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6th Grade

Earth's Systems
Part 2: Plate Tectonics and Natural Disasters

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Table of Contents: Plate Tectonics and Natural Hazards

- Pangaea
- Energy Flow
- Types of Plate Interactions and the Results
- Natural Disasters
Pangaea
At this point in your life, you are probably very familiar with this map of our Earth's appearance.

Throughout human history, the continents have been positioned just like you see above. Fossil records hint at something different though. Complete the activity to learn more!
In the last activity, you saw that areas that are very far away from each other above ended up having similar fossils. Many of the areas that match up are even separated by an ocean!
Match Up the Excavation Pairs
Move the place on the right to match the one on the left.

Southport, SC, USA

Natal, Brazil

Algiers, Algeria

Western Antarctica

Easter Antarctica

Darwin, Australia
Dakar, Senegal
Barcelona, Spain
Lagos, Nigeria
Dar es Salam, Tanzania
Possible Hypotheses:

Below, record some of the hypotheses proposed that tried to explain the mystery of the common fossils:
Scientists have tried for years to solve this mystery. One proposed theory is known as continental drift. This concept was first presented by a German scientist named Alfred Wegener in 1912.

Wegener theorized that all of the continents were once connected in one large land mass. He stated that the land then "drifted" apart, forming the land we see today.
Although Wegener provided much evidence supporting his theory, he did not yet know what caused the continents to seemingly travel across the oceans.
Plate Tectonics

Scientists in the 1960s worked to prove Wegener's idea and developed the theory of plate tectonics. This theory states that the Earth's surface is broken into large, rigid pieces (called plates) that move independently of each other.

What do you think happens when these plates move around the surface of Earth?

Talk at your table to come up with some ideas.
Plate Tectonics

It is the movement of these plates that cause changes in the Earth's geographical features, including mountains and volcanoes, as well as the shapes of the continents.
1 What is the outermost layer of Earth called?

A Mantle
B Crust
C Inner Core
D Outer Core
2. What is the thinnest layer of Earth called?

A. Mantle
B. Crust
C. Inner Core
D. Outer Core
The Continents of the World

Antarctica  
North America  
Australia  
South America  
Asia  
Africa  
Europe
Pangaea

Compare the map on the previous page to the one below. The green represents land and the modern continents are outlined:

What similarities / differences do you see between the two images?
Wegener's theory of continental drift popularized the idea that there was once a "supercontinent," now called Pangaea.

This large land mass broke apart slowly over 200 million years ago, creating the continents that we see today.

The image on the left gives you an idea of how this transition happened.
Think Back on Our Activity...

How can we use the theory of the Pangaea supercontinent to explain the results of our fossil activity from earlier in this unit?
Evidence of Pangaea

- Fossil remains of *Cynognathus*, a Triassic land reptile approximately 3 m long.
- Fossil remains of the freshwater reptile *Mesosaurus*.
- Fossil evidence of the Triassic land reptile *Lystrosaurus*.
- Fossils of the fern *Glossopteris* found in all of the southern continents, show that they were once joined.
3 Similar Mesosaurus fossils would be found in which two areas?

A  Africa and India
B  Australia and South America
C  Antarctica and Africa
D  South America and Africa
Evidence of Pangaea

Even though the continents shown above are now many miles apart, when they were all together as one supercontinent, Pangaea, the plants and animals were able to spread across these modern barriers.

This causes there to be similar fossils in these now far-apart continents.
Evidence of Pangaea

Notice that a fern plant called *Glossopteris* once inhabited the land that is now Antarctica.

Do you think you can still find this plant there? Why or why not?
Evidence of Pangaea

There are non-living clues that support this theory as well. The rocks that make up our Earth hint at the fact that Pangaea once existed.

For example, the Appalachian Mountains in North America and the Caledonian Mountains in Europe are similar in age and structure and are made of the same rock types.
4 Which can be used as an indicator of past climate and weather?

A Fossils  
B Lava flow  
C Mountain ranges  
D Ocean tides
Which of the following can be used to show continents used to be next to each other in Pangea?

