Earthquakes, Tsunamis, and Volcanoes: Who's at Risk? - Student Materials

Unit 3	Earth and Space Science

Student Materials Table of Contents

Performance Task Organizer

Unit 3 Earthquakes, Tsunamis, and Volcanoes: Who's at Risk?	Earth and Space Science

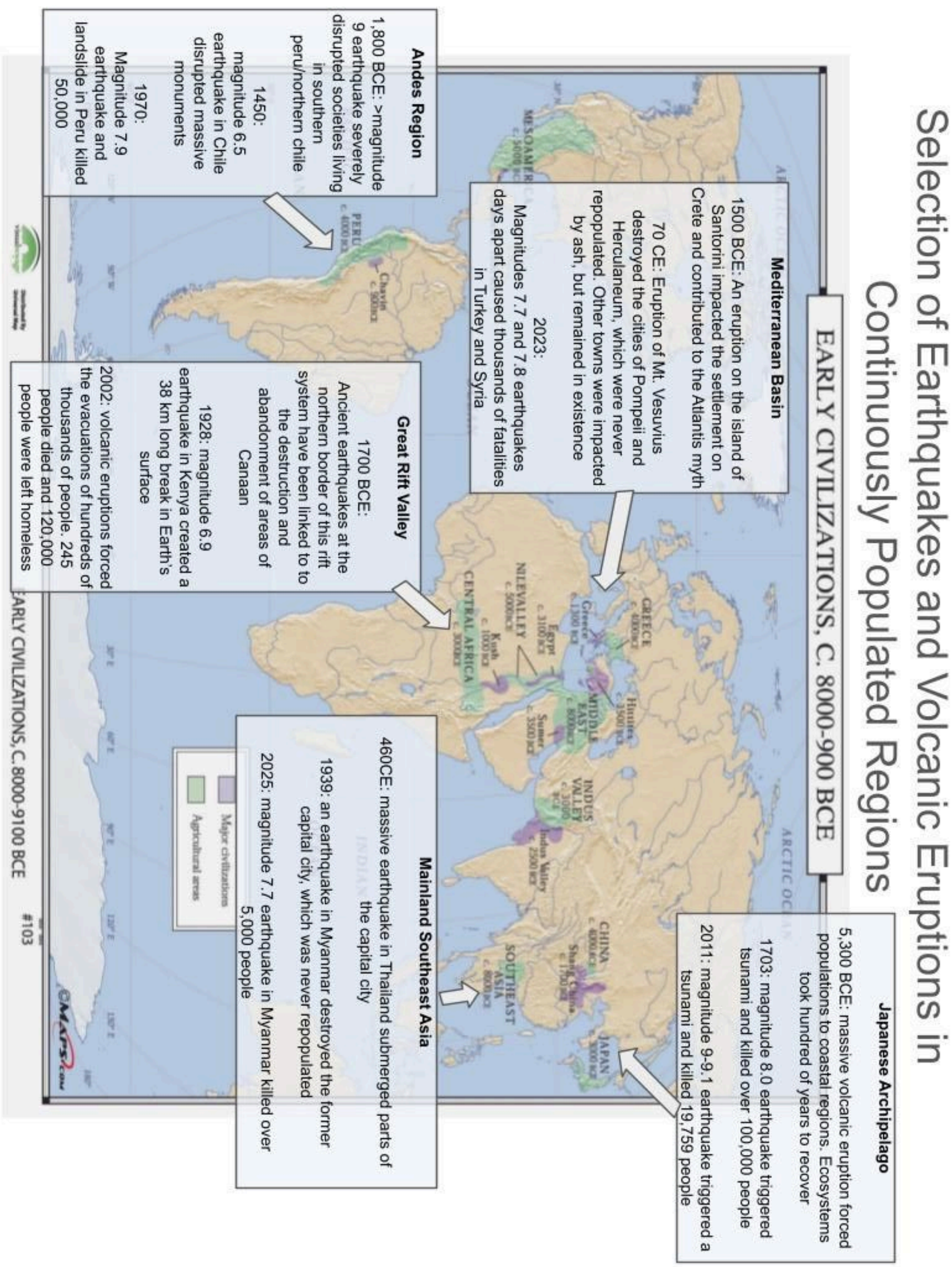
Student Name:

Tell the Story

Directions:

1. Silently read the texts below.
2. For each text, circle or jot 2-3 details that are important to telling the story of global occurrence of earthquakes, volcanic eruptions, and tsunamis.

Text #1

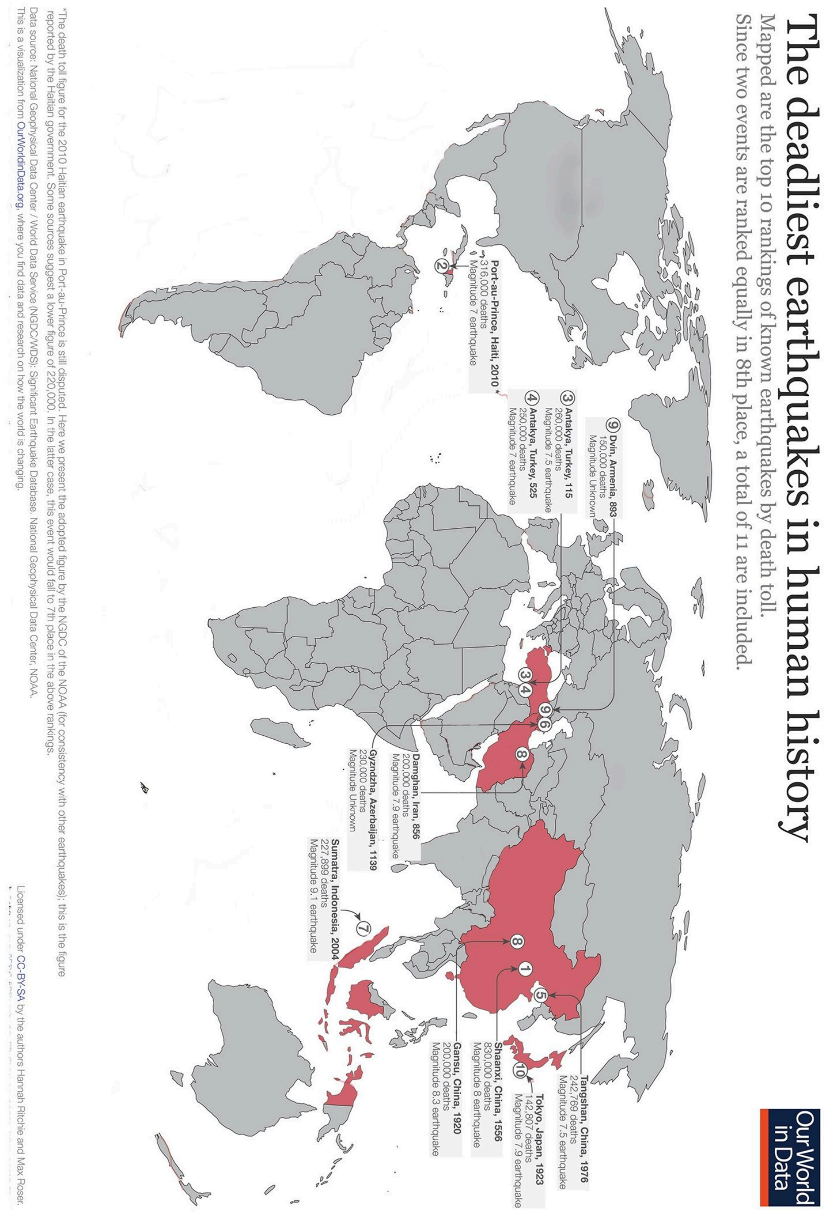


1. ____

2. ______________________________

3. ______________________________

Text #2


The deadliest earthquakes in human history
Mapped are the top 10 rankings of known earthquakes by death toll.
Since two events are ranked equally in 8th place, a total of 11 are included.
Our World in Data
9 Dvin, Armenia, 893
150,000 deaths
Magnitude Unknown
3 Antakya, Turkey, 115
260,000 deaths
Magnitude 7.5 earthquake
4 Antakya, Turkey, 525
250,000 deaths
Magnitude 7 earthquake
Port-au-Prince, Haiti, 2010 *
316,000 deaths
Magnitude 7 earthquake
Tangshan, China, 1976
242,769 deaths
Magnitude 7.5 earthquake
Tokyo, Japan, 1923
142,807 deaths
Magnitude 7.9 earthquake
Shaanxi, China, 1556
830,000 deaths
Magnitude 8 earthquake
Gansu, China, 1920
200,000 deaths
Magnitude 8.3 earthquake
Damghan, Iran, 856
200,000 deaths
Magnitude 7.9 earthquake
Gyzndzha, Azerbaijan, 1139
230,000 deaths
Magnitude Unknown
Sumatra, Indonesia, 2004
227,899 deaths
Magnitude 9.1 earthquake
*The death toll figure for the 2010 Haitian earthquake in Port-au-Prince is still disputed. Here we present the adopted figure by the NGDC of the NOAA (for consistency with other earthquakes); this is the figure reported by the Haitian government. Some sources suggest a lower figure of 220,000. In the latter case, this event would fall to 7th place in the above rankings.
Data source: National Geophysical Data Center / World Data Service (NGDC/WDS): Significant Earthquake Database. National Geophysical Data Center, NOAA.
This is a visualization from OurWorldinData.org, where you find data and research on how the world is changing.
Licensed under CC-BY-SA by the authors Hannah Ritchie and Max Roser.

1. ______________________________

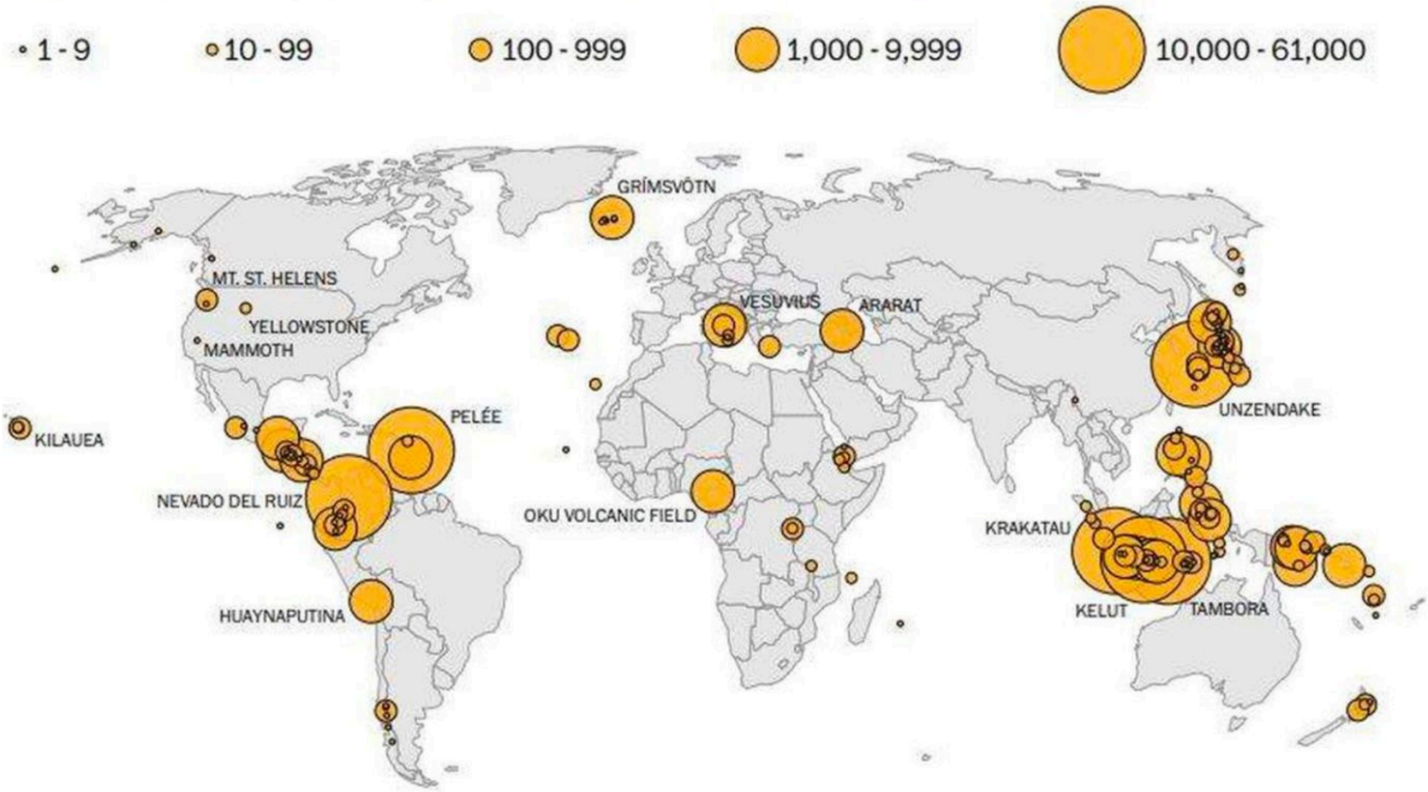
2. ______________________________

3. ______________________________

Text #3

Volcano fatalities since 1500

Circles are sized by the number of fatalities caused by each volcano since 1500 (can include multiple eruption events over that period):



Source: Brown et. al., Volcanic Fatalities Database

WAPO.ST/WONKBLOG

1. ____________________

2. ____________________

3. ____________________

Take turns sharing your details, and write down the 3-5 ideas that are most important to the story of global geologic hazard occurrence.

Important details our group surfaced (provide at least 5):

1. ____________________

2. ____________________

3. ____________________

4. ____________________

5. ____________________

Overall Story (based on group discussion):

Performance Task Introduction

Evaluating Disaster Risk
The United Nations, non-profit organizations, and governments around the world are interested in supporting populations at risk from disasters like earthquakes, volcanic eruptions, and tsunamis. Unfortunately, money available to fund this effort is limited, so decisions need to be made about how much should be invested to reduce risk in these areas.

Five areas have been identified as at risk to these disasters and of particular interest:

1. The Mediterranean Basin
2. The Great Rift Valley
3. The Japanese Archipelago
4. Southeast Asian Mainland
5. Andes Region

Performance Task: Your task in this unit is to investigate seismic disasters in order to model how they occur and explain how they have affected populations in the past in order to better understand how they put people and property at risk today.

Initial Model

What causes earthquakes, tsunamis, and volcanoes to occur across the world. How do they cause loss of life and property?

Individual: Using what you already know about earthquakes, volcanic eruptions, and tsunamis **develop an initial model** that illustrates…

- what causes an earthquake
- what causes a volcano eruption
- how each of these hazards cause loss of life and property

Questions to consider:

- How are you representing each hazard?
- How are you showing how each hazard is caused?
- Can you use your model to share your ideas with your group?

Small group: After sharing your individual ideas, you will develop a group model to represent the ideas you agree on.

Whole class: Look at other groups' models and notice how they are similar to or different from your own. List two things you saw in the other models that you think would be important for EVERYONE'S model to include.

Revisit the Performance Task: Earth's Interior 5E

Construct a model demonstrating how the structure of the Earth puts people at risk from volcanic activity

Use the data provided and your learning throughout the sequence to explain how populations near Krakatoa and in the key 5 regions have been affected by volcanic hazards.

