AmplifyScience

Plate Motion:

Mystery of the Mesosaurus Fossils

Investigation Notebook with Article Compilation

These materials are based upon work partially supported by the National Science Foundation under grant numbers DRL-1119584, DRL-1417939, ESI-0242733, ESI-0628272, ESI-0822119. The Federal Government has certain rights in this material. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation.

These materials are based upon work partially supported by the Institute of Education Sciences, U.S. Department of Education, through Grant R305A130610 to The Regents of the University of California. The opinions expressed are those of the authors and do not represent views of the Institute or the U.S. Department of Education.

Developed by the Learning Design Group at the University of California, Berkeley's Lawrence Hall of Science.

Amplify Science Elementary is based on the *Seeds of Science/Roots of Reading*® approach, which is a collaboration between a science team led by Jacqueline Barber and a literacy team led by P. David Pearson.

www.scienceandliteracy.org

Amplify.
55 Washington Street, Suite 800
Brooklyn, NY 11201
1-800-823-1969
www.amplify.com

Plate Motion: Mystery of the Mesosaurus *Fossils*
ISBN: 978-1-64089-867-7
AMP.NA18

Plate Motion:

Mystery of the Mesosaurus Fossils

Investigation Notebook

Table of Contents

Table of Contents (continued)

Table of Contents (continued)

Safety Guidelines for Science Investigations

1. **Follow instructions.** Listen carefully to your teacher's instructions. Ask questions if you don't know what to do.

2. **Don't taste things.** No tasting anything or putting it near your mouth unless your teacher says it is safe to do so.

3. **Smell substances like a chemist.** When you smell a substance, don't put your nose near it. Instead, gently move the air from above the substance to your nose. This is how chemists smell substances.

4. **Protect your eyes.** Wear safety goggles if something wet could splash into your eyes, if powder or dust might get in your eyes, or if something sharp could fly into your eyes.

5. **Protect your hands.** Wear gloves if you are working with materials or chemicals that could irritate your skin.

6. **Keep your hands away from your face.** Do not touch your face, mouth, ears, eyes, or nose while working with chemicals, plants, or animals.

7. **Tell your teacher if you have allergies.** This will keep you safe and comfortable during science class.

8. **Be calm and careful.** Move carefully and slowly around the classroom. Save your outdoor behavior for recess.

9. **Report all spills, accidents, and injuries to your teacher.** Tell your teacher if something spills, if there is an accident, or if someone gets injured.

10. **Avoid anything that could cause a burn.** Allow your teacher to work with hot water or hot equipment.

11. **Wash your hands after class.** Make sure to wash your hands thoroughly with soap and water after handling plants, animals, or science materials.

Name: ______________________________ Date: ____________________

Plate Motion: Mystery of the Mesosaurus *Fossils*
Unit Overview

Millions of years ago, a swamp-dwelling lizard lived on Earth. Known as *Mesosaurus,* this meter-long creature could not swim long distances. Today, *Mesosaurus* fossils have been discovered in South America and in Africa, almost 4,000 kilometers apart and separated by an ocean. You are a student geologist working as a consultant for a museum in Namibia. The museum is creating an exhibit about the *Mesosaurus* fossils found in southwestern Africa. You've been called in to investigate the land where these fossils have been found in order to solve the mystery of how the *Mesosaurus* fossils got so far away from each other. You'll need to consider volcanoes, earthquakes, and the rock that lies deep below Earth's surface in order to piece together as much of the story as you can.

Name: ______________________ Date: ______________

Chapter 1: Introducing Earth's Outer Layer
Chapter Overview

Mesosaurus are extinct organisms that did not swim long distances, and yet *Mesosaurus* fossils are found embedded in rock in South America and Africa—two continents separated by the Atlantic Ocean. What is the land like where *Mesosaurus* fossils are found? How can understanding more about Earth also help explain how these fossils got to be so far apart? You will start your investigation by exploring Earth's surface, looking for patterns of geologic activity that hint at what is happening to Earth's outer layer. This investigation will help you understand the characteristics of Earth's outer layer and how the outer layer moves.

Name: ______________________________ Date: ____________________

Lesson 1.2: Using Fossils to Understand Earth

What do fossils have to do with understanding the history of Earth? Surprisingly, geologists actually use the fossils that they find embedded in rock to help them make sense of our planet's long history. Today, you will watch a video that will help to explain how fossil evidence can help scientists learn about the history of Earth. You'll also meet Dr. Bayard Moraga, the lead curator at the Museum of West Namibia, who has an exciting geologic mystery for you to solve. You'll begin your work as a student geologist by learning more about what is underneath Earth's surface.

Unit Question

- Why are fossils of species that once lived together found in different locations on Earth now?

Chapter 1 Question

- What is the land like where *Mesosaurus* fossils are found?

Vocabulary

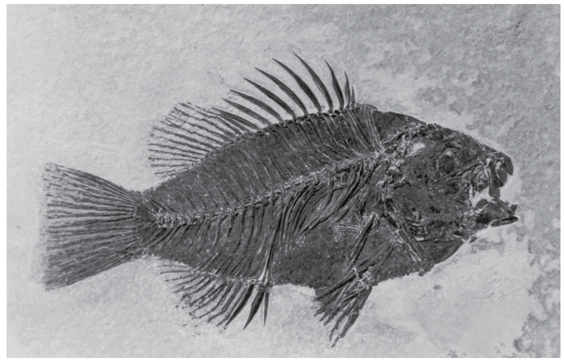
- cross section
- outer layer

Name: ______________________ Date: ______________

Warm-Up

Scientists look for fossils in rock all over the world. Fossils such as fossilized bones, footprints, or leaf prints are evidence of life from the past.

Scientist in the field, working to uncover a fossil



Sunfish fossil found in Wyoming, USA

Leaf of an extinct fern found in Antarctica

What do you already know about fossils? Describe as much as you can in the space below.

____

____

____

____

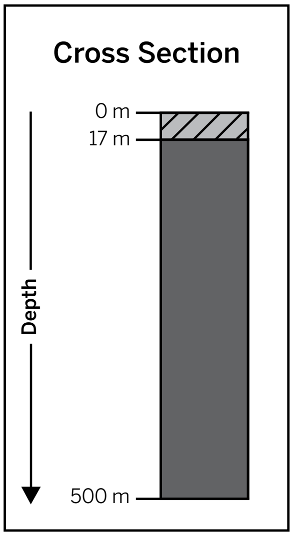
____

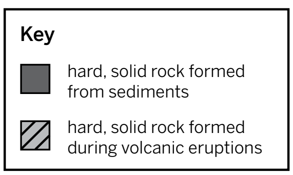
____

Name: ____________________ Date: ____________

Exploring Cross Sections

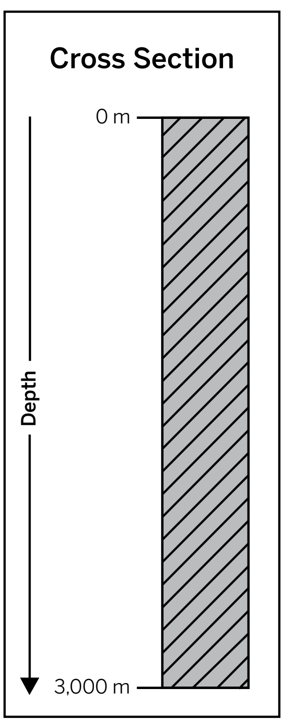
Scientific Drilling Site: Petrified Forest National Park, Arizona, USA



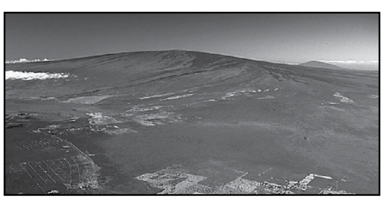


A team working on the Colorado Plateau Coring Project drilled over 500 meters into the surface of the Arizona desert. The core sample the team took revealed that underneath a very thin layer of dust and sand, the land is made of hard, solid rock. The first 17 meters of hard, solid rock was formed during volcanic eruptions. The next 483 meters was also hard, solid rock formed when sediments were cemented and compacted together at different times in geologic history.

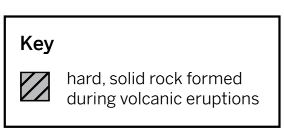
Scientific Drilling Site: Mauna Loa Volcano, Hawaii, USA

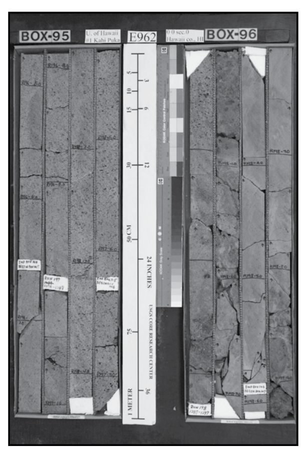


A team with the Hawaii Scientific Drilling Project drilled over 3,000 meters into the surface of the Mauna Loa Volcano. The core sample the team took revealed that underneath the surface, the volcano is made of hard, solid rock that formed when lava cooled during many different volcanic eruptions.



Mauna Loa



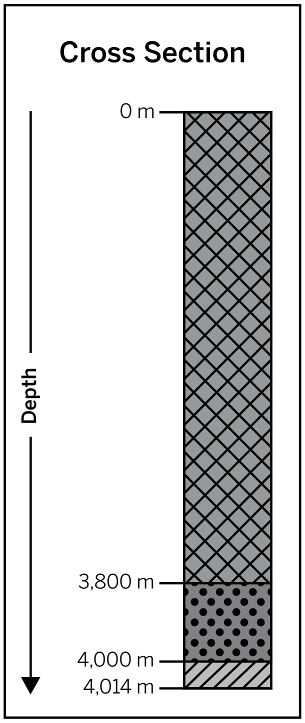


Core samples from Mauna Loa

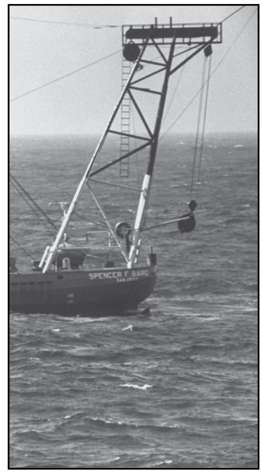
Name: ______________________ Date: ______________

Exploring Cross Sections (continued)

Scientific Drilling Site: Guadalupe Island, Mexico



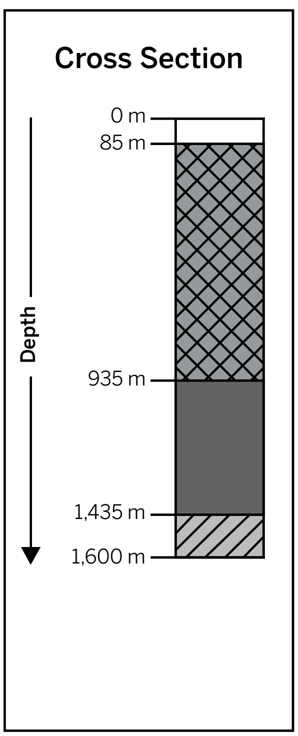
A team that worked on a scientific drilling project called Project Mohole drilled into the bottom of the ocean off the coast of Mexico. To reach the land at the bottom of the ocean, the team had to send the drill down through 3,800 meters of water. The team took a core sample of the land at the bottom of the ocean. The core sample showed that land at the bottom of the ocean is made of 200 meters of sediments such as sand and mud, and below that, there is hard, solid rock that formed during volcanic eruptions.



Key

- ocean water
- sediments such as mud and sand
- hard, solid rock formed during volcanic eruptions

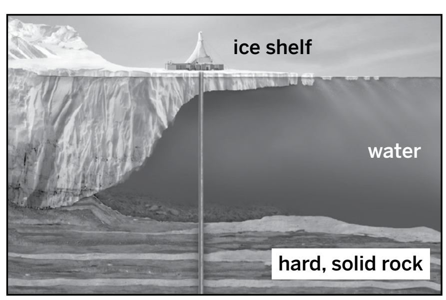
Scientific Drilling Site: Ross Ice Shelf, Antarctica



A team working on a scientific drilling project called the ANDRILL Project drilled into the surface of an ice shelf in Antarctica in order to reach the land at the bottom of the ocean below. The team had to drill through about 85 meters of surface ice, and then through 850 meters of ocean water. The team took a core sample of the land at the bottom of the ocean. This core sample is made of 500 meters of hard, solid rock that formed when sediments such as sand and mud were compacted and cemented together. Below that rock is hard, solid rock that formed during volcanic eruptions.

Key

- ice
- ocean water
- hard, solid rock formed from sediments
- hard, solid rock formed during volcanic eruptions



Name: ______________________________ Date: ____________________

Homework: Earth's Outer Layer

You have been investigating the question *What is the land like underneath Earth's surface?*

Use the map below to show your thinking about this question. Show where Earth's outer layer is made of hard, solid rock by shading those regions.

Name: ____________________ Date: ____________

Lesson 1.3: Exploring Earth's Plates

Have you ever wondered what Earth is like under the ocean water? Under the soil, trees, and buildings you see around you? In today's lesson, you will find out more about Earth's outer layer and what this rocky layer is like.

Unit Question

- Why are fossils of species that once lived together found in different locations on Earth now?

Chapter 1 Question

- What is the land like where *Mesosaurus* fossils are found?

Key Concepts

- Earth's outer layer is made of hard, solid rock.

Vocabulary

- cross section
- earthquake
- outer layer
- pattern
- plate
- plate boundary

Digital Tools

- *Plate Motion* Simulation

Name: ____________________ Date: ____________________

Warm-Up

Exploring the *Plate Motion* Simulation

Talk with your partner as you explore the *Plate Motion* Simulation. Share what you both notice.

- What did you notice about what you can change in the Sim?
- What questions do you have about the Sim?

Name: ______________________________ Date: ____________________

Exploring Earth's Outer Layer

Exploring the Cross Section of Earth's Outer Layer

In the video, you learned more about Earth's outer layer. Throughout this unit, we will be using the *Plate Motion* Sim to learn about Earth's outer layer. What does the cross section in the Sim show us about Earth's outer layer that is not visible in the Map View or in the video?

Work with your partner to do the following:

1. Open the *Plate Motion* Sim.
2. Select Region 2. Use the Add Rock tool to add continents to the map.
3. Press SET BOUNDARY to select a boundary type. You can return to Build to see what happens when you select a different boundary type after you make your observations.
4. Press RUN and observe how the Cross-Section View changes as the Sim runs. You may want to press the Reset button in the top right corner to replay the Sim.
5. As you explore the Sim, answer the discussion questions below with your partner.

Discussion Questions

- What can you see in both the Map View and the Cross-Section View?
- What can you see in the Cross-Section View that you can't see in the Map View?
- After looking at the Sim and the video, how would you describe Earth's outer layer?

Name: ______________________________ Date: ____________________

Analyzing Maps

Transparency Activity, Part 1: Plate Boundary Map

To prepare your transparency for gathering evidence about plate boundaries:

1. Place your blank transparency on top of the Plate Boundary Map and align the edges. Using the red marker, write "top" at the top of the transparency.
2. With the transparency on top of the map, use the red marker to trace the boxes around Areas A, B, C, and D. Label each Area.
3. Use the red marker to trace any plate boundary lines that are inside the boxes for Areas A, B, C, and D.

Transparency Activity, Part 2: Earthquake Map

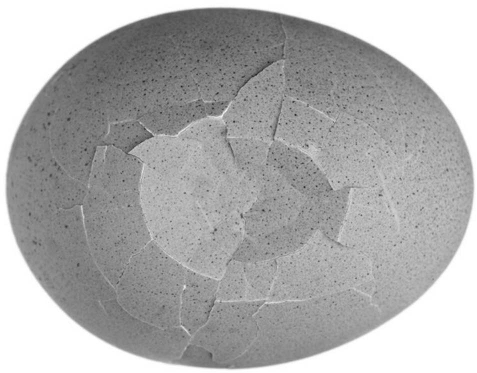
To gather evidence about earthquakes in Areas A, B, C, and D:

1. Place your transparency (with the Plate Boundary Map data you added) on top of the Earthquake Map. Make sure the top of the transparency aligns with the top of the Earthquake Map.
2. Observe what appears inside the boxes you drew for Areas A, B, C, and D. Tell your partner what you notice.
3. Use the black marker to draw a dot on your transparency for each earthquake in Areas A, B, C, and D.

Name: ______________________________ Date: ____________________

Homework: Modeling Earth's Outer Layer

Earth scientists often use models to explain different things in the natural world that are either too large or take too much time to observe. One model of Earth's outer layer is the shell of a cracked hard-boiled egg, such as the one shown in the photo below.



shell of a cracked hard-boiled egg

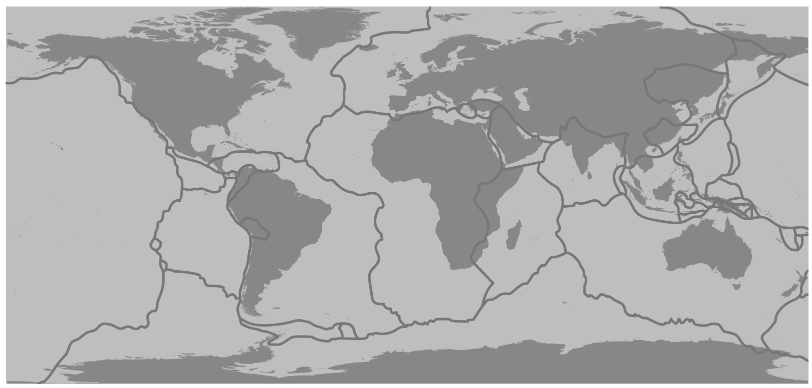


plate boundaries on Earth

How is Earth's outer layer similar to a cracked hard-boiled egg?

____

____

____

How is Earth's outer layer different from a cracked hard-boiled egg?

____

____

____

Challenge: Make another comparison.

Earth's outer layer is like ______________________________ because . . .

____

____

____

Name: ______________________ Date: ______________

Lesson 1.4: Analyzing Patterns at Plate Boundaries

How are earthquakes related to plate boundaries? Can the huge, rocky plates of Earth's outer layer actually move? Today, you will use the Sim to create some earthquakes and answer these questions!

Unit Question

- Why are fossils of species that once lived together found in different locations on Earth now?

Chapter 1 Question

- What is the land like where *Mesosaurus* fossils are found?

Key Concepts

- Earth's outer layer is made of hard, solid rock.
- Earth's outer layer is divided into sections called plates.
- Geologists look for patterns in landforms and in geologic events in order to better understand Earth.
- The plates of Earth's outer layer move.

Vocabulary

- claim
- cross section
- earthquake
- evidence
- outer layer
- pattern
- plate
- plate boundary

Digital Tools

- *Plate Motion* Simulation

Name: ______________________ Date: ______________

Warm-Up

What happens to Earth’s plates during an earthquake? (check one)

☐ **Claim 1:** Plates move, which can cause earthquakes.

☐ **Claim 2:** Earthquakes cause the plates to move.

Why did you choose this claim? Explain why you think this claim best describes what happens to Earth’s plates during an earthquake.

Name: ______________________________ Date: ________________

Simulating Earthquakes

Part 1: Earthquakes and Plate Motion

Do earthquakes cause plate motion? Or does plate motion cause earthquakes?

You and a partner will use the *Plate Motion* Sim to create earthquakes and collect evidence. Your evidence will help you to decide which of the claims is best supported:

Claim 1: Plates move, which can cause earthquakes.

Claim 2: Earthquakes cause the plates to move.

1. Open the *Plate Motion* Sim.
2. Select Region 2 of the Sim.
3. Use the Add Rock tool to create continents, and press SET BOUNDARY to select a boundary type.
4. Press RUN, and toggle on earthquakes. Make observations about when earthquakes happen.
5. Press BUILD and then press REBUILD to try a different combination of continent shapes and plate boundary types. After selecting the plate boundary type, press RUN and repeat your observations.
6. While using the Sim, refer to the information about each claim that is on the board. Discuss with your partner which claim is best supported.

Part 2: Reconsidering the Claims

Now that you've gathered evidence from the Sim, choose a claim again.

What happens to Earth's plates during an earthquake? (check one)

- ☐ **Claim 1:** Plates move, which can cause earthquakes.
- ☐ **Claim 2:** Earthquakes cause the plates to move.

Name: ______________________________ Date: ____________________

Modeling a Plate Boundary

You have been investigating the question: *What is the land like where* Mesosaurus *fossils are found?* Use the Modeling Tool activity: Modeling a Plate Boundary on the next two pages to show your thinking about this question. Follow the instructions below.

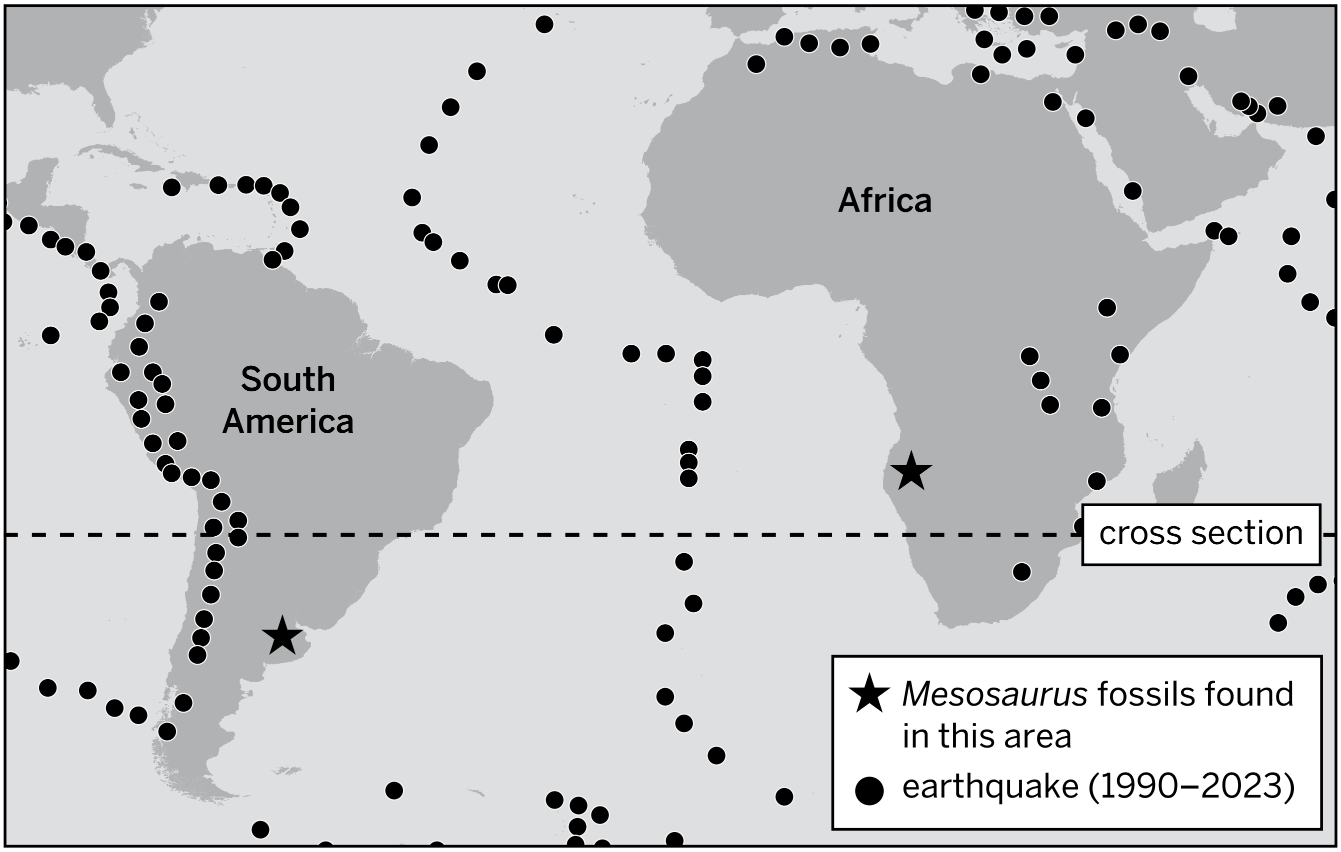
Goal: Show what the land is like where *Mesosaurus* fossils are found.

Do:

- The map below shows a pattern of earthquakes that occurred between South America and Africa. Using that pattern of earthquakes to help you, draw the most likely plate boundary between South America and Africa.
- Choose the cross section on the next page that best shows what the land is like where *Mesosaurus* fossils are found.
- Cut out the cross section you chose and glue it in the box below the map.
- In the cross section that you added below the map, draw in a line to mark the location of the plate boundary.

Name: ______________________________ Date: ________________

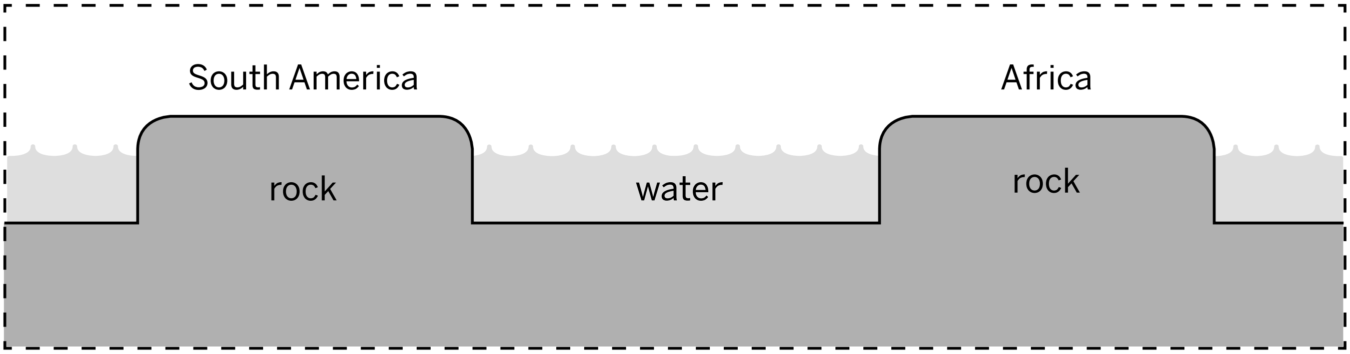
Modeling a Plate Boundary (continued)

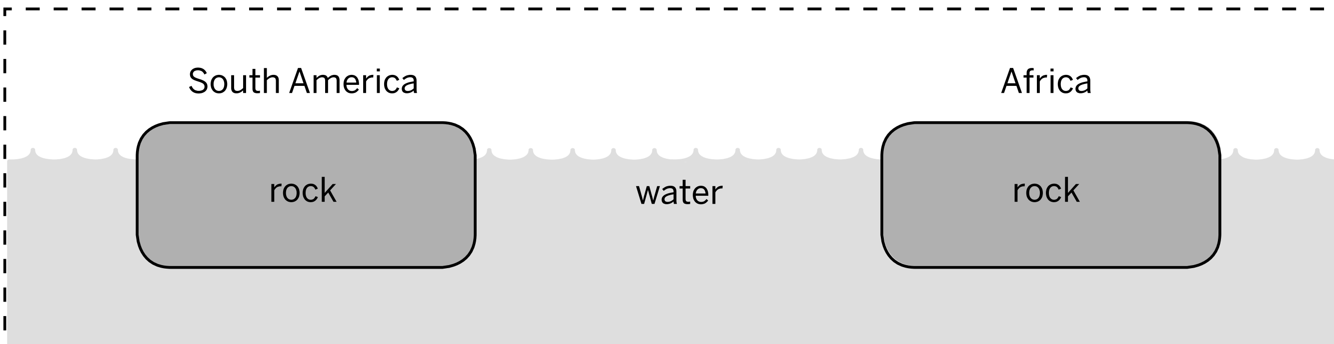


Name: ______________________________ Date: ______________

Modeling a Plate Boundary (continued)

Cross Section Options





Name: ______________________________ Date: ____________________

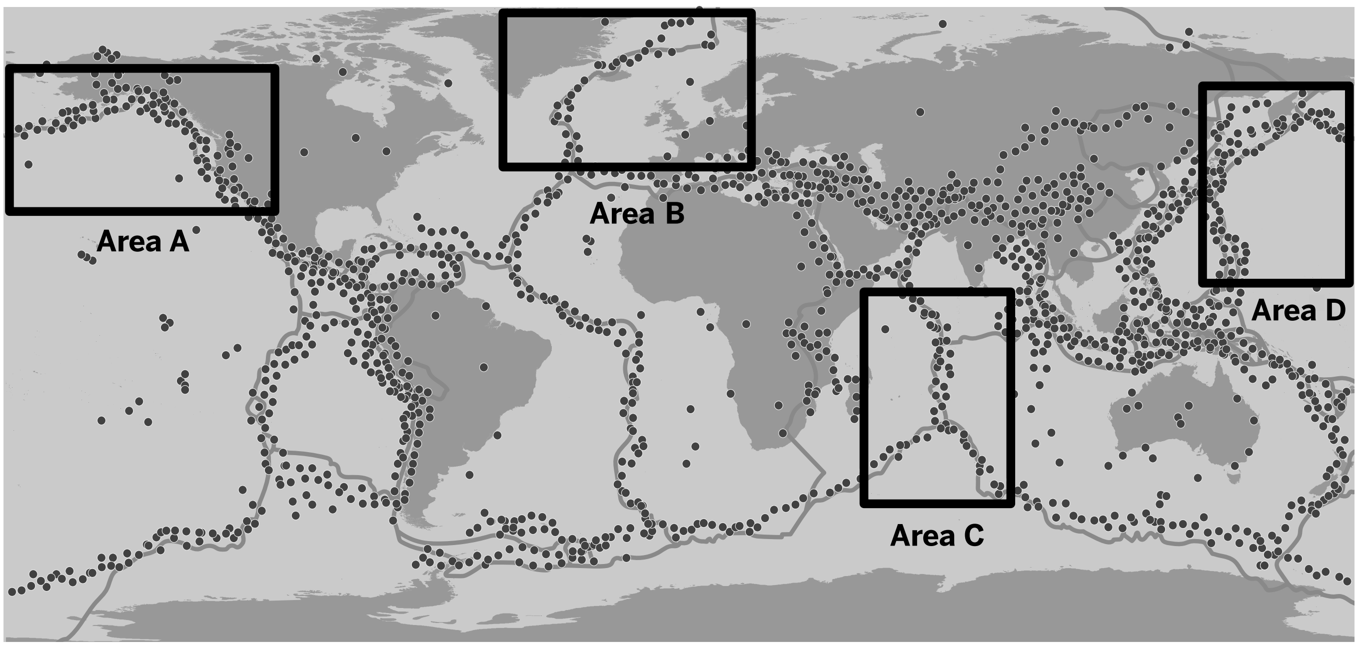
Considering the *Mesosaurus* Exhibit

Plate Motion Claims

- **Claim 1:** The South American Plate and African Plate moved apart **suddenly.**
- **Claim 2:** The South American Plate and African Plate moved apart **gradually.**

Plate Boundary and Earthquake Map

Earth's outer layer is made of hard, solid rock and is divided into plates.



