Student Activities for Studying Earthquakes in Secondary Schools

Brian K. Peterson
Kurt L. Othberg

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Staff Report 95-2
April, 1995

Idaho Geological Survey
University of Idaho
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Brian K. Peterson[1] and Kurt L. Othberg[2]

INTRODUCTION

In 1993 the Idaho Geological Survey, in cooperation with the Idaho Bureau of Disaster Services, began sponsoring field workshops for teachers on earthquakes and earthquake hazards in Idaho. To encourage teachers to apply their workshop experience to the classroom, the Survey has developed several guides to activities that teachers may incorporate into units or lessons in their own curriculum. This set of activities is designed for secondary schools. A companion set is designed for elementary schools and is published separately.

The four activities presented here are meant to augment courses in earth science at junior and senior high schools. The exercises in each activity introduce students to the causes of earthquakes, how earthquakes are measured, and where they occur along tectonic plate boundaries. We intend the activities to help students better understand Idaho's tectonic setting that has produced spectacular scenery but also generates threatening earthquakes. Magnitude and intensity are terms frequently heard in the news, but few people understand what they measure and how they differ. By doing the activities on measuring magnitude and intensity, students should be able to recognize these terms and better apply reported values to their own locations. For teachers who have access to computers that can run the earthquake graphics software, *Seismic III*, the activity on earthquakes that occur on tectonic plate boundaries will take students into the program at an interactive level where they can interpret plate boundaries from real earthquake data.

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IDAHO SEISMICITY

OBJECTIVES

After successfully completing this exercise, a student should be able to:

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

This exercise is designed to help students understand where and how often earthquakes are likely to occur in Idaho. Table 1 lists earthquakes with a Richter magnitude of 5 or greater that occurred in or near Idaho since 1884. Figure 1 is a map of faults in Idaho that have shown evidence of displacement in the last 15,000 years. Figure 2 is a map of the geologic provinces of Idaho.

WHERE DO EARTHQUAKES OCCUR IN IDAHO?

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 earthquake magnitude next to each dot.

2. Using Figure 1, answer the following questions.

   How many earthquakes occur on or very near a fault? ______

   How many earthquakes occur in areas lacking faults? ______

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

   North of 45 degrees north latitude . . . . ______________

   Between 44 degrees and 45 degrees north latitude . . . . ______________

   In southwestern Idaho . . . . ______________

   In southeastern Idaho and northern Utah . . . . ______________

In western Montana and western Wyoming .... ____________

4. Refer to Figure 2 to answer the following questions.

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

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 and last two values have already been entered.

MAGNITUDE	EARTHQUAKES	MAGNITUDE	EARTHQUAKES
5.0	27	6.6	____
5.2	22	6.8	____
5.4	____	7.0	____
5.6	____	7.2	____
5.8	____	7.4	____
6.0	____	7.6	1
6.2	____	7.8	0
6.4	____		

2. Now plot these pairs of values as points of a graph on Figure 3. The first and last two points have already been plotted.

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 a earthquakes above magnitude 5 are 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

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
1945	44.70	115.40	6.0
1947	44.75	111.75	6.3
1959	44.83	111.08	7.7
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
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
1983	44.05	113.85	7.3
1983	44.23	114.10	5.8
1983	44.10	113.90	5.6
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

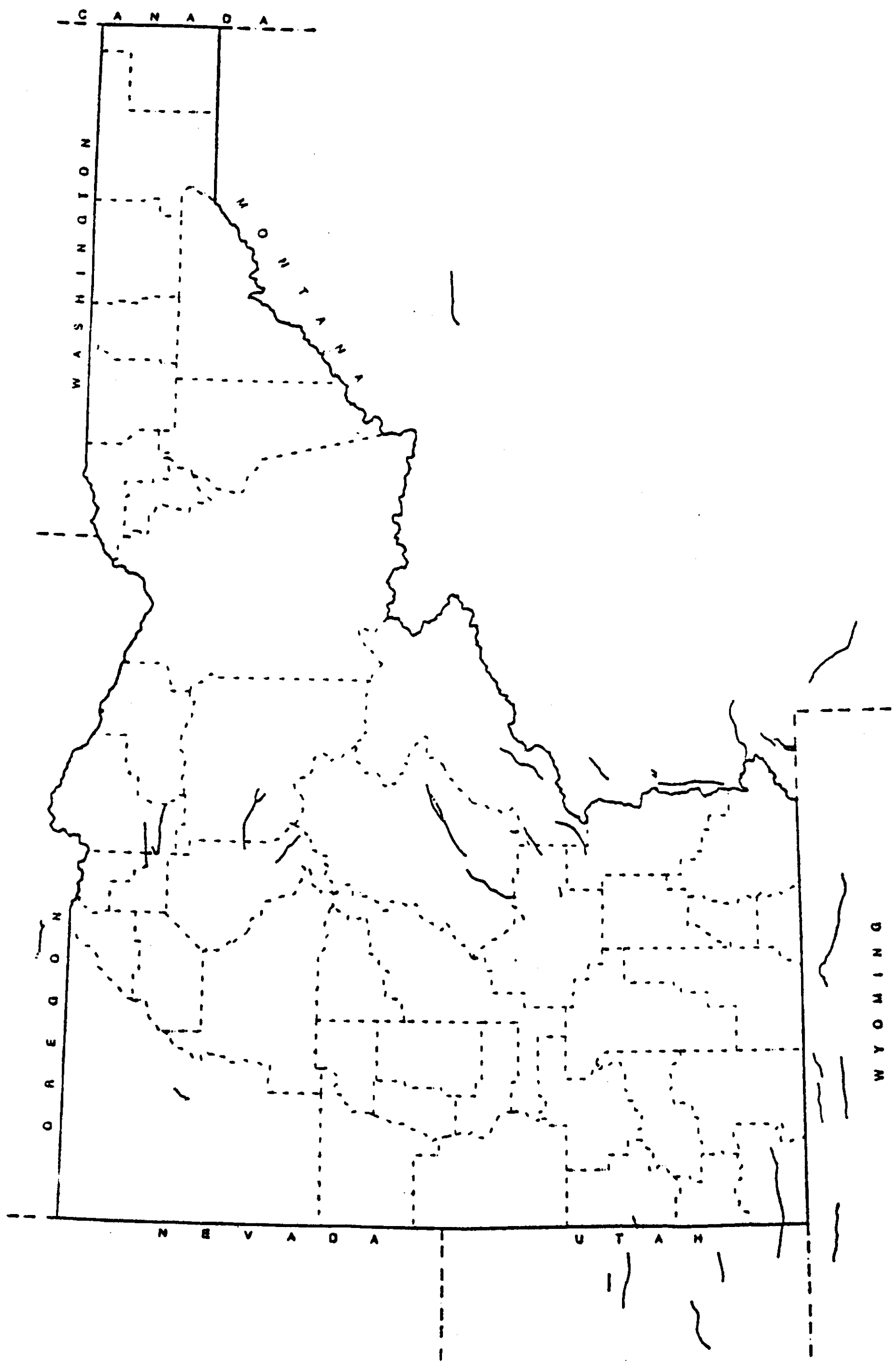

Figure 1. Neotectonic fault map of Idaho (after Hilt, A.P., Breckenridge, R.M., and Sprenke, K.F., 1994, Preliminary Neotectonic Map of Idaho, Idaho Geological Survey, Technical Report 94-1) and worksheet for plotting locations of earthquakes.

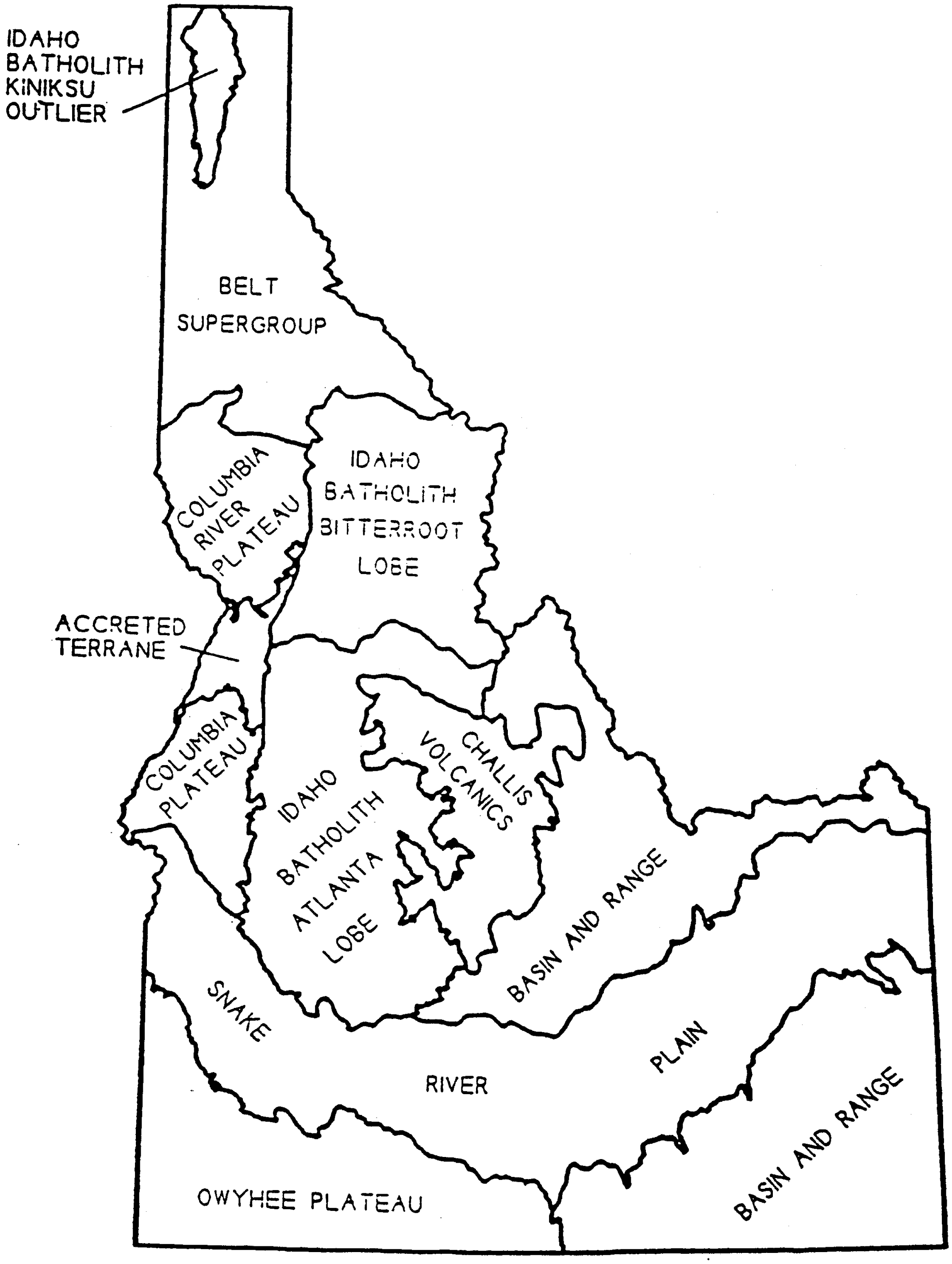

Figure 2. Geologic provinces of Idaho.

