Continental Puzzle: Exploring Pangaea and Continental Drift

By Alyssa Dehn

Grade Level: 6

Benchmarks: **NGSS**

MS.History of Earth

MS-ESS2-3: Analyze and interpret data on the distribution of fossils and rocks, continental shapes, and seafloor structures to provide evidence of the past plate motions.

Objectives:

- The students will be able to use electronic tools to explore the history of Earth's surface.
- The students will be able to identify the evidence for continental drift and locate them on a map
- The students will begin exploring movement of plate tectonics and seafloor spreading
- The students will be able to calculate the rate of continental movement.

Materials and Setup:

- Large, white sheet of construction paper
- Scissors for each student
- 9" x 12" construction paper for each student
- Glue sticks
- Markers
- One computer per student
    - Google Earth application
    - Download kml file Investigation. 1 Continental Drift V2 120907
- One shoebox
- Paper
- Calculator per student
- Ruler with millimeters per student
- Tape measure or meter stick

Safety:

None

Requisite Knowledge/skills for students:

Scientific method

Some knowledge of plate tectonics

Some knowledge of the layers of the Earth

Geography- names of continents

Some experience with Google Earth

Multiplying

Dividing

Procedure

Engage: (15 mins)

- Before focusing on the continents of the world, I created a fake world, or 'candy land', to allow the student's to come up with their own pieces of evidence for a hypothesis.
- For my candy land I divided a large piece of white construction paper into 6 pieces. I added several features that went across a few of the continents, such as candy canes, chocolate kiss mountains, fossilized gum drops, and chocolate and caramel deposits. I added individual features to each continent because not all of earth's continents are the same, including a continent with Sour Patch kids or another with York patties. After drawing and coloring the features I cut out the six pieces, ready to be handed out to 6 groups of students to fit the pieces together. The students will first observe their piece of the world and then compare it with their neighbors to see if theres any similarities. They will begin to notice some of the pieces fit together or have matching characteristics.

- Key

    Left picture:
    - Light brown portion = caramel deposit
    - Plant like drawings= fossilized laffy taffy
    - Cherries= clues of colder environment because they are associated with sundaes like in the york continent
    - Colorful circles = fossilized gumdrops

    Right picture:
    - Dark brown portion = chocolate deposit
    - Chocolate kisses = "Kiss Mountains"
    - Red tubes = twizzlers
    - Lollipops on far right

The students can come up with their own key together as a class after fitting all of the pieces together.
The teacher will inquire the class on how they decided which pieces fit together by asking each group questions such as:

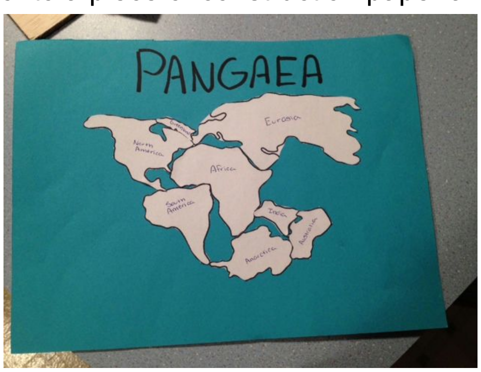
- “What features on your continent were similar to another group’s?”
- “What was different about your continent compared to others?”
- “What do you notice about the cherries? Why are some cherries on top of ice cream while other’s are not? (Think climate)”

Other questions to trigger inquiry:

- “What hypothesis could you propose about our candy world?”
- “Would you have supporting evidence for this hypothesis?”
- “Could this world be compared to our world? Puzzle like continents and features that may line up.”

The teacher can then begin introducing Alfred Wegener and tell the students he believed the continents were like a torn up piece of newspaper: you can line up the edges so that the words line up perfectly.

Explore:

1. The teacher will inform the students that one of the first things Wegner noticed about the continents was that they almost fit together like puzzle pieces. She/he will ask the students to look at a world map and ask if they see any continents that might fit together. Using the continental cutouts, the students will try to fit the continents together like a puzzle. The teacher should let the students know that they won’t fit together exactly and ask why this might be.
   After cutting out the continents and fitting them together, the students can glue them onto a piece of construction paper and use for the next activity. (15 minutes)
   

   After completing their continental puzzle and before moving on to the next activity, the teacher should explain that what they created is a supercontinent called Pangaea.

2. Students will be using Google Earth to go on a software led exploration of the evidence that supports the theory of continental drift.