Name: ______________________________ Date: ____________________

Homework: Answering the Chapter 1 Question

Answer the Chapter 1 Question using the evidence you have collected in this unit so far. Use the words in the Word Bank below if they help you complete your response.

Word Bank

apart	continent	earthquake	fossil	*Mesosaurus*
ocean	outer layer	plate	plate boundary	movement

What is the land like where *Mesosaurus* fossils are found?

____

____

____

____

____

____

____

____

Name: ______________________ Date: ______________

Homework: Check Your Understanding

This is a chance to reflect on your learning so far. This is not a test. Be open and truthful when you respond to the questions below.

Scientists investigate in order to figure things out. Are you getting closer to figuring out why the fossils of *Mesosaurus* that once lived together are found in different locations on Earth now?

1. I understand what Earth's outer layer is made of underneath the water and soil on the surface. (check one)

   ☐ yes

   ☐ not yet

Explain your answer choice.

____

____

2. I understand what happened with the plates and the mantle between South America and Africa. (check one)

   ☐ yes

   ☐ not yet

Explain your answer choice.

____

____

3. I understand what happens with the plates and the mantle when two plates move toward each other. (check one)

   ☐ yes

   ☐ not yet

Explain your answer choice.

____

____

Name: ______________________________ Date: ________________

Homework: Check Your Understanding (continued)

4. I understand how long it took for South America and Africa to move far away from each other. (check one)

   ☐ yes

   ☐ not yet

Explain your answer choice.

____

____

5. What do you still wonder about why the fossils of *Mesosaurus* that once lived together are found in different locations on Earth now?

____

____

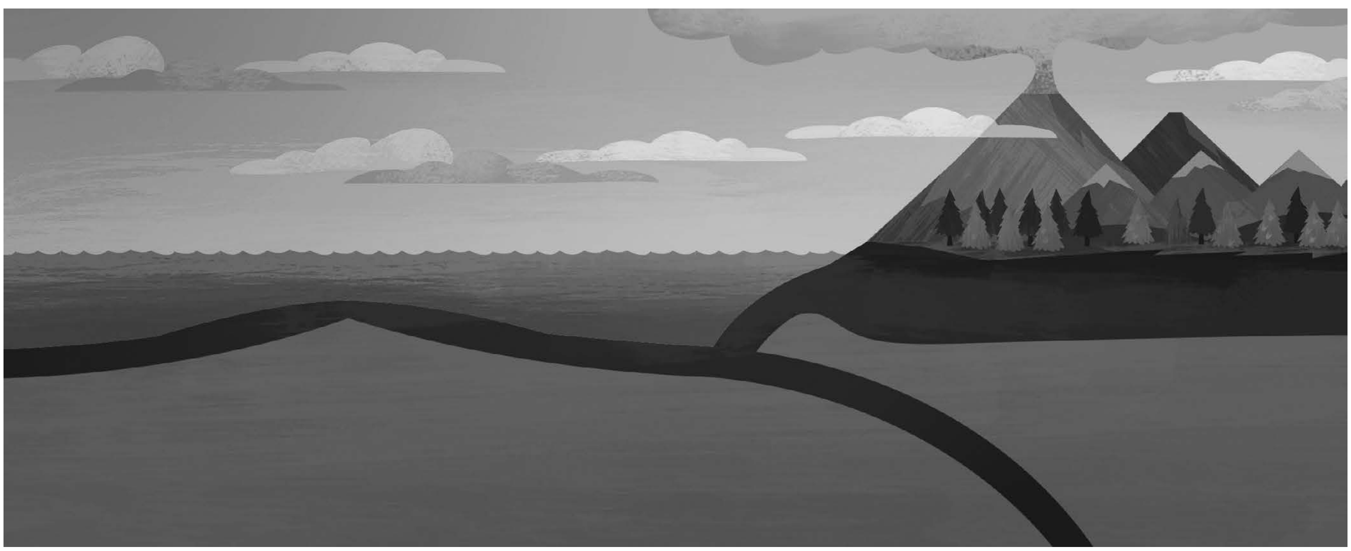
____

____

Name: ______________________ Date: ______________

Chapter 2: Understanding Plate Boundaries
Chapter Overview

Now that you know the Earth's outer layer is made of plates that move, it's time to consider how they move. What's underneath Earth's plates? What happens at plate boundaries? You will explore two types of plate boundaries and consider evidence about each in order to determine which type of boundary is between the *Mesosaurus* fossils.



Name: ____________________ Date: ____________

Lesson 2.1: Considering What's Underneath Earth's Plates

You know that *Mesosaurus* fossils are now separated by a plate boundary and that there is evidence of plate motion. How did the plates move? Was the movement sudden or gradual? Today, you're going to learn about what is under the plates and how this affects plate movement. You will gather evidence from a hands-on investigation, the *Plate Motion* Sim, and conversation with your classmates, so that you can begin to answer these questions.

Unit Question

- Why are fossils of species that once lived together found in different locations on Earth now?

Chapter 2 Question

- How did the South American Plate and African Plate move?

Vocabulary

- earthquake
- mantle
- outer layer
- pattern
- plate
- plate boundary

Digital Tools

- *Plate Motion* Simulation

Name: ____________________ Date: ____________

Warm-Up

To: Student Geologists
From: Dr. Bayard Moraga, Lead Curator, Museum of West Namibia
Subject: How Did the South American Plate and African Plate Move?

MUSEUM OF WEST NAMIBIA

Thank you for your work to determine that today *Mesosaurus* fossils are found on two different plates and these plates have a plate boundary between them. These are important pieces of the story we need to tell in our museum exhibit! Now we are curious about how the *Mesosaurus* fossils got separated by such a great distance.

We would like you to investigate this question: *How did the South American Plate and African Plate move?*

Given what you know right now, how would you respond to the question from Dr. Moraga: *How did the South American Plate and African Plate move?*

____

____

____

____

Name: ______________________ Date: ______________

Considering the Mantle

We know that Earth's outer layer is made of hard, solid rock divided into plates, and we know those plates move. But how? Below the outer layer is the mantle. In this activity, you will use the Sim to investigate how the composition of the mantle might allow the plates to move.

1. Open the Sim.
2. Select Region 1 from the Globe View.
3. Adjust the mantle setting to Hard Solid. Press RUN and observe the motion of the plates. Record your observations in the data table below.
4. Once the run has ended, press BUILD. Adjust the mantle setting to Soft Solid. Press RUN and observe the motion of the plates. Record your observations in the data table below.
5. After you complete the table, answer the discussion questions with your partner. Be ready to share your ideas about the mantle with the class.

Mantle setting	**Observations of plate motion**
Hard solid	
Soft solid	

Discuss the following questions with a partner, and then record your response:

Based on your results, what do you think the rock in Earth's mantle is like? Is the mantle made of hard, solid rock or soft, solid rock? Explain your ideas.

____

____

____

____

Name: ______________________________ Date: ________________

Exploring Characteristics of the Mantle

How is a soft, solid material different from a hard, solid material?

Use the Silly Putty and plastic cube to investigate how soft, solid materials are different from hard, solid materials. Record your observations of the materials in the data table below.

Hint: Try to answer the following questions: What can the soft, solid material do that the hard, solid material can't? What happens when you press into each of the solids?

Mantle setting	**Observations**
Soft, solid material: Silly Putty	
Hard, solid material: plastic cube	

Discuss the following question with your partner, using evidence from your investigation of the two materials: *How is a soft, solid material different from a hard, solid material?*

Name: ______________________________ Date: ____________________

Word Relationships

Some visitors at the Museum of West Namibia have never learned anything about Earth's plates, plate boundaries, or mantle. Use the Word Relationships Cards to create sentences that help explain to these visitors how these parts of Earth work together.

Create sentences that answer both of these questions:

1. How can Silly Putty and a hard, plastic cube be used to model different layers of Earth?
2. How are Earth's plates able to move?
   - Use at least two different Word Relationships Cards in each sentence. In your group of four, take turns as both the speaker and the listener.
   - Your group may use the same word more than once. You do not need to use all the vocabulary words.
   - There are many different ways to answer these questions, and you will need to create more than one sentence in order to express your ideas completely.

Word Bank

mantle	outer layer	plate	plate boundary

Name: ______________________ Date: ______________

Homework: Plate Motion on Other Planets

Scientists believe that some other planets in the universe might have a geologic structure similar to Earth's, including a mantle and an outer layer made of plates.

Imagine that scientists have found a planet with an outer layer divided into plates made of hard, solid rock, but the mantle below the plates is made of **hard,** solid rock instead of **soft,** solid rock as it is on Earth.

Word Bank

mantle	outer layer	plate	plate boundary

Do you think plate motion would take place on that planet? Why or why not? (Use the words in the Word Bank if it helps you answer the question.)

____

____

____

____

Name: ______________________________ Date: ____________________

Lesson 2.2: “Listening to Earth”

Your research has shown that a plate boundary exists between the South American Plate and African Plate, both of which are on top of the mantle. But how do the plates and mantle interact? What happens at plate boundaries? Dr. Moraga has sent you an article about a scientist who investigates plate boundaries. After reading, you’ll be able to use what you have learned to explain which type of plate boundary lies between the two plates where *Mesosaurus* fossils are found. You’ll also be able to explain what this plate boundary tells us about the history of these two plates and the fossils that are found on them.

Unit Question

- Why are fossils of species that once lived together found in different locations on Earth now?

Chapter 2 Question

- How did the South American Plate and African Plate move?

Key Concepts

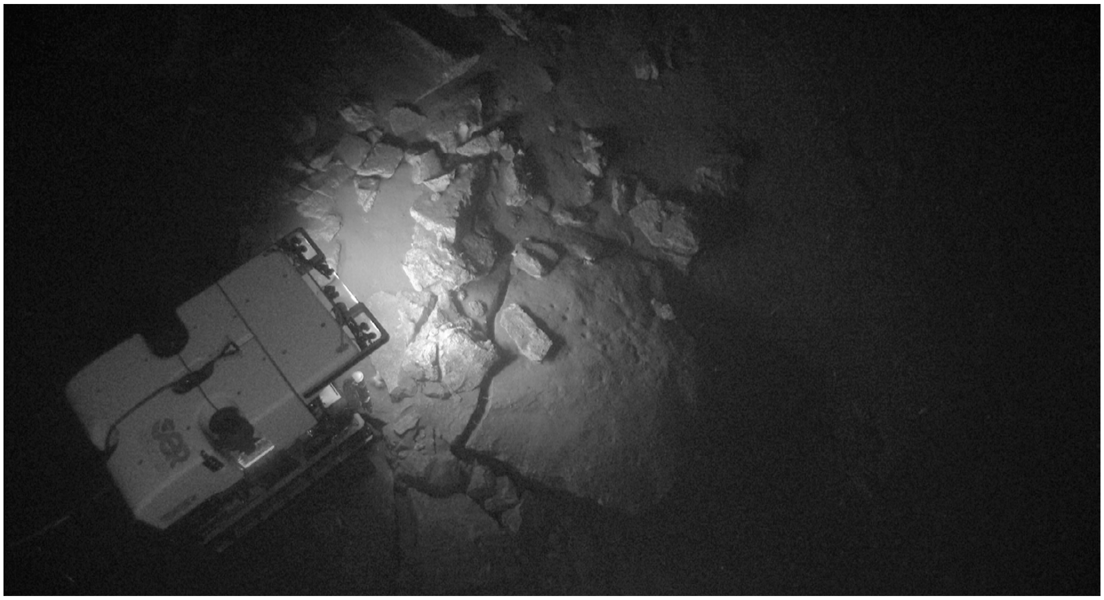
- Earth’s plates move on top of a soft, solid layer of rock called the mantle.

Vocabulary

- convergent
- cross section
- divergent
- earthquake
- mantle
- outer layer
- pattern
- plate
- plate boundary

Name: ______________________ Date: ______________

Warm-Up



Imagine that you could dive deep into the Atlantic Ocean where the South American Plate and African Plate meet at a plate boundary.

Make a prediction: What do you think you would see at the plate boundary? Would you see the mantle? Why or why not?

____

____

____

____

Name: ______________________________ Date: ____________________

Reading "Listening to Earth"

1. Read and annotate the article "Listening to Earth."
2. Choose and mark annotations to discuss with your partner. Once you have discussed these annotations, mark them as discussed.
3. Now, choose and mark a question or connection, either one you already discussed or a different one you still want to discuss with the class.
4. Answer the reflection question below.

Rate how successful you were at using Active Reading skills by responding to the following statement:

As I read, I paid attention to my own understanding and recorded my thoughts and questions.

- ☐ Never
- ☐ Almost never
- ☐ Sometimes
- ☐ Frequently/often
- ☐ All the time

Active Reading Guidelines

1. Think carefully about what you read. Pay attention to your own understanding.
2. As you read, annotate the text to make a record of your thinking. Highlight challenging words and add notes to record questions and make connections to your own experience.
3. Examine all visual representations carefully. Consider how they go together with the text.
4. After you read, discuss what you have read with others to help you better understand the text.

Name: ______________________________ Date: ________________

Homework: Making Connections to Science Ideas

Think of another science topic that you have studied in the past. What patterns did we look for when we were studying that topic? What patterns are we looking for now? How are the patterns similar or different? See if you can make connections between patterns in the *Plate Motion* unit and patterns in one of the topics below.

- geology
- evolution
- ecosystems
- light and energy
- solar system
- Earth (or Earth's atmosphere and oceans)
- a science topic that is not listed above

List the science topic you have selected here: ______________________________

In the space below, describe the patterns we looked for when studying that science topic and explain how they are similar to or different from the patterns we are looking for now.

____

____

____

____

____

____

Name: ______________________________ Date: ____________________

Lesson 2.3: Explaining Plate-Mantle Interactions

In the article "Listening to Earth," you read about sounds that can be heard deep in the ocean when the enormous plates of Earth's outer layer move. Earth's plates are constantly moving, and it is hard to imagine exactly what is happening to the plates and the mantle at plate boundaries. To gain a better understanding of this, you will use towels to model what happens when Earth's plates move toward or away from each other at convergent and divergent plate boundaries.

Unit Question

- Why are fossils of species that once lived together found in different locations on Earth now?

Chapter 2 Question

- How did the South American Plate and African Plate move?

Key Concepts

- Earth's plates move on top of a soft, solid layer of rock called the mantle.

Vocabulary

- convergent
- cross section
- divergent
- earthquake
- evidence
- mantle
- mid-ocean ridge
- plate
- plate boundary
- trench

Name: ______________________ Date: ______________

Warm-Up

To: Student Geologists
From: Dr. Bayard Moraga, Lead Curator, Museum of West Namibia
Subject: Divergent or Convergent Plate Boundary?

MUSEUM OF WEST NAMIBIA

I hope that referring to the article "Listening to Earth" will help you to decide whether the boundary between the South American Plate and the African Plate is a divergent or convergent plate boundary. If you can help us decide which type of boundary is between the plates where *Mesosaurus* fossils are found now, perhaps we will have more clues about how these fossils got so far away from each other. Keep up the good work!

Given what you know right now, do you think the boundary between the South American Plate and the African Plate is a divergent plate boundary or a convergent plate boundary? Why? Explain your answer.

____

____

____

____

Name: ______________________________ Date: ____________________

Rereading "Listening to Earth"

Take out the "Listening to Earth" article that you read in the previous lesson. Read the second paragraph of the "Listening to Convergent Boundaries" section and the first paragraph of the "Listening to Divergent Boundaries" section. Highlight any information in the text that helps answer the three questions below. Make annotations as needed.

1. How do plates move at each type of plate boundary?
2. How do the plates and mantle interact at each type of plate boundary?
3. What landforms are commonly found at or near each type of plate boundary?

Active Reading Guidelines

1. Think carefully about what you read. Pay attention to your own understanding.
2. As you read, annotate the text to make a record of your thinking. Highlight challenging words and add notes to record questions and make connections to your own experience.
3. Examine all visual representations carefully. Consider how they go together with the text.
4. After you read, discuss what you have read with others to help you better understand the text.

Name: ____________________ Date: ____________

Creating Physical Models of Plate Motion

Part 1: Creating Physical Models

Before you create physical models to represent what happens at convergent and divergent plate boundaries, consider what the parts of the model represent on Earth.

Part of the model	What that represents on Earth
Towels	
Area between the chairs	
Area under the chairs	

As you create your models of each type of plate boundary, refer to your Plate Boundary Comparison Chart and discuss the following questions with your group.

Discussion Questions

- How do the plates move at each type of plate boundary? How can you use the materials to show how this happens?
- What happens to the mantle and the plates at each type of plate boundary? How can you use the materials to show what happens?

Name: ______________________________ Date: ________________

Creating Physical Models of Plate Motion (continued)

Part 2: Reflecting on the Investigation Question

Use evidence from the "Listening to Earth" article and your physical models to answer the Investigation Question: *What happens to the plates and the mantle at plate boundaries?*

Try to include the following terms in your response: *plate, mantle, convergent boundary, divergent boundary.*

Name: ______________________________ Date: ____________________

Lesson 2.4: Modeling Plate-Mantle Interactions

How can we really understand what is taking place at plate boundaries? You created simple physical models in the previous lesson. The Sim is a more complex model of plate boundaries, and it will help you investigate plate-mantle interactions more closely. Today, you will show your understanding of what is taking place by creating visual models. Then you will use the Sim to expand your understanding before adding more detail to your models.

Unit Question

- Why are fossils of species that once lived together found in different locations on Earth now?

Chapter 2 Question

- How did the South American Plate and African Plate move?

Key Concepts

- Earth's plates move on top of a soft, solid layer of rock called the mantle.

Vocabulary

- convergent
- cross section
- divergent
- earthquake
- mantle
- mid-ocean ridge
- outer layer
- plate
- plate boundary
- trench
- volcanic activity

Digital Tools

- *Plate Motion* Simulation

Name: ____________________ Date: ____________

Warm-Up

In the previous lesson, you read about convergent and divergent plate boundaries. You also made physical models of these types of boundaries using towels and chairs or desks. The photos below show cross-section views of physical models similar to the ones you created.

Convergent Plate Boundary

Divergent Plate Boundary

How did the physical models make it difficult to show what happens to the plates and mantle at plate boundaries?

____

____

____

____

Name: ______________________________ Date: ______________

Explaining What Happens at Plate Boundaries

Modeling Convergent and Divergent Plate Boundaries

Use the Modeling Tool activity: Modeling Convergent and Divergent Plate Boundaries on the next two pages to show your thinking about what happens at two types of plate boundaries.

Goal: Show what happens to the plates and the mantle at plate boundaries.

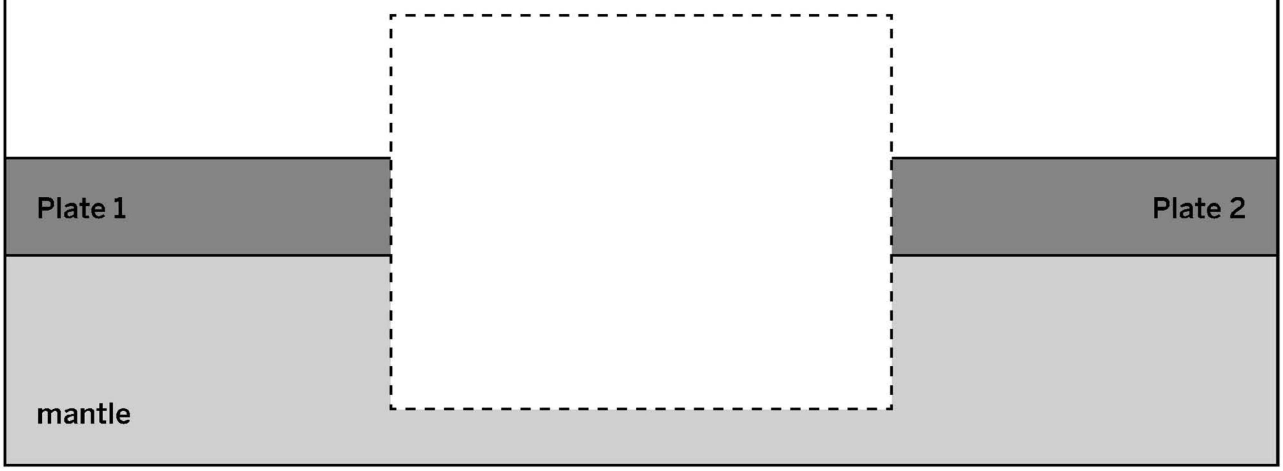
Do:

- For each plate boundary type, choose the cross section on the second page that best shows what is happening where Plate 1 and Plate 2 meet.
- Cut out the cross sections you chose and glue them in the appropriate boxes.
- In the cross sections that you added, add arrows to show the direction each plate is moving at each plate boundary.

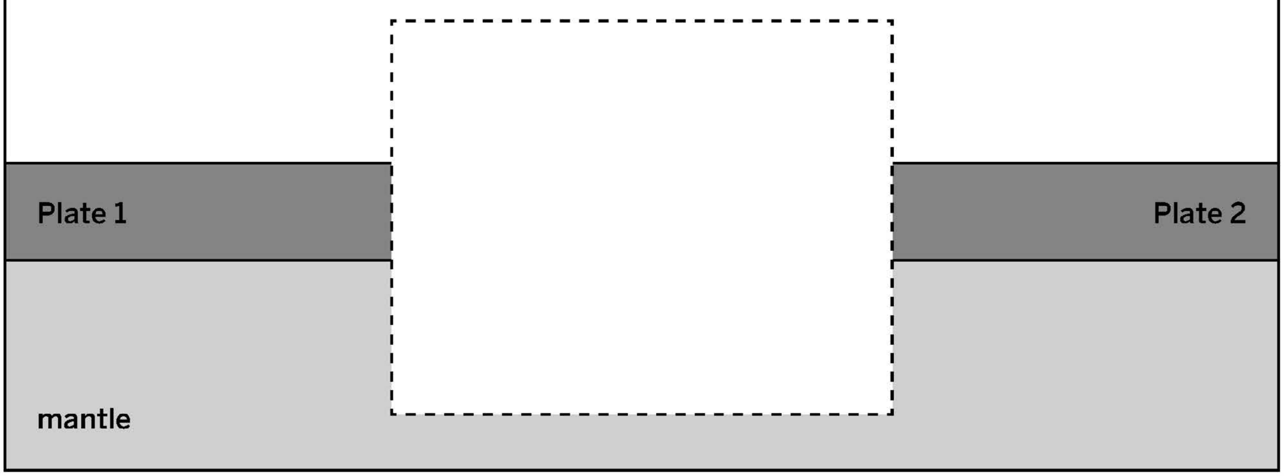
Name: ____________________ Date: ____________

Explaining What Happens at Plate Boundaries (continued)

Convergent Plate Boundary



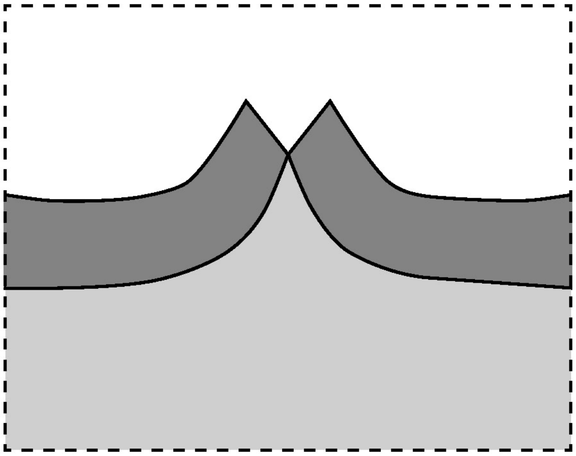
Divergent Plate Boundary

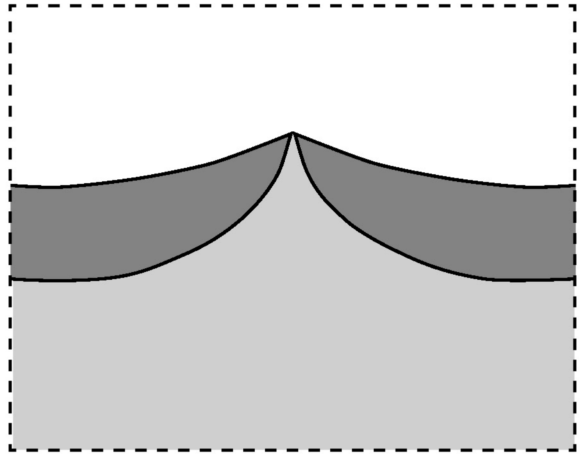


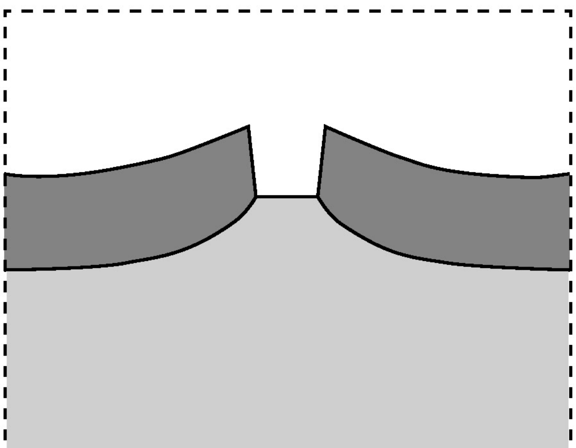
Name: ______________________ Date: ______________

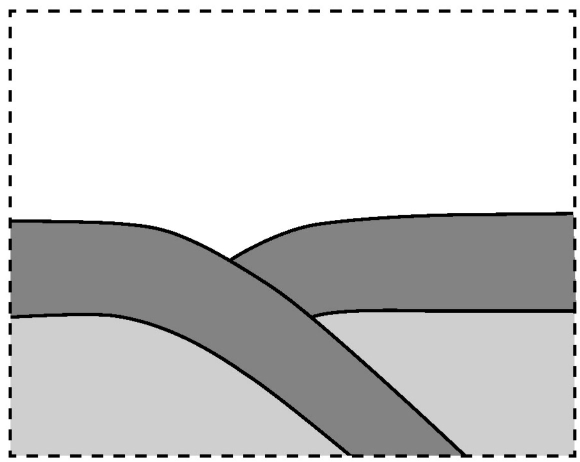
Explaining What Happens at Plate Boundaries (continued)

Cross Section Options









Name: ______________________________ Date: ________________

Exploring Plate Boundaries in the Sim

Part 1

Plate-mantle interactions change Earth's plates over time. In some places, plate material is added to the edges of both plates, and in others, one plate sinks into the mantle. With your partner, use the Sim to learn more about how the plates interact with the mantle at plate boundaries.

Mission: Show the differences in the types of interaction between the mantle and plate by creating two scenarios:

- Create one scenario in which rock is added to the edges of both plates.
- Create another scenario in which one plate sinks into the mantle.

Predictions

1. I think that rock from the mantle is added to the edges of both plates at (check one)

   ☐ convergent plate boundaries.

   ☐ divergent plate boundaries.

2. I think that one plate sinks into the mantle and is destroyed at (check one)

   ☐ convergent plate boundaries.

   ☐ divergent plate boundaries.

Instructions

1. Open the *Plate Motion* Sim.
2. Select Region 2.
3. Set up the region so that rock from the mantle will be added to the edges of both plates or a plate will sink into the mantle at the plate boundary. Press SET BOUNDARY to choose the plate boundary type.
4. Press RUN and observe what is happening in the Cross-Section View. Can you see rock being added to the edges of the plates or one plate sinking into the mantle?
5. Press BUILD and repeat Steps 3 and 4 for the other scenario.
6. Based on your observations, complete the statements on the next page.

Name: ____________________ Date: ____________

Exploring Plate Boundaries in the Sim (continued)

Observations

1. I saw that rock from the mantle is added to the edges of both plates at (**convergent** / **divergent**) plate boundaries, where the plates move (**toward** / **away from**) each other.

2. I saw that one plate sinks into the mantle and is destroyed at (**convergent** / **divergent**) plate boundaries, where the plates move (**toward** / **away from**) each other.

Part 2

With your partner, use the Sim to gather more evidence about what happens at plate boundaries. By learning more about what happens at convergent and divergent plate boundaries, we will be able to determine which type of boundary is between the South American Plate and African Plate.

