

The NASA SCI Files™
The Case of the
Shaky Quake

Segment 4

The tree house detectives continue their investigation into the cause of the tremor they felt in the tree house. Ruling out thunderstorms, they watch a Dr. Textbook segment on “Earth-shattering facts” and become even more determined to find the answer. Back in the tree house, the detectives dial up a NASA SCI Files™ Kids Club in Norfolk, Virginia to learn how the epicenter of an earthquake is located. Finally, the detectives head back to JPL to speak with Ron Baalke to learn about something totally unexpected and discover the answer to why they are “all shook up!”

Objectives

The students will

- locate the epicenter of an earthquake
- use triangulation to track a meteor's path to predict the location of meteorites.

- investigate meteor impacts on the Earth's surface.
- compare and contrast articles for fact and fiction.

Vocabulary

meteor—a meteoroid that enters Earth's atmosphere and burns up as it falls

meteorite—a meteor that reaches the Earth's surface

meteoroid—small pieces of rock that orbit the Sun, resulting from the breakup of comets

sonic boom—a sound, like that of an explosion, produced when a shock wave forms at the nose of an object traveling at supersonic speed reaches the ground

triangulation— the method in surveying of making measurements and using trigonometry to find where places are located on the Earth's surface using points whose exact location is known

Video Component

Implementation Strategy

The NASA SCI Files™ is designed to enhance and enrich the existing curriculum. Two to three days of class time are suggested for each segment to fully use video, resources, activities, and web site.

Before Viewing

1. Prior to viewing Segment 4 of *The Case of the Shaky Quake*, discuss the previous segment to review the problem and what the tree house detectives have learned thus far. Download a copy of the Problem Board from the NASA SCI Files™ web site and have students use it to sort the information learned so far.
2. Review the list of questions and issues that the students created prior to viewing Segment 3 and determine which, if any, were answered in the video or in the students' own research.
3. Revise and correct any misconceptions that may have been dispelled during Segment 3. Use tools located on the Web, as was previously mentioned in Segment 3.
4. Focus Questions-Print the questions from the web site ahead of time for students to copy into their science journals. Encourage students to take notes during the program to answer the questions. An icon will appear when the answer is near.

View Segment 4 of the Video

For optimal educational benefit, view *The Case of the Shaky Quake* in 15-minute segments and not in its entirety. If you are viewing a taped copy of the program, you may want to stop the video when the Focus Question icon appears to allow students time to answer the question.

After Viewing

1. At the end of Segment 4, lead students in a discussion of the focus questions for Segment 4.
2. Have students discuss and reflect upon the process that the tree house detectives used to solve the mystery of the tremor felt in the tree house. The following instructional tools located in the educator's area of the web site may aid in the discussion: Experimental Inquiry Process Flowchart and/or Scientific Method Flowchart.
3. Choose activities from the educator guide and web site to reinforce concepts discussed in the segment. Pinpoint areas in your curriculum that may need to be reinforced and use activities to aid student understanding in those areas. Educators can also search for resources by topic, episode, and media type under the Educator's main menu option *Resources*.



2001 – 2002 NASA Sci Files™ Programs

4. Wrap up the featured online Problem-Based Learning investigation. Evaluate the students' or team's final product generated to represent the online PBL investigation. Sample evaluation tools can be found in the educator's area of the web site under the main menu topic "Tools."
5. Have students write in their journals what they have learned about weather, hurricanes, and/or the problem-solving process and share their entry with a partner or the class.

Resources

Books

Boekhoff, P. M., Stuart A. Kallen, and Kris G. Hirschmann: *Meteors (Eyes on the Sky)*. Kidhaven, 2002, ISBN: 0737712899.

Morris, Neil: *Earthquakes*. Crabtree Publishing Company, 1998, ISBN 0865058326.

Petty, Kate: *I Didn't Know Tidal Waves Wash Away Cities*.

Copper Beech Books, 1999, ISBN 0761309225.

Prinja, Raman: *Comets, Meteors, and Asteroids (The Universe)*. Heinemann Library, 2002, ISBN: 1403406103.

Simon, Seymour: *Comets, Meteors, and Asteroids*. Mulberry Books, 1998, ISBN: 0688158439.

Walker, Sally M: *Earthquakes*. Carolrhoda Books, 1996, ISBN 0876148887.

