2.3

EARTHQUAKES in Geologic Time

ACTIVITY ONE
TWENTY CENTURIES

RATIONALE

Students have a difficult time comprehending how short the span of human history is in relation to Earth's geological history. This lesson sets the stage for paleoseismology by providing a context in geological time.

FOCUS QUESTIONS

If no earthquakes have been recorded in my area since it was settled, does that mean earthquakes never happen here?

OBJECTIVES

Students will:

Students will compare the time period of their own lives and that of human history to the age of the Earth and events in Earth's history.

MATERIALS

- Student copies of Master 2.3a, Centuries Worksheet
- Twelve 500-sheet reams (one case) of standard copier paper
- Student copies of Master 2.3b, Selected Events in Human History
- Student copies of Master 2.3c, Earth History Events
- Scissors

PROCEDURE

Teacher Preparation

1. Obtain 12 reams of standard-size paper and stack them on a desk where they will be visible to all students. Unwrap only the top ream. On each of the lower reams, cut a strip 7 to 10 cm wide from the side of each wrapper so the paper shows through. The results should be a column of exposed paper edges 11 reams high. Stack the unwrapped twelfth ream neatly on top, and place a copy of the Centuries Worksheet on top of the stack.

VOCABULARY

Index fossil: a fossil that, because its approximate date is known, allows scientists to determine the age of age of the rock in which it is imbedded.

Radiometric dating: the process of using natural radioactivity to determine the age of rocks.

Strata (s. stratum): layers of rock or other materials formed at different periods in geologic time.

2. Make a copy of Master 2.3c, Earth History Events, and cut it into strips along the dashed lines.

A. Introduction

Ask the students to tell you what they mean when they say that something happened “a long time ago.” (Answers will range from a few months to centuries and beyond.) Ask students if it was “a long time ago” that dinosaurs became extinct, and our earliest human ancestors first appeared. Then ask them to guess the order in which these events occurred. Record their guesses without comment.

Emphasize that scientists seek proof of how long ago different events occurred by studying things that record the passage of long periods of time, such as the layers in rocks (strata) and index fossils. Index fossils represent species that existed only during specific time periods, so their presence is an index to the age of the rocks. Radiometric dating techniques can also reveal how long ago rocks were formed. The dating of events that occurred a long time ago and the sequence in which they occurred are among the puzzles scientists must solve. We are constantly adding to our knowledge of Earth history.

B. Lesson Development

1. Distribute copies of the Centuries Worksheet (Master 2.3a). Holding up the copy you placed on top of the paper stack, tell the students that the stack is 12 reams high, and that every single page in it stands for the same length of time. Explain that every dot on the sheet stands for one year. The first dot on the top line represents this year. Each dot after that one is a previous year. The entire sheet contains 2,000 dots. Ask the students to circle the dot representing the year in which they were born.

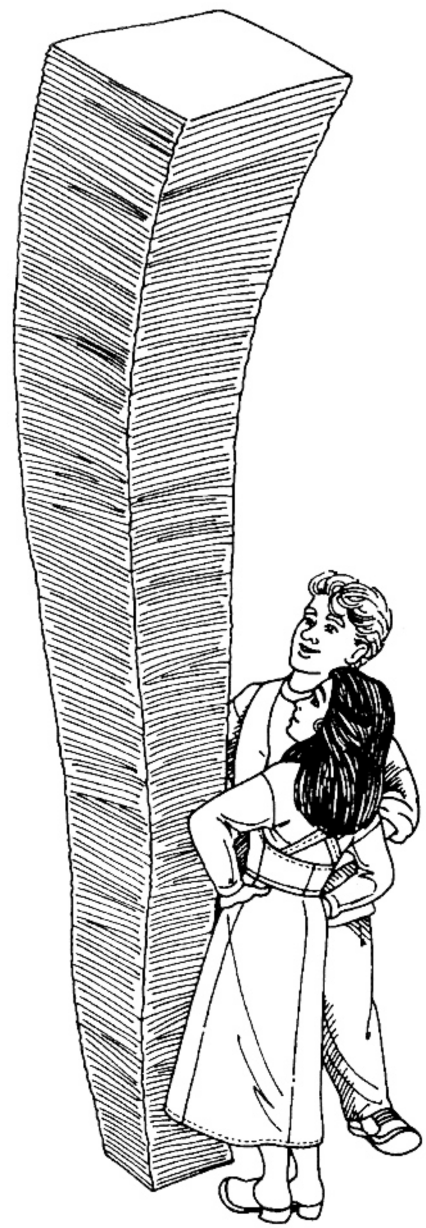
2. Distribute copies of Master 2.3b, Selected Events in Human History. With these sheets and their Centuries Worksheets in front of them, have students place the number of each event on Master 2.3b on or near the dot that represents its year.

3. Tell the class that geologic time calls for a different scale than historical time. From now on, one dot equals one hundred years. Each sheet of paper in the 12-ream stack now represents 200,000 years. The farther down the stack a sheet is, the farther back in history the time it represents. Ask the students to determine how far down the stack a sheet representing one million years ago is located. (It will be five sheets down.)