   Teacher Prep for Google Earth exploration:

1. Go to www.spatialsci.com/ce3
2. Click on “Module 3 Plate Tectonics” to the right under “Featured Content”
3. Under Investigation 1: Continental Drift download first item on the list, *Continental Drift* Google Earth file

4. Go to Google Earth application and you should be able to find the file under “Places” on the left - double click it.
5. Double click the folder icon below and it will show four different folders for each set of evidence that the students will go through themselves.

- Using the Pangaea Exploration Field Journal, the students will record their observations as they go through each step. The students can also mark their findings on their continental cutouts using different symbols for each piece of evidence, keeping track of their symbols in a key.
- As the students are working, the teacher should walk around and ask the students questions about what evidence they are finding, what supports the evidence, and how that evidence may support continental drift. More in-depth questions can be asked during the explanation. (25-30 minutes)

Explain: (40 mins)
When the students are finished, the teacher will break up the class into 6 different groups: 2 groups will discuss the geographic evidence, 2 other groups will focus on the fossil evidence, and the last two groups will discuss the rock evidence.

Each group will present what they found with their piece of evidence using a map or their continental cutouts to explain their information. The teacher can use the slide show provided to help guide the discussion.

The teacher could also provide a dry-erase map on a projector or a blank world map underneath a document camera that the students could use to present their findings for the whole class to see.
Questions the teacher can ask for each group and the class as a whole:

- *Geographic Evidence*
  - She/he can ask each group to point out two different continental connections. Ask why the continents match up. They should say something about how the edges aligned.
  - “Which two continents seem to match up the best?”
  - “Why don’t all of the continents perfectly connect like a puzzle?”
- *Fossil Evidence*
  - She/he can have one group describe 2 of the fossils and the other group will describe the other two fossils. They can mark them on the map using different colored dry-erase markers or a letter/symbol.
  - “Today, do you see the same kinds of organisms on each continent?”
  - “Could the organisms have traveled across the oceans to get to each continent?”
  - “Which organism is most likely to swim across the ocean?” ; “Do you think they could’ve swam that far?”; “How far is the distance between South America and Africa?” (Referring to their measurement of the yellow line)
  - “Could the *Lystrosaurus* swim that far? Why not? What about the *Cynognathus*?”

- ○ “Which fossil is not an animal? Could that species travel across the oceans?”
- *Rock Evidence*
  - ○ One group can discuss one of the mountain ranges such as the Andes and Antartandes while the other group discusses the Appalachians and Northern European/Greenland mountain ranges.
  - ○ “Why do these mountain ranges match up? What evidence supports the matching mountain ranges?” (Rock type and ages of formation).

Once all of the groups have shared their information, the teacher will inform the students that the only problem with Wegener’s hypothesis was that there was a lack of mechanism. He did not know why the continents were moving.

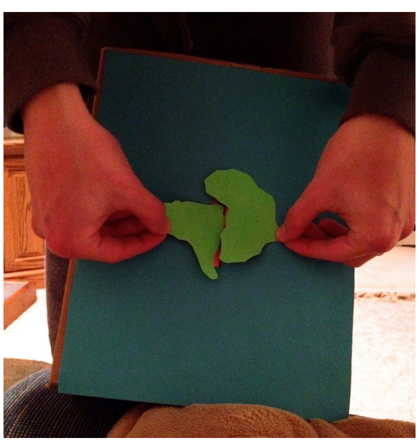
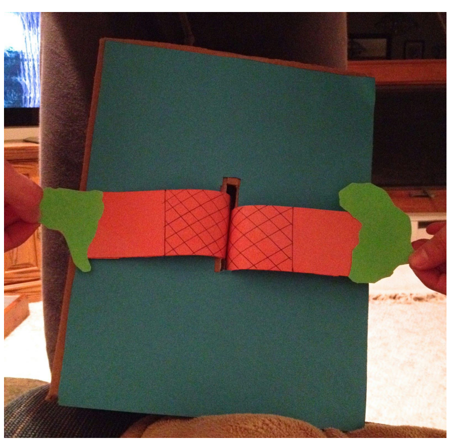
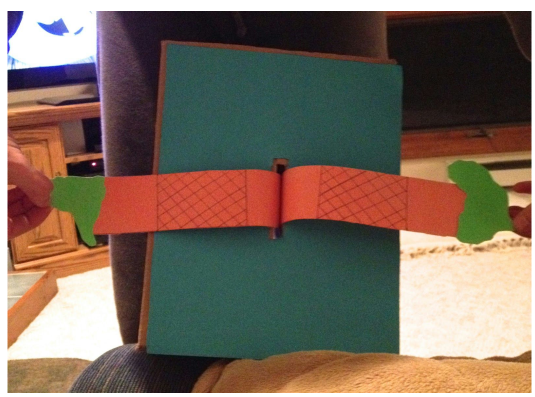
The teacher can begin discussing the causes of continental drift. She/he can first inquire what the students may think using their prior knowledge about plate tectonics.