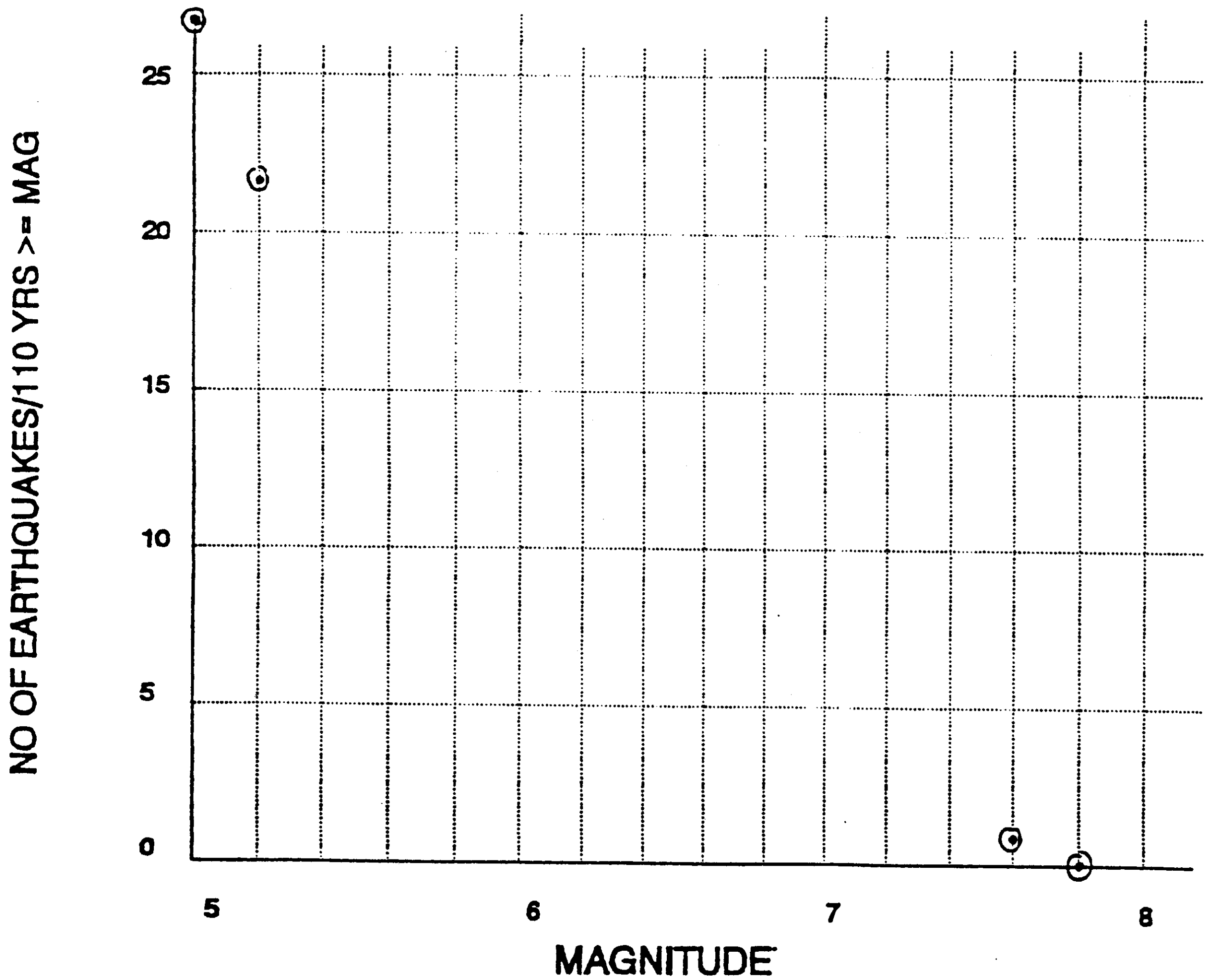

Figure 3. Worksheet for plotting frequency of occurrence of earthquakes versus magnitude for Idaho, 1884 - 1994.

EARTHQUAKE MAGNITUDE

OBJECTIVES

After successfully completing this exercise, a student should be able to:

1. Distinguish between a **seismograph** and a **seismogram**.
2. Determine the time interval between arrivals of the P-wave and S-wave on a seismogram.
3. Measure the amplitude of the largest S-wave on a seismogram.
4. Determine the Richter magnitude and distance to the epicenter, given a seismogram and a Richter magnitude nomogram.
5. Distinguish between earthquake **magnitude** and **energy** released by an earthquake.
6. Determine the energy released by an earthquake, given the magnitude of the earthquake and a graph of energy versus magnitude.

MATERIALS NEEDED

Metric ruler (centimeter and millimeter)

PROCEDURE FOR DETERMINING THE RICHTER MAGNITUDE

Before completing the steps below, take a few minutes to study the procedure for determining the Richter magnitude on page 11.

DETERMINING DISTANCE, MAGNITUDE, AND ENERGY

The Draney Peak earthquake sequence near the Idaho-Wyoming border northeast of Soda Springs began on January 30, 1994. Figure 4 shows a seismogram of one of the larger shocks recorded by a University of Idaho seismograph.

Applying the Richter magnitude techniques on page 11 to the seismogram shown in Figure 4, answer questions 1 to 3 below.

1. Find the distance of the seismograph station from the focus of the earthquake. (Hint: Use a metric scale to measure the S-P interval and the total seismogram length.)

Answer: ___________ kilometers

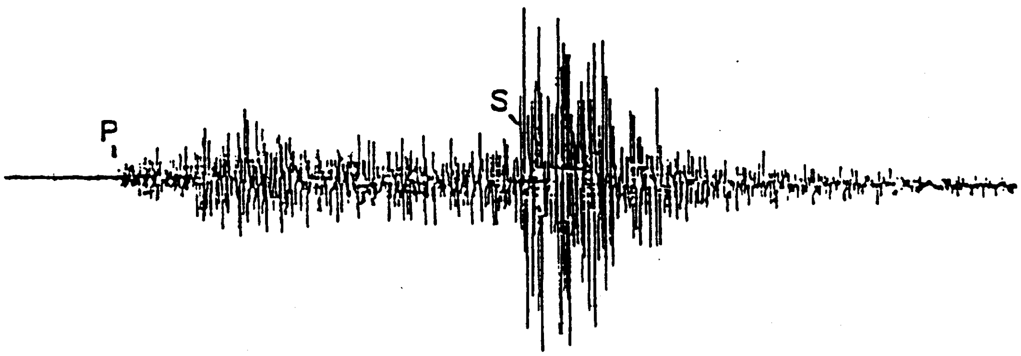

Figure 4. Seismogram of one the larger Draney Peak earthquakes, January-April, 1994. The seismogram represents 2 minutes of recording time.

2. Find the maximum amplitude shown on the seismogram.

Answer: ____ mm

3. Find the Richter magnitude, M_L, of the earthquake.

Answer: M_L = ____

Using the graph in Figure 6, answer questions 4 and 5 below.

4. Approximately how much energy was released by the shock recorded above?

Answer: ____ ergs

5. Determine the amount of energy released by other natural phenomena. Compare the results with the earthquake recorded in Figure 4.

a. lightning bolt ________________________________

b. tornado (kinetic energy) ____________________________

c. hurricane (kinetic energy) ___________________________

d. Mount St. Helens eruption ____________________________

HOW TO FIND THE RICHTER MAGNITUDE OF AN EARTHQUAKE

The seismogram of an earthquake, (a) below, shows the difference in arrival times of the first P-wave and S-waves and the amplitude of the maximum wave motion.

1. Note the time interval between arrivals of the first P-wave and the first S-wave using the scale provided. Mark this value (S minus P = 24 seconds) on scale (b) at the left below. Note that this time interval also determines the distance between the epicenter and the seismograph station, which is about 210 km on scale (b).

2. Next, note the amplitude (height) of the maximum wave motion on the seismogram using the scale provided in (a) for this purpose. Mark this value (amplitude = 23 mm) on scale © at the right below.

3. Finally, place the edge of a ruler at the time interval mark (24 seconds) on scale (b) and at the amplitude mark (23 mm) on scale (c). The edge of the ruler will cross scale (d) at the Richter magnitude (M = 5) of the earthquake. A line has been drawn below to show where the edge of the ruler crosses the magnitude scale.

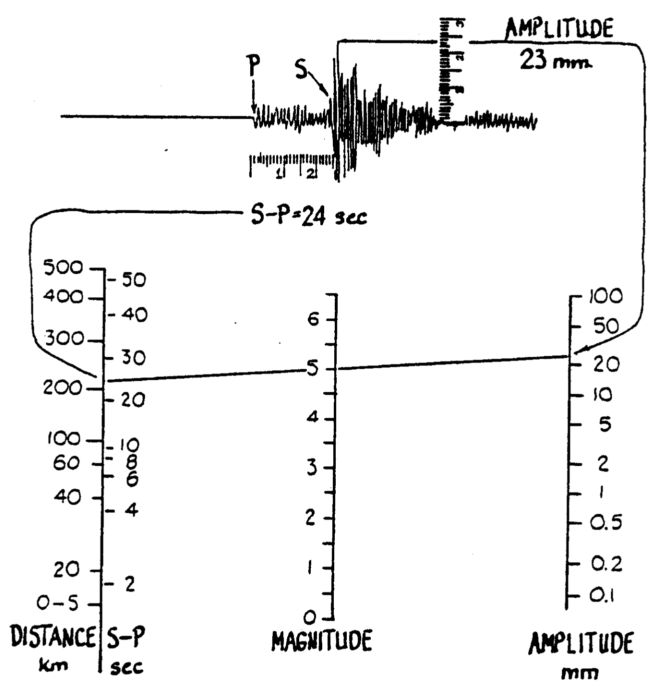

Figure 5. Graph for estimating Richter magnitude, after Bolt, B.A., 1993, Earthquakes and geological discovery: New York, W.H. Freeman, p. 58, 60.

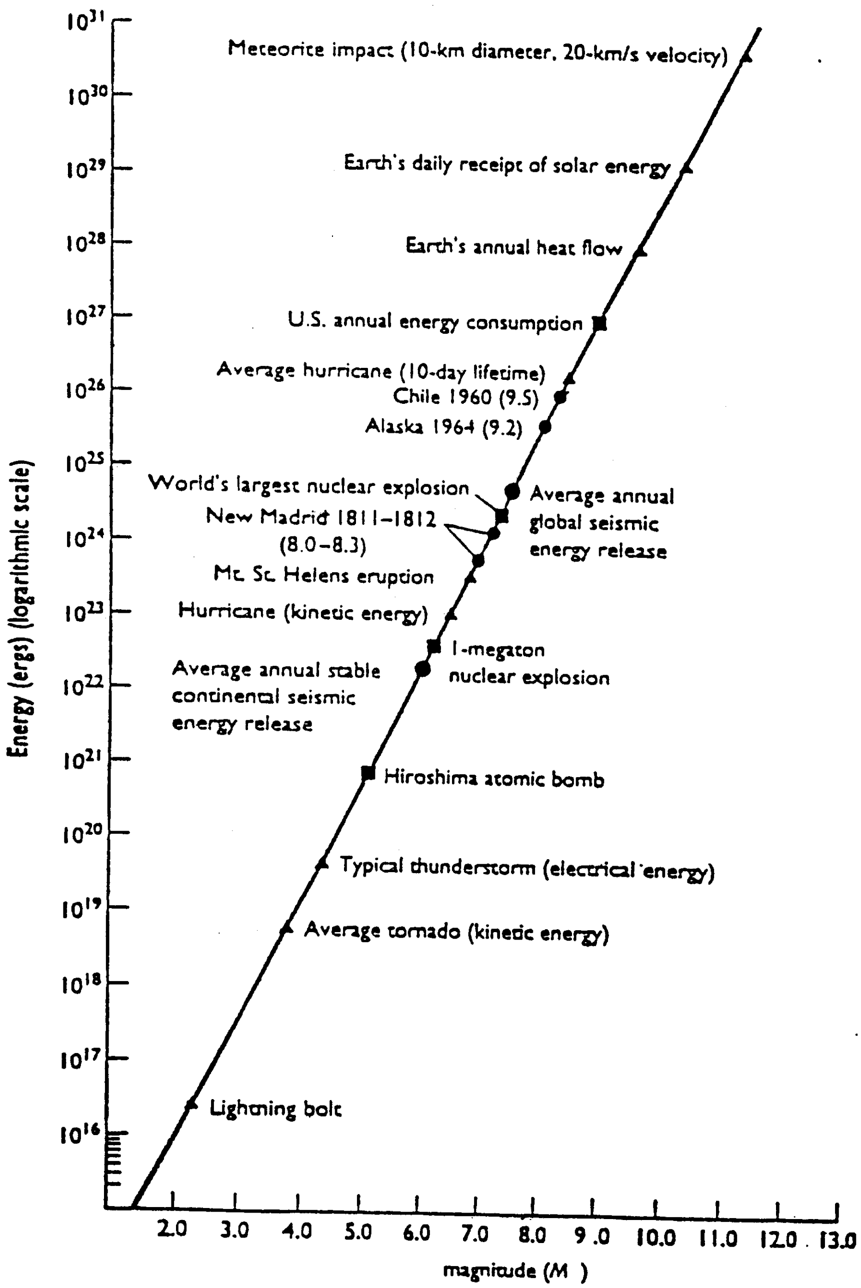

Figure 6. The energy released by an earthquake versus the magnitude of an earthquake.

EARTHQUAKE INTENSITY

OBJECTIVES

After successfully completing this exercise, a student should be able to:

1. Distinguish between earthquake magnitude and intensity.
2. Assign Modified Mercalli Intensity (MMI) values based on descriptions of damage due to earthquakes.
3. Construct an isoseismal map from MMI values and locations.
4. Interpret an isoseismal map and identify areas of greatest and least damage.

A. THE NORTHRIDGE, CALIFORNIA, EARTHQUAKE

The Northridge, California, earthquake of January 17, 1994, is noted for the great damage it caused. A **magnitude** of 6.7 was recorded for the earthquake. The **energy** released by this earthquake can be determined by using the procedure described in the *Earthquake Magnitude* exercise.

Although the **magnitude** and **energy** are indicators of the physical processes associated with an earthquake, they reveal nothing about the disruptive social and economic consequences of an earthquake. The effects on human lives and property are not measured by seismographs, but are recorded instead by trained investigators who visit the area after the earthquake. They compile information about damage and other effects of the earthquake through direct observation, interviews, and questionnaires. Areas of like earthquake damage and other effects are assigned a Roman numeral using a twelve-level **intensity** scale called the Modified Mercalli Intensity scale, shown in Table 2.