4. Ask students how many dots there would be in a ream of 500 sheets of paper if each sheet had 2,000 dots. (1,000,000 dots). If each dot represents 100 years, how many years would one ream of sheets represent? (100 years x 1,000,000 dots per ream = 100,000,000 years.)

5. Distribute the strips of paper cut from Master 2.3c, having each student choose one. Give students these directions:

a. Calculate how many years an inch of paper represents. Look at your paper strip and decide if the event it names will fit within the span of years represented by the reams of paper (1.2 billion years).



b. If it does, calculate how far down the paper stack to place your individual marker, then come forward to place it at the correct depth.

c. If it does not, use the math we have already done to calculate how much more paper would be needed. Share your findings with the class.

6. Elicit ideas from the class on the age of the Earth. (The answer, about 4.54 billion years, is on Master 2.3c.) Ask: How many reams of paper like the ones in the front of the classroom would it take to represent that many years? (46 reams)

C. Conclusion

Ask the class: Now that you have an idea of the age of the Earth, would you describe the human race as young or old? (relatively young) Which occurred more recently, the extinction of the dinosaurs or the appearance of human beings? (the appearance of humans) Compare these facts with the students' earlier guesses. Emphasize that terms like young and old, long ago and recent can have very different meanings in different contexts. Because an event such as an earthquake has not taken place in historical time does not mean it is impossible, given the great sweep or geological time.

ACTIVITY TWO

PALEOSEISMOLOGY, OR READING THE CLUES

RATIONALE

By using models, students will learn how geologists apply present knowledge to understand seismic history.

FOCUS QUESTIONS

How do we know about earthquakes that happened long ago?

OBJECTIVES

Students will:

1. State and explain several basic geologic principles.

2. Model the procedure geologists use to determine earthquake recurrence intervals.

MATERIALS

- Transparencies made from Master 2.3d, Sag Pond, 1830 to 1994
- Overhead projector
- Newspapers for covering desks
- Play clay or modeling clay, in red, blue, yellow, and white
- Student copies of Master 2.3e, Sag Pond Template
- 15-cm (6-in) lengths of dowel or other small cylinders for rolling play dough (*optional*)
- Knives for cutting the clay (Plastic picnic knives will do.)

TEACHING CLUES AND CUES

The two parts of this activity use the same materials and take approximately the same length of time. It may be convenient to do them in sequence. Alternatively, you may want to have half the class do the first activity and the rest do the second.

■ Transparencies made from Master 2.3f, Ditch Creek, 1830 to 1994

■ Student copies of Master 2.3g, Ditch Creek Template

PART ONE

SAG POND

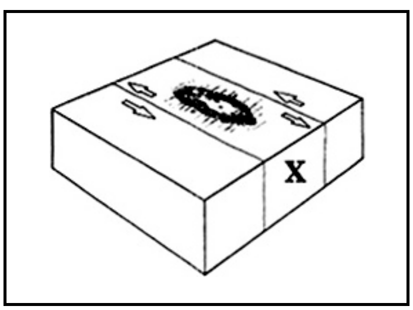
PROCEDURE

A. Introduction

Ask students: Have your parents or grandparents experienced an earthquake in their lifetime? Explain: Geologists assume that the earthquakes we observe today are similar to those that happened 50 years ago, 100 years ago, and even before human beings recorded history. Their impact may be different because of differences in human population patterns, but geologic processes and the natural principles that govern them have operated in essentially the same way throughout geological time. This assumption is expressed in the principle of uniformitarianism. By studying the traces of recurring earthquakes, those that have happened numerous times in the same area, we can speculate about the history of very old earthquake events and even make general predictions about the future. Introduce the principle of superposition and the principle of cross-cutting relationships. The activity that follows uses a generalized model of a strike-slip fault to illustrate these principles.

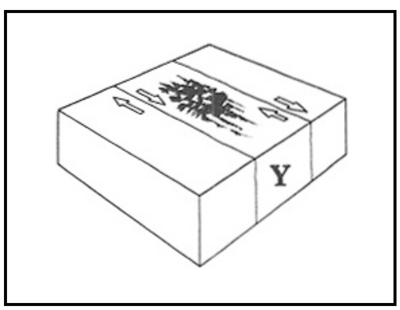
B. Lesson Development

1. Project the first transparency made from Master 2.3d, Sag Pond, 1830 to 1993. Tell students that the diagrams they see show the effect of faulting in successive earthquakes. Because faulting causes surface dislocations, certain types of faulting will form hills and valleys in the Earth's surface. With strike-slip faulting, if movement occurs as shown by the arrows, the following topography can be created:



Right Lateral Strike-Slip Fault

X = area where ground is being pulled apart or extended, forming a sagpond.



Left Lateral Strike-Slip Fault

Y = area where ground is being squeezed or compressed, forming a hill or ridge.

VOCABULARY

Paleoseismology: the study of ancient earthquakes.

Peat: a deposit of semicarbonized plant remains in a water-saturated environment. Peat is an early stage in the development of coal.

Principle of crosscutting relationships: the principle stating that a rock is always younger than any other rock across which it cuts. Earthquake faulting illustrates this principle: Faults are always younger than the rocks they cut.