A  Fossils
B  Similar Animals
C  Mountain ranges
D  all of the above
Motion of the Continents

Pangaea was not the only supercontinent that has formed on Earth, but it is the most recent one.

The image above shows how the land was distributed around 600 million years ago. 200-300 million years before Pangaea!
Activity - Changes in the Land

The continents below are still moving but we don't notice a difference because of how slow the changes are.

Use the accompanying worksheet to determine how quickly our excavation sites from the introduction activity are moving apart.
6 Which of the following statements is NOT evidence of continental drift?

A  Similar fossils
B  Matching coastlines
C  Similar present-day weather
D  Matching mountain ranges
Energy Flow
The Energy of the Earth

Earth's energy comes from two different places.
What are those 2 places?
Solar Energy

We have discussed previously how the energy from the Sun (a/k/a solar energy) impacts Earth. Use the pictures and the lines below to list 3 ways Earth's organisms use energy from the Sun.

__________________________________

__________________________________

__________________________________
Earth's Internal Energy

The energy needed to cause the changes seen in our last section though comes from beneath the surface of Earth.

The heat of the inner core, outer core and mantle is linked to many large scale Earth processes such as plate tectonics, geysers, and volcanic eruptions.
Convection in the Earth's Mantle

The materials in Earth's mantle are constantly in motion.

As you travel through the mantle, the temperature changes.

To distribute this heat evenly, there are convection currents that move between the warmer and cooler sections.

These currents are able to travel through the semi-solid rock in the mantle, causing changes to the land above.
You may have heard the term "convection" before in reference to a convection oven.

Convection refers to the warming of a substance caused by the circulation of different temperatures of air.

In a convection oven, a fan helps circulate the warm and cool air so that the food inside heats evenly.
Differences in Air Temperature

The process of convection works because warm air and cool air behave differently.

Think back on your fire safety rules.. if there is smoke in a room, why is it important that Sparky in the picture below gets as low to the floor as possible?
Warm vs Cool Air

As air temperature changes, so does its density and its behavior.

This same phenomenon happens with all gases and liquids (such as ocean water) and also happens in the semi-solid mantle of Earth.
Convection in Earth's Mantle

Follow the arrows above to track the convection in Earth's mantle.

Because the Outer Core of Earth is so hot, the material that is close to that point will warm up. As it warms, it becomes less dense, causing it to rise closer to the surface.
Convection in Earth's Mantle

As the substances get closer to the surface of Earth, they cool down, become more dense and what happens?

(Notice that the substances within the Earth have a circular motion.. not straight up and down!)
The Convection Current Continues

This process will continue to repeat endlessly.

The motion of these currents causes massive changes to the

Core
7 Which of the following statements best explains why plates move?

A Heat from the Sun provides the energy for them to move.

B The ocean pushes on the plates causing them to shift.

C Volcanoes flow over the land forcing them to move.

D Heat in the mantle causes plates to slide.
8 Which statement is correct?

A  Hot substances rise.

B  Cold substances rise.

C  Materials with lower densities sink.

D  Materials with higher densities float.
9 Materials in Earth's mantle move in a circular direction.

True

False
Types of Plate Interactions and the Results
The surface of Earth is broken up into 15 major plates that are a part of the lithosphere.

These plates fit together like a jigsaw puzzle and are in constant motion.
10 Review: Tectonic plates move due to ________.

A  convection currents  
B  Earth's increasing size  
C  magnetic reversals  
D  volcanic activity
Plate Boundaries

The black lines on the previous slide are the dividing lines between each of the plates.

Any two adjacent plates can interact in one of the following ways seen below:

Note: "Adjacent" = "Next to"
Convergent Boundaries

A convergent boundary occurs where two plates are pushing ______________ each other.

Convergent plates collide.
Types of Convergent Boundaries

- Oceanic-Continental
- Continental-Continental
- Oceanic-Oceanic
As you can see in the pictures on the previous slide, oftentimes when two plates converge, one tectonic plate moves under another. This process is known as subduction.
Convergent Boundaries

One example of a convergent boundary is between the Indian plate and the Eurasian plate.
Convergent Boundaries

Scientists hypothesize that the Indian Plate slowly moved closer to the Eurasian Plate until it finally collided.

