Name:_______________________________________ Date: ________________

SKILL and PRACTICE 11.1

Alfred Wegener

Alfred Wegener was a man ahead of his time. He was an astronomer and a meteorologist, yet his greatest work was in the field of earth science. His theory of plate tectonics is widely accepted today. Yet, in 1912 when he proposed the idea, he was ridiculed. It took fifty years for other scientists to find the evidence that would prove his theory.

The young man

Photograph courtesy of the Alfred Wegener Institute for Polar and Marine Research, Bremerhaven, Germany

Alfred Wegener was born in Berlin in 1880. He was the son of a German minister who ran an orphanage. As a boy, he became interested in Greenland, and as a scientist, he went to Greenland several times to study the movement of air masses over the ice cap. This was at a time when most scientists doubted the existence of the jet stream. Just after his fiftieth birthday, he died there in a blizzard during one of his expeditions.

Wegener graduated from the University of Berlin in 1905 with a degree in astronomy. Soon, however, his interest shifted to meteorology. This was a new and exciting field of science. Wegener was one of the first scientists to track air masses using weather balloons. No doubt, he got the idea from his hobby of flying in hot air balloons. In 1906, he and his brother set a world record by staying up in a balloon for over fifty-two hours.

The search for evidence

In 1910, in a letter to his future bride, Wegener wrote about the way that South America and Africa seemed to fit together like pieces of a puzzle. To Wegener, this was not just an odd coincidence. It was a mystery that he felt he must solve. He began to look for evidence to prove that the continents had once been joined together and had moved apart.

Fossils of a small reptile had been found on the west coast of Africa and the east coast of South America. That meant that this reptile had lived in both places at the same time millions of years ago. Wegener figured that the only way this was possible was if the two continents were connected when animals were alive. They could not have traveled across the ocean.

Geological evidence

There was also geological evidence. The rock structures and types of rocks on the coasts of these two continents were identical. Again, Wegener could find no explanation for how this could have happened by accident on opposite sides of the ocean. The rock structures had to have been formed at the same time and place under the same conditions.

A study of climates produced other evidence. Coal deposits had been found in Antarctica and in England. Since coal is formed only from plants that grow in warm, wet climates, Wegener concluded that those land masses must have once been near the equator, far from their locations today.

Ridiculed and rejected

Wegener explained that all of the continents had been part of one large land mass about 300 million years ago. This super-continent was called Pangaea, a Greek word that means “all earth.” It broke up over time, and the pieces have been drifting apart ever since. Wegener compared the drifting continents to icebergs.

Wegener’s peers called his theory “utter rot!” Many scientists attacked him with rage and hostility. Wegener had two main problems. First, he was an unknown outsider, not a geologist, who was challenging everything that scientists believed at the time. Second, he was not able to explain what caused the continents to drift. While there seemed to be evidence to show that they had indeed moved, he could not identify a force that made it happen.

About fifty years after Wegener proposed his theory, a scientist named Harry Hess made a discovery about sea floor spreading that seemed to support Wegener’s ideas. As a result, the theory of plate tectonics was finally accepted by most scientists.

Reading reflection

1. Explain the significance of Greenland in Wegener's life.
2. What world record did Wegener set in 1906?
3. Why could Wegener be called an interdisciplinary scientist? Identify the fields of science of which he was knowledgeable.
4. Explain how the fossil of a small reptile provided evidence to help prove Wegener's theory of drifting continents.
5. How did the discovery of coal deposits in England and Antarctica strengthen Wegener's argument?
6. **Research:** In his search for evidence to support his theory of drifting continents, Wegener studied the rock strata in the Karroo section of South Africa and the Santa Catarina section of Brazil. He also studied the Appalachian Mountains in North America and the Scottish Highlands. Use a library or the Internet to research these areas. What evidence do they provide for Wegener's theory? Share your findings with the class.
7. What were the two main problems that Wegener faced when he tried to convince others that his theory of drifting continents was valid?
8. **Research:** Wegener and some colleagues drew maps of what they thought the world looked like at different times as the super continent broke up and the continents drifted apart. Use a library or the Internet to find pictures of these maps. Make a poster displaying Wegener's vision of the world at:
   - 300 million years ago (Pangaea)
   - 225 million years ago (Permian period)
   - 200 million years ago (Triassic period)
   - 135 million years ago (Jurassic period)
   - 65 million years ago (Cretaceous period)
   - Today

Name:____ Date: ________________

SKILL and PRACTICE 11.2

Harry Hess

Harry Hammond Hess was a geology professor at Princeton University and served many years in the U.S. Navy. In 1962, Hess published a landmark paper that described his theory of sea floor spreading. Hess also made major contributions to our national space program.

A globe-trotting geologist

Harry Hammond Hess was born in New York City on May 24, 1906. He first studied electrical engineering at Yale University, but later changed his major to geology. He received his degree in 1927.

After graduation, Hess worked for two years as a mineral prospector in southern Rhodesia (currently Zimbabwe, Africa). He then returned to the United States to study at Princeton University. In 1932, Hess became a professor of geology at Princeton. Years later, his geological research took him to the far depths of the Pacific Ocean floor.

The Navy commander

Harry Hess was part of the Naval Reserve. In 1941 he was called to active duty. His first duty during World War II was in New York City where he tracked enemy positions in the North Atlantic. He later commanded an attack transport ship in the Pacific.

Although he was a Naval commander, Hess seized the opportunity of being on a ship to further his geological research. Between battles, Hess and his crew gathered data about the structure of the ocean floor using the ship's sounding equipment. They recorded thousands of miles worth of depth recordings.

In 1945, Hess measured the deepest point of the ocean ever recorded—nearly 7 miles deep. He also discovered hundreds of flat-topped mountains lining the Pacific Ocean floor. He named these unusual mountains "guyouts" (after his first geology professor at Princeton).

A ground breaking theory

After the war, Hess continued to study guyouts, midocean ridges, and minerals. In 1959, his research led him to propose the ground breaking theory of sea floor spreading. At first, Hess' idea was met with some resistance because little information was available to test this concept.

In 1962, his sea floor spreading theory was published in a paper titled "History of Ocean Basins." Hess explained that sea floor spreading occurs when molten rock (or magma) oozes up from inside the Earth along the mid-oceanic ridges. This magma creates new sea floor that spreads away from the ridge and eventually sinks into the deep-ocean trenches where it is destroyed. Hess' theory became one of the most important contributions to the study of plate tectonics.

The sea floor spreading theory explained many unsolved geological questions. Most geologists at the time believed that the oceans had existed for at least 4 billion years. But they wondered why there wasn't more sediment deposited on the ocean floor after such a long time period.

Hess explained that the ocean floor is continually being recycled and that sediment has been accumulating for no more than 300 million years. This is about the time period needed for the ocean floor to spread from the ridge crest to the trenches. Hess's theory helped geologists understand why the oldest fossils found on the sea floor are 180 million years old at most, while marine fossils found on land may be much older.

From the ocean to the moon

Harry Hess also played a key role in developing our country's space program. In 1962, President John F. Kennedy appointed Hess as Chairman of the Space Science Board—a NASA advisory group. During the late 1960s, Hess helped plan the first landing of humans on the moon. He was part of a committee assigned to analyze rock samples brought back by the Apollo 11 crew.

Harry Hess died in August 1969, only one month after the successful Apollo 11 lunar mission. He was buried in the Arlington National Cemetery. After his death, he was awarded NASA's Distinguished Public Service Award.