The Modified Mercalli Intensity (MMI) values are placed on a map at locations where the damages were observed. Contours are then drawn around areas of equal MMI values, creating an **isoseismal** map. Such a map permits areas of greatest damage to be identified. The area of maximum intensity generally occurs near the epicenter where the strongest ground shaking was felt. High intensities, however, may also occur where the ground shaking is amplified because of geologic conditions. These conditions may include areas of alluvial fill and lake or river deposits. An example of an isoseismal map is shown in Figure 7.

B. THE 1983 EARTHQUAKE AT BORAH PEAK, IDAHO

The Borah Peak, Idaho, earthquake of October 28, 1983, occurred at 8:06 am about 21 kilometers northwest of the community of Mackay. The epicenter was located at 44.1° N. lat., 113.9° W. long. A surface wave magnitude of 7.3 was recorded for this earthquake.

The effects of this major earthquake at various locations in Idaho are listed in Table 3. The students will be constructing an isoseismal map of damage resulting from the Borah Peak earthquake in this exercise.

1. Using the Modified Mercalli Intensity scale in Table 2, assign MMI values to each of the damage descriptions for the Borah Peak earthquake listed in Table 3.
2. Transfer these MMI values to the correct locations on Figure 8.
3. Draw isoseismal contour lines on the map, separating the areas of MMI values.

Suggestions for drawing contour lines:

- Use pencil (not pen), draw lightly, and revise and erase as often as needed.
- You may want to begin with the highest intensity values since these will have the smallest areas.
- Work on one isoseismal contour line at a time. It will be complete when it closes on itself, when it reaches the Idaho border, or where there are no data to guide you in drawing the lines.
- In drawing successive isoseismal contours, the outer contours should be generally parallel to the inner contours. The lines should be smooth, with no sharp turns or corners.
- The contour line for one intensity must not cross the contour line for another intensity. Also, it should not cross itself.
- It sometimes helps to draw contour lines by visualizing them as elevation contours on a topographic map, with the largest MMI value at the peak of the hill or mountain, and the smaller ones surrounding it farther down the slope of the mountain.

Using the completed isoseismal map, answer questions 4-8.

4. What is the location (latitude, longitude) of the highest intensity? What is the location of the epicenter?

Location of maximum intensity . . . . ____________________

Epicenter location . . . . ____________________

5. What intensity was felt at the Utah border? .... ____________

What intensity was felt at the Nevada border? .... ____________

What intensity was felt at the Canadian border? .... ____________

6. Why does the intensity become less and less as distance from the epicenter becomes greater?

Answer: ____

____

7. Explain the greater intensity at the Canadian border than at the Utah border when Utah is much closer to the epicenter than Canada?

Answer: ____

____

8. Does the **magnitude** of an earthquake depend upon the distance from the epicenter? Would it make sense to ask what the **magnitude** of the Borah Peak earthquake was at the Canadian border or at the Utah border? Explain.

Answer: ____

____

Table 2. The Modified Mercalli intensity scale.

I. Not felt except by a very few under especially favorable circumstances.

II. Felt only by a few persons at rest, especially on upper floors of buildings. Delicately suspended objects may swing.

III. Felt quite noticeably indoors, especially on upper floors of buildings, but many people do not recognize it as an earthquake. Standing motor cars may rock slightly. Vibration like passing truck. Duration estimated.

IV. During the day felt indoors by many, outdoors by a few. At night some awakened. Dishes, windows, doors disturbed; walls make creaking sound. Sensation like heavy truck striking building. Standing motor cars rocked noticeably.

V. Felt by nearly everyone; many awakened. Some dishes, windows, etc., broken; a few instances of cracked plaster; unstable objects overturned. Disturbances of trees, poles, and other tall objects sometimes noticed. Pendulum clocks may stop.

VI. Felt by all; many frightened and run outdoors. Some heavy furniture moved; a few instances of fallen plaster or damaged chimneys. Damage slight.

VII. Everybody runs outdoors. Damage negligible in buildings of good design and construction; slight to moderate in well-built ordinary structures; considerable in poorly built or badly designed structures; some chimneys broken. Noticed by persons driving motor cars.

VIII. Damage slight in specially designed structures; considerable in ordinary substantial buildings, with partial collapse; great in poorly built structures. Panel walls thrown out of frame structures. Fall of chimneys, factory stacks, columns, monuments, walls. Heavy furniture overturned. Sand and mud ejected in small amounts. Changes in well water. Disturbs persons driving motor cars.

IX. Damage considerable in specially designed structures; well-designed frame structures thrown out of plumb; great in substantial buildings, with partial collapse. Buildings shifted off foundations. Ground cracked conspicuously. Underground pipes broken.

X. Some well-built, wooden structures destroyed; most masonry and frame structures destroyed with foundations; ground badly cracked. Train rails bent. Landslides considerable from riverbanks and steep slopes. Shifted sand and mud. Water splashed over banks.

XI. Few, if any (masonry) structures remain standing. Bridges destroyed. Broad fissures in ground. Underground pipelines completely out of service. Earth slumps and land slips in soft ground. Train rails bent greatly.

XII. Damage total. Waves seen on ground surfaces. Lines of sight and level distorted. Objects thrown upward into the air.

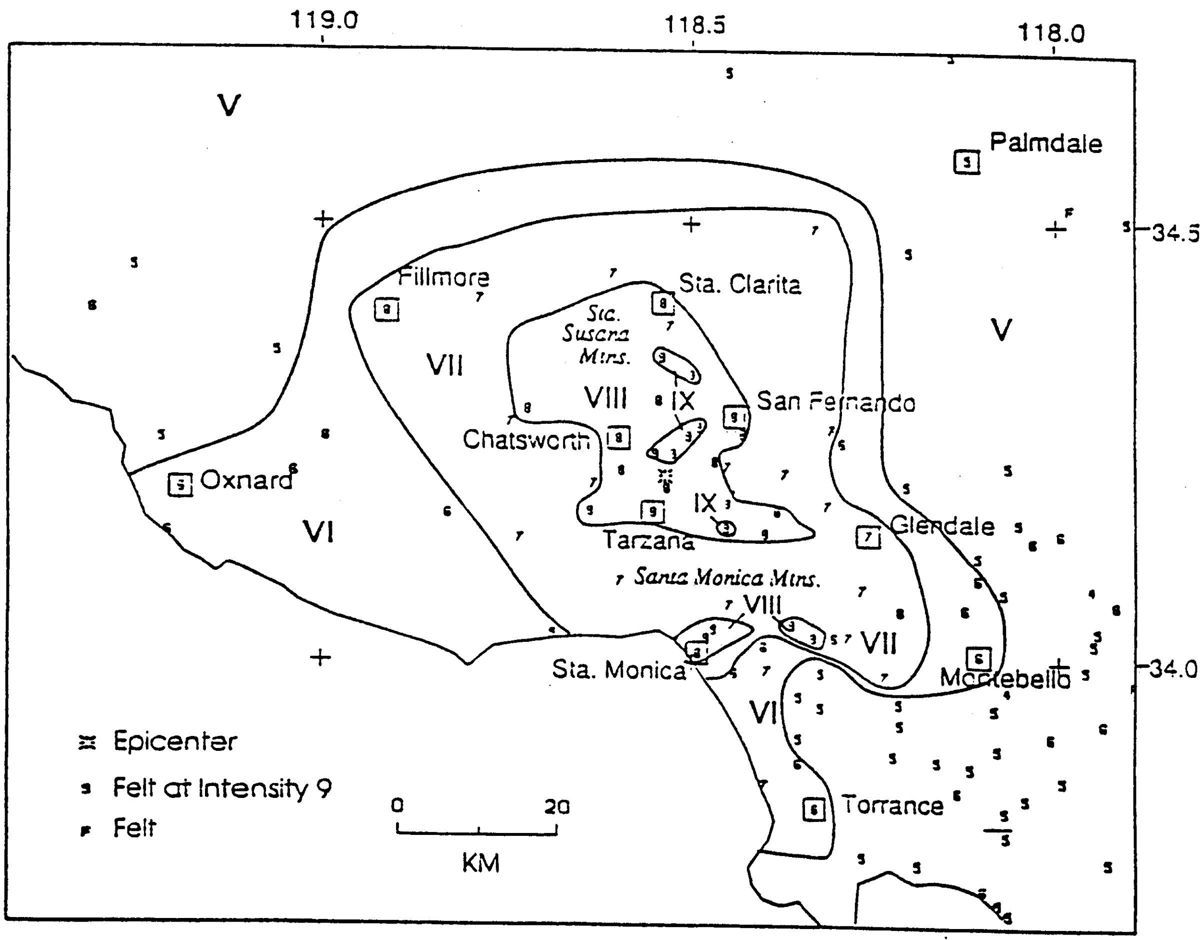

Figure 7. An isoseismal map for the January 17, 1994 earthquake at Northridge, California (after USGS, National Earthquake Information Center). Intensities according to the Modified Mercalli scale.

Table 3. Descriptions of the effects of the 1983 Borah Peak earthquake.

__1. **American Falls**. Trees and stop signs swayed. Felt by nearly everyone.

__2. **Arco**. Beds, chairs, tables moved. Felt by everyone.

__3. **Atomic City**. Heavy furniture was moved. Damage was slight. Everybody felt the shaking.

__4. **Banks**. People reported cracked plaster and overturned vases and lamps.

__5. **Basalt**. Lamps were overturned. Cracked plaster in the walls.

__6. **Bellevue**. Felt by everyone. Some chimneys were damaged.

__7. **Boise**. Felt by all. A few instances of fallen plaster and damaged chimneys.

__8. **Bonners Ferry**. Some people reported broken dishes. Felt by nearly everyone.

__9. **Borah Peak**. Ground cracked. Landslides occurred.

__10. **Caldwell**. Pendulum clocks stopped. Trees and poles swayed.

__11. **Carey**. Furniture moved. Everyone felt the shaking.

__12. **Cascade**. Many people ran outdoors. Some damaged chimneys were reported. Some furniture moved.

__13. **Challis**. Noticed by persons driving cars. Everybody ran outdoors. Considerable damage to poorly designed structures.

__14. **Cottonwood**. Many people said it was like a heavy truck striking the building. Walls made creaking sounds.

__15. **Craigmont**. Many people , including those sitting in parked or temporarily stopped cars, reported that they felt some shaking.

__16. **Deary**. People reported table lamps overturned. Some pendulum clocks stopped.

__17. **Elk City**. Some dishes, windows, and glasses were broken. Pendulum clocks stopped.

__18. **Elk River**. Everyone felt it. Damage was slight. One person reported being awakened by the noise of a moving dresser.

__19. **Fruitland**. Trees swayed. Floor and table lamps fell over.

__20. **Garden Valley**. Felt by everyone. Chimneys damaged.

__21. **Grangeville**. Felt like sensation of a heavy truck striking the building. Walls made a creaking sound.

___22. **Idaho Falls**. Reports of broken dishes. Telephone poles swayed.

___23. **Jerome**. Felt by everyone. Although many people were frightened, damage was slight.

___24. **Kendrick**. Felt by nearly everyone. Some people reported cracked plaster in some rooms of their houses.

___25. **Lapwai**. Felt like the vibration of a passing truck. Standing automobiles rocked slightly. Many people did not recognize it as an earthquake.

___26. **Lewiston**. Felt quite noticeably indoors, similar to vibration from a passing truck.

___27. **Mackay**. Slight to moderate damage in well-built ordinary structures. Some chimneys broken. Noticed by people driving cars.

___28. **McCall**. Telephone poles swayed. Some windows were shattered.

___29. **Moscow**. Felt indoors by many. Walls made a creaking sound.

___30. **Nampa**. Windows, glass doors, and dishes were broken. Some people were awakened by the shaking and noise.

___31. **New Meadows**. Some people reported that their windows and dishes rattled. Walls made a creaking sound.

___32. **Nezperce**. Windows rattled. Walls creaked. Cars rocked. No reports of broken windows.

___33. **Orofino**. Trees, poles, and other tall objects moved noticeably. A few instances of cracked plaster. Some unstable objects overturned.

___34. **Osburn**. Tall billboards swayed. Windows were broken.

___35. **Pocatello**. Some heavy furniture was moved. Damage was slight, but everyone felt it.

___36. **Post Falls**. Standing automobiles rocked noticeably. Dishes, windows, and glasses rattled. Walls creaked.

___37. **Rathdrum**. Standing cars rocked. Many people reported rattling of windows and glassware.

___38. **Shoshone**. Everyone felt the shaking. Broken windows were reported.

___39. **Soda Springs**. Felt quite noticeably on upper floors of buildings. Standing cars rocked slightly.

___40. **Sun Valley**. Some damage to plaster and chimneys. Many people were frightened. Some of them ran outdoors.

___41. **Teton**. Many people on upper floors of buildings felt the shaking. Those on ground floor reported the sensation of the vibration of a passing truck.

