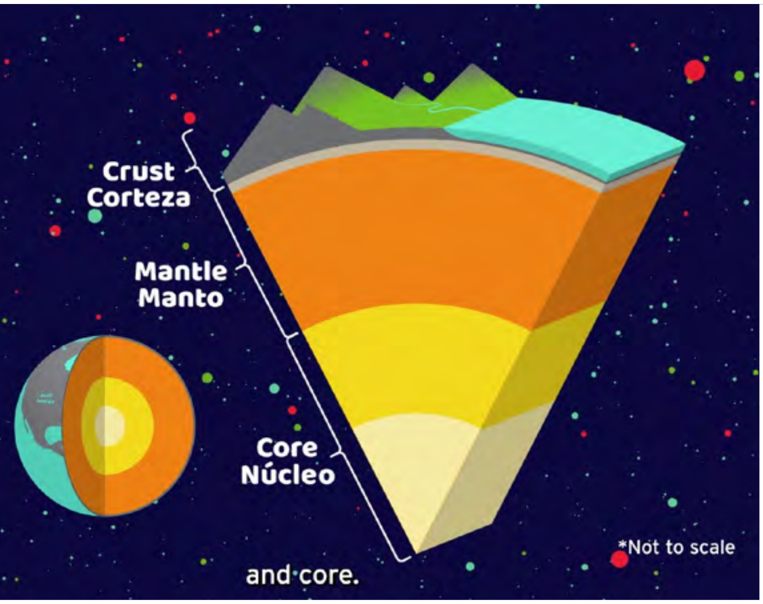
THE WHYNAUTS:

Episode 4: Plate Tectonics

EDUCATOR GUIDE SUGGESTED GRADE LEVELS 6-8



The Whynauts

Perot Museum of Nature and Science

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INTRODUCTION

HOW TO USE THIS GUIDE

The Whynauts **"Plate Tectonics"** Video explores the theory of plate tectonics and why the surface of the Earth never stops changing. This guide is designed to help you incorporate the video into a complete learning experience for your students. It is composed of three main sections:

The **Viewing Strategies and Tools** section includes suggested discussion questions and a pre- and post-assessment to track student learning.

The **Supplemental Activities** section includes four activities which can be used in any order or combination.

The **Additional Resources** section includes a glossary, reading list and links to continue learning.

LEARNING OBJECTIVES

Students will be able to:

- Identify the layers of the Earth.
- Describe how the movement of the tectonic plates leads to major geological events.
- Relate the occurrence of crustal features to the different plate boundaries.

TEKS ALIGNMENT

6.10B. Model and describe the layers of Earth, including the inner core, outer core, mantle, and crust.

7.10A. Describe the evidence that supports that Earth has changed over time, including fossil evidence, plate tectonics, and superposition.

7.10B. Describe how plate tectonics causes ocean basin formation, earthquakes, mountain building, and volcanic eruptions, including supervolcanoes and hot spots.

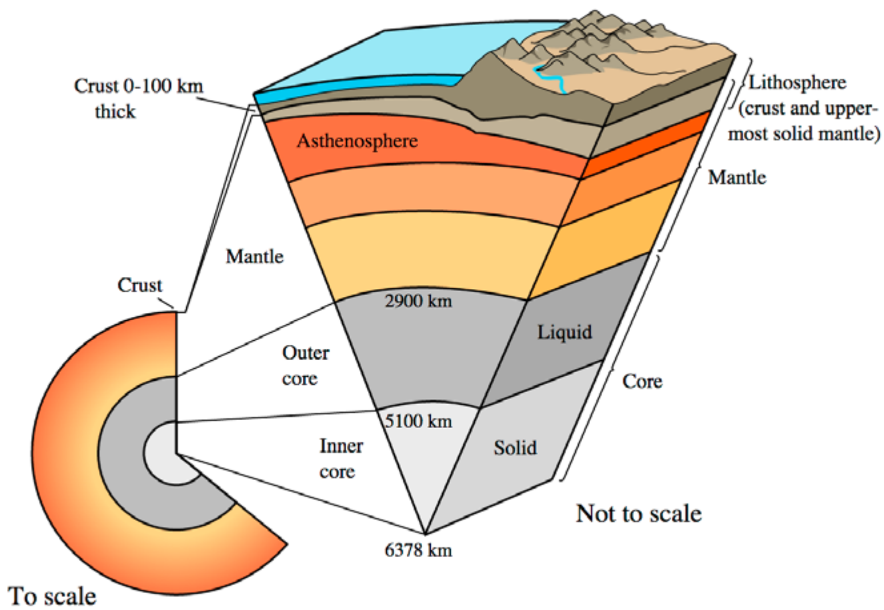
NGSS ALIGNMENT

MS-ESS2-2. Construct an explanation based on evidence for how geoscience processes have changed Earth's surface at varying time and spatial scales.

BACKGROUND INFORMATION

Layers of the Earth

Scientists classify the layers of the Earth in two ways — either based on chemical composition or on the mechanical properties of the rock.



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Compositionally, the Earth is divided into three main layers: the crust, mantle, and core.

The **crust** is the solid, outermost layer of the Earth. This layer can be divided further into:

- **Continental Crust** – composed of thicker, less dense rocks like granite. Makes up the continents.
- **Oceanic Crust** – composed of thinner, more dense rocks like basalt. Makes up the ocean basins.

The **mantle** is the middle layer of the Earth, composed mostly of rocks rich in silicates, such as peridotite. Temperature and pressure of the mantle generally increase with depth. The viscosity of the mantle also varies — the upper mantle is more rigid, while below is partially melted.

The **core** is the very dense, very hot innermost layer of the Earth. This can be divided further into:

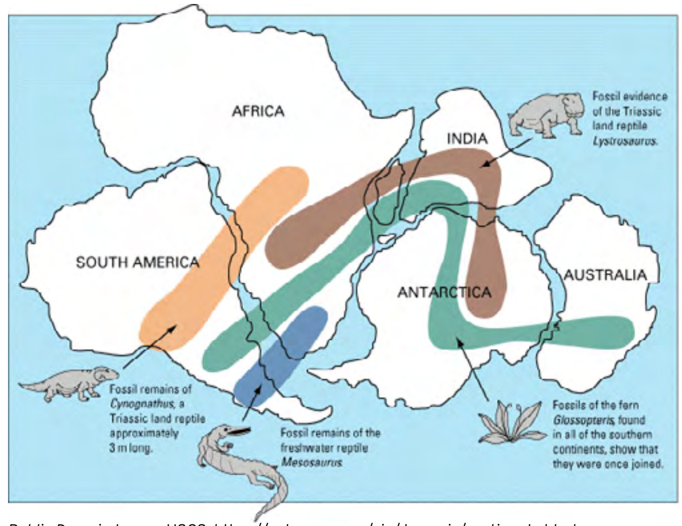
- **Outer Core** - liquid layer of the core, believed to be mostly iron and nickel. Electrical currents within this layer generate Earth's magnetic field.
- **Inner Core** – solid layer of the core composed of iron, nickel and, possibly, other heavy metals. This layer is solid due to extreme pressure.

Increasing depth — and changing temperature and pressure — also affects the mechanical strength, or rigidity, of the rock. For plate tectonics, the two important mechanical layers of the Earth are the lithosphere and asthenosphere.

- **Lithosphere** - consists of the uppermost, most rigid portion of the mantle and the crust. These two compositional layers behave mechanically as one. The lithosphere is divided into the tectonic plates.
- **Asthenosphere** - the semi-molten, denser layer of the mantle beneath the lithosphere. Although it behaves like a plastic and is more viscous, or ductile, than the lithosphere, it is NOT a liquid.

Theory of Plate Tectonics

Continental drift, proposed in 1915 by meteorologist Alfred Wegener, is the idea that the continents have changed positions over time. Wegner theorized that all of the continents were once connected into a supercontinent he called **Pangea**, and that they had since drifted apart into their current positions around the world. He used fossil and glacial evidence, similarities of coastline shapes and the exposed rock formations on those coasts, and evidence of an old mountain belt to put Pangea together.



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Although this evidence supported his idea of Pangea, Wegner still didn't know the mechanism – or how – the continents moved. Over time, technological advances allowed for new scientific exploration and evaluation. Mapping of the ocean floor revealed **mid-ocean ridges** (underwater mountain chains) in the middle of the ocean and **trenches** (long, narrow, deep depressions of sea floor) near continental margins. Geologist Harry Hess thought new sea floor was created at the ridges, pushed away and eventually destroyed at the trenches. The rocks that make up the sea floor were examined for age and magnetic polarity – revealing a striped pattern of magnetic reversals with younger rocks near the ridge and older rocks farther away. **Earthquakes** and **volcanoes** also seemed to be concentrated along ocean trenches and mid-ocean ridges.