Principle of superposition: the principle upon which all geologic chronology is based, stating that in any sequence of sedimentary layers that has not been overturned or faulted, each layer is younger than the one beneath, but older than the one above it.

Principle of uniformitarianism: the fundamental principle stating that geologic processes have operated in essentially the same way throughout geological time.

Recurrence interval: the actual or estimated length of time between two earthquakes in the some location.

Sag pond: a small body of water occupying an enclosed depression formed by strike-slip fault movement.

Strike-slip faulting: faulting in which movement is horizontal.

TEACHING CLUES AND CUES

If students have questions at this point, tell them that the activity that follows may answer them. Any questions that are not answered by the activity can be dealt with in the concluding discussion.

2. As you point to each of the figures, 1 through 6, read the accompanying text aloud to the class.

3. Divide the class into working groups of three to five students each. Distribute paper for covering desks, clay, knives, rollers (if available), and one copy of Master 2.3e, Sag Pond Template, to each group. Give these directions:

a. Pat or roll two clay patties, one white and one red, to a thickness of about 1 cm (.3 in.). Using the template provided, trim the patties to fit within the confines of the circle marked on the grid, then remove them.

b. Now make two sag pond peat deposits, one white and one blue, each 0.5 cm thick and sized according to the small sag pond template at the upper left of the grid.

c. Place the large white layer on the grid template between A-B and C-D as outlined. Place the blue clay sag pond deposit on top of this first layer, aligning the long axis of the sag pond layer with fault line E-F, and centering it between A-B and C-D. Out both layers along the fault line E-F. Lift the A-B side and raise it to the position marked Offset Line.

d. Place the red layer of clay over the offset layers and center a second sag pond deposit (the white one), as in the stop above. Cut (or trench, as geologists say) all the clay patties along line A-D. Carefully separate the sides so you have a good cross-section view and draw a cross section of each side. Compare the layers on the two sides of the fault A-D.

C. Conclusion

Build a class discussion around these questions:

- How is the principle of superposition applied in this activity?
- How is the principle of crosscutting relationships applied in this activity?
- How is the principle of uniformitarianism applied in this activity?
- What does the difference in thickness and spacing of the peat layers on the two sides of the fault indicate? (that the terrain has been disturbed)
- In what year do we know an earthquake occurred on this fault? (1857)

PART TWO

DITCH CREEK

PROCEDURE

A. Introduction

Tell students: By using age-dating methods on peat deposits and very old stream channels, geologists can determine earthquake recurrence intervals dating back several thousands of years. The shorter its recurrence interval, the more likely an area is to experience an earthquake in your lifetime. This activity is another illustration of the principles you saw in the last one. Like the previous activity, it is based on a generalized model of a strike-slip fault.

B. Lesson Development

1. Project the first transparency made from Master 2.3f, Ditch Creek. Tell students that the diagrams they see show the effect of faulting in successive earthquakes. As you point to each of the figures, 1 through 5, read the accompanying text aloud to the class.

2. Divide the class into working groups of three to five students each. Distribute paper for covering desks, clay, knives, rollers (if available), and one copy of Master 2.3g, Ditch Creek Template, to each group. Give these directions:

a. Make three layers of clay, one white, one yellow, and one red, patting or rolling the clay to a thickness of about 1 cm (1/3 in.) and trimming it to fit within the confines of Area 1 on the grid. Place the white layer on the Area 1 part of the grid and remove the others. Make a pencil-thick string of blue clay and lay it along the line marked on the grid as Stream Line, running the length of the first layer. With the knife, cut along the E-F fault line marked on the grid, which is perpendicular to the stream. Now offset the C-D section of the model, moving it to the position marked 1857 on the grid. This offset represents the movement along the fault of 1857.

b. Now place the yellow layer on top of the white layer and the offset stream. Be sure to place this second layer within the grid marks. Make another pencil-thick stream out of blue clay and place it on the same stream line indicated on the grid. Cut the layers again along the same fault line as in the previous step. Offset the C-D section to the position marked 1906.

c. Repeat this one more time with the red clay layer and one additional blue streamline.

C. Conclusion

Build a class discussion around these questions:

- How is the principle of superposition applied in this activity?
- How is the principle of crosscutting relationships applied in this activity?
- How is the principle of uniformitarianism applied in this activity?
- Would you build your home in 1994 or later near this fault?

ADAPTATIONS AND EXTENSIONS

Provide a small-scale map of a seismic area and ask students to locate other streams along fault lines and identify offset stream channels. For example, on a map of the Grand Canyon, locate Bright Angel Canyon and point out the place where it meets the Colorado River. Ask: What caused the Bright Angel Creek to cut a canyon where it did? (The Bright Angel fault caused a weak place in the rock for the water to erode.) ▲

TEACHING CLUES AND CUES

Remind students that arrows placed on fault diagrams show the relative direction of the motion.

You may want to cover the copy at the bottom of the master (Figure 2, p. 85) while you ask students to describe what they think has happened to produce the new picture.

Centuries Worksheet

Name ____ Date ____________________

Centuries Worksheet

Selected Events in Human History

1. _____—My great grandmother is born. (Estimate.)