___42. **Twin Falls**. A few people reported broken windows and glassware. Telephone poles and trees swayed.

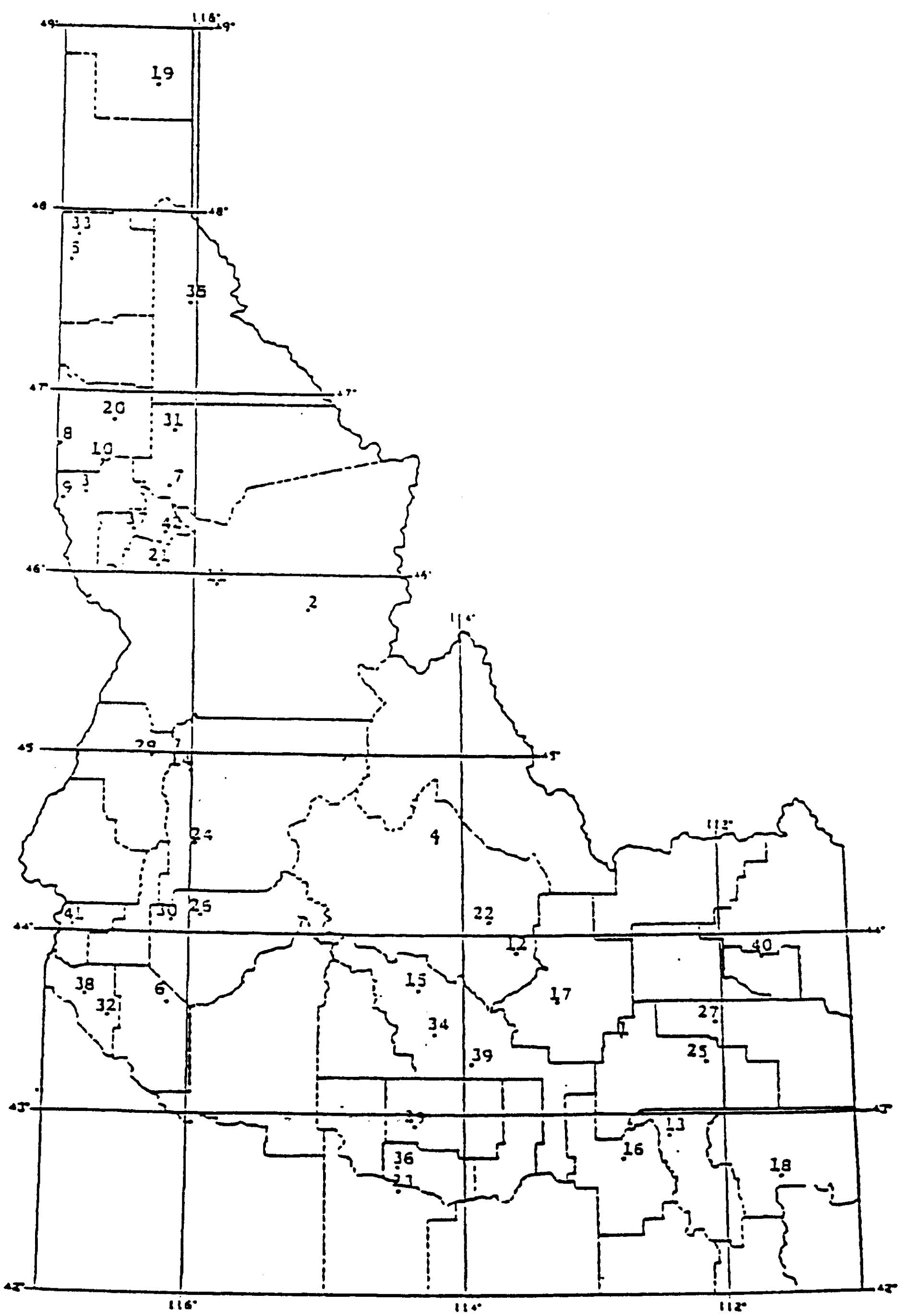

Figure 8. Worksheet for making an isoseismal map of the October, 1983 earthquake at Borah Peak, Idaho.

SEISMIC ACTIVITY AT TECTONIC PLATE BOUNDARIES

OBJECTIVES

After successfully completing this exercise, a student should be able to:

1. Name and locate at least six tectonic plates on a map of the Earth.
2. Name the three types of tectonic plate boundaries and locate an example of each on a map.
3. Describe the relations of each of the following geologic processes to the appropriate type of plate boundary: Subduction, rifting, sea-floor spreading.
4. Describe the relative motions of tectonic plates at each of the following types of plate boundaries: convergent, transform, and divergent.
5. Distinguish between an epicenter and the focus (hypocenter) of an earthquake.
6. Describe the relation between the depths and magnitudes of earthquakes along a Benioff zone.
7. Describe the relative locations, magnitudes, and depths of earthquakes at each of the following types of plate boundaries: convergent, transform, and divergent.
8. Determine the type of plate boundary from a map view that provides locations, magnitudes, and depths of earthquakes along the plate boundary.

MATERIALS NEEDED

IBM PC, IBM PS/2 or compatible with hard drive
EGA or VGA display
Mouse or trackball (optional)
3.5" high-density diskette drive
Printer, dot-matrix or laser
SEISMIC III (installed)
Protractor or calculator

GETTING STARTED

To get the program running and to explore some of its options, follow the steps below.

1. When the screen displays: **C:\>**
   Type: **CD\SEISMIC**
   Then press the **Enter** key.

The screen will then display: **C:\SEISMIC>**
You type: **SEISMIC**
Then press the **Enter** key.

2. A screen will appear with the following words at the bottom of the screen:

   E:Edit **S:Seismic** **P:Edit Profile** **Q:Quit**

   Be prepared for some excitement because the screen will come alive with earthquakes after the next step! Using the mouse, move the cursor to **S:Seismic** and click the left button.

   A map of the Earth will appear on the screen with earthquakes rapidly appearing as dots and making clicking sounds!

3. To stop the action for now, click the left button on the mouse.

   A Menu Bar will appear at the top of the screen. It looks something like this:

   Views Speed Beeps Audio Mag Dots Help Options Quit

4. To slow down the activity of the earthquakes, move the cursor to **Speed** and click the left button on the mouse.

   A pull-down menu will appear. With the cursor on **1 day/sec**, click the left button.

   Now look at the bottom of the screen. An information bar contains a **Date Window** in the middle. It displays the year and month as follows: **YEAR:MONTH**
   For example, July 1994 would be displayed as: **1994:07**

   The rate at which the date in the Date Window changes is controlled by altering the Speed on the Menu Bar.

5. To hear beeps for only the larger earthquakes, select **Beeps** on the Menu Bar, then select **6 or above** on the pull-down menu.

6. To turn off the beeps, select **Audio** on the Menu Bar, then select **No Sound** on the pull-down menu. Notice that the seismic activity continues on the screen noiselessly.

7. To display only the larger earthquakes, select **Mag** (for Magnitude) on the Menu Bar, then select **6 or above** on the pull-down menu.

Now look at the bottom of the screen. A **Magnitude Scale** is on the right side of the information bar. The sizes of the dots displayed on the screen correspond to the magnitudes of the earthquakes.

8. To display the earthquakes as circles instead of dots, select **Dots** on the Menu Bar, then select **Circles** on the pull-down menu.

   To prevent the dots from disappearing from the screen, select **Keep Large Dots** from this pull-down menu.

9. To display the tectonic plate boundaries, select **Options** on the Menu Bar, then select **Plates** on the pull-down menu.

10. Before going on to the next section, students may want to return to the Menu Bar and adjust any of the choices made above to their own liking. These may also be changed at any time during the rest of the exercise.

UNDERSTANDING TECTONIC PLATE BOUNDARIES

A Convergent Plate Boundary

Map View of Cook Inlet, Alaska

1. While watching the **Date Window** at the bottom of the screen to note the year and month when the first earthquake occurred, select **Views** on the Menu Bar, then select **Cook Inlet** from the pull-down menu.

2. When did the first seismic event occur in this data set? . . . . ____________________
   (Select **Options** from the Menu Bar, then select **Restart** from the pull-down menu to run the year and month again.)

   When did the last seismic event occur in this data set? . . . . . ____________________

3. At the bottom of the screen, the **Depth Scale** appears on the left side. Write the depth range corresponding to each of the following colors.

Red	Orange	Purple	Pink	Turquoise	Dark Blue
_____	______	_____	______	________	________

4. What are the units of measure for the depths shown above? ________________

5. What is the depth range of the focus of the deepest events? . ________________

   The shallowest events? . . . . ________________

6. What is the relation between depths and magnitudes of seismic events at this plate boundary? Record observations here.

   ____

7. What was the magnitude of the largest event? __________
   (It may be easier to see this by selecting a **Magnitude** of **4 or larger**, then **Restarting** the Cook Inlet View from the **Options** menu.)

8. What was the depth range of the largest event? . . . . ________________

Cross Section at Cook Inlet

1. To see a cross section of the map displayed above, select **Views** from the Menu Bar, then select **Cook.XS** from the pull-down menu.

2. What is the approximate depth of the focus of the deepest events?________________

   The shallowest events? . . . . ________________

3. What is the magnitude of the largest event? . . . . ________________

4. What is the depth of the largest event? . . . . ________________

5. Compare answers in Questions 2, 3, and 4 above with answers to Questions 5, 7, and 8 in the previous part. Record observations here.

____

6. Print the screen display of the cross section by selecting **Options** on the Menu Bar, then selecting **Hard Copy** from the pull-down menu.

7. Write the following labels on the printed cross section:
Subduction zone, Benioff zone, North American plate, Pacific plate.

8. Draw arrows on the printed cross section showing relative movement of the plates. Which plate has the greater density at this boundary? . . . . . ____________________

9. Determine the dip of the lower 100 km of the subduction zone. . . __________degrees

10. To see a three-dimensional view of the plate boundary, select **Views** from the Menu Bar, then select **Cook.3D** from the pull-down menu.

A Transform Plate Boundary

Map View of the San Andreas Fault Zone

1. While watching the **Date Window** at the bottom of the screen to note the year and month when the first earthquake occurred, select **Views** on the Menu Bar, then select **Loma Prieta** from the pull-down menu.

   When did the first earthquake occur in this data set? ____________

   When did the last earthquake occur in this data set? ____________

2. Write the depth range corresponding to each of the following colors by consulting the **Depth Scale** at the bottom of the screen.

Red	Orange	Purple	Pink	Turquoise	Dark Blue	Med. Blue	Light Blue
____	______	_______	_____	_______	_____	_____	_____

3. What is the depth range of the focus of the deepest events? . ____________________

The shallowest events? . . . . ________________

4. Where are the deepest events relative to the San Andreas fault zone? ________________

   The shallowest events? . . . . ________________

5. What is the approximate strike of the San Andreas fault plane? ________________

   The **direction** of dip? . . . . ________________

6. Print the screen display of the map view by selecting **Options** from the Menu Bar, then selecting **Hard Copy** from the pull-down menu.

7. Write the following labels on the printed map view: Pacific Ocean, San Francisco Bay, North American plate, Pacific plate, San Andreas fault zone.

8. Draw arrows on the printed map view showing relative movement of the plates.

Cross Section of San Andreas Fault Zone

1. To see a cross section parallel to the strike of the San Andreas Fault Zone, select **Views** from the Menu Bar, then select **Loma.XS** from the pull-down menu.

2. What is the approximate depth of the foci of the deepest events? ________________

   The shallowest events? . . . . ________________

3. Compare your answers in Question 2 above with your answers to Question 3 in the previous section. Record observations here.

   ____

4. What is the magnitude of the largest event? . . . . ________________

5. What is the depth of the largest event? . . . . ________________

6. What relation between depths and magnitudes of seismic events at this plate boundary do you see?

____

7. Print the screen display of the cross section by selecting **Options** on the Menu Bar, then selecting **Hard Copy** from the pull-down menu.

8. Write the following labels on the printed cross section: Northwest, Southeast

9. Name the plate viewed by the observer when looking at the cross section.

____

Name the plate the observer is standing on when looking at the cross section.

____

10. Compare the cross sections of the convergent boundary (Cook Inlet) and the transform boundary (San Andreas). Record observations regarding the following features:

Depths of earthquakes ____________________________________

Magnitudes of earthquakes ________________________________

A Divergent Plate Boundary

Map View of the Mid-Atlantic Ridge

1. Select **Views** on the Menu Bar, then select **Atlantic** from the pull-down menu.

2. Now select **Options** from the Menu Bar, then select **Make Your Own Map** from the pull-down menu.

3. With the mouse, move the upper left-hand corner to: +57° latitude, -35° longitude. Click the left button on the mouse.

