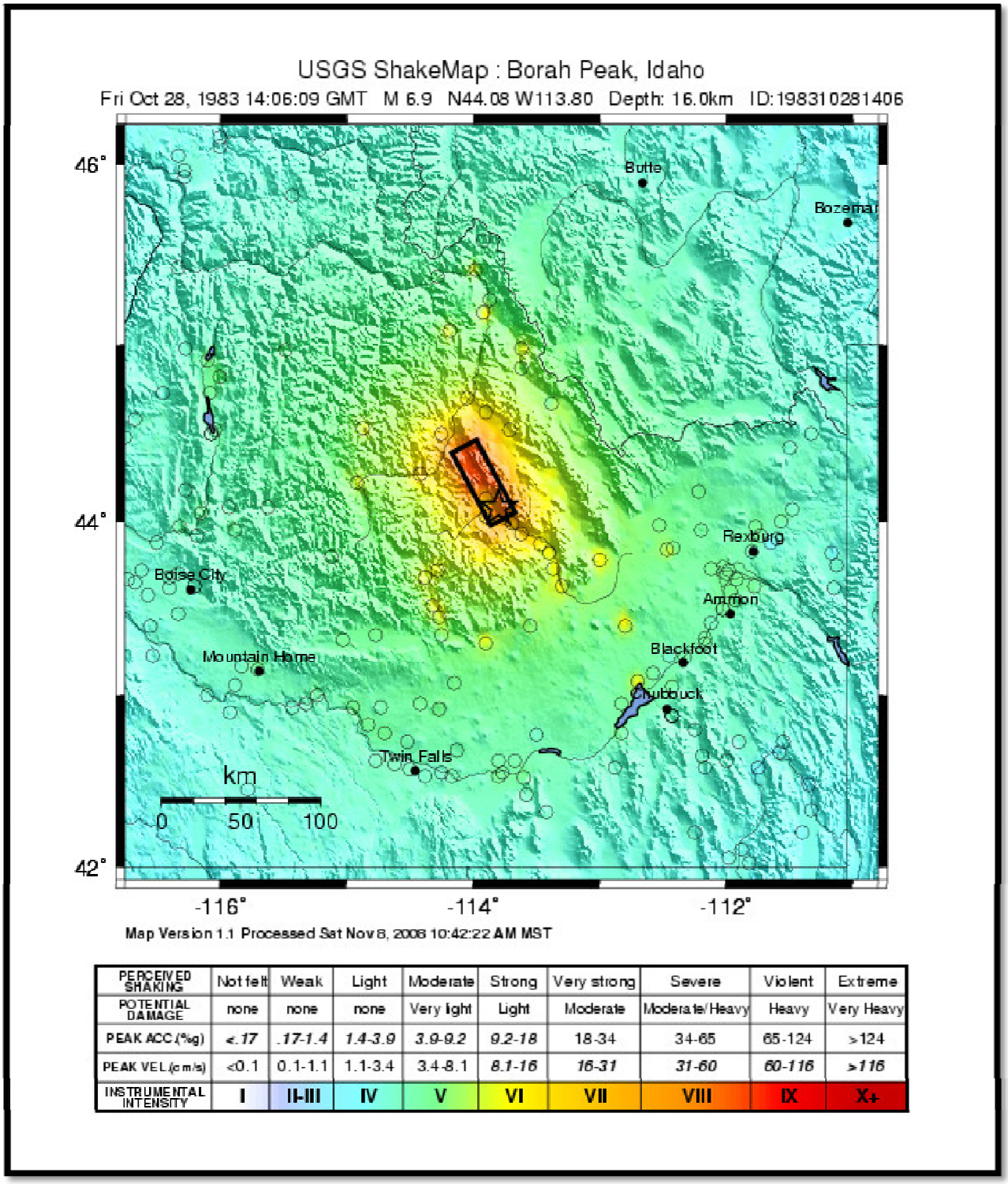
13. Based on the information found on p. 15 of *Putting Down Roots*, what is the largest expected earthquake that could happen in Idaho? Why?

14. How does the topography of Idaho amplify or reduce intensity (shaking) of an earthquake? (See p. 14)

15. How can intensity maps like the ShakeMaps help scientists and engineers reduce the damage from earthquakes?

16. **BONUS:** Look at the ShakeMap for the 1985 Mexico earthquake (Map 2). Notice the two yellow dots (Mexico City) toward the right side of the map. (a) Using the scale on the map, determine the distance from the epicenter to Mexico City. (b) What reason can you give for this area having such strong shaking at such a distance from the epicenter of the earthquake? Cite your reference sources.

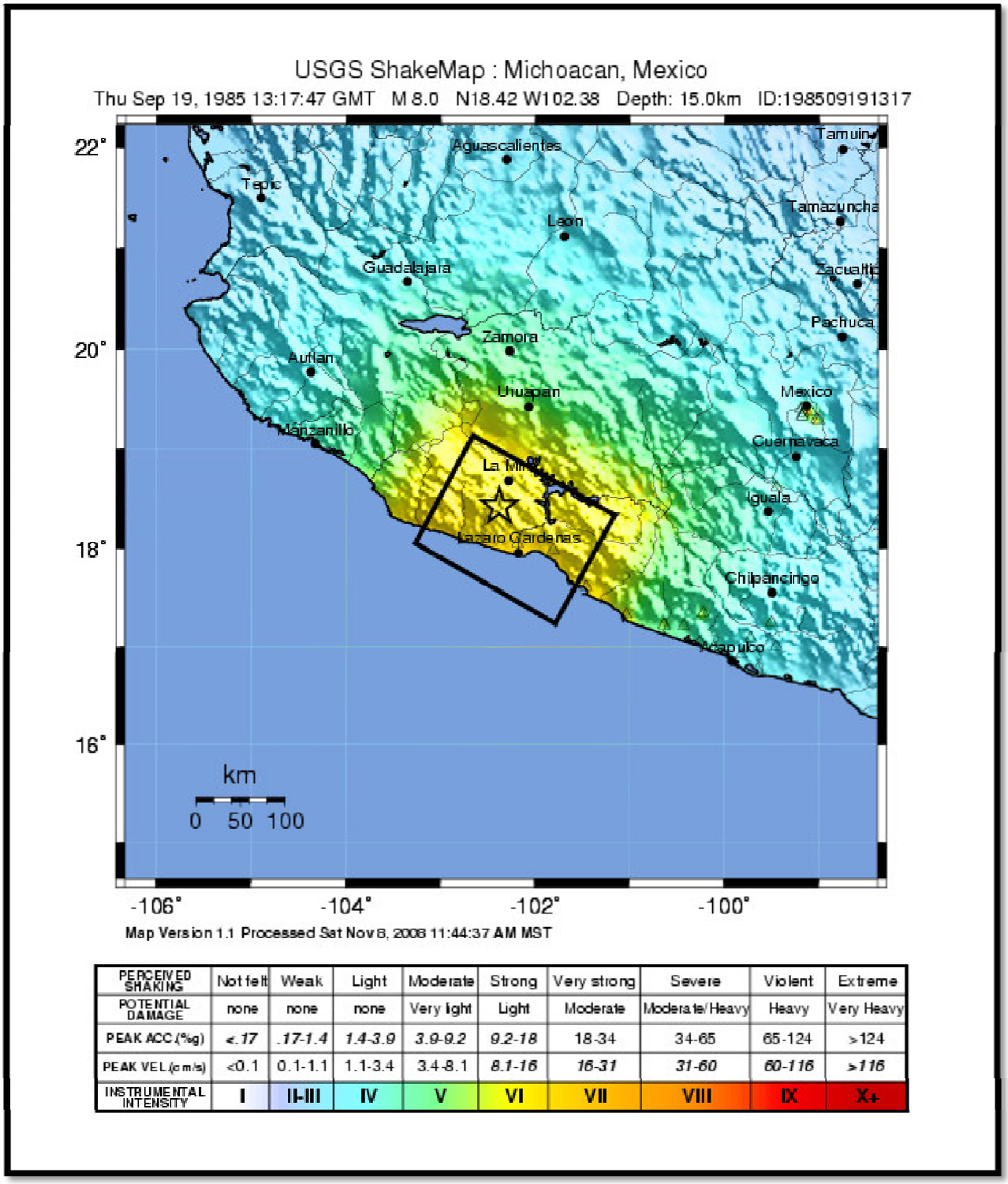
Map 1



PERCEIVED SHAKING	Not felt	Weak	Light	Moderate	Strong	Very strong	Severe	Violent	Extreme
POTENTIAL DAMAGE	none	none	none	Very light	Light	Moderate	Moderate/Heavy	Heavy	Very Heavy
PEAK ACC.(%g)	<.17	.17-1.4	1.4-3.9	3.9-9.2	9.2-18	18-34	34-65	65-124	>124
PEAK VEL.(cm/s)	<0.1	0.1-1.1	1.1-3.4	3.4-8.1	8.1-16	16-31	31-60	60-116	>116
INSTRUMENTAL INTENSITY	I	II-III	IV	V	VI	VII	VIII	IX	X+

USGS image

Map 2



PERCEIVED SHAKING	Not felt	Weak	Light	Moderate	Strong	Very strong	Severe	Violent	Extreme
POTENTIAL DAMAGE	none	none	none	Very light	Light	Moderate	Moderate/Heavy	Heavy	Very Heavy
PEAK ACC.(%g)	<.17	.17-1.4	1.4-3.9	3.9-9.2	9.2-18	18-34	34-65	65-124	>124
PEAK VEL.(cm/s)	<0.1	0.1-1.1	1.1-3.4	3.4-8.1	8.1-16	16-31	31-60	60-116	>116
INSTRUMENTAL INTENSITY	I	II-III	IV	V	VI	VII	VIII	IX	X+

USGS image

ANSWER KEY to Student Worksheet
(Using USGS ShakeMaps)

1. What information does this map show us?
   The map tells us the strength of the ground shaking at each location shown on the map.

2. Even though it is not described on the map, what do you think the star represents?
   The star represents where the earthquake occurred. This location is called the epicenter.

3. Relative to the earthquake, name and describe the location where the strongest shaking took place?
   The strongest shaking occurred close to the epicenter of the earthquake in the valley to the north of Mount Borah (the star).

4. What does an accelerometer measure? Why would this measurement be important in earthquake mitigation?
   An accelerometer measures the amount of ground shaking or movement. It can tell how strong land movement was and how it would have affected structures on the land.

5. What was the highest and lowest probable range of acceleration for the 1983 Borah Peak earthquake? What about the Mercalli value? (Mercalli value and Peak Acc. %g)
   Greatest: PA (%g) 65-124, IX
   Lowest: PA (%g) 0.17-1.4, III

6. How would you expect shaking to vary in the region around the earthquake?
   The amount of shaking will vary according to the distance and the type of ground material through which the earthquake waves travel.

7. Where would you expect to find the most damage from an earthquake? Why?
   The most damage would occur in the area closest to the epicenter and in areas where the ground motion (acceleration) was the highest. This could be in areas of thick soft soils for tall buildings and in areas of thin stiff soil for short buildings (1-2 stories). The more the land moves, the more likely structures on them will be affected.

8. If you did not have an accelerometer to measure the shaking in an earthquake, how else could you describe and quantify the shaking at different distances from an earthquake?
   Data could be collected by interviewing people about what they felt and saw during the earthquake.

9. Based on acceleration estimates, what sort of damage was likely to have occurred?
   According to the ShakeMap and the map on p. 15 of *Putting Down Roots* the earthquake would have been felt by all in Idaho. The damage would range from partial collapse of buildings, broken windows, chimney collapse, buildings shifted off foundations, underground pipes broken, and cracks in walls and in the ground.

10. Compare and contrast this ShakeMap to the map shown on p. 15, *Putting Down Roots in Earthquake Country*. How are they alike and how are they different?
Same color scheme, same area of Idaho shown. Smaller area shown on the ShakeMap, more information given on the ShakeMap, legend is attached to ShakeMap.

11. If distance is a factor that affects intensity, why isn't the shaking around an area consistent and spherical? (Look at the map on p. 15)
Soil type and thickness, as well as the presence of mountains and valleys, change the way that earthquake waves travel. If the land had the same density and structure, then it would be spherical and consistent.

12. According to the map, list the states that felt the earthquake with a Mercalli intensity of at least III.
The states are: Washington, Oregon, Nevada, Utah, Colorado, and Montana.

13. Based on the information found on p. 15 of *Putting Down Roots*, what is the largest expected earthquake that could happen in Idaho? Why?
Because of the type of faults and geology that exist in the state, a magnitude 7.5 is the largest that could be expected in Idaho.

14. How does the topography of Idaho amplify or reduce intensity (shaking) of an earthquake?
The type of soil determines how the seismic wave will behave. Soft soils (thick or thin) allow the ground motion to be amplified (increased). These are the types of soils that are found in the valleys of the Basin and Range Province of Idaho and the Snake River Plain. Most of Idaho is mountainous; therefore, the earthquake waves would not be amplified or generated.

15. How can intensity maps like the ShakeMaps help scientists and engineers reduce the damage from earthquakes?
Understanding how much the ground shakes during earthquakes of a particular magnitude in different regions helps engineers decide what kind of construction is appropriate for the different regions and areas in a region (depending on geology).

16. **BONUS:** Look at the ShakeMap for the 1985 Mexico earthquake (Map 2). Notice the two yellow dots (Mexico City) toward the right side of the map. (a) Using the scale on the map, determine the distance from the epicenter to Mexico City. (b) What reason can you give for this area having such strong shaking at such a distance from the epicenter of the earthquake? Cite your reference sources.
This ShakeMap is of the 1985 Mexico City earthquake. The epicenter was on the Pacific coast in the state of Michoacán, Mexico, a distance of ~350 km from Mexico City. The quake magnitude was 8.0. Mexico City was built on top of old lakebed sediments. This type of ground material amplified the ground shaking, causing buildings to collapse. Casualty estimates are from 10,000 to 40,000. Faulty construction practices were also cited as a reason for the large amount of damages and casualties.

Magnitude & Log Scale: A Visual Demonstration

***Putting Down Roots*, pp. 14-15**

Idaho State Standards:

8/9th Earth Science 1.2
8th Mathematics 1.1.1
9th Mathematics 1.1

Objectives:

Students will learn the earthquake magnitude scale by breaking different amounts of spaghetti. The visual scale of the pasta emphasizes the relative differences between magnitudes each whole step in magnitude.

RATIONALE

This is a teacher demonstration that visually explains the idea of the magnitude logarithmic scale for earthquakes.

FOCUS QUESTION(S):

- What is the difference between the energy released in a magnitude 5 and a magnitude 6 or 7 earthquake?

TEACHING CLUES AND CUES

The severity of an earthquake can be expressed in terms of both intensity and magnitude. However, the two terms are quite different and they are often confused.

Intensity is based on the *observed* (qualitative) effects of ground shaking on people, buildings, and natural features. It varies from place to place within the disturbed region, depending on the location of the observer with respect to the earthquake's epicenter.

Magnitude is related to the amount of seismic energy released at the hypocenter of the earthquake and is based on the amplitude of the earthquake waves recorded on instruments with a common calibration. Thus, the magnitude of an earthquake is represented by a single, *instrumentally determined value* (quantitative).

The magnitude scales for earthquakes are logarithmic scales. In particular, each increase of 1 unit on the Richter scale --say from 6 to 7--represented an increase of one order of magnitude, i.e. times 10, in the amount of motion recorded on a particular type of seismograph.

The now-common **Moment Magnitude** (Mw) scale was defined because the Richter scale does not adequately differentiate between the largest earthquakes. The new "moment magnitude" scale is a new technique for using the Richter scale. In the moment magnitude scale, a magnitude increase of one unit corresponds to a factor of 30 increase in the energy released by the breaking of the fault in an earthquake. That is why we increase the number of spaghetti noodles from 1 to 30 to 900.

MATERIALS:

- 1-lb. package of thin spaghetti
  or
- 2-lb. package of regular spaghetti

PROCEDURE:

Teacher Preparation

Bundle the spaghetti prior to the class.

A. Introduction

Hold up a piece of spaghetti. Inform students that you will be using the spaghetti to demonstrate and develop a magnitude scale similar to the Richter scale or Moment Magnitude scale for earthquakes. The scale is based on the amount of energy needed or generated during earthquakes.

B. Lesson Development

1. Hold up a piece of spaghetti. Bend the piece between your hands until it breaks. Notice the work it takes to break the spaghetti. Call this a 5 on the "Pasta Magnitude" (Mp) scale.

2. Hold up a bundle of 30 pieces of spaghetti. Bend the bundle until it breaks. Notice the work it takes to break the bundle. If the pasta scale were like the earthquake magnitude scale this would be a Pasta Magnitude 6 break.

3. Hold up the remainder of the package, about 900 pieces of pasta. Bend the bundle until it breaks. Notice the work it takes to break the bundle. This is a Pasta Magnitude 7 break (*Haiti, 01/12/10*).

C. Conclusion

To release the same amount of energy released by one **M7** earthquake would require the equivalent of 30 **M6** or 900 **M5** quakes. Did you see/hear all the little "quakes" before and after the big-quake break?

Liquefaction: That Sinking Feeling

***Putting Down Roots*, p. 17**

Idaho State Standards:

Earth Science 1.3.1, 1.3.2, 1.6.4, 4.2, 5.1

Objectives:

Students will:

1. Construct a model to demonstrate liquefaction.
2. Distinguish between soil liquefaction and soil saturation.
3. Assess potential damage to homes, lifelines, and schools.

RATIONALE

Like other earthquake-related phenomena, liquefaction may cause the loss of property and even injury or death. This model allows instructors and students to observe the effects of liquefaction and the phenomenon of sand boils on a small scale.

FOCUS QUESTION(S):

- What happens when a damaging earthquake strikes areas prone to liquefaction?

TEACHING CLUES AND CUES

If possible, substitute a small, hollow, ceramic house, measuring approximately 5 x 5 x 7 cm., for the sinker. These are sold at hobby shops for Christmas scenes, and can be filled with BBs to add weight.

MATERIALS:
for teacher

- Teacher Background Reading: Liquefaction, p. 68
- Teacher Background Reading: New Madrid Narrative, pp. 69 - 70

for the students: (work in small groups)

- 226 g (about 8 oz.) of well-sorted fine sand. Sandbox sand works well.
- One .25-1 (9 oz.) clear plastic cup
- One pie plate, diameter 23 cm (9 in.)
- 225 ml (5 oz.) of water in a pitcher
- Sinker or comparable small object weighing at least .06 kg. (2 oz.)
- One 250-ml beaker
- Newspapers to cover work surface

PROCEDURE:

Teacher Preparation

Read Teacher Background Readings "Liquefaction" and "New Madrid Narrative." Decide how you will share this information with your students. Students who like to read will find the New Madrid Narrative delightful. Gather enough materials so you can have two students per station. Before class, cover work areas with newspapers, set up the stations, and practice each activity at least once to ensure everything works.

A. Introduction

Tell students that an earthquake with a magnitude of 5.0 or greater may cause saturated sand or clay soils to liquefy. During the winter of 1811 and 1812, a series of earthquakes affected the central United States in an area known today as the New Madrid Zone that includes parts of the states of Missouri, Arkansas, Kentucky, Illinois, and Tennessee. As the soft sediments along the rivers were violently shaken, tremendous volumes of sand were liquefied and ejected onto the Mississippi River flood plain. These sand boils, as they are called, are still visible in the rural countryside today. Fortunately, the area of the earthquakes was not heavily populated in 1811-12, so loss of life, injuries, and loss of property were minimal. During the 1989 World Series in San Francisco, a 7.1 earthquake struck the Bay Area. Thanks to media coverage, millions of people viewed firsthand the fires and severe damage to buildings in the Marina District. Some of this damage occurred because soil liquefaction caused lifelines (gas, water, electrical, oil, sewage) to rupture and buildings to collapse.

B. Lesson Development

1. Write the word liquefaction on the board, and ask students to identify its root word (liquid). Emphasize that liquefaction does not cause an earthquake, but is the result of an earthquake. Liquefaction occurs only in highly saturated sand or clay soils. An earthquake with a magnitude of 5.0 or greater is usually needed to cause liquefaction. Earthquake vibrations cause soil particles to lose contact with each other, so the soil takes on the characteristics of a liquid.

2. Assign a partner to each student and designate a work station for each team. Give these directions:

a. Cut off about 5 mm from the bottom portion of the plastic cup.

b. Invert the cup and place it in the middle of the pie pan.

c. Holding the cup firmly, slowly pour the sand into the bottom of the cup to a level of 10-20 mm from the top. One student may hold while another pours. Level the sand with your fingers. Do not shake the cup to settle or level the sand (Figure 1).

d. Lightly place the sinker, model house, or other weight onto the leveled surface of the sand (Figure 1).

Figure 1

e. Again holding the cup, slowly pour the entire 225 ml of water into the pie pan around the outside of the cup and sand. (Figure 2)

f. Observe what happens and record the time it takes for the soil to reach saturation.

g. Once the soil is saturated, one student will hold the cup firmly in place while the other gives the side of the cup several sharp taps to simulate earthquake shaking. Observe what happens to the weight.

Figure 2

C. Conclusion

Help students to clean up and then initiate the discussion. Ask: If the weight in our experiment were an occupied building and liquefaction occurred over a large inhabited area, as it did in the San Francisco Bay Area in 1989, what would be the effect on:

- People?
- Private homes?
- Schools?
- Buried lifelines (gas, water, electrical, oil, sewage)?
- Agricultural lands?
- Medical facilities, fire stations, police stations?
- Large urban areas (Memphis, San Francisco, Boston)?
- Industrial areas?
- Materials that had been discarded in old sand boils (These could range from dead cows to old refrigerators to poisonous waste)?

Adaptations and Extensions

1. Make sand of various particle sizes and objects of different masses available for student experiments. Investigate the degree of liquefaction each will exhibit and the effects on the structures that rest upon them. A layer of diatomaceous earth under the sand will bubble up when the table is rapped. Try it!

2. Invite students to find ways to vary the amount of force they apply to the sand and water mix in the model.

3. Provide an aquarium or plastic gallon jars so students can experiment with larger models. Use transparent containers of any size—even a plastic sandwich box—for an interesting side view.

4. Bury objects in the sand and observe the results.

5. Develop models of overhead power lines, pipelines, sewage lines, light posts, and highways, and observe how liquefaction affects them.

6. Challenge students with this question: If a building has already been constructed on soil that has a potential to liquefy, what can be done to reduce the likelihood of damage? Invite them to design and test model structures that would reduce structural damage during liquefaction.

7. Bury a layer of sugar cubes below the sand surface to model land subsidence as the sugar cubes dissolve.

Teacher Background Reading: Liquefaction

How Liquefaction Occurs during Quakes

Liquefaction happens during an earthquake when vibrations cause the pressures to build up in the ground water that occupies the pore spaces between the grains of sand, silt, or loess. The longer the duration of the earthquake, the more likely that liquefaction will be induced. The only solid strength of such a deposit is provided by the friction between grains touching each other. When the pressure in the water that fills the pore space between the grains is sufficient to spread them apart, the solid nature of the sand, silt, or loess deposit is changed into that of a viscous liquid: "quicksand" or "quickclay."

Because it takes time for the pressures that produce liquefaction to build up underground, and because quicksand is a heavy, thick fluid that moves slowly, conditions of liquefaction, sand boiling, and associated phenomena may not be apparent during the shaking. In fact, they often do not manifest until after the shaking has already passed, sometimes not until 10-20 minutes later. The quick conditions or boiling of the sand can persist for hours or even days after the quake, sometimes as much as a week.

How Big Does It Take & How Near to the Quake?

A natural question regarding seismically-induced liquefaction concerns how big of an earthquake is required to induce quick conditions and the proximity necessary for such effects to be possible. With regard to size, several technical publications suggest that liquefaction does not occur for earthquakes less than Richter magnitudes of 5.2. However, minor liquefaction effects in areas underlain by particularly ideal predisposing conditions (loose sand deposits saturated with a near-surface water table) have been observed for earthquakes as small as 4.7 on the Richter scale in the New Madrid Seismic Zone. Minor damage to vulnerable structures has occurred in such areas. With regard to distance, an earthquake in June of 1987 with a magnitude of 5.2 in southeastern Illinois caused liquefaction phenomena near Bell City, Missouri, 150 miles (240 km) from the epicenter. A swimming pool, two large grain bins, a carport, and three houses were damaged, one severely. There were also fissuring and lateral spreading. At the same time, points nearer the epicenter of that quake did not experience such ground failures. Three years later in 1990 this same area experienced no liquefaction phenomena when a 4.7 earthquake struck only 20 miles (32 km) away.

Nearness to the epicenter implies greater amplitudes of ground motion, but distance implies a longer duration of shaking, since the wave train consists of many waves traveling at a variety of speeds. The epicenter of the magnitude 8.1 earthquake that struck Mexico City in 1985 was 240 miles (384 km) away and induced liquefaction that severely damaged some buildings. Although lasting less than a minute at its distant source, that quake lasted several minutes in Mexico City. Ground shaking amplitudes within the city, were never large, yet 400 buildings collapsed, resonating with the long-lasting wave train (or sequence of waves) amplified by underlying clays.

The New Madrid earthquakes of 1811-12 induced extreme examples of liquefaction, manifesting as sand boils and explosion cratering in the area of St. Louis, Missouri, and across the river in the flood plain of Illinois. Liquefaction also occurred from those quakes as far as Cincinnati, Ohio, more than 300 miles (480 km) away.