2. 1776—U.S. Congress adopts the Declaration of Independence.

3. 1936—Inge Lehmann demonstrates the presence of an inner core.

4. 1492—Columbus reaches the Americas.

5. 1909—Andrija Mohorovicic discovers discontinuity at crust/mantle boundary.

6. 1989—Loma Prieta quake rocks World Series fans.

7. 1811/1812—New Madrid quakes, greatest ever in continental U.S., estimated at over 8.0 on the Richter scale.

8. 1755—Offshore earthquake near Lisbon, Portugal. Earthquake, 40-foot tsunami, and fires kill 60,000 people.

9. 132—Chinese scholar Chang Heng invents seismoscope to detect earthquakes.

10. 1556—The most disastrous earthquake on record, at Shen-Shu, China, kills 830,000 people.

11. 1889—First record of a distant earthquake was received at Potsdam, Germany.

Earth History Events

1. Earth formed—approximately 4.54 billion years ago

2. North and South America joined by the closing of the Isthmus of Panama—approximately 2,800,000 years ago

3. Last trilobites died out—approximately 225 million years ago

4. Earliest known humanoid (our early ancestor) fossils deposited—approximately 2 million years ago

5. Earliest known animal fossils (jellyfish-like organisms) deposited—approximately 1.2 billion years ago

6. New Madrid rift zone opened—approximately 500 million years ago

7. Earliest known reptile fossils deposited—approximately 290 million years ago

8. Earliest known bird fossils deposited—approximately 160 million years ago

9. Earliest known mammal fossils deposited—approximately 200 million years ago

10. Earliest known flowering plant fossils deposited—approximately 135 million years ago

11. Earliest known trilobite fossils deposited—approximately 600 million years ago

12. Present day Appalachian Mountains formed—approximately 250 million years ago

13. Rocky Mountains formed—approximately 70 million years ago

14. Mass extinction of dinosaurs and other forms of life occurred—approximately 65 million years ago

15. Breakup of Pangaea began—approximately 180 million years ago

16. Earliest known fossils of land animals deposited—approximately 390 million years ago

17. Last lee Age ended—approximately 10,000 years ago

18. Oldest known rock on Earth formed in southwest Greenland—approximately 3.2 billion years ago

19. Himalayas begin forming as India joined Asian continent—approximately 30 million years ago

20. Formation of iron, copper, and nickel ores—1 billion years ago

21. Much of continental land masses underwater—330 million years ago

22. Active volcanoes in New England—210 million years ago

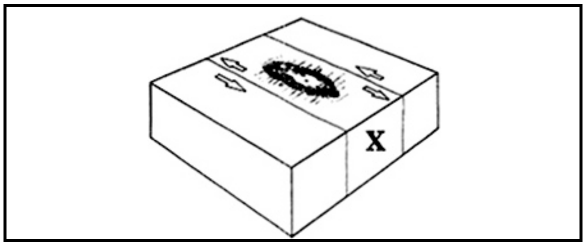
23. Earliest microfossils formed in South African chert—3.2 billion years ago

24. Algal stromatolites formed in Rhodesian limestones—3 billion years ago

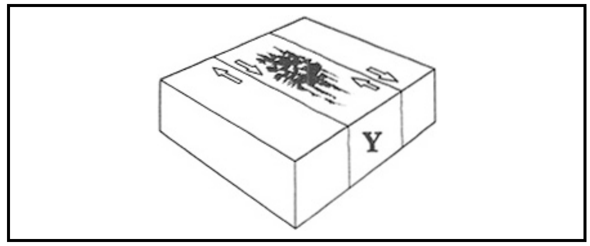
Earth History Events (key)

	Reams (and/or)	Pages	Total Pages
1.	46	—	23,000
2.	—	14	14
3.	2	125	1,125
4.	—	10	10
5.	12	—	6,000
6.	5	—	2,500
7.	2	450	1,450
8.	1	300	800
9.	2	—	1,000
10.	1	175	675
11.	6	—	3,000
12.	2	250	1,250
13.	—	350	350
14.	—	325	325
15.	1	400	900
16.	3	450	1,950
17.	—	1	1
18.	32	—	16,000
19.	—	150	150
20.	10	—	5,000
21.	3	150	1,650
22.	2	50	1,050
23.	32	—	16,000
24.	30	—	15,000

Sag Pond, 1830 to 1994



Right Lateral Strike-Slip Fault



Left Lateral Strike-Slip Fault

Figure 1, Sag pond

In the left-hand side of Figure 1 (X), there is a place where the ground has pulled apart. The depression caused by this "pull-apart" basin is called a sag pond. This is a very narrow, long or elongated pond or basin. Sag ponds are generally aligned with the long axis parallel to the faults. In the right-hand drawing, (Y), a ridge is being formed by squeezing, or compression.