Revisit the Performance Task: Surface Features and Plate Boundaries 5E

Construct a model showing how tectonic plate theory explains the seismic risk at different types of plate boundaries (moving towards each other and moving apart)
In your model, include:

- The types of risks that exist as a result of plate motion
- The role of the internal structure of the Earth in these processes.
- At least two specific locations you've observed and the surface features at those locations
- Specific evidence that supports the model

Using what you learned in this investigation and from the provided data, explain which regions of the planet are at higher risk from seismic activity and how that would impact populations living in those locations.

Revisit the Performance Task: Energy and Matter

Construct a model that demonstrates how the movement of energy and matter connects Earth's interior structure and the surface to both explain plate motion that causes tectonic hazards and also the benefits of living in these areas.

In your model, include:

- How the motion of energy explains how matter is transferred between components of the system
- How volcanic activity contributes to mineral availability in Earth's crust
- The connections between Earth's interior, Earth's surface, and surface features and plate boundaries

Using what you learned in this investigation and from the provided data, explain how living in areas near plate boundaries has impacted human populations in the key 5 regions in both negative and positive ways.

Final Performance Task

Final Explanation: Explain how technological advances and preparedness resources have decreased the impact on human populations from natural hazards and how that could influence decisions around resource allocation.

Using everything you have learned in these investigations, the vulnerability profiles, data about earthquake deaths over time, and any additional resources, explain how the damage from tectonic activity can be reduced and how that could help policy makers decide where to allocate money and other resources. In your response, be sure to include:

- How tectonic hazards can result in death and destruction
- How technological improvements have reduced negative outcomes from tectonic hazards
- How these changes can influence human behavior

Earth's Interior

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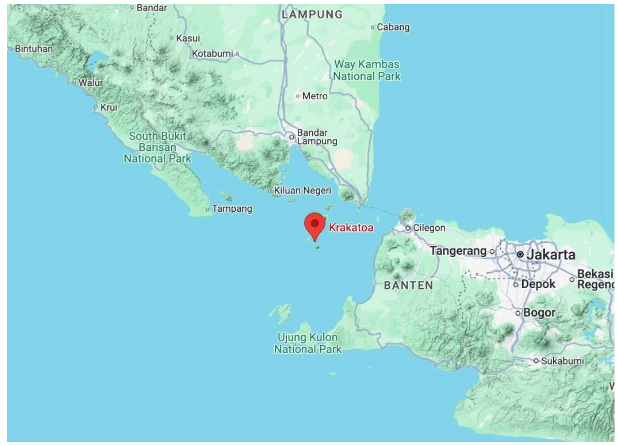
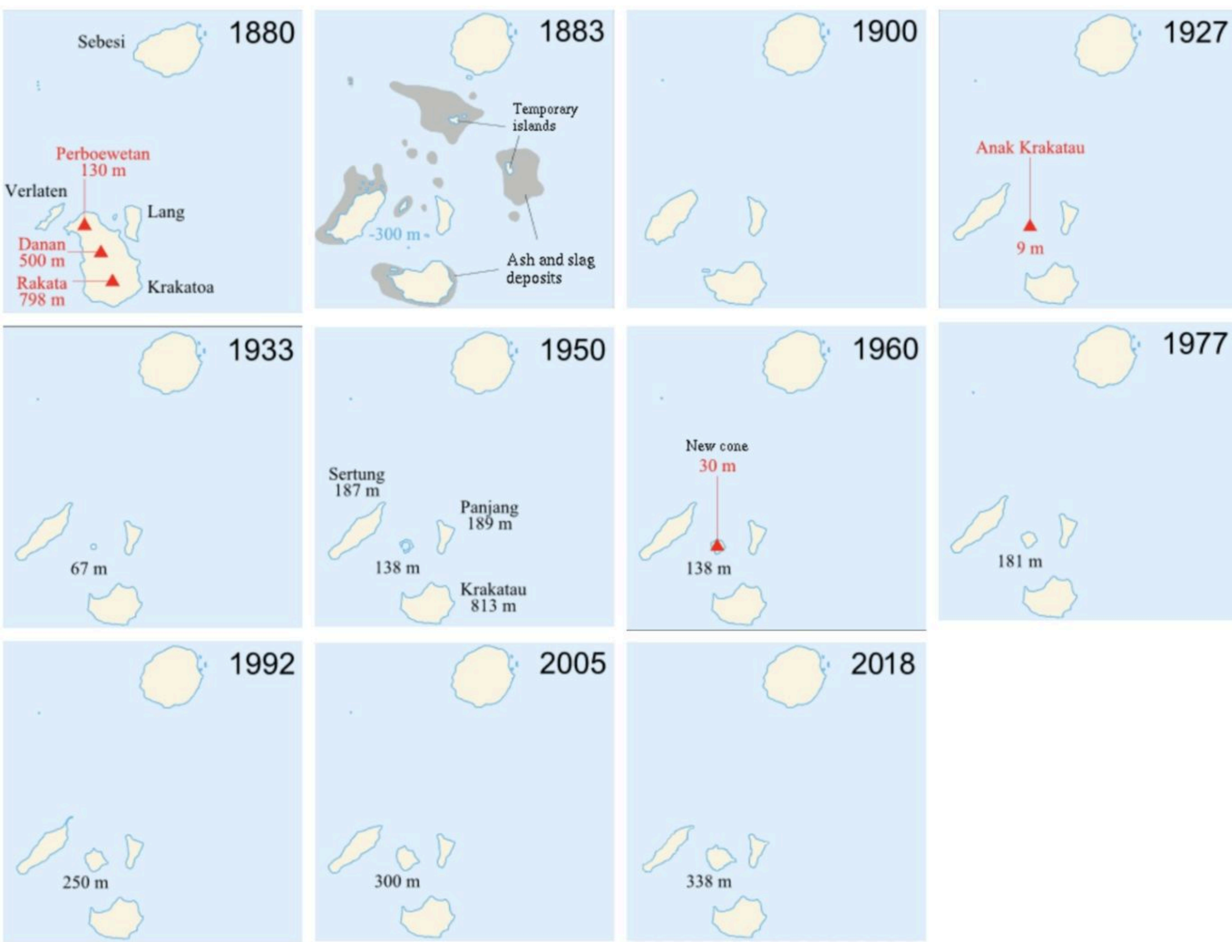
Changing Islands

Directions:
Observe the images below and then fill in the See-Think-Wonder that follows





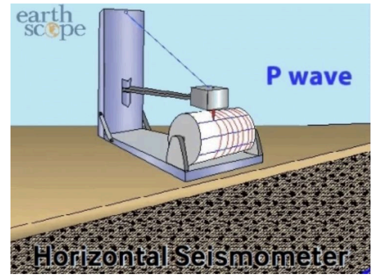
See-Think-Wonder

See What did you observe?	**Think** What do those observations make you think about?	**Wonder** What questions do you have?
What do you notice about how the land changed over time?	Where do you think the missing islands went? Where do you think the new ones came from?	

What's Inside the Earth?

Phenomenon: How do seismic waves reach different locations on Earth at different times?

Directions:



- Go to the following website: Global Seismogram Viewer
- Click on the earthquake labeled "Near East Coast of Honshu, Japan, Mag 9.1." It will appear as a large circle over Japan, and when you hover over it, the label will appear.
- The diagram shows seismometers like the one on the right around the world as they picked up that earthquake (causing the paper to shake and record it)
- The figure shows seismometers from closest to the earthquake (on the left) to the farthest away (on the right). There are multiple patterns that occur related to when earthquakes arrive at different locations around the Earth.
- Record your observations, thoughts, and wonderings below.

See-Think-Wonder

Use the graphic organizer below to record your ideas from the investigation.

See What did you observe?	**Think** What do those observations make you think about?	**Wonder** What questions do you have?

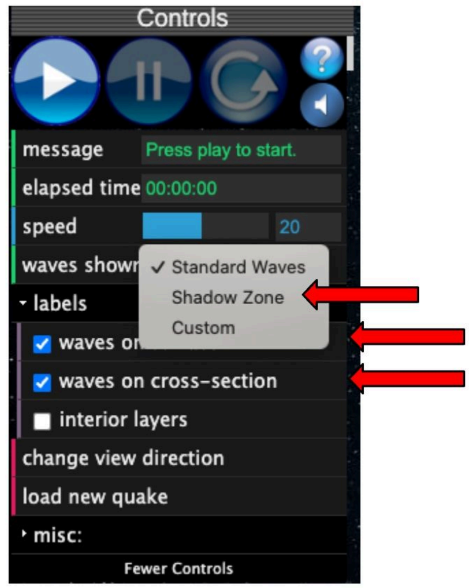
Looking at a seismic model: To understand what is going on, scientists have built a computational model of the Earth, using what they know about the different types of waves that happen from an earthquake.

Setting up the Computational Model Seismic Waves

We will start by using a simplified version of the computational model of wave energy travel from the epicenter of earthquakes. In order to do this you will need to adjust the controls for the computational model. First, click on 'waves shown' and 'label waves on' as seen in step 1 below. Then click on 'shadow zone only', 'surface', and 'cross section' as seen in step 2 below. Be sure that the controls now look like the image in step 2 before you move on.

Step 1

Step 2



Other Key Features of the Computational Model

At the bottom right of the computational model screen, you will find a 'key' (Figure 1) that helps you interpret what you are observing in the model. Be sure to examine the key and run the model and ensure that you are able to make connections between the symbols in the key and what you observe in the model.

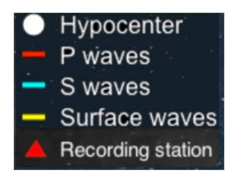


Figure 1

You will also notice the seismogram tool (Figure 2) on the left side of the computational model screen. This records the seismic wave data being collected at different seismic stations around the world as the seismic waves as they are detected. You can drag that off the screen for now and focus on observing wave energy travel on and through Earth as you run the model. We will have an opportunity to explore seismograms further later in this investigation.

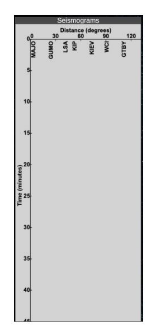


Figure 2

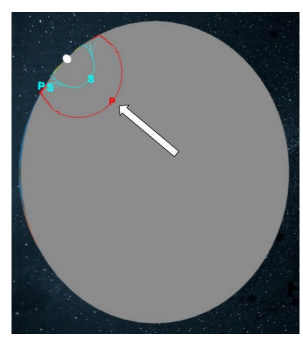
Collecting Observational Data of How Energy from an Earthquake Travels
Now you're ready to start investigating how energy generated from an earthquake travels. Note, you can click and drag the 3D Earth in order to observe different parts of the Earth after the earthquake begins.

1. Run the model several times, changing the earthquake each time, to see if you notice any evidence of patterns. To change the earthquake, click the button "load new quake" from the control bar and then select a different location on the map.

Sketch the motion of the P and S waves over time in the space below

2. Describe the differences and similarities in the movement of the P and S waves

3. Change the "waves shown" from "shadow zone" to "standard waves" and press play. Keep your eyes on the leading side of the P wave as it moves across the interior of the Earth.



How many times does a part of the P wave appear to bounce back or be reflected? Describe what you see.

Part 2. How do different materials form layers?

Materials for Each Group

- Water (20mL)
- Vegetable Oil (20mL)
- Isopropyl Alcohol (20mL)
- Graduated Cylinder (2)
- Balance that Measures in Grams
- 3 colors of food coloring

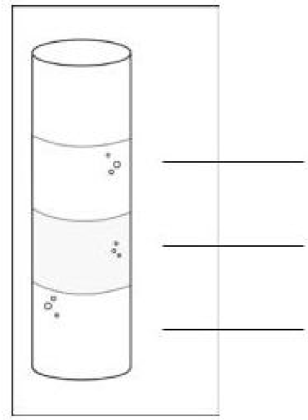
Procedure

1. Find the mass of an empty graduated cylinder and record the mass in grams in the data table.
2. Pour 20mL of water into the graduated cylinder. Be as accurate as possible by making sure that the bottom of the meniscus is at the 20mL mark.
3. Weigh the graduated cylinder with the water in it. Record the mass in grams in the data table.
4. Calculate the mass of the water alone by subtracting the mass of the empty graduated cylinder from the total mass. Record the mass of the 20mL of water in the data table.
5. Use the mass and volume of the water to calculate its density. Record that density in g/cm^3 in the data table.
6. Repeat steps 2-5 for the alcohol and then the oil. Be sure to measure the oil last because it does not rinse easily from the graduated cylinder.

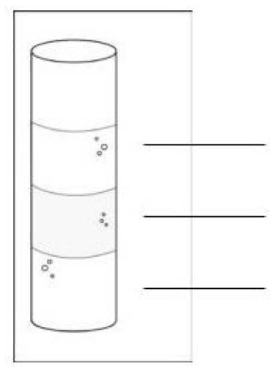
	Water	Alcohol	Oil
Mass of empty graduated cylinder (g)			
Mass of graduated cylinder and liquid together (g)			
Mass of liquid alone (g)			
Density of liquid (g/cm^3)			

Create a Density Column
You will now pour a sample of each liquid into a graduated cylinder, but before you do, make a prediction about which liquid will be at the bottom, middle, and top. Label the diagram below to show how you think the alcohol, water, and vegetable oil will be layered. Be sure to explain your thinking.

Explain your prediction:



1. Put a drop of different colored food coloring into a 10 mL sample of water and alcohol.
2. One at a time, gently pour about 10 mL of the alcohol, water, and oil into a clean graduated cylinder.
3. Observe the order in which they are layered and label the diagram to reflect your observations.
4. Repeat steps 1 and 2, but pour the liquids into the other graduated cylinder in a different order. Do they still layer in the same way?
5. Do your findings confirm your prediction about the order in which the three liquids would be layered? Review the density you calculated for each liquid and explain why you think they are layered in the order you observed.



Making Sense of the What's Inside the Earth Investigation

See What did you observe?	Think What does each observation make you think?	Wonder What questions do you have about each observation?
What patterns do you observe about p waves? What is your evidence?		
What patterns do you observe about s waves?		
What did you notice about the disturbances happening to the p wave in the "standard waves" view?	What do you think that means was happening to the P waves?	
What patterns did you observe in the sinking and rising of household substances? What is your evidence?	How do you think these patterns relate to what we saw in the p and s waves?	

Modeling the Structure of Earth's Interior

What's Different about P and S Waves? (Demonstrating P and S waves)
You will now observe a model of s and p energy waves that are produced at an earthquake's epicenter. As you observe the model of s and p waves, consider the following guiding questions:

- How are s and p waves different?
- How does what you are observing relate to what we observed from the computational model in part 1?

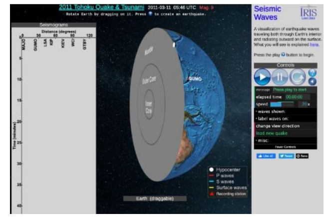
1. Record your observations in the 'See' column of the 'See-Think-Wonder' table below.

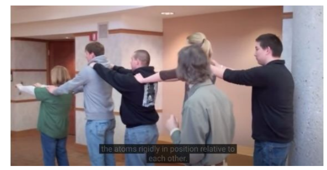
See-Think-Wonder

See **What did you observe?**	**Think** **What does each observation make you think?**	**Wonder** **What questions do you have about each observation?**
What did you notice about the motion of p-waves that allows them to transfer energy through molecules?		
What kind of materials are p-waves able to transfer energy through?	What about their structure explains this?	
What did you notice about the motion of s-waves that allows them to transfer energy through molecules?		
What kind of materials are s-waves able to transfer energy through?	What about their structure explains this?	