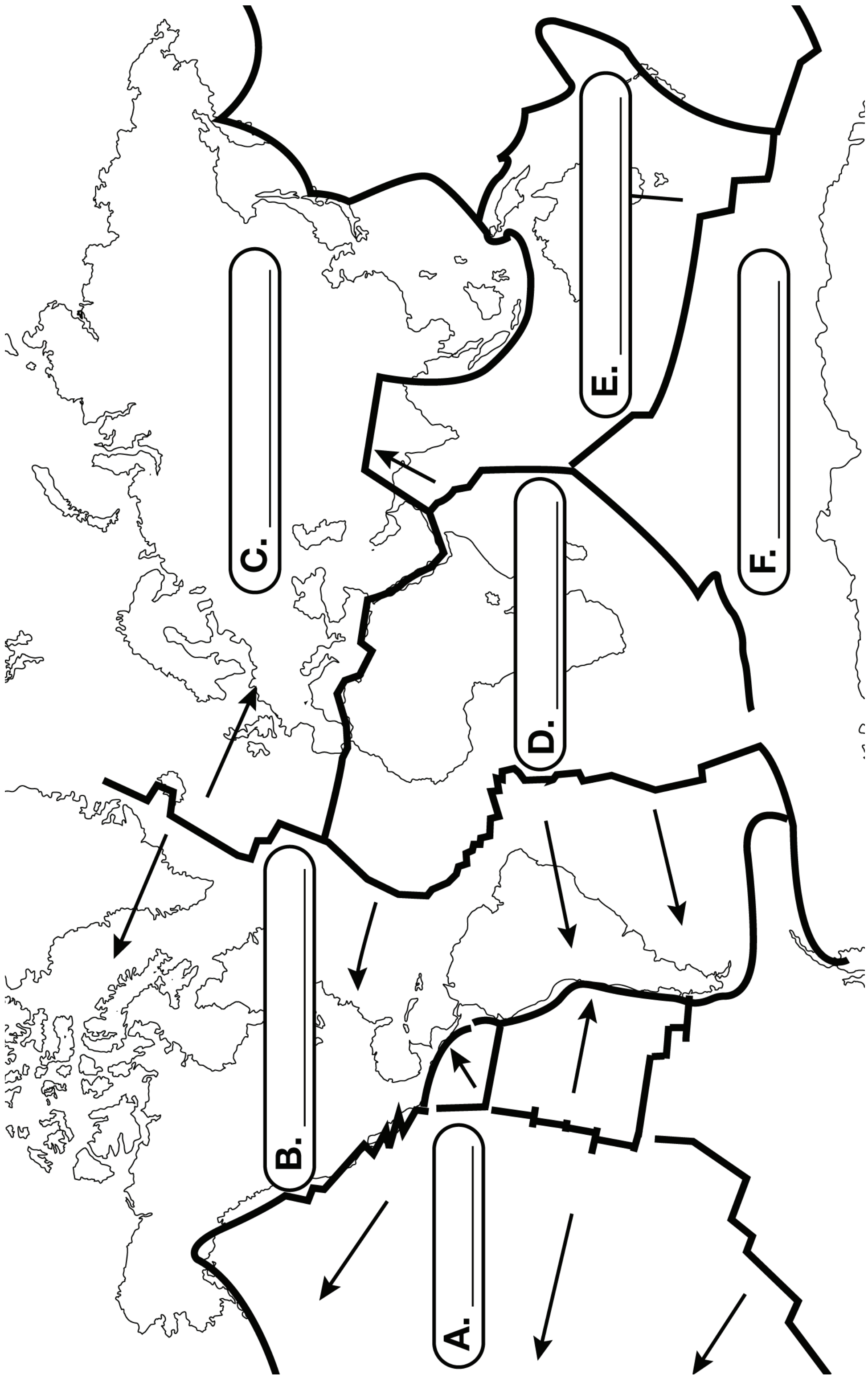
Reading reflection

1. How did Harry Hess' career in the Navy contribute to his geological research?
2. What were some of the geological discoveries Hess made while aboard his attack transport ship?
3. Describe Hess' theory of sea floor spreading.
4. How did Hess' sea floor spreading theory explain why so little sediment is deposited on the ocean floor?
5. What were Hess' contributions to space research?
6. **Research:** Harry Hess made significant contributions in the fields of geology, geophysics, and mineralogy. What scientific society established the Harry H. Hess Medal and what achievements does it recognize?

Name: ______________________ Date: ______________

SKILL and PRACTICE 11.3

Earth's Largest Plates



Name:____ Date:_________________

SKILL and PRACTICE 11.3

John Tuzo Wilson

John Tuzo Wilson was a professor at the University of Toronto whose love for adventure helped him make major contributions in the field of geophysics. His research on plate tectonics explained volcanic island formation and led to the discovery of transform faults. He also described the formation of oceans, a process later named the Wilson Cycle.

A noteworthy family

John Tuzo Wilson was born in Ottawa, Canada on October 24, 1908. His adventurous parents helped to expand Canada's frontiers. Wilson's mother, Henrietta Tuzo, was a famous mountaineer. Mount Tuzo in western Canada was named in her honor after she scaled its peak. Wilson's father, also named John, helped plan the Canadian Arctic Expedition of 1913 to 1918. He also helped develop airfields throughout Canada.

In 1930, Wilson was the first graduate of geophysics from the University of Toronto. He earned a second degree from Cambridge University. In 1936, Wilson received a doctorate in geology from Princeton University.

An adventurous scholar

Throughout his career, Wilson enjoyed traveling to unusual locations. While a student at Princeton, Wilson became the first person to scale Mount Hague in Montana—an elevation of 12,328 feet.

When World War II broke, Wilson served in the Royal Canadian Army. After the war, Wilson led an expedition called Exercise Musk-Ox. He directed ten army vehicles 3,400 miles through the Canadian Arctic. This journey proved that people could travel to Canada's north country.

In 1946, Wilson began his 30-year career as a professor of geophysics at the University of Toronto. While a professor, Wilson mapped glaciers in Northern Canada. Between 1946 and 1947, he became the second Canadian to fly over the North Pole during his search for unknown Arctic islands.

Plate tectonics and a hot idea

Many scientists contributed to the development of the plate tectonics theory. However, they had difficulty explaining the formation of volcanic islands. These islands, like the Hawaiian Islands, are thousands of kilometers away from plate boundaries.

In the early 1960s, Wilson solved the volcanic island mystery. He explained that sometimes a single hot mantle plume will break through a plate and form a volcanic island. As the plate moves over the mantle plume, a chain of islands forms. At first this theory was rejected. Finally, in 1963, Wilson published his paper.

Slipping and sliding plates

In 1965, Wilson proposed that a type of plate boundary must connect ocean ridges and trenches. He suggested that a plate boundary ends abruptly and transforms into major faults that slip horizontally. Wilson called these boundaries "transform faults."

Wilson's idea was confirmed and quickly became a major milestone in the plate tectonics theory. The San Andreas Fault of southern California is a well-known transform fault.

Opening and closing ocean basins

Wilson was one of the first geologists to link seafloor spreading with land geology. In 1967, Wilson published an article that described the repeated process of ocean basins opening and closing. This process later became known as the Wilson Cycle.

Geologists believe that the Atlantic Ocean basin closed millions of years ago. This event led to the formation of the Appalachian and Caledonian mountain systems. The basin later re-opened to form today's Atlantic Ocean.

An honored geologist

Wilson's contributions to the field of geophysics led to many honors and awards throughout his career. In 1967, Wilson became the principle of Erindale College at the University of Toronto. From 1974 to 1985, Wilson served as director of the world-renowned Ontario Science Center. On April 15, 1993, Wilson died at age 84.

Reading reflection

1. How did John Tuzo Wilson's parents contribute to his passion for the outdoors?
2. Why is Wilson sometimes referred to as an adventurous scholar?
3. Describe Wilson's theory of how volcanic islands are formed.
4. What did Wilson discover about plate boundaries and the formation of faults?
5. What is the Wilson Cycle? Give an example of this process.
6. **Research:** On which continent are mountains named in honor of John Tuzo Wilson?

Name: ______________________ Date: ______________

SKILL and PRACTICE 12.1

Averaging

READ

The most common type of average is called the *mean*. Usually when someone (who's not your math teacher) asks you to find the average of something, it is the *mean* that they want. To find the mean, just sum (add) all the data, then divide the total by the number of items in the data set. This type of average is used daily by many people. Teachers and students use it to average grades. Meteorologists use it to average normal high and low temperatures for a certain date. Sports statisticians use it to calculate batting averages and many other things.

EXAMPLE

- William has had three tests so far in his English class. His grades are 80%, 75%, and 90%. What is his average test grade?

  Solution:

  a. Find the sum of the data: 80 + 75 + 90 = 245

  b. Divide the sum (245) by the number of items in the data set (3): 245 ÷ 3 ≈ 82%

  William's average (mean) test grade in English (so far) is about 82%

PRACTICE

1. The families on Carvel Street were cleaning out their basements and garages to prepare for their annual garage sale. At 202 Carvel Street, they found seven old baseball gloves. At 208, they found two baseball gloves. At 214, they found four gloves, and at 221 they found two gloves. If these are the only houses on the street, what is the average number of old baseball gloves found at a house on Carvel Street?

2. During a holiday gift exchange, the members of the winter play cast set a limit of $10 per gift. The actual prices of each gift purchased were: $8.50, $10.29, $4.45, $12.79, $6.99, $9.29, $5.97, and $8.33. What was the average price of the gifts?

3. During weekend baby sitting jobs, each sitter charged a different hourly rate. Rachel charged $4.00, Juanita charged $3.50, Michael charged $4.25, Rosa charged $5.00, and Smith charged $3.00.

   a. What was the average hourly rate charged among these baby sitters?

   b. If they each worked a total of eight hours, what was their average pay for the weekend?

4. The boys on the sixth grade basketball team at Fillmore Middle School scored 22 points, 12 points, 8 points, 4 points, 4 points, 3 points, 2 points, 2 points, and 1 point in Thursday's game. What was the average number of points scored by each player in the game?

5. Jerry and his friends were eating pizza together on a Friday night. Jerry ate a whole pizza (12 slices) by himself! Pat ate three slices, Jack ate seven slices, Don and Dave ate four slices each, and Teri ate just two slices. What was the average number of slices of pizza eaten by one of these friends that night?

Name: ______________________________ Date: ______________

SKILL and PRACTICE 12.1

Speed

READ

If you ride your bike with your father for an hour, and the two of you cover 8 miles total, it might be obvious to you that you that you had been riding at a speed of 8 miles per hour (mph).

In this situation it's pretty easy to determine your speed (in miles per hour). In other situations, the solution may not be quite as obvious (even though the method is really the same). In those situations, you may find it useful to use this formula:

$$\text{speed} = \frac{\text{distance}}{\text{time}} \quad \text{OR} \quad s = \frac{d}{t}$$

To calculate speed, you need to divide the distance traveled by the time it took to cover that distance. Typically, we will be working with distances measured in SI units. Common SI units for speed include *kilometers per second (km/s)*, *meters per second (m/s)*, *centimeters per second (cm/s)*, and *kilometers per hour (km/hr)*.

EXAMPLE

- It took Beverly 3 seconds to walk 70 centimeters. How fast was she walking?