Today, we know the **tectonic plates**, sections of the lithosphere, are in constant (extremely slow) motion over the asthenosphere. The earthquakes and volcanoes are concentrated at or near plate boundaries – where tectonic plates interact. Interestingly, the mechanism behind the movement of tectonic plates is still a topic of debate among Earth scientists. As they continue to investigate and discover new evidence, new questions will arise that will need to be answered.

The **Theory of Plate Tectonics** combines the ideas of continental drift, sea floor spreading and seismic evidence. It is a unifying theory for Earth science; it helps explain current and past movement of rocks on the surface and it relates geological events that used to seem random – like earthquakes, volcanoes and mountain ranges.

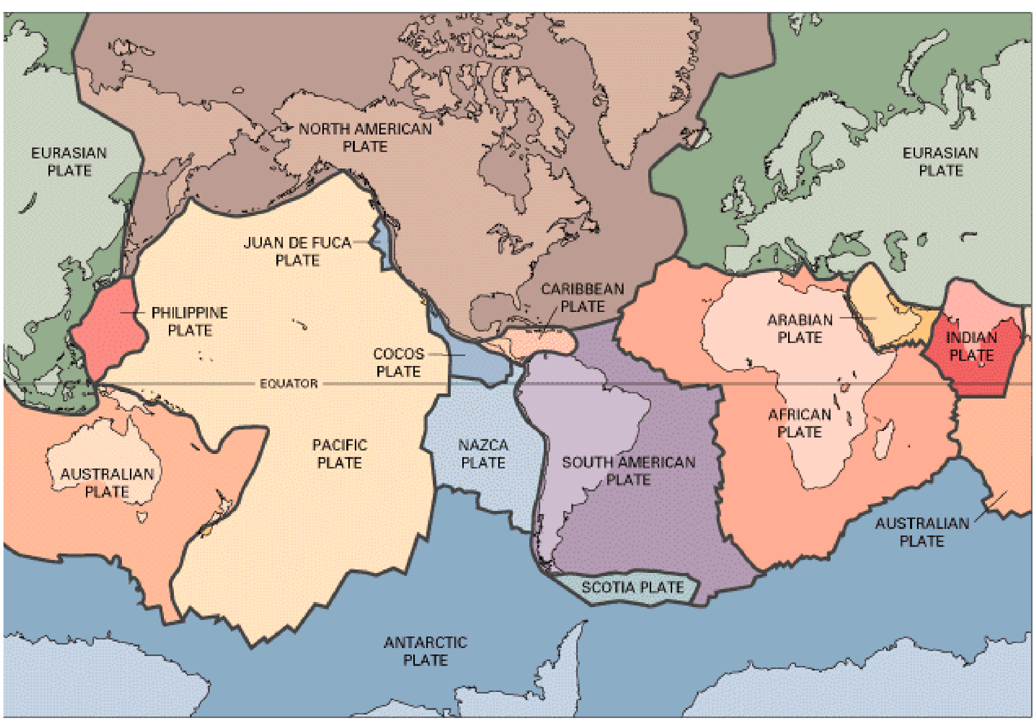

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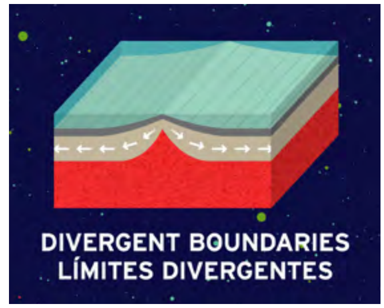
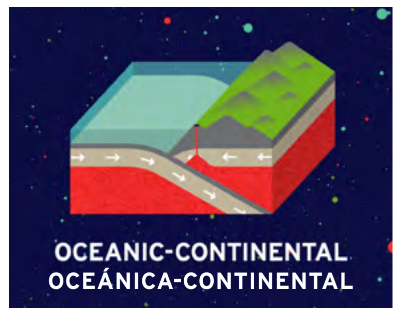
Plate Boundaries

The lithosphere is divided into roughly a dozen tectonic plates, or rigid plates that move over the asthenosphere. **Plate boundaries** occur where two or more tectonic plates meet and interact. Geological events are concentrated in these areas. There are three types of plate boundaries: divergent, convergent and transform boundaries.



Divergent boundaries occur where plates are pulling or moving away from each other. New crust is formed at divergent boundaries. The Mid-Atlantic Ridge is a great example of a divergent boundary. Found in the middle of the Atlantic Ocean, it separates the North American plate and Eurasian plate, and the South American plate and African plate. As the plates diverge and new crust is formed, the Atlantic Ocean basin gets wider. Possible geological events that can occur at divergent boundaries include volcanoes, earthquakes, mountains and **ocean basins**.

Convergent boundaries occur where plates are pushing or moving towards each other. Depending on the type of plates involved, crust can be pulled or subducted into the mantle to be "recycled" or the crust can be pushed upwards. There are three types of convergent boundaries that can occur: between one oceanic plate and one continental plate, between two oceanic plates or between two continental plates. Possible geological events that can occur at convergent boundaries include volcanoes, earthquakes, mountains and trenches.



Oceanic-Continental Convergent Boundary - The more dense oceanic plate is subducted below the less dense continental plate. As the plates collide, the oceanic plate slides beneath the continental plate, eventually slipping into the mantle. This **subduction** causes trenches, long, narrow depressions of the deep-sea floor, to form, as well as volcanic and seismic activity. Along the west coast of South America, the Nazca plate is being subducted below the South American plate.

Oceanic-Oceanic Convergent Boundary - At this type of boundary, the more dense oceanic plate is subducted beneath the less dense oceanic plate, forming a trench. This subduction can also lead to seismic and volcanic activity. Beginning as an underwater volcano, the sediment from eruptions builds up over time until it may rise above sea level. The volcanoes that occur here usually form chains parallel to the trenches, called **island arcs**. The Marianas Trench (paralleling the Mariana Islands) is formed from the collision of two oceanic plates.

Continental-Continental Convergent Boundary - At this type of convergent boundary, neither plate is subducted, since they are both less dense continental crust. Instead, the crust is pushed upward, forming mountains, like the Himalayas. The continued collision of the Indian and Eurasian plates explains the earthquakes that can occur in this region.

Transform boundaries occur where two tectonic plates move sideways past each other. Crust is neither formed nor destroyed at these boundaries. A commonly used example of this type of boundary is the San Andreas Fault in California. The Pacific and North American plates are moving sideways past each other at this location. Earthquakes commonly occur at these boundaries.

The geological events that occur at or near plate boundaries are important to understand as they impact nearby communities. The more scientists understand about the Earth's structure, plate boundaries and the associated events, the more they can help communities prepare for the future.

VIEWING STRATEGIES AND TOOLS

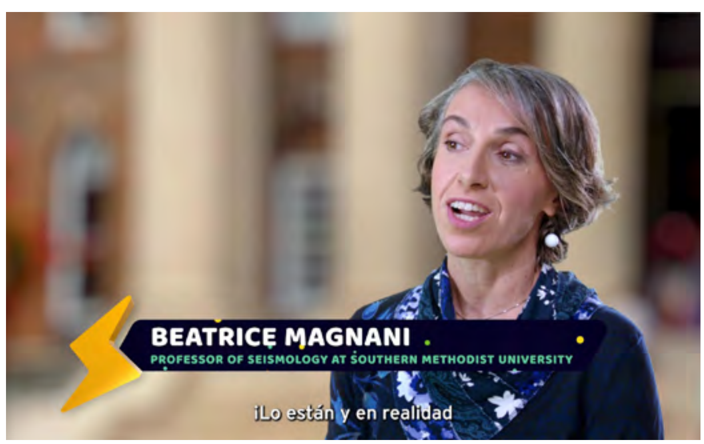
DISCUSSION QUESTIONS

SECTION 1: THEORY OF PLATE TECTONICS AND LAYERS OF THE EARTH [BEGINNING – 9:05]

1. What changes did you notice to the Earth as The Whynauts traveled back in time?
   Answers will vary. Answers may include sea level changes or some continents were in a slightly different place on the globe than where they are today, such as India being separate from Eurasia in the past.
2. What evidence do you think scientists used to reconstruct the past movement of the tectonic plates?
   Answers will vary. Answers may include the shape of continents, examining rock formations, continuous mountain chains, glacial evidence and fossil evidence.
3. How might the continual movement of the tectonic plates affect climate?
   Answers will vary. Answers may include changing ocean currents affecting weather patterns or mountain chains influencing wind.
4. If you could journey to the center of the Earth, would you? Please explain.