Three Ways to Induce Liquefaction

Liquefaction in soils can be stimulated three ways: seismically, mechanically, and hydrologically. Seismically-induced liquefaction is caused by seismic waves. Mechanically-induced liquefaction is caused by vibrations that come from railroad trains, motor vehicles, tractors, and other mechanical sources of vibratory ground motion. Hydrologically-induced liquefaction occurs when ground-water pressures increase due to rising stream levels during flooding conditions. This type of liquefaction most commonly occurs on properties protected by levees, where rivers can rise to levels above the land surface without actually flooding the land. With rivers flanked by levees and drainage ditches throughout the area, most of the New Madrid Seismic Zone falls into this category. Because of this, seismically-induced sand boils become hydrologically active during river flood stages, and can turn into quicksand and boil again, just as they did during the earthquakes that formed them. Similarly, tractors, trains, and trucks crossing over sand fissures during times of high water table can mechanically induce liquefaction, causing highways to sag, railroad tracks to get out of parallel, and farm equipment to sink into the ground.

Adapted from Stewart, David, and Knox, Ray, The Earthquake That Never Went Away: The Shaking Stopped in 1812, but the Impact Goes On, Marble Hill, MO: Gatlinburg-Richter Publications, 1993. A G U

Teacher Background: New Madrid Narrative
A 1912 Account of the 1811-1812 Earthquakes

The First Day

At 2:30 on the morning of December 16, 1811, a tremendous earthquake occurred with an epicentral region thought to lie just west of the location of present day Blytheville, Arkansas, a city that did not exist at the time. Had it been there, it would have been devastated totally, as evidenced by the numerous earthquake boils and fissures that visibly surround the city today. The Richter surface wave magnitude is thought to have been 8.6. 800 miles (1280 km) away in the White House in Washington, DC, President James Madison was shaken out of bed by the quake.

Many aftershocks immediately followed, some probably magnitude 6.0 or greater. At least two more shocks that day are thought to have equaled 8.0 on the Richter scale.

Then, sometime around 11:00 a.m., another great shock occurred in the vicinity of present-day Caruthersville, founded later in 1857. To the residents of the existing village known as Little Prairie, Missouri, this shock seemed worse than the initial earthquake. It is thought to have been another magnitude 8.0.

The River Rampages and Towns Disappear

The Mississippi River was churned into a virtual maelstrom, with miles of banks caving in, boats being swamped and sunk, and even entire islands disappearing along with their human occupants.

Two towns disappeared at this time. One settlement to disappear on December 16, 1811, was Big Prairie, Arkansas. Situated at the confluence of the Mississippi and St. Francis Rivers, the town site liquefied and sank, but slowly enough for all residents, approximately one hundred in number, to escape safely. Today, the Mississippi River occupies that site.

Another community destroyed that day was Little Prairie, Missouri, near present-day Caruthersville. Eyewitness accounts of the horror tell us of people violently thrown from their beds in the middle of the night. Although a bright full moon shone that night, shortly after the shock, large amounts of dust in the air caused everything to become pitch black. People were injured and bleeding and some were knocked temporarily unconscious.

The earth continued to jerk and rumble through the darkness until daylight, when around 8:00 a.m. the second hard shock hit the area. Throughout the morning, more shocks continued, with the ground heaving and cracking, sometimes opening and then suddenly slamming shut, spewing ground water over the tops of tall trees. In some places the ground literally exploded, blasting debris high into the air, raining sand and carbonized wood particles down upon the heads of those nearby, while leaving a deep crater in the ground where smooth land had been before. Sometimes, spreading crevasses formed in the earth beneath the bases of large trees, splitting their trunks from their roots upwards beyond the levels of their limbs. At one point during the morning, a great fissure began to form within the town. The townspeople stood around the pit and watched horrified as dark, viscous fluids gurgled from beneath the earth and gaseous fumes accompanied by the smell of sulfur and brimstone filled the air.

Many were thinking that the end of the world was at hand and that the very gates of hell itself were opening up to swallow their village. Amidst the terror, after the third great shock around 11:00 a.m., the soils of their settlement began to turn into quicksand, with dark waters oozing from the pores of the earth. As the whole town began to sink, the streets and cabins were flooded, not from the river, but from the ground itself.

Escape from Little Prairie

Hastily, the residents of Little Prairie gathered what meager possessions they could carry, lifted small children to their shoulders, and waded westward. Ahead of them, they could see rising waters far off into the horizon. For eight miles (12.8 km), the refugees waded through waist-deep waters, never knowing from one step to the next if they were going to plunge headlong into an unseen crevasse or trip over a buried stump, all the while surrounded by snakes, coyotes, and other wild creatures swimming for their lives in the turgid flood. During their escape, Little Prairie's displaced residents could not know if they would live through the day or not. However, all survived.

The First Day Was Over, but the Worst Was Yet to Come

Thus far, what has been described was only the first day of the Great New Madrid Earthquake series. More and bigger tremors were yet to come. At about 9:00 a.m. on January 23, 1812, another big one hit, with an epicenter probably lying north of Little Prairie and south of Point Pleasant, another small settlement in the area. It is thought to have been an 8.4 magnitude earthquake.

The Mississippi River bank, on which the village of Point Pleasant was situated, collapsed during the January 23 event. Fortunately, the residents had all evacuated the site prior to that catastrophe so none were injured. However, the town was lost forever.

The January 23 event also caused several huge sand boils in Tennessee that created a dam across Reelfoot Creek, creating Reelfoot Lake.

On February 7, 1812, the largest quake occurred. At approximately 3:15 in the morning, the region was rocked by an 8.8 magnitude shock. Outside Alaska, this event stands as the largest earthquake in American history and one of the largest in the world.

The quake caused the Mississippi River to run backwards. Towering waves of water were thrown over the banks, shattering thousands of acres of trees into splinters and stumps. The shaking threw boats onto dry land along St. John's Bayou at New Madrid and created two temporary waterfalls. These falls had a vertical drop of about six feet (2 m) followed by a mile (2 km) or so of shallow rapids.

During the largest of the New Madrid earthquakes, the river is said to have boiled, whirled, and heaved, with massive waves bashing from one bank to the other, sweeping boats and debris into oblivion. Some eyewitnesses from the banks said they actually saw the river open up in yawning chasms, into which the swirling waters disappeared, drawing hapless flat boats and their passengers into the maelstrom, never to be seen again. Others described water spouts that shot upwards from the water's surface like tall fountains.

The earthquakes literally destroyed the landscape with sand deposits, crevasses, and permanent flooding. Most residents of the region abandoned their properties and moved away. In the aftermath of the quakes, the boot-heel portion of Missouri became known as "Swampeast Missouri."

Two More Towns Gone Forever

The February 7 quake also destroyed two more towns. Fort Jefferson, Kentucky was swept away by landslides. The slumps are still visible today along Highway 51 leading into Wickliffe. In addition, New Madrid was itself destroyed. What remained of the settlement slumped downward 15-20 feet (5-10 m.) into the water's edge and was washed away by the spring floods of 1812.

The throbs and throes of terra firma wrought by the Great New Madrid Earthquakes of 1811-12 no longer trouble the landscape. However, though the motions of these devastating ground vibrations ceased in 1812, their impact can still be seen in the permanent traces of their violence that lie scattered over a 5,000 square mile (12,000 sq. km.) area spanning five states.

Note: This account was adapted with only minor changes from Fuller, Myron L., The New Madrid Earthquakes of 1811-1812, A Scientific Factual Field Account, USGS Bulletin 494, Washington, DC: Government Printing Office, 1912; reprinted by Southwestern Missouri University Center for Earthquake Studies, 1990. Please keep in mind that the numerical Richter magnitudes quoted in this book were not determined by instrumental measurements as they are today, because these events predated the invention of reliable seismographs.

Shake A Minute

***Putting Down Roots*, p. 14**

Idaho State Standards:

8th/9th Earth Science 1.2.1, 1.8.1
8th Mathematics 1.3.1, 5.1.1
9th Mathematics 1.1.2

Objectives:

Students will:

1. Demonstrate how long an average earthquake lasts.
2. Compare duration of different historical earthquakes.
3. Correlate earthquake duration with intensity.

RATIONALE

This activity is teacher-directed and a good "hook" or opening for instruction on hazards associated with ground shaking. Most people caught in earthquakes have a feeling of helplessness. Especially if they have never experienced an earthquake, students have no idea how long one will last or what to expect during such an event. During an earthquake, people often overestimate the length of time that the shaking of an earthquake lasts.

FOCUS QUESTION(S):

- How long do most earthquakes (ground shaking) last?
- What type of damage would occur to the classroom from a long duration earthquake?

TEACHING CLUES AND CUES

Instruct students to shake with care, so they don't hurt themselves or anyone around them. The most recent data indicates that the Borah Peak earthquake lasted approximately 9 seconds. **Do not tell students this yet**. Many factors play into ground shaking duration and intensity. These three factors are:

- Magnitude of the earthquake--in general, the larger the quake, the stronger the shaking and the larger the area affected,
- Distance to the earthquake--the closer to the source of the quake, the stronger the shaking, and
- Type of ground material and soils--may amplify or change characteristics of the shaking relative to hard bedrock.

*Page 14, *Putting Down Roots*, see diagram at the bottom left of the page or go to http://www.bhs.idaho.gov/pages/Preparedness/Hazards/NaturalHazards/Earthquake.aspx and then scroll down and click on the booklet cover. A PDF version will open and you can project the diagram in the classroom.

The only accurate way to determine the length of time that the earthquake lasted is to take the information directly from the seismogram. The seismogram however will show longer ground motion than what can be detected by humans. The 9 second value given for this activity is a time of ground shaking that could be detected by humans. The seismogram for the Borah Peak main shock shows a value of 30 seconds.

MATERIALS:

for teacher

- Large clock with a second hand or stop watch
- White board/chalk board and markers/chalk
- *Optional*: Computer with internet connection and Projection equipment if doing any of the Extension activities

for the students: (work in pairs)

- Pencil/pen
- Paper

PROCEDURE:

Teacher Preparation

Form teams of two students.

Instruct students to shake with care, so they don't hurt themselves or anyone around them.

A. Introduction

Ask students to estimate on a piece of paper how long they think an earthquake lasts. How long will the ground shake? Collect the estimates. Explain to students that in most earthquakes, shaking rarely lasts for as long as a minute in any one area. Strong shaking from a major quake usually lasts from 30 to 60 seconds. For example, the 1906 San Francisco earthquake lasted about 40 seconds. In the 1964 Alaskan earthquake, the shaking lasted 180-240 seconds (3-4 minutes) – an extremely long time. This does not happen very often.

B. Lesson Development

1. Collect the estimates and list them on the board.
2. Steps 3-7 are optional. If classroom time is limited, skip to Step 8.
3. Tell students that they are going to estimate how long a one-minute earthquake is without looking at the clock. Have them break up into pairs. One of each pair will be the timekeeper and recorder, while the other is the "earthquake."

4. When you give the signal, the earthquakes (students) are to begin shaking, and the timers are to begin timing. Ask the quakes

whose backs should be to the chalkboard or whiteboard to continue shaking until they think that a minute has passed.

5. Once the timing and shaking start, write the time elapsed on the board every five seconds. The timers, who can see the board, should record the last time listed when their partners stop shaking. Instruct the timers not to share the time with the earthquake students yet.

6. Ask the timers to report the actual times that each "quake" lasted. Write all of the times on the board. Have the class compare the times:

- How long was the shortest "earthquake"?

- How long was the longest?

- What was the average time for this group?

7. Have partners switch roles and repeat steps 4, 5, and 8. Ask the class:

- Did the second group come closer to one minute than the first?

- If the answer is yes, why? *Perhaps because the second pair of students had the advantage of observing the first pair.*

8. Now have everyone in the class shake for one minute at the same time. Tell them when to start and stop, but ask them not to watch the clock. Then ask:

- Did the time you shook seem like more or less than a minute? *Explain that even though an earthquake is over in a short time, Idaho = 9 seconds, it usually seems much longer to those people experiencing it. Why?*

- What might happen to objects in this classroom if the ground shook strongly for a minute? *Answers will vary.*

C. Conclusion

Summarize the information about ground shaking and how different factors can result in different ground shaking times (duration).

Adaptations and Extensions

Have students go on-line to determine the duration of some of the more recent earthquakes worldwide, such as Sumatra-Andaman Islands on December 26, 2004 or Tohoku, Japan, near the coast of Honshu, on March 11, 2011.

Go to the USGS site at http://earthquake.usgs.gov/earthquakes/world/historical.php to get a list of recent or historic earthquakes that have occurred in the United States or in other places throughout the world.

- You may sort by magnitude to arrange from largest to smallest or by date.
- On the left side bar, select "Seismogram Display." A map of North America with seismic symbols will load. Below, there is a list of sites you can open to display seismograms. Either click directly on one of the locations on the map or select from the list.
- A screen with "Recent Heliocorder Displays" lists a series of dates for different locations within that state. To see how it works, select the first date in the list (Broadband Vertical) and look at the seismogram displayed (click on the image to enlarge).
- Go back and select the same date from the Short Period Vertical list below and display.
- Finally go to the Long Period Vertical list and display this seismogram. It will allow you to display the same earthquake but at different frequencies of ground motion. Students can read directly off of the seismogram for the duration of the shaking by looking for the P-wave signal and the end of the L-wave signal.

Another great site for pulling up seismograms and reading the duration of detectable ground motions from around the world can be found at Global-IRIS-Rev at http://rev.seis.sc.edu/. It is possible to compare seismograms of the same earthquake, but from different stations side by side.

At the bottom of the home page of the REV site are some educational "Links of Interest." One of the best sites is the DLESE Teaching Boxes site at http://www.teachingboxes.org/earthquakes/#extraRev(), an outstanding repository of teacher resources for all areas of Earth Science and grade level. All lessons/activities on this site have been evaluated for their scientific accuracy and educational pedagogy in the classroom. From this page, scroll down to the section "EXTRA: Rapid Earthquake Viewer Lessons" to find a list of REV lessons follows, as well as a tutorial on using REV.

For more DLESE lesson boxes go to http://www.teachingboxes.org/index.jsp for a list.

Teacher Background Material

A Comparison of Magnitude and Rupture Length for Earthquakes in the United States

Magnitude	Date	Location	Rupture Length (kilometers)	Duration (seconds)
9.2	March 27, 1964	Alaska	1,000	420
7.9	November 3, 2002	Denali, AK	300	90
7.8	January 9, 1857	Fort Tejon, CA	360	130
7.7	April 18, 1906	San Francisco, CA	400	110
7.2 - 7.8	February 7, 1812	New Madrid, MO	40 - 100	13 - 30
7.3	June 28, 1992	Landers, CA	70	24
7.3	August 17, 1959	Lake Hebgen, MT	44	12
7.0	October 17, 1989	Loma Prieta, CA	40	7
6.9	October 28, 1983	Borah Peak, ID	34	9
6.8	February 28, 2001	Nisqually, WA	20	6
6.7	January 17, 1994	Northridge, CA	14	7
6.4	March 10, 1933	Long Beach, CA	15	5
5.9	October 1, 1987	Whittier Narrows, CA	6	3
5.8	June 28, 1991	Sierra Madre, CA	5	2
5.2	September 3, 2001	Yountville, CA	4	2

Source: Southern California Earthquake Center (SCEC), “Putting Down Roots Handbook,” Separating Fact from Fiction, April 11, 2011.

Lab - Modeling Elastic Rebound

***Putting Down Roots*, pp. 14 - 15**

Idaho State Standards:

8th/9th Earth Science 1.2 (all), 1.3 (all), 1.6.3, 1.8.1
8th Mathematics 3.5.1, 4.3.1, 5.1.1, 5.1.2, 5.2.1, 5.4.1, 5.5.1
9th Mathematics 1.1.1, 1.2.1, 2.1.1, 2.2, 2.3.1, 2.4.1, 3.2, 3.3, 3.5, 3.6, 4.3, 4.4, 5.1.1, 5.2.1, 5.3, 5.4, 5.5

Objectives:

Students will be able to:

1. Define earthquakes and model their occurrence.
2. Give examples of why models are important in science.
3. Explain energy transfer as applied to the model.
4. Use and explain the model to generate data that will be analyzed.
5. Critically analyze data generated by the Earthquake Machine.
6. Describe the global trends for earthquake occurrence and size.
7. Interpret a Gutenberg Richter plot (frequency v. magnitude).

RATIONALE

Tectonic earthquakes are caused by a sudden slippage along the boundary (fault) between two plates. In this activity, students explore a mechanical model of a fault to examine how energy is stored elastically in rocks and released suddenly as an earthquake. Students then use the model to understand why some earthquakes are small and some are large. They will make observations, collect data, and compare modeled data to global data. The earthquake machine model is a slip-predictable fault model that demonstrates the property of elastic rebound. This means that when an earthquake occurs on the fault, the stress in the system always releases all stored energy so that the system returns to a "zero" state. Thus, this model cannot be used to predict when the next event will occur, but can be used to predict the magnitude of the earthquake if it were to occur at any given time.

FOCUS QUESTION(S):

- How frequently do earthquakes occur?
- What is the role of a model in science?
- How frequently do large events occur?
- Can earthquakes be predicted?
- How does the model data compare to global data?

TEACHING CLUES AND CUES

This lab activity can be performed on a table top and would not require the set up listed below. However, if the surfaces are very smooth (ex. plastic laminate), then the block will tend to slide as the rubber band is stretched, rather than stick and then slip. One option for increasing friction between the block being pulled and the table is to attach a sanding belt to the table top surface. Another option is to use a strip of elastic fabric (such as Spandex), one meter long and slightly wider than the 2x4 block, taped to the table surface. It is important that the block remain on the sanding belt or elastic fabric and does not scratch the table surface.

Instructions for construction of the earthquake slip-stick model can be found on pp. 77 - 78. The attachment of a model building to the block provides a visual clue to the stick-slip motion and energy released. The further the block slips, the more energy released, and the more violently the building shakes. Through the use of the model, students will be able to see the elastic nature of earth materials by clearly seeing that energy is put into the system, stored as potential energy in the rubber band, and then suddenly released as an earthquake. Without the elastic component of the system, energy could not be stored and earthquakes could not occur.

The model accurately simulates the strain energy that slowly accumulates in rock surrounding a locked fault that is released in a sudden slip event known as the Elastic Rebound Theory, it is ultimately a simplification of a complex earth system (Bolt, 2004). Such simplifications must be understood to interpret the model accurately. Therefore the relationship between the model and reality should be clearly emphasized to students, since middle and high school aged students often think of physical models as copies of reality rather than representations (Grosslight et al., 1991). See p. 82 for a concept map of the Elastic Rebound Theory.

MATERIALS:
for one EQ Stick-Slip Model (for construction procedures see pp. 77 - 78)

- 1 – one foot piece of 2X4 scrap wood
- 1 – 4"x36" sanding belt, 50 grit
- 1 – 1/3 sheet of sandpaper, 60 grit
- 1 – screw eye 12x1-3/16
- 1 – bag of rubber bands, varying size
- 1 – cloth tape measure with both English and Metric markings (a meter stick can substitute for this)

- 1 – manila folder
- 1 – roll of duct tape (to hold down meter stick or cloth tape measure)

for teacher

- Teacher Background, pp. 79 - 81
- Answer Key, Student Lab worksheet, pp. 88 - 89
- Answer Key, Student Homework, p. 90
- Concept Map of Elastic Rebound Theory, p. 82

for the students: (work in pairs)

- 1 – Stick-slip model
- Student Lab worksheet "Earthquake Slip Model - Lab," pp. 83 - 84
- Student Homework, pp. 85 - 87
- Graph paper
- Pencil or Pen

PROCEDURE:

Teacher Preparation

In addition to gathering the materials needed for each group and constructing the Earthquake slip model (see pp. 79-80), it is important to experiment with some of the blocks of wood and the surfaces that students will use. If the surfaces are very smooth, then the block will tend to slide as the rubber band is stretched, rather than stick and then slip. There are places along the San Andreas Fault where the fault creeps, rather than sticking to generate an earthquake, so this type of behavior is possible for faults as well as for blocks of wood. However, this lab would not be very interesting if the block moved by creep rather than by stick-slip motion.

It is possible to calculate the magnitude of the "earthquake" generated on the earthquake machine. However, this is not the purpose of this lab. For instructions on how to determine magnitude, go to http://www.jclahr.com/science/earth_science/tabletop/earthshaking/index.html and access the section "Understanding the Results."

A. Introduction

Tectonic earthquakes are caused by a sudden slippage along the boundary (fault) between two plates. The type of motion that occurs between two plates is used to classify faults as strike-slip (one plate slides past another), reverse or thrust (one plate slides under another or come together) or normal (plates that are pulling apart from each other). Although one might expect earthquakes at the base of the plates where they slide over the materials of the Earth's mantle, the high temperature and material properties at 80 km depth are such that plates slide along without generating earthquakes on their lower surface.

Typical rates of plate motion are a few centimeters per year. Consider why destructive earthquakes occur in which many meters of fault slip happen so quickly that the vibrations are recorded by seismographs all around the world and are sometimes strong enough to destroy nearby buildings and bridges. This is where friction and elasticity come into play. Since the shallow portions of the plates are relatively cool, two plates cannot flow past each other, but rather the faults that form their boundaries tend to stick or lock up for years or centuries at a time. Each year, portions of plates near locked faults deform elastically by a few centimeters. The more the plates are bent and deformed, the greater the force is on the fault (shear stress). Eventually the force is sufficient to make the plates break free of one another and the elastic energy that has been stored up is released as frictional heating on the fault and ground vibrations, called seismic waves. This process of faulting is called stick-slip or elastic rebound (Figure 1).

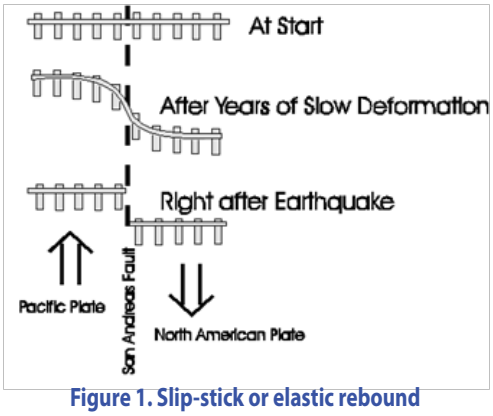


Figure 1. Slip-stick or elastic rebound

The initial force of the fault must be able to overcome static friction. Once the fault starts slipping, slip will continue until the force drops below the resistance of sliding friction. The force available to keep this fault slipping decreases as the distorted plates return to their original shape.

B. Lesson Development

1. Group students into teams of 3-4.

2. Provide students with the materials necessary to complete the lab.

3. Take a few minutes to make a string of rubber bands, by looping them together. Loop one completely through the eye bolt of the block of wood. Stick-slip motion is more likely if the rubber bands are thin and the string of rubber bands is long.

4. One student will be the "puller," one will be the observer, and one or two will take notes.

5. The puller will start with the rubber bands fully stretched, so that there is almost no tension on the block of wood. Use a pencil to pull the rubber band and the point to identify its position (Figure 2).

6. This initial position on the tape measure/meter stick of the leading edge of the block and the leading end of the string of rubber bands needs to be identified and recorded by the recorder(s). Set up a data table to keep track of the data (Table 1).

7. When everyone is ready, the puller will move the end of the rubber bands 1 cm. and then count slowly out loud, "one, one, one," move the end of the rubber bands 1 more cm., and then count slowly out loud, "two, two, two," move 1 cm., count slowly out loud, "three, three, three," and so forth. See Model Slip videos

Table 1. Sample Data Table

Event #	ΔT (cm rubber band is stretched) (1cm = 1 year)	Displacement of block (cm)
1	1	1.4
2	5	6.9
3	8	12.6
4	3	3

in folder or go to http://www.jclahr.com/science/earth_science/tabletop/earthshaking/video/index.html. Counting in this way allows for three seconds between the next stretch of the rubber band.

8. The observer will read out loud the position of the leading edge of the block at its initial position and then after each movement of the block, while the recorders(s) record the numbers. It is important that the observer take accurate measurements of "any" block movement no matter how small. *Clue: watch for motion of the building to indicate movement.* The number of centimeters that the rubber band stretched should also be recorded when movement occurs. See p. 86 for an example of how a graph for recording time v. the amount of displacement should be set up. If the block moves as the puller is moving to the next centimeter, then the movement is assigned to the higher value. This model assumes that the plates are moving at 1 cm per year. Thus, the change in rubber band stretch is referred to as ΔT.

9. Continue to take readings for the complete length of the sanding belt. While it is not necessary for the rubber band to be on the sanding belt, the block of wood should be while measurements are taken.

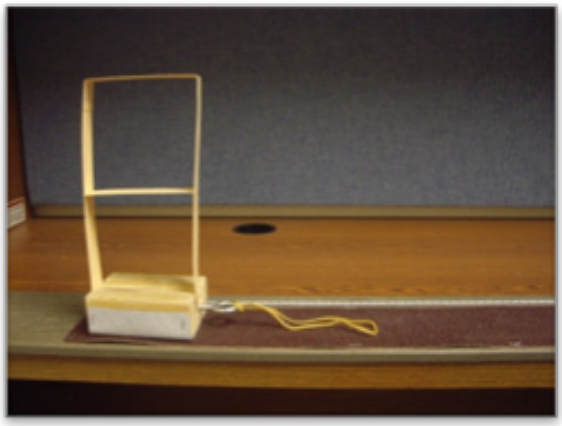


Figure 2

C. Conclusion

Now that you have an idea about how the lab works, discuss what you think is going on. How is friction related to the movement of the block? What do the different parts of the model represent in real life? Sketch a diagram of the model to show how energy is transferred. Would you expect the motion of the block to be the same if the experiment were repeated? Repeat the experiment twice, each time changing the spuller, observer, and recorder assignments. Graph the additional two sets of data.

Adaptations and Extensions

- Connecting two blocks of wood, as shown in the video, will allow for variations in the lab and demonstrate how foreshocks precede the main earthquake, as well as the occurrence of aftershocks.
- Make blocks with different grits of sandpaper. Does this change the data? How?
- Have groups compare their data to other groups.