  Solution:

  Using the formula: $\text{speed} = \frac{\text{distance}}{\text{time}}$, divide the distance (70 cm) by the time (3 s).

  Doing this arithmetic tells us that Beverly's speed is $23.\overline{3}$ cm/s (or $23.\overline{3}$ centimeters per second).
  In other words, Beverly was walking extremely slowly.

PRACTICE

1. A small ball is rolling on a flat table that is 30 centimeters wide. It takes the ball 12 seconds to complete its trip across the width of the table. How fast is the ball rolling?

2. Paul throws a paper wad to Alex who is sitting exactly 3.2 meters away. The paper wad was only in the air for 1.2 seconds. How fast was it traveling?

3. The distance from home plate to the pitcher's mound in professional baseball is about 18.44 meters. If it takes a pitched ball about 0.4 seconds to travel from the mound to home plate, how fast was the ball traveling?

4. Serina is a ballet dancer. During her dance, she dances in a "Z" pattern on the stage. It takes her about 30 seconds to complete the "Z." The top and bottom of the "Z" are equal distances of about 3 meters each. The middle part of the "Z" is about 5 meters long. How quickly (in meters per second) is she traveling during this part of the dance?

5. It takes an unmanned drone 9.5 years to travel 4,340,000,000 kilometers to Pluto. How fast is the drone traveling?

6. Jessie walks about two and one half kilometers to get to her friend Emma's house. It takes her about 1/3 hour (20 minutes) to get there. She loses track of time and has to run in order to make it back by the time her dad asked her to be home. She makes it home in just 1/6 hour (10 minutes). Answer each in kilometers per hour:

   a. How fast was Jessie traveling on her way to Emma's house?

   b. How fast was she running on her way home?

   c. What was her average speed for the entire trip?

7. Heather ran steadily at 2.5 meters/second for about 10 minutes (600 seconds). How far did she run?

8. Nate threw a football to his friend Tom who was 15 meters away. The ball was traveling slowly at just 5 meters per second. How long did it take the ball to get to Tom?

Name: ________________________ Date: ______________

SKILL and PRACTICE 12.1

Internet Research Skills

READ

The Internet is a valuable tool for finding answers to your questions about the world. A search engine is like an on-line index to information on the World Wide Web. There are many different search engines from which to choose. Search engines differ in how often they are updated, how many documents they contain in their index, and how they search for information. Your teacher may suggest several search engines for you to try.

EXAMPLE

Search engines ask you to type a word or phrase into a box known as a *field*. Knowing how search engines work can help you pinpoint the information you need. However, if your phrase is too vague, you may end up with a lot of unhelpful information.

How could you find out who was the first woman to participate in a space shuttle flight?

First, put **key phrases** in quotation marks. You want to know about the "first woman" on a "space shuttle." Quotation marks tell the engine to search for those words together.

Second, if you only want websites that contain both phrases, **use a + sign** between them. Typing **"first woman" + "space shuttle"** into a search engine will limit your search to websites that contain both phrases.

If you want to broaden your search, use the word **or** between two terms. For example, if you type **"first female" or "first woman" + "space shuttle"** the search engine will list any website that contains either of the first two phrases, as long as it also contains the phrase "space shuttle."

You can narrow a search by using the word **not.** For example, if you wanted to know about marine mammals other than whales, you could type **"marine mammals" not "whales"** into the field. Please note that some search engines use the minus sign (-) rather than the word **not**.

PRACTICE 1

1. If you wanted to find out about science museums in your state that are not in your own city or town, what would you type into the search engine?
2. If you wanted to find out which dog breeds are not expensive, what would you type into the search engine?
3. How could you research alternatives to producing electricity through the combustion of coal or natural gas?

READ

The quality of information found on the Internet varies widely. This section will give you some things to think about as you decide which sources to use in your research.

1. **Authority:** How well does the author know the subject matter? If you search for “Newton’s laws” on the Internet, you may find a science report written by a fifth grade student, and a study guide written by a college professor. Which website is the most authoritative source?
   Museums, national libraries, government sites, and major, well-known “encyclopedia sources” are good places to look for authoritative information.
2. **Bias:** Think about the author’s purpose. Is it to inform, or to persuade? Is it to get you to buy something? Comparing several authoritative sources will help you get a more complete understanding of your subject.
3. **Target audience:** For whom was this website written? Avoid using sites designed for students well below your grade level. You need to have an understanding of your subject matter at or above your own grade level. Even authoritative sites for younger students (children’s encyclopedias, for example) may leave out details and simplify concepts in ways that would leave gaps in your understanding of your subject.
4. **Is the site up-to-date, clear, and easy to use?** Try to find out when the website was created, and when it was last updated. If the site contains links to other sites, but those links don’t work, you may have found a site that is infrequently or no longer maintained. It may not contain the most current information about your subject. Is the site cluttered with distracting advertisements? You may wish to look elsewhere for the information you need.

PRACTICE 2

1. What is your favorite sport or activity? Search for information about this sport or activity. List two sites that are authoritative and two sites that are not authoritative. Explain your reasoning. Finally, write down the best site for finding out information about your favorite sport.
2. Search for information about an earth science topic of your choice on the Internet (for example: “earthquakes,” “hurricanes,” or “plate tectonics”). Find one source that you would NOT consider authoritative. Write the key words you used in your search, the web address of the source, and a sentence explaining why this source is not authoritative.
3. Find a different source that is authoritative, but intended for a much younger audience. Write the web address and a sentence describing who you think the intended audience is.
4. Find three sources that you would consider to be good choices for your research here. Write a two to three sentence description of each. Describe the author, the intended audience, the purpose of the site, and any special features not found in other sites.

Name:____ Date: __________________

SKILL and PRACTICE 12.1

Charles Richter

Richter is the most recognized name in seismology due to the earthquake magnitude scale he codeveloped. But Earth science was never a subject of interest to this bright young physicist, until a mentor made an interesting suggestion and a "happy accident" introduced him to seismology.

The unexpected path

Photo - courtesy of USGS

Charles F. Richter was born on April 26, 1900 in Hamilton, Ohio. When he was 16, Charles and his mother left their Ohio farm and moved to Los Angeles. Richter attended the University of Southern California from 1916–1917, and then earned a bachelor's degree in physics at Stanford University.

It was during his Ph.D. studies in **theoretical physics** at the California Institute of Technology (Caltech) that Richter began his work in seismology, quite by accident.

In 1927, Richter was working on his Ph.D. under the Nobel Prize winning physicist Dr. Robert Millikan. One day, Dr. Millikan called Richter into his office and presented him with an opportunity. The Caltech **Seismology** Laboratory was in need of a physicist, and although Richter had never done any Earth science work, Dr. Millikan thought he might be a good person for the job.

Richter was a little surprised, but decided to talk to Harry Wood, the lead scientist in charge of the lab. Richter became intrigued and decided to join the seismology lab located in Pasadena, California. Richter described this introduction to the science that would become his life's work as a "happy accident."

Doing something ordinary

One of Charles Richter's most famous sayings is based on looking back at his own life: "Don't wait for extraordinary circumstance to do good; try to use ordinary situations."

When he first started at the seismology lab, Richter was busy with the routine work of measuring **seismograms** and locating earthquakes, so that a catalog of epicenters and occurrence times could be set up. At the time, this kind of earthquake study was new. Harry Wood was leading the effort to use southern California's active seismic setting to gain a better understanding of earthquakes.

This creative setting allowed Richter to attempt to develop new ways to "rate" earthquakes based on the seismic waves they produced. Since the lab used seven seismographs to record activity, Richter suggested that they compare quakes to one another using the amplitude of each quake measured at all seven locations. To do this, the seismic readings needed to be corrected to take into account the differences in distance from the epicenters. Richter had learned of a method to do this based on large earthquakes, but the magnitudes that Richter was studying ranged from tiny to very large.

Collaboration and success

Richter thought that the size difference in the magnitudes was unmanageably large. Fellow scientist Dr. Beno Gutenberg suggested that they plot the magnitudes using powers of 10. A **magnitude** two earthquake would represent 10 times the amplitude of ground motion of a magnitude one. A magnitude three would be 100 times a magnitude one, a four would be 1,000 times a magnitude one, and so on.

Richter realized this was the obvious answer to his problem. When he used this method and graphed the results, it worked! At first it could be used only for southern California, because the system was only meant to compare quakes of that region using the seven **seismographs** in their lab.

A new way to rate earthquakes

In 1935, Richter and Gutenberg published their magnitude scale system. By 1936, they had worked out how their system could be used in all parts of the world, with any type of instrument. Before this, the Mercalli scale had been used to rate the magnitude of earthquakes, but it was based on local damage to buildings and people's reactions to a quake.

Richter and Gutenberg's scale allowed for a more absolute and scientific method to be used by anyone, anywhere in the world.

Reading reflection

1. Look up the definition of each boldface word in the article. Write down the definitions and be sure to credit your source.
2. What do you think you would feel like if a world reknown scientist like Dr. Robert Millikan recommended you for a job? How would you feel if accepting that job meant that you could no longer work closely with Dr. Millikan?
3. How did Richter respond to his new job?
4. Who helped Richter refine his idea into a working model?
5. Name a scale other than the Richter scale that scientists use to evaluate earthquakes.
6. **Research:** Why do scientists use different scales to rate earthquakes?
7. **Research:** What is the difference between a seismograph and a seismometer?