- “What are plate tectonics?”
- “How can we identify them on a map?” (Trenches and ridges - surrounding continents)
- “What part of the Earth do plates make up?” (Crust and uppermost mantle)

Background information for the sea-floor spreading can be found in the slide-show.
https://docs.google.com/presentation/d/1W73yR4aQHbPs0B3zoIWGBy0Z0oYCRFctCyac_838BGc/edit?usp=sharing
A demonstration of seafloor spreading created by me is included:

Demonstration:

- Using a shoebox or a small box, cut a slit on the bottom down the middle about 3 inches long.
- Cut two strips of paper, the same width as the slit and about a foot long each. It is suggested to use orange, red, or yellow paper to represent magma.
- On one end of each strip of paper you can draw a landmass or cutout landmasses to glue on. For example, for the left strip I put South America and Africa on the right strip.
- About an inch and a half from each landmass draw a 3 inch block of crossing lines to represent new land.

Q&A for demonstration:

- "The slit in the middle represents what?" (The mid-ocean ridge)
- "What happens as more ocean floor is produced?" (The continents move farther apart)
- "Where on the strips is the seafloor youngest? Oldest?" (youngest = closer to the MOR; oldest = farthest from the MOR)
- "What might the crossing lines represent?" (New seafloor or a reverse in polarity)
- "Even though this demonstration does not show it, where does the old sea floor go?" (Subduction zones)

Elaborate: (30 min) (Interdisciplinary Component - Mathematics)

1. A 2 minute PBS video can be shown that explains further evidence for continental drift and plate tectonics: http://www.pbslearningmedia.org/resource/ess05.sci.ess.earthsys.wegener2/plate-tectonics-further-evidence/

2. After reviewing sea floor spreading, the students will extend their understanding about continental drift by calculating the rate at which the plates are still moving.

   The teacher will tell the class that the plates move at a rate of 2 cm/year minimum and 6 cm/year maximum. The teacher can ask the students to show how far that is using their hands. This equation can be written on the board: rate of spreading = distance seafloor moved/length of time or R=d/t. It is generally expressed as cm/year.

   The corresponding worksheet is based on a handout created by another teacher, Mrs. Chamberlain of Piedmont High School in California. This worksheet was made simpler for 6th grade level learners and the students will not only find the rate of ocean floor spreading, but also find the amount of time given the rate of movement and distance moved. They will also find the distance when given the amount of time and rate of movement.

   To begin, the teacher can demonstrate how to do the first question and then let the class work together for the rest of the worksheet.

3. The student's can also demonstrate seafloor spreading rate in the classroom. With one student representing a continent, such as South America, and another representing Africa, they can start out standing close together.

   The teacher will tell the students the continents are moving apart at 2 cm per year. It will be important to have a large space to do this such as a hallway. The teacher will give a certain number of years and the students will figure out how far the continents have moved after that many of years using a ruler, meter stick, or measuring tape.

For example, if 10 years has gone by, the continents have moved 20 cm each in the opposite direction. The teacher could give the years in multiples of 10.

Questions:

- “What is causing the continents to move apart?” (Oceanic ridge) “What is happening here?” (Magma is pushed up to ocean floor and spreads old ocean floor apart)
- “Where is the seafloor youngest? Oldest?”
- “Where is the old seafloor going?”

Evaluate

To assess the students’ understanding the teacher can grade the field journal, evaluate their understanding from the presentations and ask individual students questions, and grade the rate of continental movement worksheet.

Scientific Background for the Teacher

Continental Drift Hypothesis proposed by Alfred Wegener (pronounced “veg-ner”) in 1915. He was a German meteorologist and geophysicist. Published his book *The Origin of Continents and Oceans.*

- Hypothesis that a single continent, or supercontinent, called Pangaea (meaning all Earth) once existed.
- During Mesozoic era, about 200 mya, Pangaea began to break apart into small continents and “drifted” to their present positions.
- Evidence that continents fit together like puzzle pieces (such as South America and Africa), the distribution of similar fossils across the continents, similar mountain ranges, and ancient climates support the hypothesis.
- Wegener’s hypothesis was rejected due to his inability to identify a mechanism that was capable of moving the continents across the globe.