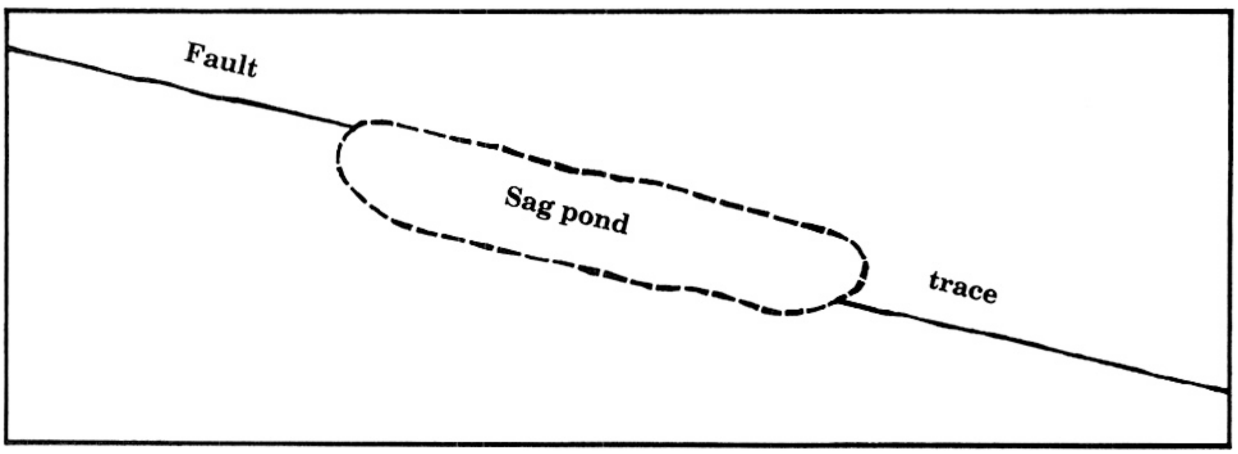


Figure 2, Sag pond 1830

Fault slippage has formed a sag pond, which has filled with water containing reeds, cattails, and algae. These organic materials die and accumulate rapidly on the bottom of the sag pond in the form of peat. Peat can accumulate as much as several centimeters per year.

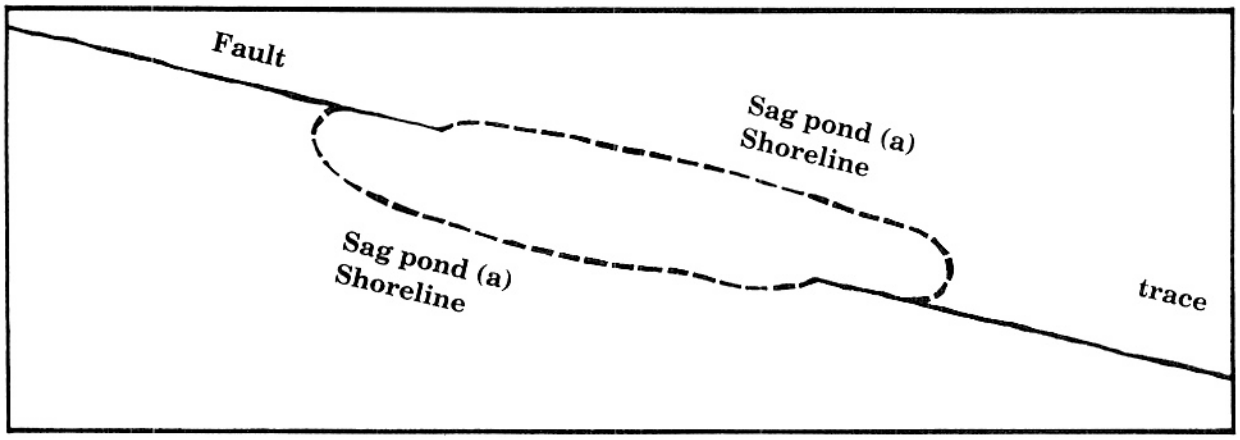


Figure 3, Sag pond 1857

Fault moves, offsetting shorelines of sag pond and organic materials (peat) on bottom.