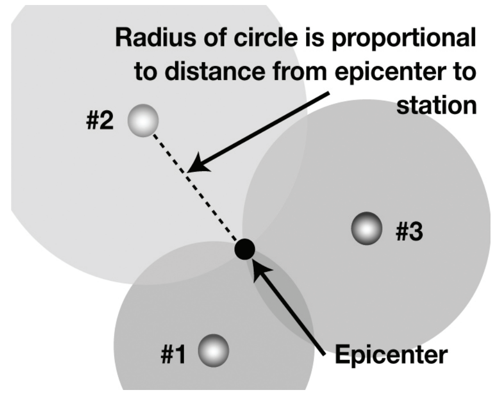
Name: ______________________ Date: ______________

SKILL and PRACTICE 12.1

Finding an Earthquake Epicenter

READ

The location of an earthquake's epicenter can be determined if you have data from at least three seismographic stations. One method of finding the epicenter utilizes a graph and you need to know the difference between the arrival times of the P- and S-waves at each of three seismic stations. Another method uses a formula and you need to know the arrival times and speeds of the P- and S-waves. The only other items you need to find an epicenter are a calculator, a compass, and a map.



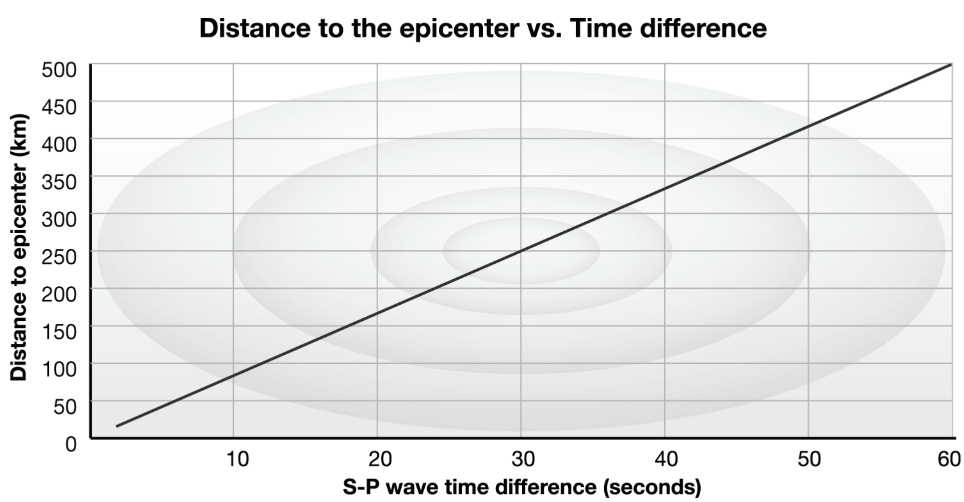
PRACTICE 1

Finding the epicenter using a graph

Table 1 provides the arrival time difference between P- and S-waves. Use this value to find the distance to the epicenter on the graph. Record the distance values in the table in the third column from the left.

Table 1: Seismic wave arrival time and distance to the epicenter

Station name	Arrival time difference between P- and S-waves	Distance to epicenter in kilometers	Scale distance to epicenter in centimeters
1	15 seconds		
2	25 seconds		
3	42 seconds		



Locating the epicenter on a map

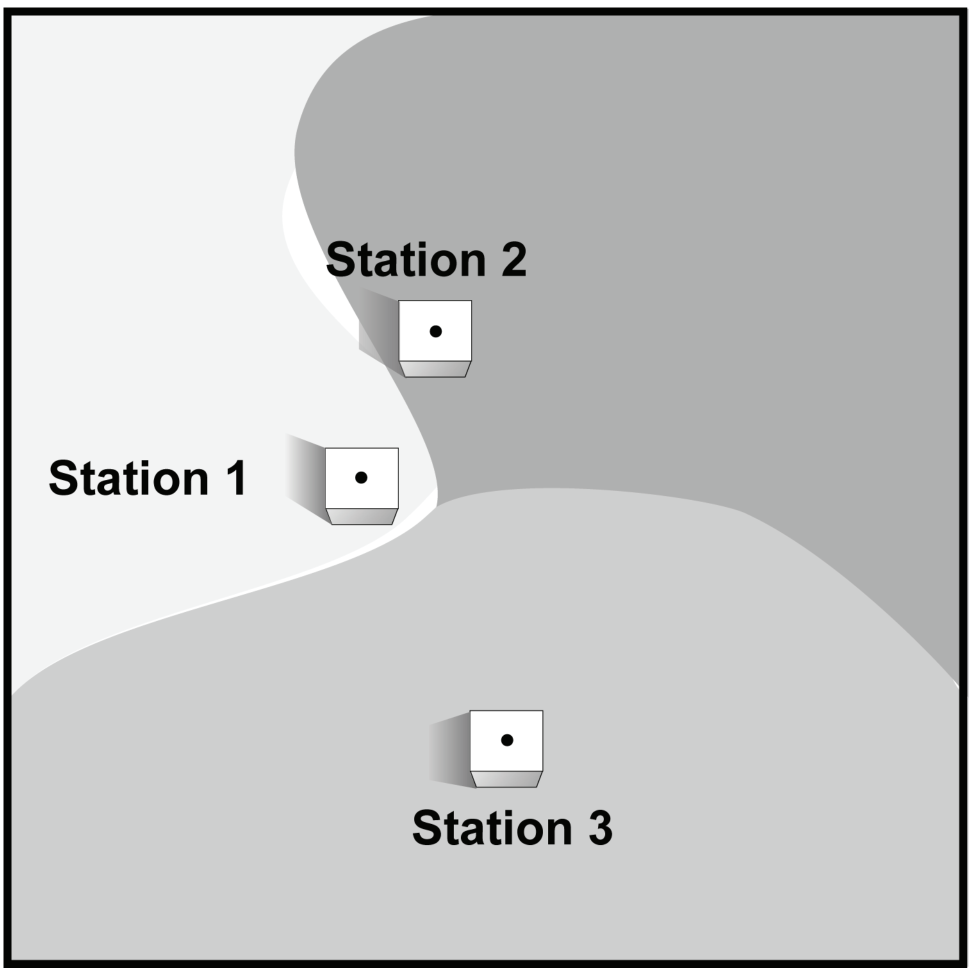
Once you have determined the distance to the epicenter for three stations in kilometers, you can use a map to locate the epicenter. The steps are as follows:

Step 1: Determine the radius of a circle around each seismographic station on a map. The radius will be proportional to distance from the epicenter. Use the formula below to convert the distances in kilometers to distances in centimeters. For this situation, we will assume that 100 kilometers = 1 centimeter. Record the scale distances in centimeters in the fourth column of Table 1.

$$\frac{1\text{ cm}}{100\text{ km}} = \frac{x}{\text{distance to epicenter in km}}$$

Step 2: Draw circles around each seismic station. Use a geometric compass to make circles around each station. Remember that the radius of each circle is proportional to the distance to the epicenter.

Step 3: The location where the three circles intersect is the location of the epicenter.



SKILL and PRACTICE 12.1

EXAMPLE ▶

Finding the epicenter using a formula

To calculate the distance to the epicenter for each station, you will use the equation:

$$\text{Distance} = \text{Rate} \times \text{Time}$$

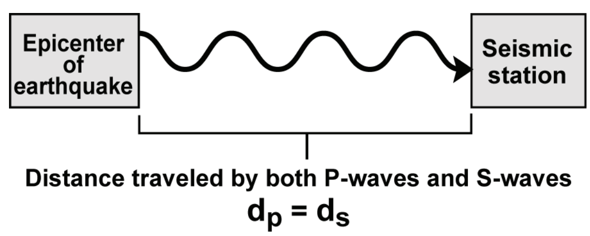
Table 2 lists the variables that are used in the equation for finding the distance to the epicenter. This table also lists values that are given to you.

Table 2: Variables for the equation to calculate the distance to the epicenter

Variable	What it means	Given
d_p	distance traveled by P-waves	r_p = 5 km/sec
r_p	speed of P-waves	r_s = 3 km/sec
t_p	travel time of P-waves	$d_p = d_s$
d_s	distance traveled by S-waves	
r_s	speed of S-waves	
t_s	travel time of S-waves	

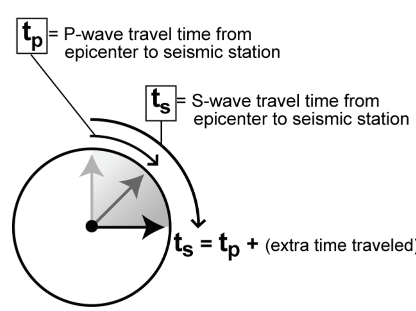
For each of the practice problems, assume that the speed of the P-waves will be 5 km/s and the speed of the S-waves will be 3 km/sec. Also, because the P- and S-waves come from the same location, we can assume the distance travelled by both waves is the same.

$$\text{distance traveled by P-waves} = \text{distance traveled by S-waves}$$
$$d_p = d_s$$
$$r_p \times t_p = r_s \times t_s$$



Since the travel time for the S-waves is longer, we can say that,

$$\text{travel time of S-waves} = (\text{travel time of P-waves}) + (\text{extra time})$$
$$t_s = t_p + (\text{extra time})$$
$$r_p \times t_p = r_s \times (t_p + \text{extra time})$$



PRACTICE 2

For each of the practice problems, assume that the speed of the P-waves is 5 kilometers per second, and the speed of the S-waves is 3 kilometers per second. The first problem is done for you. Show your work for all problems.