1. Open the Sim.

2. Open Region 2. Use the Add Rock tool to add continents to the map.

3. Press SET BOUNDARY and select Divergent as the plate boundary type. Then press RUN.

4. Toggle on earthquakes and volcanoes.

5. Observe whether earthquakes and volcanoes occur at this plate boundary. What can you see in the Map View and in the Cross-Section View?

6. Observe how the Cross-Section View changes. What landforms are associated with this type of plate boundary?

7. Repeat your observations with a convergent plate boundary.

8. Complete the Plate Boundary Comparison Chart based on your observations.

Name: ______________________________ Date: ____________________

Revising Models of Plate Boundaries

Return to your Modeling Tool activity: Modeling Convergent and Divergent Plate Boundaries on pages 45–47 and revise your models based on your observations in the Sim.

Goal: Show what happens to the plates and the mantle and what landforms are found at plate boundaries.

Do:

- Label which landform forms at each plate boundary (trench or mid-ocean ridge).
- Label where rock from the mantle is added to the edges of both plates with a plus sign.
- Label where the plate sinks into the mantle and is destroyed with a minus sign.

Tip:

- Refer to your Plate Boundary Comparison Chart!

Name: ______________________ Date: ______________

Lesson 2.5: Identifying Plate Motion at a Plate Boundary

We know that the *Mesosaurus* fossils were once together and are now far apart, and we know that plate motion is responsible for this. Are you ready to make a final determination about which type of plate boundary is between the South American Plate and African Plate? By the end of this lesson, you will be! Knowing which type of plate boundary is between these plates will help you figure out how the fossils got so far apart.

Unit Question

- Why are fossils of species that once lived together found in different locations on Earth now?

Chapter 2 Question

- How did the South American Plate and African Plate move?

Key Concepts

- Earth's plates move on top of a soft, solid layer of rock called the mantle.
- At divergent plate boundaries, rock rises from the mantle and hardens, adding new solid rock to the edges of both plates.
- At convergent plate boundaries, one plate moves underneath the other plate and sinks into the mantle.

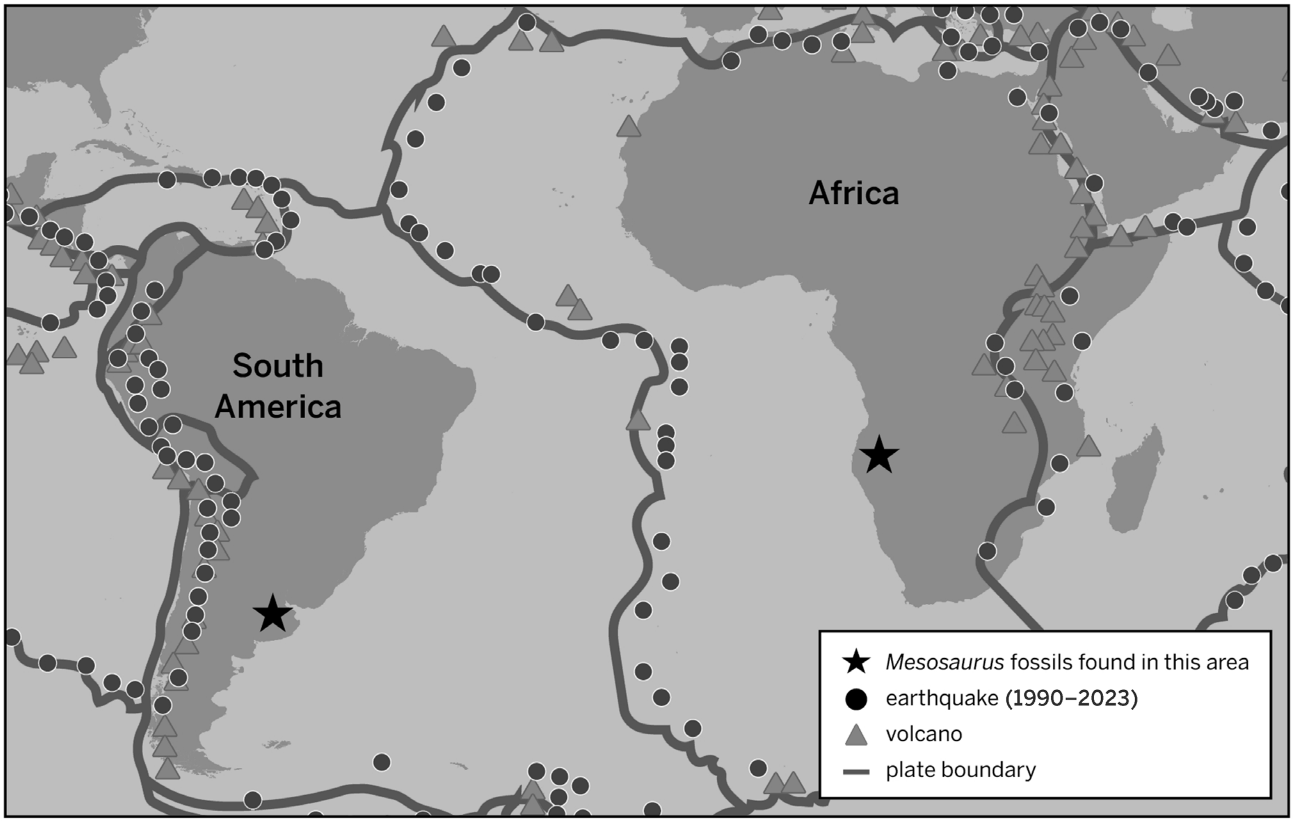
Vocabulary

- analyze
- claim
- convergent
- cross section
- divergent
- earthquake
- evidence
- mantle
- mid-ocean ridge
- outer layer
- pattern
- plate
- plate boundary
- trench
- volcanic activity

Name: ______________________________ Date: ______________

Warm-Up

This map shows the plate boundary where the South American Plate and African Plate meet, with new evidence added.



Do you notice any patterns on this map? Describe them here.

____

____

____

____

From this evidence, can you tell if this plate boundary is divergent or convergent?

____

____

____

____

Name: ____________________ Date: ____________

Interpreting Plate Boundary Evidence

To: Student Geologists
From: Dr. Bayard Moraga, Lead Curator, Museum of West Namibia
Subject: New Evidence

MUSEUM OF WEST NAMIBIA

We just received new evidence from a group of scientists studying the ocean floor at the boundary between the South American Plate and African Plate. The scientists told us that a mid-ocean ridge called the Mid-Atlantic Ridge is located along this plate boundary. We hope you will find this new evidence helpful as you work to determine how the South American Plate and African Plate moved. We eagerly await hearing about your findings!

Examine the Plate Boundary Evidence Map on the previous page, and discuss the following questions with your partner.

Discussion Questions

- Which type of plate boundary do you think this is? How are the plates moving in relation to each other?
- Which piece of evidence was most convincing in helping you determine the type of plate boundary between these two plates?

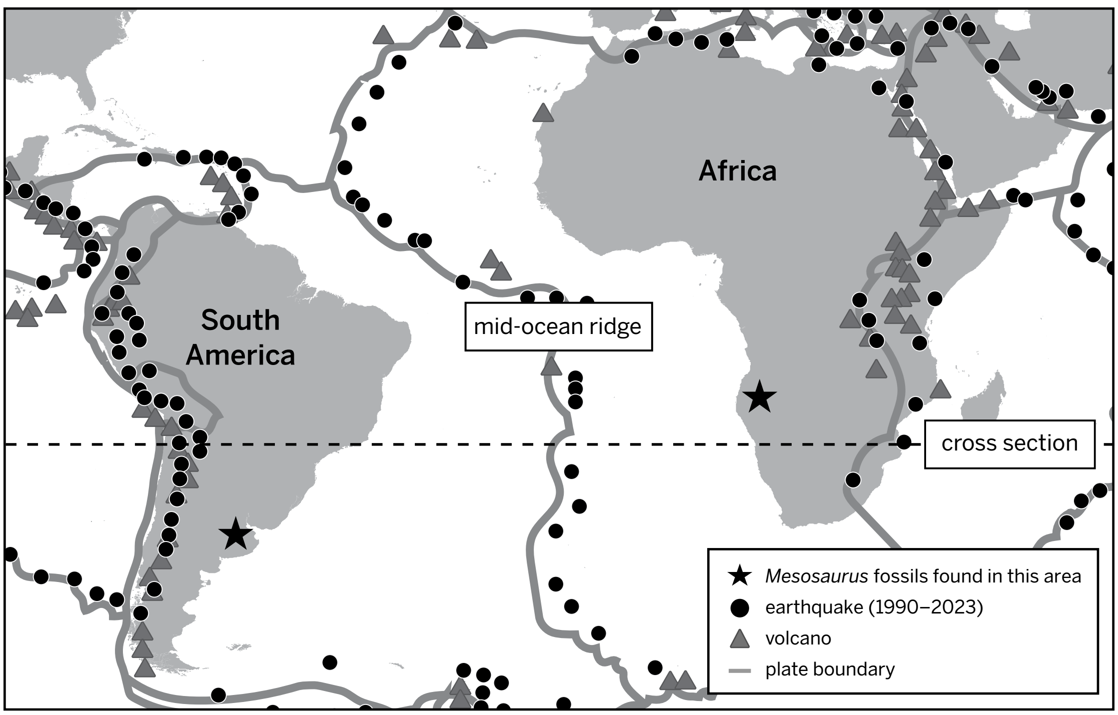
Name: ______________________ Date: ______________

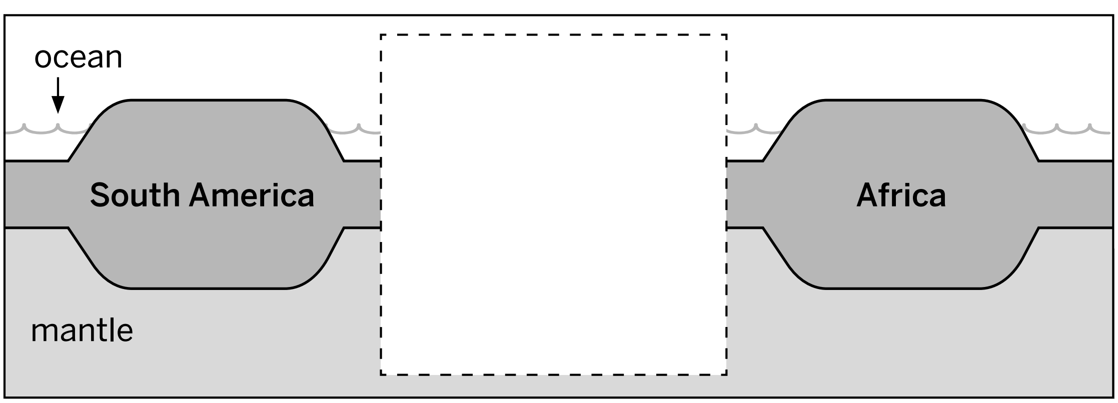
Modeling a Divergent Plate Boundary

Goal: Show how the plates and the mantle interact at the plate boundary between the South American Plate and African Plate.

Do:

- Draw in the missing part of the cross section below the map to show what happens where the South American Plate and African Plate meet.
- Add arrows to the map and to the cross section to show the direction in which each plate is moving.
- In the cross section, add a plus sign to show where rock from the mantle is added to the plates.





Name: ______________________________ Date: ____________________

Homework: How Did the South American Plate and African Plate Move?

Answer the Chapter 2 Question using the evidence you have collected in this unit so far. You may want to include the words in the Word Bank in your response.

Word Bank

away	together	continent	earthquake	ocean
outer layer	mantle	plate	plate boundary	convergent
divergent	mid-ocean ridge	trench	volcanic activity	

How did the South American Plate and African Plate move?

Be sure to include what type of plate boundary is between these plates and how you can tell. Use evidence to support your response.

____

____

____

____

____

____

____

____

Name: ______________________________ Date: ________________

Lesson 2.7: Exploring Iceland's Plate Boundary

Geologists from around the world go to Iceland to study its unique features. You'll soon find out that Iceland is an amazing place to study plate motion. In this lesson, you'll learn more about this geologic wonderland as you review what you have learned so far about plate motion.

Unit Question

- Why are fossils of species that once lived together found in different locations on Earth now?

Chapter 2 Question

- How did the South American Plate and African Plate move?

Key Concepts

- Earth's outer layer is made of hard, solid rock.
- Earth's outer layer is divided into sections called plates.
- Geologists look for patterns in landforms and in geologic events in order to better understand Earth.
- The plates of Earth's outer layer move.
- Earth's plates move on top of a soft, solid layer of rock called the mantle.
- At divergent plate boundaries, rock rises from the mantle and hardens, adding new solid rock to the edges of both plates.
- At convergent plate boundaries, one plate moves underneath the other plate and sinks into the mantle.

Vocabulary

- analyze
- convergent
- cross section
- divergent
- earthquake
- mantle
- mid-ocean ridge
- outer layer
- pattern
- plate
- plate boundary
- trench
- volcanic activity

Name: ______________________________ Date: ________________

Warm-Up

Iceland is a volcanic island in the North Atlantic Ocean that lies between Greenland and Europe. To geologists, Iceland is a wonderland, filled with geologic activity such as active volcanoes, geysers, and earthquakes. In fact, there is a plate boundary that runs right through the middle of the island! Many scientists visit the island to study plate motion.

Have you ever heard of Iceland? Record what you know about Iceland in the space below. If you don't know anything about Iceland yet, record what you observe about the photos of Iceland above.

____

____

____

____

Name: ______________________________ Date: ________________

Blue Group: Learning About Iceland

Part 1: Reading About Iceland

Read and annotate the "Journey to a Plate Boundary" article to learn more about the plate boundary in Iceland.

Part 2: Modeling Iceland's Surface

Use what you learned from the "Journey to a Plate Boundary" article to model what the land in Iceland is like. After you complete your model on the Modeling Tool activity: Modeling Iceland's Surface on page 60, discuss the article and your model with your partner.

Part 3: Reading More About Iceland

Read and annotate the *first* paragraph of the "Two Types of Plate Boundaries" article to learn more about the plate boundary in Iceland.

Part 4: Modeling Iceland's Plate Boundary

Use what you learned from the "Two Types of Plate Boundaries" article to model what happens at Iceland's plate boundary. After you complete your model on the Modeling Tool activity: Modeling Iceland's Plate Boundary on page 61, discuss the article and your model with your partner, and answer the question below.

Over time, is Iceland going to get bigger, get smaller, or stay the same size? Use your model to explain why.

____

____

____

____

Name: ______________________________ Date: ____________________

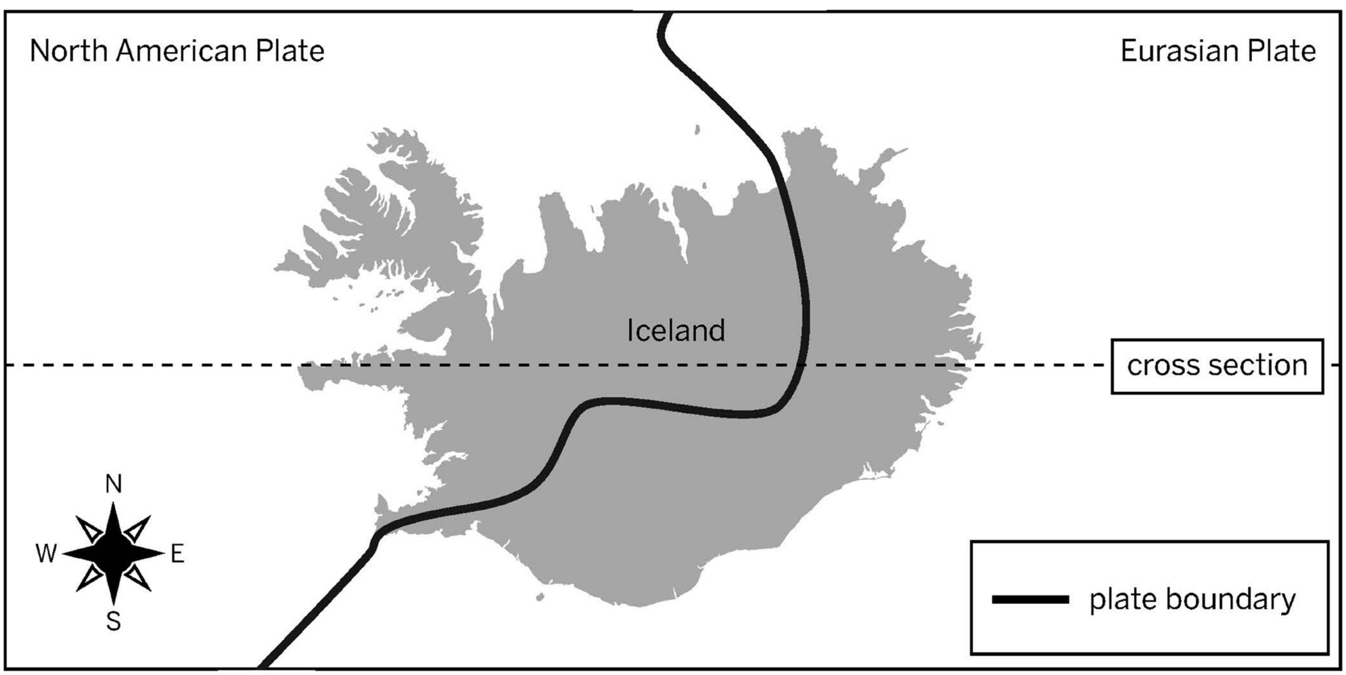
Blue Group: Learning About Iceland (continued)

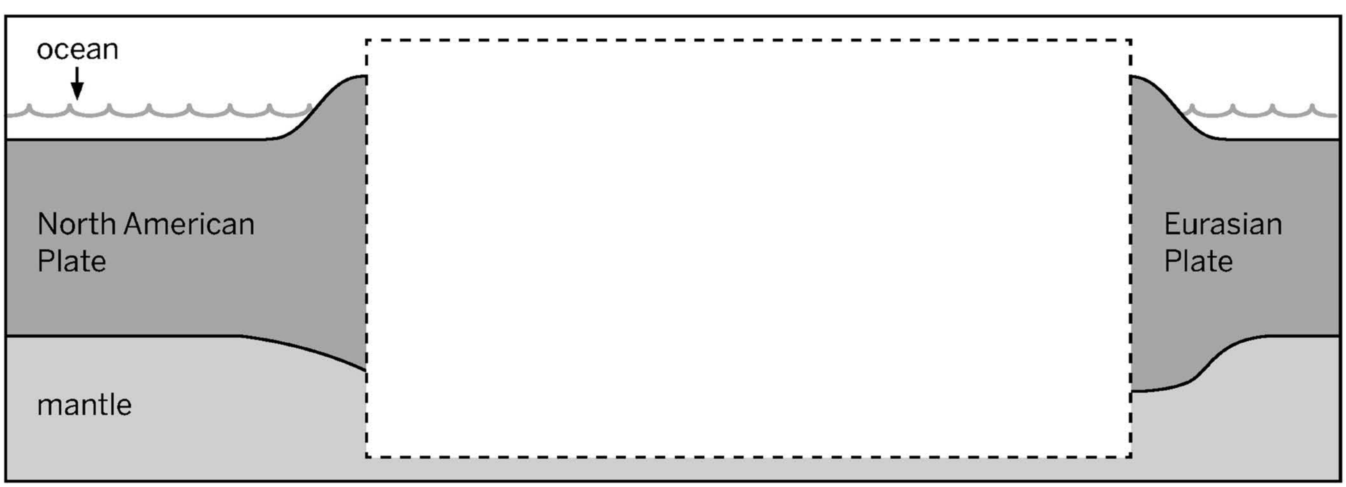
Goal: Show what the land on Iceland's surface is like.

Do:

- Show where Earth's outer layer is made of hard, solid rock on the map by shading those regions.
- In the cross section, show what it looks like at the plate boundary. What is the outer layer of Earth like where the plates meet?
- In the cross section, show where the plate boundary is located.

Modeling Iceland's Surface





Name: ______________________ Date: ______________

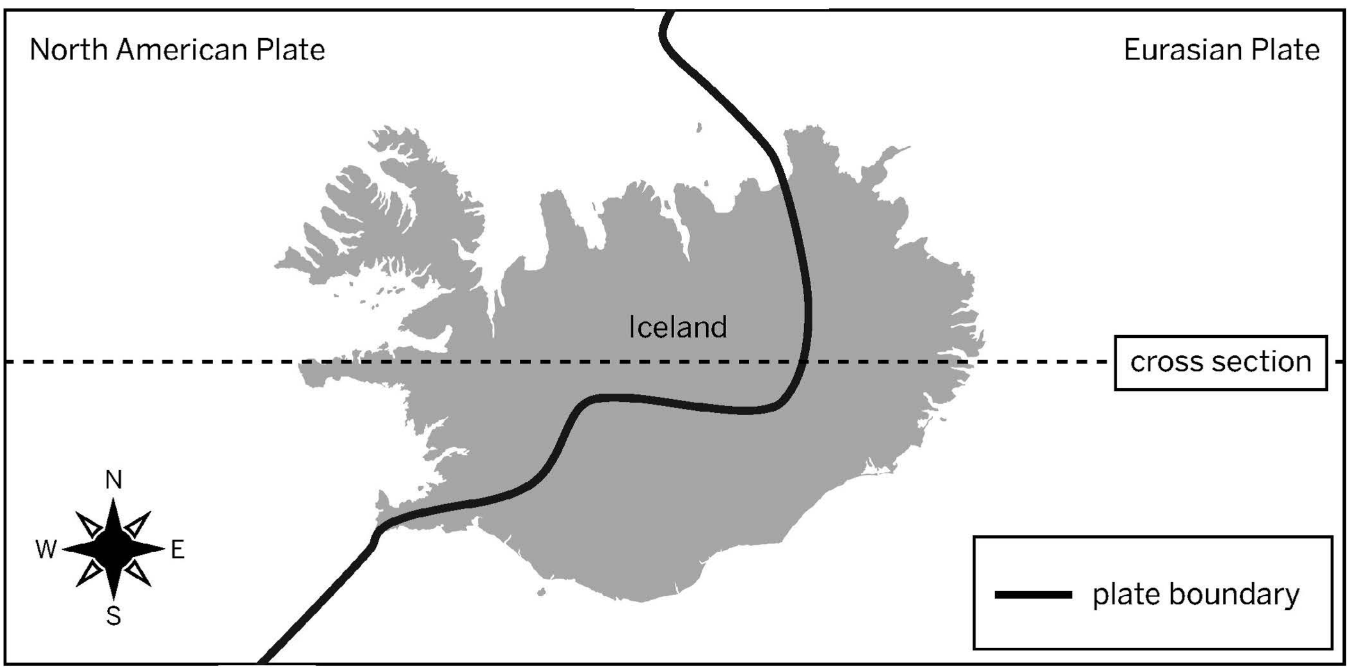
Blue Group: Learning About Iceland (continued)

Goal: Show how the plates and mantle interact at Iceland's plate boundary

Do:

- Draw in the missing part of the cross section below the map to show what happens where the North American Plate and Eurasian Plate meet.
- Add arrows to the map and to the cross section to show the direction in which each plate is moving.

Modeling Iceland's Plate Boundary

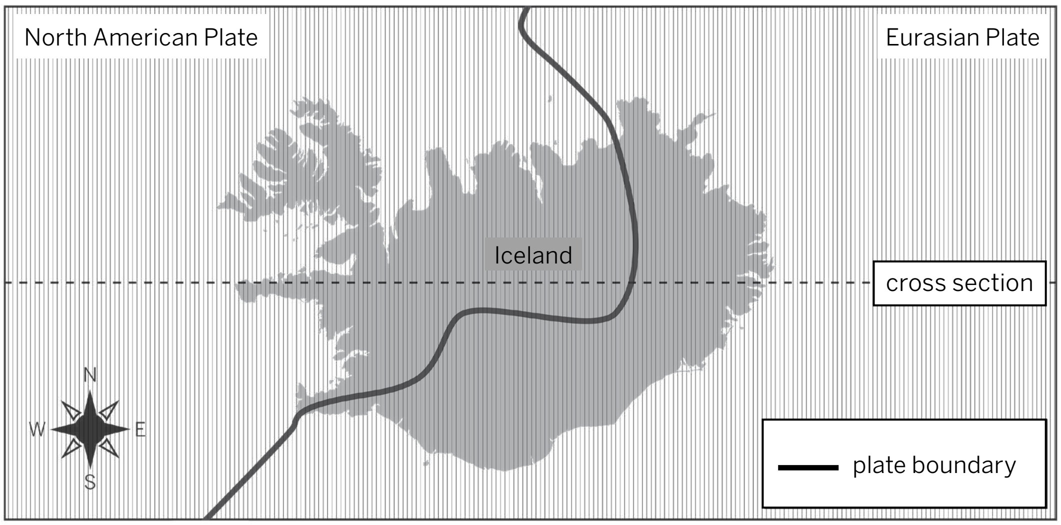


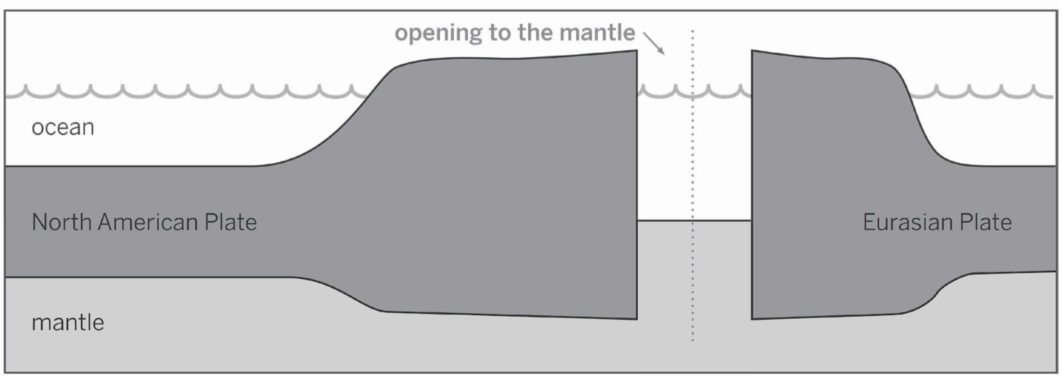
Name: ______________________ Date: ______________

Homework Blue Group: Critiquing Models of Iceland's Plate Boundary

Two other student geologists created the models below. The striped areas on the maps represent the students' ideas about which parts of Earth's outer layer are made of hard, solid rock. In the cross sections, the students have drawn their ideas about what the outer layer of Earth is like where the North American Plate and Eurasian Plate meet. Review the two models and then write about what you would change about each model.

Student A





Which parts of this model would you change and why?

____

____

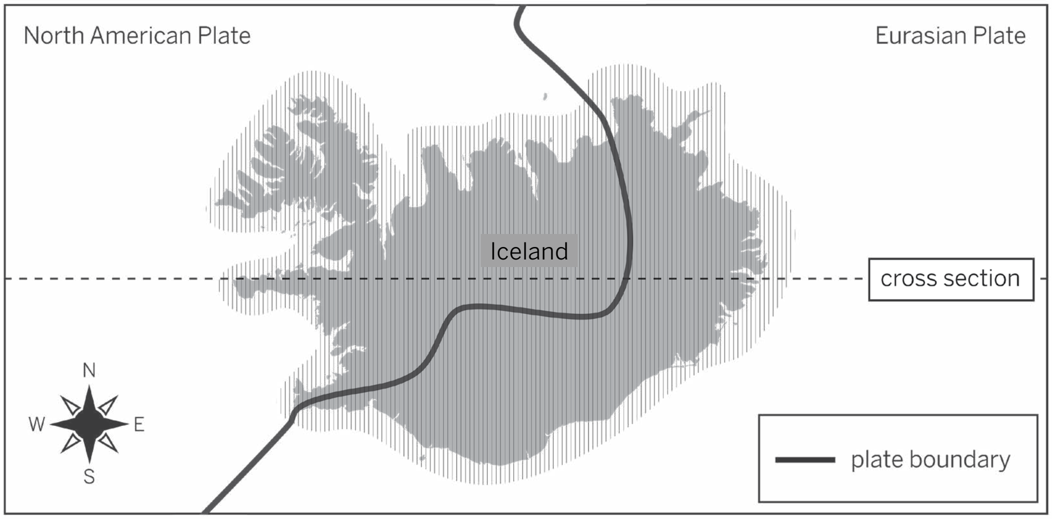
____

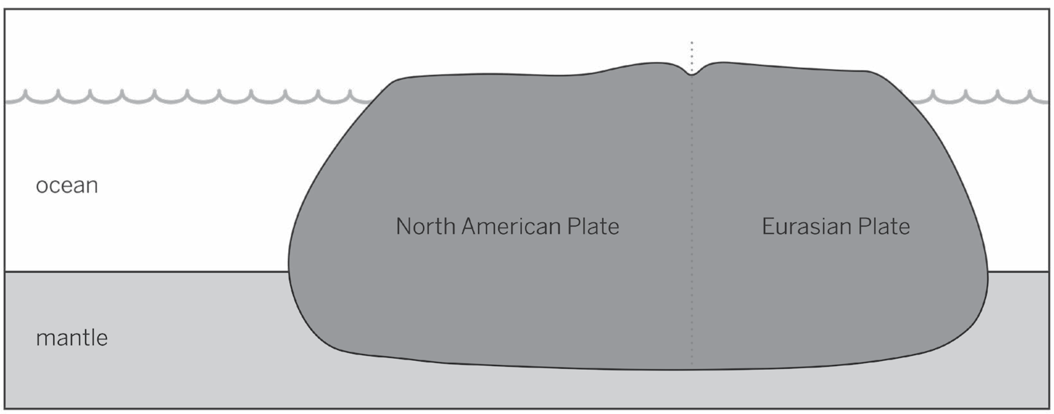
____

Name: ______________________ Date: ______________

Homework Blue Group: Critiquing Models of Iceland's Plate Boundary (continued)

Student B





Which parts of this model would you change and why?