Review slideshow printout for more information

References

Idea for engage activity:
http://www.madsciencelessons.com/2014/02/12/pangaea-project/

Rate of plate movement worksheet:
http://www.mrschamberlain.com/Geology/rate%20of%20sea%20floor%20spreading.pdf

Earth: An Introduction to Physical Geology by Tarbuck and Lutgens, pg. 37-69

Animation of magnetic reversal and seafloor spreading in slide show:
http://www.bioygeo.info/Animaciones/SeafloorMagnet.swf

Continents Adrift and Continents Aground, A. Hallam and J.R. Heirtzler pg. 3-17 and 76-86

Google Earth Exploration:
“Cyber-Enabled Earth Exploration” from the University of Montana
http://www.spatialsci.com/ce3/index.php/sID/cfbd33ab/fuseaction/curriculum.cms.htm
“Field Notebook Module 3: Introduction to Plate Tectonics”
http://www.spatialsci.com/files/documents/Version%202/Plate%20Tectonics/FieldNotebook_Mod3Inv1_V2_120907.pdf

Pangea Cutouts

Name:

Pangaea Exploration Field Journal

You are a scientist that explores the world looking for evidence to support a hypothesis that the continents were once a supercontinent. Meteorologist Alfred Wegener came up with this hypothesis in 1915 and proposed the name Pangaea meaning “all earth” in Latin for the name of this supercontinent. Was his hypothesis true? Observe the different types of evidence to find out! **As you go along mark your discoveries on your continental cutouts poster. This will help keep track of each piece of evidence. Remember to include a key/legend for your symbols.**

After the teacher instructs you to open Google Earth and the Investigation 1: Continental Drift file, read the Introduction.

1. What do you expect to learn or discover on this journey?

Geographic Evidence

Click on the circle next to folder 1: Geographic Evidence. Read the description for background information.

2. How does this compare with your continental cutouts?

3. What do you think separated the continents? Write your hypothesis.

Double-click “South America - Africa” underneath the description.

4. What do you think the orange line represents? (Hint: study the edges of the continents.)

Using the ruler tool, measure the length of the orange line. Remember to show your units!

Length: ________________

Scan the globe. Do you see any other places besides South America and Africa where the continents seem to fit together. Write them below (Ex. South America-Africa):

5. Does this evidence support Ortelius' hypothesis from the description? How so?

6. Can you say for sure that the continents were once connected based on this evidence alone? Why or why not?

Fossil Evidence

You are now a Paleontologist studying fossils at different locations around the globe. You notice something funny about your fossil discoveries. Click on the circle next to Folder 2: Fossil Evidence and read the description to find out.

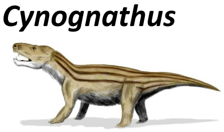
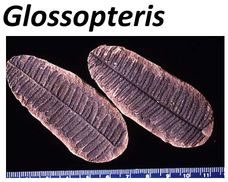
7. Based on the description, do you think you'll find a Mesosaurus fossil in just one continent or multiple?