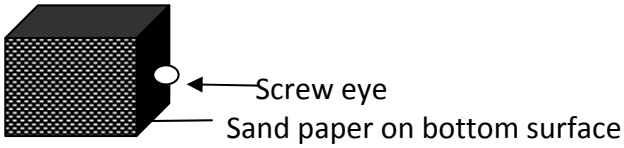
Construction of Earthquake Stick-Slip Model

A class set can be made in about 2 hours
1 – One foot piece of 2x4 scrap wood (<$1.00 @building supply)
1 – 4”x36” sanding belt, 50 grit ($5.00 @building supply)
1 – 1/3 sheet of sandpaper, 60 grit (<$2.00 @building supply)
4 – Screw eye 12x1-3/16 ($5 per bag @building supply)
1 – Bag of rubber bands, varying size, or size *117B works well* ($0.99/ bag @office supply)
16 in of duct tape ($2.48 per roll @building supply)
1 – Waxed cloth tape measure with English and Metric markings ($1.20 each @craft store) or one meter stick
1 – Manila folder

<u>Tools</u>
- Saw
- Needle nose pliers
- Scissors
- Tape/glue (white or contact cement)
- Pencil

1- Using the tape measure and pencil, divide the one-foot length of 2”x 4” into three 4” blocks.
2- Using the saw cut along your markings to create three 4” x 4” x 2” blocks.
3- Trace one of the blocks on the back of the 60 grit sandpaper & use the scissors to cut out squares that fold up over the edges of the block.
4- Use a staple gun to attach the sandpaper square to Block A so the staples are in the side edges.
5- Screw one screw eye into a cut end of the block (See figure 1.)

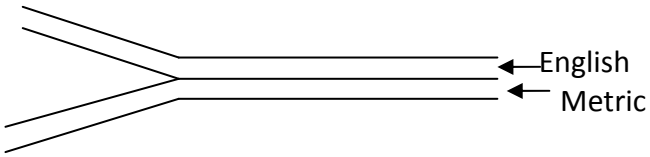
Fig. 1



6- Loop a rubber band through the eye of the screw eye or using the needle nose pliers, carefully bend the eye of the screw eye open just enough to allow a rubber band to fit through.
7- Using scissors cut the sanding belt so it is no longer a connected loop. Use a staple gun to attach the cut sanding belt to the length of board. Duct tape may also be used to attach the belt to the table. Make sure to stretch the sanding belt taut, so there are no waves in the sanding belt.
8- Using pliers remove the metal ends from the measuring tape. *If you use a meter stick, steps 8-10 are not necessary. If you choose not to cut the measuring tape, be sure that students use only the metric side).*

9- Using scissors cut the measuring tape without the metal ends up the middle lengthwise, being careful to leave the cm markings intact (See Figure 2).

Fig. 2



10- Discard the half of the split measuring tape marked in English.

11- Cut four strips out of the manila folder; two that are 3 cm wide and 15 cm long, and two that are 3 cm wide and 23 cm long. Measure in 2.5 cm from each end of the 15 cm strips and fold down. These folds will be your anchor points for taping to the 23 cm strips (Figure 3).

12- Assemble the strips of manila folder with tape as shown in Figure 4 and tape or staple to the top side of Block A.

Fig. 3

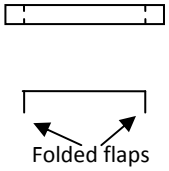
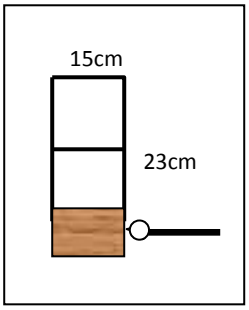
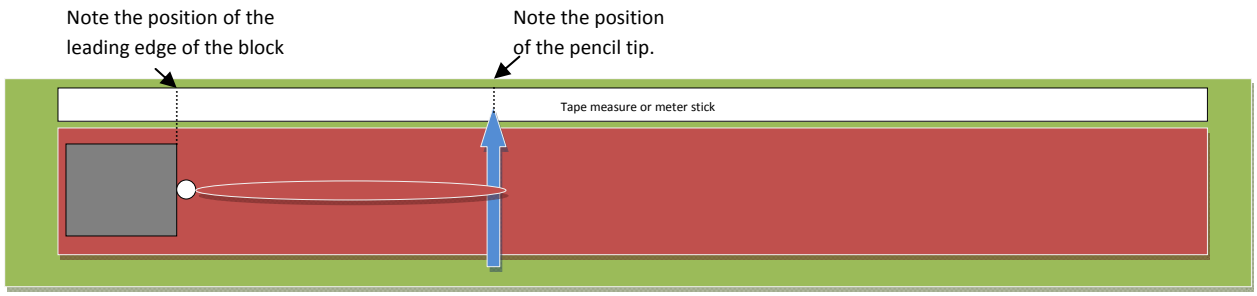


Fig. 4



Earthquake Slip Model Set-Up

Side View



Top View

Teacher Background

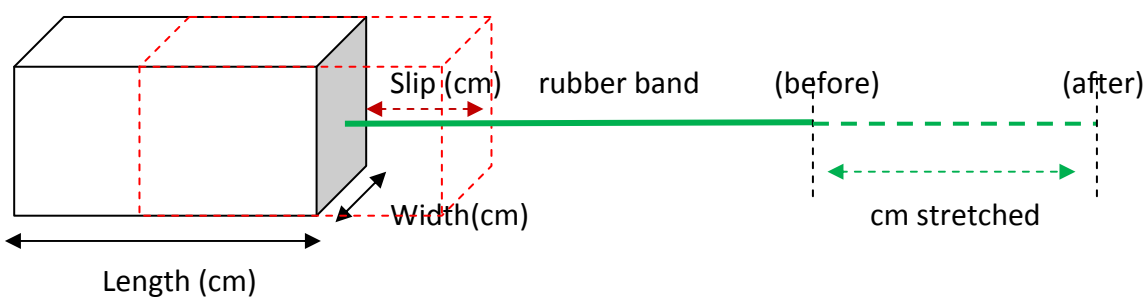
Calculating Magnitude Using the Model*

The model provides a physical perspective on the generation of earthquake's and also illustrates the concept of an earthquake's Magnitude (M_o) based on the physical features of the fault. An estimate of the energy of an earthquake is called the *Seismic Moment (M_o)* and is typically given in units of Newton-meters (Nm). It is possible to calculate the M_o of the events on the stick-slip model. All measured values from the model must be **converted to meters** (1 cm = 0.01 m).

- **S**urface Area of Fault (m^2) = Fault length x Fault width (depth)
- **D**isplacement (slip) (m) = amount that the block moved
- **μ** = Rigidity of rock along the fault (N/m^2) which is represented by the elasticity of the rubber band. This value is the amount that the bands stretched prior to movement.

$$M_o = S * D * \mu$$

- As long as the same block is used throughout, the surface area will remain constant. The rigidity or stretch of the rubber band will vary, as will the amount of displacement or slip for each event or "earthquake."



Example:

Surface area = L(10.1 cm) x W(8.7 cm)
S=87.87 cm^2 = 0.8787 m^2
Displacement = 4.5 cm = 0.045 m
μ(stretch) = 4 cm = 0.04 N/m^2

M_o= 0.8787 x 0.045 x 0.04 = 0.0015816 Nm (amount of energy released)

- To equate these values to the Richter scale, another calculation must be done. This calculation will provide the Moment Magnitude (M_w) as it relates to the Richter scale.

$$M_w = \log M_o / 1.5 - 10.7$$

- When plugging in the values for the above formula, the value calculated for each event will be extremely small, so that the magnitudes will be negative numbers. Larger events will have less negative numbers. Calculated values will be anything from -14 to -10, with value of -14 smaller than a value of -10, and corresponds to the Richter scale. When the data is plotted, students should see the relationship between the stretch of the rubber band and the magnitude of the earthquake generated. The more the rubber band was stretched, the larger the earthquake and the smaller (negative value) the Richter value calculated. S*ee sample data and graphs on CD-ROM.*

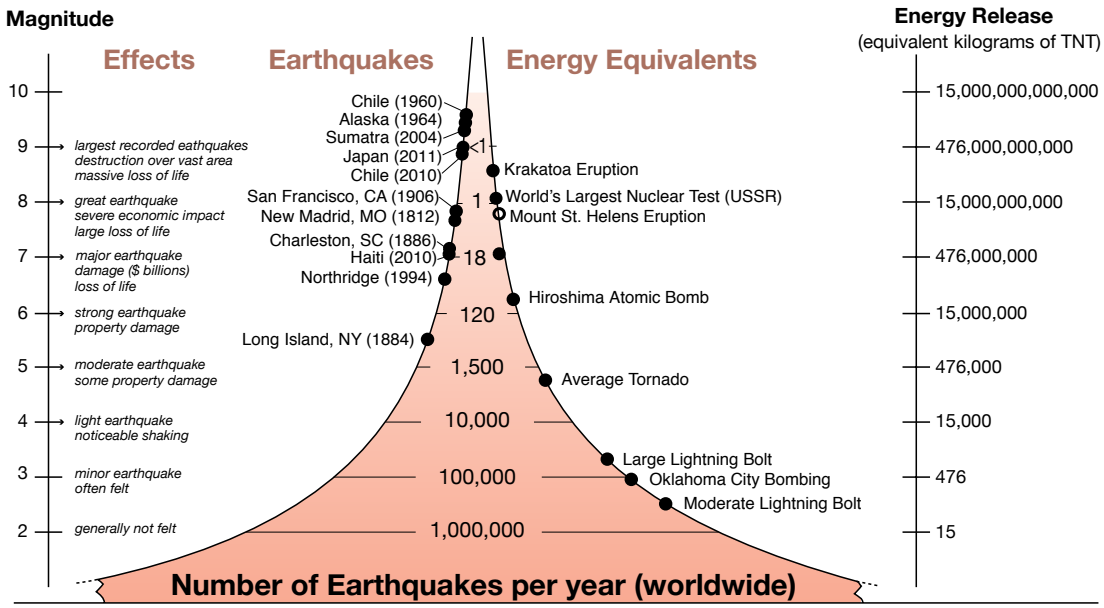
  Example:

  M_w=log 0.0015816/1.5 – 10.7
  M_w=-2.8009/1.5-10.7
  M_w=-12.567 (dimensionless value) = -12.6 Richter scale value

- While some aspects of the mathematical relationship may be premature for some students, all students will physically see this relationship by noting how much the building on top of the block moves in relationship to the amount the block slips. The further the block slips, the more energy is released, and the more violently the building shakes.

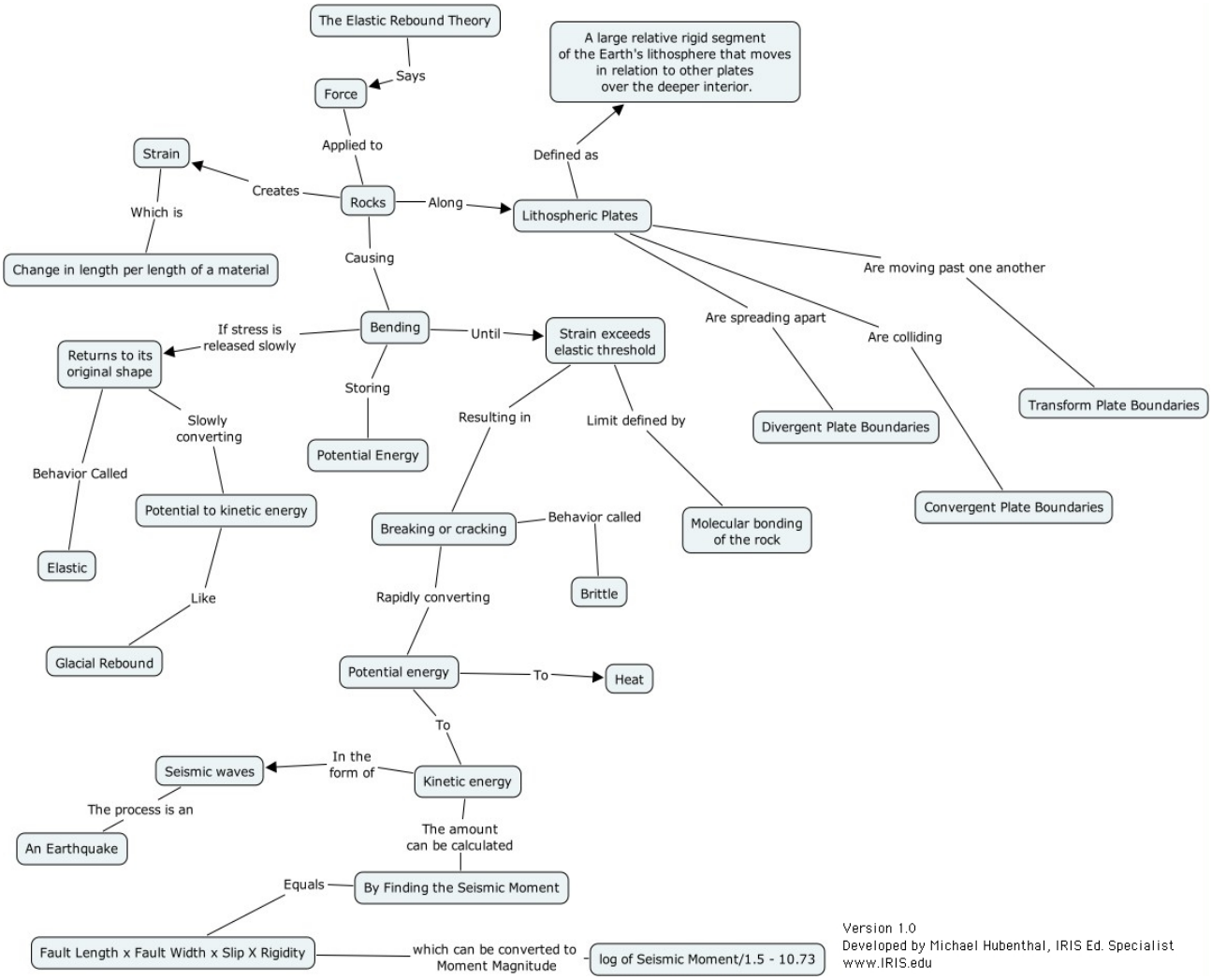
**A PowerPoint presentation entitled "Calculating magnitude" can be found on the CD-ROM in the Unit folder for this activity.*

Magnitude is a number that characterizes the relative size of earthquakes and is proportional to energy released.



The above "One-Pager" from IRIS shows the relationship between magnitude and energy. This graphic representation may help students to understand this relationship. http://www.iris.edu/hq/publications/brochures_and_onepagers/edu.

Concept Map of Elastic Rebound Theory



Student worksheet

Earthquake Slip Model – Lab

Name_____ Period _____ Date_____

Directions: Think about the model and what you did. Answer the following questions using complete sentences where appropriate.

1. Was the shaking of the building a cause or a result of the block moving?

2. Describe the sequence of steps leading up to the model building shaking.

3. Where did the energy originate that made the block move? Where might this same energy originate in the Earth to create an earthquake?

4. In what way does the force between the block and the rubber band vary as the rubber bands are stretched?

5. Does the probability that the block will slip during the next interval of time depend on the history of past block movements? Explain your answer.

6. What did this model allow you to see that you don't think you would be able to see if looking at a real fault?

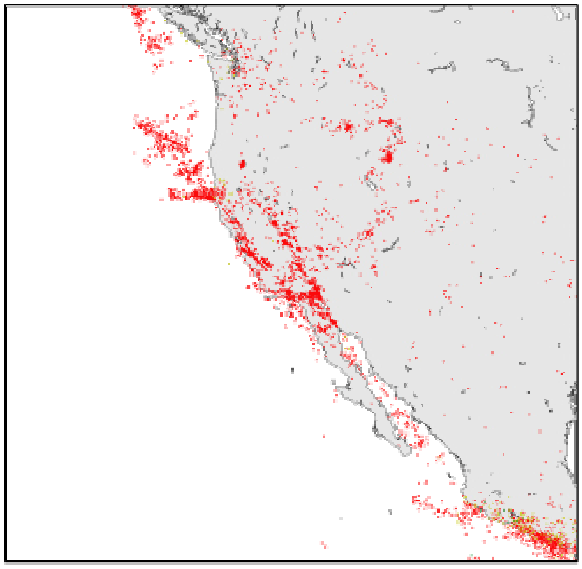
7. How might this model be like/unlike an actual fault and earthquake?

8. How would you modify the model so that it no longer stored energy? How do you think your modification would impact the model's overall operation?

9. What aspects of the model were you able to "measure" quantitatively?

10. Graph the data that you gathered from the stick-slip model. Place "Time" on the X axis and "Displacement" on the Y axis, use the graph provided, or generate the graph using a graphing program.

11. Study the map of the western United States. Use your understanding of how and why earthquakes happen to explain why the earthquakes shown are located where they are.



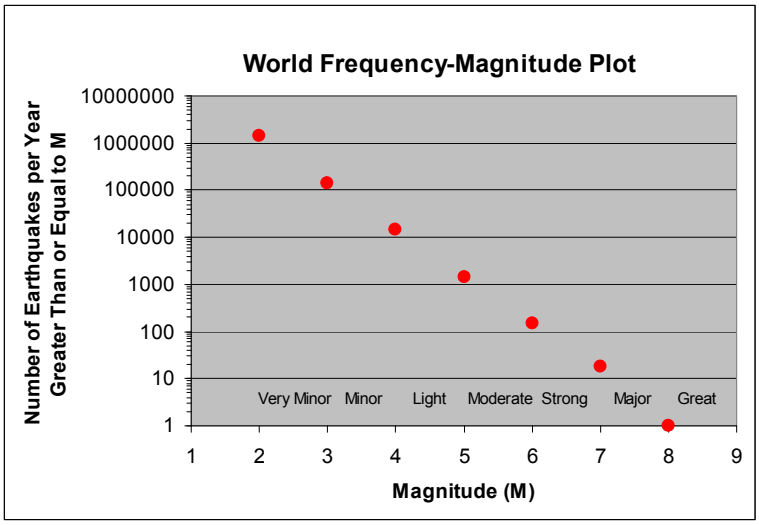
Earthquakes of the western United States
(Sawyer, 2005)

Homework

Comparing the Model and Reality

Name _____ Period_____Date_____

Directions: Review the following graph, and answer the questions using complete sentences where appropriate.



Frequency-magnitude plot; worldwide earthquakes per year. (Braile, 2004)

1. What information does the Y axis tell us?

2. What information does the X axis tell us?

3. On the Y axis, how many small lines are there between 1 and 10?

4. On the Y axis, how many small lines are there between 10,000 and 100,000?

5. With regard to question number 4 above, what is the value of each of the small lines?

6. What is the value of the small lines between 100 and 1000 on the Y axis?

7. According to the graph above, approximately how many Magnitude 8 earthquakes occur each year?

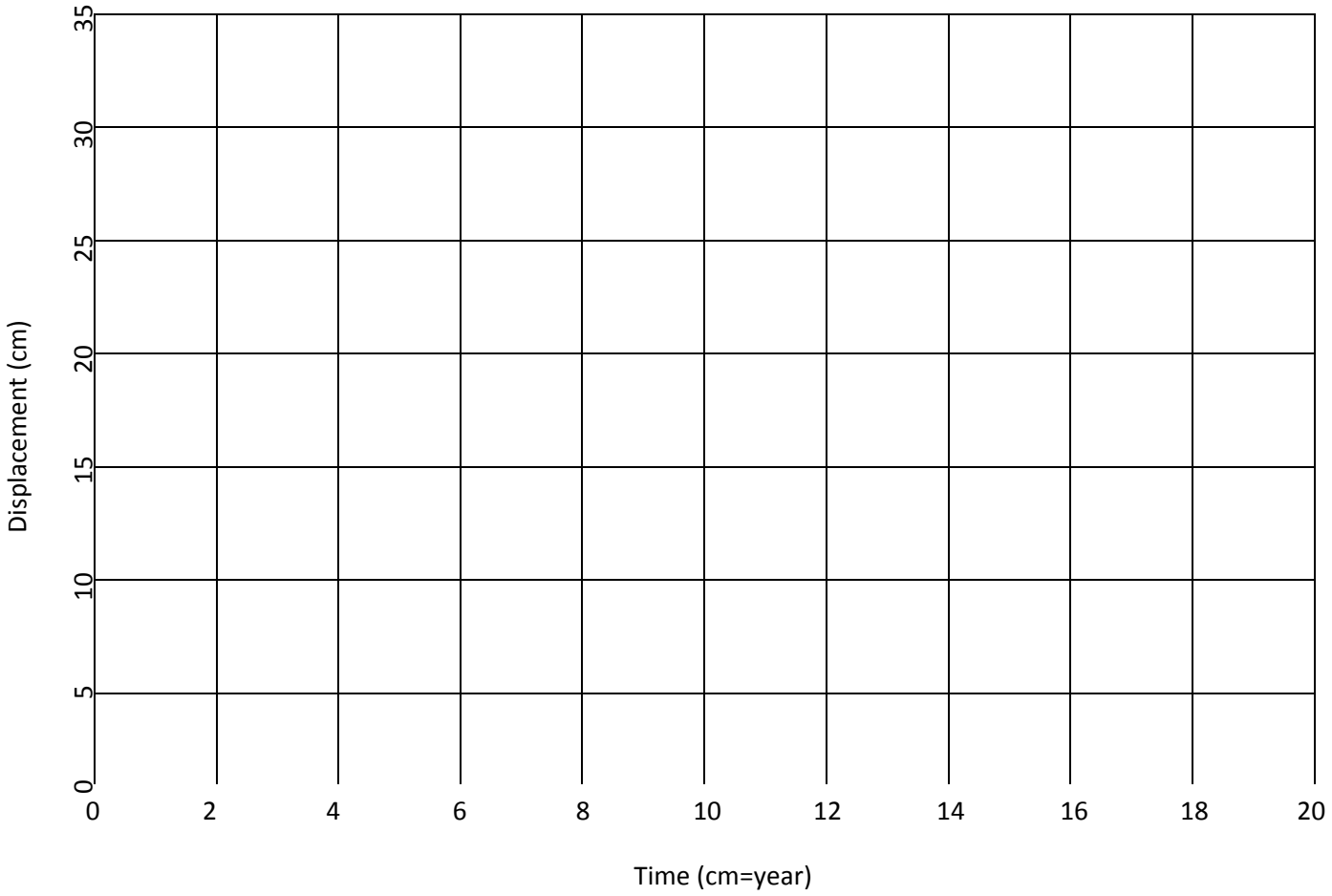
8. Approximately how many Magnitude 3 earthquakes occur each year?

9. Keeping your responses to questions #5 and #6 in mind, what would be the next major line on the Y axis below the X,Y intercept?

10. If you were to extrapolate the graph by extending the slope of the line off the bottom of the graph, approximately how frequently would you expect a Magnitude 9 earthquake to occur?

11. Is the global data shown in the graph above like or unlike the data collected from the lab using the model? How? Give specifics.

Time vs. Amount of Displacement



Answer Key to Lab

1. Was the shaking of the building a cause or a result of the block moving?
   The shaking of the building was the result of the block moving. The building didn't shake until the block moved.

2. Describe the sequence of steps leading up to the model building shaking.
   1- Pull on the rubber band 2- Energy stored in rubber band 3- Stress exceeds the rigidity of the fault 4- Block slips forward releasing energy as heat, and seismic waves. **Kinetic e*nergy was added to the rubber band to stretch it. It was stored as potential energy. When energy/force was greater than the friction between the block and the surface then the block moved. When friction became greater than the energy stored in the rubber band then the block stopped moving. The model building responded to the movement of the block since it was attached to the block. The amount that it shook correlates with the amount the block moved at any one event.***

3. Where did the energy that made the block move originate? Where might this same energy originate in the Earth to create an earthquake?
   The energy that made the block move came from the muscles of the arm pulling the rubber band. The energy that drives motion of the plates on the Earth comes from the heat of the Earths mantel. Convective motion generates the motion that puts strain and stresses on the lithospheric plates.

4. In what way does the force between the block and the rubber band vary as the rubber bands are stretched?
   As the rubber band is stretched it applies more force on the block. This elastic strain must be greater than the frictional force of the block for the block to move. Sometimes the block moves without a lot of stress and sometimes it takes more stress to get it to move.

5. Does the probability that the block will slip during the next interval of time depend on the history of past block movements? Explain your answer.
   The probability that the block will slip increases as time passes without motion. If there have been many small movements then the likelihood of a large movement decreases.

6. What did this model allow you to see that you don't think you would be able to see if looking at a real fault?
   The model allowed us to "hear" and "see" the smallest of slips. We were able to see over and over how stress was building up by looking at the stretch of the rubber band. We wouldn't be able to see that stress in a real fault. (Students may come up with more)

7. How might this model be like/unlike an actual fault and earthquake?
   Answers will vary. This is an evaluation question and all answers should be accepted.

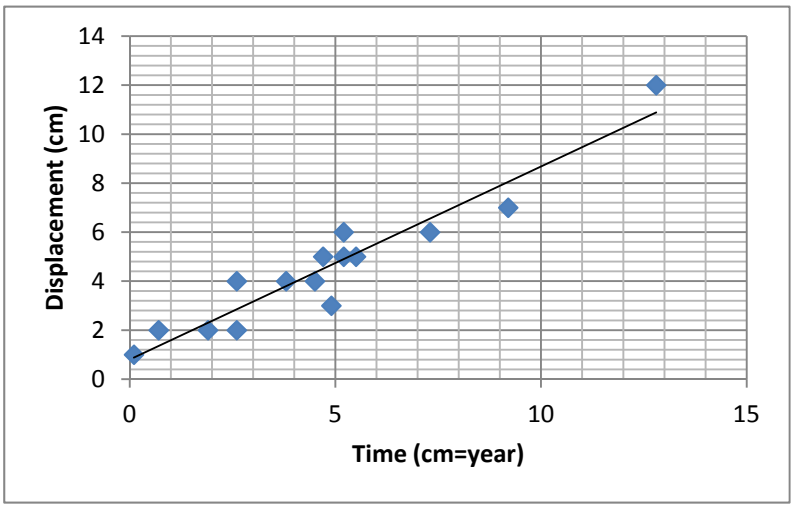
8. How would you modify the model so that it no longer stored energy? How do you think your modification would impact the models overall operation?