____

____

____

____

Name: ______________________ Date: ______________

Green Group: Learning About Iceland

Part 1: Reading About Iceland

Read and annotate the first paragraph of the "Two Types of Plate Boundaries" article to learn more about the plate boundary in Iceland.

Part 2: Modeling Iceland's Plate Boundary

Use what you learned from the "Two Types of Plate Boundaries" article to model what happens at Iceland's plate boundary. After you complete your model on the Modeling Tool activity: Modeling Iceland's Plate Boundary on page 66, discuss the article and your model with your partner, and answer the question below.

Over time, is Iceland going to get bigger, get smaller, or stay the same size? Use your model to explain why.

____

____

____

____

Part 3: Reading About Chile

Read and annotate the second paragraph of the "Two Types of Plate Boundaries" article to learn about another type of plate boundary found near Chile.

Part 4: Modeling Chile's Plate Boundary

Use what you learned from the "Two Types of Plate Boundaries" article to model what happens at Chile's plate boundary. After you complete your model on the Modeling Tool activity: Modeling Chile's Plate Boundary on page 67, answer the question below.

Over time, is the Nazca Plate going to get bigger, get smaller, or stay the same size? Use your model to explain why.

____

____

____

____

Name: ______________________________ Date: ______________

Green Group: Learning About Iceland (continued)

Part 5: Discussing Iceland's and Chile's Plate Boundaries

Answer the questions below and discuss your models and your answers with your partner.

1. Over time, I think that Iceland will ______________________________.
   (choose and write in an answer from the list below)
   - increase in size
   - decrease in size
   - stay the same size

Discuss your answer with your partner and refer to your model during your discussion.

2. Over time, I think that the Nazca Plate near Chile will ______________________________.
   (choose and write in an answer from the list below)
   - increase in size
   - decrease in size
   - stay the same size

Discuss your answer with your partner and refer to your model during your discussion.

Name: ______________________ Date: ______________

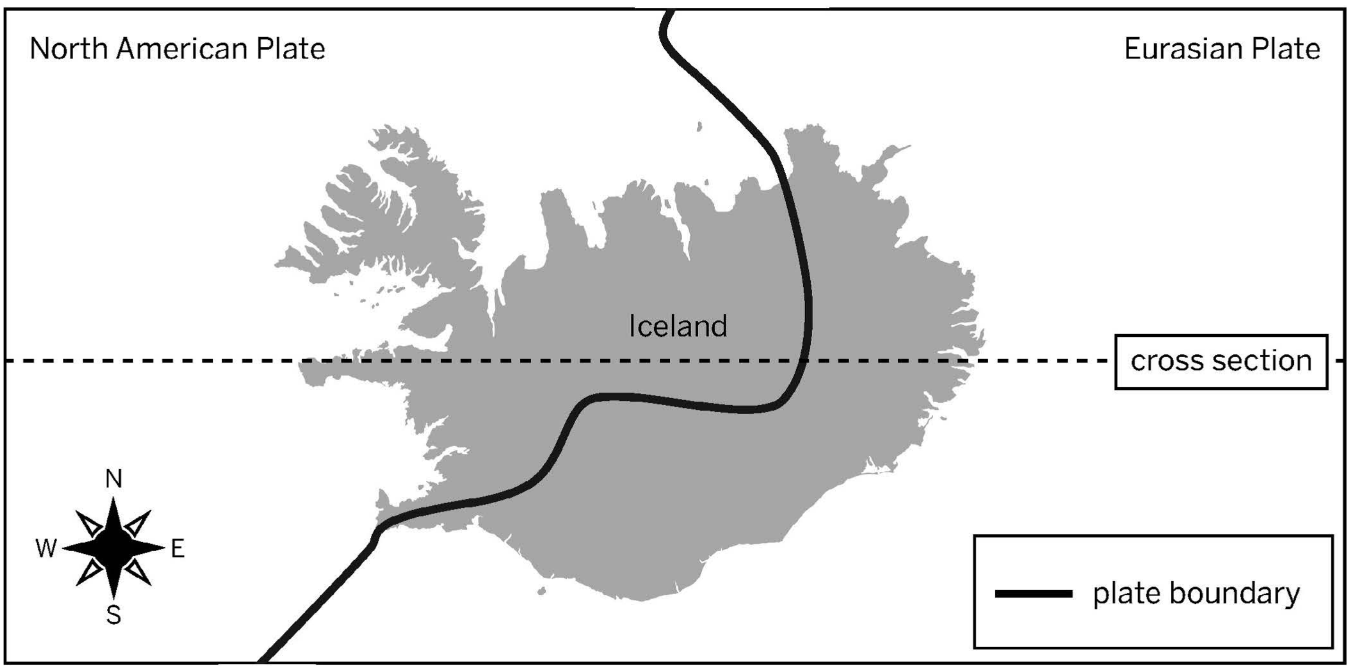
Green Group: Learning About Iceland (continued)

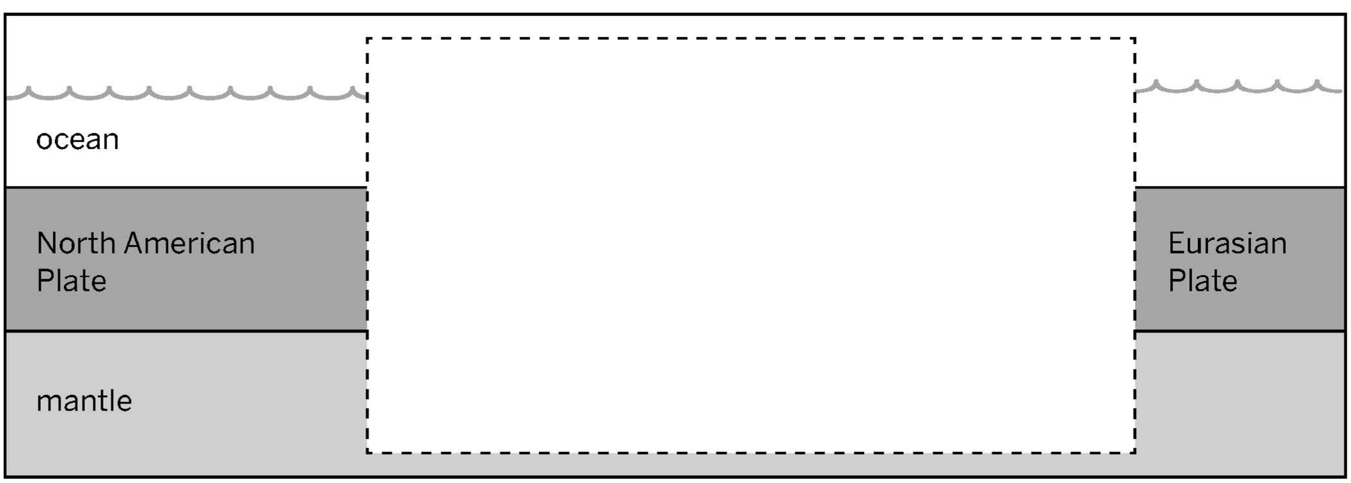
Goal: Show how the plates and mantle interact at Iceland's plate boundary.

Do:

- Draw in the missing part of the cross section below the map to show what happens where the North American Plate and Eurasian Plate meet.
- Add arrows to the map and to the cross section to show the direction in which each plate is moving.

Modeling Iceland's Plate Boundary





Name: ______________________ Date: ______________

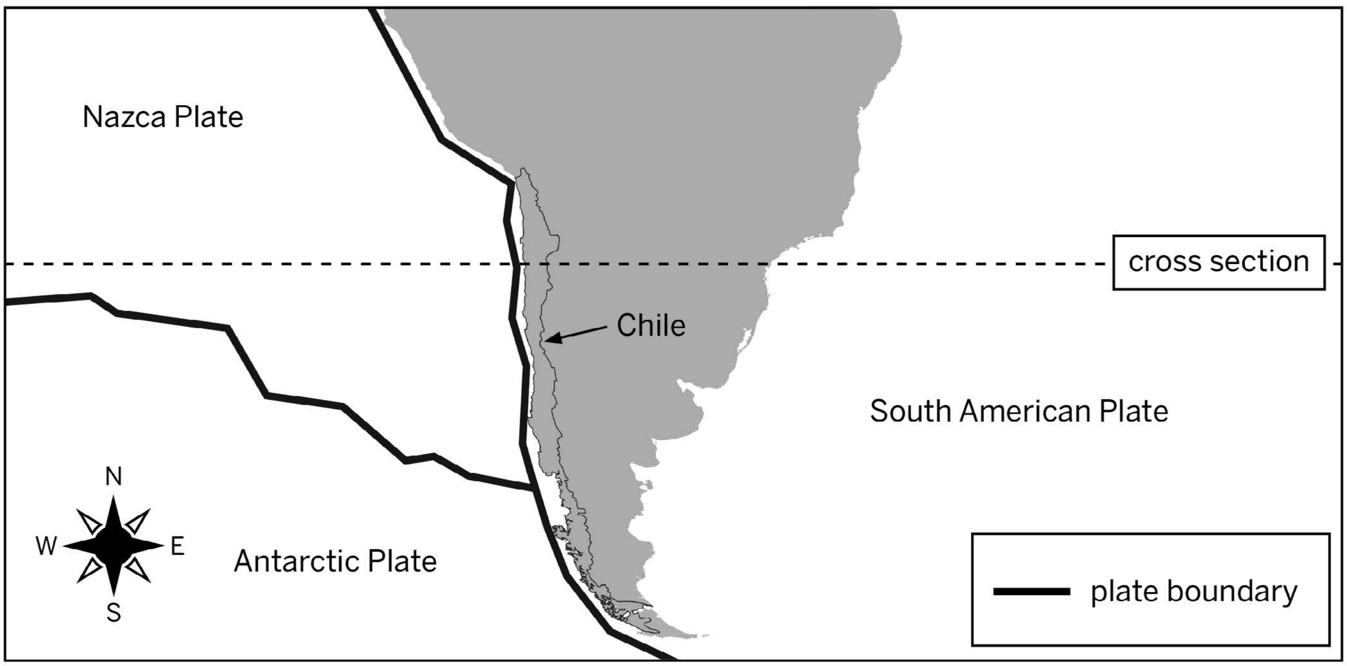
Green Group: Learning About Iceland (continued)

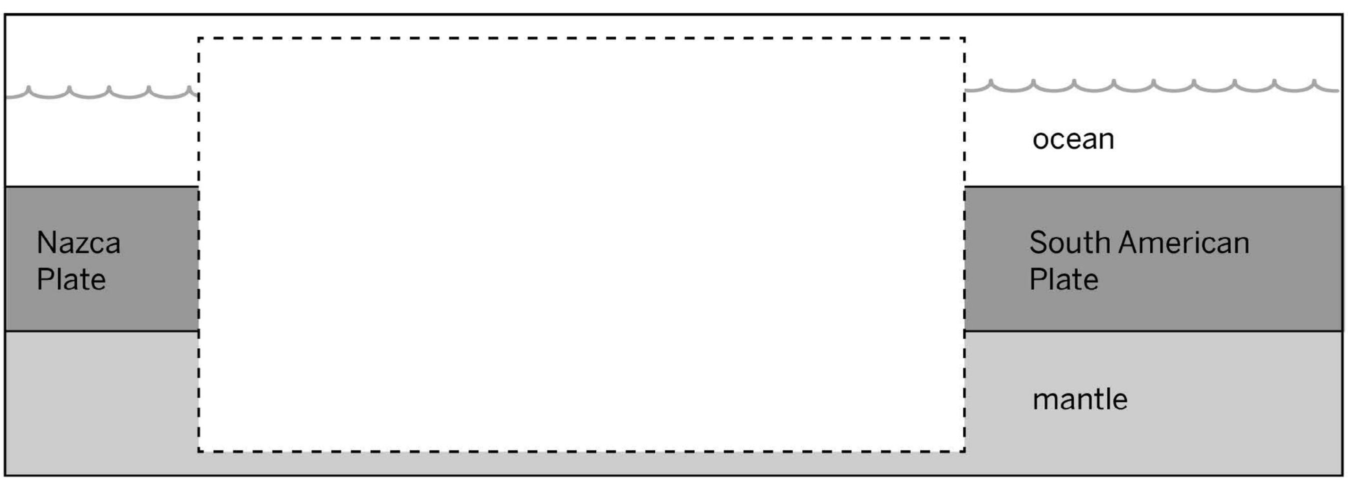
Goal: Show how the plates and mantle interact at the plate boundary near Chile.

Do:

- Draw in the missing part of the cross section below the map to show what happens where the Nazca Plate and the South American Plate meet.
- Add arrows to the map and to the cross section to show the direction in which each plate is moving.

Modeling Chile's Plate Boundary



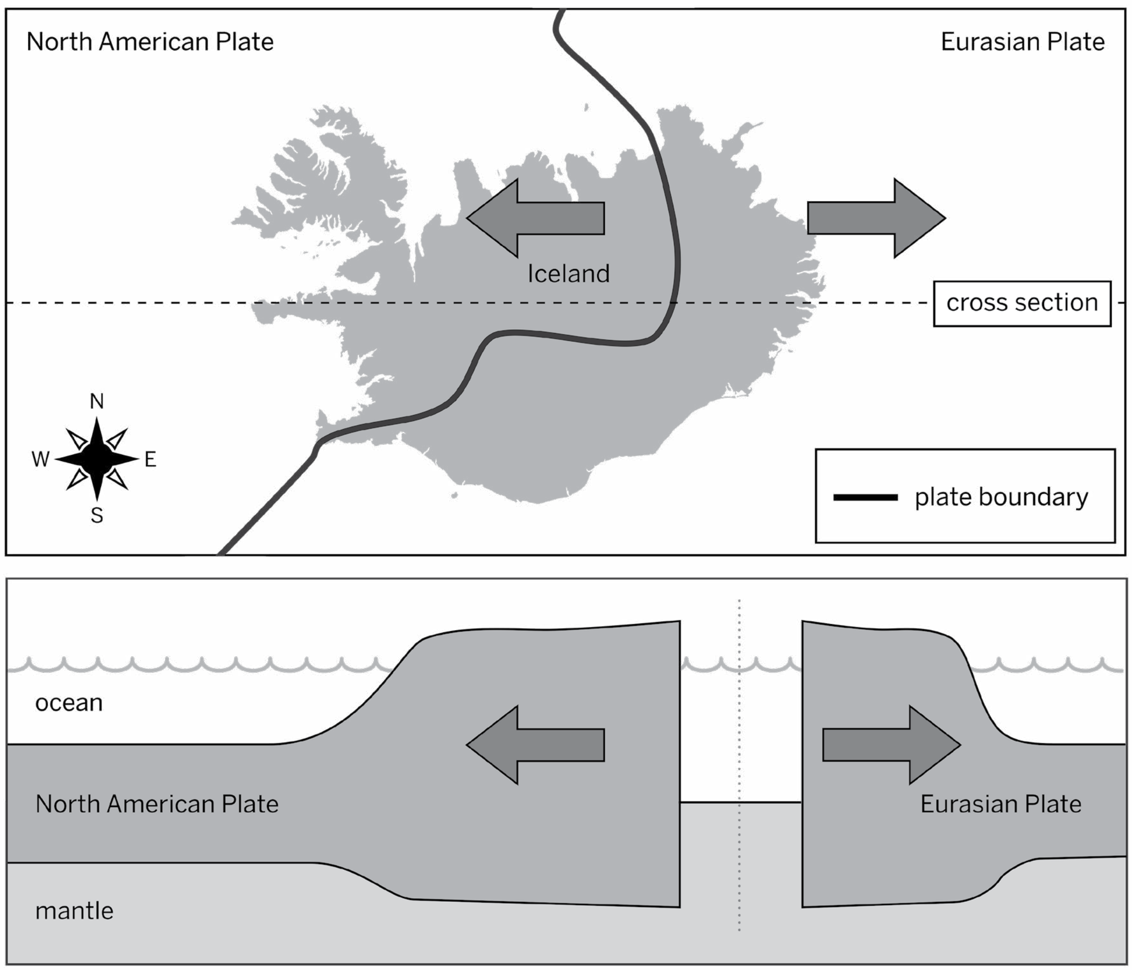


Name: ____________________ Date: ____________

Homework Green Group: Critiquing Models of Iceland's and Chile's Plate Boundaries

Two other student geologists created the models below. Review the two models and then write about what you would change about each model.

Student A



Which parts of this model would you change and why?

____

____

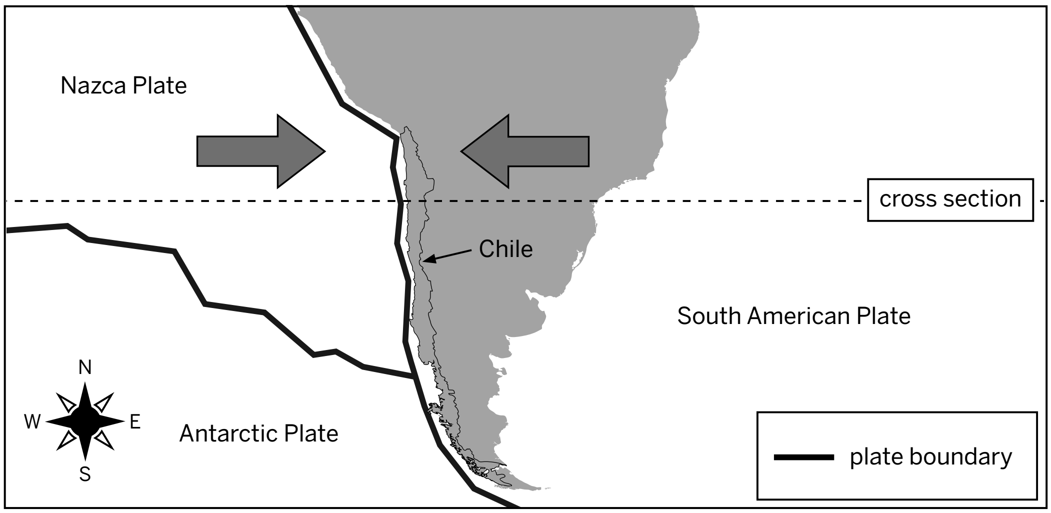
____

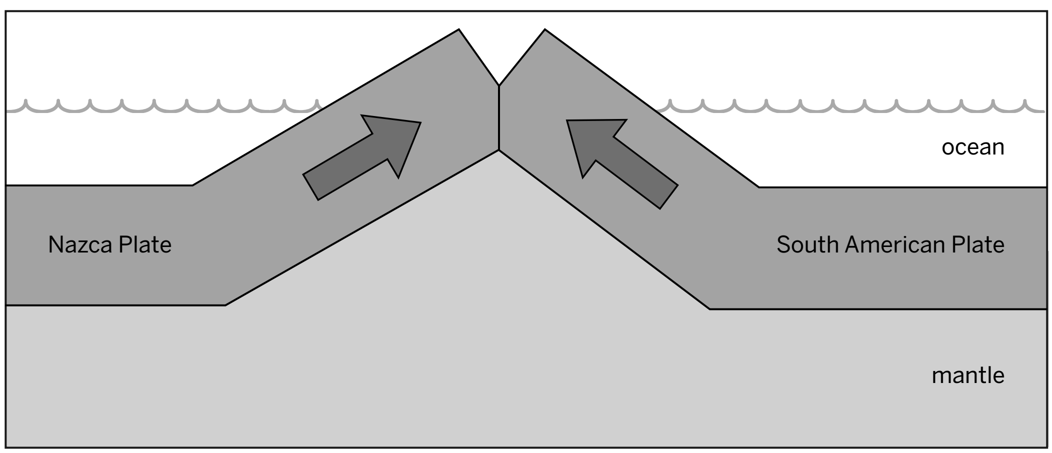
____

Name: ______________________ Date: ______________

Homework Green Group: Critiquing Models of Iceland's and Chile's Plate Boundaries (continued)

Student B





Which parts of this model would you change and why?

____

____

____

____

Name: ______________________________ Date: ________________

Purple Group: Learning About Iceland

Part 1: Reading About Iceland

Read and annotate the “Iceland’s Hotspot” article to learn about a special feature called a hotspot.

Part 2: Modeling Iceland’s Hotspot

Use what you learned in the “Iceland’s Hotspot” article to model what happens at Iceland’s hotspot and how it formed the Greenland-Iceland-Faroes Ridge (GIFR). After you complete your model on the Modeling Tool activity: Modeling Iceland’s Hotspot on page 71, answer the question below, and discuss your answer with your partner.

Which part of the Greenland-Iceland-Faroes Ridge (GIFR) is the oldest? (check one)

- ☐ The part of the ridge near Greenland is the oldest, since it formed first.
- ☐ The part of the ridge near Iceland is the oldest, since it formed first.
- ☐ The whole ridge is the same age, since it formed at the same time.

Discuss your answer with your partner and refer to your model during your explanation.

Name: ______________________________ Date: ____________________

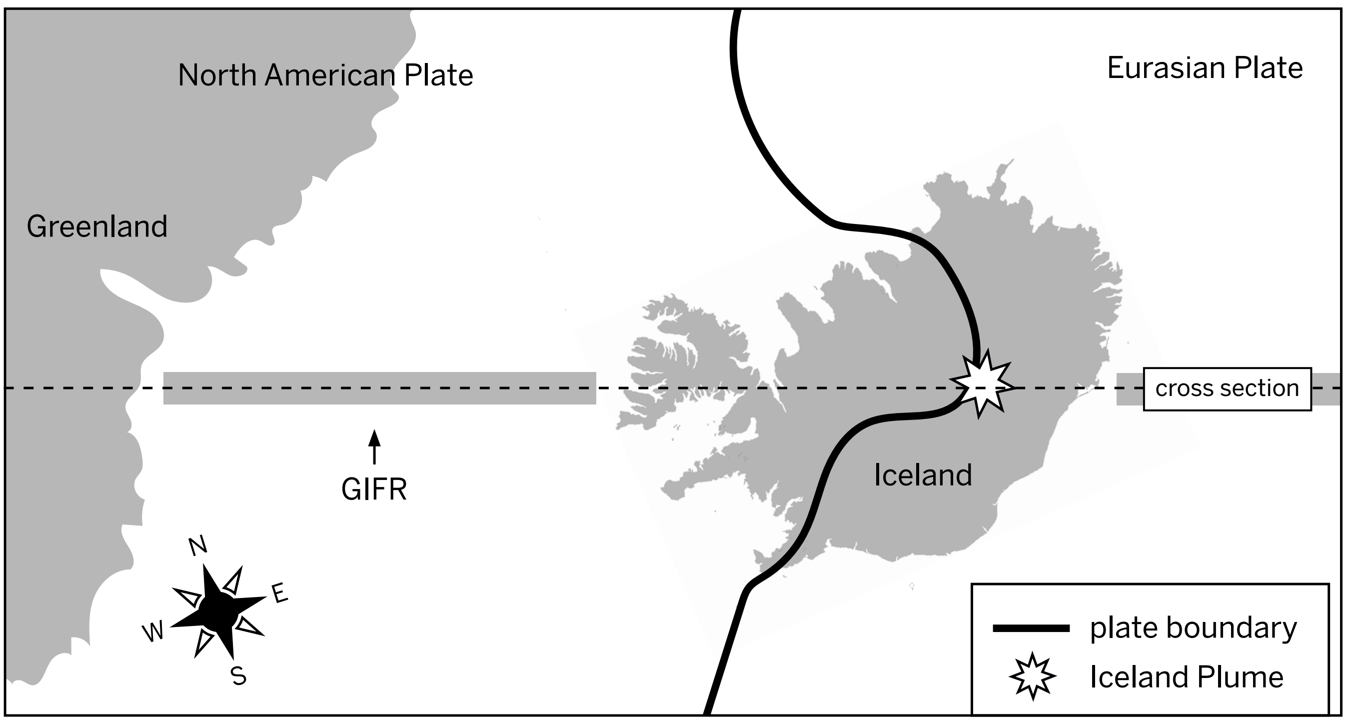
Purple Group: Learning About Iceland (continued)

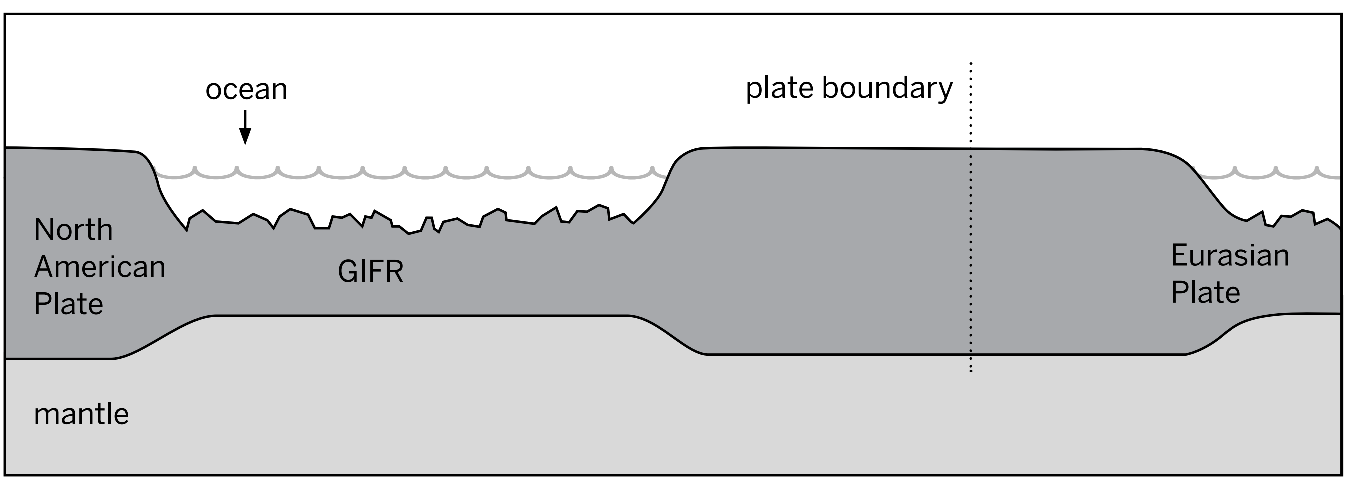
Goal: Show what is happening at the Iceland Plume, a hotspot near Iceland's plate boundary, and how it formed the Greenland-Iceland-Faroes Ridge (GIFR).

Do:

- In the cross section, add an arrow labeled "Hotspot" to show how rock from the mantle is moving at the hotspot.
- Add arrows to the map and to the cross section to show the direction in which each plate is moving.

Modeling Iceland's Hotspot



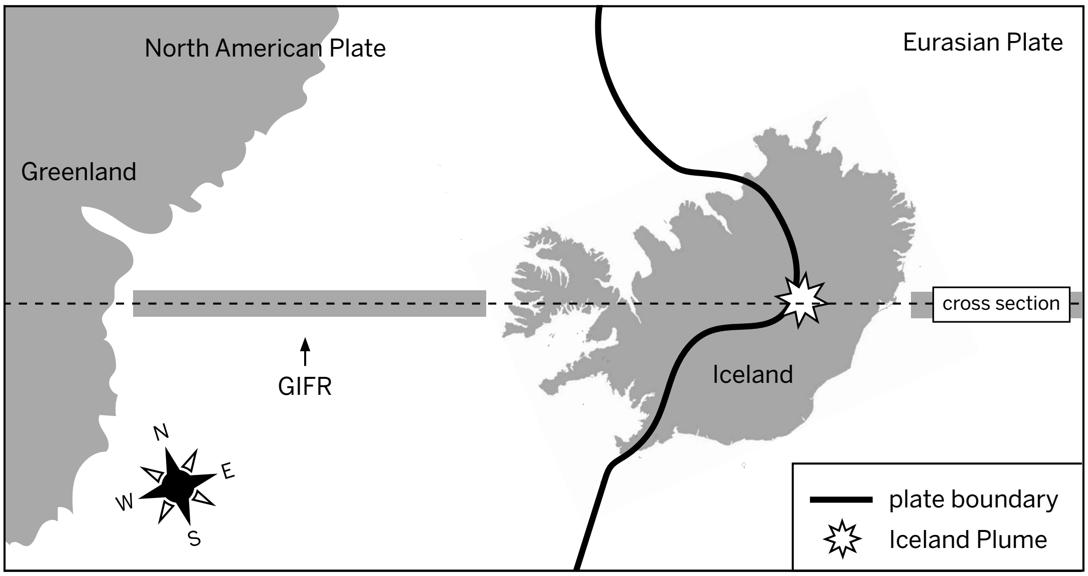


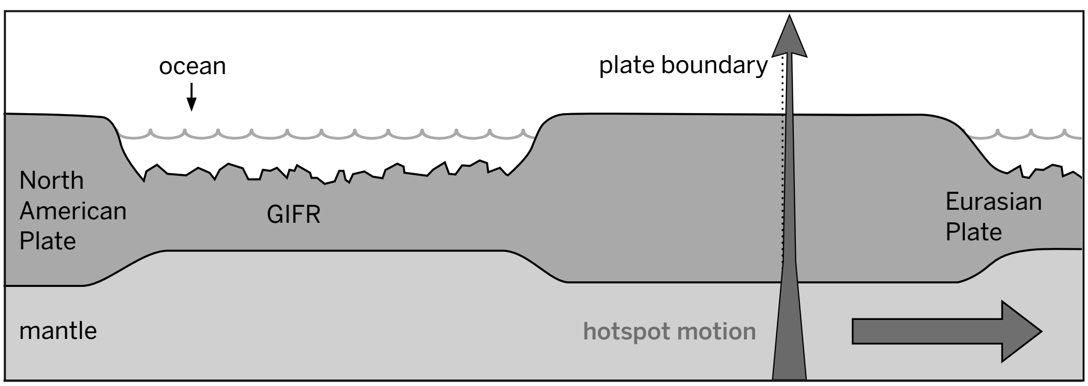
Name: ____________________ Date: ____________

Homework Purple Group: Critiquing Models of Iceland's and Chile's Plate Boundaries

Three other student geologists created the models below. Review the three models and then write about what you would change about each model.