Web Sites

Earthquakes in Illinois?

Visit this site to learn about the history of earthquakes in the New Madrid Fault System. Begin a web quest as a geologist and gather information on earthquakes.

<http://home.sullivan.k12.il.us/teachers/brunner/Earthquake.html>

Asteroid and Comet Impact Hazard

This NASA site is loaded with information about meteors. You can learn what they are, how they travel, and about the work being done by NASA

scientists in the field of meteors. You can even explore future missions such as Deep Impact where NASA plans on hitting a comet with a spacecraft and recording the contents of the comet.

<http://impact.arc.nasa.gov/>

American Red Cross

Do you know how to prepare for an earthquake? What to do when it happens and when its over? Check this site to learn how much you really know. <http://www.redcross.org/services/disaster/keepsafe/readyearth.html>

Tsunami!

This site focuses on the destructive power of these earthquake-spawned waves. It also includes the physics behind tsunamis and how humans are dealing with this major threat.

<http://www.geophys.washington.edu/tsunami/intro.html>

NASA's Observatorium

This site has information on plate tectonics and tsunamis. There are numerous other features such as games and other links.

<http://observe.arc.nasa.gov/nasa/core.shtml.html>

NASA Spacelink: Exploring Meteorite Mysteries

Go to this web site to download a PDF copy of Exploring Meteorite Mysteries. This educator guide for grades 5-12 provides information and activities related to meteorites and their origins, whether it be Mars, asteroids, or the Moon.

<http://spacelink.nasa.gov/products/Exploring.Meteorite.Mysteries/>

Careers

meteorologist
astronomer
physicist

Activities and Worksheets

In the Guide	Locating an Epicenter Use data from three seismic stations to find the epicenter of an earthquake.55
	Follow that Meteor! Learn to track the path of a meteor and predict where meteorites might be found.59
	Where Have All the Meteorites Gone? Create your own meteors and go on a meteorite hunt.60
	Shaky Word Find Locate earthquake related words in this word find.61
	Answer Key62
On the Web	Great Balls of Fire! Create your own craters to learn how meteors impact the Earth's surface.
	The Daily Shooting Star Read tabloid articles and use deductive reasoning to determine if they are fact or fiction.



Locating an Epicenter

Purpose To locate the epicenter of an earthquake

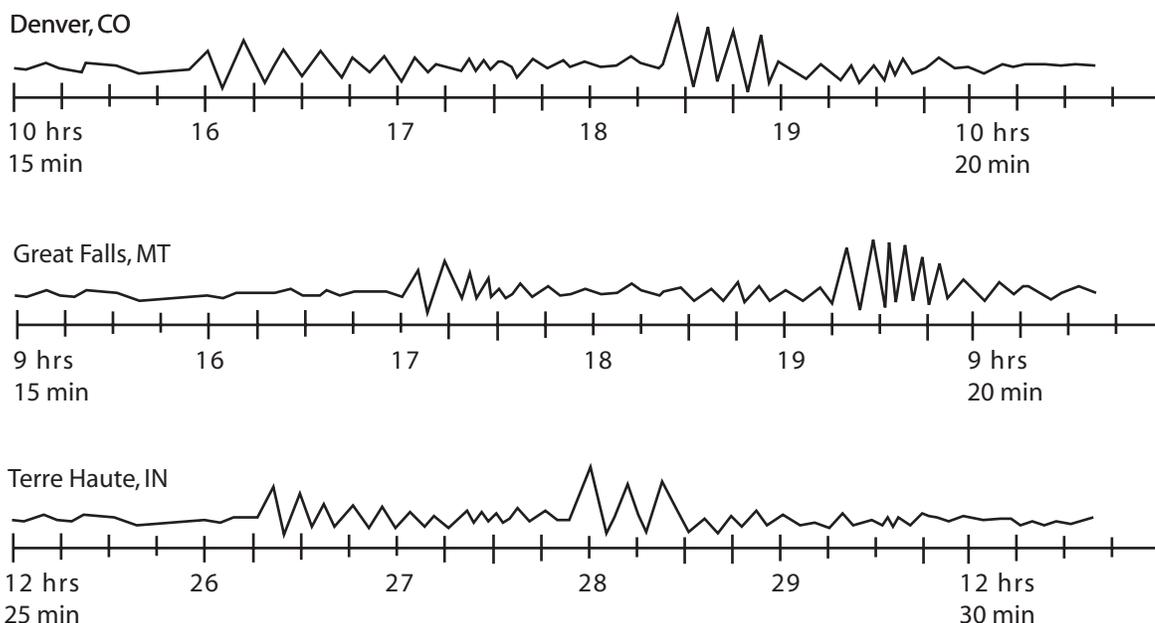
Background: An earthquake is any shaking or trembling of the Earth's crust. It is estimated that there are over 150,000 earthquakes around the world each year. However, only a few of them cause serious damage. The major cause of earthquakes is faulting, the sudden slipping or breaking of rocks beneath the Earth's surface. As the rocks break apart, the forces that have been acting upon them are relieved, causing a tremendous amount of energy to be released in the form of shock waves or vibrations. Some of the shock waves travel on the surface of the Earth and are called surface waves. The waves that travel through the body of the Earth are called Primary waves (P waves) and secondary waves (S waves). P waves can travel through solids, liquids, and gases, but S waves can travel only through solids. P waves are known to travel faster than S waves, but the speed of both P and S waves depends on the density of the rocks through which they travel. When the P and S waves reach the surface of the Earth, they set up new waves that travel along the surface of the Earth like ripples on a pond. These waves are called long waves (L waves). These surface waves are slower than the S and P waves, and they cause most of the damage and destruction to buildings.