2. Based on each observation you recorded in the 'See' column, complete the 'Think' and 'Wonder' columns in the table above. In other words what does each observation make you think and wonder?

3. How does what we observed in the human earthquake model help us make sense of what we observed in the computational model?

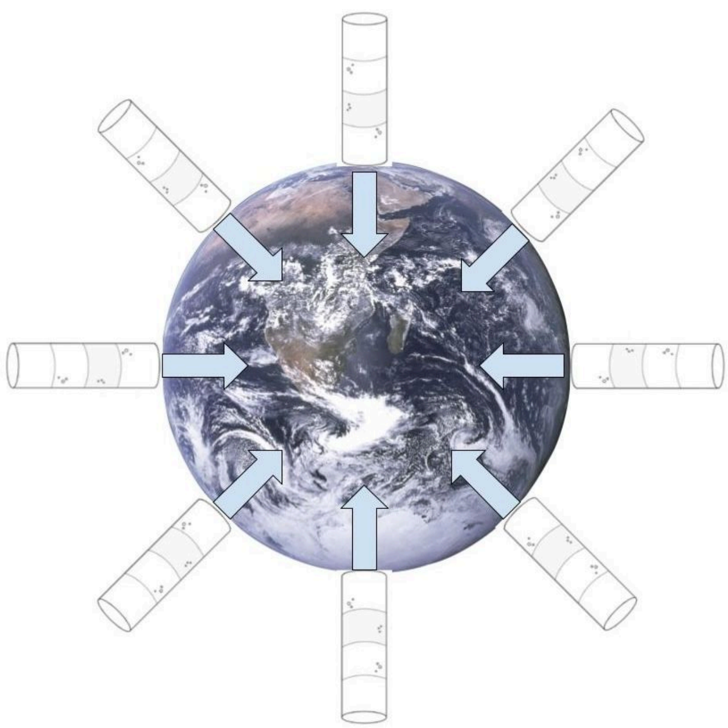




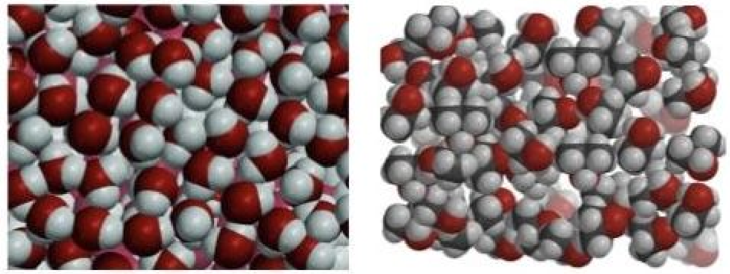
Density and Gravity

Denser materials sink when they are mixed with less dense materials because they have more mass in the same amount of space and gravity has a greater effect on them. Remember, gravity is a force that pulls things together. The heavier something is, the stronger this pull is. Because of gravity, these heavier more dense materials sink down in a mixture, pushing aside lighter materials. As the more dense materials sink, they displace less dense materials and force them up, or make them rise.

To visualize how the density column of liquids behaves as part of a round object, observe the image below:



1. Examine the structure of water and oil below. Which one is more dense? In other words, which has its molecules more tightly packed together?



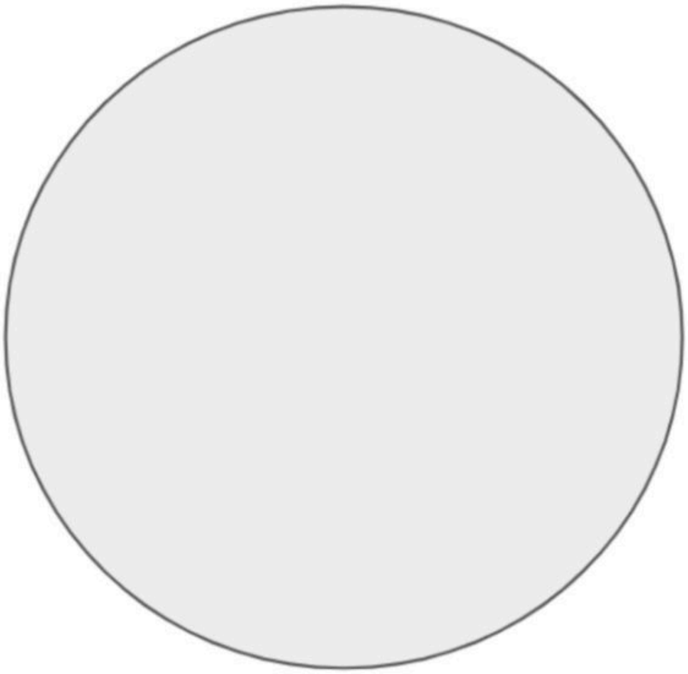
Water **Oil**

2. Using ideas from the *Density and Gravity* text, explain why the liquids in the explore 1 activity layered in the order you observed. **Be sure to cite evidence from your data.**

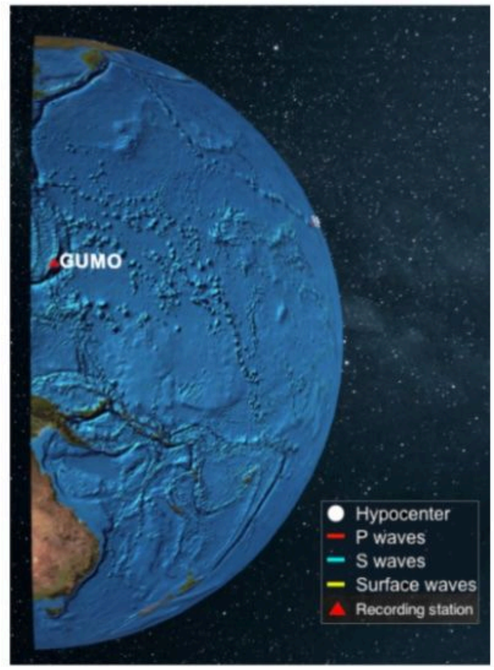
3. Consider your observations of p- and s-waves combined with this new information. What factors do you think contribute to how materials are layered inside the Earth? **Be sure to cite evidence from the investigation and explain your thinking.**

Developing a Model of Earth's Interior
Use the templates below to develop a model that represents all your ideas/learning from the investigation so far. Be sure to include ideas about the differences in how energy from earthquakes drives the motion of molecules through Earth's interior.

Earth's Interior



Earth's Surface



Summary Task

We recently completed a class consensus discussion. How did it go?

1. One thing that went well in the discussion:

2. One thing we can improve the next time we have a discussion:

3. One person who helped me learn today:

What did you learn from this person?

4. One idea that I contributed to my group or my class:

Explain what you know about the following questions, based on what we discussed today:

5. What was the evidence for patterns in seismic wave motion that you used to develop a model of Earth's interior structure?

6. Why is energy from an earthquake detected by seismic stations all around the world? Describe the different ways it gets to these seismic stations.

What are the Layers Made of?

Part 1. Earth's Samples

Materials
Rock samples provided by your teacher
Rock information cards

Introduction:

In this activity, you will observe rock samples and information cards in order to better understand what Earth is composed of.

Investigation:

1. Observe the cards. Sort them into categories based on rock type. Record any similarities you observe between rocks of the same type

Igneous	Metamorphic	Sedimentary

2. In the table below, list the elements and minerals found in all of the rocks. If more than one rock has the same material, put a check mark next to that material instead of writing it again.

Minerals	Elements

Part 2. Magnetic Earth

Materials
For teacher demo: one naturally magnetic lodestone (magnetite)
One compass per group
Various objects provided by your teacher
One bar magnet per group
Piece of clear plastic or glass (like the top of a takeout container or a glass tile)
Iron filings

Introduction:

Hints about the composition of the Earth have been observed for thousands of years in the form of lodestones and compasses.

People in China observed a special rock, called a lodestone, which, when tied on a string, would always orient in a north-south direction. By 1100 CE, explorers from China and Europe were using compasses made of magnetized needles floating in a dish of water to navigate on land and sea. These needles were magnetized by rubbing them along a lodestone, resulting in needles that always aligned in the north-south direction as well. Over time, compasses were improved by mounting them to cards labeled with the directions north, south, east, and west, allowing explorers to reliably navigate.

In this activity, you will investigate the properties of compasses to help determine the composition of Earth.

Investigation
First, explore the compass. Follow the instructions below to observe how the compass behaves in isolation, and how it interacts with other materials.

1. Examine your compass. Describe it below:

---

2. Investigate how the compass responds to the various materials at the table. Record your observations in the table below.

Object	Material it is made of	Compass reaction?

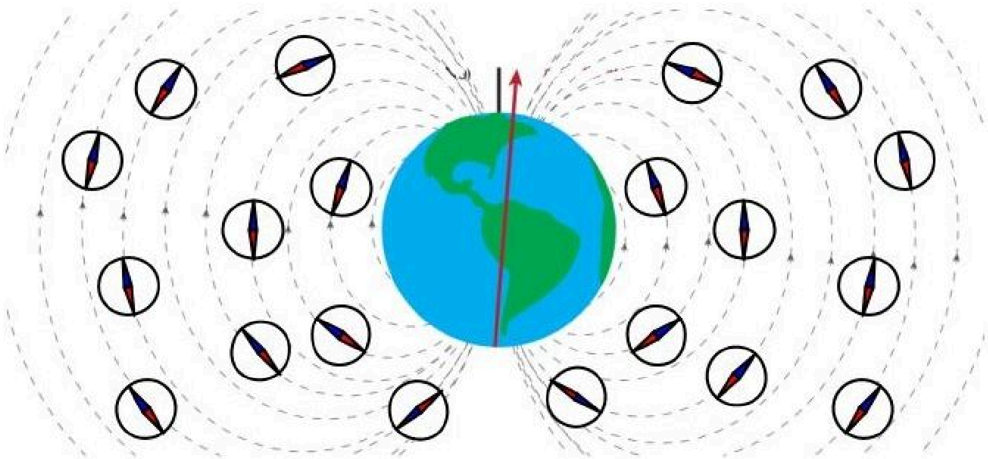
Which object did the compass react most strongly to?

3. Explore how the compass interacts as you move it around different parts of the magnet. How does its directionality change as its position changes?

4. Compass points are made of iron, so iron filings are tiny compass points. Observe how they react to the bar magnet by placing the bar magnet on the table, putting the clear glass or plastic sheet on top, and then slowly pouring the filings on top, being sure to shake them out evenly across the plastic.

Draw your observations and describe using words how the filings behave near different parts of the magnet (the ends versus the middle)

If you were to travel the globe with a compass, as you moved around, the compass would align itself as shown in the image below:

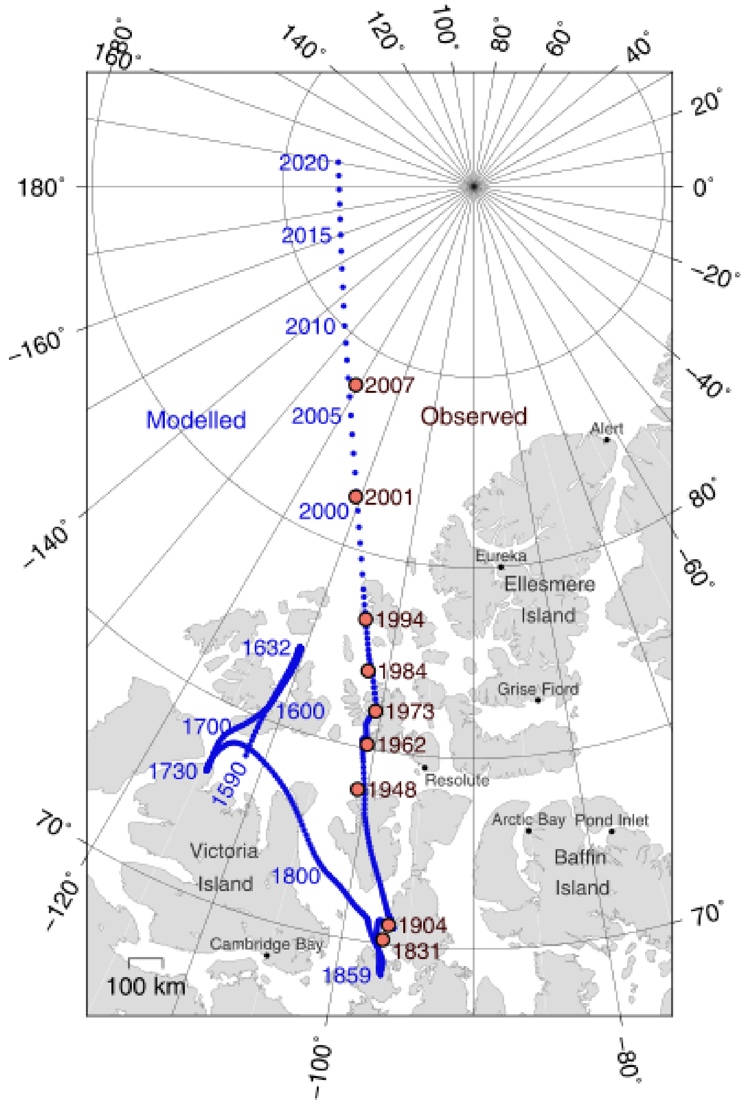


5. Describe the pattern you observe in the compass points, including how they behave at different locations on Earth.

6. Based on the behavior of the compass, what can you conclude about Earth?

Looking back in time, compasses have not always pointed in exactly the same direction.

The image below shows where compasses have been observed to be pointing since 1831, and a reconstruction of where they have pointed since 1590.



7. What do you observe happening to where the compass points over time?

Making Sense of the What are the Layers Made of? Investigation

See What did you observe?	Think What does each observation make you think?	Wonder What questions do you have about each observation?
Describe the patterns you observed in materials that are accessible from the surface of Earth		
What did you notice about the interactions of the compass with other items?	Based on that information and the fact that the compass interacts with Earth, what do you think Earth is partially made of?	
What did you notice about the stability or change of the directions that the compass points over time on Earth?	Based on that information, what do you think is happening with the materials inside Earth?	

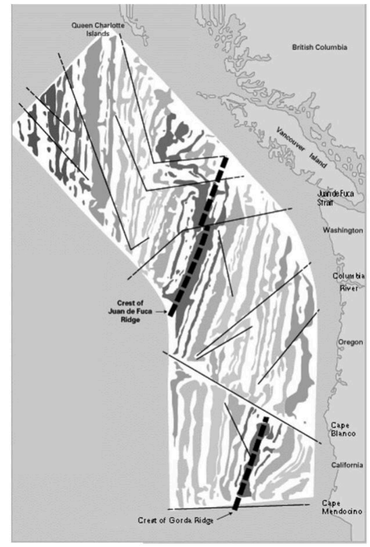
Analysis:

1. Based on the sampling and magnetic data, what materials do you think the Earth is made of?

2. Building on your previous model at the end of the last investigation, sketch a model of the layers of Earth and which materials you think each layer is made of.

Explaining Krakatoa’s New Islands

Part 1. Magnetism and Earth
In this part of the activity, you will use evidence from the investigation to determine how Earth’s magnetism is generated by the interior of Earth in order to better understand the composition of our planet.