Student A





Which parts of this model would you change and why?

____

____

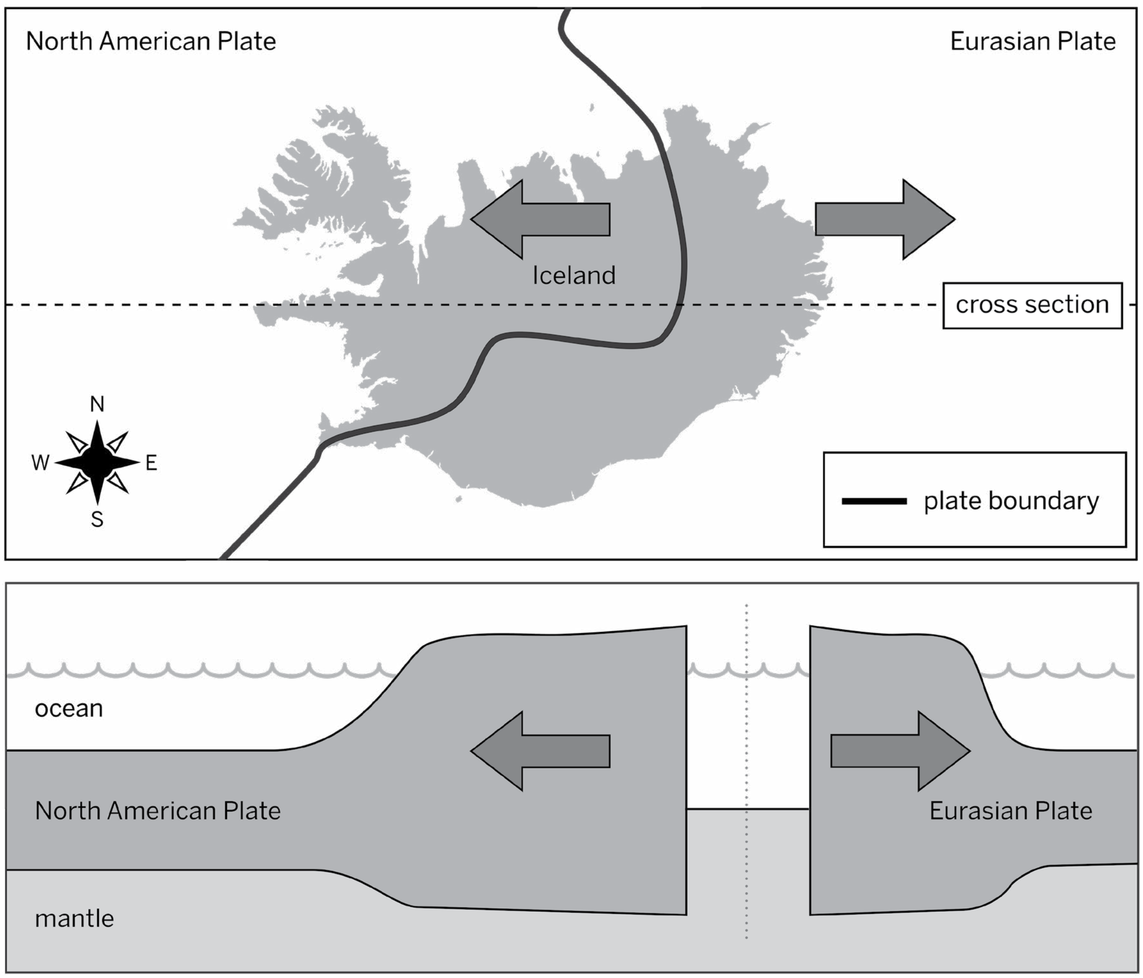
____

____

Name: ______________________ Date: ______________

Homework Purple Group: Critiquing Models of Iceland's and Chile's Plate Boundaries (continued)

Student B



Which parts of this model would you change and why?

____

____

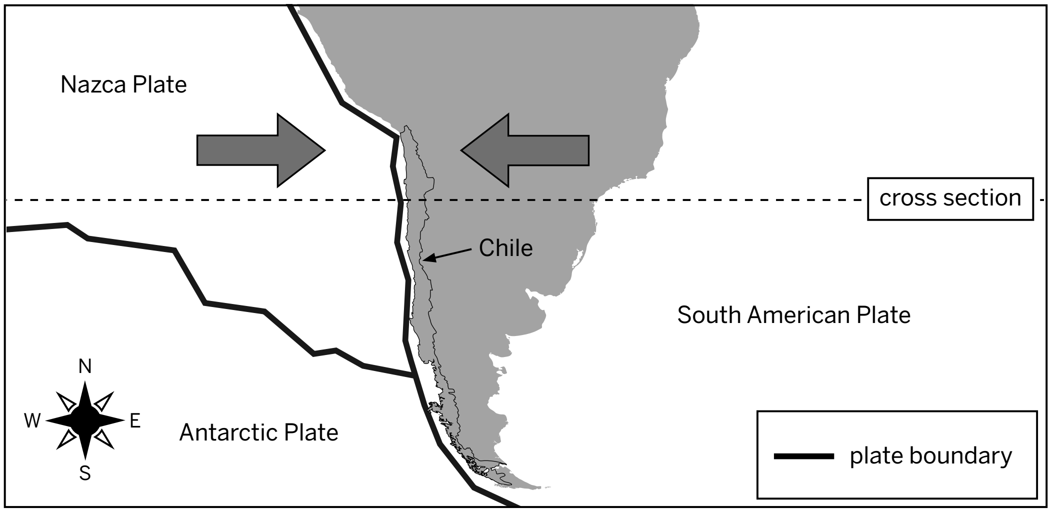
____

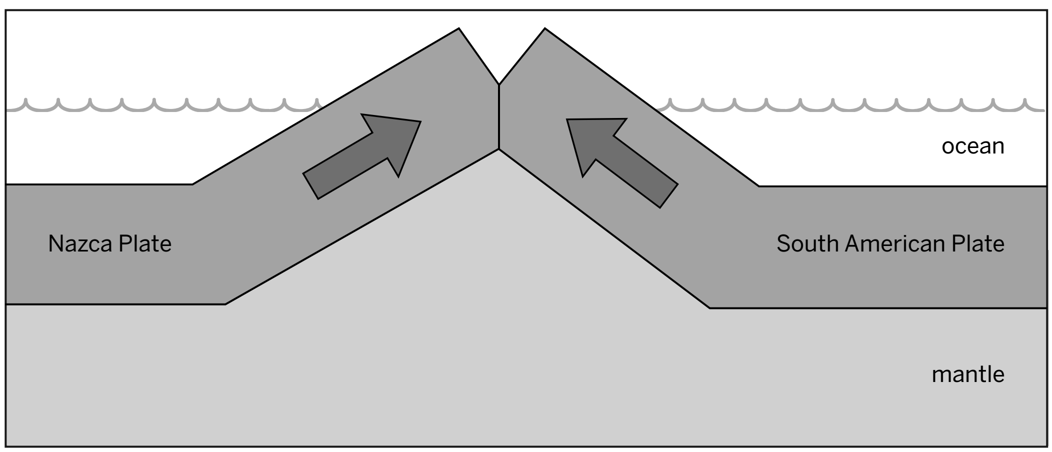
____

Name: ______________________ Date: ______________

Homework Purple Group: Critiquing Models of Iceland's and Chile's Plate Boundaries (continued)

Student C





This model shows the convergent plate boundary near Chile. Which parts of this model would you change and why?

____

____

____

____

Name: ____________________ Date: ____________

Homework: Check Your Understanding

This is a chance to reflect on your learning so far. This is not a test. Be open and truthful when you respond to the questions below.

Scientists investigate in order to figure things out. Are you getting closer to figuring out why the fossils of *Mesosaurus* that once lived together are found in different locations on Earth now?

1. I understand what Earth's outer layer is made of underneath the water and soil on the surface. (check one)

   - [ ] yes
   - [ ] not yet

Explain your answer choice.

____

____

2. I understand what happened with the plates and the mantle between South America and Africa. (check one)

   - [ ] yes
   - [ ] not yet

Explain your answer choice.

____

____

3. I understand what happens with the plates and the mantle when two plates move toward each other. (check one)

   - [ ] yes
   - [ ] not yet

Explain your answer choice.

____

____

Name: ______________________ Date: ______________

Homework: Check Your Understanding (continued)

4. I understand how long it took for South America and Africa to move far away from each other. (check one)

☐ yes

☐ not yet

Explain your answer choice.

____

____

5. What do you still wonder about why the fossils of *Mesosaurus* that once lived together are found in different locations on Earth now?

____

____

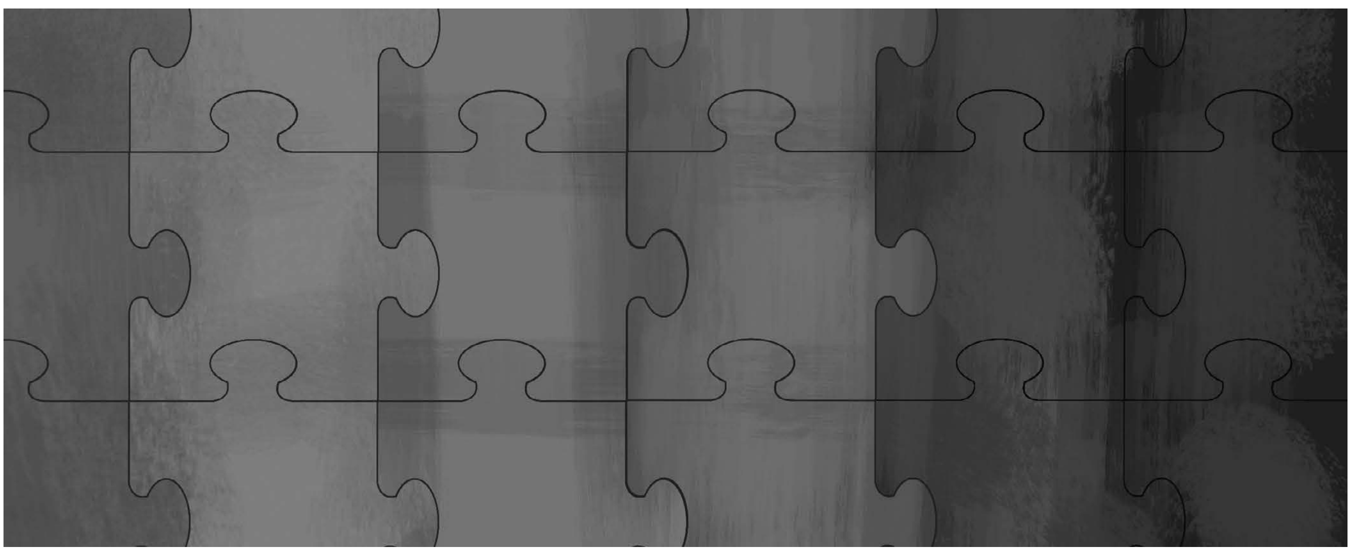
____

____

Name: ______________________________ Date: ____________________

Chapter 3: Investigating the Rate of Plate Movement
Chapter Overview

It’s time to pull the evidence together for Dr. Moraga and the Museum of West Namibia, but you will need one final piece of evidence: How fast are plates moving today? You will look at GPS data and fossil evidence of ancient organisms to learn how these sources help scientists understand plate motion. You will also use your understanding of the rate of plate motion to help you make your argument for Dr. Moraga. Which claim you choose is up to you, but make sure the evidence supports it!



Name: ______________________________ Date: ______________

Lesson 3.1: Considering Rates of Plate Movement

As you determined in the previous lesson, there is a divergent plate boundary between the South American Plate and African Plate. This means that these plates, and the continents on top of these plates, are moving away from each other. This divergent plate motion explains why the fossil remains of *Mesosaurus* that were once together are now found on continents thousands of kilometers apart. But how did this plate movement happen: suddenly or slowly? How is it even possible to figure out how fast the enormous plates that make up Earth's outer layer can travel over time? In this lesson, you will learn how geologists study plate motion and how they calculate the rate of plate movement.

Unit Question

- Why are fossils of species that once lived together found in different locations on Earth now?

Chapter 3 Question

- How did the *Mesosaurus* fossils on the South American Plate and African Plate get so far apart?

Vocabulary

- analyze
- claim
- convergent
- cross section
- divergent
- earthquake
- evidence
- mantle
- mid-ocean ridge
- outer layer
- pattern
- plate
- plate boundary
- rate
- trench
- volcanic activity

Digital Tools

- *Plate Motion* Simulation
- Optional *Plate Motion* Data Tool activity: Plate Distance vs. Time

Name: ______________________________ Date: ______________

Warm-Up

The building in this photo was damaged during an earthquake.

Can we feel plate movement when there isn't an earthquake?

____

____

How far do you think a plate can move in one day?

____

____

How far do you think a plate can move in one year?

____

____

Name: ______________________________ Date: ______________

Observing How Plates Move

How slowly do plates move? Use the Sim to measure how far plates move from each other over time and use your measurements to calculate the rate of plate motion.

1. Open the *Plate Motion* Sim.
2. Go to Region 2 of the Sim.
3. Add a GPS marker to each plate as close as possible to each other and to the plate boundary.
4. Press SET BOUNDARY and select Divergent as the plate boundary type. Then press RUN.
5. During the run, press Pause approximately every 50 million years. Record the time in the first column of the table below. Observe the distance between the two pins by pressing on either pin and reading the distance to the other and then record that number in the Distance column. You can press the Reset button in the top right corner to replay the Sim.
6. Calculate the rate for each pair of distances and times by dividing the distance by the time. Record those numbers in the Rate column.

Fill out the data table below, using evidence from the Sim.

Time (millions of years)	**Distance (km)**	**Rate (km per million years)**

Name: ______________________ Date: ______________

Word Relationships

Geologists think about "slow" and "fast" plate motion in special ways because plate motion happens so slowly. Use the Word Relationships Cards to create sentences that answer both of these questions:

What does "moving slow" mean to a geologist?

Why do you think it is difficult to tell that the plate beneath you is moving right now?

- Use at least two different Word Relationships Cards in each sentence. In your group of four, take turns as both the speaker and the listener.
- Your group may use the same word more than once. You do not need to use all the vocabulary words.
- There are many different ways to answer these questions, and you will need to create more than one sentence in order to express your ideas completely

Word Bank

mantle	outer layer	pattern
plate	plate boundary	rate

Name: ____________________ Date: ____________

Homework: Ideas About the Separation of the *Mesosaurus* Fossils

The Museum of West Namibia wants to know if the *Mesosaurus* fossils were separated in one or a series of quick, huge movements, or if the separation was the result of slow and steady movement.

Given what you learned today, which of the claims below seems best supported? Why? What questions do you still have? Write your response to these questions below, using words from the Word Bank.

Claim 1: The South American Plate and African Plate moved apart **suddenly.**

Claim 2: The South American Plate and African Plate moved apart **gradually.**

Word Bank

mantle	outer layer	pattern
plate	plate boundary	rate

Name: ______________________________ Date: ____________________

Lesson 3.2: "A Continental Puzzle"

It can be overwhelming to think about the massive changes that have happened on Earth over millions and billions of years. In this lesson, you will read an article about a curious scientist named Alfred Wegener, who thought he was just studying climate but ended up with a lot of evidence about plate motion. Once you have read this article, you will be able to apply this understanding to the *Mesosaurus* fossils and use evidence to better explain how the fossils got so far apart.

Unit Question

- Why are fossils of species that once lived together found in different locations on Earth now?

Chapter 3 Question

- How did the *Mesosaurus* fossils on the South American Plate and African Plate get so far apart?

Key Concepts

- Earth's plates travel at a rate too slow to be experienced by humans.

Vocabulary

- analyze
- claim
- convergent
- cross section
- divergent
- earthquake
- evidence
- mantle
- mid-ocean ridge
- outer layer
- pattern
- plate
- plate boundary
- rate
- trench
- volcanic activity

Digital Tools

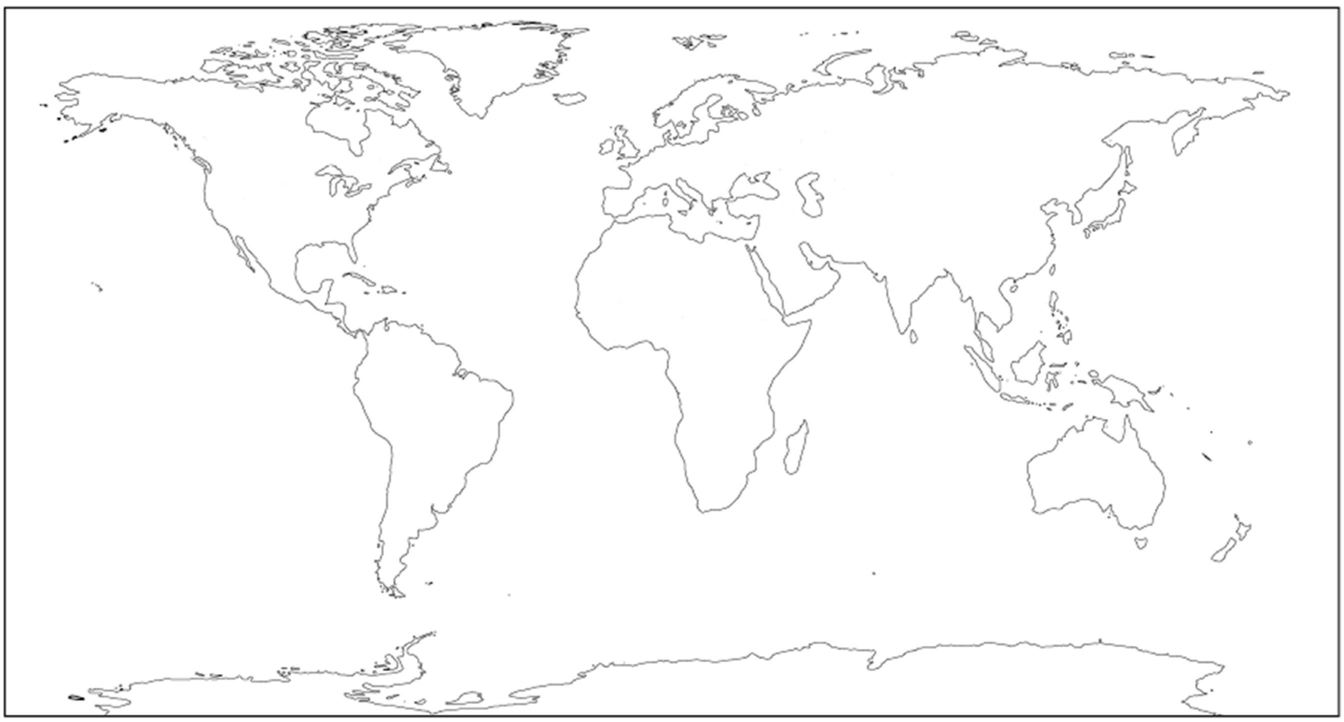
- *Plate Motion* Sorting Tool activity: Earth's History

Name: ______________________________ Date: ______________

Warm-Up

Earth's plates are constantly moving. What evidence do scientists use to support this claim?
Hint: You may choose more than one answer.

- ☐ earthquakes
- ☐ volcanic activity
- ☐ GPS measurements
- ☐ They watch the plates move with their eyes.



If Earth's plates are constantly moving, why don't we need to update the locations of continents on world maps (such as the one above) all the time?

____

____

____

____

Name: ____________________ Date: ____________________

The Value of Fossil Evidence

What evidence do we have of past plate motion?

Discuss the following questions with your partner.

1. How can understanding how plates move today help explain how plates moved in the past?
2. How could knowing about past plate motion help explain how the *Mesosaurus* fossils got separated?

Name: ______________________________ Date: ________________

Reading “A Continental Puzzle”

1. Read and annotate the article “A Continental Puzzle.”
2. Choose and mark annotations to discuss with your partner. Once you have discussed these annotations, mark them as discussed.
3. Now, choose and mark a question or connection, either one you already discussed or a different one you still want to discuss with the class.
4. Answer the reflection question below.

Rate how successful you were at using Active Reading skills by responding to the following statement:

As I read, I paid attention to my own understanding and recorded my thoughts and questions.

- ☐ Never
- ☐ Almost never
- ☐ Sometimes
- ☐ Frequently/often
- ☐ All the time

Active Reading Guidelines

1. Think carefully about what you read. Pay attention to your own understanding.
2. As you read, annotate the text to make a record of your thinking. Highlight challenging words and add notes to record questions and make connections to your own experience.
3. Examine all visual representations carefully. Consider how they go together with the text.
4. After you read, discuss what you have read with others to help you better understand the text.

Name: ______________________________ Date: ________________

Homework: Understanding Earth's History

Fossils found in rock layers have helped scientists understand the sequence of events in Earth's history, such as when different organisms evolved. The Earth's History Sorting Tool activity shows a few kinds of organisms and the approximate time they were first on Earth. Scientists use the kinds of fossils they find, as well as what kind of rock these fossils are found in, as evidence to help them determine both the relative age of the fossils and the relative age of the rocks around the fossils.

Part 1: Earth's History Sorting Tool

Open the Sorting Tool activity: Earth's History to become familiar with how long ago some of these major events occurred.

Goal: Move the images from the toolbar into the correct locations on the timeline.

After you complete the Sorting Tool, press HAND IN.

Part 2: Reading "Steno and the Shark"

Read the "Steno and the Shark" article to learn about how fossils in rock layers have helped scientists understand Earth's history. Annotate the article as you read and answer the questions below.

1. How can scientists use fossils in rock layers as evidence that one event happened earlier than another event?

____

____

____

____

____

2. Look at the events in your Sorting Tool activity and at the Geologic Time Scale diagram from the article. In what period did the first fish appear?

____

3. Use the Sorting Tool activity to find another event in Earth's history. Name the event and the period or eon in which the event occurred.

Event: ______________________ Period/Eon: ______________________

Name: ________________________________ Date: ________________

Lesson 3.3: Reconstructing Gondwanaland

In this lesson, you will interpret the evidence scientists use to understand past plate motion. To accomplish this, you will return to the article about Alfred Wegener. After closely rereading part of the article, you will complete an activity that challenges you to think about evidence of past plate motion the way Wegener did.

Unit Question

- Why are fossils of species that once lived together found in different locations on Earth now?

Chapter 3 Question

- How did the *Mesosaurus* fossils on the South American Plate and African Plate get so far apart?

Key Concepts

- Earth's plates travel at a rate too slow to be experienced by humans.

Vocabulary

- analyze
- claim
- convergent
- cross section
- divergent
- earthquake
- evidence
- mantle
- mid-ocean ridge
- outer layer
- pattern
- plate
- plate boundary
- rate
- scientific argument
- trench
- volcanic activity

Digital Tools

- *Plate Motion* Sorting Tool activity: Plate Motion Predictions

Name: ______________________________ Date: ________________

Warm-Up

Open the Sorting Tool activity: Plate Motion Predictions and follow the instructions below. You'll be revising this response for homework.

When your model is complete, press HAND IN. If you worked with a partner, write their name here:

____

Goal: Show where you think South America and Africa will be located 50 years from now and 50 million years from now.

Do:

- Place the continents labeled "50 Years Later" and "50 Million Years Later" to indicate where you think they will be located at those times.

Tip:

- The gray continents shown on the map indicate the current locations of South America and Africa.

Name: ____________________ Date: ____________

Rereading "A Continental Puzzle"

By rereading a portion of the article "A Continental Puzzle," you will be able to answer the Investigation Question: *What evidence do we have of past plate motion?*

Read and annotate the first three paragraphs in the "Evidence of Change on Earth's Surface" section. Highlight or annotate any important information you find and then answer the questions below.

How did Wegener use the shapes of the continents as evidence that the continents had moved?

____

____

____

How did Wegener use the similar mountain ranges and areas made of certain types of rock found in Africa and South America as evidence that these two continents were once connected?

____

____

____

How did Wegener use fossils as evidence that continents had moved?

____

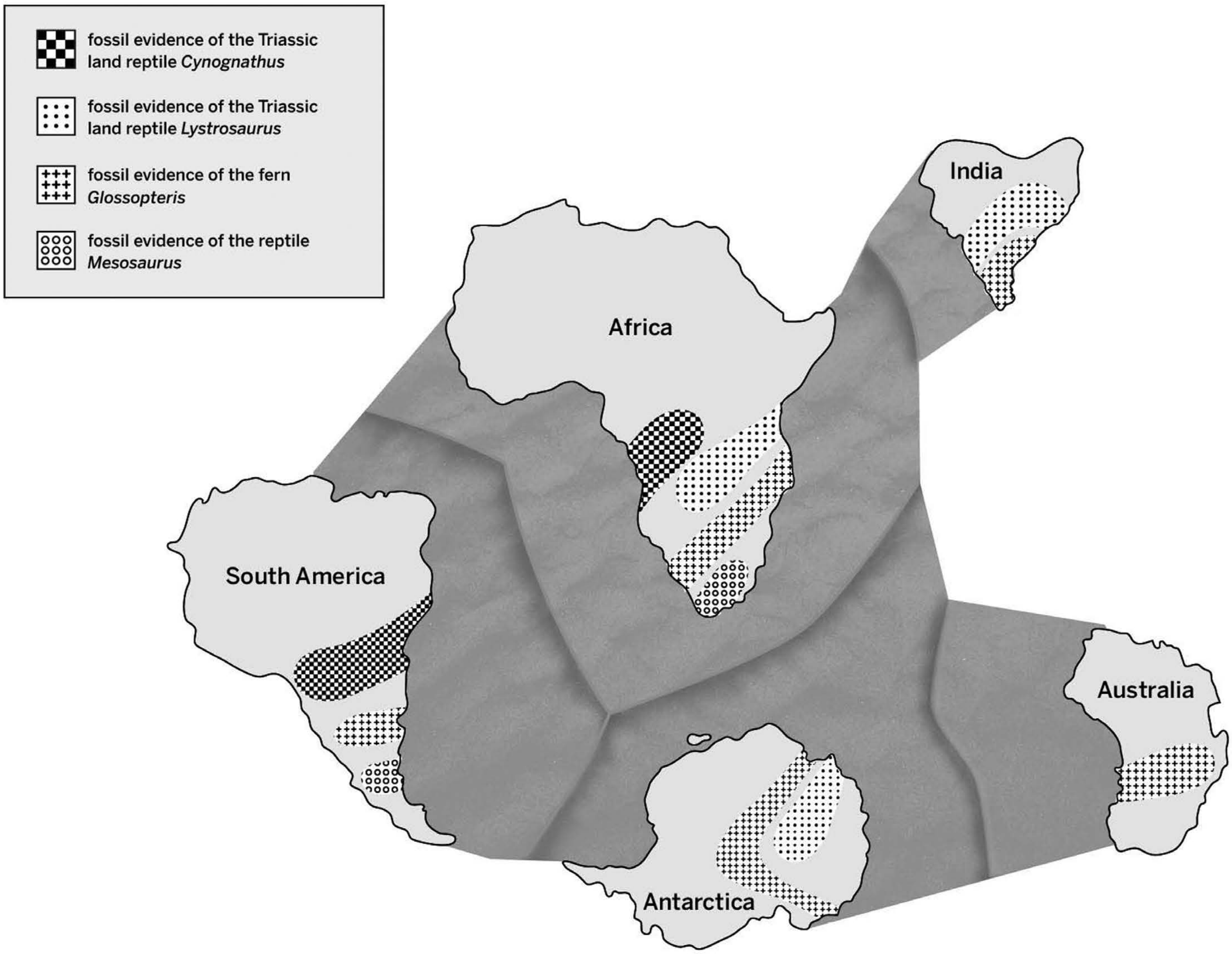
____

____

Name: ______________________________ Date: ____________________

Reconstructing Gondwanaland

Part 1: Map of Gondwanaland Today



Discussion Questions

- If you were to go back in time, to 200 million years ago, what do you think the location of these landmasses would be?
- Would there be more ocean floor between the continents or less? Why?

Name: ____________________ Date: ____________

Reconstructing Gondwanaland (continued)

Part 2: Reconstructing Gondwanaland

Instructions

1. Gather the map, a glue stick, and a blank sheet of paper.
2. Cut away and discard the white space on your map.
3. Cut the plates apart along the plate boundaries. These boundaries are found in the middle of the oceans.
4. Cut away the ocean floor. This hard, solid rock formed between the landmasses over the last 200 million years.
5. Use the fossil evidence and the shapes of the landmasses to reconstruct Gondwanaland as it was 200 million years ago.
6. Glue your Gondwanaland to the blank sheet of paper.