Materials

drawing compass
paper

- Procedure**
1. Study the three sections of seismograms shown below in diagram 1.
 2. Each seismogram indicates the arrival time of the P waves and S waves of the same earthquake, as recorded in three different cities. Locate the arrival time of the P waves for each seismogram to the nearest 15 seconds and record in data chart 1 (p.56).
 3. Locate the arrival time of the S waves for each seismogram and record in data chart 1.
 4. Determine the difference, in minutes and seconds, between the arrival time of the P and S waves on each seismogram and record in data chart 1.

Diagram 1



Locating an Epicenter (continued)

DATA CHART 1

Station	Arrival Time P Wave	Arrival Time S Wave	Difference in Time Of Arrival
Denver, CO			
Great Falls, MT			
Terre Haute, IN			

5. Look at the graph on p. 57 and answer the following:
 - a. What amount of time does each space on the vertical (y) axis represent?
 - b. How many kilometers does each space on the horizontal (x) axis represent?
 - c. How long does it take a P wave to travel 4,000 km from an epicenter?
 - d. How long does it take an S wave to travel 4,000 km from the same epicenter?
 - e. How much longer does it take an S wave to travel 4,000 km than a P Wave?
 - f. How much longer does it take an S wave to travel 5,000 km than a P wave?
 - g. In general, what happens to the difference in travel times as the distance increases?
 - h. What does any vertical distance between the P line and the S line on the graph represent?
6. Lay the edge of a small piece of paper along the vertical axis so that one end is even with the "0" coordinate. Mark off a distance on the edge of the paper that represents 3 minutes and 30 seconds (3:30).
7. Slide the marked paper along the P and S curves of the graph until the upper mark lies on the S curve, and the lower mark on the P curve. Be sure the edge of the paper lines up with the vertical lines of the graph.
8. According to the graph, how far from the epicenter does 3:30 represent?