The image at the right shows this motion over many millions of years.
11 When two continental plates collide, what are sometimes formed?

A. Islands  
B. Landslides  
C. Hot Spots  
D. Mountains
12 What do the arrows on the diagram represent?

A  Magnetic polarity
B  Ocean flow
C  Plate movement
D  Volcanic eruption
How were scientists able to come up with the hypothesis that the Indian plate collided with the Eurasian plate?

The "proof" scientists used was found in Earth's features - in this case, the Himalayan mountain range, found along the northern border of India.
What Happens When Plates Converge?

A mountain range slowly forms as tectonic plates converge and collide into one another.

This collision is similar (but much less sudden and dangerous) than a head-on collision between two cars.

This car has been in a head-on collision. What do you notice about the car's appearance now?

What specifically caused this to happen?
The Formation of Mountains

As two continental plates (such as the Indian and Eurasian plates) converge, the land begins to fold up and buckle just like the hood of the car on the previous slide. Unlike with the car crash, this transformation takes thousands of years.

What is even more interesting is that the mountains you see below are still growing as the two plates continue to converge.
Worksheet - The Growth of a Mountain

Mount Everest can be found in the Himalayan mountain range on the border of Nepal and China. It is the tallest mountain in the world and it is still growing!

This worksheet will have you estimating the future growth of Mount Everest.
Divergent Boundaries

A divergent boundary marks two plates that are moving ________ from each other.

Divergent plates divide.
One example of a divergent boundary is the Mid-Atlantic Ridge that is found in the middle of the Atlantic Ocean.
Seafloor spreading is a result of divergent boundaries. It is the process by which new oceanic crust forms along a mid-ocean ridge and older oceanic crust moves away from the ridge. As the plates separate, magma from below the surface emerges, flows onto the seafloor and cools. This pushes the older oceanic crust away.
13 New oceanic crust forms and old oceanic crust moves away from a mid-ocean ridge during:

A  Continental drift
B  Magnetic reversal
C  Normal polarity
D  Seafloor spreading
14 Where would the oldest oceanic crust be found?
Transform Boundaries

A transform boundary occurs where two plates slide alongside each other.

Transform boundaries travel past each other.
15 Which of the following is a type of plate boundary?
(Choose all that apply)

A Transform
B Subduction
C Convergent
D Divergent
E Parallel
F Mantle
Transform Boundaries

One example of a transform boundary is the San Andreas Fault which runs through California.

It is the point where the Pacific and North American plates meet.
The Results of Plate Interactions

Each of these boundary interactions results in dramatic changes to the Earth's crust.

Some of these changes may take millions of years...

but others can happen in a matter of minutes!

Click here to see the devastation that can be caused by plate tectonics
16 The diagram below is an example of a _______________.

A  Convergent Boundary
B  Divergent Boundary
C  Transform Boundary
D  Subduction Zone
17 Which of these describes what is happening in the diagram?

A  Both plates slide past each other.
B  One plate goes below the other.
C  The plates move toward each other.
D  The plates move away from each other.
Match the Plate Boundaries

- Transform
- Convergent
- Divergent
Natural Disasters
Types of Natural Disasters

This section will focus on a number of different natural disasters that can occur here on Earth as a result of plate tectonics:

- Earthquakes
- Tsunamis
- Volcanoes
What is an Earthquake?

Earthquakes are the result of a sudden release in energy in Earth's crust that makes seismic waves. Earthquakes can occur at faults which are cracks in Earth's crust along which movement occurs.

Think of these waves as the ripples created when dropping a stone into a pool of water.

The waves will travel in all directions from the center point. They are strongest at the center (the epicenter) and get weaker as they move.
Measuring Earthquakes

Earthquakes are measured using seismometers.

The magnitude (size) of the earthquake is measured on the Richter scale.