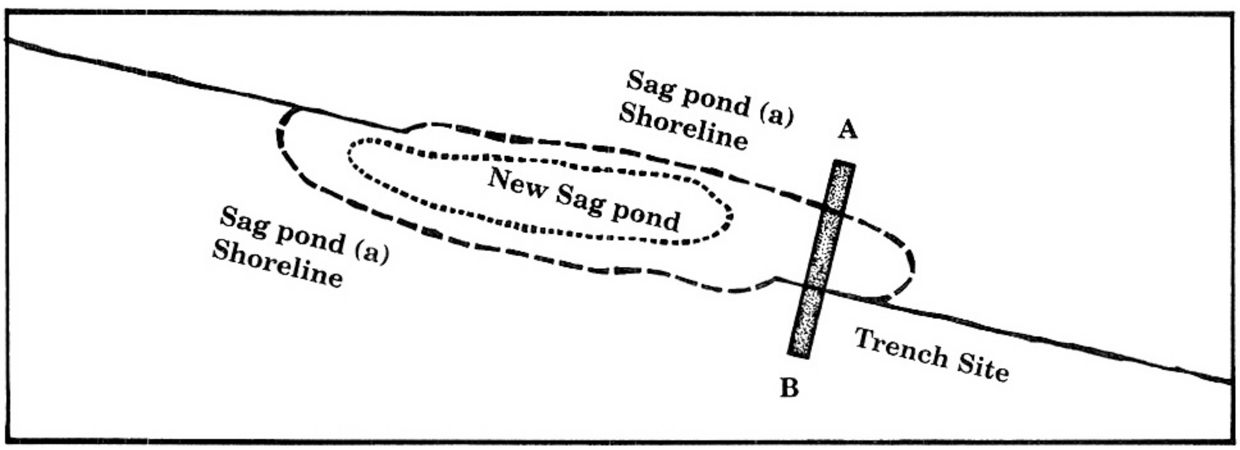
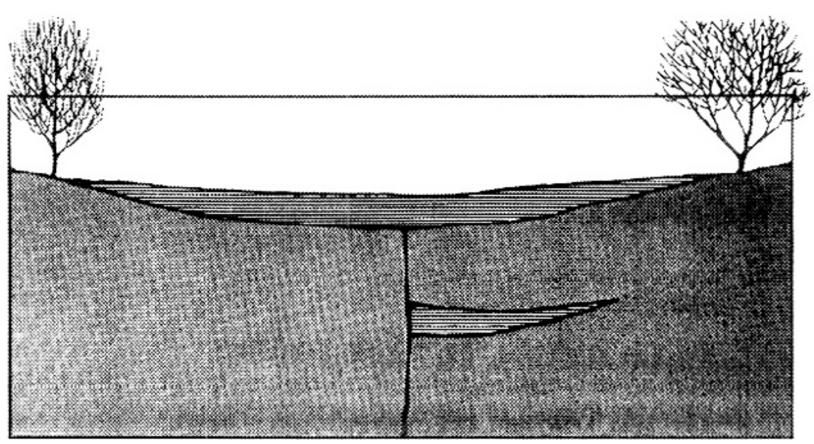


Figure 4, Sag pond 1994

Shortly after the faulting, a new sag pond forms with more reeds, cattails, and algae. Peat continues to accumulate. In 1994 the sag pond is pumped dry, and a shallow trench (A-B) is dug with excavation equipment perpendicular to the fault. A sketch of one side of the trench is reproduced below (see Figure 5).

Figure 5, Trench Log 1, 1994



Later that same year, a deeper trench is excavated across the same sag pond, and the following trench log is obtained:

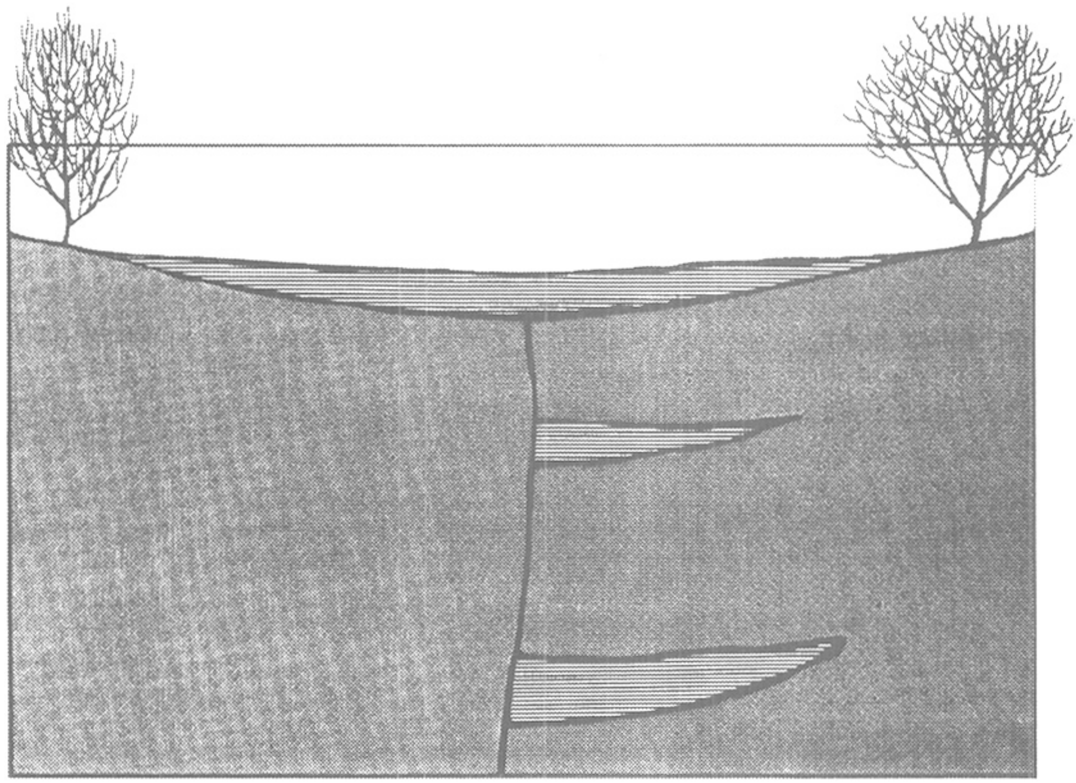
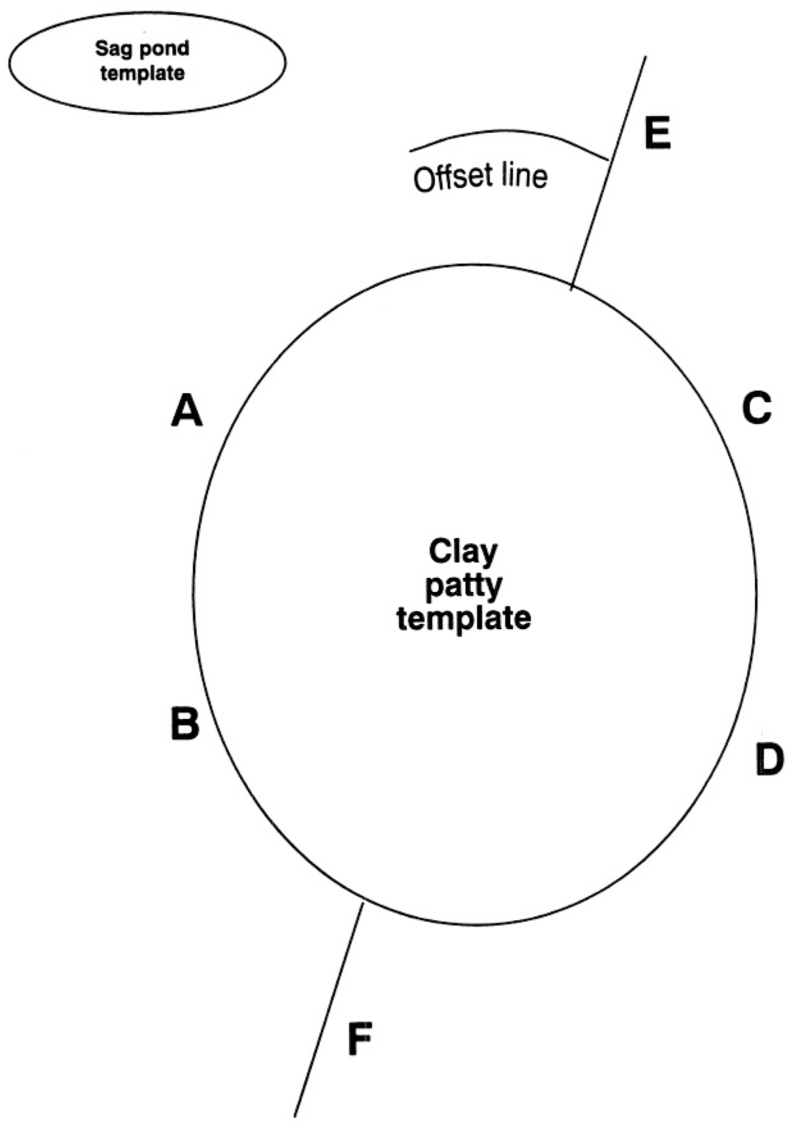


Figure 6, Trench Log 2, 1994

What are your conclusions regarding the pre-1830 seismic history (the paleoseismology) of this fault? (The peat layer shows that faulting has taken place. The depth of the layers can be measured, and the distance between the layers can be measured.)

Sag Pond Template



Ditch Creek, 1830 to 1994

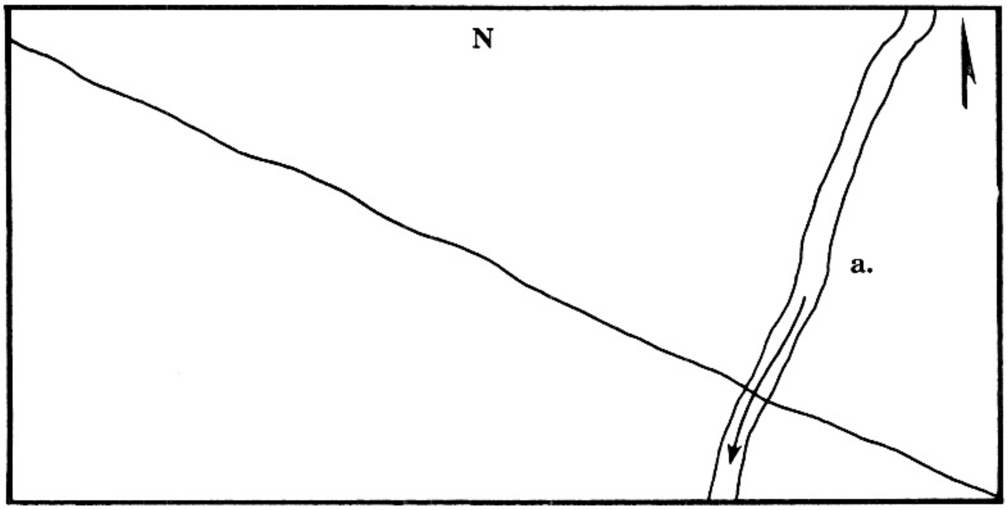


Figure 1 1830

A stream (a) flows across a strike-slip fault.