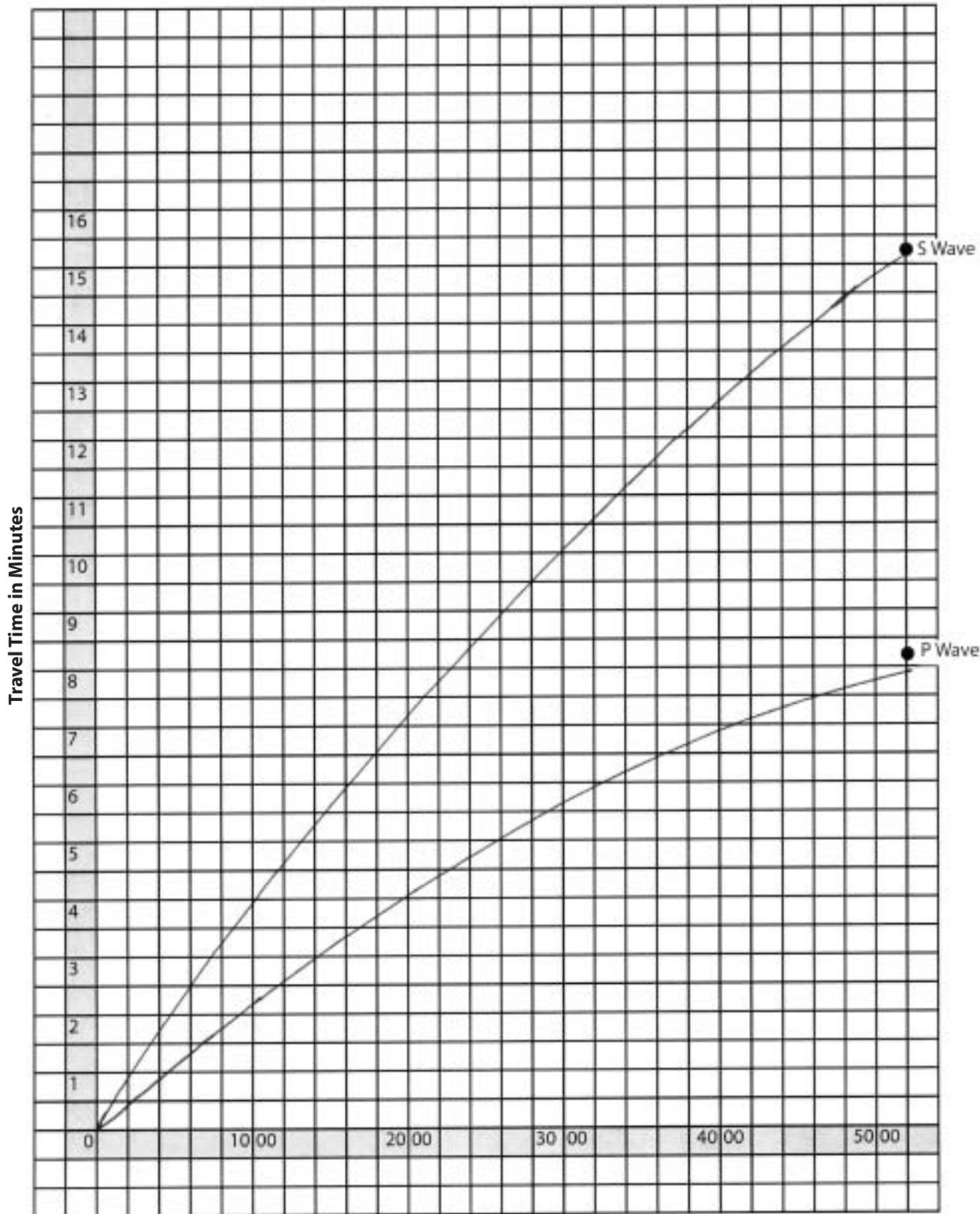
DATA CHART 2

Station	Distance of Station From Epicenter
Denver, CO	
Great Falls, MT	
Terre Haute, IN	