4. Now move the lower right-hand corner to: +55° latitude, -30° longitude. Click the left button on the mouse.

5. Next, click the left button on the mouse **twice** and a map view of the area just selected will appear.

6. Once again, select **Options** from the Menu Bar, but this time select **Edit Control File** from the pull-down menu.

7. At the top of the screen will appear a new Menu Bar. Select **Parameters** from this Menu Bar, then select **Values** from the pull-down menu.

8. Delete the existing number in **Maximum Depth** with the backspace key and type in 50. Then move the cursor down to **Minimum Magnitude**, click the left button, and change 4 to 1.

9. Move the cursor to **OK** and click the left button on the mouse.

10. Select **Quit Editor** from the bottom of the screen and answer the question **Save Yours?** by selecting **Yes**.

    The screen will now display a map view of the events along the plate boundary. If the events do not pass through the central area of the screen, or if no events appear, repeat steps 1 through 10.

11. Write the depth range corresponding to each of the following colors by consulting the **Depth Scale** at the bottom of the screen.

    Red________________ Dark Blue______________

    Orange______________ Medium Blue___________

    Purple______________ Light Blue_____________

    Pink________________ Green________________

    Turquoise___________ Yellow_________________

12. What is the depth range of the foci of the deepest events? . . ____________________

    The shallowest events? . . . . ____________________

13. What is the magnitude of the largest event? . . . . ____________________

14. What are the relationships between depths and magnitudes of seismic events at this plate boundary?

____

15. Print the screen display of the map view by selecting **Options** on the Menu Bar, then select **Hard Copy** from the pull-down menu.

16. Write the following labels on the printed map view: North American plate, Eurasian plate, Mid-Atlantic Ridge.

17. Draw arrows on the printed map view showing relative movement of the plates.

Cross section of the Mid-Atlantic Ridge

1. Select **Options** from the Menu Bar, then select **Edit Control File** from the pull-down menu.

2. Now select **Viewing** from the new Menu Bar, then select **Map, Cross section, 3-D** from the pull-down menu.

3. A dialog box appears. Select **Cross section View**, then select **Show Region**, then move the cursor to **OK** and click the left button on the mouse.

4. Select **Quit Editor** from the bottom of the screen, then select **Yes** in response to the question **Save Yours?**

   The screen will now display a cross section of the part of the map created earlier.

5. What is the approximate depth of the foci of the deepest events? ________________

   The shallowest events? . . . . ________________

6. What is the magnitude of the largest event? . . . . ________________

   What is the magnitude of the smallest event? . . . . ________________

7. Compare answers to Questions 5 and 6 above with answers to Questions 12 and 13 in the previous part. Record observations here.

____

8. Print the screen display of the cross section by selecting **Options** from the Menu Bar, then selecting **Hard Copy** from the pull-down menu.

9. Write the following labels on the printed cross section: North American plate, Eurasian plate, Mid-Atlantic Ridge.

10. Draw arrows on the printed cross section showing relative movement of the plates.

11. Compare the cross section of this divergent boundary with the **transform** boundary (San Andreas) with respect to the following features. Record observations below.

    Depths of earthquakes _______________________________

    Magnitudes of earthquakes ___________________________

12. Now compare the cross section of this divergent boundary with the **convergent** boundary (Cook Inlet) with respect to the following features. Record your observations below.

    Depths of earthquakes _______________________________

    Magnitudes of earthquakes ___________________________

IDENTIFYING TECTONIC PLATE BOUNDARIES

Map View of Mystery Boundary X

1. Select **Views** on the Menu Bar, then select **Atlantic** from the pull-down menu.

2. Now select **Options** from the Menu Bar, then select **Make Your Own Map** from the pull-down menu.

3. With the mouse, move the upper left-hand corner to: -53° latitude, -30° longitude. Click the left button on the mouse.

4. Now move the lower right-hand corner to: -58° latitude, -25° longitude. Click the left button on the mouse.

5. Next, click the left button on the mouse **twice** and the screen will now display a map view of the area just selected.

6. Select **Options** from the Menu Bar, then select **Edit Control File** from the pull-down menu.

7. At the top of the screen a new Menu Bar. Select **Parameters** from this Menu Bar, then select **Values** from the pull-down menu.

8. Delete the existing number in **Maximum Depth** with the backspace key and type in 200. Then move the cursor down to **Minimum Magnitude**, click the left button, and change 4 to 1.

9. Move the cursor to **OK** and click the left button on the mouse.

10. Select **Quit Editor** from the bottom of the screen and answer the question **Save Yours?** by selecting **Yes**.

    The screen will now display a map view of the events along a plate boundary. If the events do not pass through the central area of the screen, or if no events appear, repeat steps 1 through 10.

11. Print the map view shown on the screen by selecting **Options** from the Menu Bar, then selecting **Hard Copy** from the pull-down menu.

12. Write the following labels on the printed map view: South American plate, Scotia plate, plate boundary.

13. Draw arrows on the printed map view showing relative movement of the plates.

14. Display a cross section of this plate boundary by following steps 1 through 4 listed previously under *Cross section of the Mid-Atlantic Ridge*. Identify the South American plate, Scotia plate, and plate boundary.

15. Which of the three types of plate boundaries is Mystery Boundary X? Consider magnitudes, depths, and locations of the seismic events in arriving at the answer.

Answer:____

ENDING THE SESSION

1. Select **Quit** from the Menu Bar.

2. Now select **Quit** from the bottom of the screen.

APPENDIX 1: BACKGROUND INFORMATION

INTRODUCTION

Three general questions are addressed in the activities for studying earthquakes in secondary classrooms.

1. Where and how often do earthquakes occur in Idaho?

2. How do we measure earthquakes?

3. Why do earthquakes occur in Idaho?

The activities guide the student in exploring these questions. Background information the student will need for the activities is presented here.

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 in Figure 9.

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 present 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 batholith 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 Belt
   1. The Idaho Seismic Belt
   2. Lewis and Clark Zone
C. Yellowstone Caldera and Hot Spot
D. Extensional tectonics
   1. Possible sources of vertical stress
      a. Mantle plumes
      b. Idaho batholith isostatic adjustment
   2. Resulting strain: normal faulting
E. Mathematical skills: plotting x-y coordinates

SEISMOLOGY

While most students are aware of the "Richter Scale" as a measure of relative sizes of earthquakes, it is often unclear exactly what the distinctions are among earthquake magnitude, energy, and intensity. In the activity, *Measuring Earthquake Magnitude*, students examine seismograms, determine earthquake magnitude, and compare magnitude with the energy released by an earthquake. In the second activity, *Measuring Earthquake Intensity*, students assess earthquake damage descriptions through Modified Mercalli Intensity values and construct an isoseismal map using these values.

These activities should be accompanied or preceded by additional teaching media that present the following concepts and principles:

A. Seismic energy transmission
   1. Body waves
      a. P-waves: motion, velocity
      b. S-waves: motion, velocity
   2. Surface waves
      a. Love waves: motion, velocity
      b. Rayleigh waves: motion, velocity
B. Ground motions associated with earthquakes
C. Seismographs
   1. Principles of operation
   2. Seismograph stations: X, Y, Z orientations
D. Seismograms
   1. Duration
   2. Amplitude
   3. Arrival times

E. Physical principles
   1. Wave properties
      a. Peak, trough, amplitude
      b. Wavelength
      c. Frequency
      d. Velocity
   2. Energy
      a. Definition
      b. Units of measure
   3. Physical measurements
      a. Objective
      b. Subjective

EARTHQUAKES

The role that plate tectonics plays in producing earthquakes is fundamental to understanding the basic attributes of earthquakes, including their distribution, magnitudes, and focal depths. Relative movement along tectonic plate boundaries is responsible for the great majority of earthquakes that occur worldwide. To show this, a detailed computer-based activity has been prepared using a sophisticated software package called Seismic-III. In *Earthquakes at Tectonic Plate Boundaries,* students explore earthquakes worldwide that are associated with plate boundaries.

While this exercise will serve to reinforce and illustrate many of the concepts and principles listed below, they should also be presented through other teaching media in association with this exercise.

A. Physical properties
   1. Density
   2. Buoyancy
B. Faults
   1. Types
   2. Elastic rebound theory
C. Structure of the lithosphere and upper mantle
   1. Continental crust and oceanic crust
      Composition, thicknesses, densities, rigidity
   2. The Moho discontinuity
      Base of crust, transition between crust and mantle
   3. The upper mantle
      Composition, thickness, density, rigidity
   4. The asthenosphere

a. Base of lithosphere
b. Composition, temperature, plasticity

D. Plate motions
1. Earlier configurations: Pangaea to present time
2. Boundary types
a. Divergent: normal faulting, oceanic ridges
b. Convergent: subduction, island arcs
c. Transform: strike-slip faulting, fracture zones

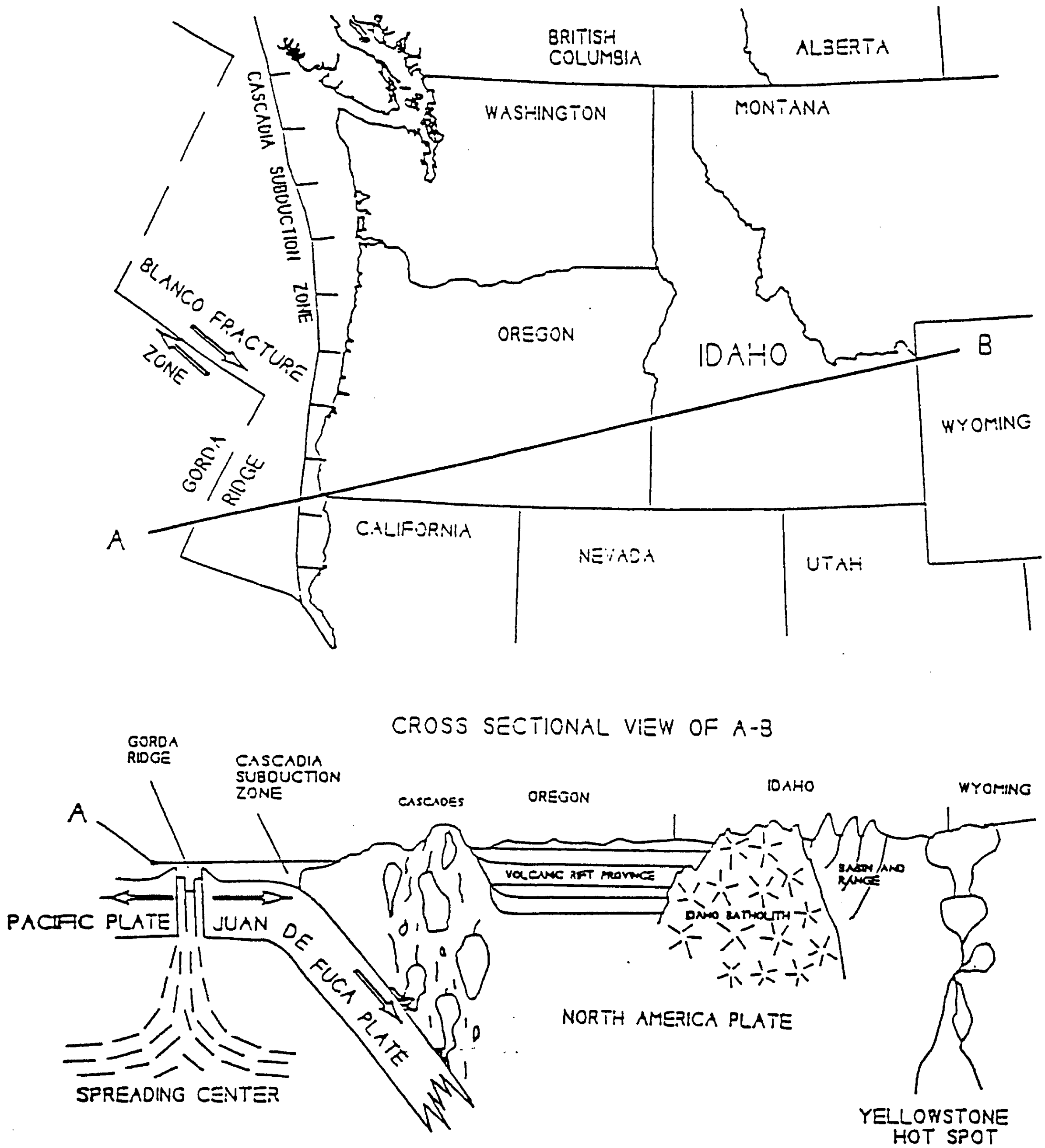

Figure 9. Idaho's relationship to tectonic plates of the Northwest (after Hilt, A.P., Breckenridge, R.M., and Sprenke, K.F., 1994, Preliminary Neotectonic Map of Idaho, Idaho Geological Survey, Technical Report 94-1). The cross section shows some of the causes of regional uplift and faulting in Idaho.

APPENDIX 2: SOLUTIONS TO *IDAHO SEISMICITY*

WHERE DO EARTHQUAKES OCCUR IN IDAHO?