Discussion Questions

- Why did you cut away the hard, solid rock on the ocean floor that formed between the landmasses over the last 200 million years?
- After cutting away the hard, solid rock that makes up the ocean floor, what was your strategy for putting the landmasses of Gondwanaland back together, as they were 200 million years ago?
- How did your knowledge of plate motion help you complete the Gondwanaland puzzle?

Name: ______________________ Date: ______________

Homework: Revising Your Predictions

Open the Sorting Tool activity: Plate Motion Predictions and revise your response, if needed.

When your model is complete, press HAND IN. If you worked with a partner, write their name here:

____

Goal: Show where you think South America and Africa will be located 50 years from now and 50 million years from now.

Do:

- Place the continents labeled "50 Years Later" and "50 Million Years Later" to indicate where you think they will be located at those times.

Tip:

- The gray continents shown on the map indicate the current locations of South America and Africa.

How is your revised response different from your Warm-Up response? Why did you make these changes?

____

____

____

Name: ______________________ Date: ______________

Lesson 3.4: Writing About *Mesosaurus*

It's almost time! Dr. Moraga needs to know how the *Mesosaurus* fossils got so far apart from each other, and by the end of this lesson, you'll be ready to explain that to him. In the meantime, you and your fellow student geologists will review the evidence and discuss how it can be used to make the most convincing scientific argument to Dr. Moraga and his team at the Museum of West Namibia.

Unit Question

- Why are fossils of species that once lived together found in different locations on Earth now?

Chapter 3 Question

- How did the *Mesosaurus* fossils on the South American Plate and African Plate get so far apart?

Key Concepts

- Earth's plates travel at a rate too slow to be experienced by humans.
- It takes a long time for Earth's plates to travel great distances.

Vocabulary

- analyze
- claim
- convergent
- cross section
- divergent
- earthquake
- evidence
- mantle
- mid-ocean ridge
- outer layer
- pattern
- plate
- plate boundary
- rate
- reasoning
- scientific argument
- trench
- volcanic activity

Digital Tools

- *Plate Motion* Simulation

Name: ______________________ Date: ______________

Warm-Up

Use the fossil function in the Sim to re-create what happened to the *Mesosaurus* fossils over time.

1. Open the Sim.
2. Select Region 3. Use the Add Rock tool to set up the land as it was when the *Mesosaurus* was alive.
3. Drag and drop fossils onto the land.
4. Add GPS markers near two fossils, one on each side of the plate boundary.
5. Press SET BOUNDARY and select the plate boundary type.
6. Press RUN and observe what happens to the fossils.
7. How far apart are the fossils after 200 million years? Is this what happened to the *Mesosaurus* fossils? If not, press BUILD and try setting up the landscape differently.
8. After you have re-created what happened to the *Mesosaurus* fossils in the Sim, describe what happened to the fossils below.

____

____

____

Be prepared to discuss the following questions with a partner.

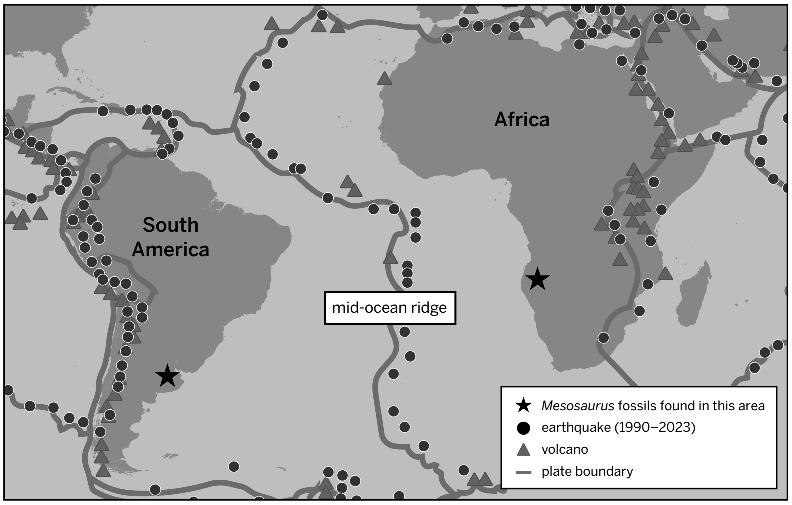
Discussion Questions

- What happened to the fossils over time in the Sim?
- How is this similar to what you know about *Mesosaurus* fossils? How is this different from what you know about *Mesosaurus* fossils?
- What can you observe about how Earth's surface changed over time?

Name: ______________________ Date: ______________

Examining Evidence About Plate Motion

Read the evidence cards below. Then, record any notes you think will help you better understand the evidence and help you prepare to write your final argument.



Evidence Card A
Earthquakes occur in a pattern along the plate boundary between the South American Plate and African Plate.

Evidence Card B
A mid-ocean ridge landform is found along the plate boundary between the South American Plate and African Plate.

Evidence Card C
Volcanic activity happens in a pattern along the plate boundary between the South American Plate and African Plate.

Notes about this evidence:

____

____

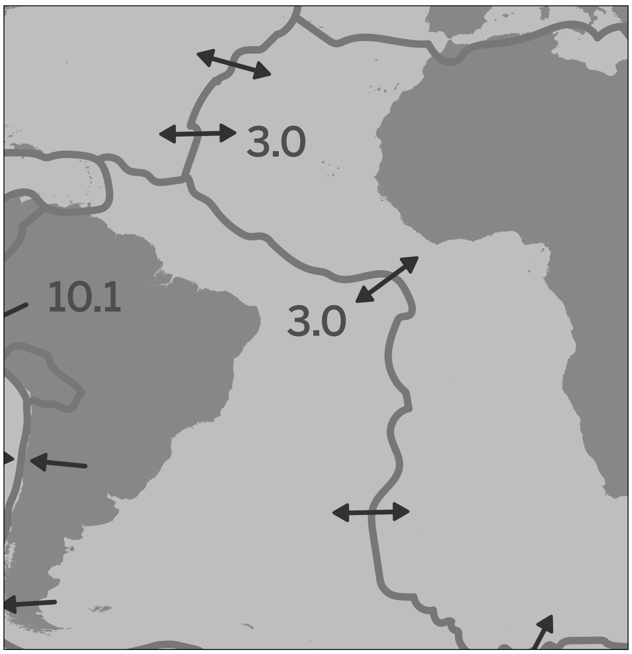
____

____

Name: ______________________________ Date: ________________

Examining Evidence About Plate Motion (continued)

Read the additional evidence card below. Then, record any notes you think will help you better understand the evidence and help you prepare to write your final argument.



Evidence Card D

The continents of South America and Africa, where *Mesosaurus* fossils are located, are currently about 4,000 km apart and separated by the Atlantic Ocean. GPS measurements show that the South American Plate and African Plate are currently spreading apart from each other at a rate of 3.0 cm per year.

Notes about this evidence:

____

____

____

____

Name: ____________________ Date: ____________

Reasoning About Plate Motion

With your group, use the Reasoning Tool to connect each piece of evidence to the claim you think is strongest.

Question: How did the *Mesosaurus* fossils on the South American Plate and African Plate get so far apart?

Claim 1: The South American Plate and African Plate moved apart **suddenly**.

Claim 2: The South American Plate and African Plate moved apart **gradually**.

Evidence	**This matters because . . .**	**Therefore, . . .** (claim)
A. Earthquakes occur in a pattern along the plate boundary between the South American Plate and African Plate.		
B. A mid-ocean ridge landform is found along the plate boundary between the South American Plate and African Plate.		
C. Volcanic activity happens in a pattern along the plate boundary between the South American Plate and African Plate.		
D. The continents of South America and Africa, where *Mesosaurus* fossils are located, are currently about 4,000 km apart and separated by the Atlantic Ocean. GPS measurements show that the South American Plate and African Plate are currently spreading apart from each other at a rate of 3.0 cm per year.		

Name: ______________________________ Date: ____________________

Homework: Advising the Museum of West Namibia

Use the notes you recorded about the evidence and the work you did with your group using the Reasoning Tool to help you write a message to Dr. Moraga about the *Mesosaurus'* history. You may wish to use some of the vocabulary words listed in the Word Bank below to help you write.

Question: How did the *Mesosaurus* fossils on the South American Plate and African Plate get so far apart?

Claim 1: The South American Plate and African Plate moved apart **suddenly.**

Claim 2: The South American Plate and African Plate moved apart **gradually.**

Word Bank

plate	plate boundary	rate
convergent	divergent	pattern

Write a message to Dr. Bayard Moraga explaining how the Museum of West Namibia's exhibit should tell the story of the *Mesosaurus.*

First, state your claim about how the *Mesosaurus* fossils got separated. Then, use evidence to support your claim. For each piece of evidence you use, explain how the evidence supports your claim.

Name: ______________________ Date: ______________

Homework: Check Your Understanding

This is a chance to reflect on your learning so far. This is not a test. Be open and truthful when you respond to the questions below.

Scientists investigate in order to figure things out. Are you getting closer to figuring out why the fossils of *Mesosaurus* that once lived together are found in different locations on Earth now?

1. I understand what Earth's outer layer is made of underneath the water and soil on the surface. (check one)

   ☐ yes

   ☐ not yet

Explain your answer choice.

____

____

2. I understand what happened with the plates and the mantle between South America and Africa. (check one)

   ☐ yes

   ☐ not yet

Explain your answer choice.

____

____

3. I understand what happens with the plates and the mantle when two plates move toward each other. (check one)

   ☐ yes

   ☐ not yet

Explain your answer choice.

____

____

Name: ______________________________ Date: ________________

Homework: Check Your Understanding (continued)

4. I understand how long it took for South America and Africa to move far away from each other. (check one)

   ☐ yes

   ☐ not yet

Explain your answer choice.

____

____

5. I understand that theories are based on a lot of evidence gathered by many scientists over time. (check one)

   ☐ yes

   ☐ not yet

Explain your answer choice.

____

____

6. What do you still wonder about why the fossils of *Mesosaurus* that once lived together are found in different locations on Earth now?

____

____

____

____

Name: ______________________ Date: ______________

Chapter 4: Science Seminar
Chapter Overview

Now that you've helped explain how plate motion caused the separation of the *Mesosaurus* fossils, Dr. Moraga's colleague needs your help to explain a different plate-motion mystery. This time, the mystery you will consider is about the Jalisco Block, a section of the North American Plate located in Mexico. The Jalisco Block has a lot of geologic activity. You will help Dr. Moraga's colleague explain to the people of Jalisco the most likely cause of the intense geologic activity in their region.

Name: ______________________ Date: ______________

Lesson 4.1: Plate Motion Near Jalisco, Mexico

Student geologists, your work with Dr. Moraga established you as valuable contributors to the Museum of West Namibia. Your help is needed once again. Dr. Moraga has been contacted by a colleague in Guadalajara, Mexico, eager to uncover a current geologic mystery. A pattern of volcanic activity and earthquakes in and near the Jalisco area seems to be emerging over the past several thousand years—but why? Dr. Moraga's colleague has sent over some information, but she needs your help to figure out what it all means.

Unit Question

- Why are fossils of species that once lived together found in different locations on Earth now?

Chapter 4 Question

- What best explains the pattern of volcanic activity and earthquakes on the Jalisco Block?

Key Concepts

- Earth's outer layer is made of hard, solid rock.
- Earth's outer layer is divided into sections called plates.
- Geologists look for patterns in landforms and in geologic events in order to better understand Earth.
- The plates of Earth's outer layer move.
- Earth's plates move on top of a soft, solid layer of rock called the mantle.
- At divergent plate boundaries, rock rises from the mantle and hardens, adding new solid rock to the edges of both plates.
- At convergent plate boundaries, one plate moves underneath the other plate and sinks into the mantle.
- Earth's plates travel at a rate too slow to be experienced by humans.
- It takes a long time for Earth's plates to travel great distances.

Name: ______________________ Date: ______________

Lesson 4.1: Plate Motion Near Jalisco, Mexico (continued)

Vocabulary

- analyze
- claim
- convergent
- cross section
- divergent
- earthquake
- evidence
- mantle
- mid-ocean ridge
- outer layer
- pattern
- plate
- plate boundary
- rate
- reasoning
- scientific argument
- trench
- volcanic activity

Name: ____________________ Date: ____________

Warm-Up

Welcome to Guadalajara, Mexico

Guadalajara is a city in the state of Jalisco, in western Mexico. On the map below, the country of Mexico is shown in dark gray. The state of Jalisco is shown in white.

- Look at the map below and then answer the question.
- Share your ideas with your partner.

Look at where the state of Jalisco is on this plate boundary map. What do you notice about Jalisco and the plate boundaries near it? Can you make any predictions based on what you see?

____

____

____

____

____

____

Name: ______________________ Date: ______________

Introducing the Jalisco Block

To: Student Geologists
From: Dr. Bayard Moraga, Lead Curator, Museum of West Namibia
Subject: Jalisco Block

MUSEUM OF WEST NAMIBIA

Thank you so much for all your help with our *Mesosaurus* exhibit. I've submitted your work to our museum's exhibit builders, and they are getting started building and painting a display that tells the *Mesosaurus* story. You've done a great job helping us communicate how the *Mesosaurus* fossils got so far apart!

I just got an email from a colleague who lives in Guadalajara, a city in Jalisco, Mexico. Jalisco is a state located on the North American Plate. This is an interesting area to geologists because it's near many plate boundaries. Many people live in this area of Mexico. I told my colleague about your great work for us here at the Museum of West Namibia, and she wants your help to explain the geologic activity in the area to local residents.

Geologists can't agree on how plates are moving in this area. The data they've collected doesn't point to one clear explanation. We need your help considering the evidence about plate motion in the area.

I'm forwarding you the data the geologists sent over that might be useful. Please contact us as soon as you have analyzed the data.

Science Seminar Question: *What best explains the pattern of volcanic activity and earthquakes on the Jalisco Block?*

Claim 1: Convergent movement between the Jalisco Block and the Rivera Plate best explains the pattern of volcanic activity and earthquakes on the Jalisco Block.

Claim 2: Divergent movement of the Jalisco Block away from the North American Plate best explains the pattern of volcanic activity and earthquakes on the Jalisco Block.

Name: ______________________________ Date: ____________________

Analyzing Evidence

Part 1: Analyzing Evidence Card A

Examine Evidence Card A. Annotate the card to help you think about the evidence. Then, discuss the evidence with your partner using the discussion questions below.

Discussion Questions

- What does this evidence tell you about whether the Jalisco Block is moving?
- What does this evidence tell you about which kind of movement might cause this geologic activity?

Part 2: Analyzing Evidence Cards B, C, D, and E

Examine the rest of the evidence (Evidence Cards B, C, D, and E). Annotate the cards to help you think about them. Then, discuss the evidence with your partner using the discussion questions below.

Discussion Questions

- **Evidence Card B:** What do you notice about the pattern of volcanic activity on the Jalisco Block?
- **Evidence Card C:** What does this evidence tell you about the boundary between the Rivera Plate and the Jalisco Block?
- **Evidence Card D:** How can the movement of two plates form a trench?
- **Evidence Card E:** What can the pattern of recent earthquakes tell you about plate motion on the Jalisco Block?

Part 3: Evaluating the Evidence: Plate Motion in Jalisco

Based on this evidence, do you think it is possible that the Jalisco Block is moving? (check one)

☐ yes

☐ no

Based on all the evidence you just analyzed, what type of plate motion do you think is most likely causing the patterns of volcanic activity and earthquakes in this area? (check one)

☐ Divergent movement of the Jalisco Block away from the North American plate at the TZ Rift Zone.

☐ Convergent movement between the Jalisco Block and the Rivera Plate.

☐ A and B are equally likely.

Name: ______________________________ Date: ____________________

Sorting Evidence

1. With a partner, discuss whether each piece of evidence supports or goes against a claim. Use the sentence starters below to help you talk with your partner.
2. Make annotations on each evidence card:
   - If the evidence supports a claim, write "supports Claim 1 *or* 2" on that card.
   - If the evidence goes against a claim, write "goes against Claim 1 *or* 2" on that card.
   - If the evidence on one card connects with evidence on another evidence card, write "connects with Evidence Card A (*or* B, C, D, E)" on that card.
3. Sort the evidence by placing each card underneath the claim it supports, on the appropriate Argument Organizer.

Sentence Starters

I think this piece of information supports this claim because . . .

I don't think this piece of information supports this claim because . . .

I agree because . . .

I disagree because . . .

I think that . . .

Name: ____________________ Date: ____________

Homework: Reading "How Baja Was Born"

Geologists often look for examples of similar cases when they are trying to explain a mystery. Read and annotate the "How Baja Was Born" article, which provides a short explanation of rifting that happened in Baja California. Then, answer the questions.

What is similar between what is happening in Jalisco and what happened in Baja?

____

____

____

____

What is different between what is happening in Jalisco and what happened in Baja?

____

____

____

____

Active Reading Guidelines

1. Think carefully about what you read. Pay attention to your own understanding.
2. As you read, annotate the text to make a record of your thinking. Highlight challenging words and add notes to record questions and make connections to your own experience.
3. Examine all visual representations carefully. Consider how they go together with the text.
4. After you read, discuss what you have read with others to help you better understand the text.

Name: ____________________ Date: ____________

Lesson 4.2: Participating in a Science Seminar

What is causing the volcanic activity and earthquakes in the Jalisco area? Today, you'll discuss this topic, using what you know about plate motion and evidence about the Jalisco Block to build an argument. Is it convergent movement between the Jalisco Block and the Rivera Plate, or is it divergent movement of the Jalisco Block away from the North American Plate? Time to make your case, student geologists!

Unit Question

- Why are fossils of species that once lived together found in different locations on Earth now?

Chapter 4 Question

- What best explains the pattern of volcanic activity and earthquakes on the Jalisco Block?

Key Concepts

- Earth's outer layer is made of hard, solid rock.
- Earth's outer layer is divided into sections called plates.
- Geologists look for patterns in landforms and in geologic events in order to better understand Earth.
- The plates of Earth's outer layer move.
- Earth's plates move on top of a soft, solid layer of rock called the mantle.
- At divergent plate boundaries, rock rises from the mantle and hardens, adding new solid rock to the edges of both plates.
- At convergent plate boundaries, one plate moves underneath the other plate and sinks into the mantle.
- Earth's plates travel at a rate too slow to be experienced by humans.
- It takes a long time for Earth's plates to travel great distances.

Vocabulary

- analyze
- claim
- convergent
- cross section
- divergent
- earthquake
- evidence
- mantle
- mid-ocean ridge
- outer layer
- pattern
- plate
- plate boundary
- rate
- reasoning
- scientific argument
- trench
- volcanic activity

Name: ______________________ Date: ______________

Warm-Up

Revisiting the Evidence

Take out your Argument Organizers and evidence cards from the previous lesson. Look back at the evidence cards and review your annotations. Then, use the evidence cards to answer the questions below.

What best explains the pattern of volcanic activity and earthquakes on the Jalisco Block?

Which claim do you think is the most convincing? (check one)

- ☐ **Claim 1:** Convergent movement between the Jalisco Block and the Rivera Plate best explains the pattern of volcanic activity and earthquakes on the Jalisco Block.
- ☐ **Claim 2:** Divergent movement of the Jalisco Block away from the North American Plate best explains the pattern of volcanic activity and earthquakes on the Jalisco Block.

Draw a star on the evidence card that best supports your claim, then explain in the space below why you chose that evidence.

____

____

____

____

Name: ______________________________ Date: ______________

Preparing for the Science Seminar

Preparing Your Science Seminar Argument

1. With your partner, take turns sharing which claim you think is the most convincing and why.
2. Use your Warm-Up responses, your Argument Organizers, and the Argumentation Sentence Starters to help you share ideas.

What best explains the pattern of volcanic activity and earthquakes on the Jalisco Block? (check one)

- ☐ **Claim 1:** Convergent movement between the Jalisco Block and the Rivera Plate best explains the pattern of volcanic activity and earthquakes on the Jalisco Block.
- ☐ **Claim 2:** Divergent movement of the Jalisco Block away from the North American Plate best explains the pattern of volcanic activity and earthquakes on the Jalisco Block.

Name: ______________________ Date: ______________

Science Seminar Observations

Write a check mark in the right-hand column every time you hear one of your peers say or do something listed in the left-hand column. If you hear an interesting idea, write it in the last row of the table.

Observations during the seminar	**Check marks**
I heard a student use evidence to support a claim.	
I heard a student respectfully disagree with someone else's thinking.	
I heard a student explain how her evidence is connected to her claim.	
I heard a student evaluate the quality of evidence.	
I heard an idea that makes me better understand one of the claims. That idea is:	

Name: ______________________________ Date: ________________

Homework: Reflecting on the Science Seminar

Now that the Science Seminar is over, think back on the claim you selected. After participating in the discussion, you may have changed your mind about which claim is best. Describe your current thinking by answering the questions below.

What best explains the pattern of volcanic activity and earthquakes on the Jalisco Block? (check one)

- ☐ **Claim 1:** Convergent movement between the Jalisco Block and the Rivera Plate best explains the pattern of volcanic activity and earthquakes on the Jalisco Block.
- ☐ **Claim 2:** Divergent movement of the Jalisco Block away from the North American Plate best explains the pattern of volcanic activity and earthquakes on the Jalisco Block.

Did the Science Seminar cause you to change your thinking about the claims? Explain your answer.

____

____

____

____

Name: ______________________________ Date: ____________________

Lesson 4.3: Writing a Scientific Argument

It's time to make your final scientific argument! You've discussed the claims and the evidence about the Jalisco Block. Now, it's time for you to make your case in writing. Today, you'll review the evidence and use the Reasoning Tool to organize your thinking. Then, you'll write a scientific argument to Dr. Moraga and his colleague in Guadalajara, stating which type of plate motion you think best explains the pattern of geologic activity on the Jalisco Block. Get ready to choose a claim, student geologists!

Unit Question

- Why are fossils of species that once lived together found in different locations on Earth now?

Chapter 4 Question

- What best explains the pattern of volcanic activity and earthquakes on the Jalisco Block?

Key Concepts

- Earth's outer layer is made of hard, solid rock.
- Earth's outer layer is divided into sections called plates.
- Geologists look for patterns in landforms and in geologic events in order to better understand Earth.
- The plates of Earth's outer layer move.
- Earth's plates move on top of a soft, solid layer of rock called the mantle.
- At divergent plate boundaries, rock rises from the mantle and hardens, adding new solid rock to the edges of both plates.
- At convergent plate boundaries, one plate moves underneath the other plate and sinks into the mantle.
- Earth's plates travel at a rate too slow to be experienced by humans.
- It takes a long time for Earth's plates to travel great distances.

Name: ____________________ Date: ____________

Lesson 4.3: Writing a Scientific Argument (continued)

Vocabulary

- analyze
- claim
- convergent
- cross section
- divergent
- earthquake
- evidence
- mantle
- mid-ocean ridge
- outer layer
- pattern
- plate
- plate boundary
- rate
- reasoning
- scientific argument
- trench
- volcanic activity

Name: ______________________ Date: ______________

Warm-Up

Making a Convincing Argument

In a scientific argument, reasoning is the thinking you use to connect ideas and evidence to your claim. Sometimes the same evidence can be used to support two different, opposing claims. When this happens, it is often the reasoning that is different for each argument. Read the evidence and claims in the Reasoning Tool below, then think about how the same evidence can be used to support different claims by using different reasoning for each example.

- What reasoning could you use so that the evidence supports the claim that running causes injury?
- What reasoning could you use so that the same evidence supports the claim that running prevents injury?

Fill in the middle column of each Reasoning Tool.

Evidence	**This matters because . . .** (How does this evidence support the claim?)	**Therefore, . . .** (claim)
Running puts more pressure on the knee joint and makes muscles work harder than walking does.		Running **causes** injury.

Evidence	**This matters because . . .** (How does this evidence support the claim?)	**Therefore, . . .** (claim)
Running puts more pressure on the knee joint and makes muscles work harder than walking does.		Running **prevents** injury.

Name: ______________________ Date: ______________

Using the Reasoning Tool

Why Is Reasoning Important?

When scientists support a claim, they show their reasoning process, making it clear how the evidence connects to the claim. This makes their arguments convincing.

Use the Science Seminar Reasoning Tool sheet to explain how the evidence supports your claim. Follow the instructions below.

1. Record the claim that you think is best supported by the evidence (in the **Therefore, . . .** column). If you prefer, you can also write and record your own claim.
2. Tape the evidence cards that support your claim to the Reasoning Tool (in the **Evidence** column). You do not need to use all the cards, but you can use more than one to support your claim.
3. Use the middle column (**This matters because . . .**) to record how the evidence in the left column connects to the claim in the right column.

Claim 1: Convergent movement between the Jalisco Block and the Rivera Plate best explains the pattern of volcanic activity and earthquakes on the Jalisco Block.

Claim 2: Divergent movement of the Jalisco Block away from the North American Plate best explains the pattern of volcanic activity and earthquakes on the Jalisco Block.

Name: ____________________ Date: ____________

Organizing Ideas in the Reasoning Tool

Plan how you will use your completed Reasoning Tool to write your argument. Use the example below to guide you.

- Draw a circle around your strongest piece of evidence.
- Draw an X over a piece of evidence if you do not plan to use it in your argument.
- Draw an arrow to connect two pieces of evidence if you think that they go together.

Example

Evidence	This matters because . . . (How does this evidence support the claim?)	Therefore, . . . (claim)
Example Evidence Card A	Your ideas about how the evidence supports the claim	Your claim
Example Evidence Card B	Your ideas about how the evidence supports the claim	
Example Evidence Card C	Your ideas about how the evidence supports the claim	

Name: ______________________________ Date: ____________________

Writing a Scientific Argument

On the next page, write your scientific argument to Dr. Moraga and his colleague. As you write, remember to:

- Review your completed Reasoning Tool. Be sure to include your strongest piece of evidence and make a connection between pieces of evidence that go together.
- Use the Scientific Argument Sentence Starters to help you explain your thinking.

Write a scientific argument that addresses the question *What best explains the pattern of volcanic activity and earthquakes on the Jalisco Block?*

1. First, state your claim.
   - **Claim 1:** Convergent movement between the Jalisco Block and the Rivera Plate best explains the pattern of volcanic activity and earthquakes on the Jalisco Block.
   - **Claim 2:** Divergent movement of the Jalisco Block away from the North American Plate best explains the pattern of volcanic activity and earthquakes on the Jalisco Block.
2. Then, use evidence to support your claim.
3. For each piece of evidence you use, explain how it supports your claim.

Scientific Argument Sentence Starters

Describing evidence:	**Explaining how the evidence supports the claim:**
The evidence that supports my claim is . . .	If ___, then . . .
My first piece of evidence is . . .	This change caused . . .
Another piece of evidence is . . .	This is important because . . .
This evidence shows that . . .	Since, . . .
	Based on the evidence, I conclude that . . .
	This claim is stronger because . . .

Name: ____________________ Date: ____________

Writing a Scientific Argument (continued)

Name: ______________________ Date: ______________

Homework: Revising an Argument

1. Reread the scientific argument you wrote in class. Finish writing your argument, if needed.
2. Look for ways you could make your argument more clear and convincing.
3. Use the following questions to help you review your argument:
   - Does your argument clearly explain how the geologic activity in the Jalisco area is connected to the type of plate movement you chose?
   - Do you describe your supporting evidence?
   - Do you thoroughly explain how the evidence supports your claim?
4. Rewrite any sections of your argument that could be more clear and convincing.

Name: ______________________ Date: ______________

Homework: Check Your Understanding

This is a chance for you to reflect on your learning so far. This is not a test. Be open and truthful when you respond to the questions below.

1. What are the most important things you have learned in this unit about why fossils of species that once lived together are found in different locations on Earth now?