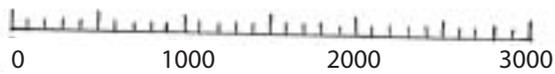
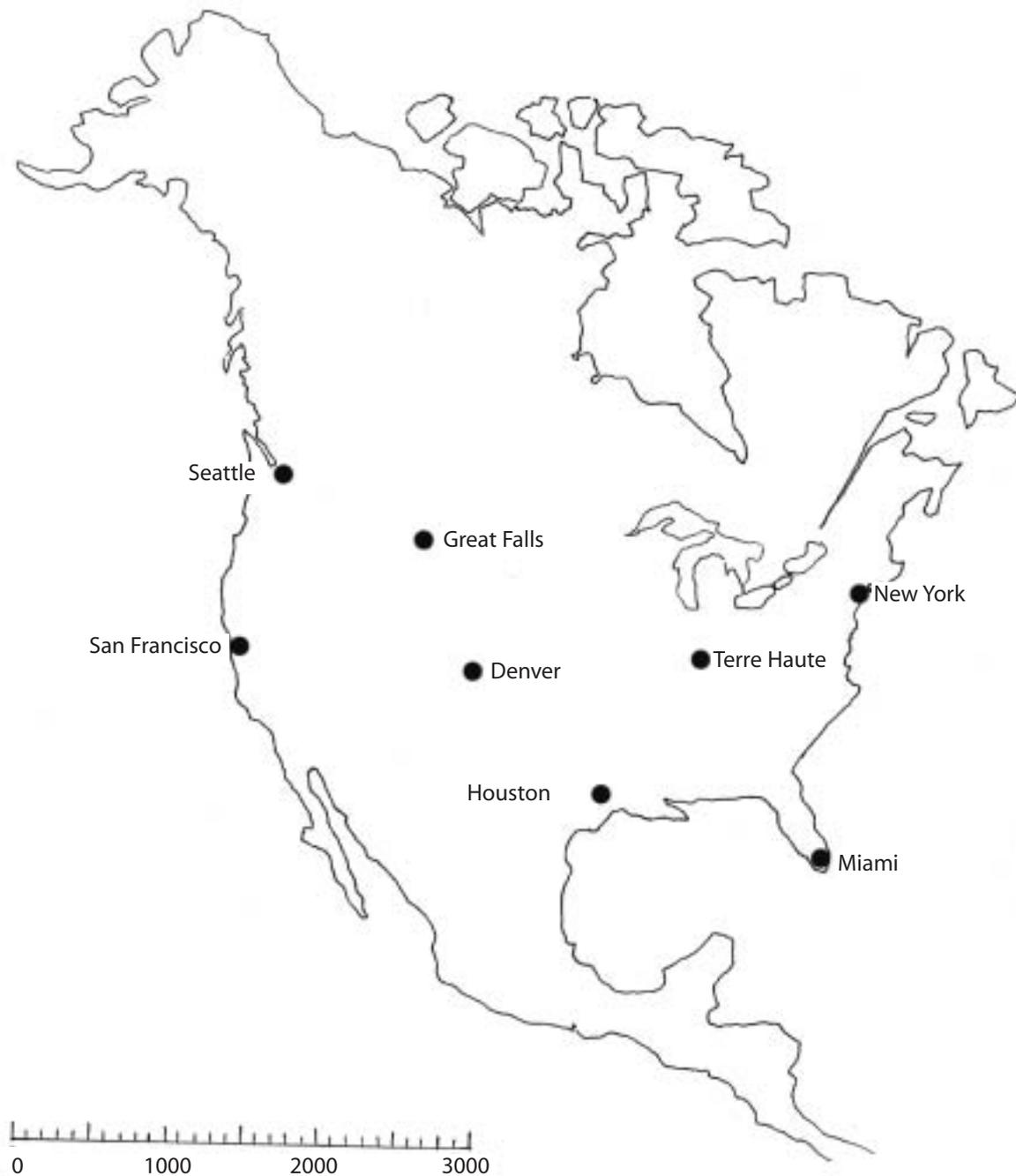
9. To find the distance to the epicenter of the earthquake, repeat steps 6-8 for the three stations by using the "Difference in Time of Arrival" for each. Record in data chart 2.
10. Which city is the farthest from the epicenter?
11. Look at the map scale for the U.S. map (p. 58). Determine the distance that each small division on the scale represents. _____
12. Using the map scale, set your compass radius to the distance of the epicenter from Great Falls, MT. With this radius and Great Falls as the center, draw a circle on the map. The epicenter of the earthquake lies somewhere on this circle. Why can't its exact position be determined from this circle?
13. Repeat step 12, setting your compass for the radius for the distance of the epicenter from Denver. At how many points do the two circles intersect? _____
14. The epicenter must lie on one of these two points. Why?
15. Repeat step 12 for Terre Haute, IN. At how many points do the three circles intersect? _____ What does the point where they intersect represent? Explain.
16. Near what city shown on the map might the earthquake have occurred?



Locating an Epicenter



North America

**KILOMETERS**

1000 km = 2.2 cm

Follow that Meteor!

Purpose

To use triangulation to track a meteor's path and to predict where meteorites might be found

Procedure

One clear starry night, two observers, Aric and Amber, were outside looking at the night sky. Even though they lived in different towns, they each saw a meteor streak across the sky. They both noticed a sudden "spark," and two seconds later there was an explosion. Eager to add meteorites to their rock collections, they decided that they needed to determine the path of the meteor at the time of the spark and where the meteor exploded. Aric lived in Drygulch Flats and Amber lived in Bubbling Bayou. Aric quickly e-mailed Amber and told her that he was looking 110° East of North when he saw the meteor spark and 80° East of North when it exploded. Amber said that she saw it spark at 60° East of North and it exploded at 40° East of North. Follow the directions below to help Aric and Amber find the location to begin looking for meteorites.