1. See Figure 10.

2. 13, 14

3. North of 45 degrees: 0
   44 to 45 degrees: 17
   SW Idaho: 3
   SE Idaho & Utah: 7
   Montana & Wyoming: 7

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

HOW OFTEN ARE EARTHQUAKES LIKELY TO OCCUR IN IDAHO?

1. 27, 22, 16, 15, 12, 9, 6, 3, 3, 2, 2, 2, 1, 1, 0

2-3. See Figure 10.

4. 27 earthquakes

5. 110 years ÷ 27 earthquakes = 4.1 years per earthquake

6. 8 earthquakes

   110 yrs ÷ 8 earthquakes = 13.75 years per earthquake

7. 2 earthquakes

   110 yrs ÷ 2 earthquakes = 55 years per earthquake

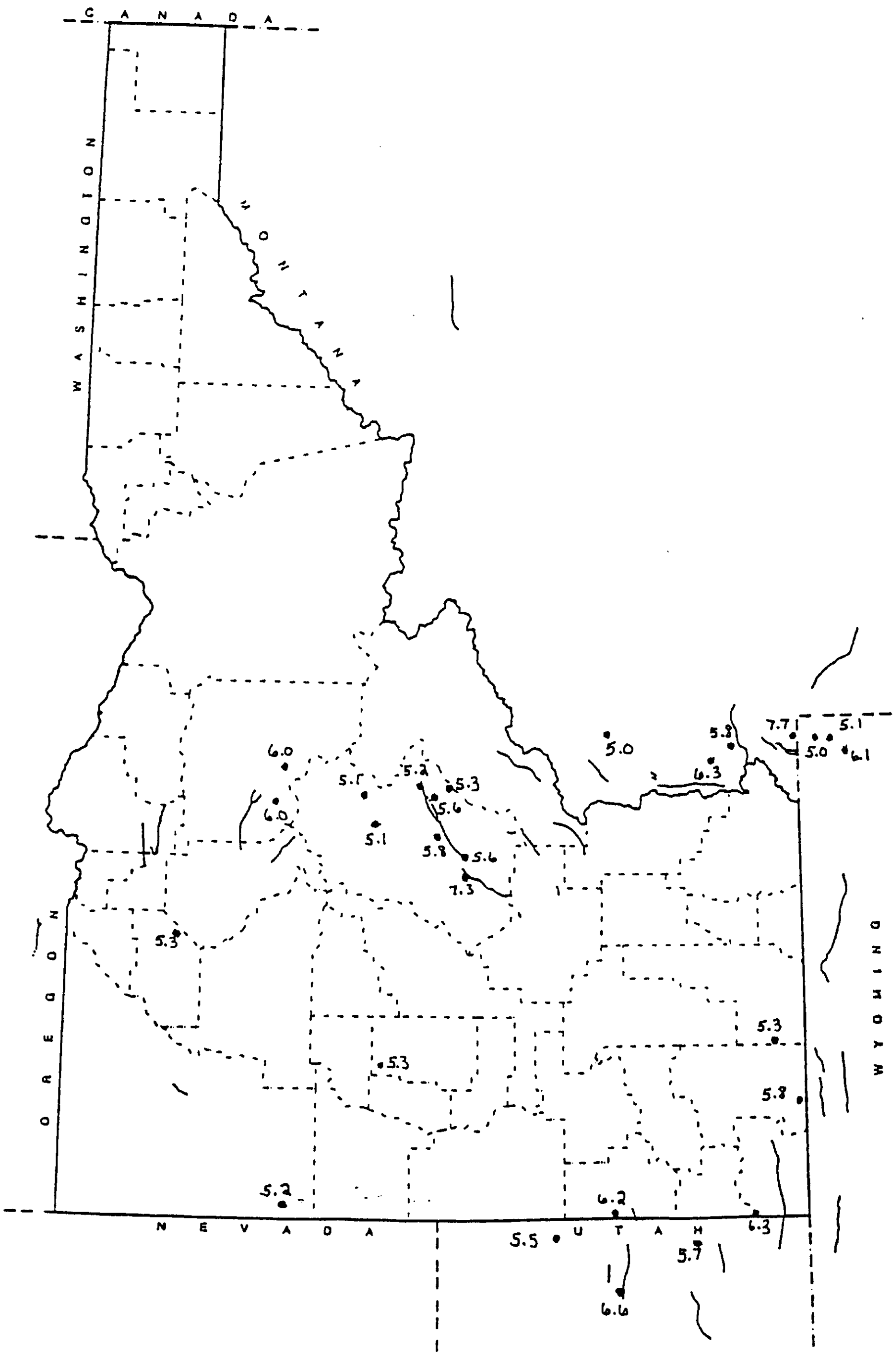

Figure 10. Solution to *Idaho Seismicity, Where do Earthquakes occur in Idaho?*, problem number 1: Idaho earthquakes with magnitudes of 5 or greater plotted on the neotectonic fault map of Idaho.

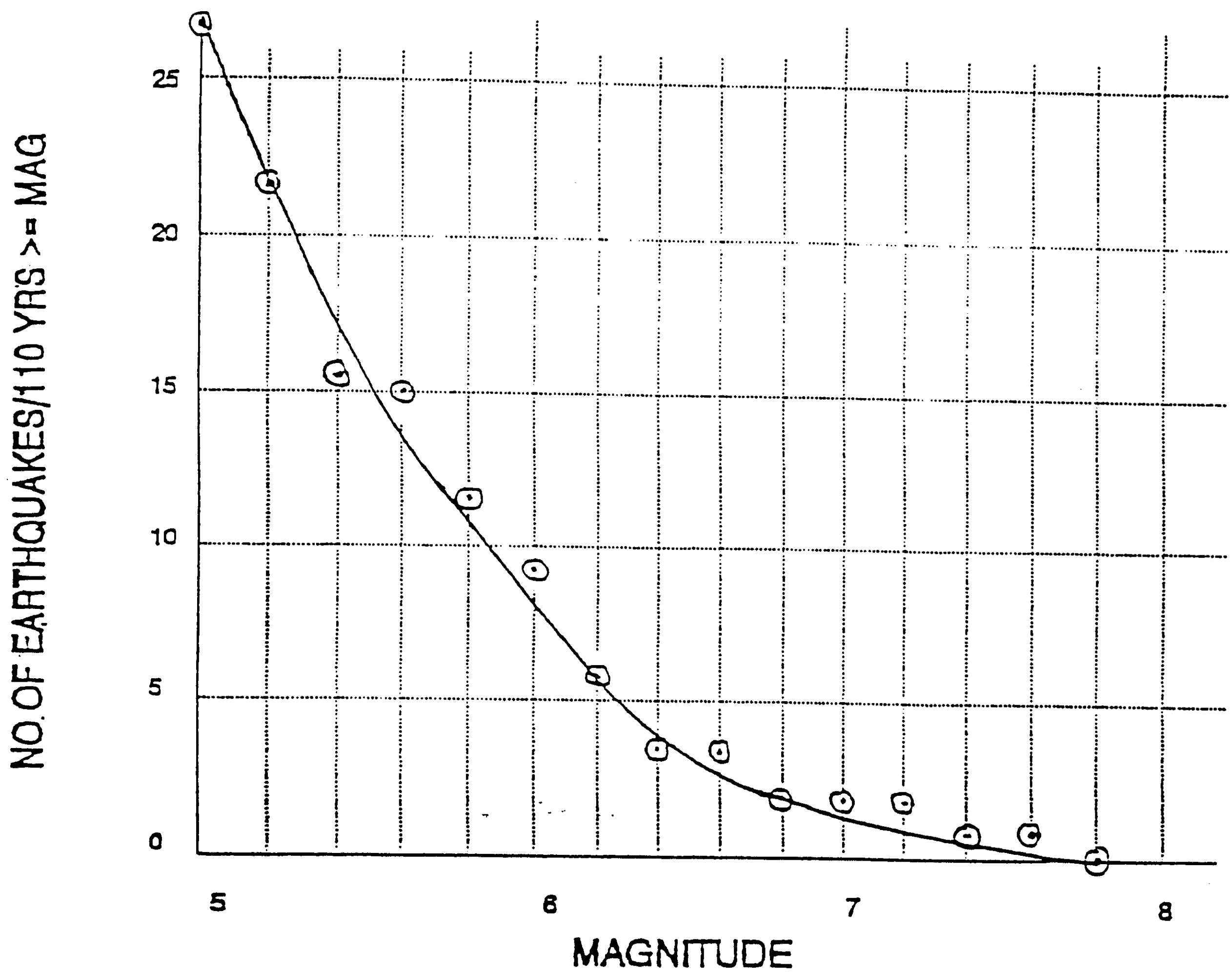

Figure 11. Solution to *Idaho Seismicity, How often are Earthquakes likely to occur in Idaho?*, problem numbers 2 and 3: frequency of occurrence of earthquakes versus magnitude in Idaho from 1884 to 1994.

APPENDIX 3: SOLUTIONS FOR MEASURING EARTHQUAKE MAGNITUDE

1. Solution:

   S-P interval = 5.2 cm
   Total seismogram length = 13.2 cm
   Total seismogram length = 2 minutes = 120 seconds
   Travel time = (5.2/13.2) x 120 seconds = 47.3 sec
   Find 47.3 seconds on scale b on page 11.
   The corresponding distance on scale b is about 420 km.

2. About 23 mm

3. About 6.0

4. About 2×10^{22} ergs. Note that the y-axis is a logarithmic scale. This means that halfway between marked intervals on this axis represents about 3 times the lower interval value, not 5 times the lower interval value as on a linear scale.

5. a. If a lightning bolt releases about 2×10^{16} ergs and the earthquake released about 2×10^{22} ergs, then the earthquake released about $(2 \times 10^{22})/(2 \times 10^{16}) = 1 \times 10^{6}$ times as much energy as the lightning bolt.

   b. Tornado: about 6×10^{18} ergs

   Therefore,, $(2 \times 10^{22})/(6 \times 10^{18}) = 3333$ times as much energy as a tornado.

   c. Hurricane: about 1×10^{23} ergs

   Therefore,, $(2 \times 10^{22})/(1 \times 10^{23}) = 0.20$ or one-fifth as much energy as a hurricane.

   d. Mount St. Helens: about 3×10^{23} ergs

   Therefore, $(2 \times 10^{22})/(3 \times 10^{23}) = 0.067$, which is less than one-tenth of the energy of Mount St. Helens eruption.

APPENDIX 4: SOLUTIONS FOR MEASURING EARTHQUAKE INTENSITY

THE BORAH PEAK, IDAHO, EARTHQUAKE

1.

V	AMERICAN FALLS	IV	IDAHO FALLS
VI	ARCO	VI	JEROME
VI	ATOMIC CITY	V	KENDRICK
V	BANKS	III	LAPWAI
V	BASALT	III	LEWISTON
VI	BELLEVUE	VII	MACKAY
VI	BOISE	V	MCCALL
V	BONNERS FERRY	IV	MOSCOW
IX	BORAH PEAK	V	NAMPA
V	CALDWELL	IV	NEW MEADOWS
VI	CAREY	IV	NEZPERCE
VI	CASCADE	V	OROFINO
VII	CHALLIS	V	OSBURN
IV	COTTONWOOD	VI	POCATELLO
III	CRAIGMONT	IV	POST FALLS
V	DEARY	III	RATHDRUM
V	ELK CITY	V	SHOSHONE
VI	ELK RIVER	III	SODA SPRINGS
V	FRUITLAND	VI	SUN VALLEY
VI	GARDEN VALLEY	III	TETON
IV	GRANGEVILLE	V	TWIN FALLS

2-3. See Figure 12. Note that the isoseismal map drawn by each student will be different although the same general pattern should emerge.

4. Max intensity: About 44° N. Latitude, about 114° W. Longitude
Epicenter: 44.1° N. Latitude, 113.9° W. Longitude

5. Utah border: (East of 114° W. Latitude) III
Nevada border: (West of 114° W. Latitude) V
Canadian border: V

6. The energy carried by seismic waves is dissipated as it travels through rock. This is called attenuation. The farther from the epicenter that a structure is located, the less

energy is left to produce damage to the structure.

7. Some types of rock absorb more energy than others. The rocks north of the epicenter apparently transmit energy carried by seismic waves more efficiently than the rocks south of the epicenter.

8. Magnitude represents the amplitude of an S-wave measured at the seismograph station after adjusting that amplitude for distance from the epicenter. The magnitude of an earthquake is therefore the same at all seismograph stations, regardless of their distances from the epicenter. The magnitude is a measure of the energy of an earthquake at the source. The intensity represents the damage produced by the energy remaining after traveling from the epicenter through rock.