____

____

____

____

____

____

2. What questions do you still have?

____

____

____

____

____

____

Plate Motion Glossary

analyze: to examine in detail for a purpose

analizar: examinar en detalle y con un propósito

continent: any of Earth's main continuous areas of land, such as Africa, Asia, and North America

continente: cualquiera de las principales áreas continuas de terreno de la Tierra, como África, Asia y Norteamérica

convergent: moving toward the same place

convergente: que se mueven hacia el mismo lugar

cross section: a diagram that shows what the inside of something looks like

corte transversal: un diagrama que muestra cómo es el interior de algo

divergent: moving apart in different directions

divergente: que se mueven y se separan en diferentes direcciones

earthquake: a sudden shaking of Earth's surface

terremoto: una sacudida repentina de la superficie de la Tierra

eruption: the sudden pushing out of something, such as lava from a volcano

erupción: la expulsión repentina de algo, como la lava de un volcán

fossil: evidence of life from the past, such as fossilized bones, footprints, or leaf prints

fósil: evidencia de vida del pasado, como huesos, huellas o impresiones de hojas fosilizados

geyser: a natural spring that sends hot water and steam suddenly into the air from a hole in the ground

géiser: un manantial natural que repentinamente lanza agua caliente y vapor hacia el aire desde un agujero en la tierra

landform: a feature that forms on the surface of a planet, such as a mountain, channel, or sand dune

accidente geográfico: un rasgo que se forma sobre la superficie de un planeta, como una montaña, un canal o una duna de arena

lava: hot liquid rock on the surface of Earth

lava: roca líquida y caliente sobre la superficie de la Tierra

Plate Motion Glossary (continued)

magma: hot liquid rock below the surface of Earth

magma: roca líquida y caliente bajo la superficie de la Tierra

mantle: the layer of soft, solid rock underneath Earth's plates

manto: la capa de roca sólida y blanda que se encuentra bajo las placas de la Tierra

Mesosaurus: an extinct reptile that lived about 300 million years ago

Mesosaurio: *un reptil ya extinguido que vivió hace cerca de 300 millones de años*

mid-ocean ridge: an underwater mountain range formed when two plates move apart

cordillera oceánica: una cadena montañosa submarina que se forma cuando se separan dos placas

model: an object, diagram, or computer program that helps us understand something by making it simpler or easier to see

modelo: un objeto, diagrama o programa de computadora que nos ayuda a entender algo haciéndolo más simple o fácil de ver

outer layer: Earth's outermost layer of hard, solid rock that is underneath the soil, vegetation, and water

capa externa: la capa más exterior de la Tierra, hecha de roca dura y sólida, que está bajo el suelo, la vegetación y el agua

pattern: something we observe to be similar over and over again

patrón: algo que observamos que sea similar una y otra vez

plate: one of the very large sections of hard, solid rock that make up Earth's outer layer

placa: una de las muy grandes secciones de roca dura y sólida que forman la capa externa de la Tierra

plate boundary: the place where two plates meet

límite de placas: el lugar donde se juntan dos placas

rate: how often or fast something happens

ritmo: qué tan frecuente o qué tan rápido pasa algo

rifting: the slow pulling apart of land that is caused by plate movement

fracturación: la separación lenta de terreno que es provocada por el movimiento de las placas

Plate Motion Glossary (continued)

surface: the outside or top layer of something

superficie: la parte exterior o la capa más externa de algo

system: a set of interacting parts forming a complex whole

sistema: un conjunto de partes que interactúan formando un todo complejo

trench: a long, deep indentation in the ocean floor formed when two plates move together

fosa: una hendidura larga y profunda en el piso oceánico que se forma cuando dos placas se juntan

volcanic activity: any of the many processes (such as eruptions and lava flows) in which gas, lava, and ash are pushed out on the surface of Earth

actividad volcánica: cualquiera de los muchos procesos (tales como erupciones y flujos de lava) en los cuales se expulse gas, lava y cenizas sobre la superficie de la Tierra

Lawrence Hall of Science:
Program Directors: Jacqueline Barber and P. David Pearson
Curriculum Director, Grades K–1: Alison K. Billman
Curriculum Director, Grades 2–5: Jennifer Tilson
Curriculum Director, Grades 6–8: Suzanna Loper
Assessment and Analytics Director: Eric Greenwald
Learning Progressions and Coherence Lead: Lauren Mayumi Brodsky
Operations and Project Director: Cameron Kate Yahr
Student Apps Director: Ari Krakowski
Student Content Director: Ashley Chase

Leadership Team: Jonathan Curley, Ania Driscoll-Lind, Andrew Falk, Megan Goss, Ryan Montgomery, Padraig Nash, Kathryn Chong Quigley, Carissa Romano, Elizabeth Shafer, Traci K. Shields, Jane Strohm

***Plate Motion: Mystery of the* Mesosaurus *Fossils* Unit Team:**

Stacy Au-yang
Elizabeth Ball
Carla Barger
Maite Barloga
Candice Bradley
Jill Castek
Benton Cheung
Lisa Damerel
Juliet Randall Dana
John Erickson
Lauren Esposito
Abigail Hines
Sybil Lockhart
M. Lisette Lopez
Deirdre MacMillan
Christine Mytko
Catherine Park
Natalie Roman
Trudihope Schlomowitz
Michelle M. Selvans
Claire Spafford
Megan Turner
Sara R. Walkup
Lauren Wielgus

Amplify:

Irene Chan
Samuel Crane
Shira Kronzon
Charvi Magdaong
Thomas Maher
Rick Martin
Matt Reed
Eve Silberman
Steven Zavari

Credits:
Illustration: Cover: Tory Novikova
Photographs: Pages 6 (l), 7 (t), 8 (Antarctica map), 9, 14, 55, 57–60, 63–66, 68–71, 81, 88: Shutterstock; Pages 6 (tr, br), 7 (bl, br): USGS; Page 8 (t): Fritz Goro/The LIFE Picture Collection/Getty Images; Page 8 (Central America Map); Page 8 (b): ANDRILL Science Management Office, University of Nebraska-Lincoln via CC BY 4.0; Page 14 (l): Creative Crop/Photodisc/Getty Images; Page 33 (b): NOAA Okeanos Explorer Program/2013 Northeast U.S. Canyons Expedition; Page 76: Bureau of Land Management via CC BY 2.0

Plate Motion:

Mystery of the Mesosaurus Fossils

Article Compilation

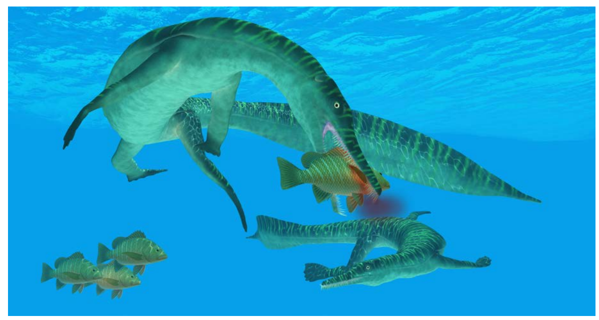
Table of Contents: Articles

The Ancient *Mesosaurus*

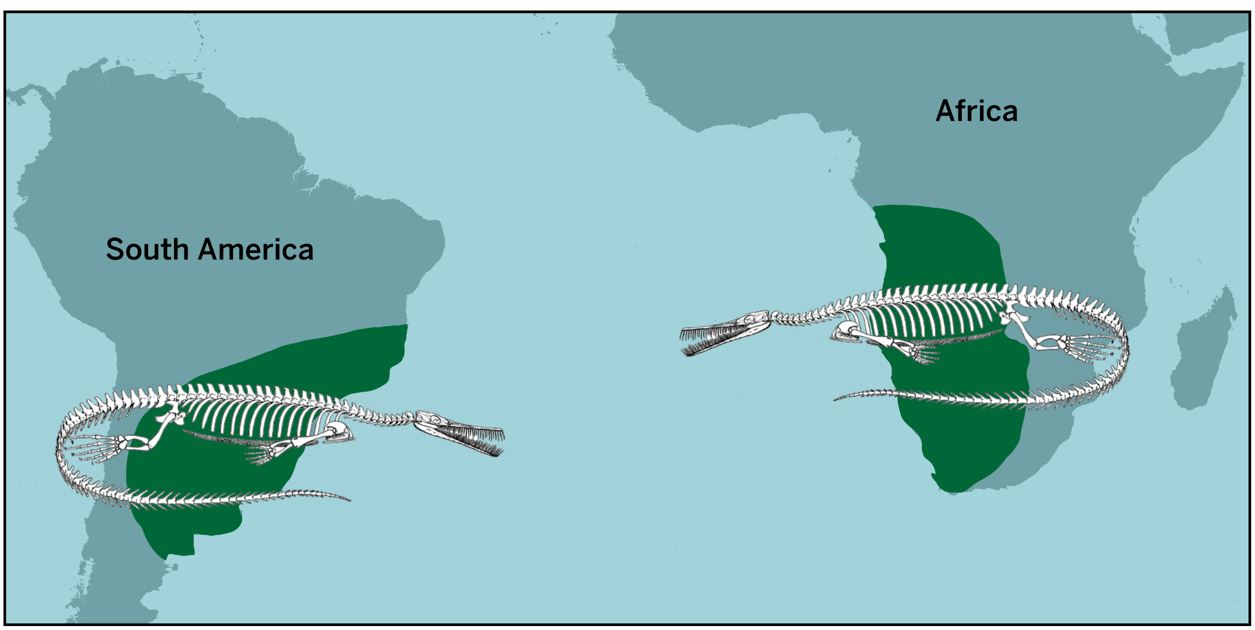
Scientists can use the fossils of an extinct creature called the *Mesosaurus* to study Earth's past. They find these fossils embedded in hard, solid rock. *Mesosaurus* fossils have been found in South America and Africa.

Mesosaurus means "middle lizard," and these creatures were ancient lizards that looked a bit like small crocodiles, with narrow heads and long tails. They had webbed feet and grew to about 1 meter (3.3 feet) long. The earliest fossil evidence for these animals indicates that they were alive about 300 million years ago, and their species went extinct about 260 million years ago. *Mesosaurus* were among the first reptiles to live in and around water, and they spent most of their lives in the water. However, their bodies weren't built for swimming long distances, so they stayed close to land. Like all reptiles, *Mesosaurus* had lungs instead of gills and breathed in oxygen from the air instead of getting it underwater. Their nostrils were located high up, allowing them to breathe air through their nostrils while the rest of their bodies stayed underwater.

The *Mesosaurus* died out hundreds of millions of years ago, but their fossils can teach us about Earth's history.



***Mesosaurus* was an ancient lizard that lived about 300 million years ago. This illustration was made by an artist to show what *Mesosaurus* might have looked like.**

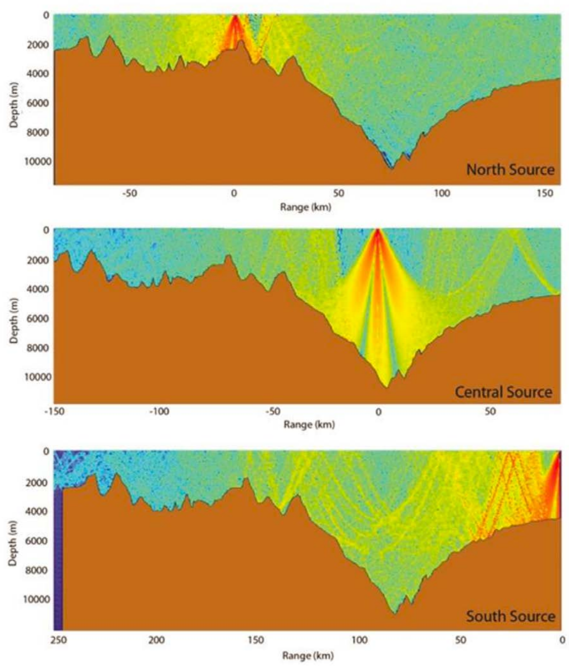


***Mesosaurus* fossils have been found in South America and in Africa. Although the *Mesosaurus* lived in and around the water, it was not able to swim long distances; it could not have made the journey across the Atlantic Ocean.**

Listening to Earth

Bob Dziak (zee-AK) studies plate boundaries in a surprising way: he listens to them. Dziak is a scientist who works for the National Oceanic and Atmospheric Administration (NOAA), a government department that studies the ocean and the atmosphere. Dziak and his team wanted to know more about what happens on the ocean floor, especially at plate boundaries. Sending people to the bottom of the ocean is difficult, so Dziak and his team used hydrophones—powerful microphones that are built to travel deep under water. The team sent hydrophones 10.99 kilometers (6.83 miles) down into the deepest place in the ocean, an area known as Challenger Deep. Challenger Deep is an underwater canyon,

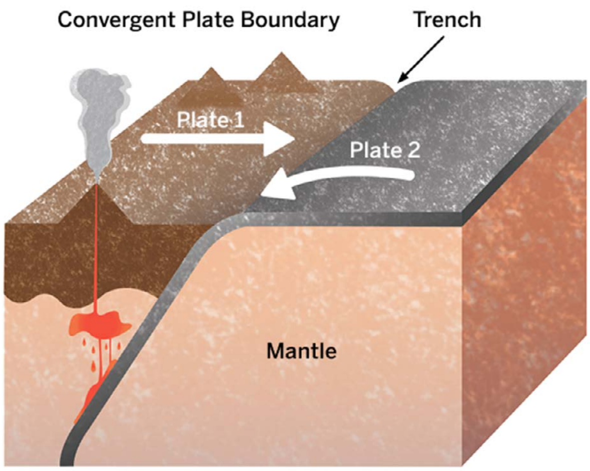
Bob Dziak is a scientist who studies sound in the ocean.



This diagram shows how sound travels around deep trenches like the Mariana Trench. Here, sound is represented by red and yellow lines. If the source of a sound is directly over the trench, like it is in the middle panel, sound will easily travel into the deepest parts of the trench. However, if the source of the sound is not directly over the trench, most of the sound does not make it to the bottom of the trench.

part of a larger landform called the Mariana Trench. Dziak and his team didn't expect to hear very much noise so deep below the ocean's surface. What they actually found surprised them—their hydrophones picked up sounds from many different sources!

One type of sound collected by Dziak and his team was the sound of plate motion in the form of earthquakes. Earthquakes happen at plate boundaries all over the world—they are caused by the motion of plates. Dziak travels all over the world studying plate boundaries under the ocean and using hydrophones to collect data about the earthquakes that happen there. By recording earthquakes at different plate boundaries, Dziak and his team are using sound to study the ways that plates move on Earth.



This is a cross section of a convergent boundary. At convergent boundaries, two plates are moving toward one another. One plate is forced underneath the other.

Listening to Convergent Boundaries

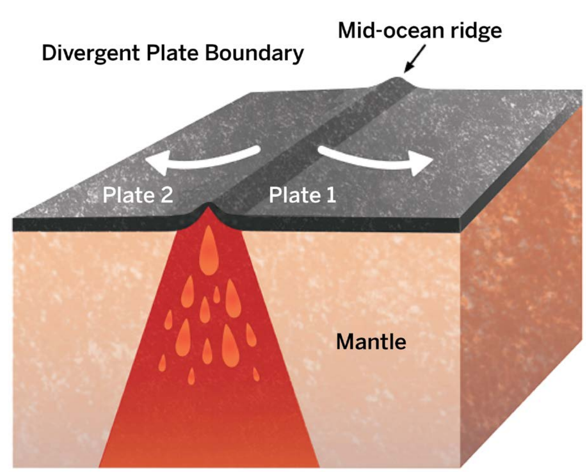
The Mariana Trench lies on a convergent boundary. In fact, the trench IS a convergent boundary, formed by one plate sinking under another. Since plate boundaries tend to have a lot of earthquakes, Dziak and his team weren't surprised to hear some earthquakes on their recordings. However, they heard many more earthquakes than they had expected! Dziak explained that when they recorded sounds from Challenger Deep, "there were even more earthquakes than we thought there would be. Our recordings taught us that plate motion is always moving along."

At convergent boundaries, two plates are moving toward each other. When the two plates collide, or run into each other, one is forced underneath the other. This collision is very slow, but the forces that cause it are very strong and affect both plates. Over long periods of time, the plate that is on top can bend and fold. The plate on the bottom is shoved into the mantle, bending downward and forming a deep trench at the boundary. As the bottom plate sinks into the mantle, it is destroyed and becomes part of the mantle. Both earthquakes and volcanic activity are common at convergent boundaries.

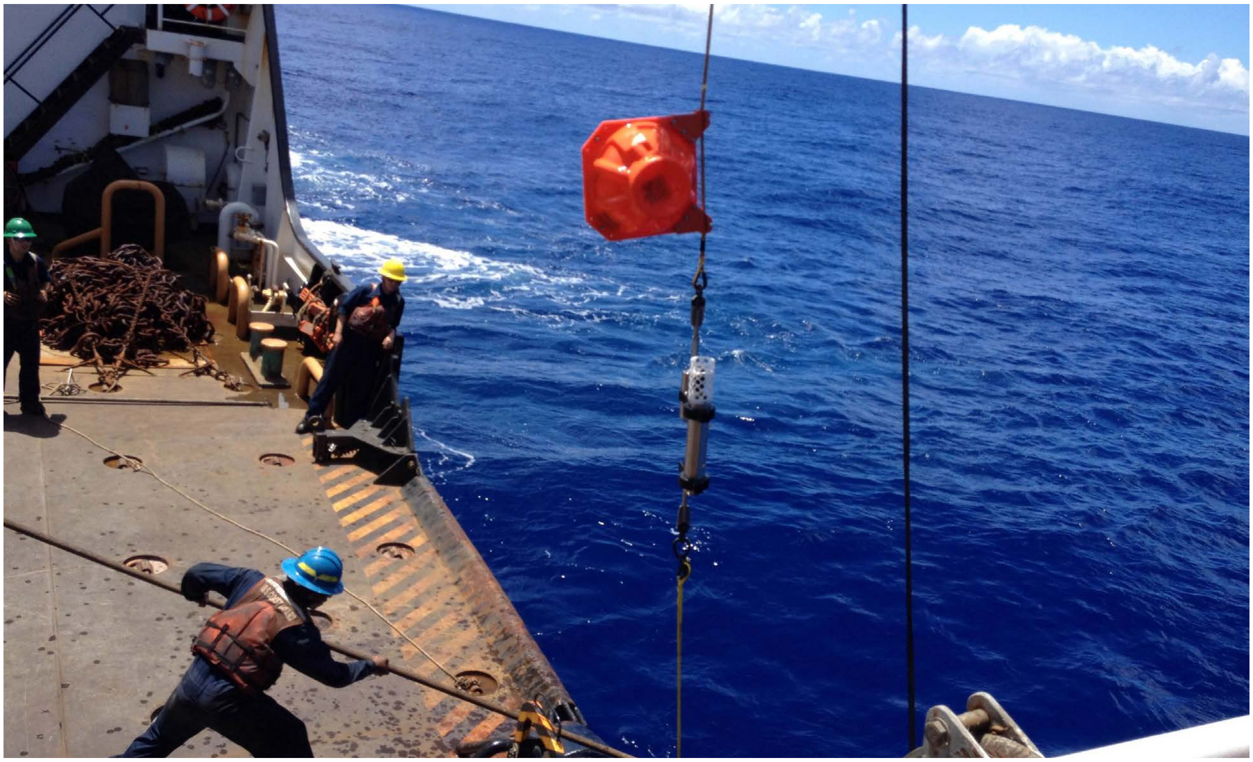
Listening to Divergent Boundaries

Bob Dziak and his team don't just listen to the ocean near convergent boundaries. They also use their hydrophones to listen in on divergent boundaries. Divergent boundaries are the opposite of convergent boundaries: they are places where two plates are moving away from each other. As the plates move, hot material from the mantle comes up to fill the space between them. The hot mantle material cools and hardens and adds new rock to the edge of each plate. Over time, these additions of rock form a mountain range, made up of a long chain of volcanoes. When this process happens on the ocean floor, scientists call the landform a mid-ocean ridge. Mid-ocean ridges can be thousands of kilometers long!

By listening to the ocean around divergent boundaries, Dziak and his team can detect earthquakes and volcanic eruptions that humans wouldn't know about in any other way—after all, mid-ocean ridges are deep underneath



This is a cross section of a divergent boundary. At divergent boundaries, two plates move away from each other. Magma from inside Earth rises into the empty space between them and hardens, forming a ridge.



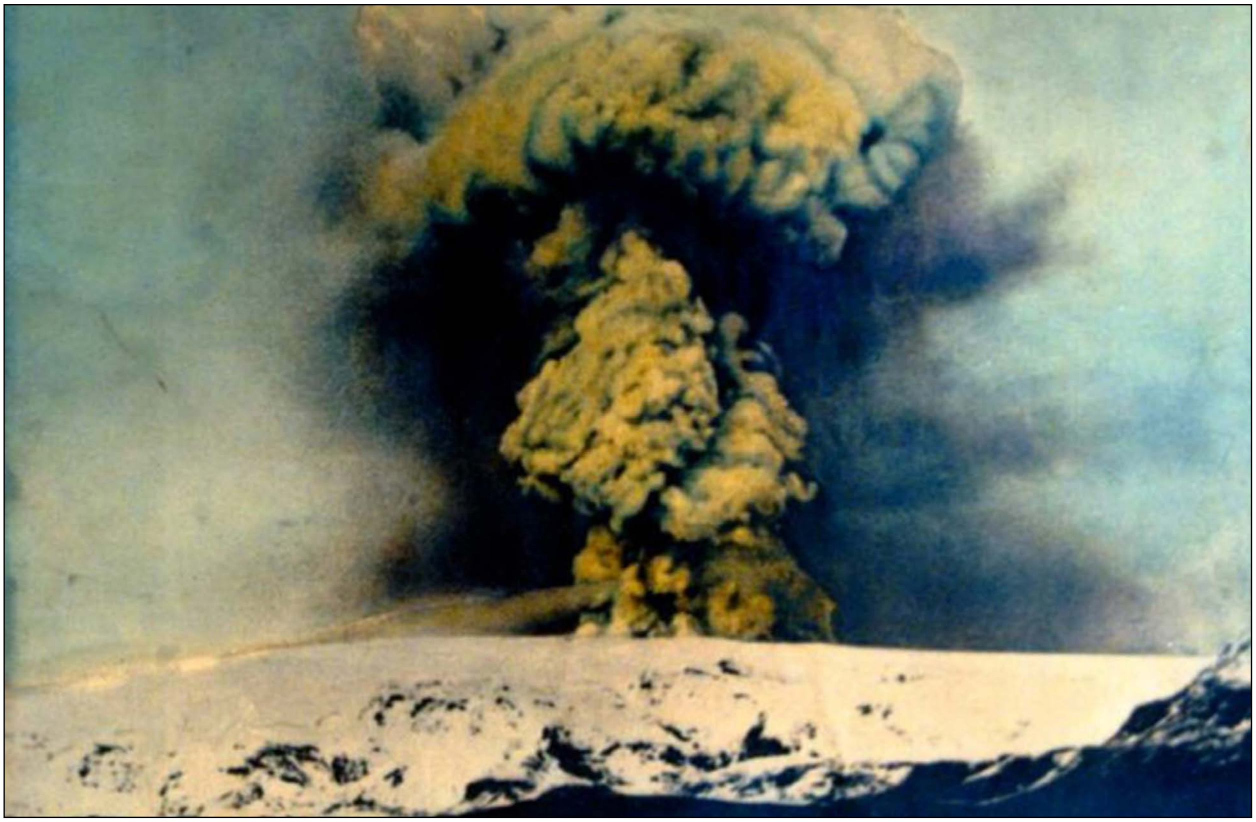
This person is pulling a hydrophone out of the deep ocean, where it's been recording sound.

the ocean's surface and may also be thousands of kilometers from land where people can easily observe them. By lowering a hydrophone into the water near a mid-ocean ridge and letting it record for a long time, Dziak and his team can hear how many earthquakes and volcanic eruptions are taking place.

Dziak uses hydrophones to study the smaller earthquakes, called foreshocks, that occur at divergent boundaries before major earthquakes. "Big earthquakes at divergent boundaries have a clear pattern of foreshocks," he says. "It's not something you see on land, and we're finding this pattern at divergent boundaries all over the world." Dziak believes studying earthquakes in the middle of the ocean may help scientists refine the tools they use to study earthquakes on land. "If earthquakes had this kind of predictability on land, it might be something we could use later on," he says.

Putting It All Together

By studying both convergent and divergent plate boundaries, Dziak is studying the ways that plates move all over our planet. In some places, the motion of Earth's plates works like a conveyor belt: most plates have a convergent boundary on one side and a divergent boundary on the other. On the side with the convergent boundary, plate material is sinking into the mantle and being destroyed. On the side with the divergent boundary, new plate material is being made at a mid-ocean ridge. The motion takes place at a rate of only centimeters per year, but since one side of the plate is being destroyed and the other keeps getting new plate material, they keep moving. Dziak's research is helping us understand more about how plate motion happens—we just have to listen!



This photograph shows the 1918 eruption of Katla, one of the largest and most dangerous volcanoes in Iceland. Katla usually has a large eruption every 13 to 95 years. It hasn't had a large eruption for about 100 years, and geologists think it might erupt soon.

Journey to a Plate Boundary

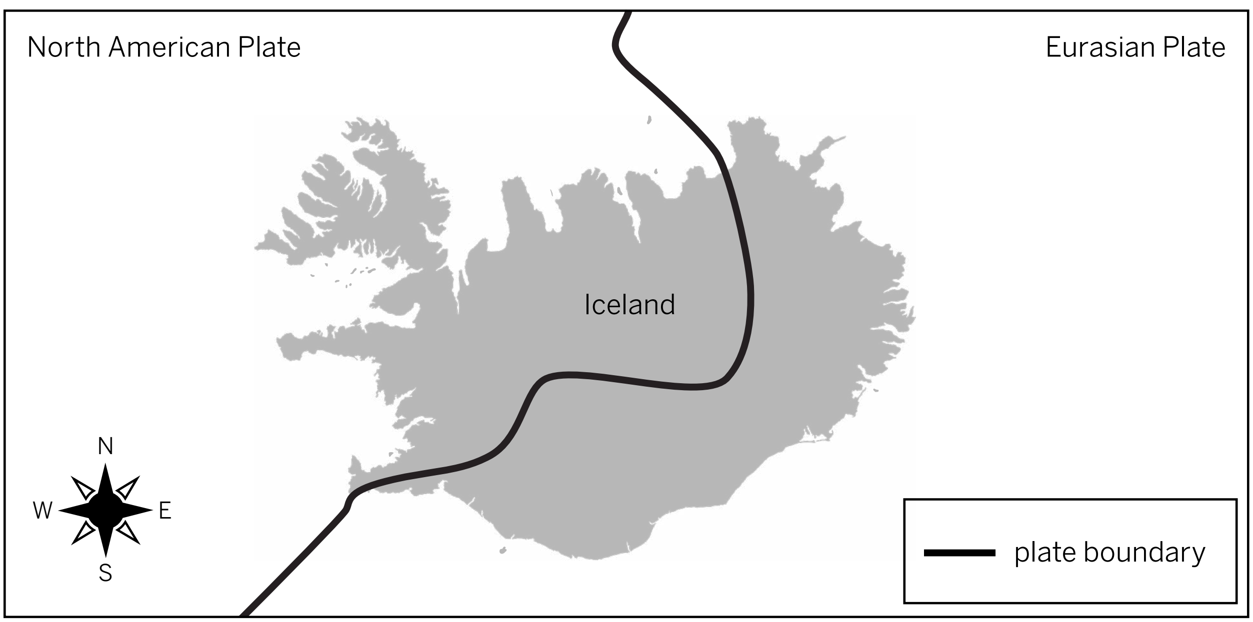
Iceland is a small island country in the Atlantic Ocean. It has a large number of active volcanoes because plates beneath Iceland are moving and have been for a long time. In fact, Iceland sits on a plate boundary between two large plates, and Iceland itself formed because of plate movement.

Iceland is on the Mid-Atlantic Ridge. This mid-ocean ridge formed at a plate boundary where two large plates are constantly moving away from each other. As these two plates moved apart, soft solid rock from underneath the plates rose and became part of the

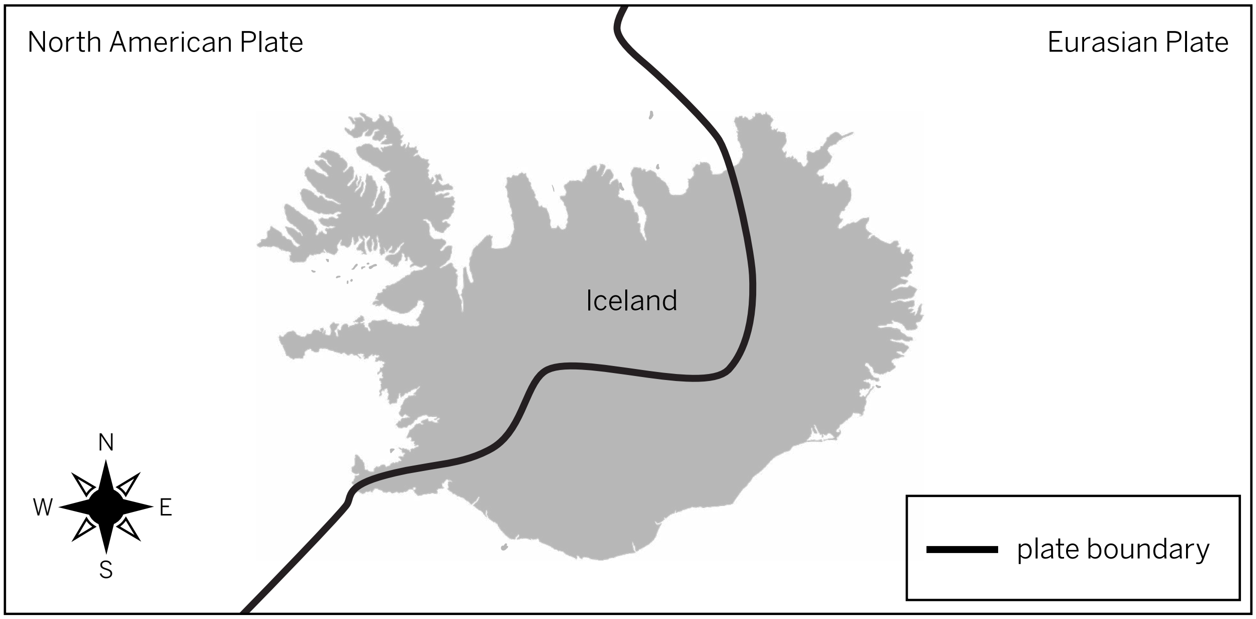
This rocky ridge in Iceland is part of the boundary between two plates that are always moving away from each other.

plates. Iceland was formed from the new rock material that was added to the edges of these plates. This process happens at all divergent plate boundaries, so even when plates move away from each other, Earth is still always completely covered by plates.

Plate movement causes geologic events such as earthquakes and volcanic activity. Since a plate boundary runs right through the middle of the island, it's no surprise that Iceland experiences a lot of volcanic activity!



A plate boundary between the North American Plate and the Eurasian Plate passes through the middle of Iceland.