SECTION 2: PLATE BOUNDARIES AND GUEST SCIENTIST [9:05 – END]

1. Have you ever experienced an earthquake? Where were you? Would you like to share about your experience?
2. Earthquakes in Texas are relatively minor and infrequent in comparison to those in California. Why might this be?
   Texas is not near a major plate boundary, while California is along the boundary between the Pacific and North American plates. These two plates slide past each other very slowly building up friction, causing some parts to "snag" and then jerk free. This motion and resulting release of energy causes the ground to shake, or earthquakes.
3. Apart from two continental plates colliding or glacial melt, what is another factor that can affect the height of mountains?
   Time and/or erosion from wind, water, ice and plants. For example, the Appalachian Mountains formed roughly 300 million years ago (mya), while the Rockies formed more recently, roughly 75-60 mya. Ice, water, wind and plants have had much more time to erode the Appalachians than the Rockies.
4. Why is learning about the different composition and movement of the Earth's layers important?
   Answers will vary. Answers may include understanding where and how earthquakes form can help us engineer safer buildings and bridges, understanding that the active, molten outer core generates Earth's magnetic field, which protects us from harmful solar radiation, or that by understanding the geology of our planet, we can better understand the geology of other terrestrial planets.



Pre- and Post-Video Assessment

1. What are tectonic plates?

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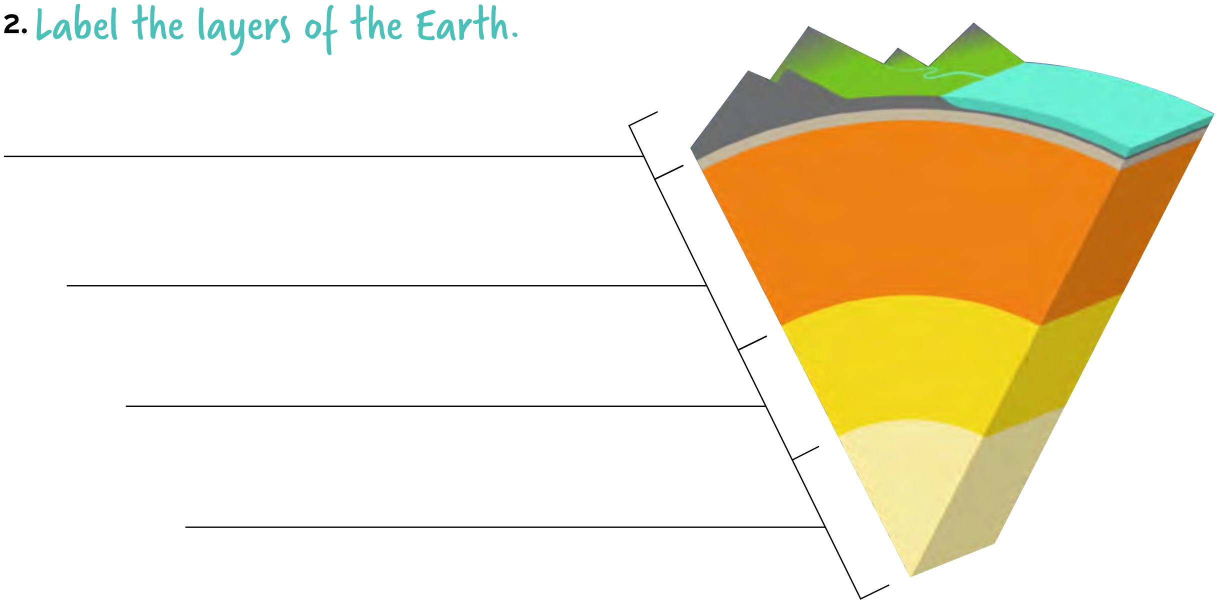
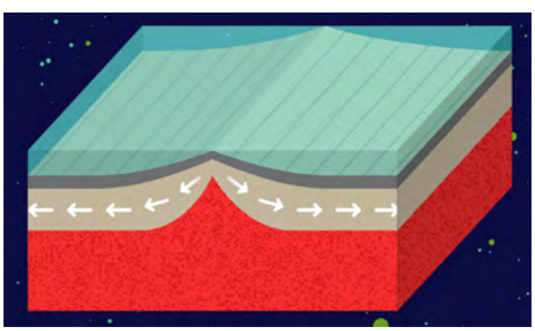
2. Label the layers of the Earth.



3. This model is an example of what type of plate boundary?



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Which of the following events does NOT occur at this type of boundary?

A. Formation of ocean basins

B. Formation of trenches

C. A volcanic eruption

D. Mountain building

Pre- and Post-Video Assessment

1. What are tectonic plates?

Tectonic plates are large, rigid pieces of earth that float above the Earth's asthenosphere, joined together in a puzzle pattern that covers our planet.

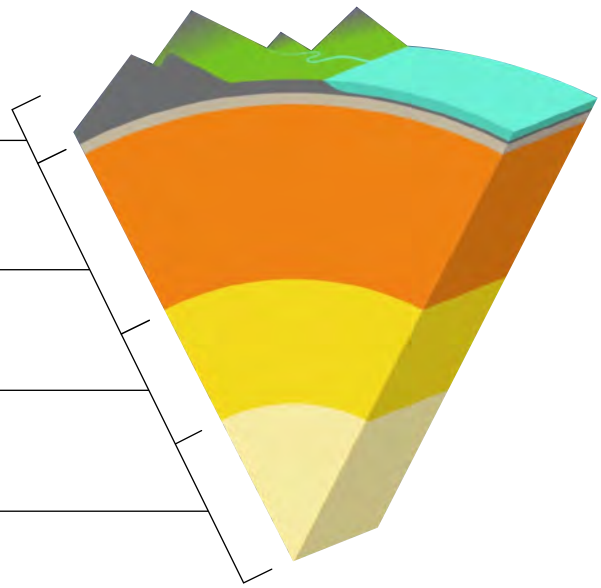
2. Label the layers of the Earth.

Crust

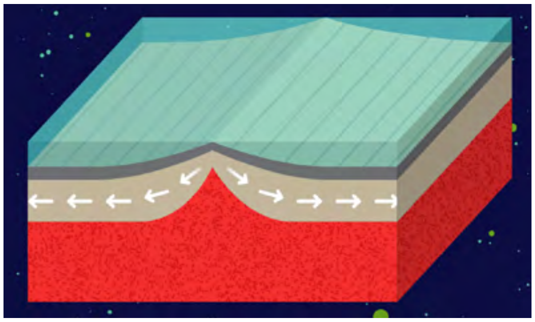
Mantle

Outer Core

Inner Core



3. This model is an example of what type of plate boundary?



Divergent Plate Boundary

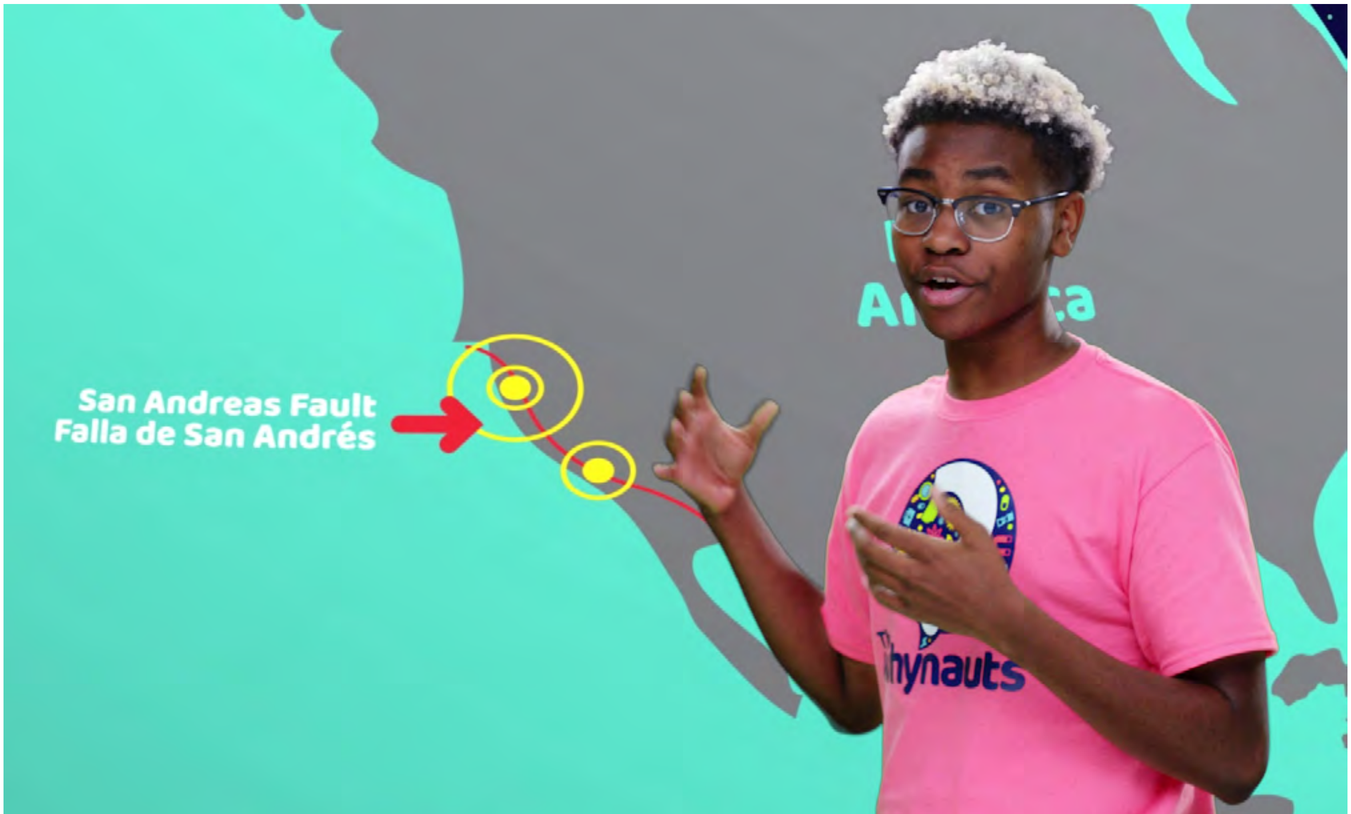
Which of the following events does NOT occur at this type of boundary?