Some of Earth’s rocks contain iron, which have recorded the magnetic field of Earth. As the rock solidified, iron pieces aligned to the Earth’s magnetism, and hardened into that pattern. However, the iron is not all magnetized in the same direction. In fact, they switch directions at various points in time.

In the image, stripes of rocks with iron pointing the way we’d expect are shown in gray. These rocks show iron lining up with the current magnetic north pole.

However, in the white stripes, the polarity is reversed: the iron in the rocks is “pointing” the other direction.

1. What does the reversal of polarity make you think could be happening inside Earth?

2. Based on what you know about the composition of Earth’s interior so far, what properties do you think the layer would have that is most likely to be able to produce the effects you observed above?

Part 2: How does this apply to Earth's interior?

Based on sampling data and the magnetic properties of Earth, scientists have determined the composition of Earth. Using seismic data and the fact that the magnetic pole wobbles, scientists have determined that some layers are liquid and others are solid. However, the way that the materials stack into layers is based on density.

The table below shows different materials that make up Earth's interior, their densities, if they are magnetic, and if they are found on Earth's crust.

Common Materials in Earth's Interior

Dominant Material(s)	Density (g/cm^3)	Magnetism	Sampling Data
iron and nickel alloy (solid form)	12.8-13.1	Not magnetic	Not found on Earth's surface in this form
iron and nickel alloy (liquid form)	9.9 - 12.12	magnetic	Not found on Earth's surface in this form
silicic rocks (like granite and rhyolite), andesite, and basalt	2.2 - 2.9	Not magnetic	Abundantly found on Earth's surface, in a layer called the "crust"
Magnesium oxide (magnesium and oxygen) and silicon dioxide (silica and oxygen)	4.4 - 5.6	Not magnetic	Not found on Earth's surface in this form
peridotite, olivine, garnet	3.4 - 4.4	Not magnetic	Found in select locations on Earth's surface, and frequently found in samples underneath the ocean floor, in a layer where the "mantle" meets the crust

Revising Our Models of Earth's Interior
Revise your model of Earth's interior below. Be sure to include:

- evidence from the Composition of Earth's Core investigation
- Ideas from the Density and Gravity text, including how structure determines density
- The data table of common Earth materials above

Revised model of Earth's Interior:

Provide evidence and reasoning with science ideas:

Where did the new islands in Krakatoa come from?

Sampling data from the islands that have grown after the eruption of Krakatoa reveal the islands are composed primarily of andesite, dacite, and basalt, materials high in oxygen, iron, magnesium, and silica.

Based on that information, which layer(s) did the material that created the new islands come from?

Summary Task

We recently completed a class consensus discussion. How did it go?

1. One thing that went well in the discussion:

2. One thing we can improve the next time we have a discussion:

3. One person who helped me learn today:

What did you learn from this person?

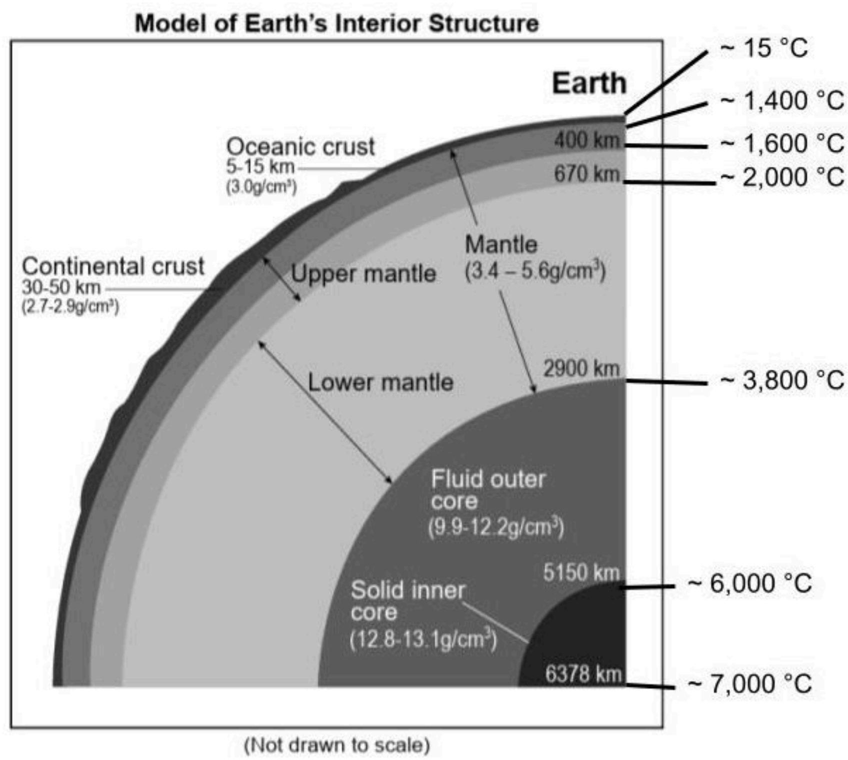
4. One idea that I contributed to my group or my class:

Explain what you know about the following question, based on what we discussed today:

5. How did the additional empirical evidence and patterns you observed help strengthen your model of Earth's interior, including the relationships between components of the system?

How do materials move to create new islands?

To understand how materials move between the mantle and the crust, it is important to observe the differences between parts of the Earth.

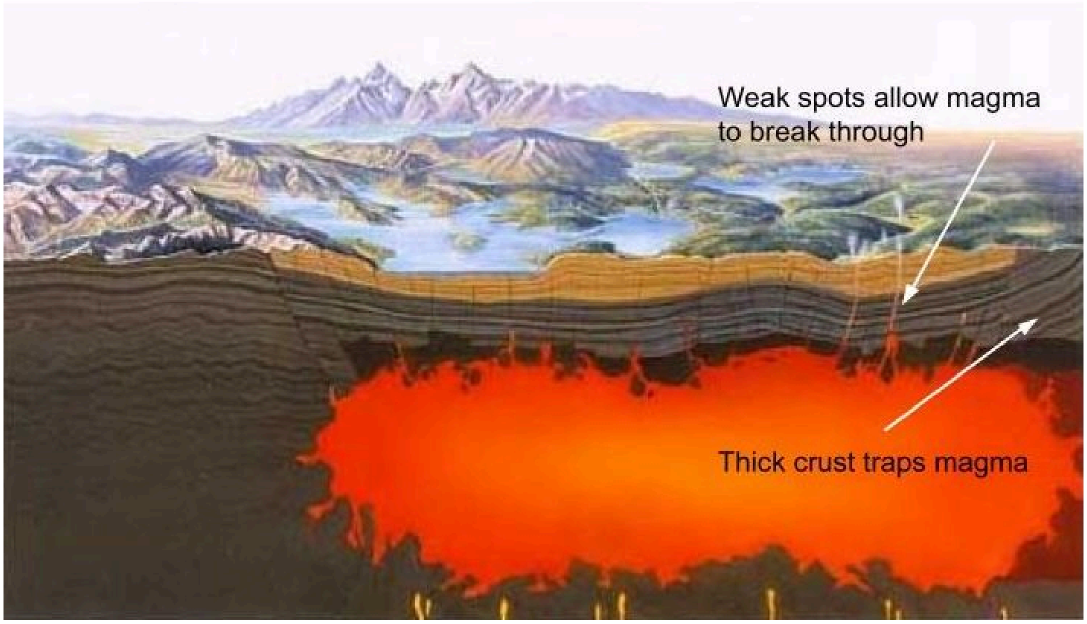


1. State the relationship between temperature and earth's layers.

When materials like iron, nickel, silica, and magnesium increase in temperature, their density changes in the pattern shown below:

2. Based on what you've learned about density, predict how materials move as they increase in temperature.

Materials like silica, iron, and magnesium are molten hot in the mantle, in a liquid called magma. The hottest magma is less dense than cooler magma, and it rises to the top of the mantle, pushing against the solid crust above. In areas with thick, solid crust, it stays trapped beneath the crust.



However, when there are weak spots in the crust, things change.

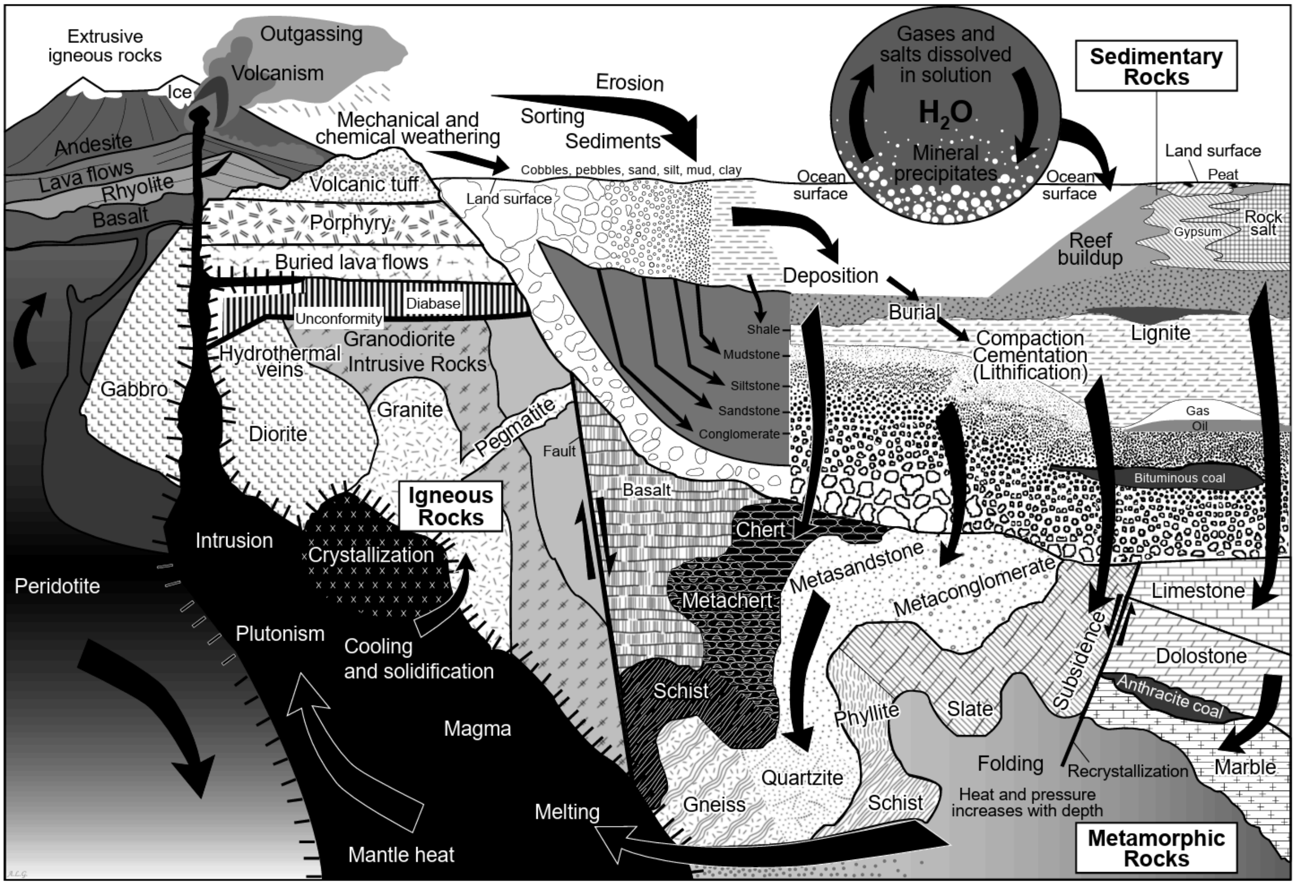
- First, in some weak spots, water can travel downwards from the crust into the mantle. Water lowers the melting point of rocks, meaning that they can melt at a lower temperature.
- Second, when the magma pushes up against weak or thin parts of the crust, it can get up through the crust, moving towards the surface of the Earth

Examine the Rock Cycle Infographic and answer the questions:

3. Review: what parts of this diagram have you already learned about in other units? Describe that part(s)

4. Examine the infographic. Locate the section showing mantle heat, magma, and cooling. Outline the magma in a red marker or pen. This section shows magma moving up through a weak part in the crust, bringing materials from the mantle upwards.

Rock Cycle Infographic

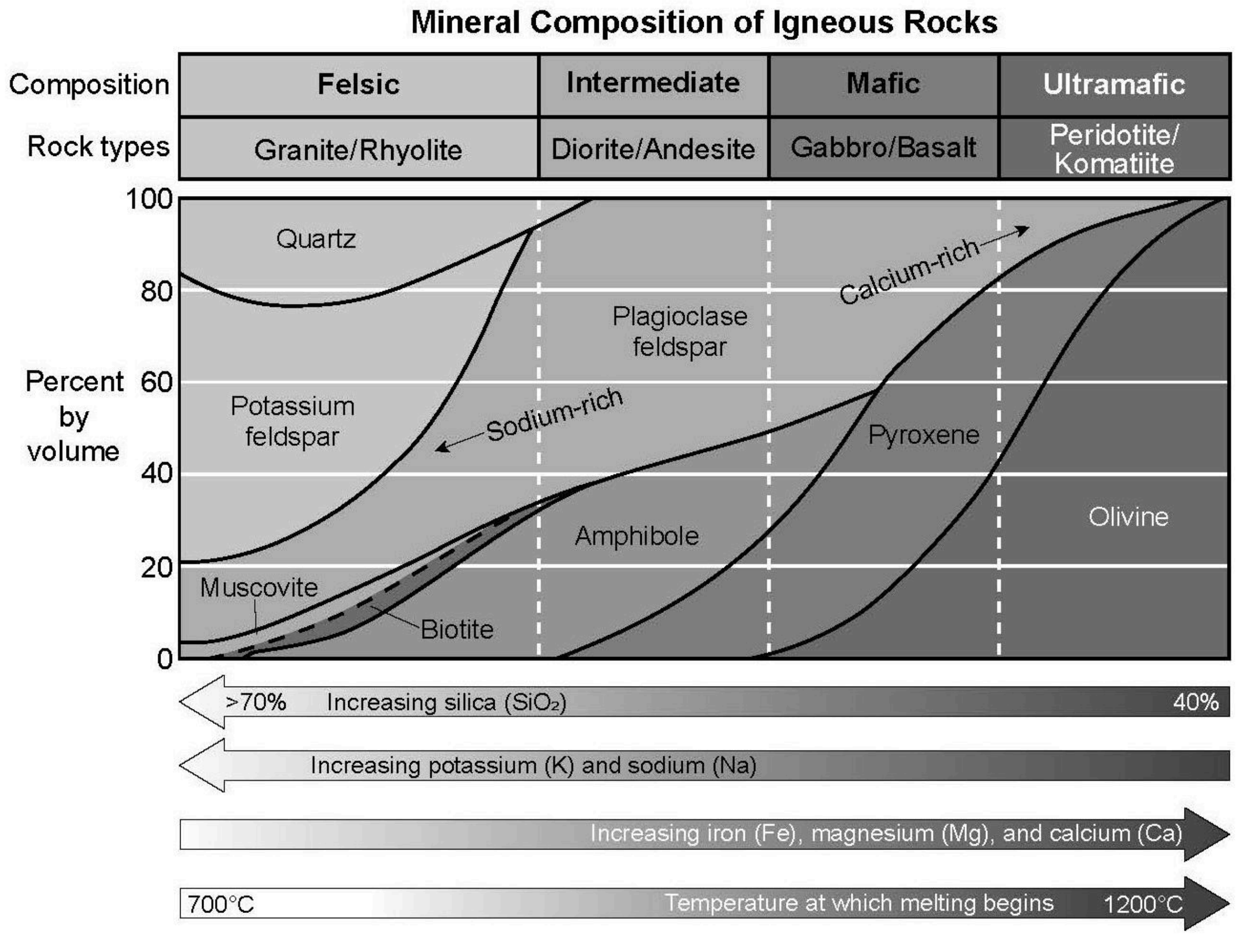


5. Look for the words "cooling and solidification" and "crystallization." What rock type (metamorphic, sedimentary, or igneous) are being formed by these processes?