1. S-waves arrive to seismographic station A 85 seconds after the P-waves arrive. What is the travel time for the P-waves?

$$\frac{5\text{ km}}{\text{sec}} \times t_p = \frac{3\text{ km}}{\text{sec}} \times (t_p + 85\text{ sec})$$

$$\left(\frac{5\text{ km}}{\text{sec}}\right)t_p = \left(\frac{3\text{ km}}{\text{sec}}\right)t_p + 255\text{ km}$$

$$\left(\frac{2\text{ km}}{\text{sec}}\right)t_p = 255\text{ km}$$

$$t_p = 128\text{ sec}$$

2. S-waves arrive to another seismographic station B 80 seconds after the P-waves. What is the travel time for the P-waves to this station?

3. A third seismographic station C records that the S-waves arrive 120 seconds after the P-waves. What is the travel time for the P-waves to this station?

4. From the calculations in questions 1, 2, and 3, you know the travel times for P-waves to three seismographic stations (A, B, and C). Now, calculate the distance from the epicenter to each of the stations using the speed and travel time of the P-waves. Use the equation: distance = speed × time.

5. Challenge question: You know that the travel time for P-waves to a seismographic station is 200 seconds.
   a. What is the difference between the arrival times of the P- and S-waves?
   b. What is the travel time for the S-waves to this station?

6. Table 3 includes data for three seismographic stations. Using this information, perform the calculations that will help you fill in the rest of the table, except for the scale distance row.

Table 3: Calculating the distance to the epicenter

	Variables	Station 1	Station 2	Station 3
Speed of P-waves	r_p	5 km/sec	5 km/sec	5 km/sec
Speed of S-waves	r_s	3 km/sec	3 km/sec	3 km/sec
Time between the arrival of P- and S-waves	$t_s - t_p$	70 seconds	115 seconds	92 seconds
Total travel time of P-waves	t_p			
Total travel time of S-waves	t_s			
Distance to epicenter in kilometers	d_p, d_s			

Table 3: Calculating the distance to the epicenter

Scale distance to epicenter in centimeters				

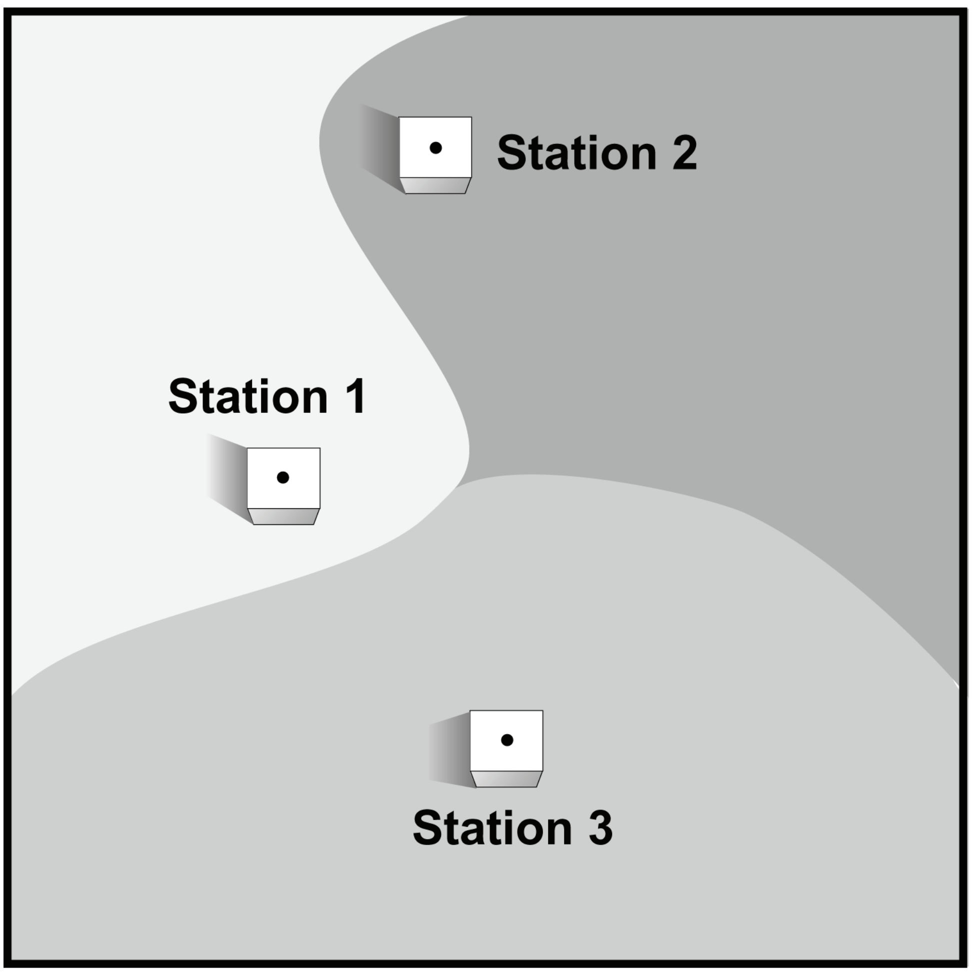
Once you have determined the distance to the epicenter for three stations in kilometers, you can use a map to locate the epicenter. The steps are as follows:

Step 1: Determine the radius of a circle around each seismographic station on a map. The radius will be proportional to distance from the epicenter. Use the formula below to convert the distances in kilometers to distances in centimeters. For this situation, we will assume that 200 kilometers = 1 centimeter. Record the scale distances in centimeters in the last row of Table 3.

$$\frac{1\text{ cm}}{200\text{ km}} = \frac{x}{\text{distance to epicenter in km}}$$

Step 2: Draw circles around each seismic station. Use a geometric compass to make circles around each station. Remember that the radius of each circle is proportional to the distance to the epicenter.

Step 3: The location where the three circles intersect is the location of the epicenter.



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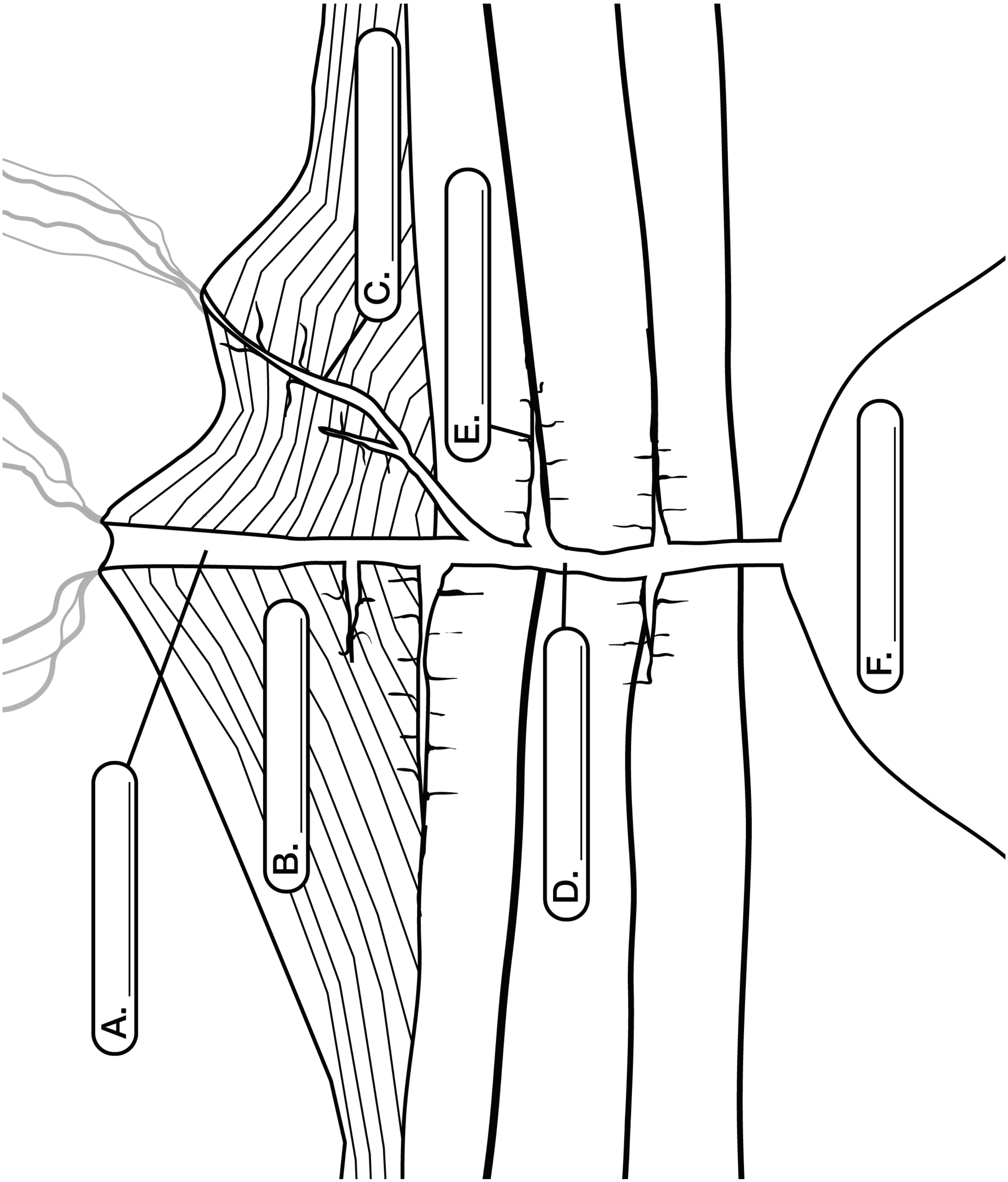
SKILL and PRACTICE 12.2

Volcano Parts



Name: ______________________ Date: ______________

SKILL and PRACTICE 12.2

Responding to Natural Disasters

READ

You have learned that plate tectonics helps explain why certain natural disasters like earthquakes, volcanic eruptions, and tsunamis occur. You have also learned about storms and global warming—two conditions that can cause coastal flooding.