Materials

metric ruler
 protractor
 pencil
 colored pencils

1. On the map, locate the dashed line. Using the Compass Rose, determine which direction the line runs and record in your science journal.
2. Place your protractor along the dashed line so that the straight edge lines up evenly with the dashed line and the hole is centered over Drygulch Flats. Measure and mark an 80° angle.
3. With a colored pencil, draw a long line from Drygulch Flats through the mark you made.
4. Repeat steps 2-3 for Bubbling Bayou and mark a 40° angle with the same color pencil.
5. To calculate in km where the two lines intersect, use the map scale and a metric ruler.
6. Record in your science journal where the meteor exploded.
7. Using a different colored pencil, repeat steps 2-6 to determine where the meteor sparked.

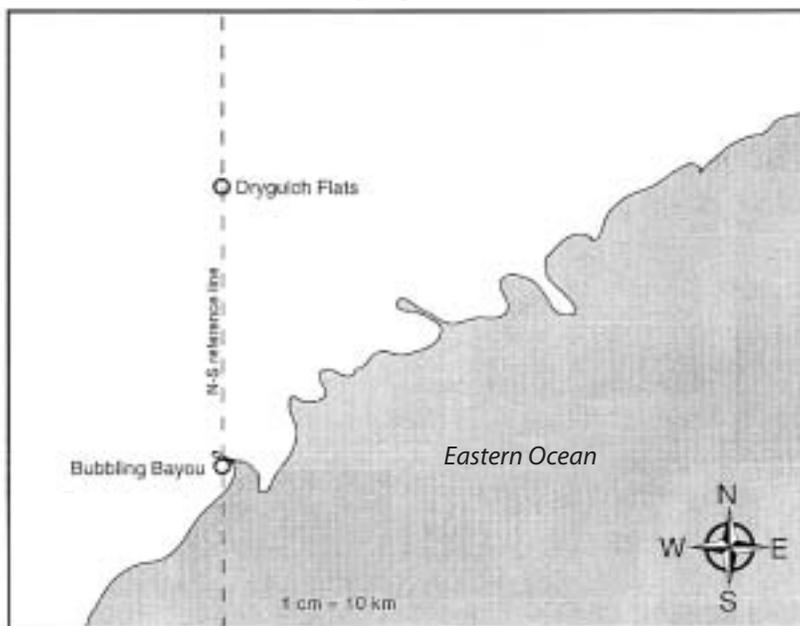
Conclusion

1. Using the position of the spark and the explosion, which direction was the meteor traveling?
2. How far was it from where the meteor sparked to where it exploded?
3. Where would you first look for meteorites that might have fallen from the explosion? Is it guaranteed that Aric and Amber will find meteorites?
4. Using the formula $V = d/t$ estimate how fast the meteor was going in km/sec.

Bonus: determine the speed of the meteor in km/sec.
 Hint: Remember there are 60 minutes in an hour and 60 seconds in a minute.

Extension

1. Outside set up a meteorite hunt and give the students compass directions so that they learn to use a magnetic compass.
2. Place a ball bearing in a field to represent a meteorite. Provide a map of the field and triangulation observation angles. Have students attempt to find the "meteorite."



1 cm = 10 km

Where Have All the Meteorites Gone?

Purpose To demonstrate the difficulty of locating meteorites

Teacher Note: Locate several good areas around the school grounds such as concrete pavement, sandy area, or grassy field where this activity can be performed.

Procedure

1. Place a funnel in the neck of the balloon and fill balloon with approximately 0.1 liters (1/2 cup) of flour. Flour tends to pack, so it should be poured into the funnel slowly. Being careful not to puncture the balloon, use the skewer to keep the flour flowing if needed.
2. Add pebbles one at a time, noting number of pebbles and color. To tag your pebbles, write your initials with a marker on each one.
3. Fill the balloon 3/4 full with water. Do not shake the balloon and be sure to tie it securely.
4. Go outside to the areas designated to launch your balloon.
5. In your group, determine where and how each person will launch his/her balloon. Have each person throw his/her balloon differently, such as at an angle, lobbing it, or throwing it straight up so that it can impact vertically. Predict how many pebbles will be recovered from each launch.
6. After everyone in the group has thrown balloons, go to your impact site and sketch in your science journal the scatter pattern created by your balloon.
7. Try to locate as many of your original pebbles as possible.
8. Clean up all balloon fragments and leave the impact areas as clean as possible.
9. Make a graph of the percentage of pebbles recovered from each impact surface.