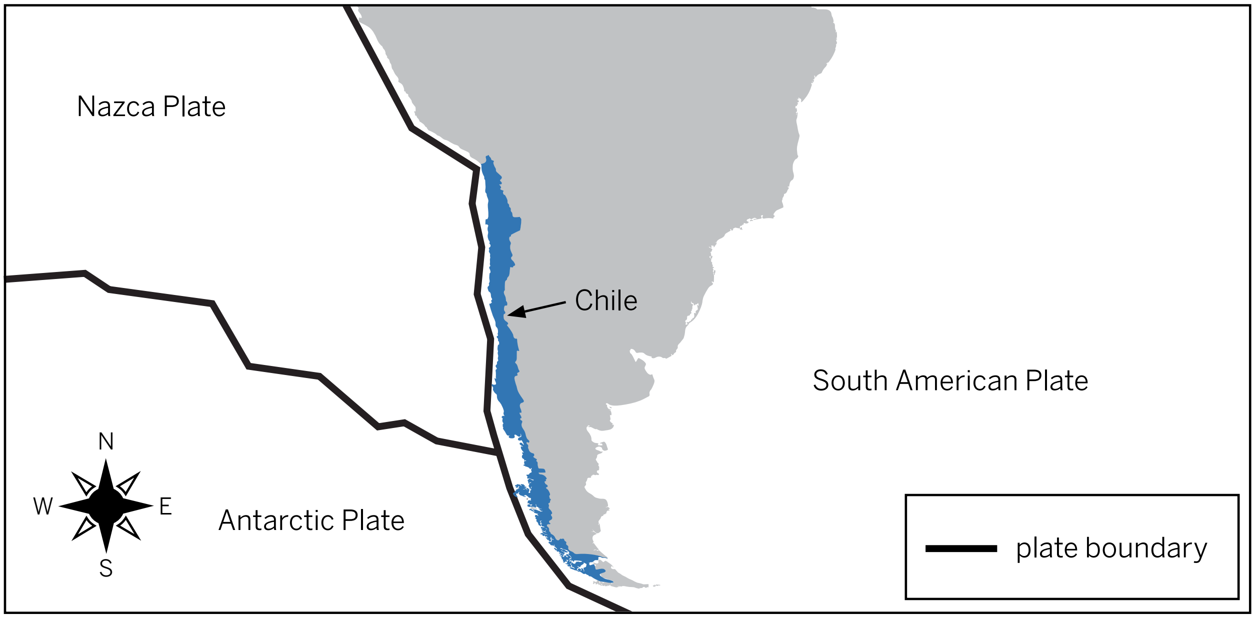
Iceland is divided by the Mid-Atlantic Ridge, which runs along the divergent plate boundary between the North American and Eurasian plates.

Two Types of Plate Boundaries

Iceland

Iceland is an interesting place for geologists to study because it is one of very few places on Earth where it's possible to see a divergent plate boundary on land. Iceland is located on the Mid-Atlantic Ridge, which formed at a divergent boundary where two large plates are moving away from each other. When two plates move away from each other, rock from the mantle rises to fill the gap. This results in the formation of a ridge of new rock. Divergent plate boundaries are very active areas—there are usually lots of volcanoes, geysers, and earthquakes nearby.

Iceland is the only place on Earth where the Mid-Atlantic Ridge can be observed above the surface of the ocean.



Chile is located along the convergent boundary between the Nazca Plate and the South American Plate, so it experiences a lot of earthquakes and volcanic activity.

Chile

Earthquakes and volcanic activity are also common at another type of boundary: convergent boundaries. Chile is a South American country that lies along a convergent plate boundary. Convergent boundaries are found where two plates move toward each other. As the plates collide, one plate goes underneath the other. The plate underneath sinks into the mantle and is destroyed. In Chile, landforms like the Andes mountains and the Peru-Chile Trench were formed by plate motion at the convergent plate boundary. Like Iceland, Chile experiences earthquakes and volcanic activity due to the nearby plate boundary. In fact, the largest earthquake ever recorded was a magnitude 9.5 quake near Valdivia in southern Chile in 1960.

This historical picture shows the damage from an earthquake in Valdivia, Chile in 1960.

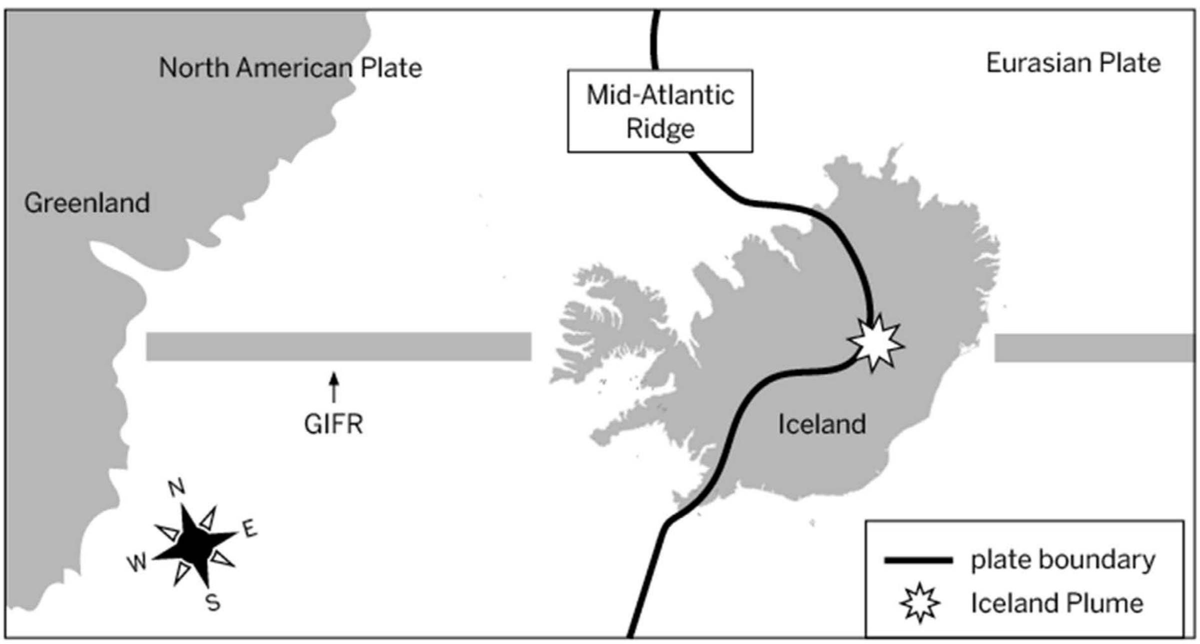
The Mid-Atlantic Ridge passes through Iceland, making it one of the most geologically active places on Earth.

Iceland's Hotspot

Iceland is one of the most geologically active places on Earth. It is divided by a divergent plate boundary, where two plates are moving away from each other and new land is being formed as material from the mantle is added to the plate. Because of this, the island is spreading apart and experiences a lot of volcanic activity.

One part of the island experiences even more volcanic activity than the other regions along the plate boundary. Scientists have evidence that this is due to a geologic hotspot called the Iceland Plume. Hotspots are fixed locations on Earth, far below the plates moving above them, where mantle material pushes up from deep below. It is unclear exactly why hotspots form. However, they can form anywhere on Earth, even far from plate boundaries. When the mantle material reaches the surface and cools, new material is added to the plates, forming volcanoes and other landforms.

The Iceland Plume is also thought to be responsible for a nearby underwater ridge called the Greenland-Iceland-Faroes Ridge (GIFR). Typically, a ridge that forms near a plate boundary lines up with the boundary: the plate boundary and the ridge both run in the same direction. The GIFR is different from a typical ridge because it doesn't line up with a plate boundary: instead, it runs in the direction that the plates are moving. As the plates spread, they move across the hotspot and the hotspot adds magma to the surface. This results in a ridge that follows the movement of the plates.



Iceland is split by a divergent plate boundary and is located above a hotspot. These two aspects of Iceland's geology contribute to the abundant geologic activity that occurs on the island.

Alfred Wegener argued that the continents had changed their positions on Earth, but his claim wasn't accepted by other scientists until many years later.

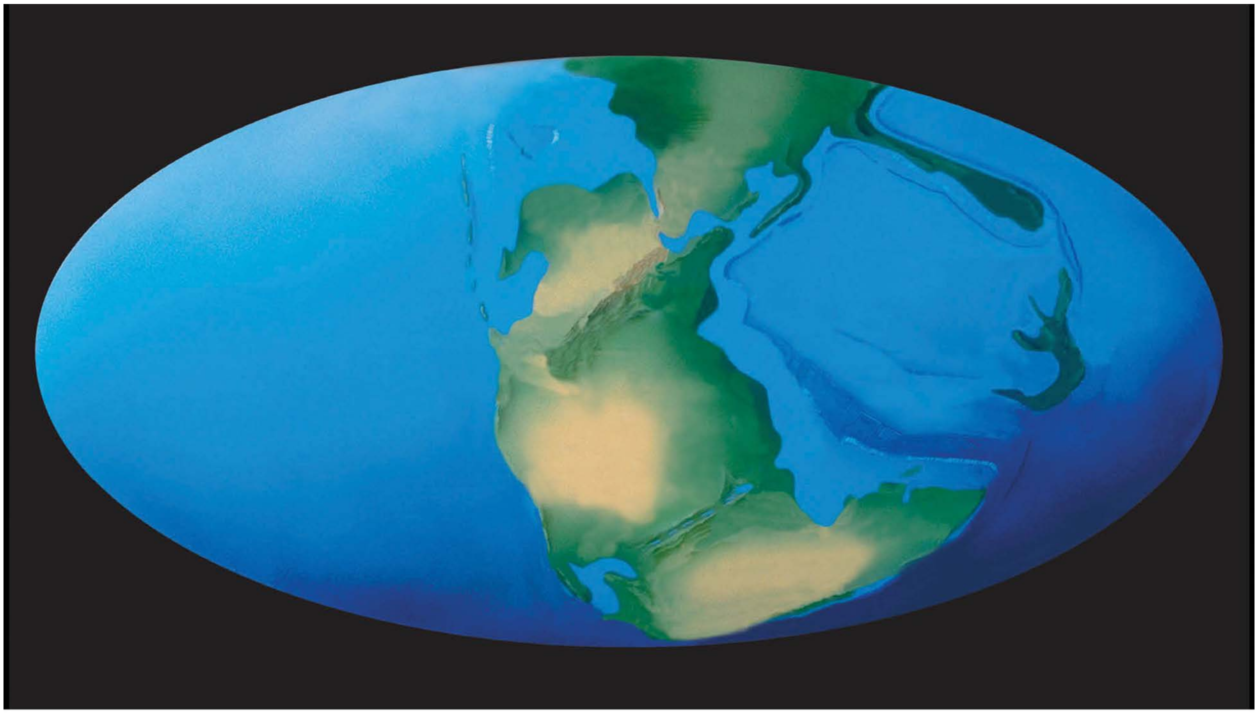
A Continental Puzzle

For scientists, making big discoveries and sharing them with the public can be a big deal. Often, their discoveries come after years of hard work, and they finally get to see the results of what they've done. In some cases, their work is welcomed by other scientists, and can even make them celebrities! However, this is not what happened to Alfred Wegener (1880–1930). Wegener (VAY-geh-ner) was the German scientist who first argued that continents on the Earth's surface had moved over long periods of time. During Wegener's lifetime, other scientists thought his claim was too strange to be true. They also said that Wegener did not have convincing evidence to support his ideas. At the time, many scientists mocked Wegener's claims. It wasn't until many years after his death that other scientists came to accept his argument.

In 1915, Wegener shocked other scientists when he made the claim that the continents haven't always been where they are today. He argued that the continents had all been together in one large supercontinent, which he named Pangea. Wegener said the continents have since traveled thousands of miles to their current locations, and will continue to travel thousands more. He concluded that these movements happen very slowly—but they add up over hundreds of millions of years. Scientists later accepted Wegener's claim as accurate and gathered additional evidence to support and build on his ideas. However, at the time, his argument was not well received at all!

Evidence of Change on Earth's Surface

How did Wegener come up with the claim that the continents were once together, but have moved over time? Since humans didn't exist hundreds of millions of years ago, there's no written record of what conditions

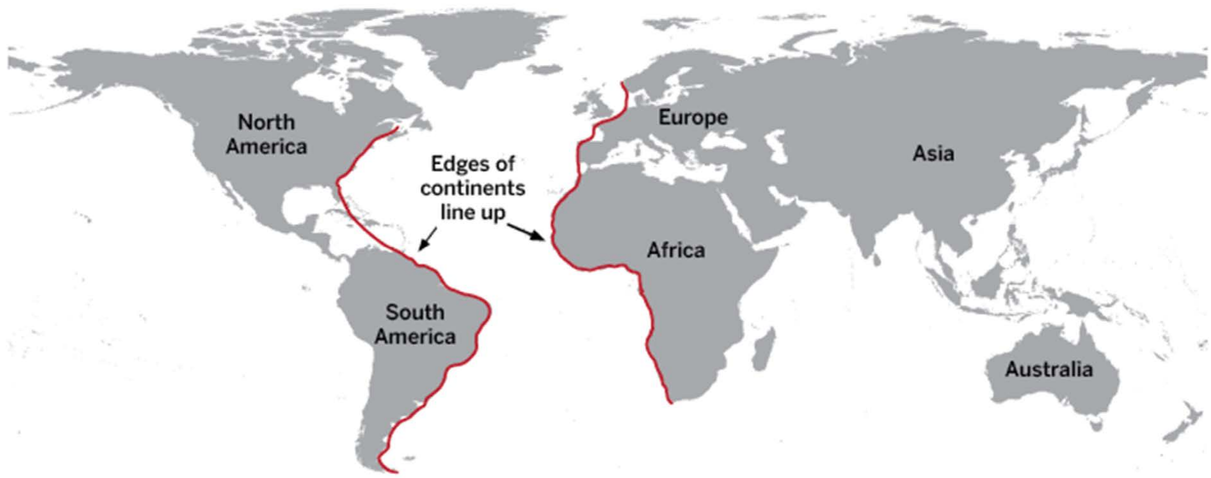


Alfred Wegener argued that the continents had once been joined together in a supercontinent called Pangea. This map shows how Pangea may have looked hundreds of millions of years ago.

on Earth might have been like. To support his claim, Wegener turned to evidence from Earth itself, just as scientists do today. Wegener was interested in what Earth's climate was like before humans existed. His study of ancient climate led him to think about how the continents might have been arranged millions of years in the past.

One type of evidence Wegener considered as he developed his ideas was the shapes of the continents and the landforms that appeared on them. He noticed that the edges of the continents matched, as if they had once fit together like puzzle pieces. Wegener wasn't the first to notice how similar the edges of the continents were, but he was the first to publicly argue that the way they appeared to fit together was evidence that they had once been connected. At the same time, he found that some identical landforms could be found on more than one continent. For instance, mountain ranges and areas made of certain types of rock that were found on the continent of South America could also be found on the continent of Africa. When scientists compared these similar mountain ranges and rocks on the two separate continents, they matched. Not only that: when people placed the matching rocks and mountains together, they appeared to fit perfectly, like two puzzle pieces.

Another source of evidence Wegener used to support his claim—and a type of evidence still used by scientists today—was the study of similar fossils found on different continents. Fossils are the remains and impressions of living things preserved in rock. They can tell us about life on Earth millions or even billions of years ago. By studying fossils and where they're found, scientists can tell when the organisms that formed the fossils lived and what conditions were like at the time. The oldest fossils on Earth are found in the hard, solid rock on land, because the plate material that makes up land is older than plate material that makes up the



Wegener noticed that the edges of some continents seem to match up like puzzle pieces.

ocean floor. The plate material that makes up the ocean floor is much younger because the plates of the ocean floor are always being destroyed at convergent boundaries, while new plate material is being created at divergent boundaries. In fact, the oldest plate material on the ocean floor is only 180 million years old! That may sound like it's been around for a long time, but plate material on land can be much older: up to four billion years old! Fossils are an important source of evidence as scientists support ideas about where the continents were located hundreds of millions of years ago

In Wegener's case, he noticed that the same types of fossils were sometimes found in very different parts of the world. The fossils were sometimes thousands of miles apart or in places where the organism that formed the fossil wouldn't be able to survive. For example, Wegener studied fossils of tropical plants that had been found in Antarctica, where the cold climate would have killed the warm-weather plants. This evidence led Wegener to the claim that the entire continent where the fossils were found had once been located somewhere warmer. He concluded it had traveled to its current position over millions of years.

Fossils, like these trilobites, are one source of evidence that is still used today as scientists support ideas about Earth's history.

Wegener's Legacy

Wegener found evidence that the Earth's continents had moved apart over time, but he didn't explain how that motion happened—that's one important reason why the scientific community didn't accept his claims. Over the years other scientists collected additional evidence and made hypotheses, or claims, about how the continents moved apart. The evidence didn't support all of the claims, but those claims that were supported by the evidence became part of the accepted explanation. The work of many scientists, including Wegener, and a lot of evidence led to what we now call the "theory of plate tectonics." Scientific theories are explanations for an observable phenomenon that have a lot of evidence gathered over time. Although he didn't get credit for his research during his lifetime, Wegener is now famous for his contribution to the theory of plate tectonics.

The fossils once known as “tongue stones” are actually the teeth of ancient sharks.

Steno and the Shark

Believe it or not, some of the most important scientific thinking about how to determine the age of a rock came from a scientist who was studying sharks. In 1666, fishermen caught a huge great white shark off the coast of Italy. Because it was so large and interesting, they sent the dead shark to Nicholas Steno, a Danish scientist working in Italy who enjoyed studying the animals, plants, and rocks he found in nature.

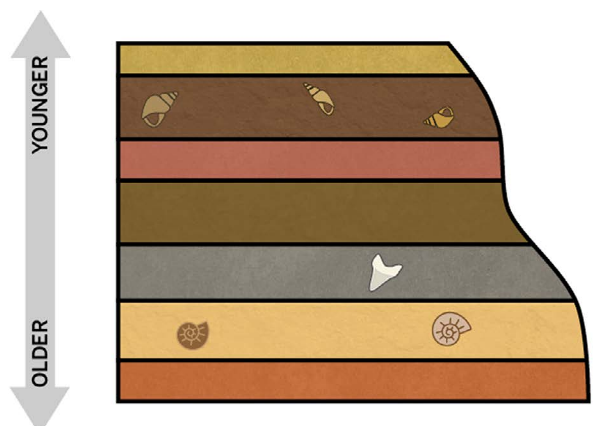
As Steno studied the shark, he noticed something surprising about its teeth: they looked like triangular rocks that he had seen before. These triangular rocks were known as “tongue stones.” Scientists had found tongue stones stuck inside rocks all over the world, but could not explain where they came from.

This diagram of a shark and “tongue stones” was based on Steno’s sketches.

Some scientists claimed that tongue stones grew inside rocks. This did not make sense to Steno, because the tongue stones fit so perfectly inside the rocks. The tongue stones were completely surrounded by rock, with no breaks or cracks. Steno reasoned that the tongue stones could not have grown inside the rocks. Comparing the tongue stones to the teeth of his shark, Steno realized that tongue stones must be the teeth of sharks that had lived long before. How could teeth end up inside solid rock?

Steno argued that the rock around the tongue stones had not always been solid. He claimed that the rock had once been sand or mud at the bottom of an ocean. Sharks swimming in that ancient ocean had lost their teeth, and the teeth fell to the bottom of the ocean and were covered with sand or mud. Eventually, the sand or mud hardened into rock. The sharks' teeth became fossils embedded in the hard rock. The end result was a tongue stone: a fossil in the shape of a tooth, surrounded by rock.

Steno's study of fossils helped him explain how rock layers form. He argued that certain kinds of rock formed in layers, with older layers below and newer layers added on top. Steno explained that the lower a rock layer was, the older it was. Steno's ideas about how rocks can form in layers, with the older layers on the bottom and the newer ones on top, are still used by geologists today, about 350 years later. For example, when scientists study a rock with many layers in order to understand how it was formed, they often make observations about the position of each layer compared to all the others. When they compare one rock layer to another just above it, they know that the lower layer of rock was formed before the one on top of it. This process of determining which layers are older or younger is also called relative dating.



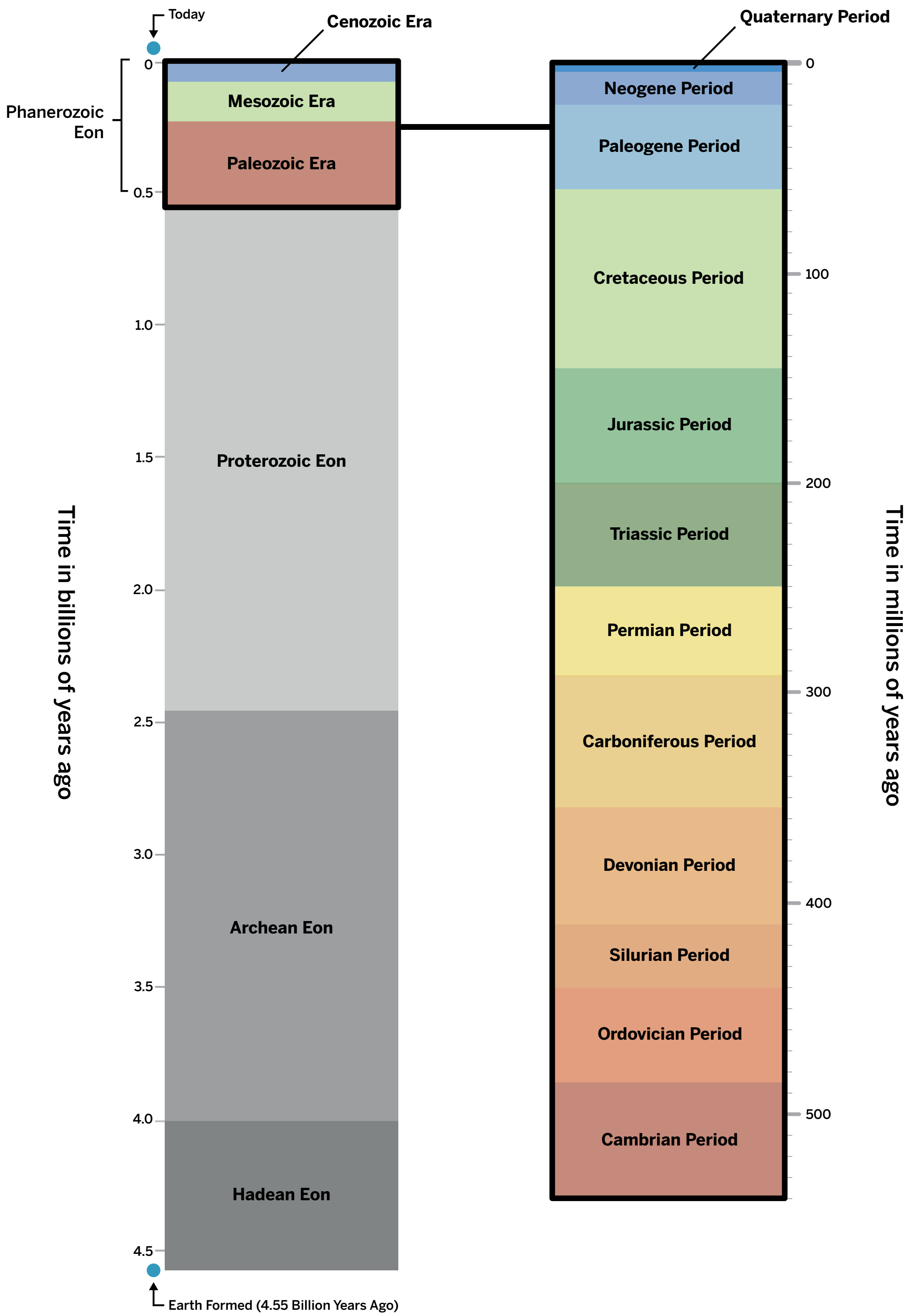
Much of the rock beneath our feet is layered, with the oldest layers on the bottom and the newest layers on top. Different fossils can be found in different layers, and the layer they're found in can give us clues about how old they are. For example, using the idea of relative dating, scientists can explain that fossils found in a rock layer near the bottom are older than fossils found in any layer above them.

Steno couldn't say exactly how old rock layers were, but he introduced the concept of relative dating. This concept helped scientists understand that some rock layers are older than others. He also explained what fossils were. These important insights led to our current understanding of Earth's history.

Geologic Time

Steno's work helped scientists to interpret and understand the history of specific rock layers in a certain location. However, scientists eventually needed a way to organize and explain the entire history of all the rock (and everything else) that exists on Earth. Since Earth is approximately 4.6 billion years old, that is a long history! It is almost impossible to talk or even think about a timeline that is 4.6 billion years long. Scientists began to break Earth's history into different units of time. The result was what scientists call the geologic time scale. Eons are the largest unit of time. Thinking about Earth's history at this scale makes it possible to talk about huge chunks of time. How long is an eon? Well, it depends. Like all units of time on the geologic time scale, eons are identified based on important events in Earth's history. Eons can range from several hundred million years to two billion years long. An eon is still a huge amount of time. Eons are broken into smaller chunks of time, called eras, which can range from about 65 million years to hundreds of millions of years. An era is still an extremely long time! Eras are broken into smaller units of time called periods, which are then broken into smaller units of time, and so on. The geologic time scale is a tool that provides scientists with an easy way to talk about Earth's history.

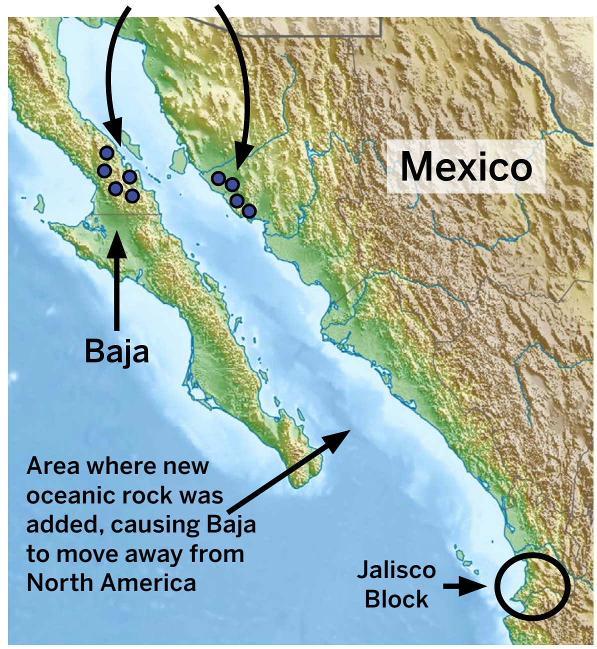
Geologic Time Scale



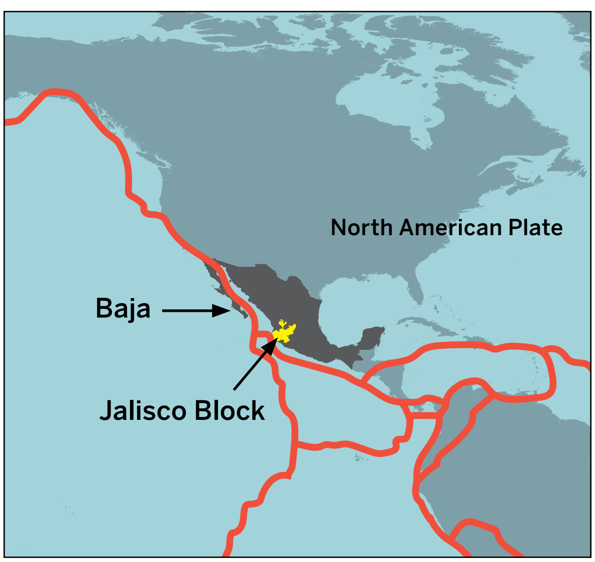
How Baja Was Born

The Baja (ba-ha) Peninsula is a thin strip of land connected to the western coast of Mexico, south of the United States-Mexico border. It is a popular place to visit because of its beautiful beaches and the varied wildlife that can be found there, both on land and in the Pacific Ocean. For geologists, Baja is an important place to visit for other reasons. Plate movement formed the Baja Peninsula. Geologists have been studying this movement for a long time, and the information they have gathered from studying the Baja Peninsula is helping them to gain a better understanding of geologic changes that may be happening to another area called the Jalisco Block.

The Baja Peninsula is located about 500 kilometers (about 300 miles) north of the Jalisco Block. Scientists have observed that geologic changes may be taking place in the Jalisco Block, but they aren't sure what kind. However, some scientists think comparing it to the Baja Peninsula might be helpful.



Rock of the same type and age has been found on Baja and across the Gulf of California on the Mexican mainland. There is younger rock of a different type in the middle



The border of the North American plate runs along the edge of Mexico.

Rock of the same type and age that formed during a volcanic eruption is found both on the Baja Peninsula and the coast of Mexico. This evidence shows that mainland Mexico and Baja used to be connected. However, this rock is now separated, with different, younger rock found between. By determining the ages of these rocks, geologists can tell that from 12 million to 6 million years ago, divergent movement in the middle of the North American plate caused the land that is now the Baja Peninsula to separate from Mexico.

In Baja, this divergent movement in the middle of a plate, called rifting, formed a new divergent plate boundary. The Gulf of California formed between Baja and the rest of Mexico because new material from the mantle was added to the plates on the ocean floor along this new divergent plate boundary. However, not all rifting forms new divergent plate boundaries. In Baja, the evidence that a new plate boundary formed is clear. In the Jalisco Block, it is not yet clear to geologists whether rifting is currently happening or whether a new plate boundary will form in the future.

Plate Motion: Mystery of the *Mesosaurus* Fossils

THE LAWRENCE HALL OF SCIENCE
UNIVERSITY OF CALIFORNIA, BERKELEY

Amplify.

Published and Distributed by Amplify.
www.amplify.com

AMP.NA18

ISBN 978-1-64089-867-7