6. Examine and circle the names of the rocks formed in these processes in the Rock Cycle Diagram. List these rocks:

As the *Rock Cycle Infographic* shows, there are many different rocks that form from volcanic lava. They can be distinguished by the different minerals they are made of, as shown in the diagram, the *Mineral Composition of Igneous Rocks*.

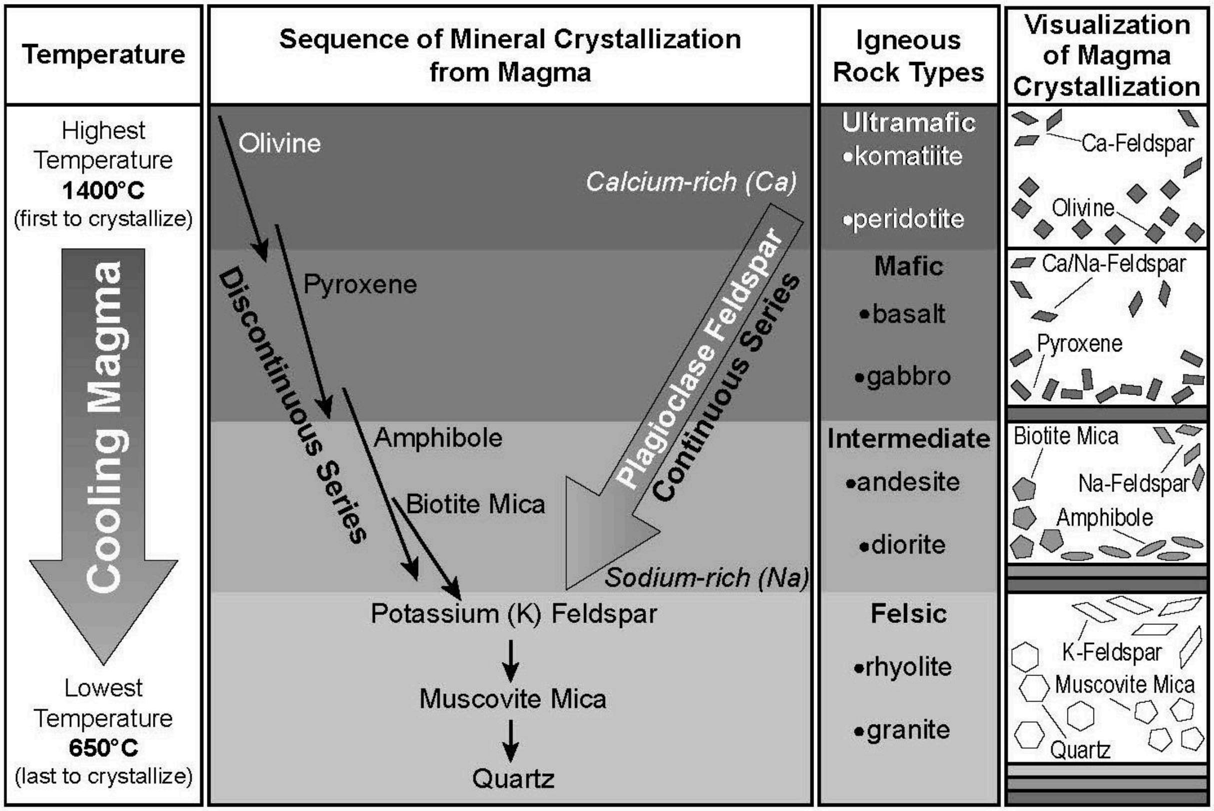
7. On the diagram below, circle the names of the rocks that also appear on the *Rock Cycle Infographic*.



Those rocks become separated from each other based on the temperatures they solidify at. These variations have been organized in the *Model of Bowen's Reaction Series* below.

8. On the model below, circle the rocks that also appear on the *Rock Cycle Infographic.*

Model of Bowen's Reaction Series



9. Using both the *Mineral Composition of Igneous Rocks* and the *Model of Bowen's Reaction Series,* fill in this table to describe the physical characteristics of the igneous rocks listed in the *Rock Cycle Infographic*.

Rock	Temperature of crystallization	Igneous Rock type (felsic, mafic, etc)	Describe the composition

10. Using everything you've learned in this sequence, explain how the information provided in Bowen's reaction series explains the layering of materials in the Earth, both between and within layers.

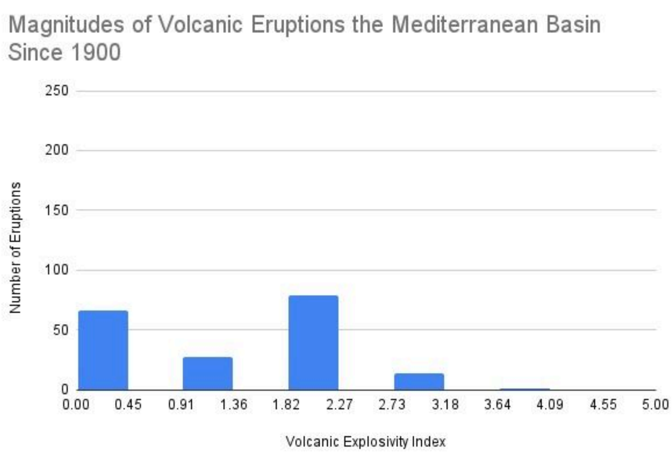
Who is most at risk?

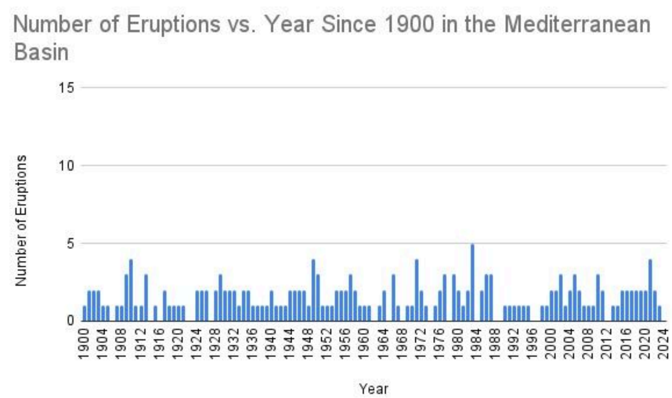
1. Does the structure of the interior of the Earth give you any information about which locations would be most at risk from seismic hazards?

2. Observe the data below:

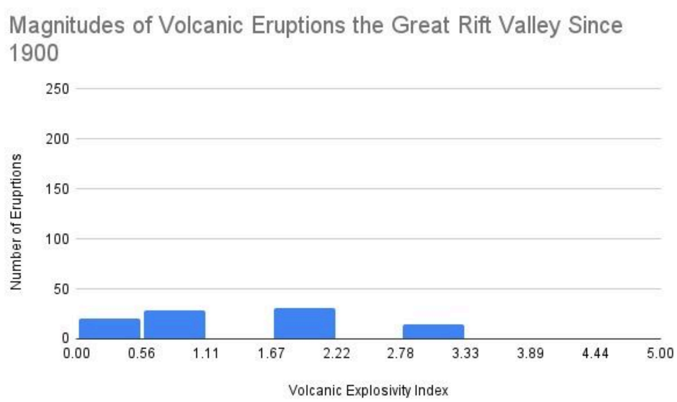
Eruption magnitudes and frequencies across the Key 5 Regions

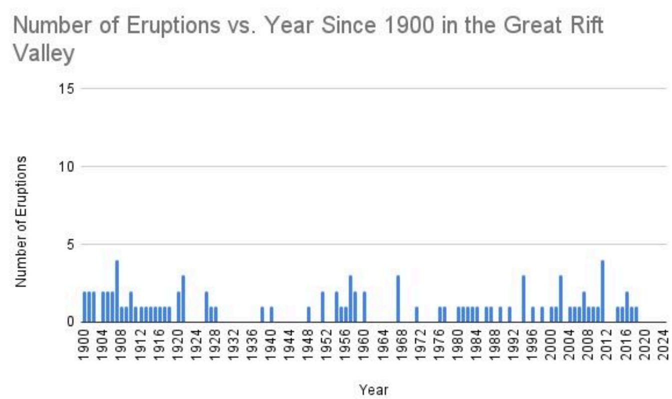
Mediterranean Basin



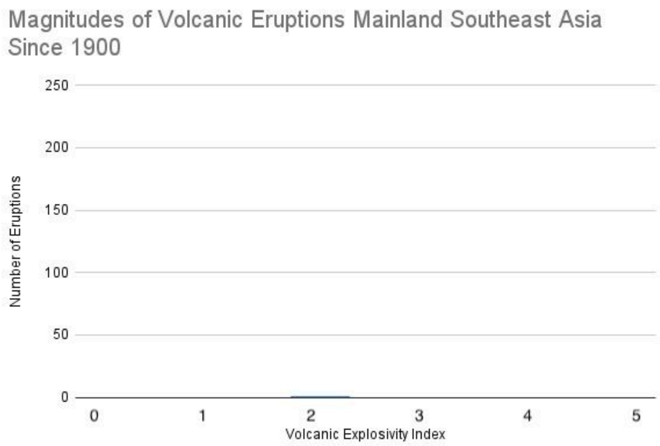


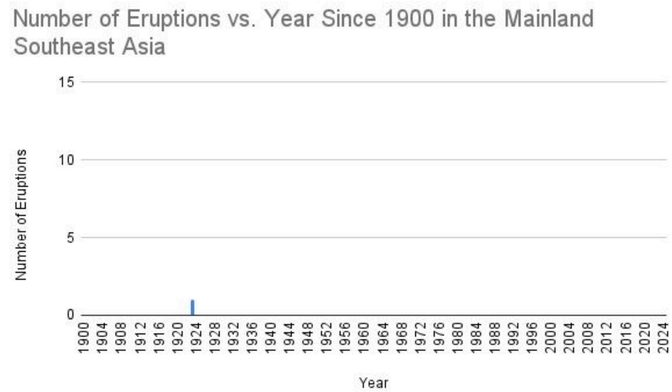
Great Rift Valley



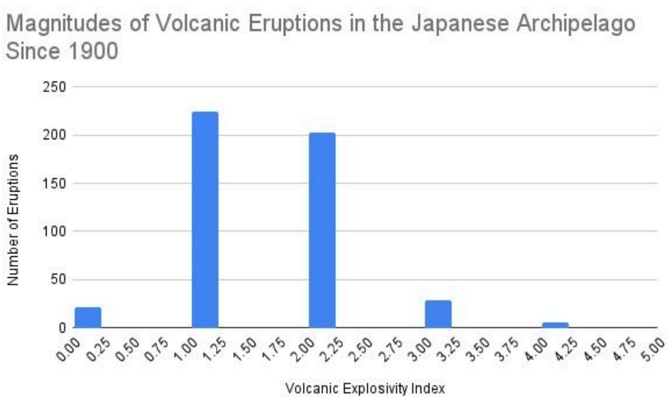


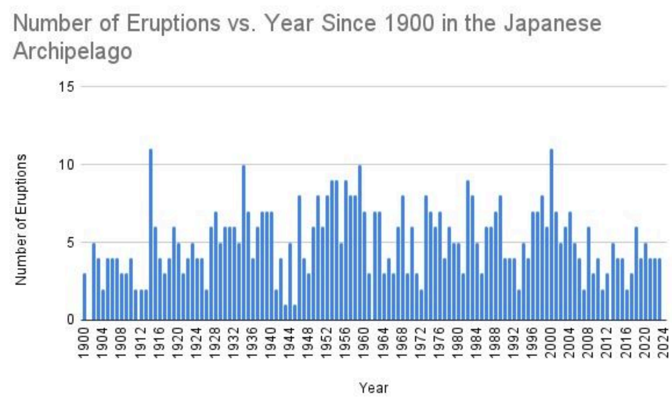
Mainland Southeast Asia



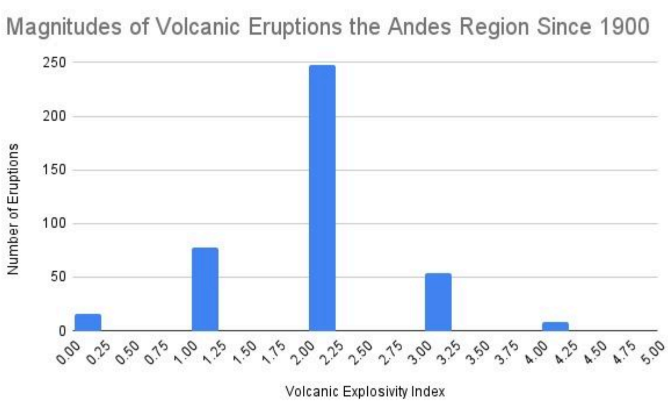


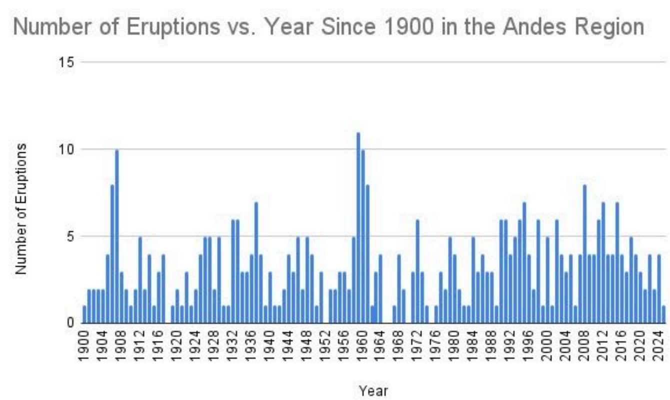
The Japanese Archipelago





Andes Region





Deaths from Volcanic Eruptions in the Key 5 Regions

	Mediterranean Basin	Great Rift Valley	Mainland Southeast Asia	Japanese Archipelago	Andes Region
Deaths from Volcanic Eruptions since 1900	254	378	0	501	84
Deaths from Volcanic Eruptions since 1990	2	308	0	110	1

3. Brainstorm ways that volcanic activity has affected populations around the world. Take evidence from
    a. The unit launch
    b. The engage phase of this learning sequence
    c. The data provided in this phase

Earth's Interior Model Rubric

Earth's Interior	Proficient	Developing
Model based on Waves Inside the Earth	The model effectively and accurately represents the layers and properties of Earth's interior and includes all of the components below: • solid inner core, a liquid outer core, a solid mantle and crust. • an indication of how density increases • the material components of each layer of Earth • the conditions that allow the movement of materials within and between layers The components of the model "speak for themselves" for the most part. **OR** There are legends, keys, or written captions to clarify the components. Relevant evidence is identified for changes to the model and scientific reasoning to link the evidence to each change to the model is provided.	The model is incomplete in showing the layers and properties of Earth's interior, **missing one or more** of the components below: • solid inner core, a liquid outer core, a solid mantle and crust. • an indication of how density increases • the material components of each layer of Earth • the conditions that allow the movement of materials within and between layers The components of the model do not really "speak for themselves." **OR** Legends, keys, or written components are insufficient to clarify the model. Some evidence identified for changes to the model is not relevant and / or scientific reasoning to link the evidence to each change to the model is not provided.
Patterns	Annotation clearly articulates how tracking the movement of matter caused by energy of an earthquake helps to figure out earth's interior structure.	Annotation does not clearly articulate how tracking the movement of matter caused by energy of an earthquake helps to figure out earth's interior structure.
Student Self- Score	**Circle One** **Proficient** **Developing**	**Glow**: **Grow**:
Teacher Score	**Circle One** **Proficient** **Developing**	**Glow**: **Grow**:

Earth's Interior Explanation Rubric

Earth's Interior	Proficient	Developing
Explanation	The explanation connects the structure of Earth to the presence of volcanic eruptions and their impact on human populations. The explanation is supported with relevant/accurate evidence from the investigations, including: • frequency of volcanic eruptions • magnitude of volcanic eruptions • Conditions of Earth's structure that create moving magma • Conditions of Earth's structure that allow magma to erupt Reasoning is provided to support the explanation, including	The explanation connects the structure of Earth to the presence of volcanic eruptions and their impact on human populations. The explanation is weakly supported with evidence from the volcano data set, investigations, or readings. Reasoning is not provided to support the claim.
Patterns	Argument includes the patterns identified from the earthquake data set. Empirical evidence for patterns is cited.	There is little or no consideration of patterns identified from the earthquake data set.
Student Self- Score	**Circle One** **Proficient** **Developing**	**Glow**: **Grow**:
Teacher Score	**Circle One** **Proficient** **Developing**	**Glow**: **Grow**:

Relevance to your life: Think about everything that you have learned throughout this unit so far.