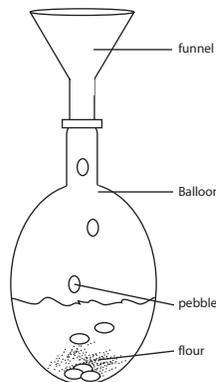


Diagram 1

Materials

balloon
0.1 liter of flour
10 to 20 small pebbles
water
funnel
metric measuring cup
skewer
graph paper
science journal

Conclusion

1. How did your data compare with your prediction for pebbles recovered?
2. Based on your data, which surface was the easiest for pebble recovery? Why?
3. Did the result match your prediction?
4. What kind of land surface might be most productive for searching for meteorites? Why?
5. How is the scatter pattern affected by the ground surface? By the angle of impact?
6. How might a scientist use this type of information to help locate meteorites?

Extension

1. Dramatize the impact and scatter pattern of pebbles by using students as pebbles and doing the dramatization in slow motion.
2. Vary the materials used in the balloons to add difficulty in locating the "meteorites."

Shaky Word Find

Word Bank

continental drift
 crust
 earthquake
 fossil
 epicenter

mantle
 outer core
 inner core
 Pangaea
 seismograph

tremor
 plate tectonics
 convergent
 divergent
 fault

focus
 GPS
 P waves
 S waves
 Richter

USGS
 meteorite
 meteoroid
 sonic boom
 meteor

O N C R U S T D S W A V E S P P A R A T U M
 U N M O S P S M G P S A B E H A G U Y I N A
 T A C E M O R P S W V C A C X N R O L M D N
 E B F O T P E R U A K M E I C G I P E E C T
 R N S A N E O M B V H T I H B A L C H T O L
 C H E D L T O U A E R A U X S E L I S E N E
 O K A I W O I R N S I N E T I A I I I O V E
 R J I L I E S N O D C J I L P L L E U R E N
 E L S T Y I D J E I B L S T R E M O R I R T
 Z R E T H C I R E N D A I E S I R V A T G I
 R E T N E C I P E I T E E T H S C A R E E E A
 Q Z Q U I C K I A T H A M T F R T E P U N L
 R N L D S H I N D P R I L T I S I I T I T L
 Y G E A R S Z A A O V U O D R O N C Y A I I
 K I V N R T S R T R A I D N R N E N H J K S
 J S E Y K O G N Q F Y I Y I I I W N B O N S
 H F R T J O E C R E O P E L L C F I I D A O
 P E N E M G Y A E R T C K C I B A T S T R F
 U E R S R G S I D K Z U U A E O I S H I C T
 Y K I E I I T G A D T B I S B O L L I I I S
 T E V E S B E K I S R I H Y O M J A C O N I
 S I E M A I M O S C I N O T C E T E T A L P
 D G W I N N E R C O R E I K K I N Y I R P V
 O F A E A R T H Q U A K E L F U R O E T E M



Answer Key

Locating an Epicenter

DATA CHART 1

Station	Arrival Time P Wave	Arrival Time S Wave	Difference in Time of Arrival
Denver, CO	10hrs. 16min	10:18:30	2:30
Great Falls, MT	9:17:00	9:19:15	2:15
Terre Haute, IN	12:26:15	12:28:00	1:45

5. a. 30 seconds; b. 200 km; c. about 6 minutes and 45 seconds (6:45); d. 12 minutes and 30 seconds (12:30); e. 5 minutes and 45 seconds (5:45); f. 4 minutes and 30 seconds (4:30); g. the travel time increases; h. it represents the difference in travel time between the P and S waves

DATA CHART 2

Station	Distance of Station From Epicenter
Denver, CO	1600 km
Great Falls, MT	1400 km
Terre Haute, IN	1000 km

8. 2,400 km
10. Denver, CO
11. 100 km
12. This result only tells us how many miles it is from the epicenter. It could be this many miles in any direction.
13. 2
14. The intersections tell you that both of these points are the possible epicenter because they are both the correct distance from the epicenter.
15. 1; this point represents the epicenter. It is the only point that is the correct distance from all three stations.