To modify the model a string could be used to pull the block instead of rubber bands. String would not allow the energy to be stored. The block would not stick-slip. Another modification could be to have the block placed on a smooth surface so that it did not stick. This would produce a slow and steady "creeping" motion without sudden movements.

9. What aspects of the model were you able to "measure" quantitatively?

The number of events, the distance the block moved on each event, the number of centimeters the rubber band was stretched between events.

10. Graph the data that you gathered from the stick-slip model. Place "Time" on the X axis and "Displacement" on the Y axis, use the graph provided, or generate the graph using a graphing program. *Sample graph from actual data, N=15.*



11. Study the map of the western United States. Use your understanding of how and why earthquakes happen to explain why the earthquakes shown are located where they are.

The western part of the United States is under a lot of stress. There is shear stress from the interaction of the Pacific and North American plate. There is compressional stress from the subduction of the Juan de Fuca plate (Cascadia subduction zone) beneath the North American plate and there is tensional stress from the presence of the Yellowstone Hot Spot located in southeastern Idaho/southwestern Montana.

Answer Key to Homework

1. What information does the Y axis tell us?
   The Y axis tells us the number of earthquakes that occur yearly.

2. What information does the X axis tell us?
   The X axis tells us the magnitude of the events.

3. On the Y axis, how many small lines are there between 1 and 10?
   There are eight small lines between 1 and 10 on the Y axis.

4. On the Y axis, how many small lines are there between 10,000 and 100,000?
   There are eight small lines between 10,000 and 100,000 on the Y axis.

5. With regard to question number 4 above, what is the value of each of the small lines?
   Each small line is equal to 10,000 earthquakes per year.

6. What is the value of the small lines between 100 and 1000 on the Y axis?
   Each small line is equal to 100 earthquakes per year.

7. According to the graph above, approximately how many Magnitude 8 earthquakes occur each year?
   One Magnitude 8 earthquakes should occur each year.

8. Approximately how many Magnitude 3 earthquakes occur each year?
   Between 100,000 and 200,000 Magnitude 3 earthquakes should occur each year.

9. Keeping your responses to questions #5 and #6 in mind, what would be the next major line on the Y axis below the X,Y intercept?
   The next major line long the graph below the X,Y intercept on the graph should be 0.1 earthquakes per year.

10. If you were to extrapolate the graph by extending the slope of the line off the bottom of the graph, approximately how frequently would you expect a Magnitude 9 earthquake to occur?
    One would expect 0.1 Magnitude 9 earthquakes to occur each year, or one every 10 years.

11. Is the global data shown in the graph above like or unlike the data we collected from the stick – slip model? How? Give specifics.
    The data from the model is quite similar to the global data set. Using the model we saw that we had a variety of different sized events occur, but there were significantly more small events and large ones. The same thing happens globally as shown by the graph. There are many, many more small events than large ones.

Earthquakes and Buildings Don't Mix

***Putting Down Roots*, p. 18, "Response of Buildings to Earthquakes"**

Idaho State Standards:

8th/9th Earth Science 1.2.1, 1.2.2, 1.2.3, 1.6.3, 1.6.4 5.1, 5.2.1, 5.2.2, 5.2.3

Objectives:

Students will:

1. Explore earthquake hazards and damage to buildings by constructing model buildings and subjecting the buildings to ground vibration on a small shake table.

2. Compare the results of the building contest with photographs of earthquake damage to reinforce concepts of building design and earthquake risk.

RATIONALE

Students enjoy building the "best." This activity is designed for groups of 2-3 students working cooperatively to construct a model poster board building. The students must take into consideration the forces that act upon buildings during an earthquake. Most of the buildings constructed will withstand vertical or static loads. However, with horizontal motion most buildings will not survive shaking without the installation of diagonal bracing. Showing images of buildings that have collapsed from earthquake shaking will emphasize design weaknesses (see the PowerPoint "eqdamage" located on the CD-ROM).

Earthquake ground shaking and damage are related to the size (magnitude) of the earthquake, the distance from the epicenter, the local geological conditions, and the characteristics of buildings. Assessment of earthquake effects involves evaluating the hazard and the risk.

FOCUS QUESTION(S):

- What is the difference between an earthquake hazard and an earthquake risk?
- Can the risk of damage to buildings and the number of people that are expected to be hurt or killed from an earthquake be mitigated?
- How can buildings be made "earthquake proof?"

TEACHING CLUES AND CUES

The USGS definitions for earthquake hazard and earthquake risk can be found at http://earthquake.usgs.gov/image_glossary/. Inform students that earthquake hazard maps are used by structural engineers and government agencies to revise building codes. Show PowerPoint images of building and structural damage. The Discovery Channel has two good short video segments (1:40 min.) that discuss structural reinforcement techniques: "Engineering the Impossible: Arches vs. Beams" at http://science.discovery.com/videos/engineering-the-impossible-clips-arches-vs-beams.html and "Engineering the Impossible: Earthquake Proof" at http://science.discovery.com/videos/engineering-the-impossible-earthquake-proof.html. There is also a six slide presentation on "5 Reasons Buildings Fail in Quakes" at http://news.discovery.com/tech/five-reasons-buildings-fail-quakes.html.

Construct the simple shake table and either use the accelerometer set up or manually move the table (see instructions for Shake Table, p. 93).

Make sure that the materials for each group are measured and pre-cut. Measure the mass (g) of the different washers you will be using for weights in this activity. Write the mass on the washers with a permanent marker. Different-sized washers can be purchased at hardware stores. Time requirements for this activity are 3-4 class periods.

- Day 1, discuss the activity and show the videos and images. Show the students the materials that they will be using. Explain the activity and how the materials will be used. Give students time to collaborate with their team.
- Day 2, construction of building.
- Day 3, testing of their building.
- Day 4, discussion and wrap up.

Testing. Buildings are tested on the horizontal motion shake table. The base of the building is taped to the base plate of the shake table. The way you orient the building on the shake table will affect the integrity of the building. Most buildings will be able to survive the shaking using small masses (30-50 g). However, few buildings with these materials will withstand strong (about 1 g, 1 g = acceleration of gravity which is 980 cm/s^2 or 9.8 m/s^2), shaking with larger masses (50-80 g). If the shake table is large enough (16 x 50 cm), you can attach and test two or three buildings at the same time to provide a comparison of building responses. Just be sure you have enough washers of the same mass to place on each of the buildings. The use of tape or spring clips may be needed to keep the washers on the building.

MATERIALS:
for teacher

- Computer with internet access and projection system (images can be put on view graph and displayed on overhead projector is needed.

- Poster board, cut into the following dimensions /group:
    - 4 – 8 x 8 cm squares (floors)
    - 12 – 2 x 10 cm strips (uprights)
    - 12 – 1.5 x 15 cm strips (reinforcing)
    - 1 – 30 x 8 cm (cut and use as you wish)

  Note: There is a difference in quality and strength of lightweight poster board; the best poster board has one smooth, almost glossy side and one dull side
- Scotch Tape (2 cm or ¾" wide) 100 cm length/ group
- Scissors
- 30 cm. ruler
- Shake table with optional accelerometer (see instructions)
- Washers of different weight (g): Ten each of 3/4", 5/8", 1/2"

for student groups

- Pre-cut poster board
    - 4 – 8 x 8 cm squares (floors)
    - 12 – 2 x 10 cm strips (uprights)
    - 12 – 1.5 x 15 cm strips (reinforcing)
    - 1 – 30 x 8 cm (cut and use as you wish)
- Scotch Tape (3/4" wide)100 cm lengthm more or less may be needed
- Scissors
- 30 cm ruler

Figure 1. A completed lightweight poster board model building.

PROCEDURE:

Teacher Preparation

Cut up the poster board into the dimensions given. Inform students that the building 1) must be at least 30 cm high, 2) with at least 3 stories, 3) that there can be no central post or uprights (weights must be able to be placed on floors), and 4) that materials are limited to what is given to them. Inform students of the amount of time allotted to teams for construction. Be sure to allow a realistic amount of time for this activity.

A. Introduction

The design of the building will be up to students. Simple, rectangular building designs are effective. Many design options, particularly for the bracing, are possible. When it is time to test the design, the base will be taped to the base of the shake table. Masses (washers) will be placed on the floors and roof of the building and held in place by tape or bull clips.

B. Lesson Development

1. Discuss the difference between hazards and risk. Show images of structural damage from earthquakes. Show video segments on engineering techniques for building design.

2. Tell students they will be in teams of 2-3 and that they will be constructing a 3-story building at least 30 cm tall using the materials provided.

3. Give students time to discuss, collaborate, design, and construct their building.

4. Set up the shake table and test the buildings.

5. After the initial testing, discuss the specific design issue/ problem with the model buildings

C. Conclusion

Some design problems may be poor quality construction, weak joints or uprights, too much rigidity or flexibility, lack of reinforcement or diagonal bracing, etc.

Adaptations and Extensions

Have students construct water towers instead of buildings. Use paper cups held up with poster board strips as the water container. While testing, weigh the paper cup down with washers. You decide on height, materials, quantity, etc.

Model Building and Shake Table Construction

Simple, rectangular building designs are effective (Figure 1). Many design options, particularly for the bracing, are possible.

Testing:

- Buildings are tested on the horizontal motion shake table (Figure 1). Tape the base of the building to the base plate of the shake table. Choose the direction in which you wish to orient the building.

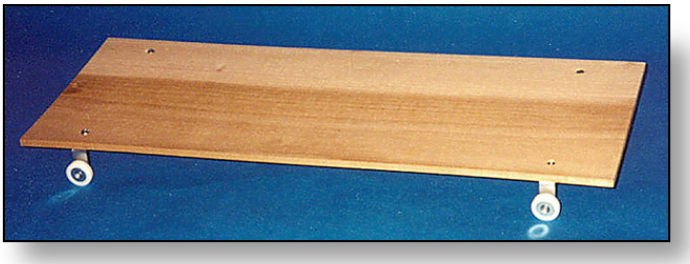


Figure 2. A simple, horizontal motion shake table. Wheels are nylon cabinet or drawer wheels and are attached to the board with "L" brackets, machine screws and nuts.

- Weights (steel washers) are attached to each floor and the roof. Small (5-g) horizontal accelerometers are attached to the shake table and to the top of the building. The results of shake table testing (acceleration versus time of the shake table and the top of the building as the shake table is moved back and forth) can be monitored on the computer screen or projected using an LCD projector for everyone to see.
- If accelerometers are not used,manually move the table back and forth at a constant rate. You will need to practice this. Masking tape applied to the surface on which the shake table sits will allow you to mark distances and that will allow you to push-pull the shake table at a more consistent rate and distance.
- Shake building at three frequencies – low, medium and high – and at three amplitudes – low, medium and high. An accelerometer on the base plate can be used to quantify the shaking and make comparisons between the testing of different buildings more consistent. A second accelerometer can be attached to the top of the building to observe amplification and resonance effects. Small, relatively inexpensive accelerometers, an analog to digital interface for the accelerometers (Serial Box Interface or LabPro), and software (LoggerPro) for the interface are available at Vernier Software (www.vernier.com) or other vendors of "probeware". High School or College physics departments often have Vernier or similar equipment, so you may only need to obtain the accelerometers.
- If your shake table is large enough (a convenient size is about 16 x 50 cm.), you can attach and test two or three buildings at the same time which provides an interesting comparison of building responses.
- After the initial testing, it is possible to illustrate specific design issue/problems with model buildings that were successful. For example, you can create the "soft first story" problem by reducing the shear support in the first story of the building. Sometimes buildings are damaged by a mainshock earthquake and then further damaged or destroyed in an aftershock. Also, poor quality construction or mistakes made in construction can result in specific weak elements of a building. These situations can be simulated in a model building by weakening an upright or a joint by cutting or partially cutting the poster board material or tape. Other building design and construction variations, such as very rigid or very flexible buildings, can be specifically built and tested. Comparing the responses and failure levels of these structures with the original designs that were successful is an excellent method of reinforcing the principles of effective building design and earthquake risk related to structures.
- If time permits, students can construct a second set of buildings that benefit from the lessons learned in the first building contest and shake table testing.

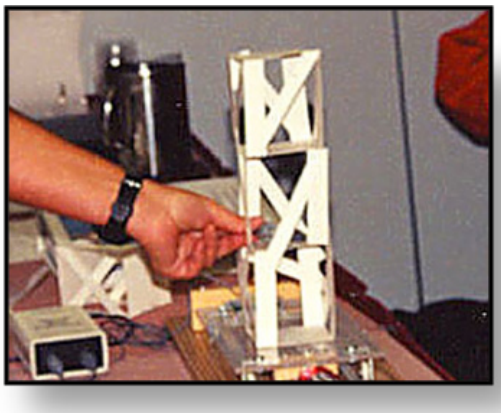


Figure 3. A model building on a shake table.

Alternate Activities: Constructing Earthquake-Proof Buildings

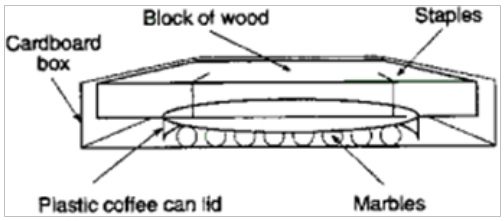
Grade: 6-8
Duration: 3-4 class periods

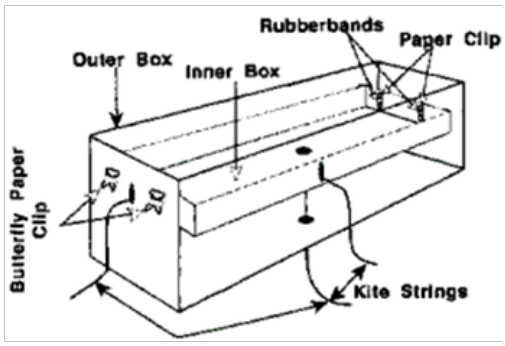
Discovery Education at http://www.discoveryeducation.com/teachers/free-lesson-plans/constructing-earthquake-proof-buildings.cfm. This site has a complete Lesson Plan for constructing Earthquake-Proof buildings.

In this activity, students explore different materials, shapes, and design options that affect the durability of buildings. This activity is much more material intensive, but is suitable for students in grades 6-8. It is also inquiry-based and requires students to test different variables in their construction. It is not a contest, but is more of an experiment on how different models (buildings) perform under controlled conditions.

Science Buddies at http://www.sciencebuddies.org/science-fair-projects/project_ideas/CE_p023.shtml. This site includes an activity that demonstrates how different soil types can affect structures during an earthquake. Simple to follow instructions, materials, and a video make it easy to understand. This activity is better suited for younger students, grades 4-6 (accessed July 26, 2011).

MCEER Building a Shake Table at http://mceer.buffalo.edu/infoservice/Education/shakeTableLessonPlan.asp. This site provides instructions for construction of two different styles of shake tables. Diagrams of the two models are below (accessed July 26, 2011).





Quake - Site Smart

***Putting Down Roots*, p. 18 - 23**

Idaho State Standards:

8th/9th Earth Science 1.2, 1.3.2, 1.6.1, 1.6.2, 1.6.4, 1.8, 4.1.3, 5.1, 5.2

Objectives:

Students will:

1. Interpret soil- and earthquake-related geologic maps.
2. Apply these interpretations in evaluating or choosing a building site.
3. Identify possible hazards associated with a location on the surface map due to the liquefaction Class, geology, or topography of a quadrangle section.
4. Generate a mitigation plan for the area of analysis.

RATIONALE

City planners, developers, builders, and buyers need information about soil and subsoil geology in order to choose sites and design structures that will best withstand ground shaking and other earthquake hazards. In this activity, students analyze maps displaying different types of data to determine the hazards associated with earthquakes present in Idaho communities.

FOCUS QUESTION(S):

- What are the important geologic considerations when choosing a building site and designing or reinforcing a building for earthquake survivability?
- Have these conditions been taken into account in the planning of towns and cities?

TEACHING CLUES AND CUES

Southeastern Idaho is more susceptible to liquefaction and has a higher probability of earthquakes than other parts of Idaho. For this reason, the maps that are included in this activity are from southeastern Idaho. Nevertheless, other cities in the state could also be subject to the same hazards, but at a different scale. It would be appropriate for students to correlate the hazards of Rexburg or Idaho Falls to other cities and towns in the state.

Read the background reading "Site Characteristics." Make copies of this for students to be given as homework prior to the activity. Review general and specific terminology for each map. In the legend, the letters PLSS stand for Public Lands Survey System and identify the sections of the quadrangle that are used. Project an image of each of the maps for discussion purposes. Utilizing the jigsaw technique would be a good method for classroom management for this activity. Group students into teams of 4-5 and have each student responsible for the information on one of the maps. Each student meets with students from other groups with the same map to discuss what they see and understand. In this way, the teacher can focus instruction for each group on their specific map. After instruction/discussion, students should return to their original group to share information on their map.

Project earthquake probability maps of the area or make copies of the map area. When using the USGS probability map site, type in the zip code (Rexburg: 83441, Idaho Falls: 83404) and set the "Time Span" for 100 years and the "magnitude" for 5.2 (the minimum magnitude needed for liquefaction to occur). Rexburg and Idaho Falls are shown in the same probability map area because they are within a 50 km. radius, but if you type in a Rexburg zip code a small triangle will be displayed for the position of Rexburg, north of Idaho Falls, without the printed name.

Making copies of the surface map on overhead transparency film will make it easier for students to correlate surface features to data on the liquefaction class, geology, and topographic maps. Students can then place the surface map on the other maps for analysis. Protecting the surface map with plastic covers will allow students to make marks on the cover while protecting the surface map.

Notes about the Maps:

- On the Surface map, some canals have breaks in their pattern when the canal goes underground. Canals can usually be identified by their straight linearity as compared to natural curves of rivers or streams.
- Accompanying this activity are two word documents titled "Idaho Falls Geologic Text Units" and "Rexburg Geologic Text Units." These contain information in greater depth about the geologic units shown on the Geologic Map. Their description had to be extremely abbreviated for the map legend.
- All maps are to scale, therefore, placement of a feature on one map would be located in the same position on another map even when not displayed.
- When printing the maps make sure that when using the print command, the Page Scaling is set to "Shrink to Printable Area" or "Fit to Printable Area." Otherwise, some information in the legends for the surface and geologic maps will be cut off.
- Assign each group of students to a specific PLSS section of the map, i.e. Sec. 24 or Sec. 18. There are 16 PLSS sections on the map that are within the area of analysis. Choose the most interesting sections to assign to student groups.

MATERIALS:

for teacher

- Background Reading "Site Characteristics," pp. 97 - 98
- Vocabulary, p. 98
- Copies of the following maps, one each per student group
  - -Surface (Color or B/W version), pp. 99 - 100
  - -Liquefaction Class (Color or B/W), pp. 101 - 102
  - -Geologic (Subsoil geology) (Color or B/W), pp. 103 - 104
  - -Topographic (Color only), pp. 105
- Computer and projection equipment to project maps
- *Putting Down Roots in Earthquake Country* booklet, BHS (see address below)
- USGS Seismic Probability map of the area (Rexburg or Idaho Falls) https://geohazards.usgs.gov/eqprob/2009/index.php
- USGS U.S. Seismic Hazard Map, *Putting Down Roots,* p. 19 (or see image in file)
- Idaho Seismic Probability Hazard Map, *Putting Down Roots,* p. 14 (or see images in file)

for student groups

- Copies of background reading, "Site Characteristics" (homework)
- Copies of the 5 maps (1 set of 5 maps)
- Colored pencils or colored transparency markers
- Pen or pencil
- Ruler
- *Optional* - Hand lens, for reading details on the Topographic map

PROCEDURE:

Teacher Preparation

The maps associated with this activity are from two different areas of southeastern Idaho--Rexburg and Idaho Falls. In these areas, the soil type is more likely to undergo liquefaction due to ground shaking. However, many areas of the state can be prone to hazards such as landslides, flooding, and liquefaction due to weather related events other than ground shaking caused by earthquakes.

A. Introduction

Assign students the Background Reading "Site Characteristics" as homework prior to class or read it with them in class. Explain and amplify any unfamiliar terms. Discuss the relationship between liquefaction soils, subsoil geology, and the suitability of a site for building. Explain that the locations of roads, utility lines, reservoirs, and other facilities also involve seismic considerations. (See *Putting Down Roots,* p. 14 , bottom left corner).

B. Lesson Development

1. Divide the students into small groups. Decide if you will be using the colored versions or the black and white versions. Give each group one copy of each of the following maps: Surface, Geology, Liquefaction Class, Geologic Province, and Topographic. Use the map keys to review the special symbols and markings on each map. Instruct students to interpret the information shown on the specialized maps. Assign each group to a specific PLSS section of the map, i.e. Sec. 24 or Sec. 18. There are 16 PLSS sections on the map which are within the area of analysis. Choose the sections that are the most interesting to assign to student groups. Copying the Surface map on transparency film will allow students to mentally or physically transfer data to the surface map. Use overhead markers to show this.

2. Within each group, discuss what type of building would be most earthquake resistant in each area of the maps the group has developed (see *Putting Down Roots,* p. 14 , bottom left diagram "Amplification of Earthquake Shaking" and accompanying information). Ask: "Are there some areas where construction is not advisable no matter what the building materials?" Instruct students to add these notations to the maps.

3. Have students identify water features (rivers/creeks, ponds, canals, etc.), roads, power transmission lines, railroad tracks, etc., that could pose a problem during an earthquake.

4. When all maps have been completed, site hazards have been noted, and mitigation recommendations have been made, inform groups they will need to select a representative within their group to present the group's findings and recommendations.

5. Ask for a volunteer from the group's representatives to report on their group's findings and recommendations. Have the surface map projected or on a transparency so that student presenters can mark on them.

C. Conclusion

Stack the specialized maps on the projector at the same time so various kinds of information are all displayed simultaneously. Discuss the conclusions drawn by students and answer any questions. Have each group submit a final copy of their surface map and a description of their recommendations, along with justification for the recommendations that were made.

Background Reading: Site Characteristics

"Earthquakes don't kill people, buildings do." Architects and engineers consider this a fair one-sentence summary of earthquake-related deaths, injuries, and damage. Yet, underneath every building is the Earth, which can shake and damage or destroy the buildings. In the final analysis, the cause of the death and destruction may not be the earthquake or the building, but rather someone's lack of knowledge about the soil and subsoil under the building.

Much of the scientific study surrounding earthquakes is focused on the geological characteristics of building sites, the relationship of building sites to earthquake damage, and how buildings respond to ground shaking induced by earthquakes. Location is just as important as building design for making sure that a building can survive an earthquake. Geological site considerations include the location and history of faults, sedimentary deposits, landfill, liquefaction, steep slopes and landslides, tsunami and seiche, and human-made hazards.

Faults: Displacement and Ground Shaking. Earthquakes happen when two sides of a fault are displaced, releasing energy in waves. Buildings can be damaged either by direct displacement on the fault or by ground shaking.

Geologists have mapped the locations of many of the most dangerous fault zones in the U.S., yet many faults are not yet recognized. A building within a fault zone can be severely damaged by an earthquake on that fault, but this kind of damage is rare. Most buildings are not in fault zones, and the recurrence interval for any particular fault may be hundreds or thousands of years. The most common cause of damage in earthquakes is the ground shaking caused by the earthquake waves. These attenuate, or die off, with distance, so the two most important factors controlling the amount of shaking are the magnitude of the earthquake and the distance of the building from the fault.

The distance from the fault, rather than from the epicenter, determines the amount of damage. Energy is produced by all the parts of the fault that move in an earthquake. In big earthquakes, the fault might be hundreds of miles long. Thus, a structure may be hundreds of miles from the epicenter and still lie within the quake's impact zone.

Several other factors can affect the amount of shaking. Waves do not travel evenly in all directions from the fault. The orientation of the fault and the way in which displacement on the fault occurs can change the characteristics of the waves. More importantly, variations in local topography – the lay of the land, including the Geology or subsoil layers – may trap or amplify seismic energy, as will the type of rock and soil that underlie buildings.

Sediments and Landfill. Ground shaking is greatest on soil that has arrived in place fairly recently, whether deposited by natural processes geologists call sedimentation, or by artificial ones, called landfill. Unfortunately, most of the world's urban centers are sited on relative young, loose, sedimentary deposits. Sediment age and particle size are important in predicting how soil will respond to shaking during an earthquake. Areas near the shores of rivers and oceans are especially likely to contain young sediments washed there by the water.

Structures located on former watercourses (such as old river beds) or on sites that have been artificially filled with sand dredged up from the bottom of a body of water are among the worst locations for construction in earthquake country because the soil can shift so easily. In Mexico's devastating 1985 earthquake, Mexico City, located 320 km (200 miles) from the epicenter, suffered far more damage than the shoreline towns closer to the epicenter. While the shoreline is made of solid rock, Mexico City is built on the sediments of an ancient lake bed.

Old watercourses are usually low and wet, so they are frequently filled when someone wants new land on which to build and sell. Landfill is usually a mixture of soil, rock, and decaying organic material in particles of varying sizes. Because it is not natural to the area where it has been deposited, landfill in one spot is likely to be of a different composition from landfill in a nearby spot. When seismic waves are transmitted through landfill, they are amplified and their period is lengthened. Long earthquake waves are particularly destructive to some types of surface structures. Landfills commonly settle and sink during a strong earthquake.

Liquefaction. Where poorly consolidated soil or fine sand becomes saturated, an earthquake is likely to cause soil liquefaction. Earthquake vibrations compact the soil, causing water mixed with sand to flow upward. Structures may settle several feet or even topple, causing considerable damage. In a related phenomenon, sand or muddy soils may behave like liquids, flowing out onto the surface as sand boils or mud boils. This was the case on the Lost River valley floor during the Borah Peak earthquake of 1983.