In this project, you will:

(1) Review articles about a natural disaster and evaluate the science in these articles,

(2) Discuss how communities and the world at large respond to natural disasters, and

(3) Develop a plan for how your class can respond to this disaster and help the community affected by it.

Examples of where to find articles and information on the Internet	
Web site	**Description**
Any news agency web site	
http://www.usgs.gov/ http://neic.usgs.gov/	The web site for the United States Geological Survey (USGS), and The Current Worldwide Earthquake List
http://www.fema.gov/	The web site for the United States Federal Emergency Management Agency (FEMA)
http://www.noaa.gov/ http://www.noaanews.noaa.gov/	The web site and news magazine for the National Oceanographic and Atmospheric Agency
http://ochaonline.un.org/	The web site for the United Nations Office for the Coordination of Human Affairs
http://www.unicef.org/	The web site for the United Nations Children's Fund (formerly United Nations International Children's Emergency Fund).
http://www.redcross.org/ http://www.icrc.org/	The web sites for the American Red Cross and the International Red Cross
http://www.disasterrelief.org/EarthWatch	A web link that shows a map of recent natural disasters.

PRACTICE

Part 1: Reviewing articles

1. Obtain copies of local and national papers to learn about recent natural disasters. As a class, select a natural disaster for this project. You may want to chose an event that has occurred close to where you live. Here is a list of natural disasters that received extensive news coverage:

- Hurricane Katrina: Category 5 Atlantic Hurricane that hit the Gulf Coast of the United States in August 2005.
- Earthquakes in Iran: (1) the 6.6 magnitude quake in Bam, December 2003, or (2) the 6.4 magnitude earthquake in central Iran, February 22, 2005.
- Tsunami: The Indian Ocean tsunami that resulted from two undersea earthquakes—one at 9.0 magnitude and one at 7.3, December 26, 2004
- Hurricanes in Florida: Five hurricanes hit Florida's coastline during the hurricane season of 2004.
- Storms and mudslides: Record rains in 2004-05 and storms caused severe mudslides, tornadoes, and avalanches in Los Angeles, California in February, 2005.

2. From a number of different papers, magazines, and news sites on the Internet, collect at least five articles.
   a. Read each article carefully and highlight important statements.
   b. Create a display for your articles. Either paste them to a poster board or make a portfolio of the articles.
3. Based on these articles, write a brief description of the disaster. In the description include the following information: the date it happened, where it happened, what caused the disaster, and the impact of the disaster on people and communities.
4. Discuss the science presented in the articles you collected. Does it seem correct? Did the reporters writing the articles seem to understand the science that caused the natural disaster? (Your teacher may invite an expert to come to your class to help you with this step of the project.)
5. Based on your reading, research, and discussions, write another paragraph describing why this disaster happened. For example, the 2004 tsunami was caused by movement of tectonic plates. Be as detailed as you can in your paragraph. For more information about the science, you may need to visit government web sites such as www.noaanews.noaa.gov or www.usgs.gov.

Part 2: Discussion

In response to a natural disaster, people tend to work together to help victims, raise money, provide medical aid, and rebuild the disaster area. Research and find out what is being done in response to the natural disaster your class chose to focus on for this project.

1. What is the affected community doing?
2. What is the United States doing?
3. What is the world doing?

Part 3: Taking action

1. With your class brainstorm a list of things you could do to help victims of the natural disaster. List one thing your class could to for each of the following categories. How could your class:
   a. Raise awareness about the type of disaster so people are safer in the future?
   b. Raise money to help victims of the disaster?
   c. Volunteer to help victims of the disaster or organizations that help the disaster victims?

2. With your class, choose one thing to do in response to this natural disaster. Then, create a time line and an action plan for accomplishing this project. The action plan should include a list of tasks that need to happen and who will accomplish those tasks.

Name: ______________________________ Date: ______________

SKILL and PRACTICE 13.1

Mohs Hardness Scale

READ

The Mohs hardness scale was developed in 1812 by Friedrick Mohs (an Austrian mineral expert) as a method to identify minerals. This scale uses 10 common minerals to represent variations in hardness. You can identify a mineral's place on the hardness scale by whether it can scratch another mineral. For example, gypsum (hardness = 2) scratches talc (hardness = 1). The hardest mineral, a diamond, can scratch all other minerals. Pure minerals of the same hardness scratch each other. During this activity, you will practice using Mohs Hardness Scale and work with the minerals in your Rocks and Minerals Set.

Collecting the minerals of Mohs Hardness Scale

1. From your Rocks and Minerals Set, collect the minerals listed in Table 1. **To complete the activity, you will need to obtain gypsum, topaz and corundum from your teacher.** The only mineral you will not find is a diamond. Why?
2. The piece of ceramic tile (known as the streak plate) in your set is used to determine the streak color of minerals. Scratch each mineral on the streak plate and record the streak color in the third column of Table 1.
3. In the fourth column, describe what each mineral looks like. Describe its color, texture, and anything else that would help you distinguish this mineral. Use the small magnifying glass in the kit to help you.

Table 1: Mohs Hardness Scale

Mineral	Hardness	Color of Streak on Streak plate	Description
Talc	1		
Gypsum	2		
Calcite	3		
Fluorite	4		
Apatite	5		
Orthoclase (Feldspar)	6		
Quartz	7		
Topaz	8		
Corundum	9		
Diamond	10	N/A	clear, sparkly

PRACTICE

1. Prove to yourself that the placement of the minerals on the Mohs Hardness Scale is correct. How would you do this? Write your procedure as a short paragraph and then perform the procedure.
2. Is the Mohs Hardness Scale value for a mineral quantitative or qualitative? Justify your answer.
3. List two pros and two cons for using the Mohs hardness scale to identify minerals.
4. Is the Mohs Hardness Scale useful for identifying rocks? Why or why not?
5. Some varieties of the mineral corundum are gemstones. Rubies and sapphires are two examples. Imagine that you have heard a report that there is a newly discovered mine that is rich in corundum. You have been hired to verify the reports. For your first field trip, design two tests you will use to determine if the mineral in the mine is in fact corundum.
6. **Challenge:** Find the hardness values for other objects.

   When geologists are in the field, they do not have a whole set of mineral samples to represent each hardness value on the Mohs Hardness Scale. Instead, they often use things like a pocket knife or fingernail to identify the hardness of mineral samples.

   Use the clues (a - g) to help you identify the hardness values for the objects listed in Table 2. First, read the following instructions for how to fill in the table.

   Instructions for filling in Table 2: In the top row are items that you could use to identify the hardness of a mineral. Read the clues to identify the hardness of each. The information in Table 1 will be helpful to you as well. Place a circle (**O**) in the table cell where the object and its hardness match. Where hardness and the object do not match up, place an **X**. The first two clues are done for you to illustrate how to fill in the table.

   Clues:

   a. A diamond is considered to be the hardest mineral.

   b. Pyrite is harder than calcite. (You can find pyrite in your Rocks and Minerals Set).

   c. The hardness of a fingernail is 2.5. Ice does not leave scratches on a fingernail.

   d. Calcite and copper have similar hardness.

   e. A pocket knife is helpful in that it can scratch half of the minerals on the Mohs Hardness Scale.

   f. Pure apatite and fluorite can be scratched by iron. Iron can be scratched by quartz.

   g. A pocket knife can scratch fool's gold.