A. Formation of ocean basins

B. Formation of trenches

C. A volcanic eruption

D. Mountain building



SUPPLEMENTAL ACTIVITIES

Exploring Earth's Layers

WHY Action News: Geological Events

Puzzling Pangea

Earthquake Challenge

Exploring Earth's Layers

HOW CAN WAVES BE USED TO STUDY THE LAYERS OF THE EARTH?

Objective

- Students will explore how sound waves travel in a solid, a liquid and a gas and use the results to make a conclusion about how waves can be used to investigate the layers of the Earth.

Materials (per group/pair)

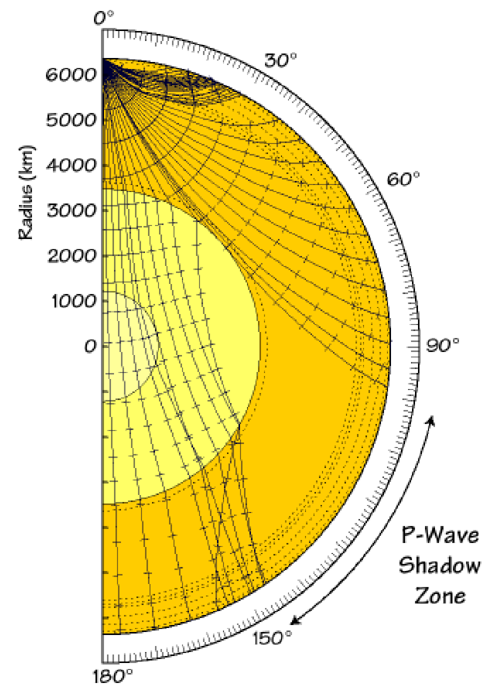
- Table, or nearby door
- 2 Metal spoons
- Bucket
- Water bottle – without the lid
- Scissors
- Water
- Balloon

Background Information

Scientists called seismologists study how waves of energy travel through the Earth. Sometimes seismologists study seismic waves from natural sources, like **earthquakes**, and sometimes they make their own seismic waves using controlled sources of energy.

Waves travel through different substances or materials at different speeds. For example, sound travels faster in water than in air. (This is one reason why sounds seem distorted to our ears when we are underwater.) Sound travels fastest through solids, where molecules are packed close together, and slowest through gases, where molecules are spread widely apart.

Seismic waves change speed as they travel through Earth's layers, which helps seismologists study the interior of the Earth. Some seismologists study the factors that contribute to earthquake occurrence and strength. This research could help guide engineers in designing new buildings to prevent damage and keep people safe. The seismologist featured in the video uses seismic waves to study how the continental **lithosphere** has changed over time.



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Lesson Outline

1. Before class, gather supplies. Cut each water bottle in half, keeping the top portion for the activity and recycling the bottom portion. (Students will use the bottle like a funnel.) Optional: fill buckets halfway with water.
2. As a class, review the layers of the Earth.
3. Have students build a model of the layers of the Earth.
   - Models should include: inner core, outer core, mantle, crust, asthenosphere and lithosphere

4. Have a class discussion about what materials were used and why.

- What are the limitations and advantages of their model?
- How do the materials used relate to the compositional and/or mechanical layers of the Earth?

5. Discuss how the interior of the Earth is studied.

- How would you learn about what is inside an egg if you are not allowed to crack it open?
- It is impossible to travel to the center of the Earth, so how do you think scientists are able to study the interior of the Earth?
- Seismologists study how waves travel through the Earth.
  - What kind of waves do you know about? How do they travel?

6. Have students complete the activity in pairs or small groups. Students will explore how sound waves travel through different materials.

7. Have a wrap-up discussion about the activity.

- What are the advantages and limitations of this model?
- How did the sound travel differently in different materials?
- Why do you think it was different?
- How is this related to how seismologists study the layers of the Earth?

Extensions

- Art Extension - Pretend to take a journey to the center of the Earth! Use index cards to create a postcard from each layer of the Earth (crust, lithosphere, asthenosphere, mantle, core). On each index card, draw a picture and label the name of the layer on one side. On the reverse side, write a message to describe what you would have seen and experienced at that part of your journey. Make a title or front-page postcard showing the whole Earth. Tape all the postcards together, with the title postcard first and then fold up at the taped edges to make a postcard book.
- Career Connection – connect your students with an Earth scientist! You can reach out to scientists in your community or use a resource such as skypeascientist.com

Exploring Earth's Layers

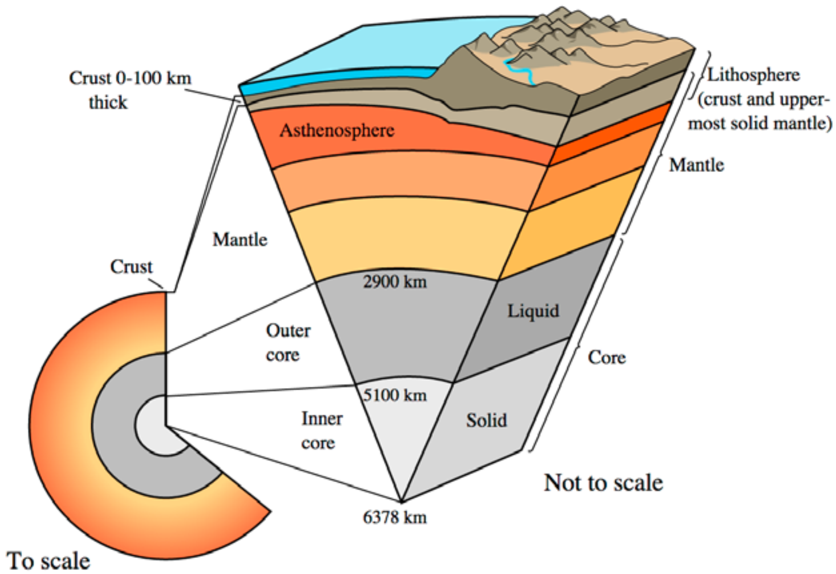
HOW CAN WAVES BE USED TO STUDY THE LAYERS OF THE EARTH?

Materials (per group/pair)

- Table, or nearby door
- 2 Metal spoons
- Bucket
- Water bottle – without the lid
- Scissors
- Water
- Balloons

INTRODUCTION

The Earth is divided into layers. Those layers are:



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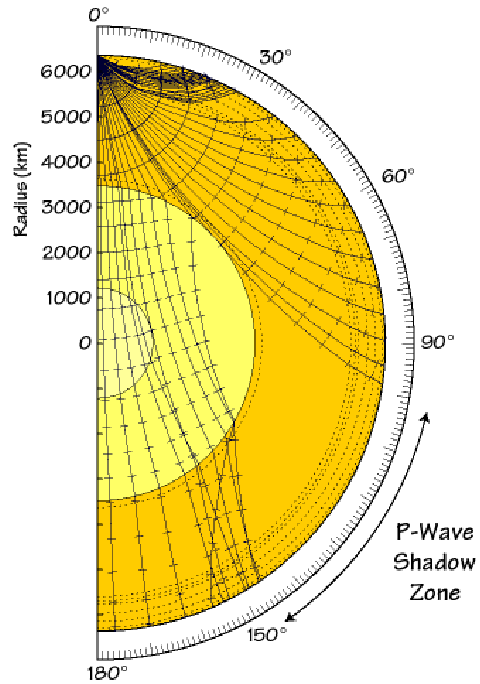
The **crust** is the solid, outermost layer of the Earth. **Continental crust** makes up the continents, and the **oceanic crust** makes up the **ocean basins**.