This scale goes from less than 2 (an earthquake not even noticed by humans) to 9+ (a catastrophic quake).
Where do Earthquakes Occur?

Earthquakes typically occur at transform boundaries, like the one seen below in red.

Can you remember the name of this transform boundary in California?
Sliding Plates

At these transform boundaries, the plates are sliding past one another.

As you see below, this isn't a smooth motion and the plates oftentimes get stuck.

An earthquake occurs when these plates finally break free from each other and slide past.

(Keep in mind that these movements are very small... oftentimes only a few centimeters!)
18 Which best describes the epicenter?

A  The only point that experiences the earthquake.

B  The most populated city affected by the earthquake.

C  The point where the earthquake is felt at its strongest.

D  The location of the seismograph that captured the earthquake tremors.
Earthquake Damage

The amount of damage done by an earthquake depends on the magnitude of the quake.

An earthquake that is in the 2 - 5 range on the Richter scale is quite common and results in very minor damage, if any.

Earthquakes that chart above 8 on the Richter scale result in major damage or complete destruction, permanent changes to Earth's surface, and usually thousands of lives lost.

An example of the damage done in the 2010 earthquake in Haiti - a 7 magnitude quake.
Powerful Earthquakes

Since 1900, there have been only 5 earthquakes that have registered above a 9 on the Richter scale, including a 2011 earthquake in Japan. (We will discuss this earthquake later in this section.)
The amount of damage done by earthquakes depends on the magnitude of the quake as well as the area that it occurs.

The 2010 earthquake in Haiti was not as powerful as some other recent quakes, but because the area was so densely populated and not ready for an earthquake, the death toll was over 316,000.
Predicting Earthquakes

The black dots on this map each mark where an earthquake has measured on the Richter scale. With your group, explain why the dots are located in the places they are. Why are there areas with more earthquakes?
Predicting Earthquakes

Because earthquakes occur within the Earth's crust, there is no way to accurately predict when one will occur.

While the month and day cannot be predicted, there are areas of the world that experience an above-average number of quakes. These areas are those that sit on the most-active transform faults, such as the San Andreas Fault in California.
19 Which best explains why California is at an increased risk of earthquake?

A  It is below sea level.
B  It rests on a transform boundary.
C  It borders an ocean.
D  It has the largest population.
20 High energy earthquakes occur:

- A  Away from plate boundaries
- B  Away from divergent plate boundaries
- C  On convergent plate boundaries
- D  On transform plate boundaries
21 Earthquakes measuring 8 or above on the Richter scale are very common and happen many times a year.

True
False
Activity - Tabletop Earthquake

Earthquakes occur when two surfaces that are pulling against each other build up a lot of tension and eventually move past.

We will demonstrate this process on a tabletop using the friction between a block and a piece of sandpaper!
What is a Tsunami?

A tsunami is a series of water waves that occur as the result of a large volume of water being displaced because of an earthquake.

Do you think earthquakes that cause tsunamis are located on land or in the ocean?

Come up with a reason for your answer and be prepared to share.
Everyday Tsunamis

Think of the ocean as a bathtub:

If you were to fill this tub up to the very top with water and then climb in, what would happen?
How do Tsunamis Form?

Tsunamis occur when the surface of the ocean changes and pushes the water out onto the land. The water has no other place to go but out!

The reason this water is displaced is because of earthquakes under the ocean floor.

These earthquakes produce massive waves that travel in all directions.
Tsunami Damage

Tsunamis can do massive damage to coastal towns.

One of the most recent tsunamis was also one of the most catastrophic.

In 2011, a 9.0 magnitude earthquake off the coast of Japan produced a tsunami 33 feet (10 m) high.

Click here to see an animation of the tsunami in the Pacific Ocean.
The 2011 tsunami in Japan caused massive flooding and destroyed many homes and villages.

It also caused a meltdown at a nuclear power plant in Japan that threatened the safety of all in that area.

More than 18,000 people were reported as dead or missing as a result of this tsunami.
It is difficult to predict when a tsunami will occur because it is oftentimes the result of an earthquake.