SKILL and PRACTICE 13.1

Table 2: Mohs Hardness Scale

	Copper wire	Pocketknife	Pyrite	Diamond	Iron nail	Ice
1.5			X	X		
3			X	X		
4-5				X		
5.5				X		
6-6.5				X		
10	X	X	X	O	X	X

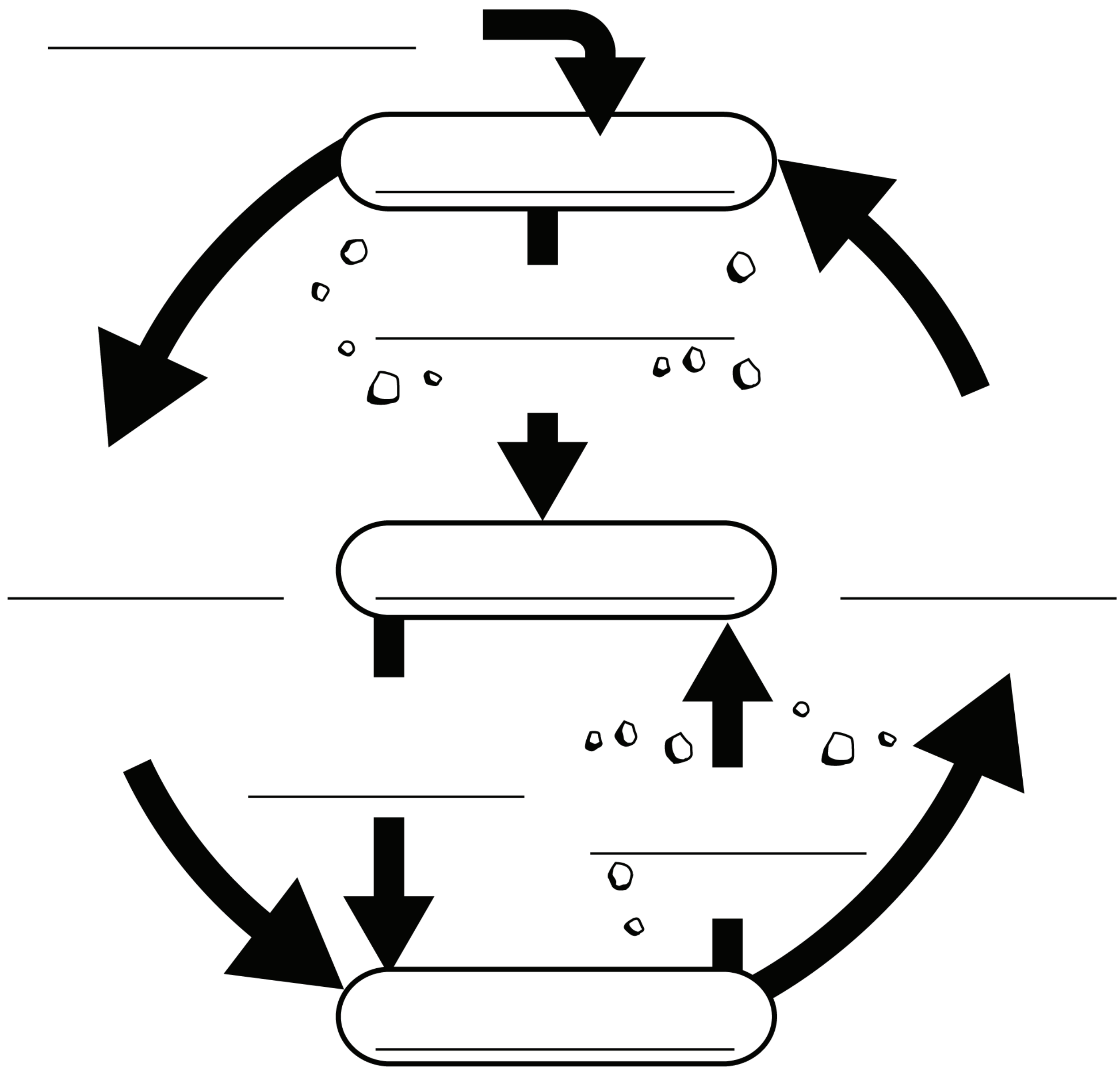
Name: ______________________ Date: ______________

SKILL and PRACTICE 13.1

The Rock Cycle

PRACTICE

In Section 13.1 of your student text, you will learn about the rock cycle. Place the three main groups of rocks in the ovals below. Then, fill in the blank lines with the materials or processes at work in each stage of the rock cycle. Use this diagram as a study aid. Describe to a friend or family member what is happening at each stage.



Name: ______________________________ Date: ______________

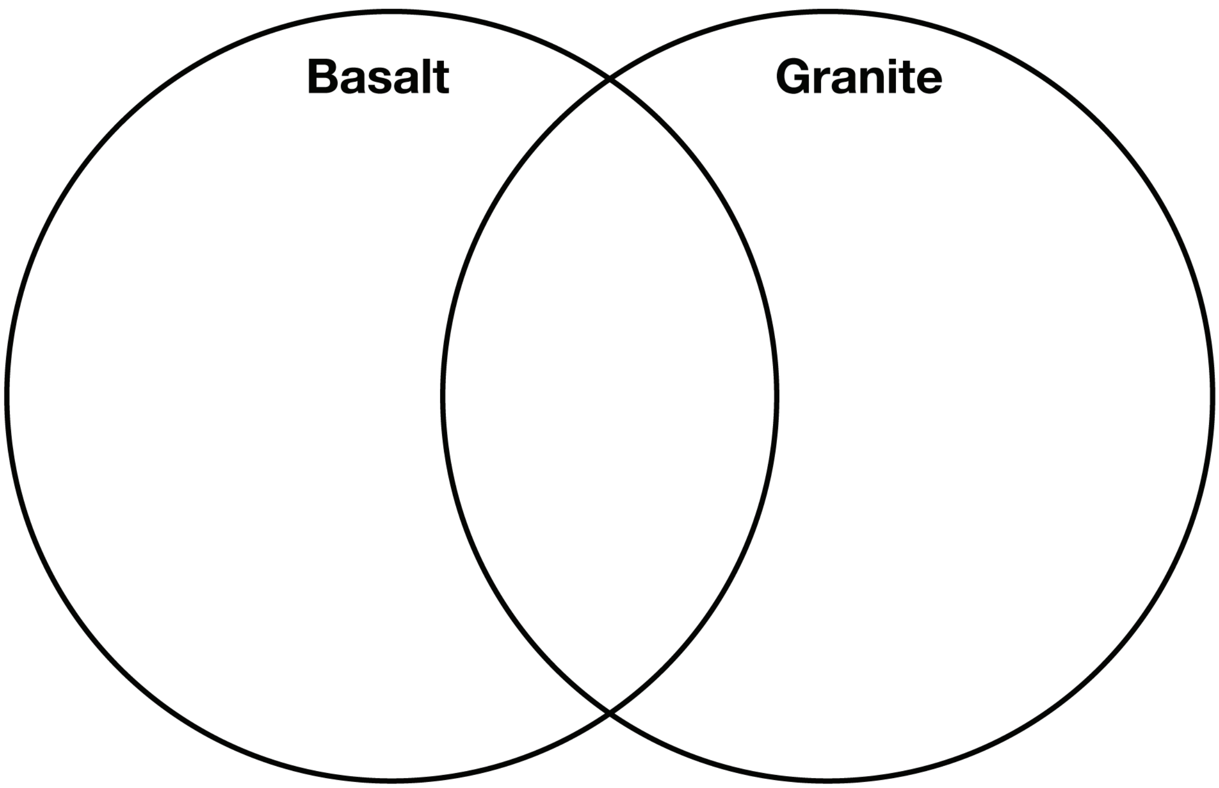
SKILL and PRACTICE 13.2

Basalt and Granite

READ

As you read Section 13.2 of your student text, you will learn about how basalt and granite form. You'll learn about ways they are alike and ways that they are different. The Venn diagram below can help you organize this information. As you learn about these types of rock, place facts that apply to both in the space where the circles intersect. Place facts that apply to only one type of rock in its individual space. Use this diagram as a study aid.

PRACTICE



1.

Name: ______________________________ Date: ____________________

PRACTICE 14.3

Continental United States Geology

READ

You have learned about the plates that make up the surface of Earth. You have also learned how plates are formed at mid-ocean ridges and are destroyed at subduction zones. Here is a very brief look at how plate tectonics formed the land mass that we call the United States. It covers only the last chapter of the Earth history of the 48 contiguous states.

The full history of the surface of Earth is a very long and complicated story. To give you an idea of the difficulty of understanding the full story, imagine this: A young child is given a new box of modeling clay. In the box are four sticks of differently colored clay. The child plays with the clay for hours making different figures. First a set of animals, then a fort, and so on. Between each idea, the child balls up all of the clay. Now imagine that it's the next day and the ball of swirled clay colors is in your hand. Your task is to figure out what the child made and in what order.

That sounds impossible, and it probably is. The amazing thing is that geologists have figured out a lot of the equally difficult story of Earth's surface. We have a pretty good idea about how the early crust was formed. And we know that there was a super continent called Rodinia that formed before Pangaea, the last super continent. But like the child's clay figures, the further back we look, the more the clues are mixed up.

The last chapter

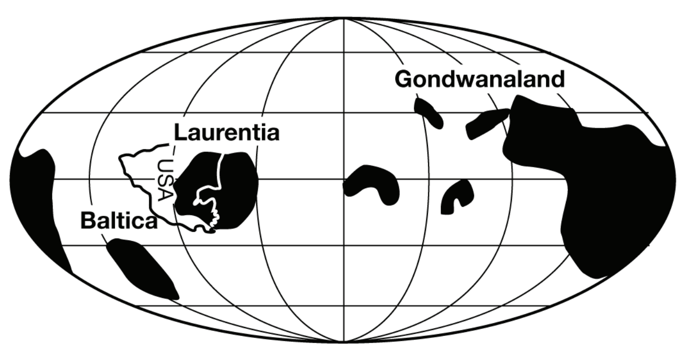
Our story begins late. Most of the history of Earth has already passed. During this time rift valleys formed that split continents into smaller pieces. First the land moved apart on both sides of a rift valley. Then, once the rift valley opened wide enough, water flooded in and a new ocean was born. Underwater, the rift valley then became a mid-ocean ridge.

At the same time, subducting plates acted like conveyor belts. Anything that was part of a subducting plate was carried toward the subduction zone. In this way continents were carried together. Collisions between continents welded them together. Mountain ranges formed at the point of contact.

The combination of rifting and subduction worked together to form, destroy, and reform the early continents. You can see that the result is very much like playing with modeling clay.