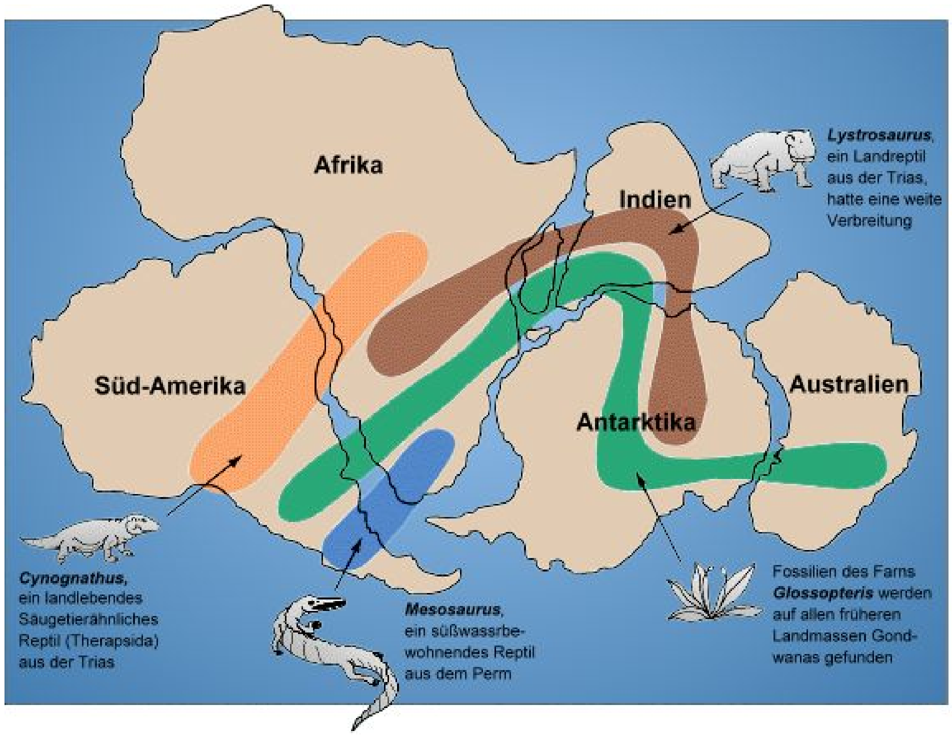
Click the circle for "Fossil Finds." Rotate around the world to see where each of the 4 fossils have been found. Use the legend and your path tool to make at *least* 3 lines connecting different continents that share a similar fossil. Mark them in the table below:

Location	Fossil

8. How do you think the organisms ended up on different continents? Could they swim or fly? What about the plants? Write your hypothesis

After clicking on “Research” you can begin exploring the 4 different fossil types and record your observations in the table.

Name	Age/Era	Type of Organism	Habitat	Place of Discovery
Mesosaurus 				
Lystrosaurus 				
Cynognathus 				
Glossopteris 				



9. After researching the 4 organisms, what can you conclude about their ability to travel from one continent to another? Does this support your hypothesis?

10. What is odd about the *Glossopteris'* location in Antarctica? What does this suggest?.

Rock Evidence

You are now a geologist studying rocks around the world at four different mountain ranges. You begin to notice similarities between the rocks at each one. Click on the the circle next to folder 3: Rock Evidence to find out what those similarities are. First read the description and answer the questions below.

11. When were the Andes Mountain Range formed?

12. What mountain range does it match up with? What evidence supports this?

13. What other two mountain ranges match up with each other?

14. How long ago did these mountain ranges form?

Click on the circle next to “Mountain Ranges” to see their locations. Create paths that connect the similar mountain ranges.

15. How many connections did you find? Can you name two different locations besides the two listed above? Ex. South America - Antarctica counts as one connection.

Investigation Summary

16. Which type of evidence is stronger? Geographic fit or fossil evidence? Explain your reasoning.

17. Based on your geographic observations, which two continents have the strongest evidence for a former connection?

18. Do you think the continents are still moving today? Explain.

19. After researching each piece of evidence, do any of your hypotheses need to be changed?

20. During this exploration, did we discover any evidence that explains what caused the continents to break apart?

Name: Answer Key

Pangaea Exploration Field Journal

You are a scientist that explores the world looking for evidence to support a hypothesis that the continents were once a supercontinent. Meteorologist Alfred Wegener came up with this hypothesis in 1915 and proposed the name Pangaea meaning “all earth” in Latin for the name of this supercontinent. Was his hypothesis true? Observe the different types of evidence to find out! **As you go along mark your discoveries on your continental cutouts poster. This will help keep track of each piece of evidence. Remember to include a key/legend for your symbols.**

After the teacher instructs you to open Google Earth and the Investigation 1: Continental Drift file, read the Introduction.

1. What do you expect to learn or discover on this journey?
   The evidence for continental drift

Geographic Evidence

Click on the circle next to folder 1: Geographic Evidence. Read the description for background information.

2. How does this compare with your continental cutouts?
   The edges of the continents lined up together
3. What do you think separated the continents? Write your hypothesis.

Double-click “South America - Africa” underneath the description.

4. What do you think the orange line represents? (Hint: study the edges of the continents.)

Using the ruler tool, measure the length of the orange line. Remember to show your units!