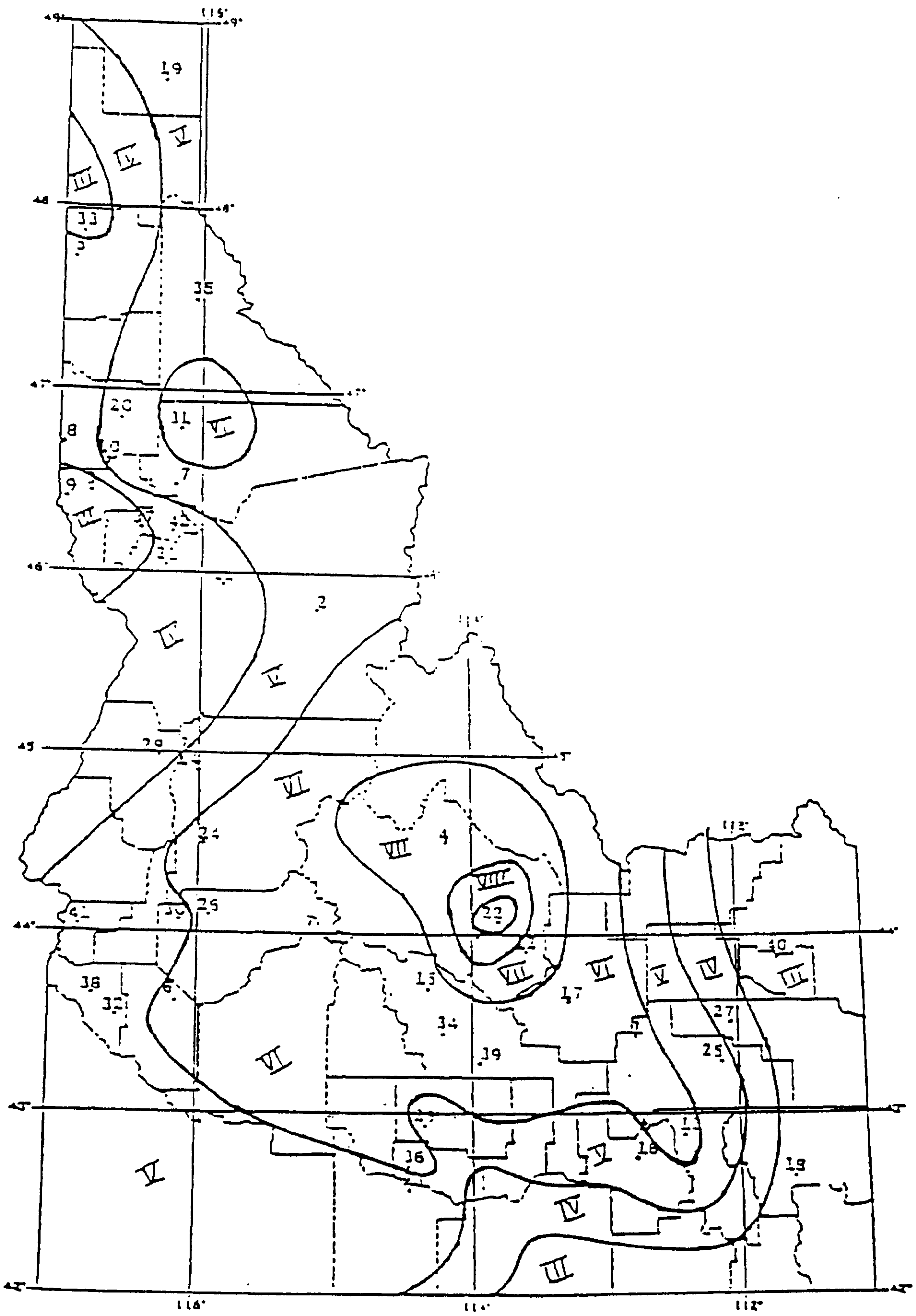

Figure 12. Solution to *Earthquake Intensity, B. The 1983 Earthquake at Borah Peak, Idaho*, problems 2 and 3: an isoseismal map of the 1983 Borah Peak earthquake.

APPENDIX 5: SOLUTIONS FOR EARTHQUAKES AT TECTONIC PLATE BOUNDARIES

MAP VIEW OF COOK INLET

1. —
2. January 1985, May 1989
3. 0-40 40-80 80-120 120-160 160-200 200-240
4. kilometers
5. 160-200 km, 0-40 km
6. The larger the event, the deeper it is. Note that all events of magnitude 4 or greater are at depths of 80 km or greater.
7. 5
8. 120-160 km

CROSS SECTION AT COOK INLET

1. —
2. 200 km, 0 km
3. 5
4. 140 km
5. The same magnitude-depth pattern is seen here.
6. —
7. See Figure 13.
8. Pacific plate
9. About 50 degrees

MAP VIEW OF SAN ANDREAS FAULT ZONE

1. October 1989, December 1990
2. 0-2 2-4 4-6 6-8 8-10 10-12 12-14 14-16 kilometers
3. 14-16 km, 0-2 km
4. To the southwest. To the northeast.
5. N.45°W., S.45°W.
6. —
7. See Figure 14.
8. See Figure 14.

CROSS SECTION OF SAN ANDREAS FAULT ZONE

1. —
2. 20 km, 0 km
3. Deepest event in map view is 16 km. Deepest event in cross section is 20 km.
4. 6
5. 16 km
6. No relation between depths and magnitudes is seen here.
7. —
8. See Figure 15.
9. North America, Pacific
10. The deepest events are found at the convergent plate boundaries. There is no difference in magnitudes between the two types of boundary.

MAP VIEW OF MID-ATLANTIC RIDGE

1-10. —

11. 0-5 25-30
    5-10 30-35
    10-5 35-40
    15-20 40-45
    20-25 45-50 kilometers
12. 30-35 km, 10-15 km
13. 5
14. No relation between depths and magnitudes is seen here.
15. —
16. See Figure 16.
17. See Figure 16.

CROSS SECTION OF MID-ATLANTIC RIDGE

1-4. —

5. 35 km, 10 km
6. 5, 4
7. The depths agree and the magnitudes agree.
8. —
9. See Figure 17.
10. See Figure 17.
11. The events are shallower on the transform boundary.
    The events are larger on the transform boundary.

12. The events are deeper on the convergent boundary.
    The magnitudes are the same on both boundaries.

MYSTERY TECTONIC PLATE BOUNDARY

1-11. —
12. See Figure 18.
13. See Figure 18.
14. South America plate on northeast subducted beneath Scotia plate on southwest.
15. Convergent

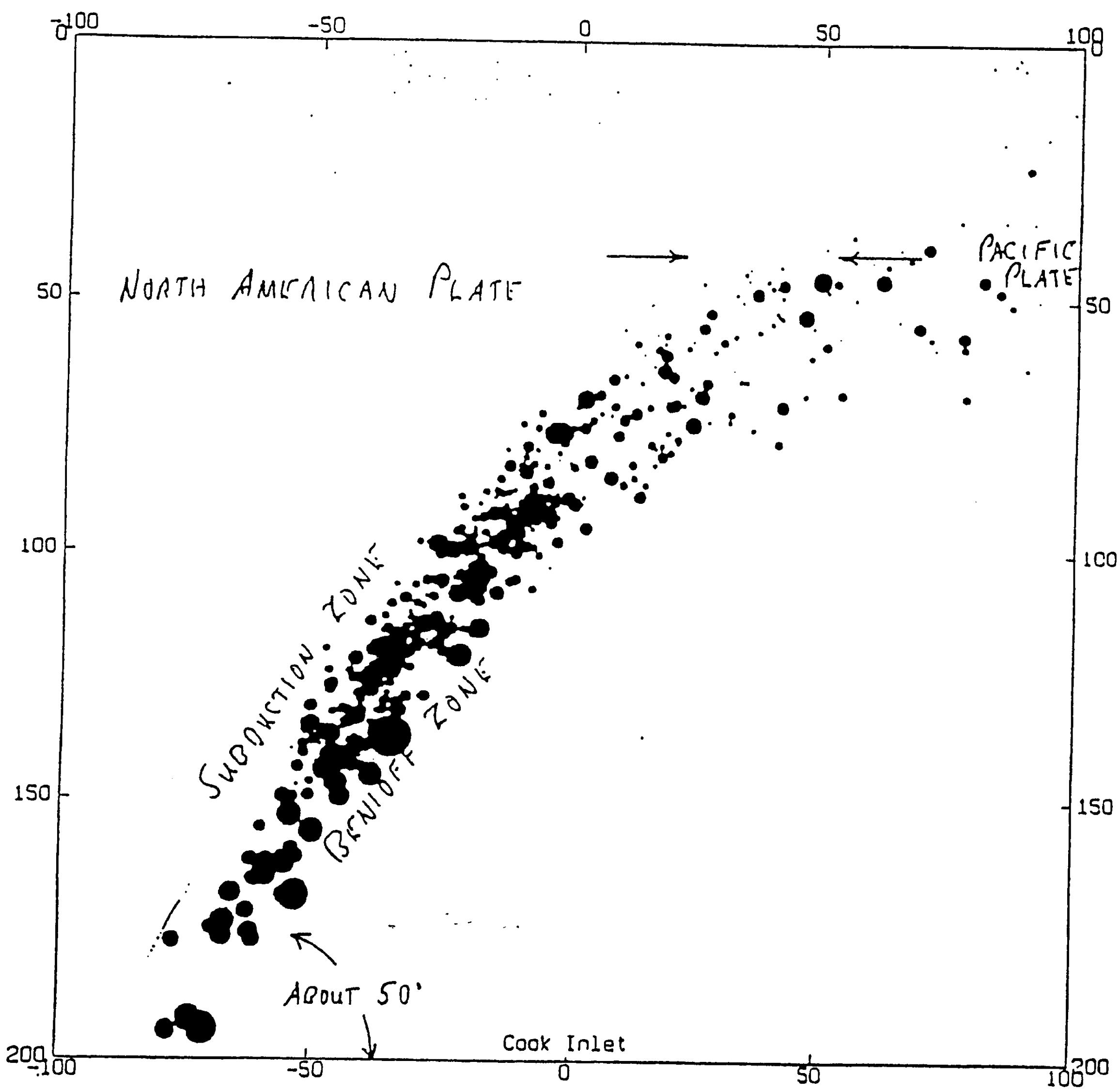

Figure 13. Cross section at Cook Inlet.

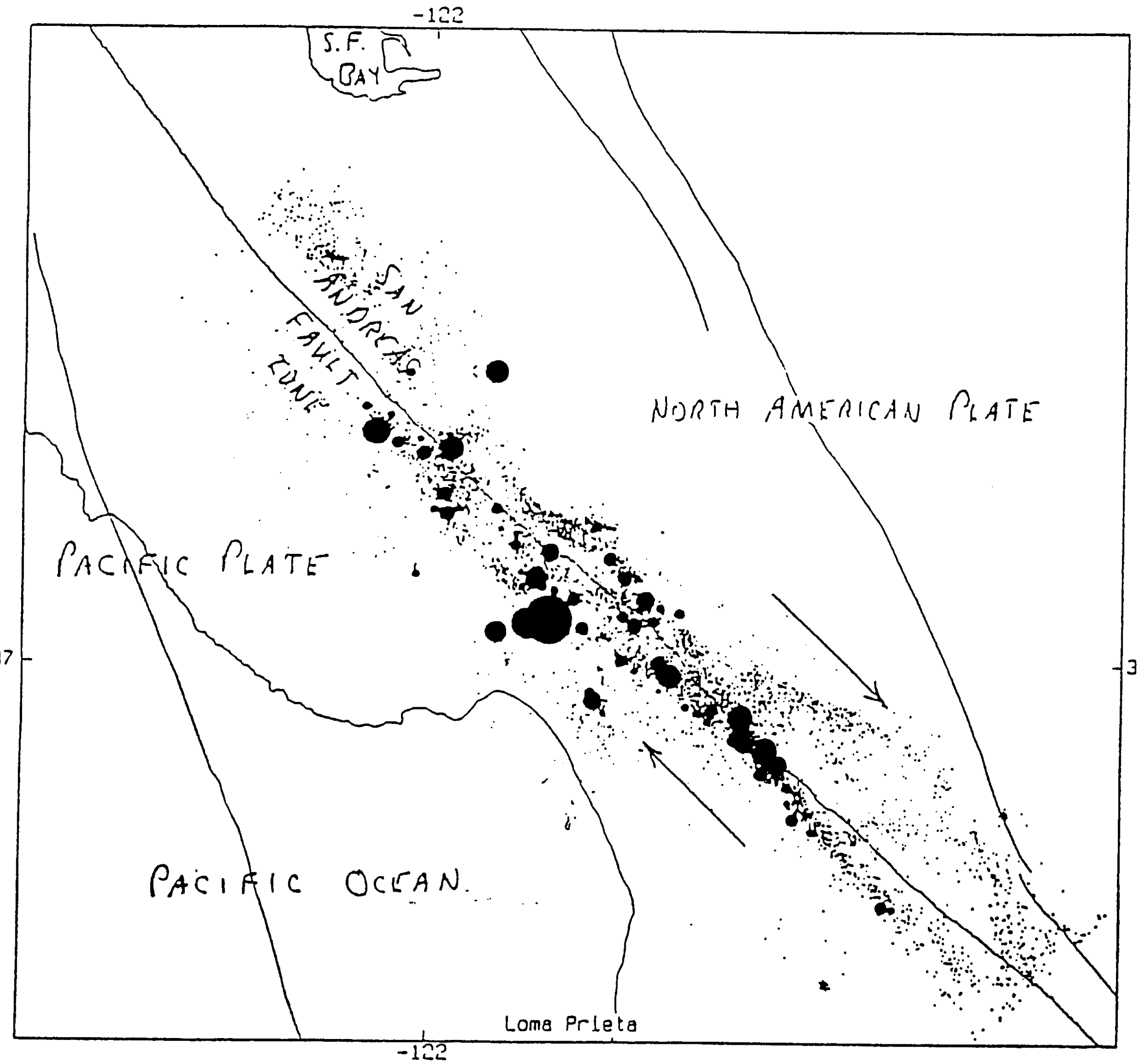

Figure 14. Map view of San Andreas fault zone.