Follow that Meteor!

- The meteor exploded 40-43 km east-northeast of Drygulch Flats (near where the two lines intersect.)
 - The meteor was 50-52 km northeast of Bubbling Bayou, or near the coastline by the peninsula.
1. north-northwest
 2. 23-25 km
 3. Aric and Amber should look for meteorites northeast of Drygulch Flats, near where the lines crossed on the map. There is no guarantee that there will be any meteorites because they could have all burned up before they reached the ground.

4. Approximately 11.5 to 12.5 km per second
Bonus: approximately 41,400 to 45,000 km per hour. The distance the meteor traveled in 2 seconds was 23-25 km. If you divide the distance by the time of 2 seconds, you get 11.5 and 12.5, respectively. To calculate how many km per hour the meteor was traveling, you must first know that there are 60 seconds in a minute and 60 minutes in an hour: 60 multiplied by 60 equals 3,600. Multiply 3,600 seconds (hour) by 11.5 and 12.5. The answer is 41,400 and 45,000 km per hour.

Where Have All the Meteorites Gone?

1. Answers will vary.
2. Answers will vary but might include surfaces that have no similar rocks, are very flat, have a contrasting background, and do not have thick vegetation.
3. Answers will vary.
4. Smooth, flat, contrasting surfaces would make locating meteorites the easiest. For example, meteorites are rarely found in forests or fields because they become lost or buried among the plants. In rocky areas, meteorites are hard to find because they tend to be the same color as Earth rocks. The best areas to find meteorites are at the polar ice cap in Antarctica and in deserts.
5. Answers will vary depending upon the surfaces and angles used.
6. After determining the angle of impact and the surface that the meteor struck, scientists look at scatter patterns created by similar impacts to help them determine where meteorites might be located after an impact.



Answer Key (continued)

Shaky Word Find

O N C R U S T D S W A V E S P P A R A T U M
 U N M O S P S M G P S A B E H A G U Y I N A
 T A C E M O R P S W V C A C X N R O L M D N
 E B F O T P E R U A K M E I C G I P E E C T
 R N S A N E O M B V H T I H B A L C H T O L
 C H E D L T O U A E R A U X S E L I S E N E
 O K A I W O I R N S I N E T I A I I I O V E
 R J I L I E S N O D C J I L P L L E U R E N
 E L S T Y I D J E I B L S T R E M O R I R T
 Z R E T H C I R E N D A I E S I R V A T G I
 R E T N E C I P E I T E E T H S C A R E E A
 Q Z Q U I C K I A T H A M T F R T E P U N L
 R N L D S H I N D P R I L T I S I I T I T L
 Y G E A R S Z A A O V U O D R O N C Y A I I
 K I V N R T S R T R A I D N R N E N H J K S
 J S E Y K O G N Q F Y I Y I I W N B O N S
 H F R T J O E C R E O P E L L C F I I D A O
 P E N E M G Y A E R T C K C I B A T S T R F
 U E R S R G S I D K Z U A E O I S H I C T
 Y K I E I I T G A D T B I S B O L L I I I S
 T E V E S B E K I S R I H Y O M J A C O N I
 S I E M A I M O S C I N O T C E T E T A L P
 D G W I N N E R C O R E I K K I N Y I R P V
 O F A E A R T H Q U A K E L F U R O E T E M

On the Web

Great Balls of Fire!

1. The craters were all similar in shape but differed in size. The heaviest object created the largest crater (diameter).
2. When the drop height was increased, the crater diameter also increased. The higher the balls were dropped, the greater the impact.
3. Answers will vary.

The Daily Shooting Star

1. Amateur Astronomer Discovers Comet—True
2. Annihilation Narrowly Avoided—True
3. Intelligence Enhancing Meteorites—False
4. Extraterrestrials Hurl Rock at Earth—False
5. Longevity Secret Revealed—False
6. Giant Impact Thought to Cause Mass Extinction—True
7. Huge Diamond Discovered in Meteorite—False
8. History of Solar System Revealed—True
9. Oldest Meteorite Found—True
10. Phenomenal New Energy Resources Discovered—False
11. Microbes from Mars—True