Length: __about 3,385 miles___

Scan the globe. Do you see any other places besides South America and Africa where the continents seem to fit together. Write them below (Ex. South America-Africa):

Madagascar - East Africa
India - East Africa
Saudi Arabia - Northeast Africa
Europe - Northern Africa
North America - Europe
East North America - Northwest Africa
Australia - Antarctica

6. Can you say for sure that the continents were once connected based on this evidence alone? Why or why not?

   No, because it could just be coincidence that that is how they are shaped

Fossil Evidence

You are now a Paleontologist studying fossils at different locations around the globe. You notice something funny about your fossil discoveries. Click on the circle next to Folder 2: Fossil Evidence and read the description to find out.

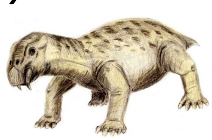
7. Based on the description, do you think you'll find a Mesosaurus fossil in just one continent or multiple?

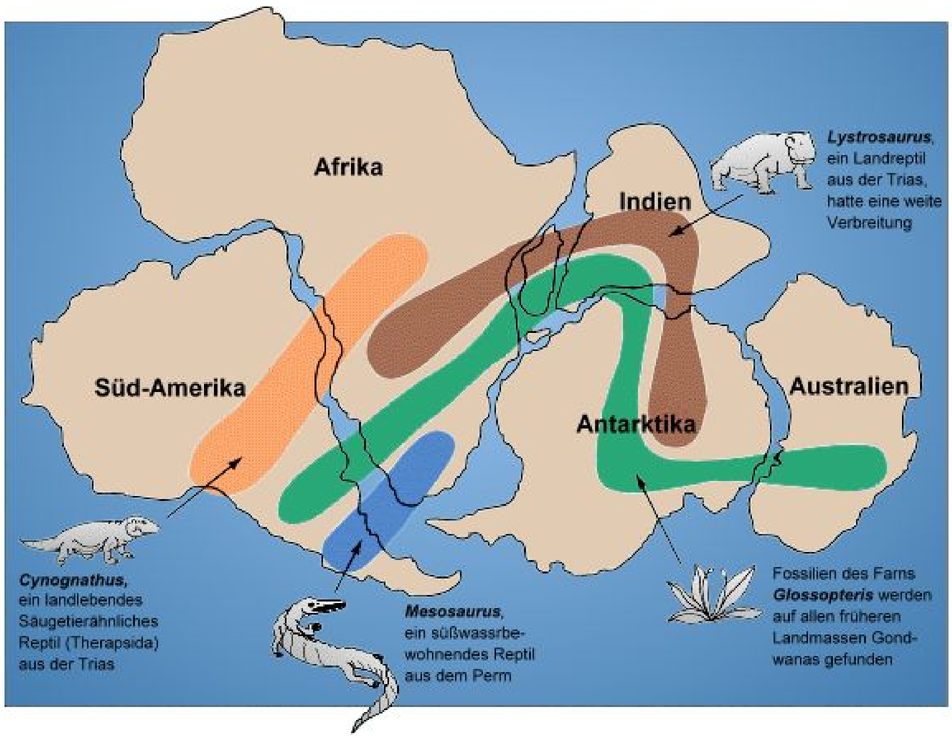
Click the circle for "Fossil Finds." Rotate around the world to see where each of the 4 fossils have been found. Use the legend and your path tool to make at *least* 3 lines connecting different continents that share a similar fossil. Mark them in the table below:

Location	Fossil
South Africa - Antarctica	Lystrosaurus
South America - Africa	Mesosaurus
South America - Africa	Cynognathus
India - Australia	Glossopteris

8. How do you think the organisms ended up on different continents? Could they swim or fly? What about the plants? Write your hypothesis.

After clicking on “Research” you can begin exploring the 4 different fossil types and record your observations in the table.

Name	Age/Era	Type of Organism	Habitat	Place of Discovery
Mesosaurus 	Early Permian 299-250 ma	Reptile	Marine	Africa and S. America
Lystrosaurus 	Late Permian- Middle Triassic 250ma	Therapsid (mammal -like) Herbivorous	Terrestrial	Antarctica India South Africa
Cynognathus 	Early and Middle Triassic 247-237Ma	Therapsid predator	Terrestrial	South Africa, South America, China, Antarctica
Glossopteris 	Permian 298.9 Ma	Plant - gymnosperm	Terrestrial - tropical	Southern Hemisphere continents



9. After researching the 4 organisms, what can you conclude about their ability to travel from one continent to another? Does this support your hypothesis?

Mesosaurus was a marine organism but he could not have swam that far

The Lystrosaurus was primarily terrestrial, as was the Cynognathus.