The **mantle** is the middle layer of the Earth, composed of mostly rocks rich in silicates. Temperature and pressure of the mantle generally increase with depth. The viscosity of the mantle also varies — the upper mantle is more rigid, while below is partially melted.

The **core** is the very dense, very hot innermost layer of the Earth. The **outer core** is liquid, believed to be mostly iron and nickel. The **inner core** is solid, composed of iron, nickel and, possibly, other heavy metals.

Increasing depth — and changing temperature and pressure — also affects the mechanical strength, or rigidity, of the rock. For plate tectonics, the two important mechanical layers of the Earth are the lithosphere and asthenosphere. The **lithosphere** consists of the uppermost, most rigid portion of the mantle and the crust.

These two compositional layers behave mechanically as one. The lithosphere is divided into the **tectonic plates**. The **asthenosphere** is the semi-molten, denser layer of the mantle beneath the lithosphere. Although it behaves like a plastic and is more viscous, or ductile, than the lithosphere, it is NOT a liquid.



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Scientists called seismologists study how waves of energy travel through the Earth. Sometimes seismologists study seismic waves from natural sources, like **earthquakes**, and sometimes they make their own seismic waves using controlled sources of energy.

Waves travel through different substances or materials at different speeds. For example, sound travels faster in water than in air. (This is one reason why sounds seem distorted to our ears when we are underwater.) Sound travels fastest through solids, where molecules are packed close together, and slowest through gases, where molecules are spread widely apart.

Seismic waves change speed as they travel through Earth's layers, which helps seismologists study the interior of the Earth. Some seismologists study the factors that contribute to earthquake occurrence and strength. This research could help guide engineers designing new buildings to prevent damage and keep people safe. The seismologist featured in the video uses seismic waves to study how the continental lithosphere has changed over time.

Now it is your turn to explore how sound waves travel through different mediums.

BEFORE YOU BEGIN

Make a hypothesis.

How do you think sound will travel through the different materials?

PROCEDURE

1. Find your workspace. Gather and prepare the materials.
    - Cut the water bottle in half, keeping the top half for the activity and recycling the bottom half. This will be used like a funnel.
    - Fill bucket halfway with water.
    - Inflate the balloon.
2. Start with the gas or inflated balloon. Taking turns, one partner will hold the balloon to one ear. The other partner will hit the spoons together to make sound. Record your observations in the chart.
3. Next, test the solid. Stand on opposite sides of a door. Taking turns, one partner will listen with their ear against the door. The other partner will hit the spoons together. If you are using a table, one partner will rest their ear on the surface of the table. The other will hit the spoons together below the table surface. Record your observations in the chart.
4. Lastly, test the liquid. One partner will put the mouth of the bottle to their ear and the bottom portion in the water. The other partner will bang the spoons together underwater. Take turns and record observations in the chart.

MATERIAL	OBSERVATIONS
GAS AIR	
SOLID DOOR OR TABLE	
LIQUID WATER	

QUESTIONS

1. Did your observations match your hypothesis? Please explain.

2. Think about the how molecules in solids, liquids and gases behave. Do you think that contributed to how sound traveled through those materials? Please explain.

3. How do you think this model represents how seismologists are able to study the layers of the Earth?

4. What layer(s) of the Earth do the water and door/table represent?

5. The inner core is solid. Based on your observations, how do you think sound travels through this layer?

MATERIAL	OBSERVATIONS
GAS AIR	
SOLID DOOR OR TABLE	
LIQUID WATER	

QUESTIONS

1. Did your observations match your hypothesis? Please explain.

Answers will vary.

2. Think about the how molecules in solids, liquids and gases behave. Do you think that contributed to how sound traveled through those materials? Please explain.

Answers will vary. The molecules in solids are more densely packed than those of a liquid or gas. The more densely packed molecules transfer vibrations faster than less densely packed molecules do.

3. How do you think this model represents how seismologists are able to study the layers of the Earth?

Answers will vary. Seismologists use seismic waves to study the interior of the Earth. In this model, the different media may represent different layers of the Earth. How seismic waves travel through those layers can reveal physical properties of the layers inside the Earth.

4. What layer(s) of the Earth do the water and door/table represent?

Water represents the liquid inner core, and the door/table represents solid layers like the crust or outer core.

5. The inner core is solid. Based on your observations, how do you think sound travels through this layer?

Answers will vary. Seismic waves should travel quickly through this layer, since it is solid and the molecules are more densely packed.

WHY Action News: Geological Events

HOW ARE GEOLOGICAL EVENTS RELATED TO PLATE BOUNDARIES?

Objective

- Volcanoes, earthquakes and tsunamis, oh my! Students will research geological events that occur at or near tectonic plate boundaries and their impacts to the surrounding environment and population.

Materials

- Computer/tablet with internet access
- Art supplies (paper, markers, scissors, etc.)

Lesson Outline

1. Begin with a class discussion about **plate boundaries** and types of geological events that can occur at or near the boundaries.
2. Separate the class into pairs/groups. Assign each group a type of geological event. Have them read the article on the event type.
   - Volcanoes
   - Earthquakes
   - Tsunamis
3. Let them know they are now reporters working for WHY Action News. Have each group choose one specific event, such as the tsunami that occurred in the Indian Ocean in 2004, or one listed in the factsheet, and create a news report for the event. (Optional variation: do a news segment for the general type of event, such as tsunamis.)
   - They should include any relevant information people may want to know, such as what the event was, what caused it and when it occurred. In addition, because we are looking at connections to plate tectonics, if there is a plate boundary nearby, describe the type of boundary and plates involved.
   - They should also consider if they want any visuals for their report. Have them draw out any visual aids they would like to include.
   - Students should also consider how long the segment will be – aim to be between 2-5 minutes.
4. If time allows, have them report the news.

Extensions

- As students are reporting their specific events, mark where they occur on a map with plate boundaries. Do any patterns occur?
- Art Extension: Make a brochure about the different types of plate boundaries. Include pictures, fun facts, geological events and features that occur nearby.

WHY Action News: Geological Events

HOW ARE GEOLOGICAL EVENTS RELATED TO PLATE BOUNDARIES?

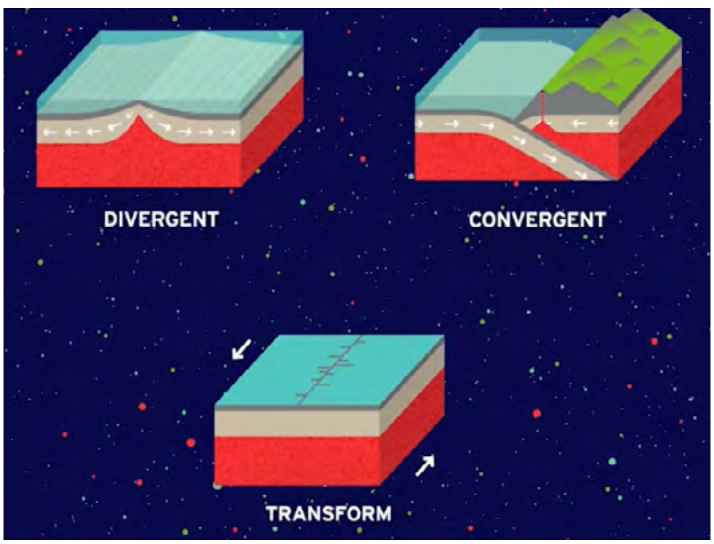
Materials

- Computer/tablet with internet access
- Art supplies (paper, markers, scissors, etc.)

INTRODUCTION

During the "Plate Tectonics" episode, The Whynauts anchored the WHY Action News segment on **plate boundaries**.

As **tectonic plates** move over the **lithosphere**, they interact with each other. They may pull apart, push together or slide past each other. **Divergent boundaries** are where plates move away from each other. New crust is formed here. **Convergent boundaries** are where plates push together. Crust can be subducted at these locations. **Transform boundaries** are where plates move sideways next to each other. Crust is neither formed nor destroyed here.



These interactions between tectonic plates can cause geological events such as **volcanoes** and **earthquakes**!

Now it is your turn to anchor WHY Action News! This time the segment is about geological events.

PROCEDURE

1. Research a type of geological event.
   - Volcanoes
   - Earthquakes
   - Tsunamis
2. Choose a specific event on the factsheet to research and report for the news segment. Use the WHY Action News Report below to help you write the news segment.
   - Try keeping the news segment between 2-5 minutes long.
   - Consider visuals you may want to use in your report.
3. Report the news for WHY Action News for your friends, family, pets or plants.