1. What is one idea and/or skill you learned that you think is important to teach someone in your family or community?

2. To whom do you intend to teach this idea and/or skill? Why do you think it is important for this person to learn this idea and/or skill?

Surface Features & Plate Boundaries 5E

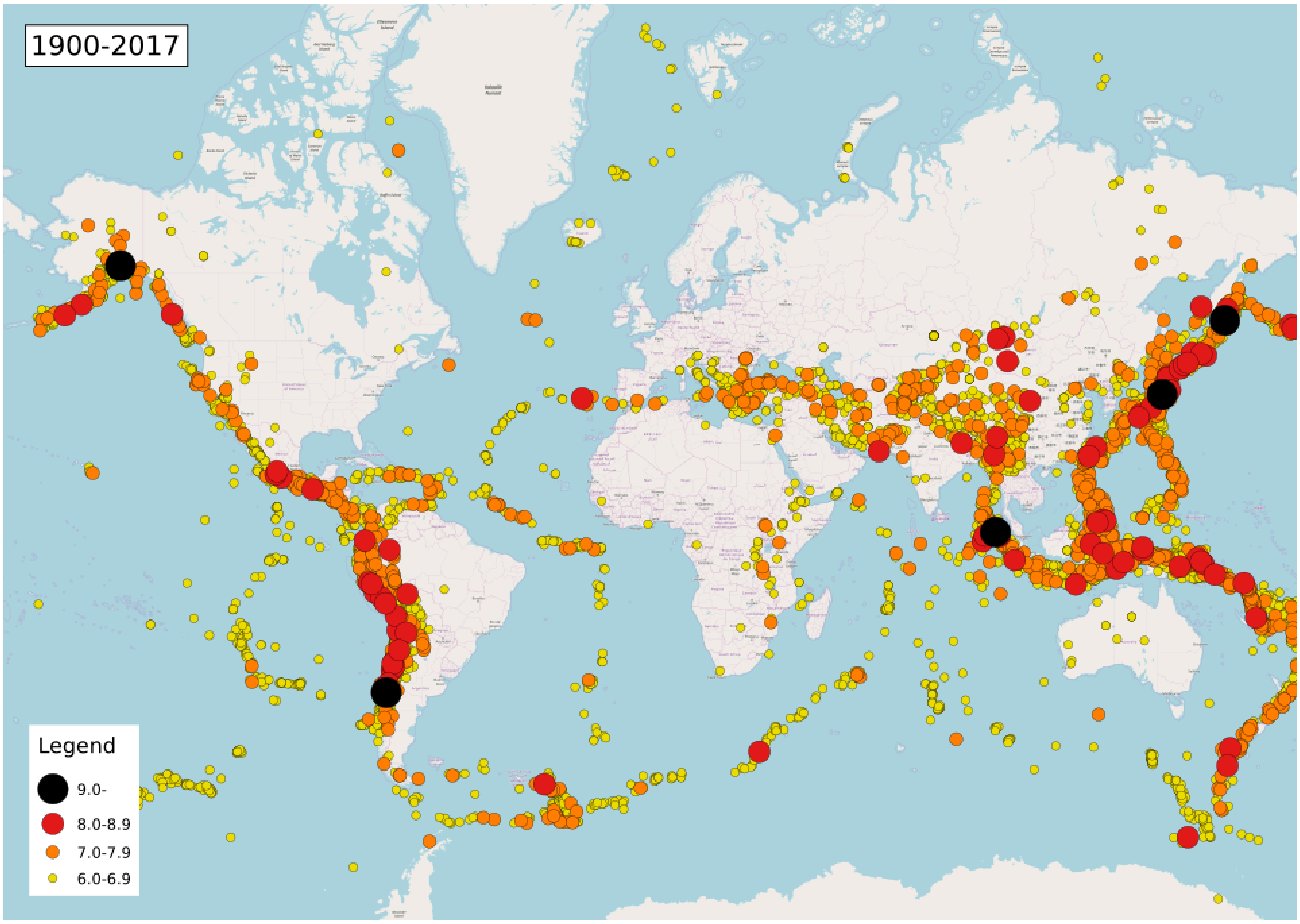
Unit 3 Earthquakes, Tsunamis, and Volcanoes: Who's at Risk?	Earth and Space Science
Student Name:	

Global Patterns of Seismic Activity

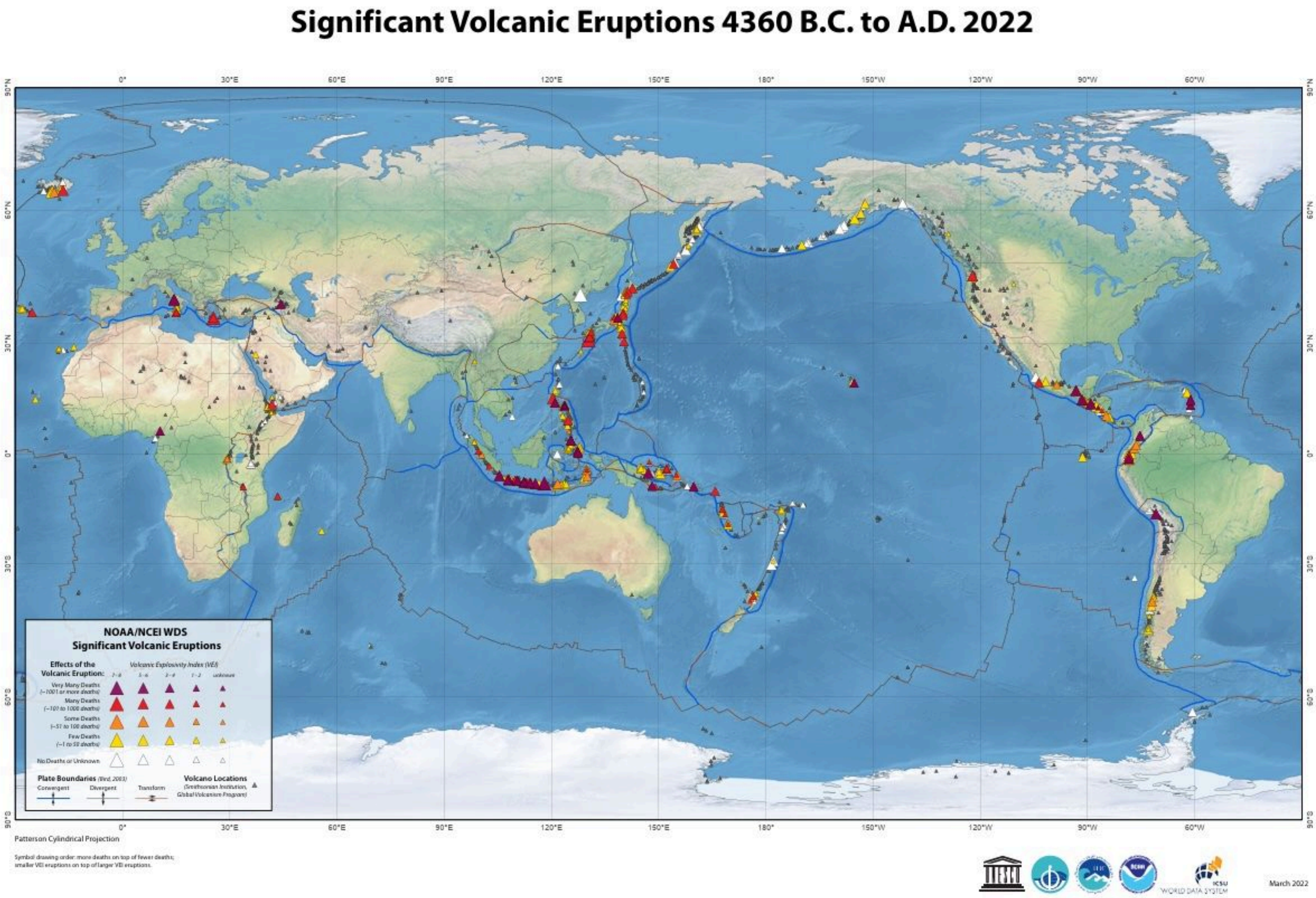
Directions:
The animation and maps below show the occurrence of Earthquakes, Tsunamis, and volcanic eruptions around the world. Examine the maps and the animation, then note your observations, thoughts and questions in the See-Think-Wonder organizer that follows.

Text 1: 120 Years of Earthquakes and Their Tsunamis: 1901-2020

Text 2:Earthquakes from 1900–2017



Text 3: Significant Volcanic Eruptions - Click to view a larger map (1st page)

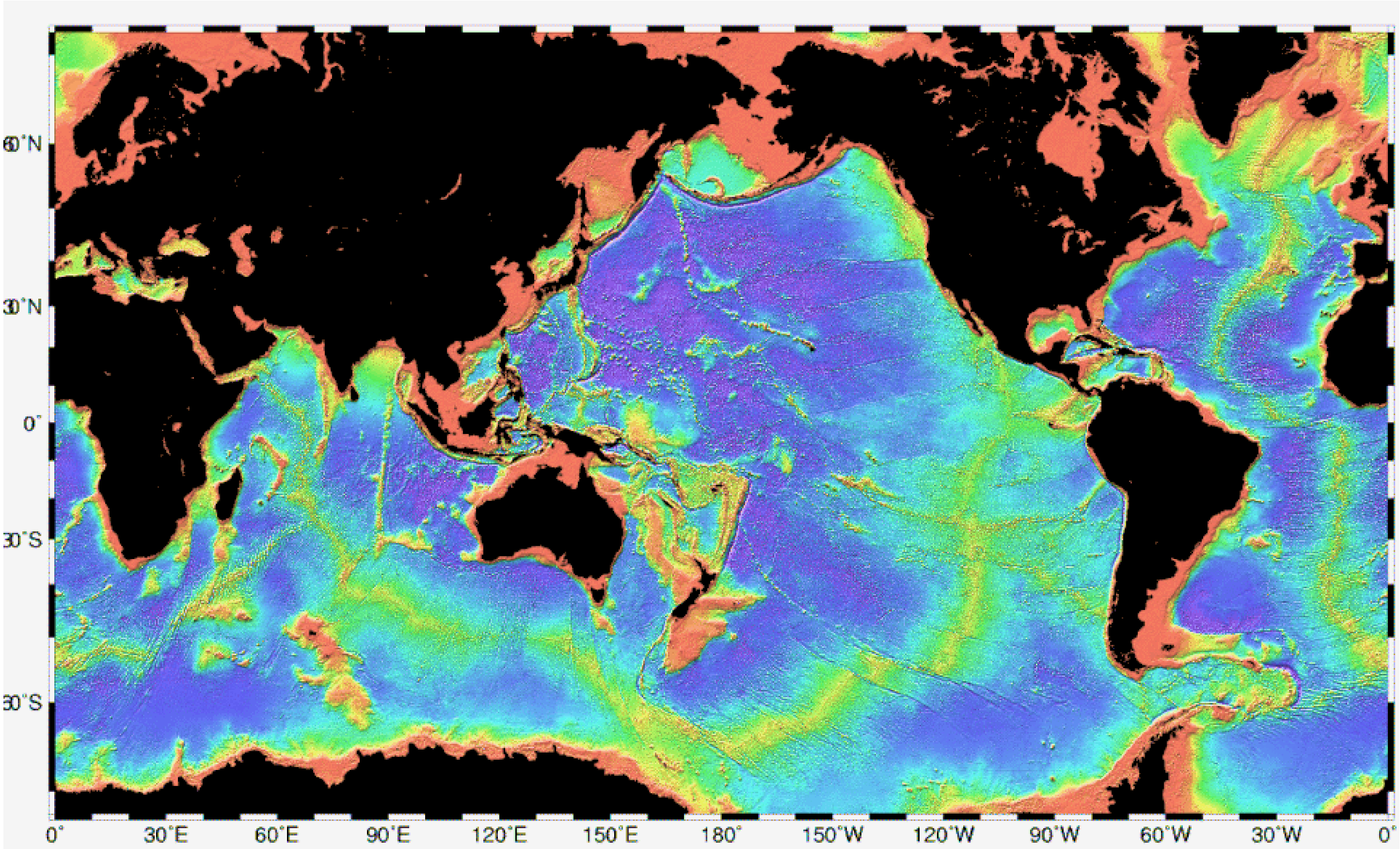


See-Think-Wonder

See What did you observe?	**Think** What do those observations make you think about?	**Wonder** What questions do you have?
What patterns do you notice in Earthquakes, volcanic eruptions and Tsunamis? What is your evidence? Where do the largest earthquakes occur? What is your evidence? Where do the most explosive volcanoes erupt? What is your evidence?		