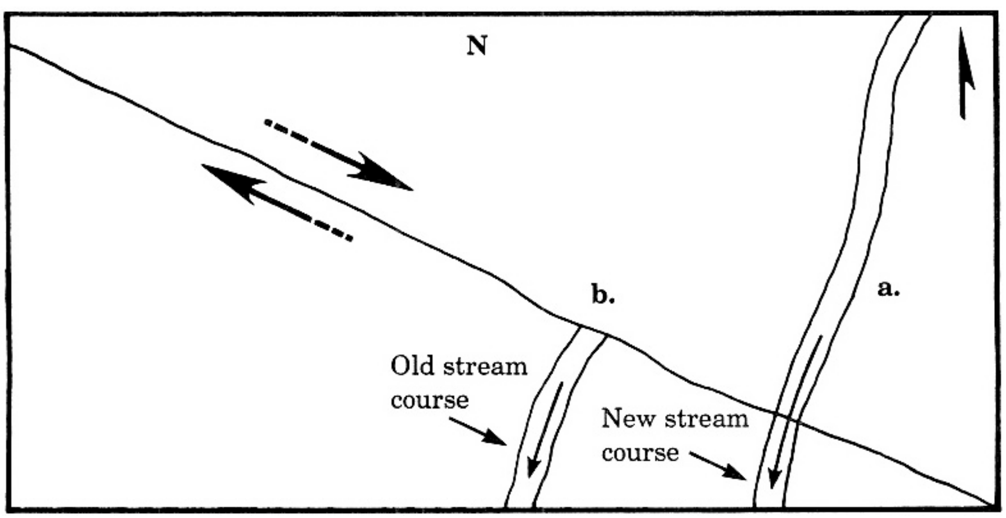


Figure 2 1857

An earthquake with movement along the fault in 1857 causes displacement of stream (a) as shown. The amount of displacement probably represents the amount of offset the earthquake caused. As the years go by, soil and sand may bury and cover up parts of the original stream course (b).

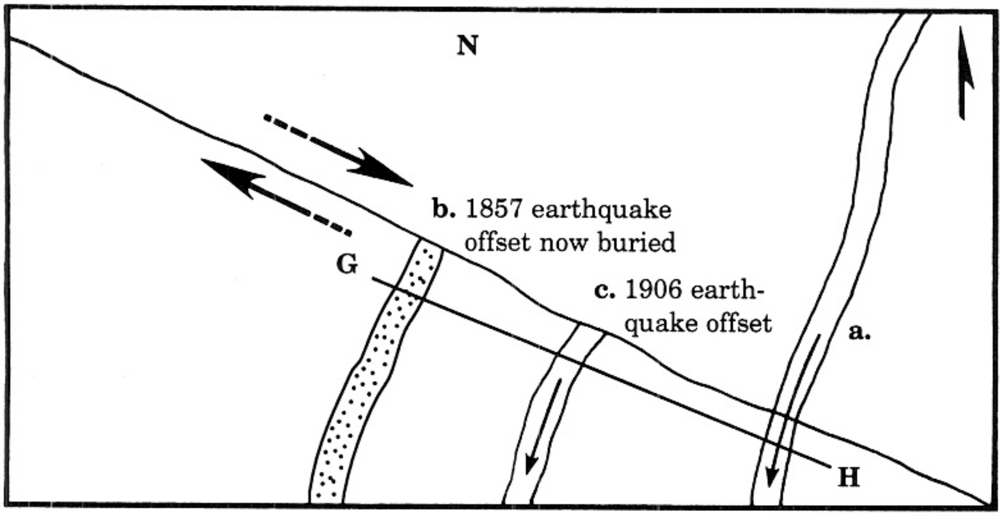


Figure 3 1906

Another earthquake with movement along the same fault in 1906 causes further offset of the course of the stream. Soil and sand will continue to bury and cover up parts of the 1857 (b), and the 1906 (c) offset. A shallow trench (line G-H) cut parallel to and south of the fault in 1994 might show the following relationship (Figure 4) on the southern side of the trench:

SECTION VIEW

Ground surface

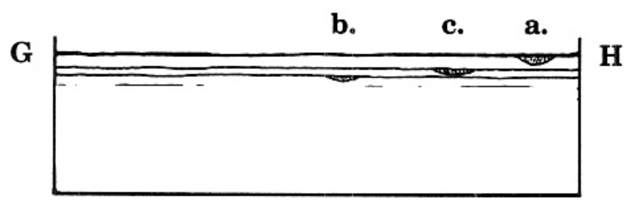


Figure 4 Trench Log 1, 1994

The rate of movement and timing of earlier earthquakes can be determined from the age of the sand and gravel deposits in the stream channel.

If a second longer and deeper trench is excavated in the area of trench G-H, the following log might be obtained (Figure 5):

SECTION VIEW

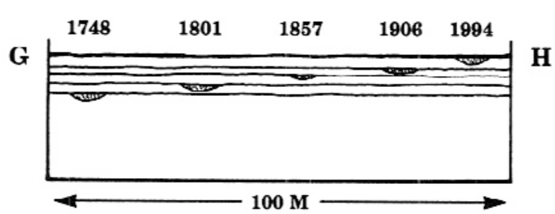


Figure 5 Trench Log 2, 1994

Ditch Creek Template