WHY Action News Report

USE THIS TO RECORD ANY NOTES OR INFORMATION FROM THE FACTSHEET OR YOUR OWN RESEARCH.

TYPE OF EVENT	
DESCRIPTION	
WHERE DOES THIS TYPE OF EVENT OCCUR?	
HAZARDS	
IMPACT TO PEOPLE	
ECONOMIC IMPACT	
PREVENTION OR PROTECTION STRATEGIES	
CONNECTION TO PLATE BOUNDARIES	
VISUALS NEEDED FOR SEGMENT	

Now, use the information above to write a 2–5-minute news segment on the geological event.

Puzzling Pangea

HOW WAS THE IDEA OF PANGEA DEVELOPED AND HOW IS IT RELATED TO PLATE TECTONICS?

Objective

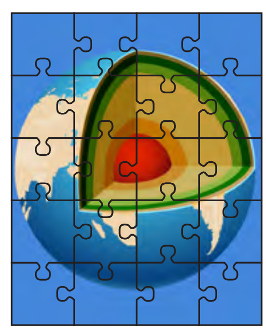
- Students will use scientific reasoning to solve an unknown puzzle using the evidence provided, and apply that reasoning to recreate the supercontinent, Pangea.

Materials

- Marker/crayons/colored pencils
- Blank puzzle pieces
- Scissors
- Bag (Ziploc or paper)
- Pangea puzzle pieces
- Glue or tape

Lesson Outline

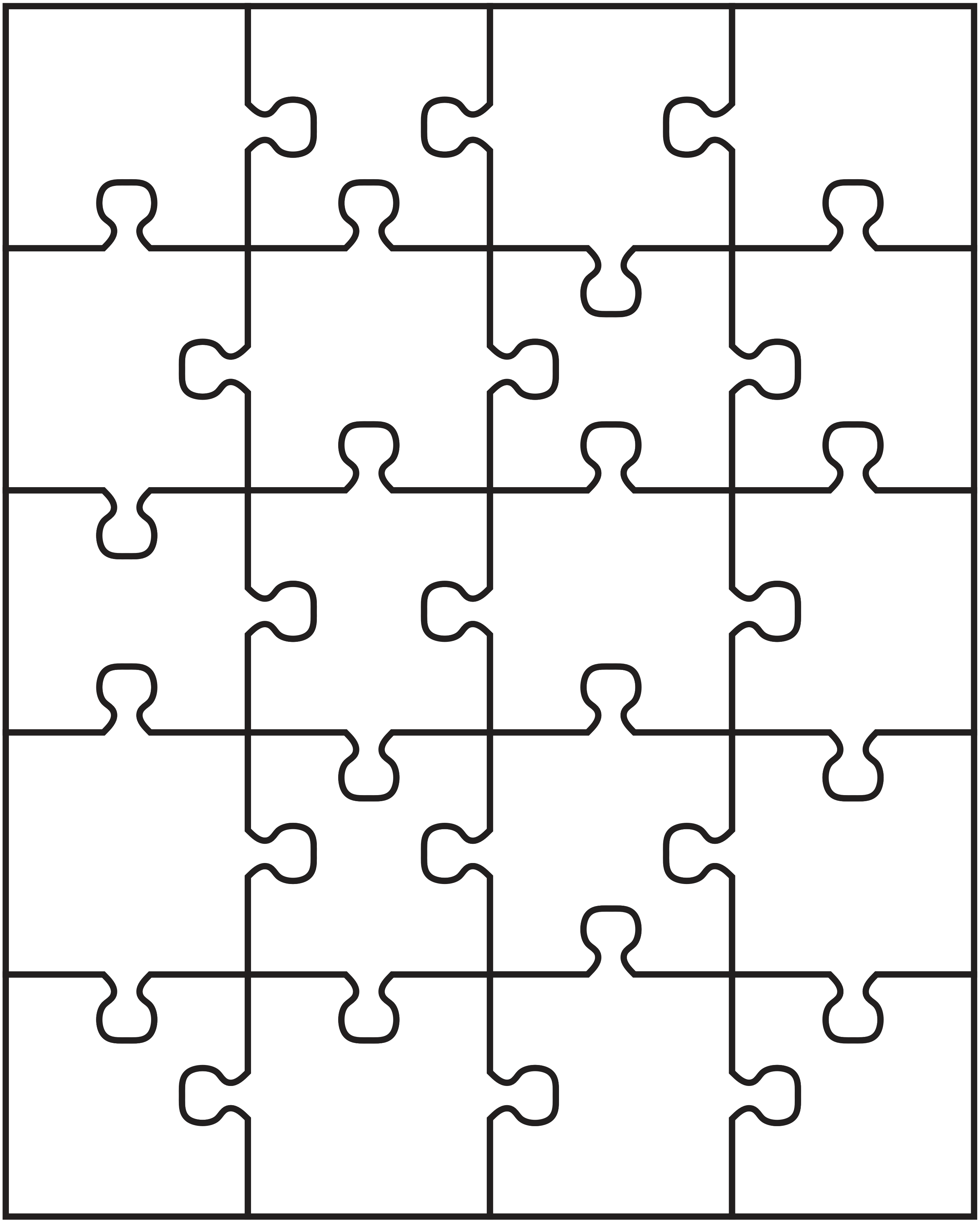
1. Begin with a class discussion about how scientific theories are developed and modified as time goes by and new technology is developed.
   - You might use the **Theory of Plate Tectonics** as an example. See background information for overview.
2. Have students complete the first activity. (blank puzzle)
   - Work in groups to design and create a new puzzle for classmates to solve later. Have them cut out the pieces and place them in a bag.
   - Have groups switch puzzles.
   - Give the groups a designated amount of time to put the new unknown puzzle together (~2-3 minutes). Then have students write for 1 minute about how they set out to solve the puzzle. Have students randomly switch papers with others not in their group and, for 1 minute, write how their response compared to the first student's. Was the method they used to go about solving the puzzle similar or different to the first student's response? If time allows, randomly switch one more time.
   - Either return to groups or, as a class, discuss the activity.
     - What methods did you use to solve the puzzle?
     - Did you face any challenges trying to solve the puzzle without knowing what the final product should look like?
     - What are some careers or occupations that would need to formulate ideas through trial and error, research, or experience?
3. Have students complete the Pangea puzzle. The different colors on the pieces represent evidence used to support the existence of Pangea.



Example Puzzle

Extensions

- Have students research one of the Pioneers of Plate Tectonics and their contribution to the theory. Create and submit a video of their response.
- Art Connection: Turn students' artwork into the "unknown" puzzle. Have an art lesson on any desired topic, and then turn the artwork into the puzzle pieces.



QUESTIONS

1. What strategies did you use while attempting to solve the unknown puzzle?

2. Did you face any challenges while solving the unknown puzzle? Please explain.

3. Label the continents and oceans.

4. Look at the map on the previous page. Do you see any clues that might suggest the continents were once in different locations?

5. Over time, more and more evidence was discovered that pointed toward one giant landmass, later called Pangea. Examine the Pangea puzzle pieces that have some of the evidence highlighted. What do you notice/observe?

6. Why do you think the same fossils are found in different parts of the world today? Explain.

7. Glue/tape completed Pangea on following blank page.

QUESTIONS

1. What strategies did you use while attempting to solve the unknown puzzle?

Answers will vary.

2. Did you face any challenges while solving the unknown puzzle? Please explain.

Answers will vary.

3. Label the continents and oceans.

4. Look at the map on the previous page. Do you see any clues that might suggest the continents were once in different locations?

Answers may include the similarities of coastline shape between the continents on either side of the Atlantic Ocean, especially between South America and Africa. The two continents appear to fit together like pieces of a jigsaw puzzle.

5. Over time, more and more evidence was discovered that pointed toward one giant landmass, later called Pangea. Examine the Pangea puzzle pieces that have some of the evidence highlighted. What do you notice/observe?