Seismic Activity in the Ocean

Part 1. The Topography of the Ocean Floor



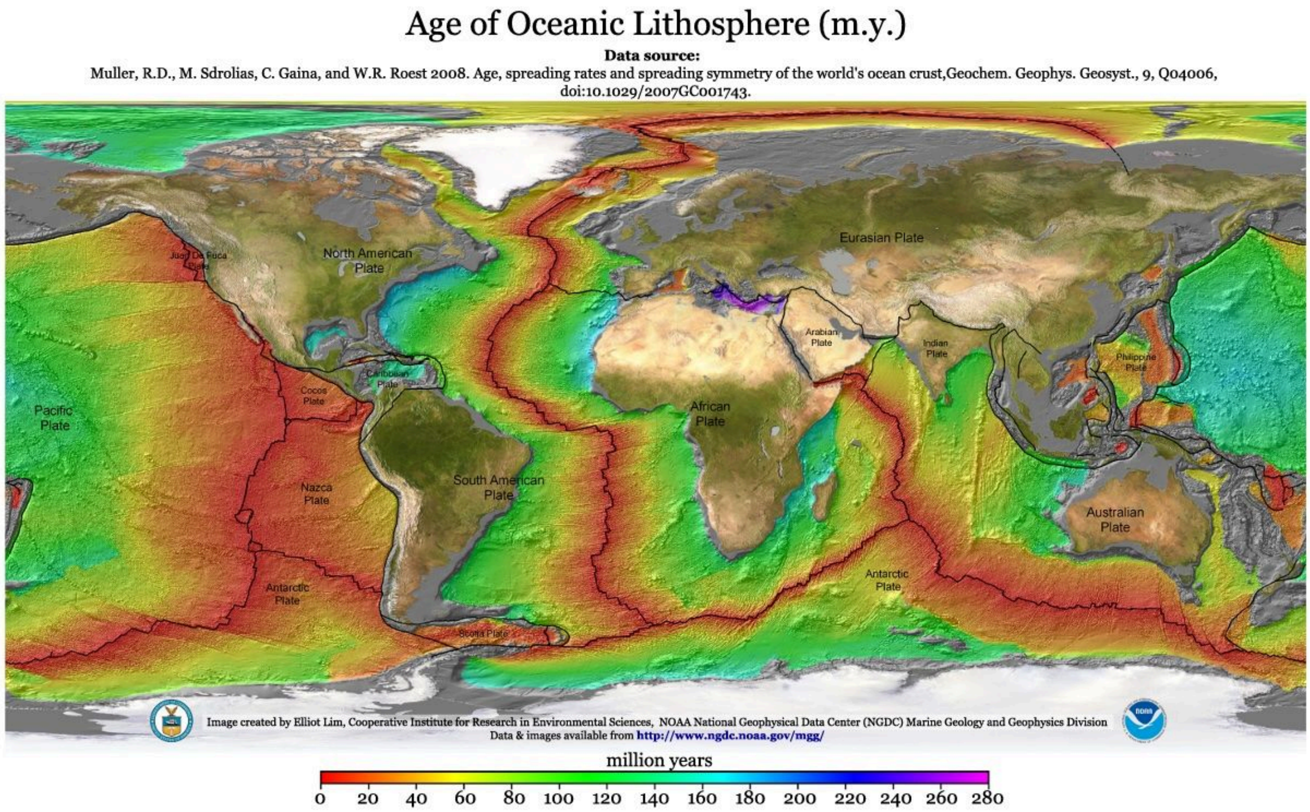
The ocean floor showing the continental shelves and oceanic plateaus (red), the mid-ocean ridges (yellow-green) and the abyssal plains (blue to purple)

1. Compare this image to the maps in the Engage phase. On this map, mark areas of high earthquake and volcanic activity.

2. What patterns do you notice? Are there any types of ocean floor that seem connected to the seismic hazards?

Part 2: The Age of Bedrock on the Ocean Floor
Below is a map of the ocean floor that is color coded to indicate the age of rock, determined by radiometric dating, on the ocean floor.

Examine the map and respond to the questions that follow.



1. What patterns do you notice in the age of the ocean floor rock as it moves closer or further from the continents?

____

____

____

2. What do you think might be causing that pattern?

____

____

____

Part 3: Calculating Seafloor Change

Follow the directions to measure the rate of seafloor change at the Mid Atlantic Ridge.

Remember the metric conversion factors: 1 km = 1000 m 1 m = 100 cm so 1 km = 100,000 cm or 10^5 cm	The scale of distance in the map provided by your teacher is below: On normal copy paper, 1 cm = 2100 km

For the North Atlantic Ocean (using the map in the lab)

1. Measure the distance between the center of the new crust (red) and the border between dark yellow and light green (65 Ma point)

2. Since the scale on the map is 1 cm = 2100 km, calculate the real distance that the plate has moved over the past 65 Ma

3. Determine the length of time that the plate has been moving

4. Use the equation below to calculate spreading rate

Rate of Spreading = distance the sea floor moved / length of time or R = d/t. It is generally expressed as cm/yr.

Part 4. Iceland Earthquakes from Below

1. Go to Iris Interactive Earthquake Viewer
2. On the right side, set the 'maximum number of earthquakes' to 1000, and then click "apply".

What does the color of the dots indicate about the earthquakes?

What does the size of the dots indicate about the earthquakes?

3. Locate "Iceland" and click and drag the map to center it in the middle of the screen
4. Zoom in until the earthquakes appear, and draw what you see in the box below:

What are the minimum and maximum depths of the earthquakes in that area?

What are the minimum and maximum magnitudes of the earthquakes in that area?

5. Click the "3D view" button on the bottom right
6. Use your mouse to click and drag to rotate the picture and see the bottom of the earthquakes. Draw what you see in the box below:

Making Sense of the Seismic Activity in the Ocean Investigation

See *What do you see in the data*	**Think** *What does the data make you think about?*	**Wonder** *What does the data make you wonder about?*
What patterns did you see in the age of the ocean floor? What is your evidence?	What do you think is happening to the sea floor?	
What patterns did you see in the seismic activity under Iceland?	How do you think that activity relates to what you saw happening to the sea floor?	

Analysis:

1. Based on the evidence from all of the investigations, construct an initial model illustrating what you think is happening to create the patterns you've observed. Support your model with annotations detailing the evidence you are using.

What explains the patterns in the age of the ocean floor?

The accepted explanation for the pattern of seismic activity in the oceans is that continents are on top of moving plates, called tectonic plates, whose position slowly shifts over time. In the case of these ocean ridges, the plates are moving away from each other and new oceanic crust forms in between from the rising magma. As it cools, it creates rock types like basalt and gabbro, which are the most common rocks found in oceanic crust. During that movement, earthquakes and volcanic eruptions can occur.

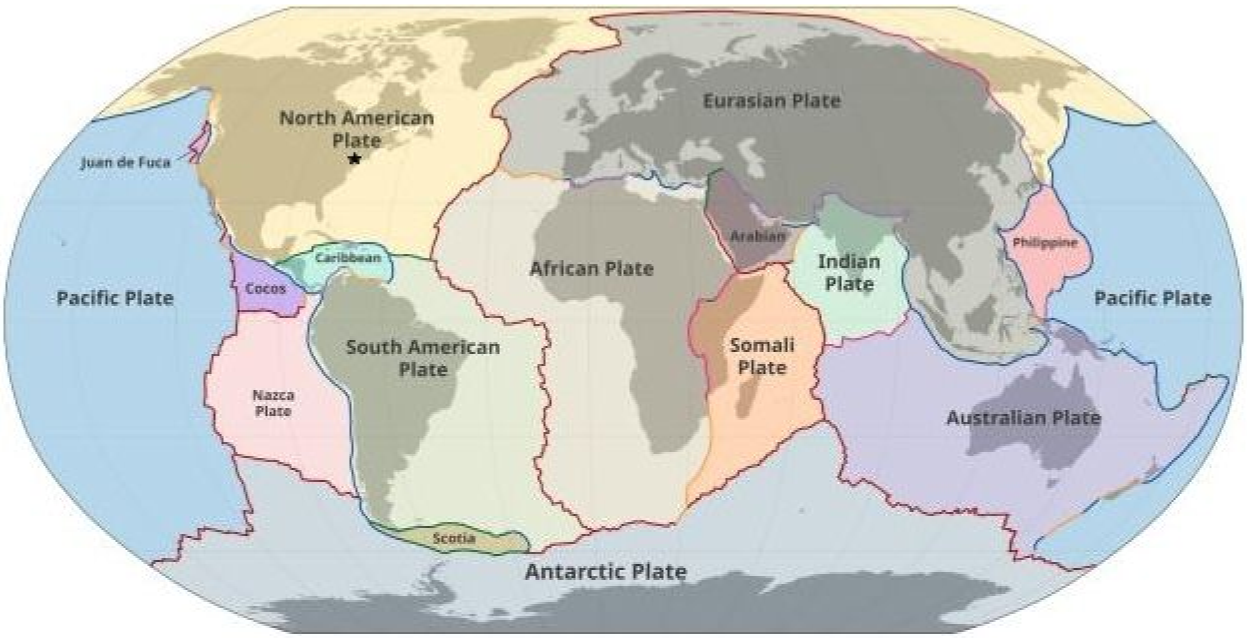
After discussion with your group and using information from the investigations and the text above, construct a revised model demonstrating the spread of tectonic plates at oceanic ridges, including annotations of the evidence for each part of your model.

Use your model to answer the following questions:

1. Which pieces of evidence do you think most strongly support the explanation? Why?

2. Based on what you've learned throughout this unit, explain how that plate motion could result in earthquakes and volcanic eruptions.

3. Use your model and the evidence from this learning sequence to annotate the map below to show the directions that you think the tectonic plates are moving.



Summary Task

We recently completed a class consensus discussion. How did it go?

1. One thing that went well in the discussion:

2. One thing we can improve the next time we have a discussion:

3. One person who helped me learn today:

What did you learn from this person?

4. One idea that I contributed to my group or my class:

Explain what you know about the following questions, based on what we discussed today:

1. How did combining multiple lines of evidence help you identify patterns and support their explanations?

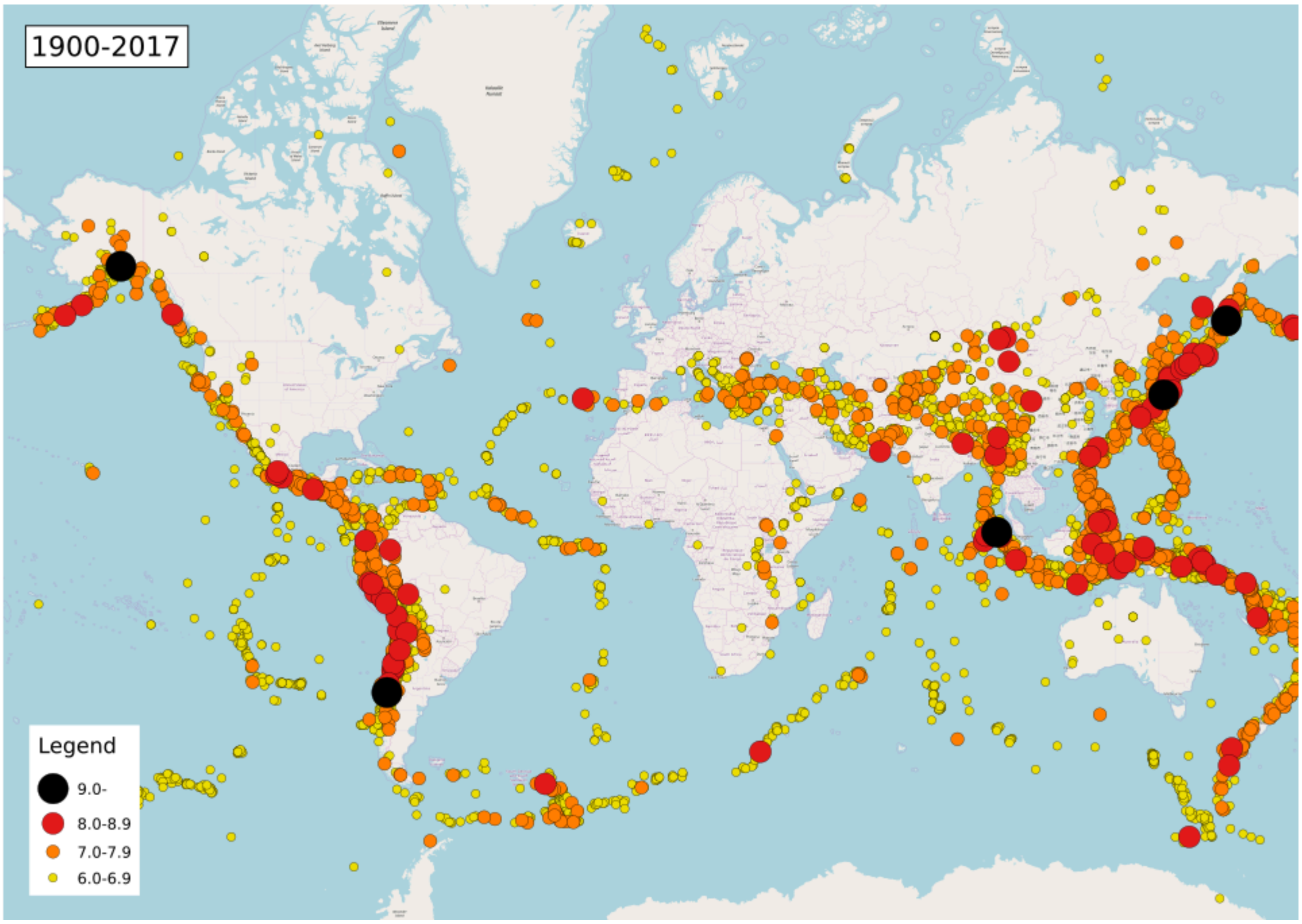
2. Describe how constructing models helped you understand how changes in the ocean crust occur over time.

Coastal and Continental Seismic Activity

Part 1. How does plate movement create hazards?

Not all areas of seismic activity are at ocean ridges where plates are spreading. Looking at the two maps below:

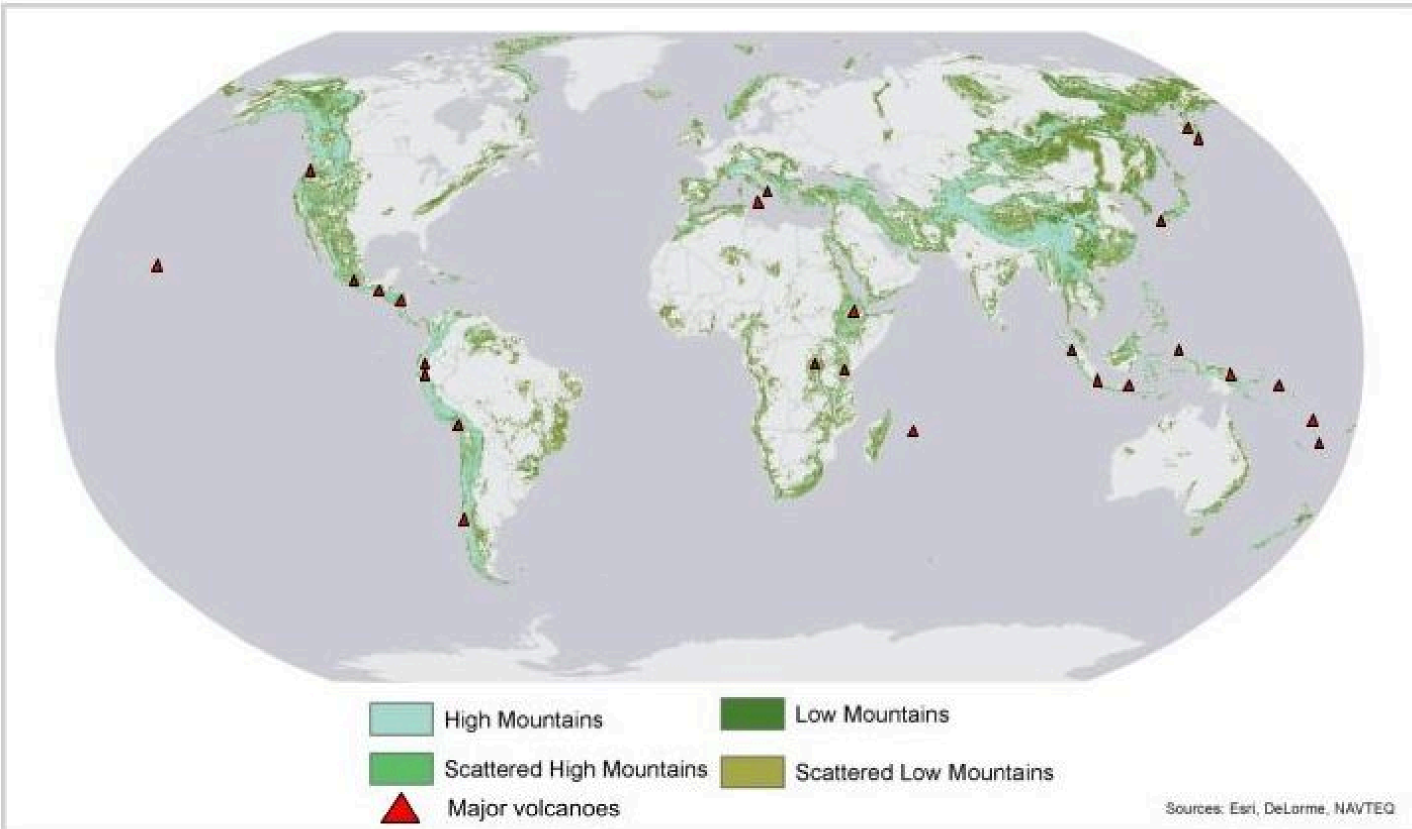
1. Identify and circle areas of high seismic activity that don't appear to be on midocean ridges.