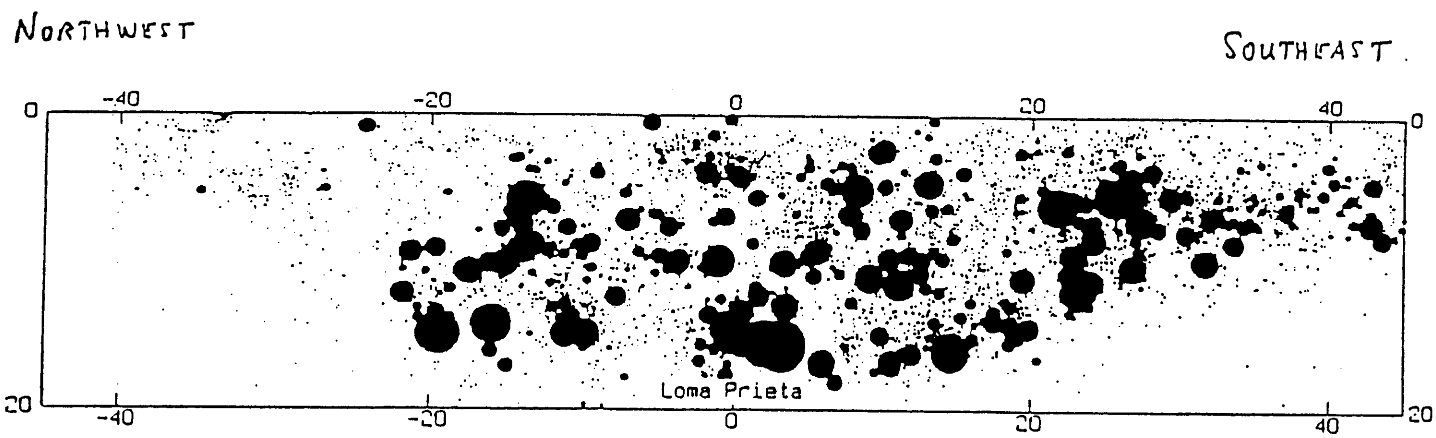

Figure 15. Cross section of San Andreas fault zone.

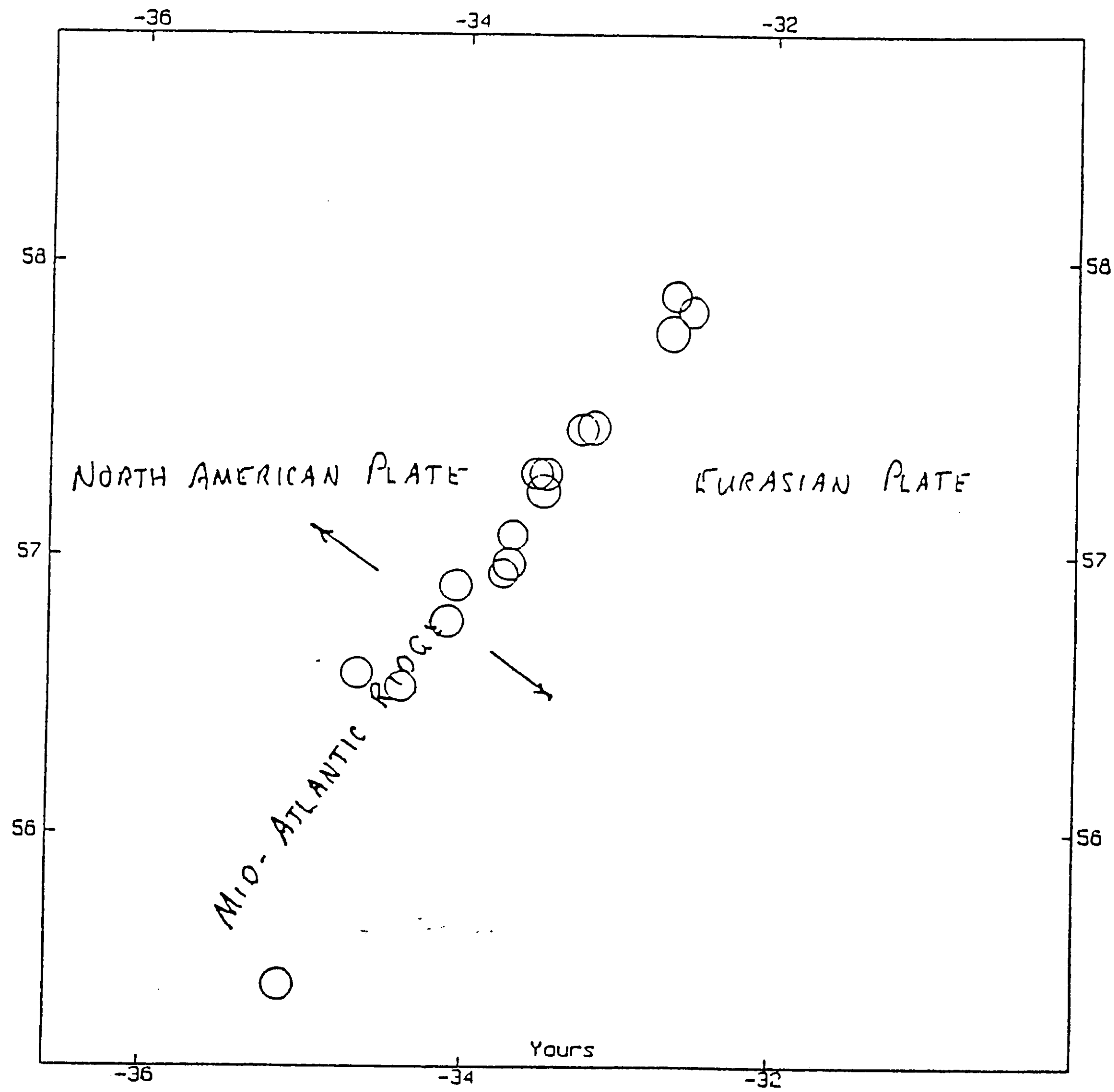

Figure 16. Map view of Mid-Atlantic Ridge.

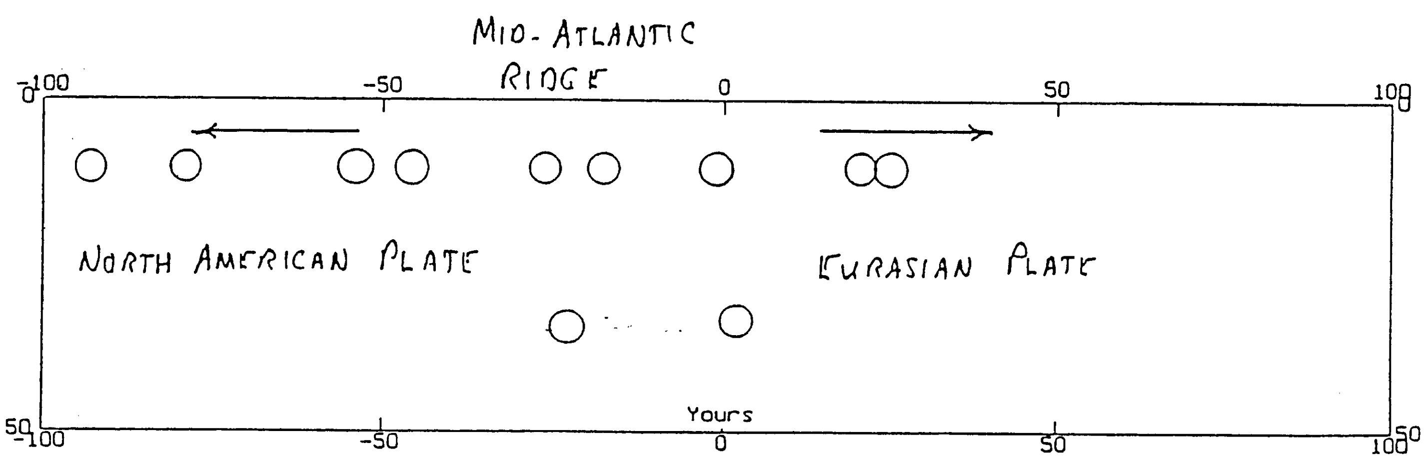

Figure 17. Cross section of Mid-Atlantic Ridge.

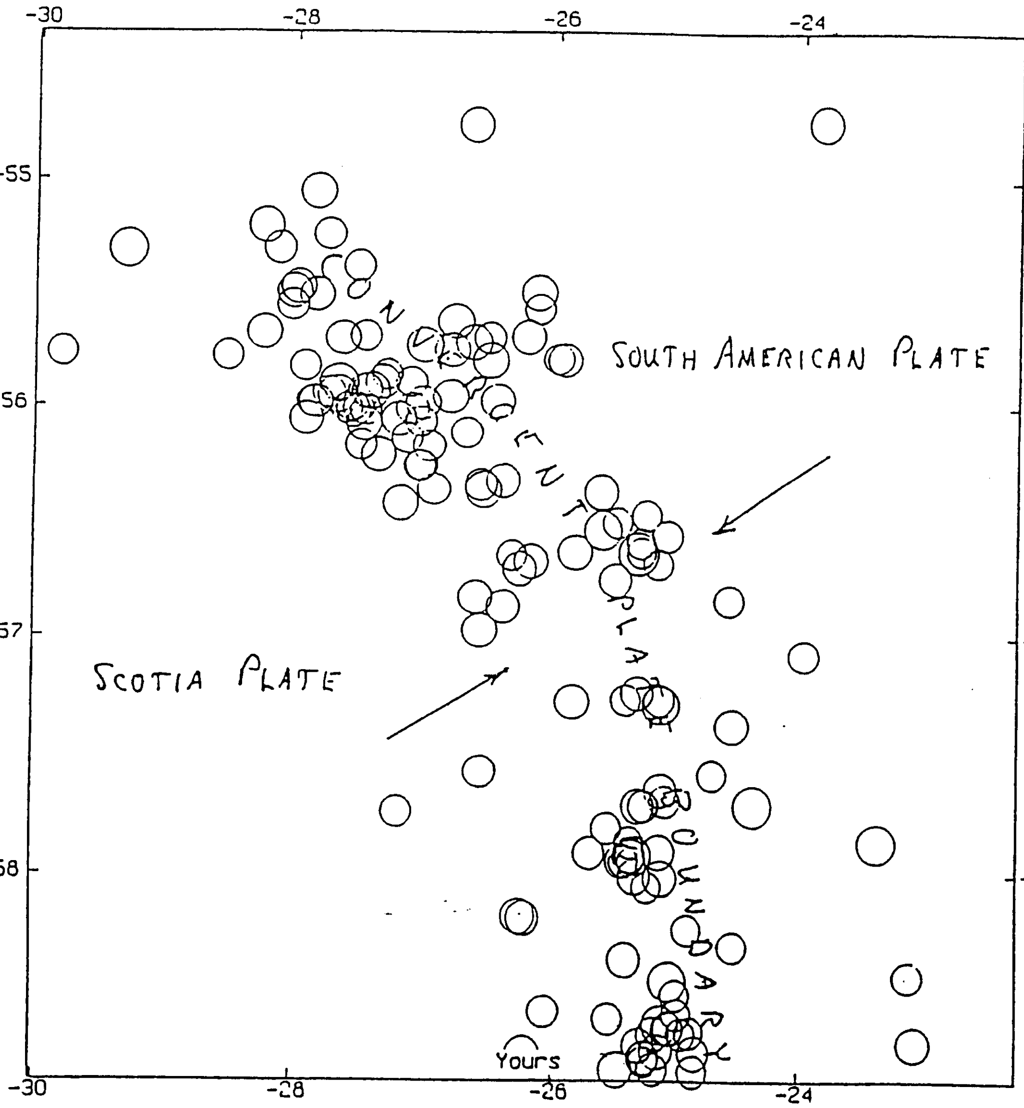

Figure 18. Map view of mystery boundary.