Slopes and Landslides. Structures on cliffs and ridges are also at high risk for earthquake damage; even if they are built on strong bedrock. Earthquake waves appear to be reflected and amplified by topographic highs like cliffs and ridges. Earthquakes also dramatically increase the potential for landslides in areas where landslides are common, such as those where sedimentary rocks lie just under the soil. The probability of an earthquake-related landslide depends on the strength of the slope materials, the steepness of the slope, and the severity and duration of ground shaking. Structures on cliffs and ridges need to be designed to the highest earthquake standards, and should be fully insured.

Tsunami and Seiche. Tsunami are caused by faulting and the abrupt movement of the ocean floor during an underwater earthquake. A wave generated by this movement can travel as fast as 640 km./hr. (400 mph) on the open ocean, where it may not be much above normal height. When it approaches the shore, however, it may attain a height of 15-20 m. (50 feet) – in some cases, even 32 m. (105 feet). Tsunami present a distinct hazard to low-lying coastal areas, particularly the west and northwest shorelines along the western North American coast and the northerly facing coast of Hawaii. Low-lying waterfront properties in these areas are

at high risk from tsunami.

A **seiche** (SAYSH) is the sloshing of an enclosed or partially enclosed body of freshwater, such as a reservoir or lake. Seiches are usually associated with weather phenomena but they are also associated with earthquakes and landslides. A seiche has the ability to cause dam failure as a result of over spilling of a dam. In 1959, a magnitude 7.3 earthquake struck Hebgen Lake, Montana. The seiche generated by the earthquake was the result of the lake bottom dropping 6.7 meters (22 feet). The resulting rock slide and seiche accounted for most of the 28 deaths of people camping in the Rock Creek public campground on the Madison River, about 9.5 km. (5.7 miles) below the Hebgen dam.

Lakes in seismically active areas, such as Lake Tahoe in California and Nevada, are significantly at risk from seiches. Geological evidence indicates that the shores of Lake Tahoe may have been hit by seiches as much as 10 m. (33 feet) high in prehistoric times. Visit http://unofficialnetworks.com/tahoe-tsunami-26376/ to see animation of the event. Local researchers have called for the risk to be factored into emergency plans for the region.[1]

The eruption of Mount Saint Helens in 1980 generated a seiche type of event called a "wave runup," in which the debris avalanche pushed the water of Spirit Lake up the surrounding basin walls a maximum of 250 m. (825 feet) above the 1980 lake level.

Human-Made Structures

Human-made structures, such as canals, dams, reservoirs, water tanks, and tall buildings, can present special earthquake hazards and need to be considered during site selection. Every building decision needs to consider the exposure to geologic hazard and the probability of an earthquake, bearing in mind that earthquakes are possible anywhere in the world at any time.

Vocabulary

Fault: a break or fracture in Earth's crust along which movement has taken place.

Landfill: a site where soil has been deposited by artificial means – often, where garbage or rubbish has been disposed of, then covered with dirt and compacted.

Landslide: an abrupt movement of soil and bedrock downhill in response to gravity. Landslides can be triggered by an earthquake or other natural causes (see image, *Putting Down Roots*, p. 17).

Liquefaction: the process in which a solid (soil) takes on the characteristics of a liquid as a result of an increase in pore pressure and a reduction in stress.

Sedimentary deposits: accumulation of solid particles that originated from the weathering of rocks and that have been transported or deposited by wind, water, and ice.

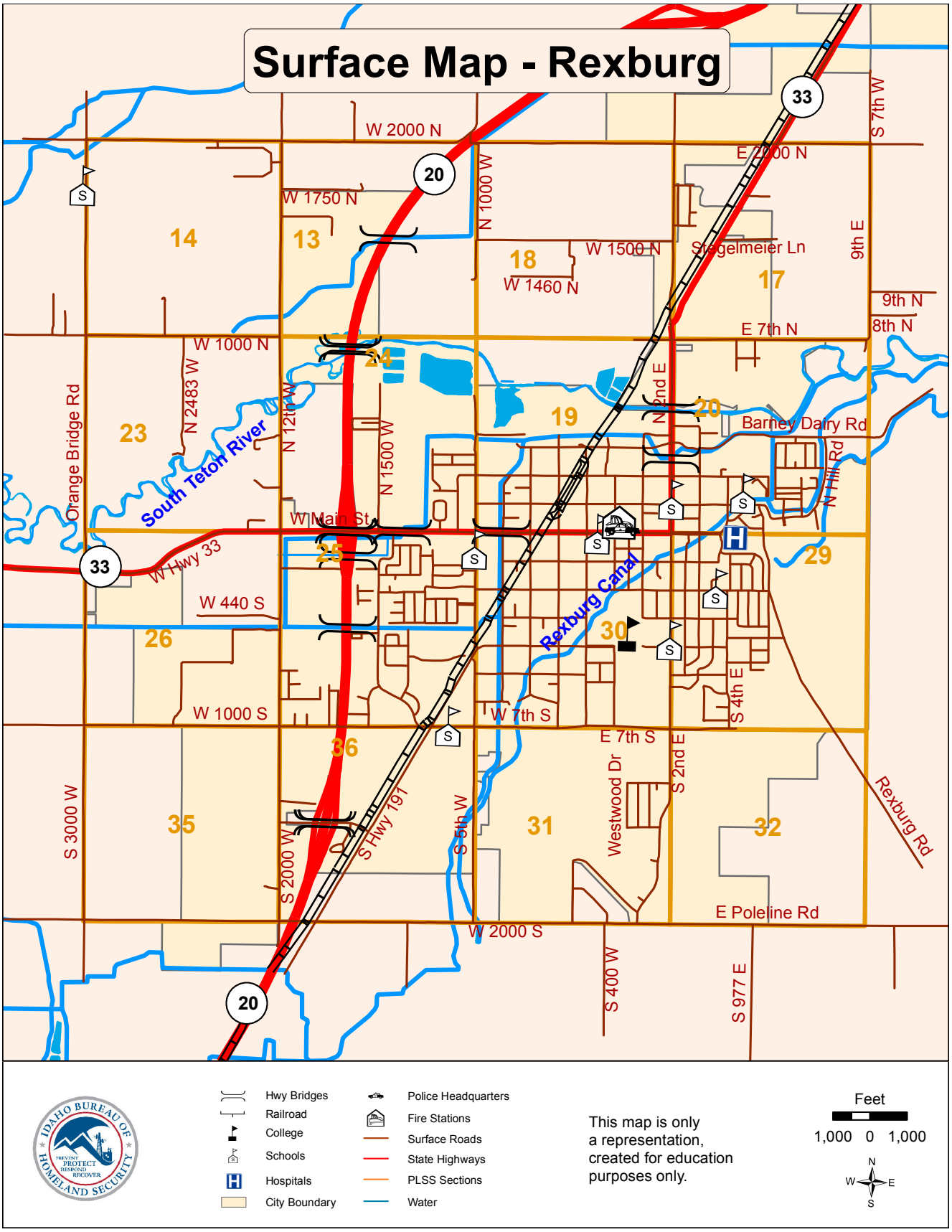
*Seiche***:** the sloshing of an enclosed or partially enclosed body of freshwater, such as a reservoir or lake. Swimming pools often **have seiches during earthquakes.**

Seismic: of or having to do with earthquakes.

Slump: A type of landslide in which a block of rock or soil moves along a curved surface and rotates.

Tsunami: a potentially destructive ocean wave created by an earthquake or other large-scale disturbance on the ocean floor, a seismic sea wave. This Japanese word has the same form in both the singular and the plural.

[1]Waitt, R.B., Geologist. Communication with Jon J. Major. U.S. Geological Survey, Cascade Volcano Observatory, Vancouver, WA. August 22, 2011, via email: jjmajor@usgs.gov.


Surface Map - Rexburg
W 2000 N
E 2000 N
S 7th W
W 1750 N
N 1000 W
W 1500 N
Siegelmeier Ln
9th E
W 1460 N
9th N
8th N
E 7th N
W 1000 N
N 2483 W
N 12th W
N 1500 W
N 2nd E
Barney Dairy Rd
Orange Bridge Rd
South Teton River
N Hill Rd
W Main St
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Hwy Bridges
Railroad
College
Schools
Hospitals
City Boundary
Police Headquarters
Fire Stations
Surface Roads
State Highways
PLSS Sections
Water
This map is only a representation, created for education purposes only.
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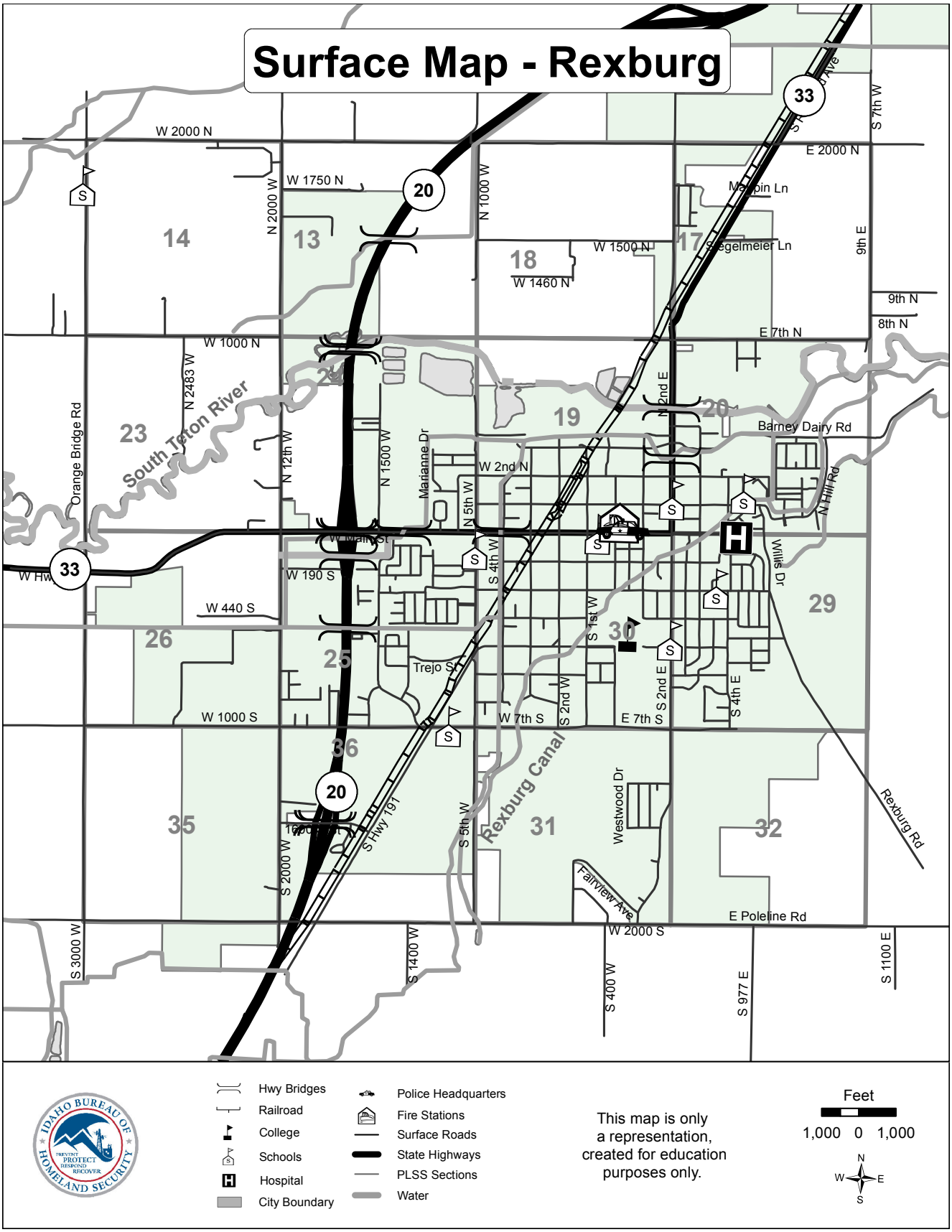
Surface Map - Rexburg
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South Teton River
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Barney Dairy Rd
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Willis Dr
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Hwy Bridges
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City Boundary
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Fire Stations
Surface Roads
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PLSS Sections
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This map is only a representation, created for education purposes only.
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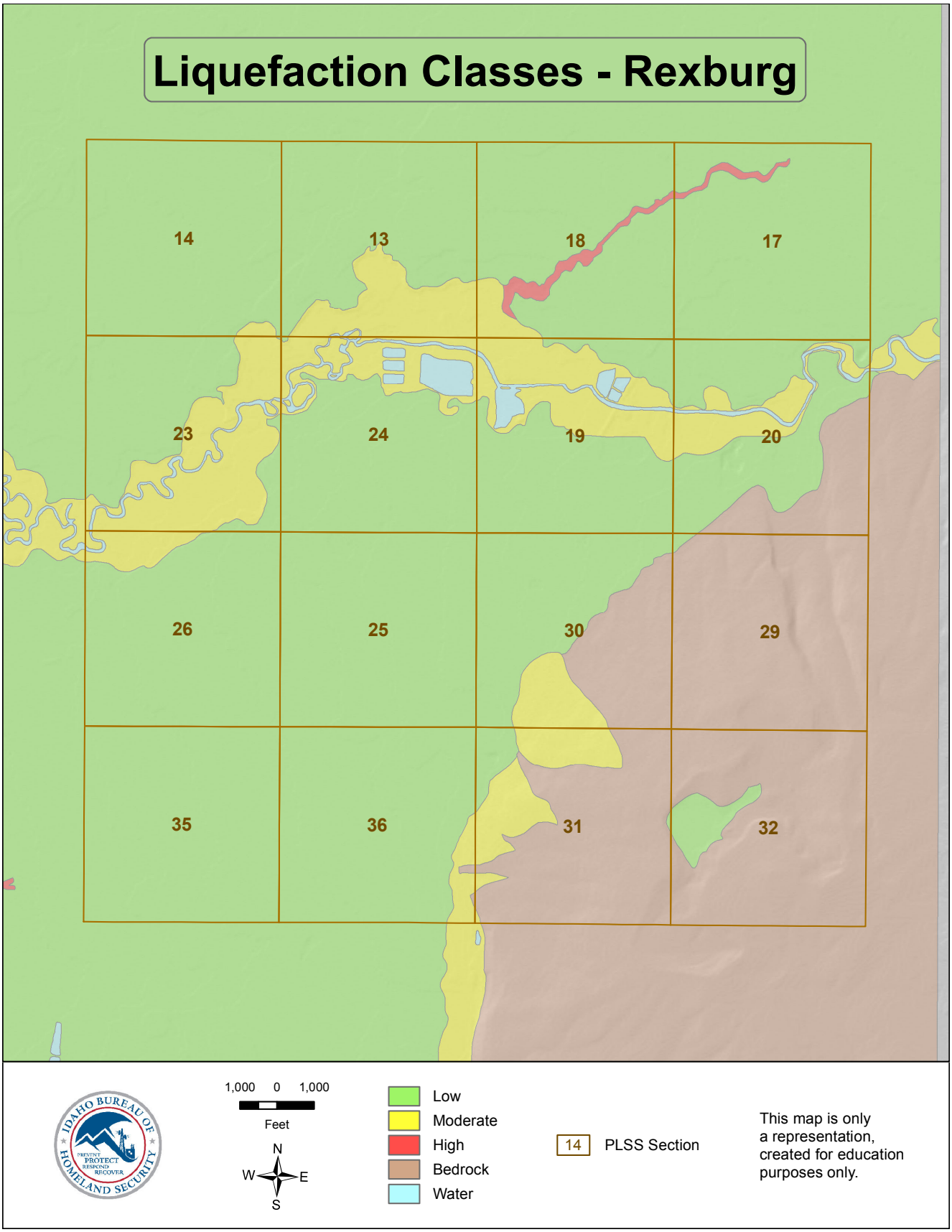
IDAHO BUREAU OF HOMELAND SECURITY
PREVENT PROTECT RESPOND RECOVER


Liquefaction Classes - Rexburg
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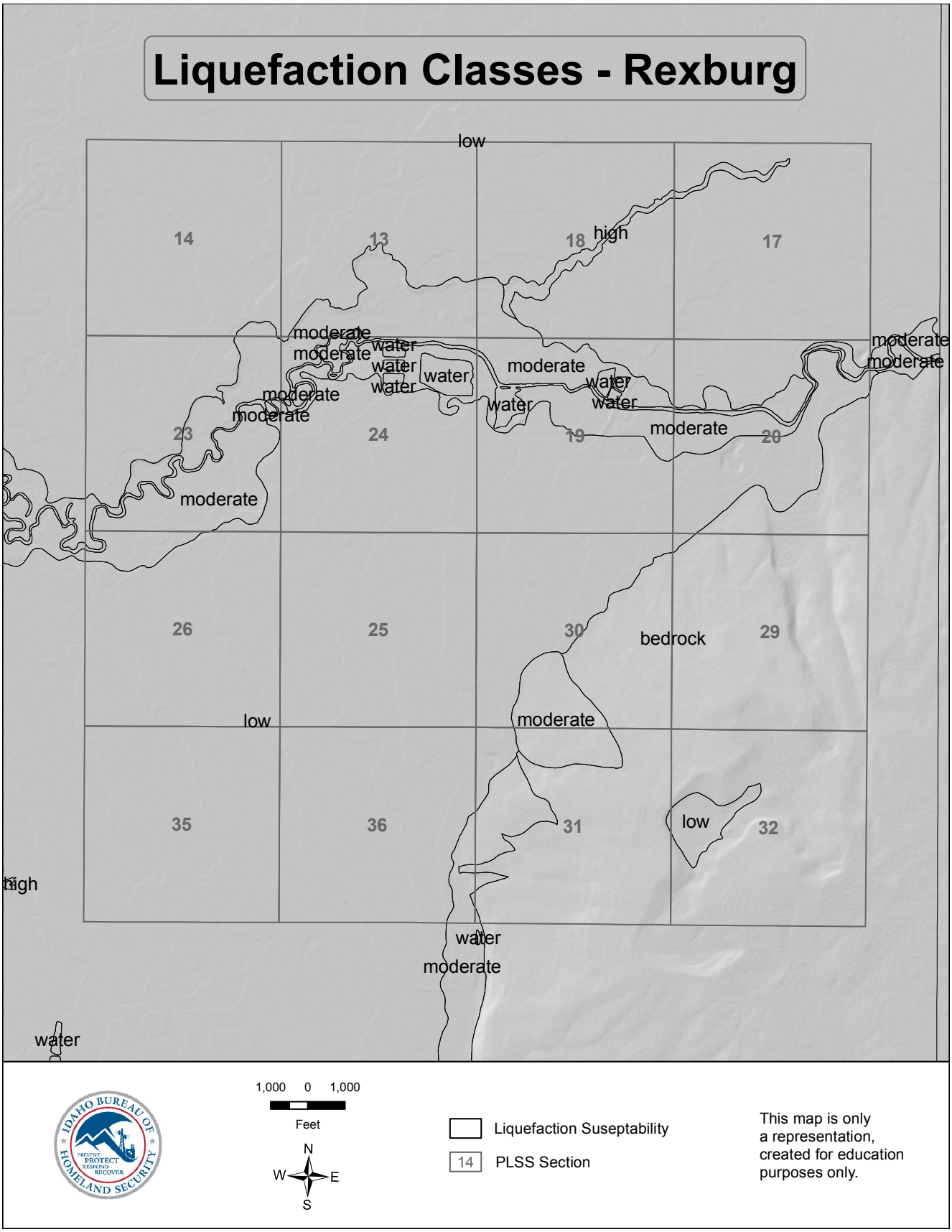
Liquefaction Classes - Rexburg
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PLSS Section
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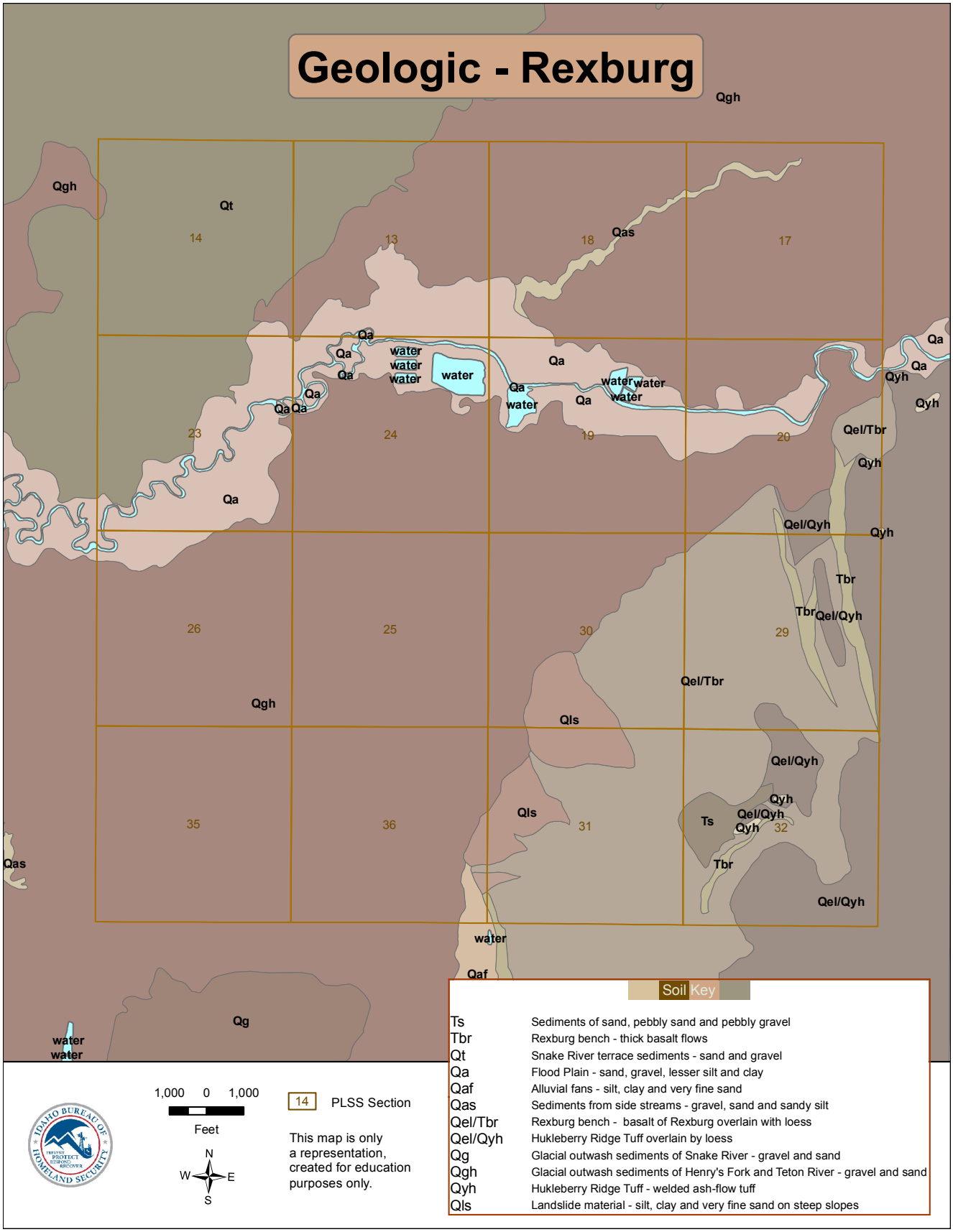
Geologic - Rexburg
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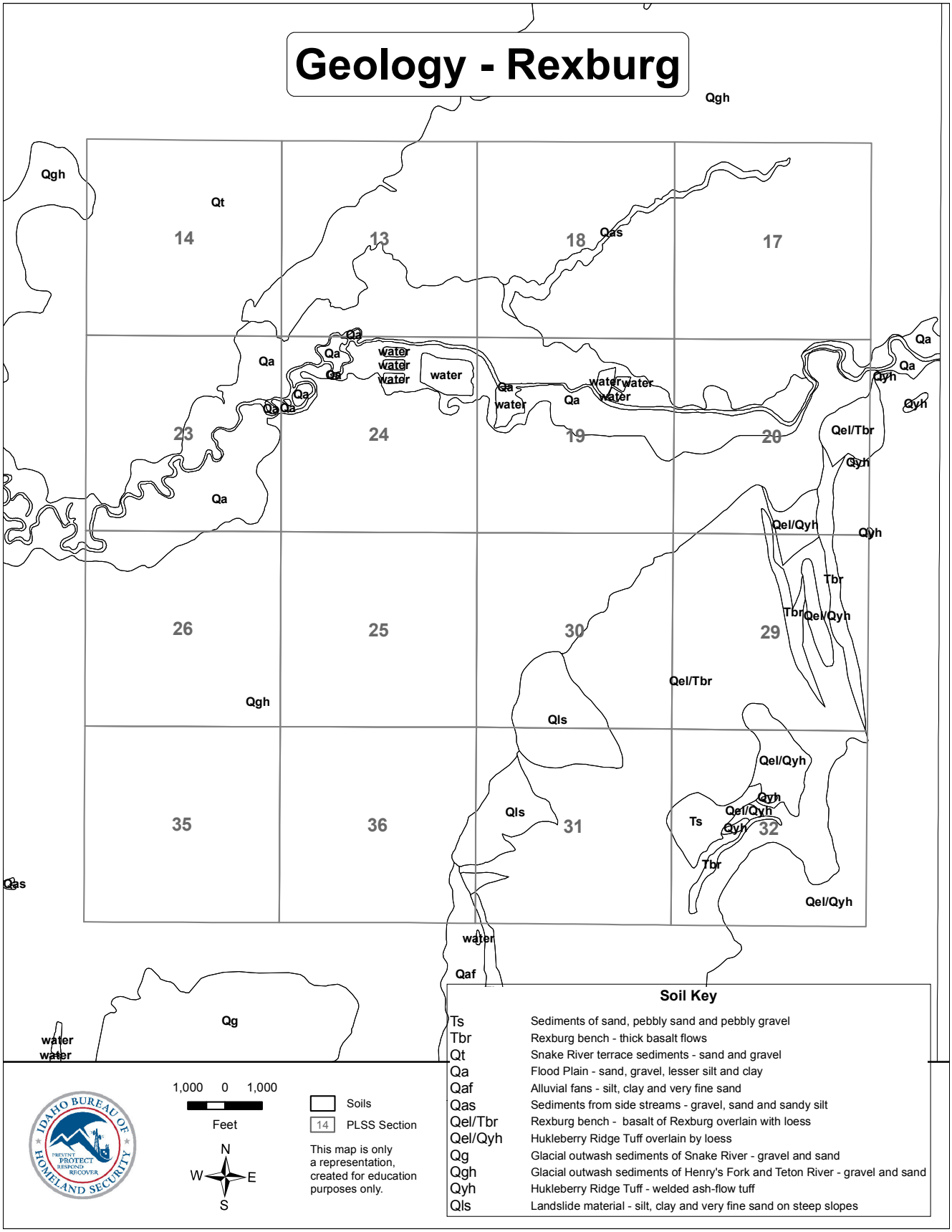
14 PLSS Section
This map is only a representation, created for education purposes only.
Soil Key
Ts Sediments of sand, pebbly sand and pebbly gravel
Tbr Rexburg bench - thick basalt flows
Qt Snake River terrace sediments - sand and gravel
Qa Flood Plain - sand, gravel, lesser silt and clay
Qaf Alluvial fans - silt, clay and very fine sand
Qas Sediments from side streams - gravel, sand and sandy silt
Qel/Tbr Rexburg bench - basalt of Rexburg overlain with loess
Qel/Qyh Hukleberry Ridge Tuff overlain by loess
Qg Glacial outwash sediments of Snake River - gravel and sand
Qgh Glacial outwash sediments of Henry's Fork and Teton River - gravel and sand
Qyh Hukleberry Ridge Tuff - welded ash-flow tuff
Qls Landslide material - silt, clay and very fine sand on steep slopes