Glossopteris was a plant, so unless the wind carried it all the way across the oceans, the plant could not have traveled from continent to continent.

10. What is odd about the *Glossopteris'* location in Antarctica? What does this suggest?.

The Glossopteris is a tropical plant, but fossils of it have been found in a very non-tropical and arctic location. This suggests that Antarctica used to have a warmer climate.

Rock Evidence

You are now a geologist studying rocks around the world at four different mountain ranges. You begin to notice similarities between the rocks at each one. Click on the the circle next to folder 3: Rock Evidence to find out what those similarities are. First read the description and answer the questions below.

11. When were the Andes Mountain Range formed?

    80 - 60 Ma; Late Cretaceous and early Tertiary

12. What mountain range does it match up with? What evidence supports this?

    Antartandes of Antarctica because they contain the same rocks.

13. What other two mountain ranges match up with each other?

    Kjolen Mountains in Norway and the Appalachians of Eastern United States

14. How long ago did these mountain ranges form?

    490 - 390 Ma; Ordovician and early Devonian

Click on the circle next to "Mountain Ranges" to see their locations. Create paths that connect the similar mountain ranges.

15. How many connections did you find? Can you name two different locations besides the two listed above? Ex. South America - Antarctica counts as one connection.

    North America - Greenland

    Greenland - Norway

    Greenland - Great Britain

    North America - Northern Europe

Investigation Summary

16. Which type of evidence is stronger? Explain your reasoning.

17. Based on your geographic observations, which two continents have the strongest evidence for a former connection?

    South America and Africa

18. Do you think the continents are still moving today? Explain.

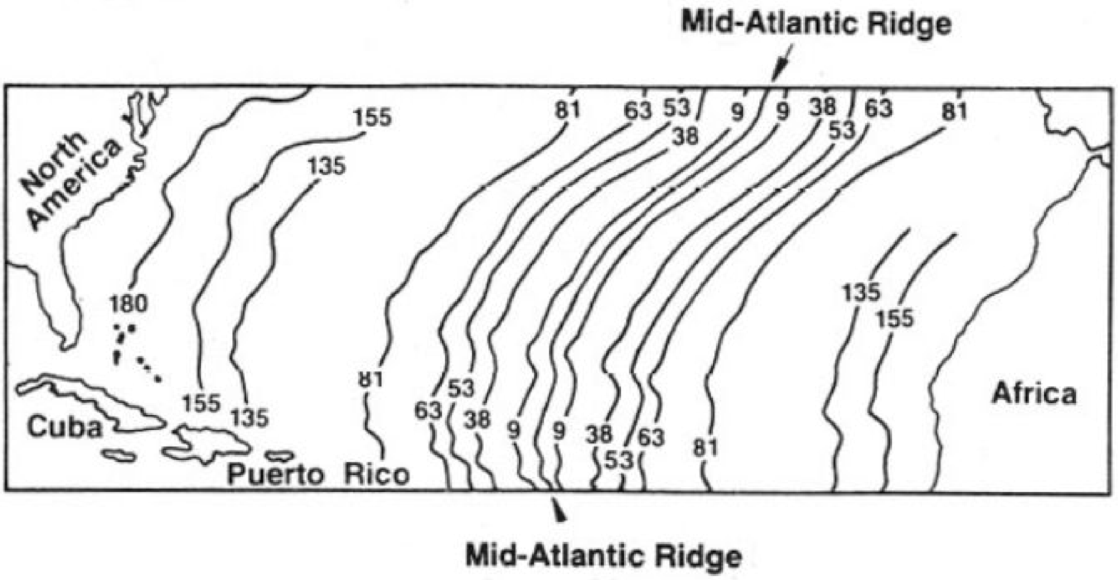
19. After researching each piece of evidence, did any of your hypotheses need to be changed?

20. During this exploration, did we discover any evidence that explains what caused the continents to break apart?

    No, we did not discover how the continents moved apart.

Name:

Are the Continents Still Moving?



The numbers on each line represent the age in millions of years. 1 mm on this map = 65 km. There are 100,000 cm in one km. Use the following equation and round to the nearest tenth:

Rate of Spreading (cm/yr) = distance the sea floor moved (cm) / length of time (years)
or R=d/t

1. How far has the seafloor moved for the line labeled 81 million years? Measure the distance from the Mid-Atlantic Ridge to that line in mm. (1cm = 10 mm)

   What is the rate of movement of that line?