Answers may include:

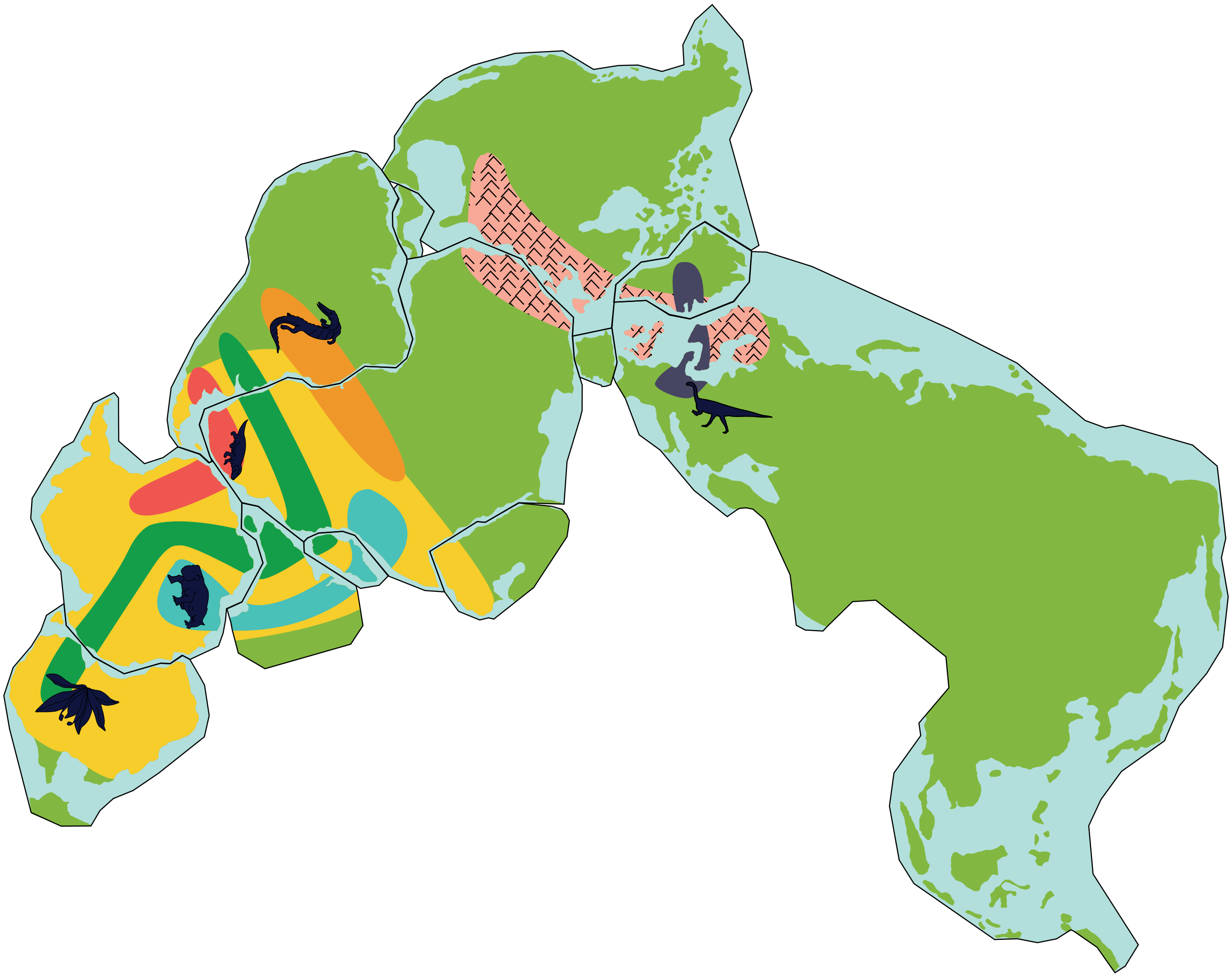
- Fossils of the same land animal were found across two or more continents that are now separated by an ocean.
- Fossils of the same species of plant were found on all of today's southern continents.
- There is evidence of the same, continuous mountain belt across part of modern-day North America, Africa, Greenland, Ireland, England, Scotland, and Scandinavia.

6. Why do you think the same fossils are found in different parts of the world today? Explain.

All the continents were once joined into one supercontinent, allowing terrestrial animals and plants to move and spread out across available land. Over millions of years, the continents have drifted apart to their current positions. It is unlikely that a species of land reptile would have swam across an ocean in breeding pairs to start a population on another continent. It is also unlikely that the same species of fern would be found on all the southern continents millions of years ago, if the continents were in their current positions today (given the drastically different climate of Antarctica).

7. Glue/tape completed Pangea on following blank page. See following page.

PUZZLING PANGEA



Earthquake Challenge

HOW ARE BUILDINGS ENGINEERED TO WITHSTAND EARTHQUAKES?

Objective

- Students will learn about the factors that affect how a building responds to an earthquake and test these principles using the Engineering Design Process to build their own model structure that can resist damage caused by a simulated earthquake.

Materials

(This supply list can be modified to use what you have available.)

- Cardboard box – 9x9 or any size that fits on a baking sheet
- Long pasta – fettuccine works best
- Round pasta – penne or rigatoni works best
- Masking tape
- Marshmallows
- Rubber bands
- Baking sheet
- Objects that can move/roll, such as tennis balls or marbles

Lesson Outline

1. Prior to the lesson:

- Assemble the shake table. For this shake table, place tennis balls (rolling objects) on the baking sheet. When students are done building, the cardboard base will go on top of this and you (or another student) can move the baking sheet back and forth to simulate an earthquake.
    - Note: This is a VERY simple DIY shake table. There are many different choices available online. Use what works best for your classroom!
- Prepare supplies. Students will work in groups. If limiting supplies, please divide and prepare for your class as you see fit. For example, provide the following to each group:
    - 2 feet of masking tape
    - 1/8 pack of each pasta type
    - 6 rubber bands
    - 4 marshmallows
    - 1 cardboard base

2. Begin the activity with a class discussion about earthquakes, where they occur, the damage they cause and how they affect people and communities. Possible visuals to show:

- Shaking of Atwood Building, Mw 7.0 November 30, 2018, Anchorage Quake
- Shaking of BP Exploration Building, M7 Nov. 30, 2018, Anchorage Quake
- Shaking of Frontier Building, M7.0 November 30, 2018, Anchorage Quake

3. Have students go through the Engineering Design Process to design, create and test an earthquake-resistant structure.

- Communicate any constraints and limitations you are giving them – including supply or time limitations or height restrictions.

4. End with a class discussion.

- What did you find challenging?
- How did you and your group members communicate and collaborate?
- What are the strengths and weaknesses of your model structure and shake table?

Extensions

- Math Extension — Assign monetary values to each material. For example, you may decide that 1 foot of tape costs $50 or a marshmallow costs $100. Give your students a budget that they are not allowed to exceed.
- History Extension — Today in Earthquake History: Have students look up their birthdate or other significant date in history to see if any earthquakes occurred.

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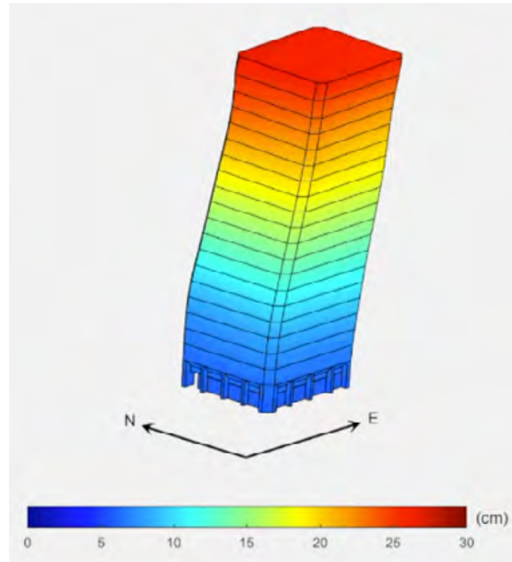

USGS, https://gallery.usgs.gov/media/videos/shaking-atwood-building-mw-70-november-30-2018-anchorage-quake

INTRODUCTION

Tectonic plates interact with each other at **plate boundaries** – where they move towards, away or slide past one another. Most **earthquakes** occur at or near these plate boundaries. An earthquake happens when shifting or slipping rocks suddenly release stored energy. The waves of energy, or seismic waves, move through the earth, causing the ground at the surface to shake.

Earthquakes can be described by magnitude and intensity. Magnitude refers to the size of an earthquake at the source. Currently the United States Geological Survey (USGS) uses the moment scale to report magnitude. Intensity refers to the severity of an earthquake, or the shaking and damage that occurs at the surface. In the United States, intensity is reported on the Modified Mercalli (MM) Intensity Scale. This scale is based on observable data, such as how many people felt it, if furniture was moved, or if and how many people were woken up. Each earthquake will only have one magnitude, but intensity can vary from location to location.

Buildings and structures can be damaged by the ground shaking. Variables such as the soil type, how close the building was to the source and building materials all play a role in how much a structure is affected by an earthquake. How well structures can withstand ground shaking is incredibly important for communities in seismically active areas. Engineers building in those areas utilize a number of techniques to fortify buildings against damage.

Now it is your turn! Can you design an earthquake-resistant structure?

PROCEDURE

First, set up the Shake Table.