Soil Key

Ts	Sediments of sand, pebbly sand and pebbly gravel
Tbr	Rexburg bench - thick basalt flows
Qt	Snake River terrace sediments - sand and gravel
Qa	Flood Plain - sand, gravel, lesser silt and clay
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Qyh	Hukleberry Ridge Tuff - welded ash-flow tuff
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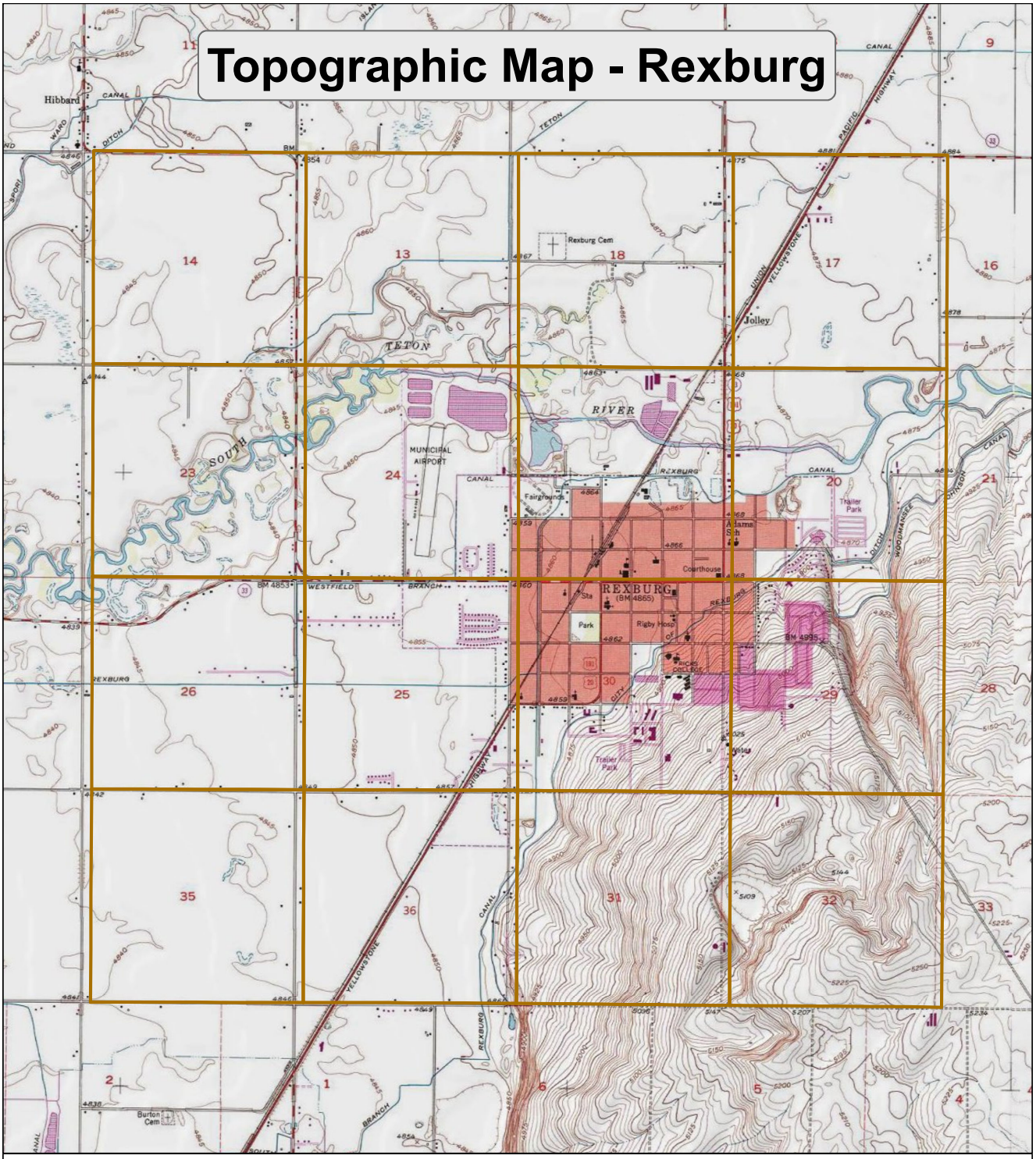

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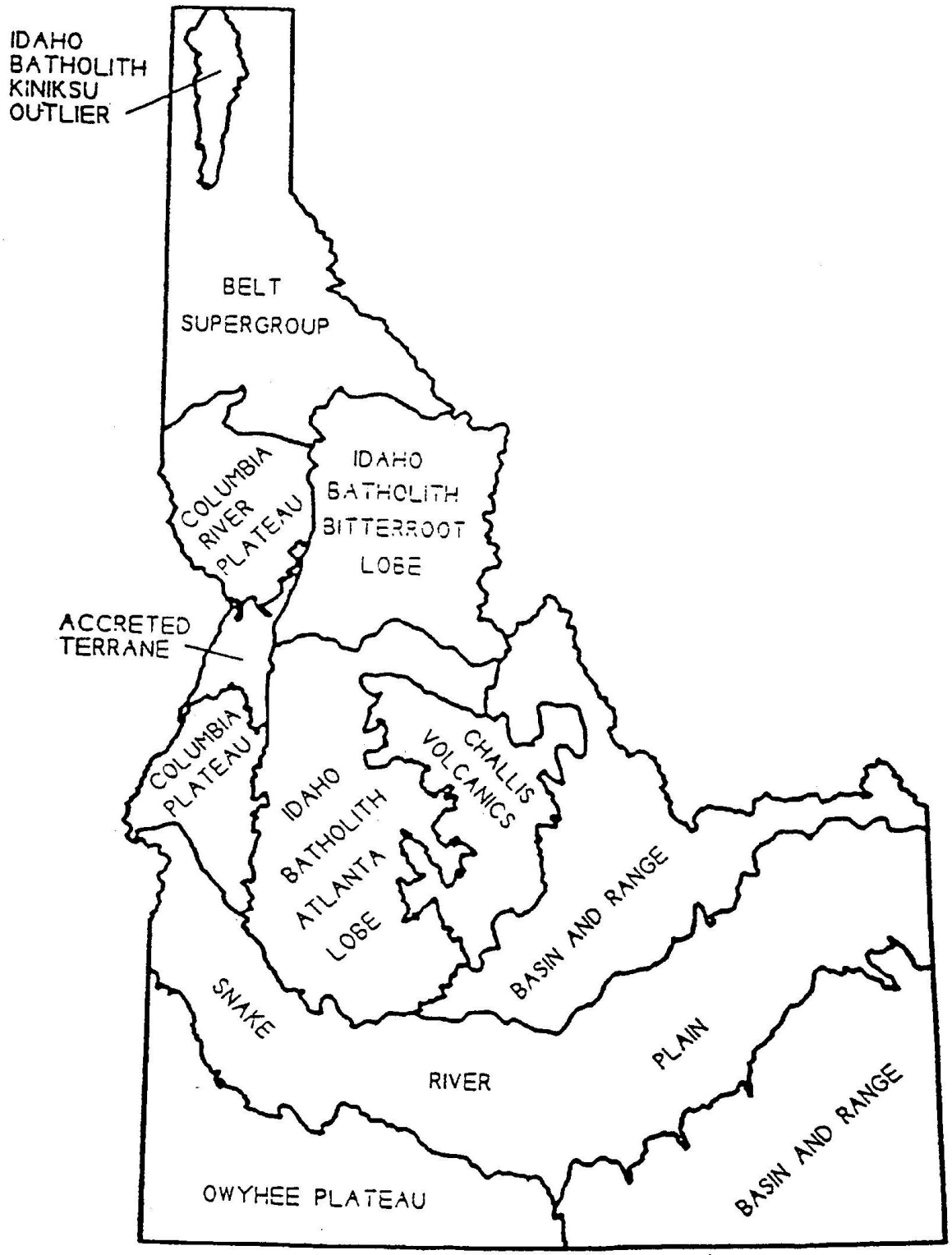


Figure 2. Geologic provinces of Idaho.

Rapid Visual Screening (RVS): Before, During, and After an Earthquake

***Putting Down Roots*, pp. 24 - 34**

Idaho State Standards:

Earth Science 5.1
8th Mathematics 2.2.1

Objectives:

Students will:

1. Recognize non-structural earthquake hazards in the classroom
2. Develop a rapid visual screening (RVS) format to use in the students homes.
3. Devise methods to reduce earthquake hazards in school and at home.
4. Develop a preparedness plan for the home.

RATIONALE

Students who have rehearsed what to do in the event of an earthquake or other emergency are more likely to stay calm and proceed rationally than students who have not. Most students will not be at home during an earthquake or natural emergency. Students may be at school, parents may be at work, etc. Knowing what to do in such a situation is part of being prepared. With that in mind, you will focus on what to do to be prepared if an earthquake occurs.

FOCUS QUESTION(S):

- If an earthquake happened here, right now, what would you do?
- Can you imagine what your classroom would be like during an earthquake?
- How could you make your classroom and your school a safer place to be?
- How could you make your home safer?

TEACHING CLUES AND CUES

Every teacher wants the classroom to be a safe environment for students. In this activity, the teacher and students will assess the safety of the classroom using Rapid Visual Screening (RVS) techniques and make plans to remedy any earthquake hazards. Explain the difference between a structural and nonstructural hazard. Show the Quick Time movies after students have completed their RVS of the classroom and/or after they have completed their home RVS. Hold a discussion of what they observe and the hazards that were displayed. Movie 071100-5 shows a typical kitchen/office of a house, while movie 071100-6 shows a child's room.

Students will also assess their own homes and develop a preparedness plan with their families. It is important to ensure students are not frightened by this activity. Tell them that knowledge is power. If they know what to do and how to prepare for a hazardous event, they are more likely to remain calm if an event should occur.

Putting Down Roots in Earthquake Country, pp. 24-34, lists and describes the "Seven Steps to Earthquake Safety." Familiarize yourself with the additional information in this section of the publication. As a follow-up to students' home RVS, you may want them to complete the "Structural Safety Quiz" on p. 30 of the publication.

MATERIALS:

for teacher

Copies of the following materials for each student:

- RVS Checklist for the classroom, pp. 109 - 110
- RVS Checklist for the Home, p. 111
- Student worksheet: "Developing a Preparedness Plan," pp. 112 - 113
- Computer and Projection equipment for Quick Time Movie's of Shaking
- Download video clips; Kitchen/Office (5.3MB and Child's Bedroom (4.1MB) from http://www.abag.ca.gov/bayarea/eqmaps/fixit/videos.html

for students

- Pencil
- RVS Checklist for classroom, pp. 109 - 110
- RVS Checklist for home, p. 101
- Student worksheet: "Developing a Preparedness Plan," pp. 112 - 113

PROCEDURE:

Teacher Preparation

Copy the materials needed for this activity for each student. The Student worksheet will need to be done at home under adult supervision, so additional time may be needed to accommodate family schedules. Once these assignments are done then complete the Structural Safety quiz from the *Putting Down Roots*,p. 30. Be cognizant that there may be some resistance from parents to fill in the "Family Communications Plan."

Students may feel they are helpless when it comes to earthquakes. They may be surprised to learn that what they do and learn in the classroom can make a difference to their own and their family's

safety during an earthquake or other hazardous event. Prepare for the before, practice what to do during, and know what to do after an earthquake.

A. Introduction

The general questions addressed in these activities are: will students know what to do before, during, and after an earthquake? Can students identify non-structural hazards? What do they do during an earthquake (DROP, COVER, AND HOLD ON) and what responses are required after an earthquake, i.e. location of utility shut off valves, and communication with family members?*

B. Lesson Development

1. Have students work in teams to identify non-structural hazards in the classroom.

2. Make a list on the board of the hazards that students identified.

3. Discuss what is classified as a structural and non-structural hazard.

3. Explain the homework section of the activity, including the RVS check sheet, the Home footprint of shut-off valves, and the Family Communications Plan.

C. Conclusion

This is a good activity for personal awareness. It would be hard to grade other than for the degree of completion. Nevertheless, this lesson in awareness is an important part of mitigation of natural hazards. For accountability, have parents sign-off on the activity.

Adaptations and Extensions

Visit Ready.gov for additional resources and information on RVS and earthquake preparedness.

*** For your safety, never attempt to turn your utilities back on. It is important to contact your utility company to provide this service**.

RVS Checklist for the Classroom

Name_____ Date_____

Instructions

1. Check yes or no for each of the following items. Skip any items not applicable to your classroom.
2. Go back and circle all the no's. These are the items that you have identified as potentially dangerous to you and your classmates.
3. For each no, suggest a way to remove the danger (use the comments space).
4. For each yes, explain why your team thinks the feature is earthquake resistant.

Yes **No**

☐ ☐ Are desks and tables located where they cannot slide and block exits?
Comments:

☐ ☐ Are large, heavy office machines secured to the wall or floor and located where they cannot slide, fall, or, block exits?
Comments:

☐ ☐ Are the tops of tall (4-5 drawer) file cabinets securely attached to the wall?
Comments:

☐ ☐ Do file cabinet doors have latches?
Comments:

☐ ☐ Are desktop computers securely fastened to work spaces?
Comments:

☐ ☐ Are bookshelves, cabinets, and coat closets secured to the wall and/or attached to each other?
Comments:

☐ ☐ Are display cases or aquariums protected against overturning or sliding off tables?
Comments:

☐ ☐ Is floor-supported, freestanding shop equipment secured against overturning or sliding?
Comments:

☐ ☐ Is free standing equipment on wheels protected against rolling?
Comments:

Yes No

☐ ☐ Are all wall-mounted objects that weigh more than five pounds firmly anchored to the building's structural framing?
Comments:

☐ ☐ Are all heavy, sharp, or breakable wall decorations securely mounted, for example, with closed-eye hooks?
Comments:

☐ ☐ Do books or materials stored on shelves have adequate restraints to keep them from flying off the shelves?
Comments:

☐ ☐ Are laboratory chemicals on shelves restrained? Are potentially hazardous chemicals stored securely? Are chemical storage areas vented and located away from exits and corridors? Is there an up-to-date inventory of all chemicals stored?
Comments:

☐ ☐ Are the fluorescent light fixtures merely resting on the hung ceiling grid, or do they have supports?
Comments:

☐ ☐ Will hanging light fixtures swing freely without hitting each other if allowed to swing a minimum of 45 degrees?
Comments:

☐ ☐ Are fire extinguishers securely mounted?
Comments:

☐ ☐ If there are potted plants and other heavy items on top of file cabinets or in other overhead locations, are they restrained?
Comments:

☐ ☐ Do you see other hazards not included on this list? Specify.
Comments:

RVS Check list for the Home

Name _____ Date_____

Yes	No	
☐	☐	1. Are beds placed next to large windows?
☐	☐	2. Are beds placed below hanging lights?
☐	☐	3. Are beds placed below heavy mirrors?
☐	☐	4. Are beds placed below framed pictures?
☐	☐	5. Are there shelves above beds with objects on them that can fall?
☐	☐	6. Are there heavy lamps on bed tables?
☐	☐	7. Are hanging house plants in heavy pots?
☐	☐	8. Do hanging plants, lamps, etc. have closed hooks?
☐	☐	9. Are hooks for hanging plants, lamps, etc. attached to studs?
☐	☐	10. Are there heavy objects on high shelves?
☐	☐	11. Are there breakable things on high shelves?
☐	☐	12. Are Televisions and/or home entertainment systems secured and attached to studs?
☐	☐	13. Do cabinets have latches that will hold during an earthquake (nonmagnetic)?
☐	☐	14. Are glass bottles in medicine cabinets on lower shelves? **PARENT NOTE:** If there are small children around, make sure you use childproof latches when you move things to lower shelves.
☐	☐	15. Are there glass containers around the bathtub/shower?
☐	☐	16. Are materials that can easily catch fire moved so they are not close to heat sources?
☐	☐	17. Is the water heater strapped to the studs of the nearest wall?
☐	☐	18. Are there heavy objects that could fall in the way of exit routes in your house?
☐	☐	19. Are objects on wheels blocked so that they cannot roll?
☐	☐	20. Is tall heavy furniture, such as bookshelves, attached to studs in walls?
☐	☐	21. Are there flexible connectors where gas lines meet appliances such as stoves, water heaters, and dryers?
☐	☐	22. Do heavy or floor mounted stoves and refrigerators have anti-tipping devices installed or are they attached to studs?
☐	☐	23. Do tall chimneys have bracing?
☐	☐	24. Are heavy mirrors fastened to walls to prevent movement or falling?
☐	☐	25. Are heavy pictures fastened to walls to prevent movement or falling?
☐	☐	26. Are window air conditioners well braced?
☐	☐	27. Are tiles on the roof secured?
☐	☐	28. Is the house bolted to the foundation?
☐	☐	29. Is the outside chimney braced?
☐	☐	30. Are there dead or diseased tree limbs that could fall on the house?

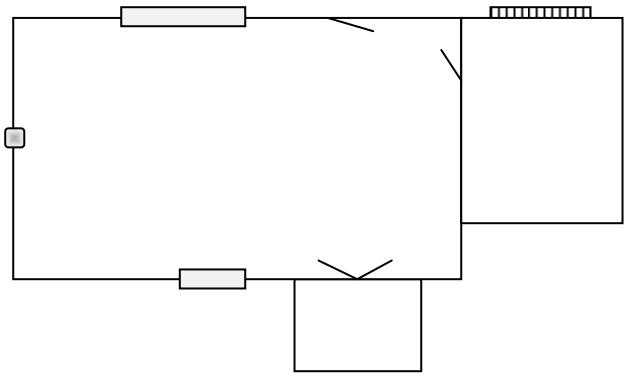
Student worksheet

Developing a Preparedness Plan

Locate the positions of different utility shut-off valves. Teach responsible members of your family how to turn off electricity, gas, and water at main switches and valves. **Caution: do not shut off gas unless an emergency exists. If gas is ever turned off, a professional must restore service.** Contact your local utilities for more information.

On a separate sheet of paper, sketch an outline or footprint of your home or dwelling (see Figure 1 below). If you have more than one level, sketch a separate footprint for each of those levels if appropriate. Make the sketch large enough to work with. A standard sheet of paper should be used.

Figure 1



Procedure:

1. On your sketch, label where doors are located that lead to the outside with this symbol.
2. On your sketch, label where large windows are located with this symbol.
3. If you have a chimney, indicate its location with this symbol.
4. Locate and label the position of the following:
   a. Electrical circuit box or main power source (E)
   b. Gas meter (G)
   c. Main water meter (WM) outside the house and the position of the shut-off valve where the water enters the house (WSV).
   d. Hot water heater (WH)
   e. The shut-off valves to all water supplied fixtures (sinks, toilets, etc.) (x)
5. Locate the position of stairs with this symbol.
6. With the help of an adult, collect information that would be necessary to have during an emergency and fill out the family Communications Plan form (Figure 2).

Questions:

1. As a family, determine the safest spots <u>in each room</u> of your home. What is the location for DROP, COVER and HOLD ON for each room?

2. As a family, determine the danger spots in each room.

3. Determine an emergency evacuation plan for each room of your home. Write down the evacuation plan for your bedroom. What if the hallway is blocked?

4. Agree on a safe gathering place outside the house where all family members will meet after an earthquake. Where would that be?

5. The Borah Earthquake occurred around 8:00am. What would you have been doing and where would you have been at that time? What about your parents and siblings?

6. What if the earthquake occurred at 1:00pm? Where would you have been during that time of day? How would you have communicated with your parents or siblings?

Figure 2. Family Communications Plan, www.ready.gov

Shake-Out Survivor

***Putting Down Roots*, pp. 20 - 23, 32 - 34**

Idaho State Standards:

8th/9th Earth Science 5.1, 5.3

Objectives:

Students will:

1. Play a game to determine their preparedness under emergency conditions.

2. Recognize the importance of advanced planning for personal or family emergency response.

RATIONALE

This activity is designed to help students understand how their life could change unexpectedly following an earthquake or other major natural hazard. Earthquakes in Idaho are inevitable; how someone responds to the aftermath of an earthquake will be determined by their preparedness. The Federal Emergency Management Agency (FEMA) and state and local emergency planners have determined that individuals should plan to be self-supporting for a minimum of 72 hours (3 days) following a major disaster. How well a person is able to be self-supporting is determined by conditions following a major disaster and their personal/family preparedness plan.

FOCUS QUESTION(S):

- What are the critical emergency supplies one needs to survive for 72 hours after a natural disaster?
- If an earthquake happened when you were home by yourself what would you do?
- What would a disaster preparedness plan involve?

TEACHING CLUES AND CUES

Group students into teams of 2-3. Each team will roll the die to determine the conditions that apply to them after an earthquake. The purpose of the game is to encourage students to think about how they would respond to conditions imposed upon them during an emergency. Groups should write down each condition determined by the roll of their dice. Students can either write a report or present their scenario to the class and explain how they would handle (survive) the situation. You may want to challenge the students by having them roll their die twice for each of the columns.

MATERIALS:

for teacher

- Copies of the "Shake-Out Survivor" instructions, pp. 116 - 117 for each student
- Dice: one per group

for student groups

- "Shake-Out Survivor" game instructions, pp. 116 - 117
- Dice: one per group
- Paper and pen or pencil

PROCEDURE:

Teacher Preparation

Read pp. 20-23 and pp. 32-34 of *Putting Down Roots in Earthquake Country*. This will give you the background to question students about their decisions. Make copies of the game instructions for the students. Decide how you will group students for this activity.

A. Introduction

Instruct the students that they will be playing a game to determine conditions for their group's earthquake scenario before, during, and after a major event. The conditions that will exist for each group will be different and will be determined by the roll of a die. How they respond is subject to these conditions. Instruct students that they will be preparing a report or presentation that justifies the choices they made under the conditions of their team's scenario.

B. Lesson Development

1. Have students read pages 20-23 from *Putting Down Roots*.

2. Each team should begin playing the game by shaking the die to determine whether students are alone or with a younger sibling.

3. Roll a second time to determine what type of dwelling students live in.

4. Roll a third time to determine the time of day the event occurs and the weather conditions during the event.

5. Roll once for each of the six categories: Dwelling, Medical, Communication, Water/Gas/Electricity, Transportation, and Miscellaneous. Each roll of the die imposes conditions upon the player for which they must account in their survival.

6. Players will write a report or prepare a presentation to describe what they would do under the conditions imposed.

C. Conclusion

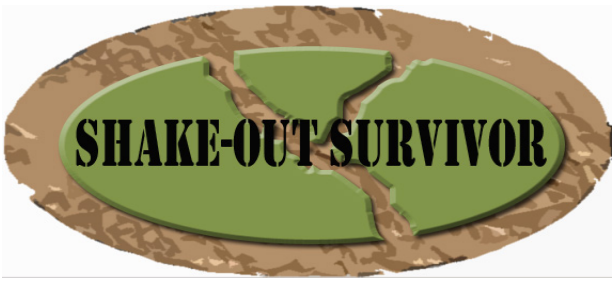
At the next class meeting, set aside time for a debriefing of student reactions to what they have learned. Pose the following questions to each team of students:

- Is your plan or response realistic? Is it comprehensive (does it take everything into consideration)?
- Did you have the resources to implement your plan?
- What were some of the limiting factors in your survival?

Adaptations and Extensions

If your area is one of low seismicity or is susceptible to other natural hazards, you may rework the game to address other types of major disasters, such as flooding, wildfire, or major winter storms. Contact the Idaho Bureau of Homeland Security at Citizen.corp@bhs.idaho.gov to get information, maps and/or guest speakers. You may also send your request to

Idaho Bureau of Homeland Security
Attn: Citizen Corps Coordinator
4040 Guard St., Bldg. 600
Boise, ID 83705-5004
208-422-3040



The Game

The Event: An earthquake with a magnitude of 6.5 has just occurred. At the moment, you are unhurt. No adults are at home with you. Roll your die three times to determine the basic conditions under which you will play for the rest of the game. The first roll will determine your scenario. The second roll will determine the type of dwelling you live in and the third roll will determine the time of day, the temperature, and weather trend at the time that the earthquake occurred. Note: the Federal Emergency Management Agency has determined that a person should be prepared to fend for themselves for a minimum of 72 hours (3 days) following a major natural disaster in the event that help from first responders is delayed or unavailable.