2. Find the rate of movement for 3 more lines and calculate the average out of all 4

Age	Distance (mm)	Distance (km)	Distance (cm)	Rate

Average for the 4 rates:

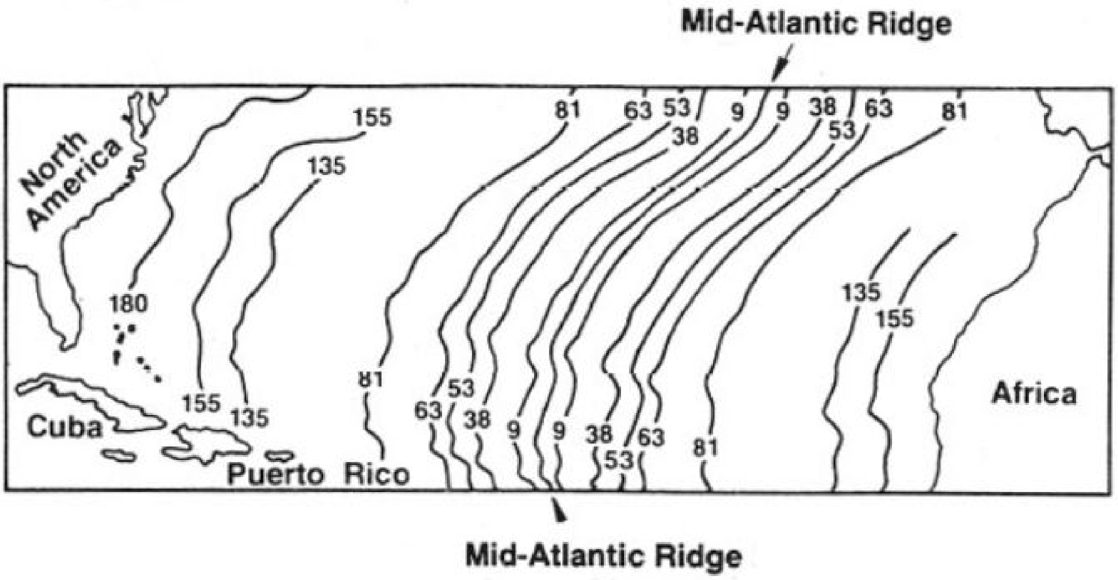
3. The Hawaii chain of islands is about 65 million years old. If they move at an average rate of 9 cm/year, how far have they moved from the hotspot within the mantle?

   Why do you think these islands are moving at a much faster rate?

4. North America is moving relative to Europe at a rate of about 2 centimeters per year. The distance off the coast of North America to a part of the Mid-Atlantic Ridge is about 2,872 km. Using this information, roughly how long ago was North America connected to Europe?

Name: Answer Key

Are the Continents Still Moving?



The numbers on each line represent the age in millions of years. 1 mm on this map = 65 km. There are 100,000 cm in one km. Use the following equation and round to the nearest tenth:

Rate of Spreading (cm/yr) = distance the sea floor moved (cm) / length of time (years)

or R=d/t

1. How far has the seafloor moved for the line labeled 81 million years? Measure the distance from the Mid-Atlantic Ridge to that line in mm. (1cm = 10 mm)

   20mm x 65= 1,300 km

   1,300 km x 100,000 = 130,000,000 cm

   What is the rate of movement of that line?

   R = 130,000,000 cm/81,000,000 years

   R= 1.6 cm/year

2. Find the rate of movement for 3 more lines and calculate the average out of all 4

Age	Distance (mm)	Distance (km)	Distance (cm)	Rate

Average for the 4 rates:

3. The Hawaii chain of islands is about 65 million years old. If they move at an average rate of 9 cm/year, how far have they moved from the hotspot within the mantle?

9cm/year = d / 27,000,000 years

27,000,000 x 9 = d x 27,000,000 / 27,000,000

d = 243,000,000 cm

Why do you think these islands are moving at a much faster rate?

4. North America is moving relative to Europe at a rate of about 2 centimeters per year. The distance off the coast of North America to a part of the Mid-Atlantic Ridge is about 2,872 km. Using this information, roughly how long ago was North America connected to Europe?

2,872 km x 100,000 = 287,200,000 cm

2 cm/year = 287,200,000 cm / t

t x 2 = t x 287,200,000/t

t = 287,200,000 / 2

t = 143,600,000 years ago