Place tennis balls (or rolling objects) on top of the baking sheet. When you are done building, the cardboard base will go on top of this and you can move the baking sheet back and forth to simulate an earthquake. This will be used to test your design.

Then, use the Engineering Design Process Workbook to guide you through the challenge!

THE MODIFIED MERCALLI INTENSITY SCALE

Intensity	Shaking	Description/Damage
I	Not felt	Not felt except by a very few under especially favorable conditions.
II	Weak	Felt only by a few persons at rest,especially on upper floors of buildings.
III	Weak	Felt quite noticeably by persons indoors, especially on upper floors of buildings. Many people do not recognize it as an earthquake. Standing motor cars may rock slightly. Vibrations similar to the passing of a truck. Duration estimated.
IV	Light	Felt indoors by many, outdoors by few during the day. At night, some awakened. Dishes, windows, doors disturbed; walls make cracking sound. Sensation like heavy truck striking building. Standing motor cars rocked noticeably.
V	Moderate	Felt by nearly everyone; many awakened. Some dishes, windows broken. Unstable objects overturned. Pendulum clocks may stop.
VI	Strong	Felt by all, many frightened. Some heavy furniture moved; a few instances of fallen plaster. Damage slight.
VII	Very strong	Damage negligible in buildings of good design and construction; slight to moderate in well-built ordinary structures; considerable damage in poorly built or badly designed structures; some chimneys broken.
VIII	Severe	Damage slight in specially designed structures; considerable damage in ordinary substantial buildings with partial collapse. Damage great in poorly built structures. Fall of chimneys, factory stacks, columns, monuments, walls. Heavy furniture overturned.
IX	Violent	Damage considerable in specially designed structures; well-designed frame structures thrown out of plumb. Damage great in substantial buildings, with partial collapse. Buildings shifted off foundations.
X	Extreme	Some well-built wooden structures destroyed; most masonry and frame structures destroyed with foundations. Rails bent.

Engineering Design Process Workbook

Engineering Design Process Workbook

Name(s): ______________________________

ASK	
	What is the problem you are trying to solve?
	What are the criteria (requirements for success)?
	What are the constraints (limitations like time or materials)?

IMAGINE	
	Research strategies used in construction of earthquake resistant structures. • How Earthquake-Proof Buildings are Designed • 5 Keys to Designing Earthquake-Resistant Buildings Brainstorm possible solutions:

PLAN

Choose a solution that you think will work best to solve the problem. Do not forget the criteria and constraints!

Draw a diagram and label the different parts:

What materials will you need?

CREATE

Follow your plan to build a prototype.

TEST

Try it out! Test and evaluate your prototype.

Record your observations:

Was your design successful? What worked? What didn't?

IMPROVE

Redesign and retest your prototype as needed.

What changes did you make to your design? What effect did they have?

SHARE

Communicate your solution.

What did you learn?

How did you communicate with others throughout the design process?

ADDITIONAL RESOURCES

GLOSSARY

Asthenosphere – the semi-molten, denser layer of the mantle beneath the lithosphere. Although it behaves like a plastic and is more viscous, or ductile, than the lithosphere, it is NOT a liquid.

Continental Crust – portion of the crust composed of thicker, less dense rocks like granite. Makes up the continents.

Core – the very dense, very hot innermost layer of the Earth. This can be divided further into the inner and outer core.

Convergent Boundary – occur where plates are pushing or moving towards each other. There are three types of convergent boundaries: between one oceanic plate and one continental plate, two continental plates or two oceanic plates.

Crust – the solid, outermost layer of the Earth. This layer can be divided further into continental and oceanic crust.

Divergent Boundary – occur where plates are pulling or moving away from each other. New crust is formed here. The Mid-Atlantic Ridge is a divergent boundary.

Earthquake – felt at the surface as the sudden shaking of the ground; caused when shifting or slipping rocks suddenly release stored energy. These waves of energy, or seismic waves, move through the Earth.

Inner Core – solid layer of the core composed of iron, nickel and, possibly, other heavy metals. This layer is solid due to extreme pressure.

Island Arc – chain of islands formed from volcanic activity along a tectonic plate boundary

Lava – molten rock above the surface

Lithosphere – consists of the uppermost, most rigid portion of the mantle and the crust. These two compositional layers behave mechanically as one. The lithosphere is divided into the tectonic plates.

Magma – molten rock below the surface

Mantle – the middle layer of the Earth composed mostly of rocks rich in silicates, such as peridotite. Temperature and pressure of the mantle generally increase with depth. The viscosity of the mantle also varies – the upper mantle is more rigid, while below is partially melted.

Mid-Ocean Ridge – chain of (mostly) underwater volcanic mountains in the middle of the ocean basin. It occurs along a divergent plate boundary, where tectonic plates separate and new ocean crust is formed.

Mountain Building – geologic processes by which mountains are formed

Ocean Basin – the low-lying Earth formation that contains the ocean's water

Oceanic Crust – portion of the crust composed of thinner, more dense rocks like basalt. Makes up the ocean basins.

Outer Core – liquid layer of the core, believed to be mostly iron and nickel. Electrical currents within this layer generate Earth's magnetic field.

Pangea – supercontinent, proposed by Alfred Wegener, that was a combination of all the individual continents.

Plate Boundary – location where the edges of tectonic plates meet. There are three types of boundaries: divergent, convergent, and transform boundaries.

Plate Tectonic Theory – theory that recognizes the lithosphere is divided into rigid plates that move over the asthenosphere. It combines the ideas of continental drift and seafloor spreading and seismic evidence. Plate tectonics is a unifying theory; it explains the past and current movements of the rocks at Earth's surface. It also explains how major landforms are created as a result of movement in layers below the Earth's surface.

Subduction – occurs at convergent boundaries, when plates collide, one (more dense) plate is forced below the other (less dense) plate.

Tectonic Plate – sections or pieces of the lithosphere that move relative to each over the surface of the Earth.

Transform Boundary – occur where two tectonic plates move sideways past each other. Crust is neither formed nor destroyed at these boundaries. The San Andreas Fault is an example of a transform boundary.

Trenches – long narrow depressions of the deep-sea floor formed by subduction.

Volcano – a vent or mountain from which volcanic materials pass through the Earth's crust to the Earth's surface.

READING LIST

- Burleigh, Robert. *Solving the Puzzle Under the Sea: Marie Tharp Maps the Ocean Floor.* Simon & Schuster/ Paula Wiseman Books, 2016.
- Chin, Jason. *Island: A Story of the Galápagos.* Roaring Brook Press, 2012.
- Guillain, Charlotte. *The Street Beneath My Feet.* words & pictures, 2017.
- Ince, Martin. *Continental Drift: The Evolution of Our World from the Origins of Life to the Far Future.* Blueprint Editions, 2018.
- James, Josie. *Marie's Ocean: Marie Tharp Maps the Mountains Under the Sea.* Henry Holt Books for Young Readers, 2020.
- Nargi, Lela & Soldati, Arianna. *Absolute Expert: Volcanoes.* National Geographic Society, 2018.
- Winchester, Simon. *When the Earth Shakes: Earthquakes, Volcanoes, and Tsunamis.* Viking Books for Young Readers, 2015.

STEM Articles

- Does the Shape of a Volcano Reflect its Personality?
- How Can We Make Mountain Disasters Less Disastrous?
- Making a Map of Earth's Magnetic Field
- Mapping the Oceans
- The Life of Volcanic Rocks During and After an Eruption
- Three Time Tectonics Changed the Climate
- What To Do Before, During, and After an Earthquake

ONLINE RESOURCES

Perot Museum

- Amaze Your Brain at Home
  - Hunger for Plate Tectonics
  - Earth from Space

ArcGIS Story Maps – Digital storytelling with maps

- Plate Tectonics and Paleogeography
- Motion of Tectonic Plates
- The Deep (4 part collection)
- Mapping Mount Everest

Incorporated Research Institutions for Seismology

- Plate Boundaries: Three Types
- Myth-conceptions: Plate vs. Crust
- Earth's Layers
- Plate Tectonic Theory: A Brief History

Satellite Images

- NASA Earth Observatory Image of the Day
- NOAA Satellite Image of the Day Gallery
- NOAA Satellite Images of Major Events

TEDEd

- The Pangaea Pop-up – Michael Molina
- What Happens When Continents Collide? - Juan D. Carrillo

The Geological Society of London

- The Geological Society Factsheets
- Plate Tectonics Microsite

USGS

- Latest Earthquakes
- The Dynamic Earth
- The Science of Earthquakes
- Understanding Plate Motions
- Webcams

STEM Careers

- Dr. Beatrice Magnani, Seismologist
- IF/THEN Collection
  - Wendy Bohon, Geologist and SciComm Specialist
- Skype a Scientist
- USGS Careers Virtual Job Shadow

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