Scenario:
Roll an even number (2, 4, 6): Home alone
Roll an odd number (1, 3, 5): Home with a younger sibling

Dwelling: you live in a
Roll an even number (2, 4, 6): Single family home
Roll an odd number (1, 3, 5): Multiple family home (apartment)

Time and Temperature:
Roll 1: 8:00 a.m., 10°F and rising
Roll 2: 8:00 a.m., 50°F and rising
Roll 3: 12:00 noon, 70°F and rising
Roll 4: 12:00 noon, 30°F and falling
Roll 5: 4:00 p.m., 90°F and rising
Roll 6: 4:00 p.m., 40°F and falling

Roll the die one more time for each of the six categories below to determine which conditions you will need to apply to your scenario. For example, if you roll a 2 for the dwelling category and a 1 for the Medical category, your scenario will include the conditions "Chimney has fallen through the roof" and "No First Aid/CPR training." Repeat for each of the remaining categories.
Optional Challenge: roll twice for each category.

Dwelling
1 - Dwelling must be evacuated
2 - Chimney has fallen through the roof
3 - Neighbors' dwelling is on fire
4 - Family has a pet
5 - Exterior doors blocked/jammed
6 - Dwelling located on floodplain

Medical
1 - No First Aid/CPR training
2 - Medicine needs refrigeration
3 - Neighbor trained in First Aid/CPR
4 - Neighbor or sibling bleeding
5 - Hospital damaged/evacuated
6 - 911 response not an option

Communication
1 - Cell phone works, but battery is low
2 - Internet, TV, and land lines are down
3 - No radio or working flashlight
4 - Cell phone charger missing
5 - Have a working radio and flashlight
6 - Have a family emergency plan

Water, Gas, Electricity
1 - Public water supply contaminated
2 - Electricity is out
3 - Smell of natural gas is detected
4 - Water lines under house burst
5 - Gas line is broken outside home
6 - Water main is broken on street, no water to house

Transportation
1 - Train wreck blocking road
2 - Car gas tank is close to empty
3 - Car cannot be moved
4 - Public transportation not running
5 - Gasoline pumps at service station unable to pump gas
6 - Car keys cannot be found

Miscellaneous
1 - Have working fire extinguisher
2 - Have $10 in cash
3 - Limited canned food supply in house
4 - Canal/reservoir/dam leaking
5 - Unable to contact parents
6 - Family pet ran away

Now that you have all the conditions that resulted from the earthquake, prepare a report that describes what you would do to care for yourself--and, if applicable, a sibling-- immediately after the earthquake and for the next 72 hours. Make sure you take into consideration the time of day, weather conditions, and weather trends.

Aftershock!!

An aftershock has occurred 5 hours later and is larger than the 6.5 that occurred earlier. It has started to rain/snow (depending on your temperature conditions). Roll the die once for each of the categories to determine what additional conditions now exist. If you roll a condition that is already in place in your scenario, roll again. **Note: prior conditions still apply.**

Dwelling
1 - Dwelling must be evacuated
2 - Chimney has fallen through the roof
3 - Neighbors' dwelling is on fire
4 - Family has a pet
5 - Exterior doors blocked/jammed
6 - Dwelling located on floodplain

Medical
1 - No First Aid/CPR training
2 - Medicine needs refrigeration
3 - Neighbor trained in First Aid/CPR
4 - Neighbor or sibling bleeding
5 - Hospital damaged/evacuated
6 - 911 response not an option

Communication
1 - Cell phone works, but battery is low
2 - Internet, TV, and land lines are down
3 - No radio or working flashlight
4 - Cell phone charger missing
5 - Have a working radio and flashlight
6 - Have a family emergency plan

Water, Gas, Electricity
1 - Public water supply contaminated
2 - Electricity is out
3 - Smell of natural gas is detected
4 - Water lines under house burst
5 - Gas line is broken outside home
6 - Water main is broken on street, no water to house

Transportation
1 - Train wreck blocking road
2 - Car gas tank is close to empty
3 - Car cannot be moved
4 - Public transportation not running
5 - Gasoline pumps at service station unable to pump gas
6 - Car keys cannot be found

Miscellaneous
1 - Have working fire extinguisher
2 - Have $10 in cash
3 - Limited canned food supply in house
4 - Canal/reservoir/dam leaking
5 - Unable to contact parents
6 - Family pet ran away

Describe how these new conditions have changed the way you would respond to your survival?

24 Hours later: Roll the die one more time to add one of the conditions below to your scenario:

1 - You have injured, possibly broken, your arm
2 - The canal/dam has failed; flooding is imminent in your area
3 - Due to a ruptured petroleum or natural gas pipeline, a large fire has broken out in the street
4 - Your next door neighbor has no food or water
5 - Outside temperatures have dropped 20°F
6 - Closest emergency shelter is full (no room for you & sibling). You are sent to another shelter.

Describe how your situation has changed and how you will respond for the next 48 hours.

Rapid Visual Screening (RVS) in the Community – Field Trip

***Putting Down Roots*, pp. 30 - 31**

Idaho State Standards:

8th/9th Earth Science 1.2.1, 1.2.3, 5.1.1

Objectives:

Students will:

1. Conduct a sidewalk survey of non-structural building hazards in their community.
2. Record their observations on data collection forms.
3. Identify non-structural building hazards.

RATIONALE

Students will perform an informal rapid visual screening (RVS) to determine the non-structural hazards to people and property that could result from damage to buildings in their community during an earthquake.

FOCUS QUESTION(S):

- What buildings in your town or city might pose a serious risk of casualties, property damage, and/or severe limitations of public services if a damaging earthquake happened here?
- What are non-structural hazards and can you identify them on a building?

TEACHING CLUES AND CUES

This activity makes for a great field trip. It may also serve as an independent study by students. In addition, the instructor may display pictures of buildings in the community and have students identify the non-structural hazards that exist. Use the diagram, p. 120, along with the vocabulary, p. 121, to prepare students for their analysis.

If conducting a field trip, it would be good public relations to contact any businesses that occupy the buildings you will be evaluating to let them know when and what you will be doing. It is important that students do not block public entrances to businesses while they are evaluating the building. It may also be appropriate to let students know that they may be questioned by passersby asking "what they are doing." Rehearse appropriate responses with students prior to the field trip.

Read pp. 30-31 of *Putting Down Roots in Earthquake Country* for background information. Contact BHS (see sources below) to request a guest speaker to come to the classroom to prepare students for the walk-about of their community. Have digital cameras available for students to use during the walk-about. This activity has the ability to pull together the concepts of hazards, building structures and the effects of earthquakes.

MATERIALS:

for teacher

- Transparency or projection of USGS National Seismic Hazards Map, p. 124
- Copies of Non-structural Hazards diagram, p. 120, one for each student
- Vocabulary terms for non-structural hazards diagram, p. 121
- Answer key for non-structural hazards diagram, p. 122
- Student copies of the RVS Observation Sheet, p. 123, six for each team
- Google maps or MapQuest image of observation site

for student groups

- Clipboard or notebook for holding observation sheets
- Student copy of Non-structural Hazards diagram, p. 120
- Pens or pencils
- Camera (cell phone, digital, etc.)

PROCEDURE:

Teacher Preparation

Select site(s) for the class field assignments, choosing the nearest large concentration of buildings. Students may choose buildings to survey or they may be assigned.

A. Introduction

Tell the students that they are going to assume the role of building inspectors in completing an informal sidewalk survey of buildings in their community.

B. Lesson Development

1. Ask students whether their region of the country is thought to be at low, moderate, or high risk for earthquakes. Make a copy of the USGS National Hazards Map, p. 124, or project the image. The image can be found on p. 19 of *Putting Down Roots* and an Idaho-specific image on p. 14. If your school is located in a region pictured on the map as low seismic hazard, remind students that they may not always live where they live now and other natural disasters may affect the buildings.

2. Tell students that a building may be structurally sound, but its exterior decorations may create a hazard. These are called non-structural hazards. Project the image of Non-structural Hazards, p. 120, and elicit student descriptions of non-structural hazards on the outside of buildings in the drawing (see Non-structural Hazards Key, p. 122).

3. Tell students that for the purpose of this exercise they will assume that a major earthquake is likely in their area in the next several years. They will take a walk and record their observations of non-structural hazards.

4. Assign each student a partner. Distribute six copies of the RVS Observation Sheet, to each pair and ask each pair of students to complete the following steps for six buildings, noting all the following information on their observation sheets.

- Record a description of the building and its address or location.
- Note materials used in construction.
- Estimate the year of its construction (sometimes a plate on the corner of the building gives this).
- Record its size (number of floors, area, shape, and other information).
- Determine the current use (business, apartments or other).
- List the readily visible non-structural hazards.
- Photograph the building (if no camera is available then make a sketch).

5. Back in the classroom, suggest ways for students to fill in any missing information. Students may need to contact the public works department at city hall to get date of construction information. Complete the form and then have students compare their data with another group(s) who evaluated the same building. The goal of this process should be an assessment of each building surveyed that represents the students' best consensus.

C. Conclusion

Open a class discussion on what students have learned. Using Google Maps or MapQuest, pull up a map of the area where the evaluation took place. Use a red marker to circle any block or group of blocks where concentrated non-structural damage could be expected in the event of an earthquake. If students have not already expressed an opinion, ask if the sidewalks they travel would be safe places during an earthquake. Generally, the most dangerous places are building exits and areas directly adjacent to buildings (on the sidewalks, for example).

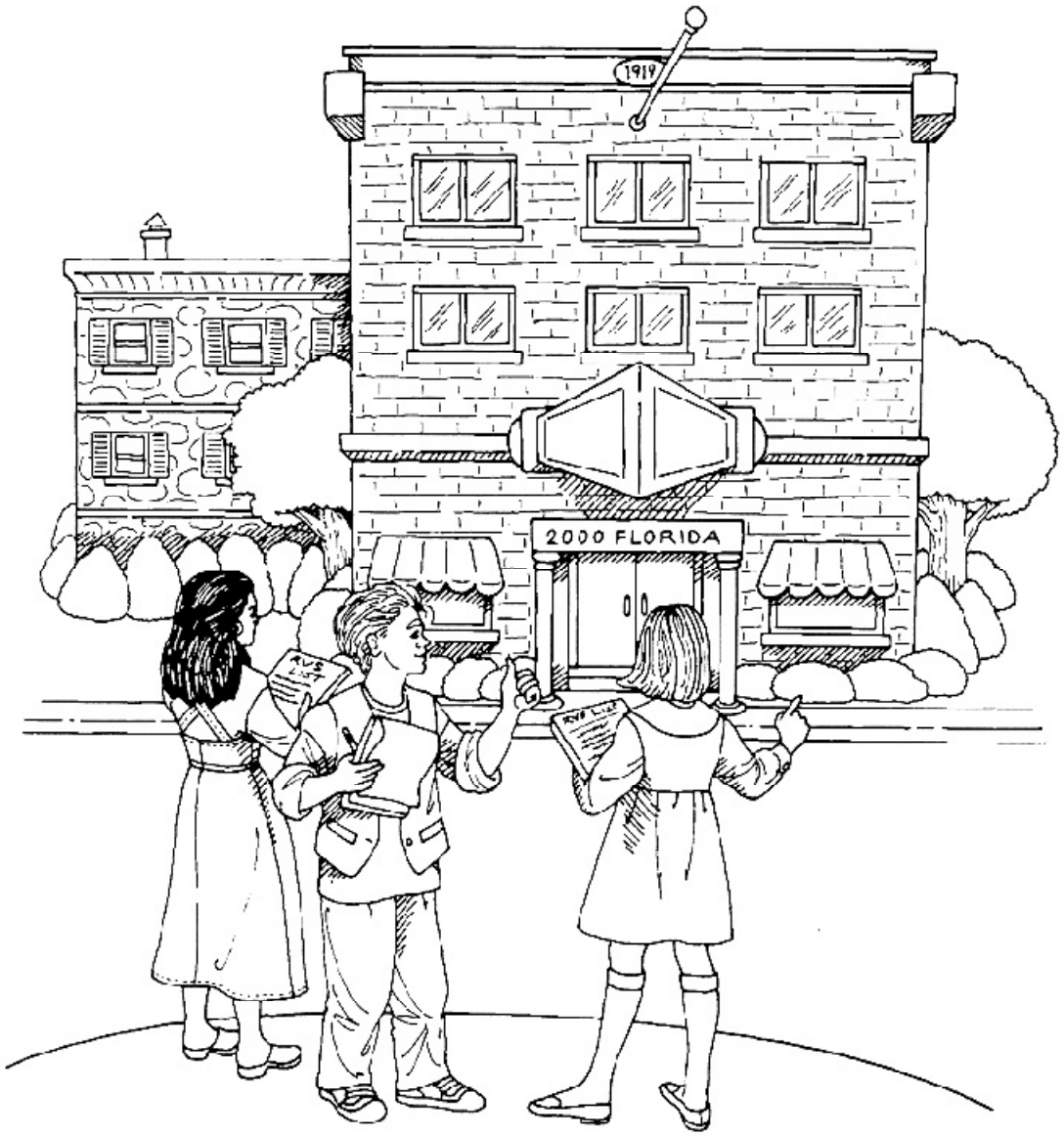
Adaptations and Extensions

1. If a structural engineer is present or structural information is available from the building manager, students may also informally judge which buildings could be expected to withstand earthquake shaking.

2. Have students cut out pictures from magazines that show buildings with non-structural building hazards and identify those hazards as a homework assignment.

Nonstructural Hazards

Name_____ **Date**_____



AGU/FEMA Seismic Sleuths

Vocabulary Nonstructural Hazards

Canopy: a covered area that extends from the wall of a building, protecting an entrance.

Cantilever: a beam, girder, or other structural member which projects beyond its supporting wall or column.

Cladding: an external covering or skin applied to a structure for aesthetic or protective purposes.

Cornice: the exterior trim of a structure at the meeting of the roof and wall.

Glazing: glass surface

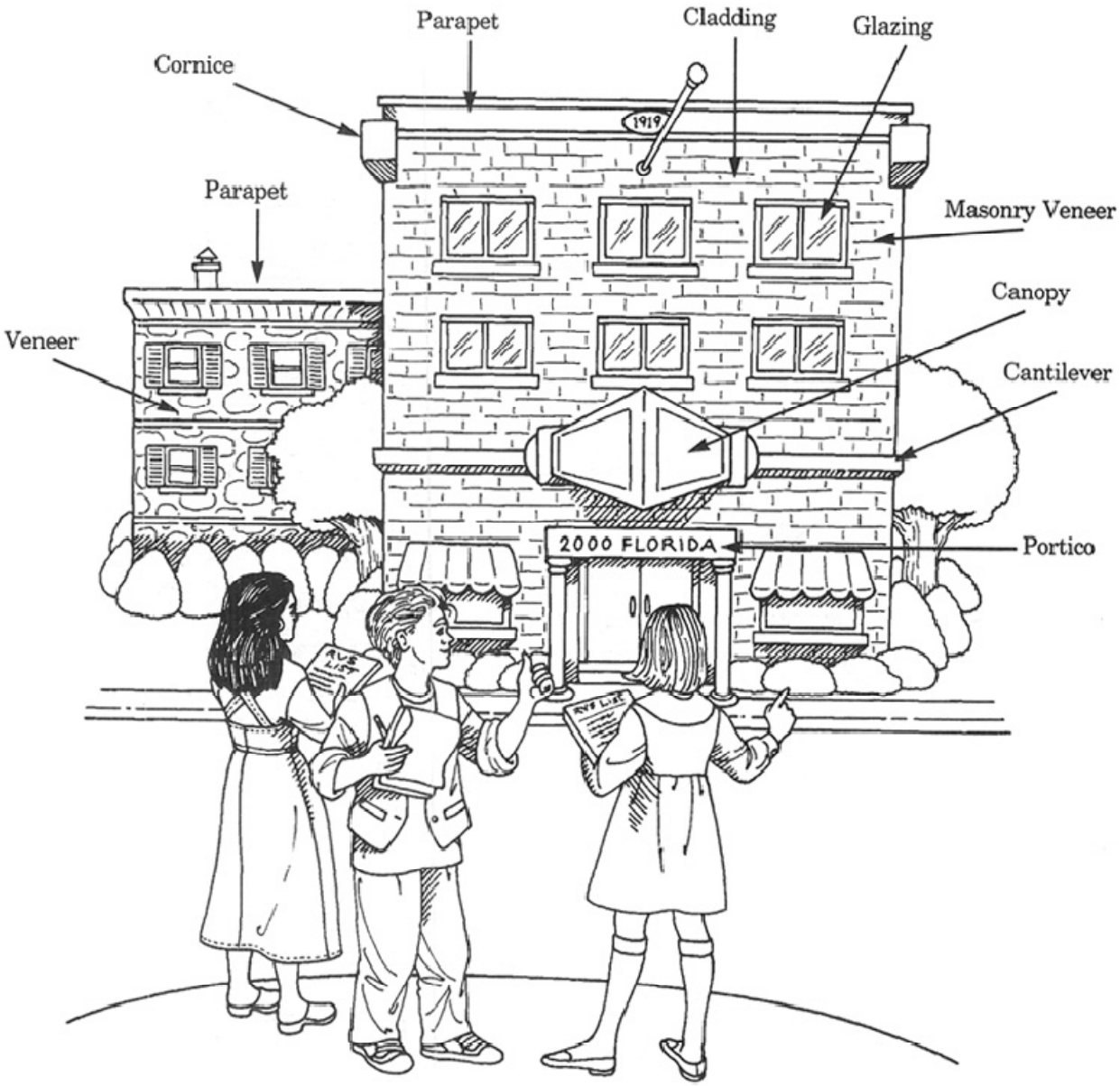
Masonry veneer: a masonry (stone or brick) facing laid against a wall and not structurally bonded to the wall.

Parapet: part of a wall which is entirely above the roof.

Portico: a porch or covered walk consisting of a roof supported by columns.

Veneer: an outside wall facing of brick, stone, or other facing materials that provides a decorative surface but is not load-bearing.

Nonstructural Hazards (key)



AGU/FEMA Seismic Sleuths

RVS Observation Sheet

Name_____ **Date**_____

1. Building name _____
2. Street Address _____
3. Materials used in construction _____
4. Year of construction _____
5. Size (number of floors), area, and shape _____
6. Current use _____
7. List of nonstructural hazards (see diagram and use appropriate vocabulary)

a._____

b._____

c._____

d._____

e._____

f._____

g._____

h._____

i._____

j._____

k._____

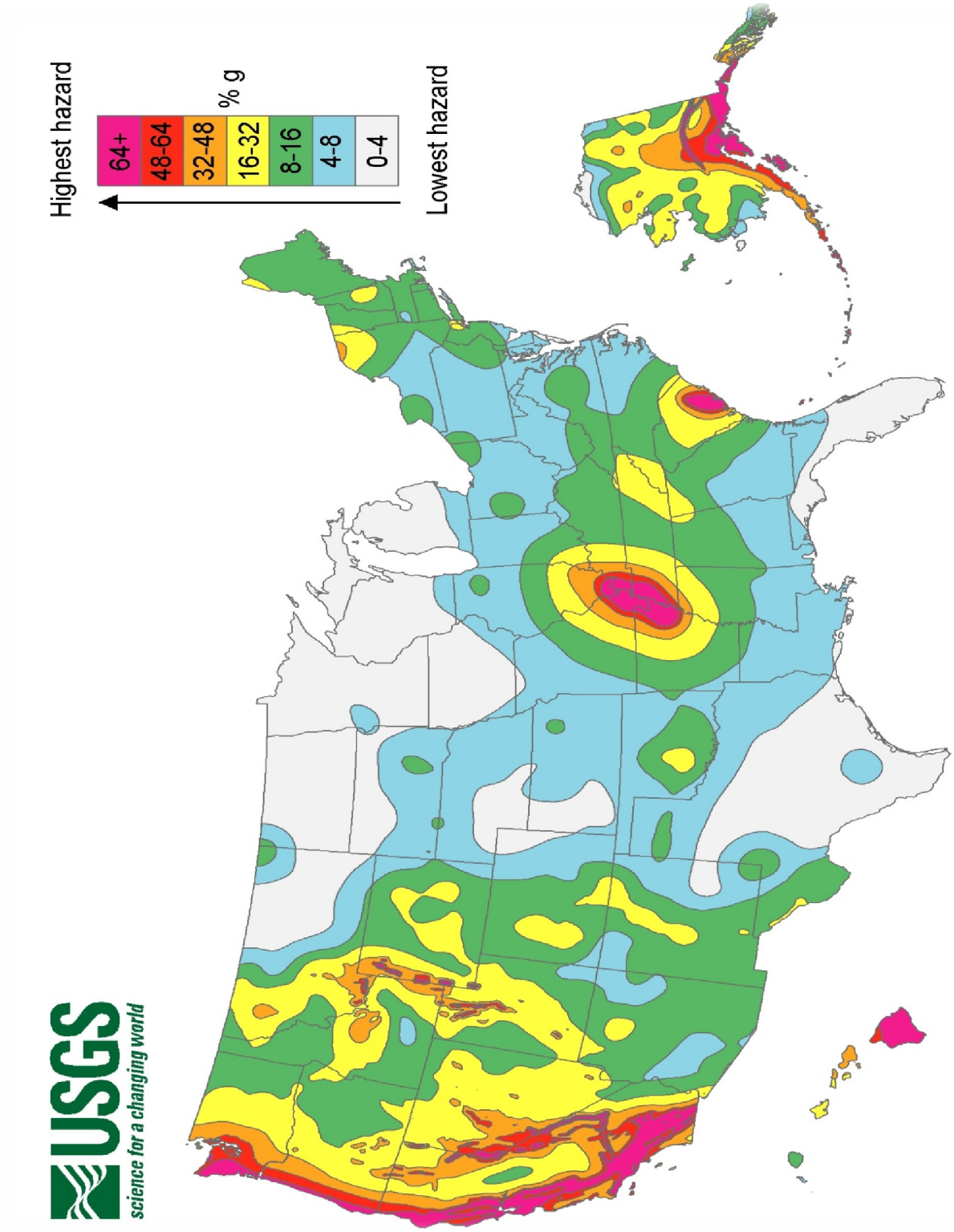
l._____

m._____

(Continue on back if necessary)

Attach photo or sketch building

USGS National Seismic Hazard Map



Introduction to Earthquakes

Idaho State Standards:

N/A

Objectives:

To determine the present level of knowledge of students prior to instruction on earthquakes and/or the use of the Idaho Bureau of Homeland Security publication *Putting Down Roots in Earthquake Country.*

RATIONALE

This activity is designed as an anticipatory set, to introduce the students to earthquakes, and to allow the teacher to see how much the students know about earthquakes and earthquake mitigation.

FOCUS QUESTION(S):

- If an earthquake happened here, right now, what would you do?
- Can you imagine what your classroom would be like during an earthquake?
- How could you make your classroom and your school a safer place to be?
- How could you make your home safer?

TEACHING CLUES AND CUES

This activity is best done as an introduction to Unit 1: Why Should I Care? However, it may also be used as a review or facts check after using the Bureau of Homeland Security's booklet *Putting Down Roots in Earthquake Country*.

MATERIALS:

- *Putting Down Roots in Earthquake Country* booklet, one for each student
- Copies of the student worksheet, p. 126 - 127, one for each student
- Teacher Answer Key, p. 128

PROCEDURE:

Teacher Preparation

Make copies of the student worksheet, p. 126 - 127

A. Introduction

Students will circulate within the classroom and ask other students if they know any of the answers to the questions on the student worksheet. If possible, find a different person to answer each of the questions given. In order to complete the worksheet, have students write the name of the person providing the answer to a question in the margin and their answer in the space provided.

B. Lesson Development

1. Hand out copies of the student worksheet to students.

2. Inform students that the aim of this activity is to find different people, within the class, to provide the answers to each one of the questions.

3. Once they have, write the person's name in the space provided and their answer to the question.

C. Conclusion

Lead a class discussion on the answers to the questions.

Student worksheet

Introductory Activity – Earthquakes

Instructions: Your aim is to find a different person who can answer each of the questions below. Once you have, write the person's name in the margin and their answer to the question.