The craton

Even though most of Earth's history had passed, it was still an incredibly long time ago. Rifting had broken up Rodinia, but subduction had not yet formed Pangaea. The break-up of Rodinia left six continents scattered across the world oceans. These continents were not the continents that we see today. One of these, Gondwanaland, was larger than the others put together.

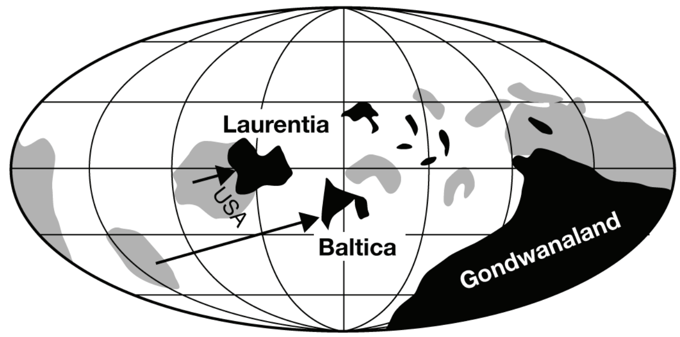


Two other continents are important to our story. They are called Baltica and Laurentia. At the center of Laurentia was a core piece that was very old even then. This core piece is called the craton. The craton had been changed again and again, but it was stable inside Laurentia. Today the craton of Laurentia forms the central United States.

You may wonder where these names came from. After all, these continents were gone many millions of years before humans appeared on Earth. They are modern names proposed and adopted by geologists.

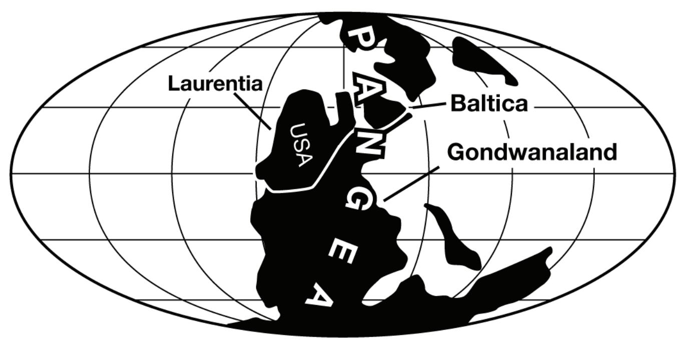
The first collision

Rifting and subduction caused Baltica to move in a jerky path. Eventually, Baltica collided with Laurentia to form a larger combined continent. This new continent is called Laurasia. A high mountain range formed where the colliding continents made contact. This mountain range lay deep inside Laurasia. Today the remains of this high mountain range form our northern Appalachian Mountains.



Gondwanaland collides

Subduction continued to bring continents together. Next mighty Gondwanaland was drawn ever closer to Laurasia. Gondwanaland collided just below where Laurentia and Baltica collided with each other. This new collision raised another set of mountains that continued the northern Appalachians into what are now the southern Appalachians. The combined Appalachians were as high as the Himalayans of today! The super continent Pangaea was then complete and the lofty Appalachian Mountains stood near its center.



Pangaea breaks up

Pangaea did not remain together for very long, only a few tens of millions of years. The same rifting process that broke up Rodinia split the new super continent into smaller pieces. Our future East Coast had been deep inside the central part of Pangaea. But in the break-up, a rift valley split our eastern shore away from what is now Africa. Instead of an inland place, our East Coast became an eastern shore.

The East Coast after Pangaea

One of the amazing things in geology is how quickly mountain ranges are eroded away. After Pangaea broke up, the Appalachians completely eroded away. All that was left was a flat plain! The sediments produced from this erosion formed deep layers on the eastern shore and near-shore waters. These coastal margin sediments make up most of the eastern states today. But wait a minute; today we see rounded mountains where there had been only flat plains. What formed the rounded Appalachian Mountains of today?

When a mountain is formed, some of it is pressed deep into the mantle by the weight of the mountain above. It's like stacking wood blocks in water. As the stack grows taller, it also sinks deeper. Erosion takes a tall mountain down quickly. With the top gone, its bottom rebounds back to the surface. In this way, the Appalachian Mountains that we see today are actually the rebounded lower section of the mountains that once had been pressed deep below Earth's surface.

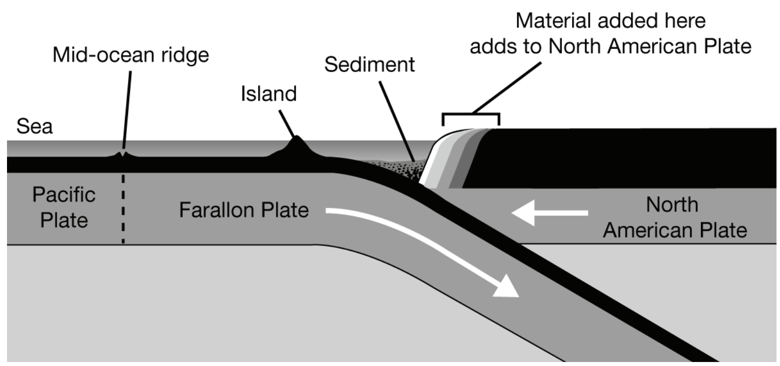
The West Coast and the Ancestral Rocky Mountains

There are two Rocky Mountain ranges. The first is called the Ancestral Rocky Mountains. The Ancestral Rocky Mountains were formed when subduction caused an ancient collision with Laurentia. The collision struck Laurentia on the side that would become our western states. In other words, the Ancestral Rocky Mountains already existed before Pangaea formed. The Ancestral Rockies were then heavily weathered and the sediment deposited on the surrounding plains. Today the Front Range of Colorado is part of the exposed remains of the Ancestral Rocky Mountains.

Pangaea and the West Coast

Our West Coast did not exist as Pangaea began to break up. The shoreline was near the present eastern border of California. What would become our West Coast states were sediments and islands scattered in the ocean to the west.

North America began to move westward as it was rifted apart from Pangaea. A subduction zone appeared in front of the moving continent. As the ocean floor dove under the westward-moving continent, these sediments, islands and even pieces of ocean floor became permanently attached to the continent. Our western shore grew in this way, forming the shape that we see today.

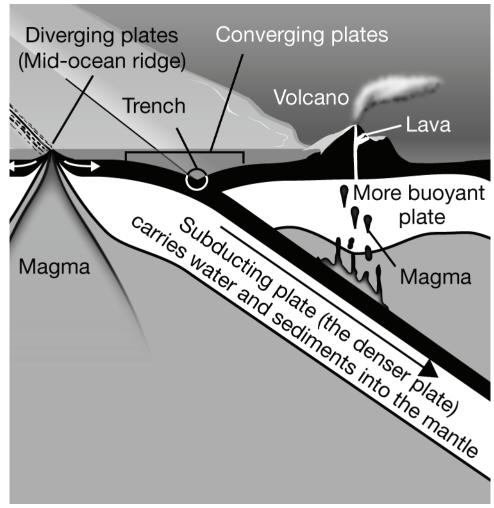


The modern Rocky Mountains

The mid-ocean ridge that was forming the subducting ocean plate was not too far away to the west. As the plate subducted, the mid-ocean ridge got closer and closer to the edge of the continent. This changed the way that the plate subducted. The result was that stronger push pressure caused the continent to buckle well back from its edge. In this way, the modern Rocky Mountains were formed near the remains of the Ancestral Rocky Mountains.

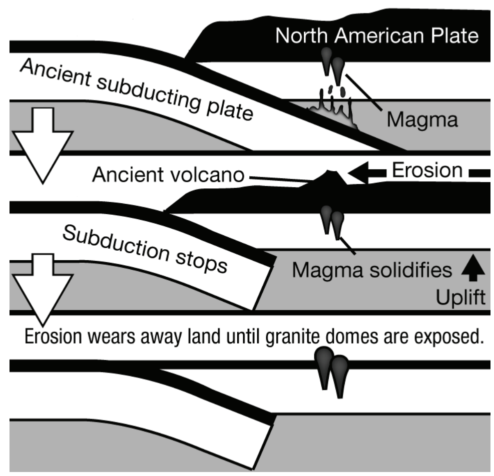
Inland volcanoes

The subducting plate also caused volcanoes to form and erupt inland. These eruptions produced the Sierra Nevada Mountains to the south and High Cascades to the north.



A small plate disappears

The plate that had been subducting along the southern West Coast was small. Eventually it disappeared when its mid-ocean ridge was subducted. This changed the western edge of the United States from a converging boundary to a transform boundary. Now instead of one plate diving under another, the remaining Pacific Plate slides by the West Coast. Today this slide-by motion is well known as the San Andreas Fault.



When subduction stopped along the lower West Coast, the Sierra volcanoes became extinct. Magma cooled and solidified below the surface. Today this cooled magma is exposed as the domes of Yosemite National Park. Further north, the Pacific Plate is still subducting under the West Coast. That subduction continues to drive the volcanoes of the High Cascades.

The United States today

In geologic terms, the East Coast is quiet and the West Coast is active. The contiguous United States are part of the North American Plate. The active eastern boundary of the plate lies in the middle of the Atlantic Ocean, far from our East Coast. But the active western boundary is also our western shore. The San Andreas Fault slowly moves slivers of California northward. Baja California will eventually be attached to San Diego. Map makers won't have to redraw New England, but they will have to watch for West Coast changes. The good news is that they'll have plenty of time to make those changes.