Areas that are at high risk of tsunami damage have taken precautions to protect themselves.

One of the most common tactics is the building of sea walls. These walls serve as barriers that hold back the water.

Sea walls help protect against small tsunamis, but are no match for large ones such as in 2011.
22 When two plates suddenly slip past each other at a transform boundary, ____________.

A an earthquake occurs
B a volcano occurs
C the sea-floor spreads apart
D subduction occurs
23 If you feel the tremor of an earthquake, what could potentially follow?

A  A typhoon
B  A tsunami
C  A tornado
D  A hurricane
Activity - Tabletop Tsunami

Tsunamis occur when oceanic crust changes shape and the water found there is displaced. The larger the earthquake, the more damage it does to the ocean floor and therefore the more water that will be pushed away.

We will demonstrate this process on a tabletop using a bucket of water for our ocean and some deformations to the "ocean floor!"
What is a Volcano?

A volcano is an opening, or a vent, in Earth's crust that allows hot magma, ash and gases to escape. Where do you think most volcanos on Earth are located?

Image: NASA
Where do Volcanoes Form?

Volcanoes can form at two different plate boundaries:

**Convergent Plates**

When oceanic crust is involved in a converging plate boundary, it gets pulled further below the surface of Earth.

This motion then pushes the hot, less-dense magma up to the surface where it emerges from a volcano.
Where do Volcanoes Form?

Divergent Plates

As the plates break apart, it leaves an opening for the hot magma to emerge as lava.

Despite being underwater, these rifts release an incredible amount of heat!
Types of Volcanoes

Volcanoes are categorized in three different ways: Active, Extinct, or Dormant. (Click the stars to learn more!)

Active Volcanoes:

Extinct Volcanoes:

Dormant Volcanoes
Volcanic Eruptions - Mt Vesuvius

There have been a number of instances throughout history of cities and regions being destroyed by volcanic eruptions.

One of the most famous eruptions was that of Mount Vesuvius in Italy in 79 AD.

When Mount Vesuvius erupted, it buried and destroyed the Roman towns of Pompeii and Herculaneum.
Like many Roman cities, Pompeii was very advanced. It had a complex water system (including sewage), an amphitheater, a gymnasium and a port. It also had paved roads and many temples to the Roman gods.

We know so much about Pompeii today because when Vesuvius erupted, it practically "froze" the city in time. The features listed above, as well as living creatures, were instantly covered in 4-6 meters of volcanic ash.

Only upon being excavated more than 1,000 years later did we learn anything more about Pompeii.
Volcanic Eruptions - Mount St. Helens

More recently, the United States experienced the eruption of Mount St. Helens in Washington in 1980.

The resulting blast was so violent, it blasted out the side of the volcano, killing 57 individuals, including scientists studying the volcano. It also caused one of the largest landslides in history.
Mount St. Helens

The eruption of Mount St. Helens released a large amount of ash and gas into the atmosphere. Like most volcanoes, water vapor was released as well as carbon dioxide (CO$_2$) and sulfur gases, such as sulfur dioxide (SO$_2$).

The eruption also had an affect on our country's wallet: it is estimated that the blast cost an estimated $1.1 billion in clean-up (equal to about $2.7 billion today!)
Ring of Fire

While this phrase may best be known as a 1963 Johnny Cash song, the Ring of Fire that is of importance to geologists is the area surrounding the Pacific Ocean that has 452 volcanoes and is home to over 75% of the active and dormant volcanoes here on Earth!
24 Which of these is a sudden destructive event that can change Earth's surface?

A Volcanic eruption
B Mountain building
C Erosion of rock

Answer
25 The trembling of Earth caused by the sudden movement of Earth's crust is called a (an) ____________.

A volcano
B subduction zone
C earthquake
D hurricane
26 The Richter Scale measures which type of natural disaster?

A  A volcano
B  A tornado
C  An earthquake
D  A hurricane
Activity - Tabletop Volcano

Volcanic eruptions are some of the most violent phenomena here on Earth. In this activity, we will simulate a volcanic eruption. It is an experiment that you can even complete at home as well!