1. Someone who has stood on a major fault: _____ Name of fault:_____

2. Someone who has felt the shaking of the ground or a building during an earthquake:_____ _____

3. Someone who has personally observed damage from an earthquake:_____

4. Someone who can name 3 kinds of tectonic plate boundaries: _____
   Name the boundaries: _____, _____, _____

5. Someone who knows what the Yellowstone Tectonic Parabola is:_____
   What zones make up this parabola?_____, _____
   _____,_____

6. Someone who knows the three steps to take for personal safety during an earthquake:_____ _____ These step are _____, _____ and _____

7. Someone who can name three types of seismic waves:_____
   Name the three types of waves: _____, _____ and _____

8. Someone who can tell you how many magnitude 8+ earthquakes occur in the world each year: _____ How many?_____

9. Someone who can tell you when and where the largest historic earthquake occurred in Idaho_____ Where:_____
   When:_____

10. Someone who can tell you when and where the largest historic earthquake occurred in the U.S.: _____ Where:_____
    When:_____

11. Someone who can name a magnitude scale which is now used more widely than the Richter scale to describe the size of an earthquake:_____
    Name the magnitude scale: _____

12. Someone who can tell you the difference between magnitude and intensity of an earthquake: _____ Intensity is:_____
    and Magnitude is:_____

13. Someone who can tell you how often magnitude 6.0 earthquakes occur in Idaho?_____
    _____ How often:_____

ANSWER KEY to Introductory Activities – Earthquakes

1. Answers will vary
2. Answers will vary
3. Answers will vary
4. Divergent, Convergent, Transform
5. The Yellowstone Tectonic Parabola is a region of earthquakes, active faulting, and topographic uplift surrounding the eastern Snake River Plain. It is associated with the Yellowstone Hotspot. The 4 zones are: Intermountain Seismic Belt Zone, Central Idaho Seismic Zone, Western Idaho Seismic Zone, and Lewis and Clark North Idaho Zone.
6. Drop, Cover, Hold on
7. Primary, Secondary, Longitudinal
8. Approx. 1/year
9. Borah Peak 1983, M 6.9 (Note: The 1959 Hebgen Lake earthquake was a M 7.3 but its focus was in Montana even though it was felt and affected Idaho)
10. New Madrid, MO, 1811-1812, three M8 earthquakes. (Note: Some students may want to include the 1964 Prince William Sound Alaska earthquake, M 9.2, since Alaska is part of the U.S.)
11. Moment Magnitude Scale (Mw) – This scale takes into account the length of the fault that moved or ruptured. It is related to the total energy released in the earthquake. This scale is different from the Richter scale because it takes into consideration the amount of fault surface that slips and not just the energy released.
12. An earthquake has one magnitude, but many intensities. Intensity: is a qualitative measurement and is subjective and is a measurement of the earthquake effects and is expressed as a Roman numeral I-XII. Intensity can be influenced by distance to hypocenter, type of ground material, and strength. Magnitude: is a quantitative and exact measurement of the size of the earthquake (amount of energy released). It is expressed as a number usually from 1-10. In reality the top end of the scale is open. In order for an earthquake of 10.5 to occur would require a fault that circles the Earth to move at once – no such fault exists. The largest earthquake ever recorded was a Mw 9.5 on May 22, 1960 in Chili. This occurred on a fault that is almost 1,000 (1600 km)miles long. The earthquake ruptured along the entire length of the fault. In the U.S. – Alaska, 03/27/1964 Mw 9.2, rupture 620 miles (1,000 km), San Andres Fault, San Francisco, CA 04/18/1906 Mw 7.7 rupture is only 800 miles (1290 km) long 250 miles (400 km). [1]
13. Based on historic data and probability an earthquake of 6.0 could occur approximately every 10 years in Idaho.

[1] Earthquake Country Alliance, "Separating Fact from Fiction," Southern California Earthquake Center. April 11, 2011. http://www.earthquakecountry.info/10.5/MajorMovieMisconceptions.html, accessed June 28, 2011.

Teacher Resources and Student Activities: Earthquakes in Middle and Secondary Schools

DLESE (Digital Library for Earth System Education) **http://www.dlese.org/library/index.jsp**
A free searchable site for high quality Earth Science lessons of all topics. This site has taken the best of the best available on the web and elsewhere and placed them on one site. Teachers can search by grade level, resource type, collections (published materials from other sources) and by standards. Just typing in the word "Teaching Boxes" in the search box provides a wealth of resources. This is the only site that science teachers will need as they search for lessons pertaining to the topic they are teaching. The DELSE collections meet seven specific review criteria: high scientific accuracy, good pedagogical effectiveness, ease of use, clarity and completeness of documentation, motivating for learners, show robustness, and illustrate significance of content.

DLESE Teaching Boxes-Earthquakes **http://www.teachingboxes.org/earthquakes/**
The goal of this Teaching Box is to teach students about how and why earthquakes cause damage. **Living in Earthquake Country** explores seismic waves, the ability of scientists to predict the likelihood and severity of earthquakes at specific locations, the difference between magnitude and intensity, the occurrence of earthquakes along patches of planar faults, and the potential damage caused by landslides, liquefaction, or structural failure related to earthquakes. At the end of the six lessons there are EXTRA lessons using the interactive **Rapid Earthquake Viewer** visualization tool (REV). These lessons are also meant to augment the original lessons in the "Living in Earthquake Country" Teaching Box with additional data-related activities. REV provides access to data from seismograph stations around the world and is a collaborative effort of the University of South Carolina and IRIS.

EarthScope **http://www.earthscope.org/eno** EarthScope and its partners have developed activities, lesson plans, map tools, visualizations, and much more to help students and teachers work with EarthScope data and science results. Free EarthScope materials include teachable moments, research summaries, links to research projects, and interactions with EarthScope scientists and staff.

Exploratorium **http://www.exploratorium.edu/faultline/index.html**
Faultline Seismic Science at the Epicenter . A site that has hands-on activities, graphics, podcasts, videos, music, photos and web links. There are five categories from which to choose: **Live Eye on the Earth**, **Great Shakes**, **Quake Basics**, **Damage Control** and **Active Zone**.

IGS (Idaho Geological Survey) **http://www.idahogeology.org/** A publication available for download titled "Student Activities for Studying Earthquakes in Secondary Schools," Idaho Geological Survey S-95-2. Go to the home page. In the search box, at the top, type in S-95-2. These four activities were designed by B. Peterson and K. Othberg shortly after the Borah Peak 1983 Earthquake and can be found at the above link. The activities are meant to "augment

courses in earth science." The first three activities apply directly to Idaho and can be used in conjunction with the Idaho Bureau of Homeland Security Publication "Putting Down Roots in Earthquake Country." The fourth activity, "Seismic Activity at Tectonic Plate boundaries" is a computer activity, but is outdated and not usable. However, there are many websites that teachers can now access to actively involve students in data analysis or demonstrate similar information. Some of the resources available on the web can be found at the following web sites.

IGS (Idaho Geological Survey) **http://www.idahogeology.org/** On the home page, select Geologic Hazards from the left side bar. This opens a page where you can select one of three hazards—Earthquakes, Landslides, or Volcanoes. Each hazard's site contains additional links and information related to hazards in Idaho. Select Earthquakes to open a page with many options related to earthquakes. Tag this site in your "Favorites."

- Idaho Miocene – Quaternary Interactive Fault Map (Locate faults and view information about rates and sense of movement)
- Idaho Miocene – Quaternary fault Map – Google Earth Version (Use the popular Google Earth viewer to locate faults and view information about the faults.)

IRIS (Incorporated Research Institutions for Seismology)
http://www.iris.edu/hq/audience/educators A university consortium sponsored by the National Science Foundation that is dedicated to the operation of scientific facilities for the acquisition, management, and distribution of freely available seismic data. The site lists materials for Teaching About and Exploring Earthquakes, as well as Educational Opportunities, Materials, and Networking capabilities. The Slip-Stick model and activity were taken from this site.

IRIS Education & Outreach "One-Pagers" **http://www.iris.edu/edu/onepagers.htm**
IRIS has created one-page handouts related to seismology for use in the classroom. These "one-pagers" are available upon request form IRIS headquarters or you can download Adobe Acrobat (.pdf) formatted copies of these high quality handouts from the site. IRIS, 1200 New York Ave. NW, Suite 800, Washington DC 20005. Phone: 202-682-2220 Fax: 202-682-2444.

IRIS Educational Software
http://www.iris.edu/hq/programs/education_and_outreach/software This web page lists many programs that can be used in the classroom, depending on the type of computer system you use. Select the one that applies to your needs.

IRIS Videos
http://www.iris.edu/hq/programs/education_and_outreach/videos#N This web page lists the many videos available to be used in the classroom. They can be presented in YouTube or Quick Time formats. Some movies also have a PowerPoint component to them.

SCEC (Southern California Earthquake Center)
http://www.data.scec.org/Module/module.html Investigating Earthquakes Though Regional Seismicity Education Module – Activities list. Section 1 "What is an Earthquake?" has fourteen activities to choose from. Section 2 "The Distribution of Earthquakes" has twelve activities. Section 3 "Measuring Earthquakes" has four activities to choose from. At the time of printing, this site section was still under construction.

USArray **http://www.usarray.org/edu/k12** In collaboration with the seismological and educational communities, the USArray Education and Outreach program develops and implements programs designed to enhance seismology and Earth Science education in K-12 schools, colleges and universities, and in adult education.

USGS (United States Geological Survey) **http://earthquake.usgs.gov/earthquakes/**
The USGS has a website for earthquakes. This site has interactive maps of the latest earthquakes nationally and internationally. In addition, there are links to two different formats—a live feed (Atom XML) that monitors earthquakes and the Google Earth KML format. Both would be useful in the classroom. Within the USGS site, an application allows students and teachers to look at Probability Mapping for Earthquakes. All that is needed are zip codes of the state.
Another mapping option at the USGS site is the Interactive or Static Fault Maps for the state/s. Additional maps and tools can be found at the Online Seismic Analysis Tools site in the Earthquakes Hazards Program website (scroll down to the heading).

Virtual Earthquake
http://vcourseware4.calstatela.edu/VirtualEarthquake/VQuakeExecute.html
A program developed by California State University LA (CSULA). Unlike most websites, Virtual Earthquake involves the students in an interactive simulation. Students will learn how to read seismograms and plot earthquake locations and magnitudes. They participate by estimating measurements on screen and inputting data. From their measurements and estimations, students will observe how earthquake locations and magnitudes are determined. If students make mistakes, they are allowed to go back and try again. Upon completion of the simulation, a personalized "certificate of completion" can be printed out and kept in the student's notebook or turned in for a grade as proof that they successfully completed the assignment.

Stop Disasters
http://www.stopdisastersgame.org/en/home.html
This is an interactive disaster simulation game from the UN/ISDR International Strategy for Disaster Reduction. Teachers will want to select the **information tab** at the top to access additional resources or information. It is advisable for the teacher to play the game first to get an idea of how it works. The player selects from one of the five scenarios: wild fires, tsunamis, hurricanes, earthquakes or flood. They then select the difficulty level and read background information about the scenario. The players are given a specific amount of money and a maximum of 25 minutes to mitigate the hazard for the area. This game allows students to put

into practice the facts that they have been learning in the classroom about mitigation for disasters.

The Interactive Game: You can reduce human, physical, and financial catastrophe by making quick choices to plan and construct a safer environment, but you have limited funding. Expect good and bad advice along the way.

1. Go to **www.stopdisastersgame.org/en/home.html** and touch
   PLAY GAME > Launch game > Play game (again)
2. **Select a Scenario:** Type : **Earthquake** / Select: **SELECT DIFFICULTY LEVEL** (Start "EASY" to learn)
3. Roll over each building to choose from Info, Develop or Demolish, and Defences or Upgrades. Each has a cost.

WARNING: 25 minutes goes by quickly. Fix big, older buildings first.

Bonus - Yellowstone Activity

WILL IT BLOW?

Monitoring Yellowstone's Volcanic Activity

LESSON PLAN

By:
Denise Thompson, Orting High School WA

National Standards:

Physical Science Standard B	Motion and Forces Transfer of Energy
Earth and Space Science Standard D	Energy in the Earth System Geochemical Cycles Origin and Evolution of the Earth System
Science and Technology E	
Science in the Personal and Social Perspective F	Natural and Human-Induced Hazards

Objectives:

Following completion of these activities and demonstrations students will be able to:

- Describe why and how volcanoes are monitored
- Explain the role that GPS has played in advancement of science overall
- Graph GPS data either by hand or using a spreadsheet
- Interpret the meaning of graphed GPS data
- Describe how volcanic processes alter the surface of the earth
- Explain the source of the force and energy required for volcanic processes
- Describe how matter and energy are conserved during volcanic processes
- Discuss the hazards associated with volcanic processes

Time:

Why do scientists monitor volcanoes discussion	15 minutes
The Science of Prediction PowerPoint	30 minutes
Where AM I: the evolving technology of navigation	1 class period
Will it Blow	3-class periods

Outline:

Why do scientists monitor volcanoes?

(Discussion with examples of hazards)

Ask students how they benefit from the USGS' Volcanic Monitoring Program

For example:

- Self, family or friends live on a volcano (Ash, Lahar, Pyroclastic Flow, Lava Flow)
- Live near a volcano (Ash, Lahar)
- Like to visit volcanoes (hiking, fishing, 4-wheeling, hunting, rock climbing)
- Fly on airplanes (ash)
- Live on Earth (ash, volcanic aerosols and greenhouse gases)

This is a good time to discuss the hazards that are associated with volcanic processes. Students are usually familiar with eruptions and lava flows, but not likely to relate to hydrothermal features, gas emissions, or volcanic mud flows

USGS Types and Effects of Volcano Hazards
http://volcanoes.usgs.gov/hazards/

USGS Fact Sheet What are Volcano Hazards
http://pubs.usgs.gov/fs/fs002-97/fs002-97.pdf

The Science of Prediction: Monitoring Volcanic Activity
(PowerPoint)
www.unavco.org/cws/modules/cws/modules/yellowstone/

Students learn about how scientists monitor volcanic activity and how such monitoring detected the impending eruption of Mt. St. Helens in 1980.

For more information about volcanic hazards and monitoring check out these resources:

Volcano and Hydrologic Monitoring Techniques
http://vulcan.wr.usgs.gov/Monitoring/techniques.html#seismic_monitoring

USGS Volcanic Gas Fact Sheet
http://vulcan.wr.usgs.gov/Glossary/Emissions/Publications/OFR95-85/

USGS Fact Sheet "Steam Explosions, Earthquakes, and Volcanic Eruptions—What's in Yellowstone's Future?" http://pubs.usgs.gov/fs/2005/3024/fs2005-3024.pdf

Mt Rainier NP "Living with a Volcano in your Backyard" curriculum
http://vulcan.wr.usgs.gov/Outreach/Publications/GIP19/framework.html

Tree kills
http://pubs.usgs.gov/fs/fs172-96/

Where AM I: the Evolving Technology of Navigation
(worksheet)
www.unavco.org/cws/modules/cws/modules/yellowstone/

Students will use several web pages to research the history of navigation leading to the development of GPS. They will then design a timeline to illustrate and communicate their findings.

Adaptations:
Students with disabilities Print out "The History of Navigation

http://www.boatsafe.com/kids/navigation.htm" from the WebQuest document. Have students cut out important technological advances and paste on a timeline. Students could also illustrate their timelines.

No Access to Computers Print out each of the WebQuest web pages. Have students work in groups to construct a timeline from the available information

Advanced Students Have students decide which type of technology on their timeline they consider the most important step leading to the design of GPS and present their reasoning to the class. Have students predict a future application of GPS and write about it.

What is GPS?
(PowerPoint, worksheet)
http://www.unavco.org/cws/modules/cws/modules/readingGPStimeseries/

If students are unfamiliar with GPS and how it works, you might want to do this activity as a starter

Will It Blow: Monitoring Yellowstone's Volcanic Activity?
(PowerPoint, worksheet, Yellowstone GPS Data Set)
www.unavco.org/cws/modules/cws/modules/yellowstone/

Students interpret historical and real-time monitoring data for Yellowstone NP to determine if there is a space suitable for building a golf resort in the park. Students are asked to construct a presentation or written report to submit to the developer based on the National Science Standards format

The Yellowstone GPS data set uses only vertical data, however if you plan on using other EarthScope activities, this PowerPoint is good background material.
How to read GPS time series plots (PowerPoint)

Adaptations:
Students with disabilities Print out diagrams from PowerPoint "The Science of Prediction" or use the USGS Fact Sheet "Steam Explosions, Earthquakes, and Volcanic Eruptions—What's in Yellowstone's Future?" http://pubs.usgs.gov/fs/2005/3024/fs2005-3024.pdf. Have students place X's on a map to represent unsuitable development sites. They can then verbally discuss where development could take place or shade suitable sites on the map

No Access to Computers Print out each of the materials. Have students work in groups to collect and interpret data. Classroom copies of USGS "Steam Explosions, Earthquakes, and Volcanic Eruptions—What's in Yellowstone's Future?" can be printed from the internet or requested from the USGS publications office.

Advanced Students Students can go deeper into the analysis of GPS data by analyzing time series for each station and plotting vectors on their maps Instructions for plotting GPS vectors can be found at

http://cws.unavco.org:8080/cws/modules/gps_pacificnw_cascadia/. Have students research additional hazards such as forest fires and flooding to add to their reports. Students could present their findings to the "developer" and then debate any differences.

Extension Ideas:

Students can research hazards at St. Augustine volcano
http://www.avo.alaska.edu/activity/Augustine.php
Students can prepare a volcanic hazards map for Yellowstone based on their research
Students can discuss possible mitigation techniques for Yellowstone's hazards such as signage, emergency drills, emergency supplies etc.
Compare the volcanic hazards at Yellowstone to those of other types of volcanoes such as Kilauea, Mt. St. Helens, Mt Rainier, Mt. St. Augustine, Mt. Fuji etc.

WILL IT BLOW?

Monitoring Yellowstone's Volcanic Activity

STUDENT WORKSHEET

By:
Denise Thompson, Orting High School WA

Objective:
Interpret historical and real-time monitoring data for Yellowstone National Park
Analyze monitoring data to detect regions of high and low risk of volcanic hazards
Construct a report communicating your findings

Problem:

- Congratulations! You're a private consultant and you have just been awarded a $100,000 contract from a major developer.
- This developer would like to build a 3500 acre (5.5 mi^2 or 8 km^2) resort and golf course in Yellowstone National Park.
- Your task is to prepare a report advising the developer as to the most risk-free place (if there is one) in the park to build his resort.

Introduction:
Review PowerPoint "The Science of Prediction: Monitoring Volcanic Activity" (www.unavco.org/cws/modules/cws/modules/yellowstone/) before beginning this activity.

Materials:
Map of Yellowstone NP
Colored Pencils
Graph paper or Excel/spreadsheet program
Monitoring Yellowstone's Volcanic Activity PowerPoint (computer, print copies or projection screen)
Yellowstone GPS data set (Excel file or print copies)
Real-time data (Access to Internet or print copies)

Procedure:

1. Open the PowerPoint "Instructions for Monitoring Yellowstone's Volcanic Activity" (www.unavco.org/cws/modules/cws/modules/yellowstone/)
   This PowerPoint describes the current and historical monitoring data at Yellowstone NP
   Some slides will ask you to follow a link to real-time data using the internet or your teacher may provide print copies for you to analyze

   You will also be graphing data from the "Yellowstone GPS data set" (www.unavco.org/cws/modules/cws/modules/yellowstone/)
2. As you follow along with the presentation, use the "Yellowstone National Park map" on the last page to record your data. Here are a few suggestions to complete this task:
   **Construct a key for your map
   **You may want to do a field "notes" copy of your map and a final copy
   **Accuracy and detail are important but it needs to be readable too
   **Use colored pencils

GPS Part I

When you get to the section on Ground Deformation follow these steps

a. Find four (4) GPS stations (green dots on the map) located along the same transect "line" as the Leveling Data (Lake Butte to Mount Washburn)
b. Look up each of these stations on the "Yellowstone GPS data set" using it's 4-letter station ID
c. Construct a line graph using the **station ID as the X-axis** (in the same order as would be recorded on the Leveling data) and the **change in height on the Y-axis**. *The X-axis will NOT be to scale like the Leveling Data is. If you would like to use the same scale, you can use a map of the park and measure the distance each station is from Lake Butte*
d. Use a different color for each year's data or construct a separate graph for each year
e. Answer the questions in the analysis portion of the activity

3. GPS Part II
   a. Using the "Yellowstone GPS data set" construct a scatter plot FOR ALL OF THE GPS STATIONS using the **station longitude as the X-axis** and the **change in height on the Y-axis**
   b. Use a different color for each year's data or construct a separate graph for each year
   c. Repeat steps a and b only this time use the **station's latitude as the X-axis** instead of longitude. *If you are using Excel to graph your data, another useful graph is the "circle plot". Use Longitude for the X-axis and Latitude for the Y-axis. The Z-value (size of the circle) is the change in height. This graph can give you a good picture of where deformation is taking place on the surface.*

Data: Your data will be your labeled map and your graphs

Analysis: Answer each of the following questions regarding the data you collected

Volcanic Eruption data:
How often does the Yellowstone Hot-spot create a new caldera?

What types of volcanic eruptions are associated with Yellowstone?

How are these volcanic eruptions dangerous?

In your professional opinion, is there an immediate (next 100 years or so) danger related to volcanic eruptions at Yellowstone?

Volcanic Gasses data:
What gasses are monitored at Yellowstone?

How are these gasses dangerous?

In your professional opinion, is there an immediate (next 100 years or so) danger related to release of volcanic gasses at Yellowstone?

Hydrothermal Activity data:

How is hydrothermal activity dangerous?

In your professional opinion, is there an immediate (next 100 years or so) danger related to hydrothermal activity at Yellowstone?

Earthquake Activity data:
How are earthquakes dangerous?

How many modern day large (greater than magnitude 5) earthquakes have occurred at Yellowstone?

What is the most common size of earthquakes recorded at Yellowstone?

Does the pattern of earthquakes at Yellowstone suggest movement of magma? (Remember the pattern at Mt. St Helens.

In your professional opinion, is there an immediate (next 100 years or so) danger related to earthquakes at Yellowstone?

Ground Deformation data:
How is ground deformation dangerous?

What pattern do you observe in the historic data?

Is this pattern observed in the real-time GPS data?

Why might the Leveling data be different than the GPS data? (HINT: think about how and when each is measured)

In your professional opinion, is there an immediate (next 100 years or so) danger related to ground deformation at Yellowstone?

Conclusions:
Here is your opportunity to demonstrate what you learned about the hazards and monitoring at Yellowstone NP.
Your conclusions should include all of the following components

RESTATE THE PROBLEM—remind the developer of what he is paying you to do

SUMMARIZE THE DATA YOU COLLECTED—developers are not usually scientists, that's why they had to hire you. Explain to them what data you collected and what it means.

DESCRIBE YOUR RECOMMENDATIONS—be specific as to where you think it is appropriate for development to take place.

SUPPORT YOUR RECOMMENDATIONS—explain why the developers should accept your recommendations. Use specific details from your data. You should also describe any further data collection that needs to take place.

Yellowstone National Park

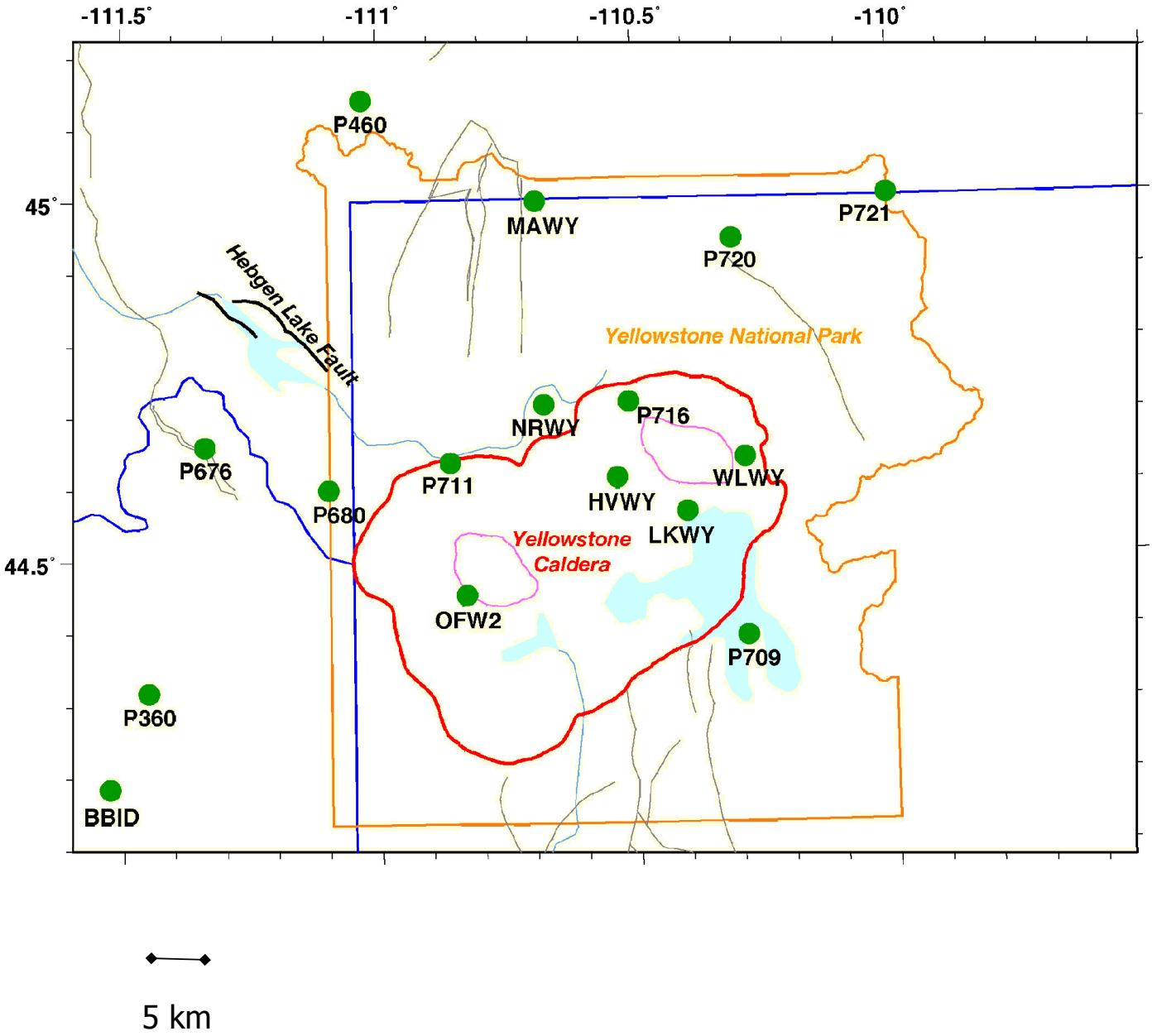


Image from University of Utah College of Mines and Earth Sciences "Continuous GPS Station Information" http://www.mines.utah.edu/~ggcmpsem/UUSATRG/GPS/time_series.html

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