2. Make a prediction. What do you think is causing this additional set of seismic activity?

Part 2. The surface of the crust

Compare the locations you identified in part 1 with the map below.



1. What relationship do you notice between the surface features of the Earth and the areas of high seismic activity?

2. What does that pattern make you think might be happening in those locations?

Part 3. Underneath the earthquakes

1. Open the Iris Interactive Earthquake Viewer
2. Zoom out so the map shows the whole planet
3. On the right side, set the ‘maximum number of earthquakes’ to 25000, and then click “apply”.
4. Look for the earthquakes that follow the ocean ridges.

What color dots show up in the areas you identified above?

Based on those colors, what are the minimum and maximum depths of the earthquakes in those areas?

5. Now look at the areas that have a lot of earthquakes but don’t match where ocean ridges are. How do the colors and configurations of the dots differ compared to the dots along the ocean ridges? What do those differences mean?

6. On the map, locate one of the coastal/island areas you identified in Part 1 and zoom in

What area did you choose?

7. Based on the colors and sizes of the dots, what are the minimum and maximum depths and magnitudes of the earthquakes in that area?

Depths:

Magnitudes:

8. Click on the “3D View” button in the bottom right corner and draw the configuration of the earthquakes below the surface

9. On the map, locate one of the inland areas you identified in Part 1 and zoom in

What area did you choose?

---

10. Based on the colors and sizes of the dots, what are the minimum and maximum depths and magnitudes of the earthquakes in that area?

Depths:

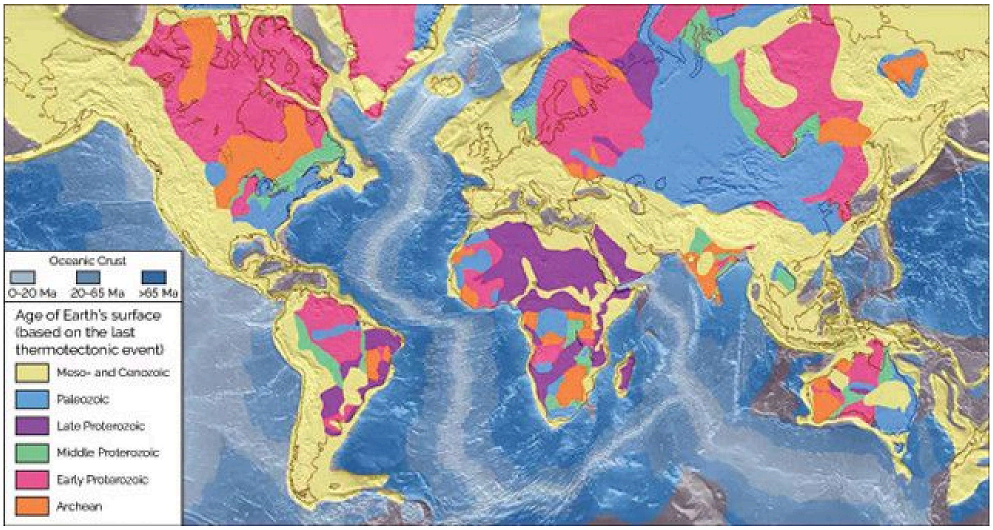
Magnitudes:

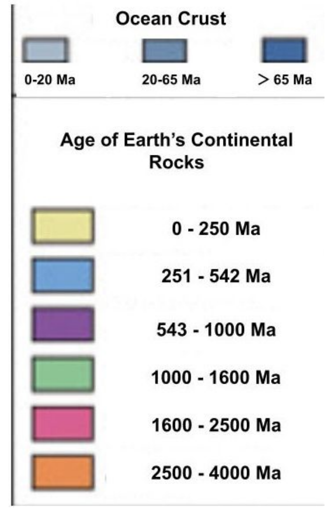
---

11. Click on the "3D View" button in the bottom right corner and draw the configuration of the earthquakes below the surface

Part 4. The Continental Crust

The Age of Continental Rock





1. Describe any patterns you see in the age of the continental rocks

2. Compare that pattern to the pattern of ages in the ocean floor. How might those patterns fit together?

Making Sense of the Coastal and Continental Seismic Activity Investigation

See	Think	Wonder
What patterns did you notice connecting surface features and seismic activity?	What evidence did you use to identify those patterns? How did that help you determine what is happening in those areas?	
What patterns did you observe happening underneath the surface of the Earth in areas with high seismic activity?	What evidence did you use to identify those patterns? How did that help you determine what is happening in those areas?	

Analysis:

1. Based on all the evidence from the ocean ridges, the edges of the tectonic plates, and the ages of the continental crust, sketch an initial model of what you think is happening that could explain all of these patterns.

2. Comparing the depths and magnitudes of the earthquakes you observed in different types of areas (mid-ocean ridges, coastal plate boundaries, and continental plate boundaries), where do earthquakes seem to be most impactful?

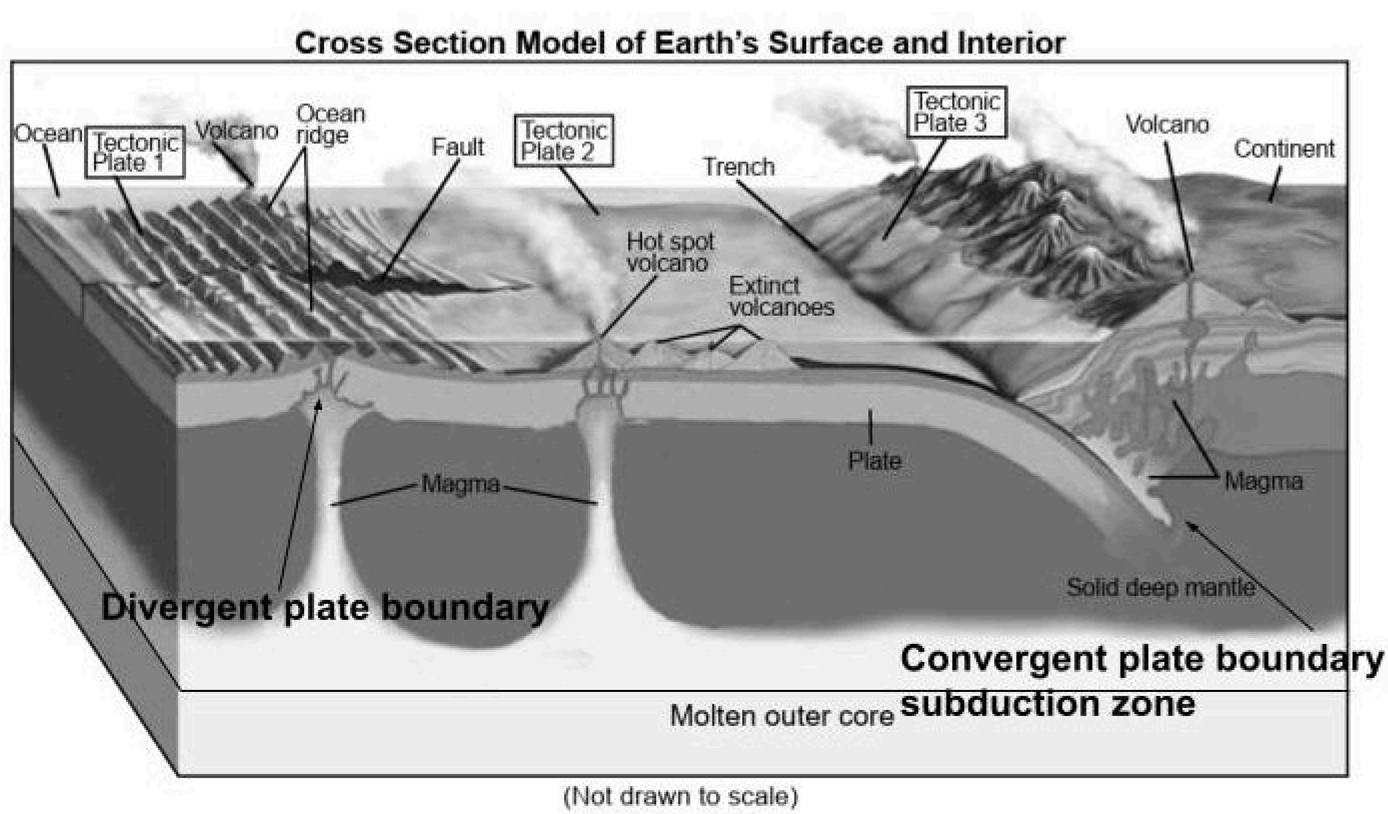
Part 1. Evaluating Evidence for Plate Tectonic Theory

In the 1960s, geologists had a few different ideas about what explained the differences in age of the ocean crust. While the scientific community could agree that new crust was being produced at Earth's mid-ocean ridges, some geologists believed that meant the Earth had to be getting bigger.

Other geologists proposed another explanation called plate tectonics. The geologists behind plate tectonics claimed that the Earth was not getting bigger. They proposed that while magma creates new crust at mid-ocean ridges (where plates are spreading apart from each other), Earth's crust is destroyed and sinks back into the Earth's interior at other locations, where plates are colliding. In cases where two continental plates are colliding, the crust will stack and accumulate, forming mountains.

In the process of ocean-continental plate collisions, the denser ocean plate sinks below the lighter continental plate, eventually going back to the mantle below in the process of subduction. Subduction creates areas with a lot of heat and friction, which can melt rocks back into magma and result in volcanism. The lighter continental plate on top experiences crushing and lifting, forming mountains above.

Annotate the diagram below to show the direction of the plate motion, and then complete the table below.



Evaluating the Evidence of Plate Tectonics Theory Claim

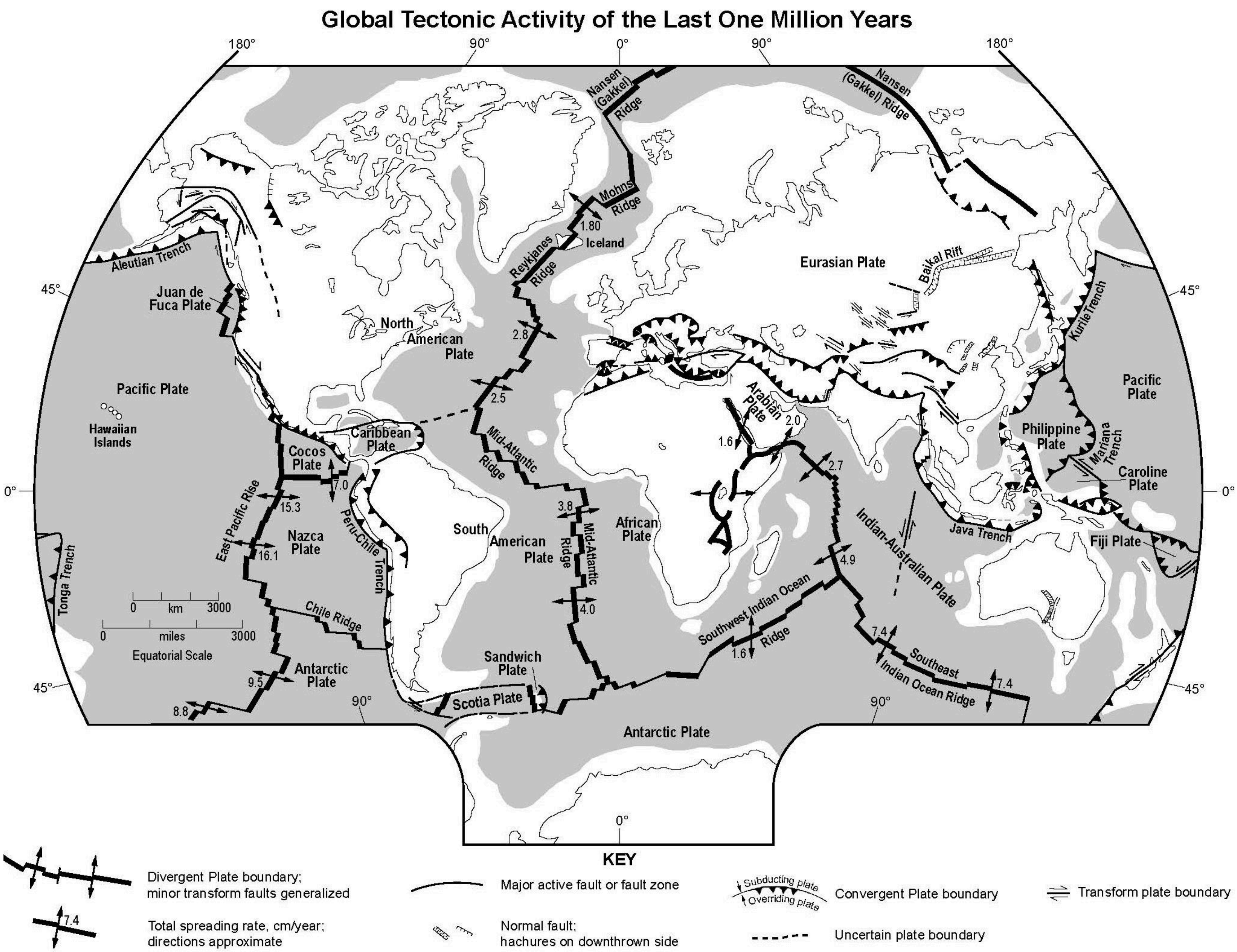
What claims / ideas are represented in the model?	Is the idea supported by evidence? If so, what is the evidence?	What mechanism connects the evidence to the claim?

Part 2. Explaining the Pattern of Seismic Activity

With all the evidence in this learning sequence and the map below, explain the pattern of seismic activity. In your explanation, be sure to include:

- Evidence from all of the investigations
- Evidence from the maps and diagrams
- An explanation of how that evidence connects to seismic activity

Global Tectonic Activity of the Last One Million Years



Summary Task

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1. One thing that went well in the discussion:

2. One thing we can improve the next time we have a discussion:

3. One person who helped me learn today:

What did you learn from this person?

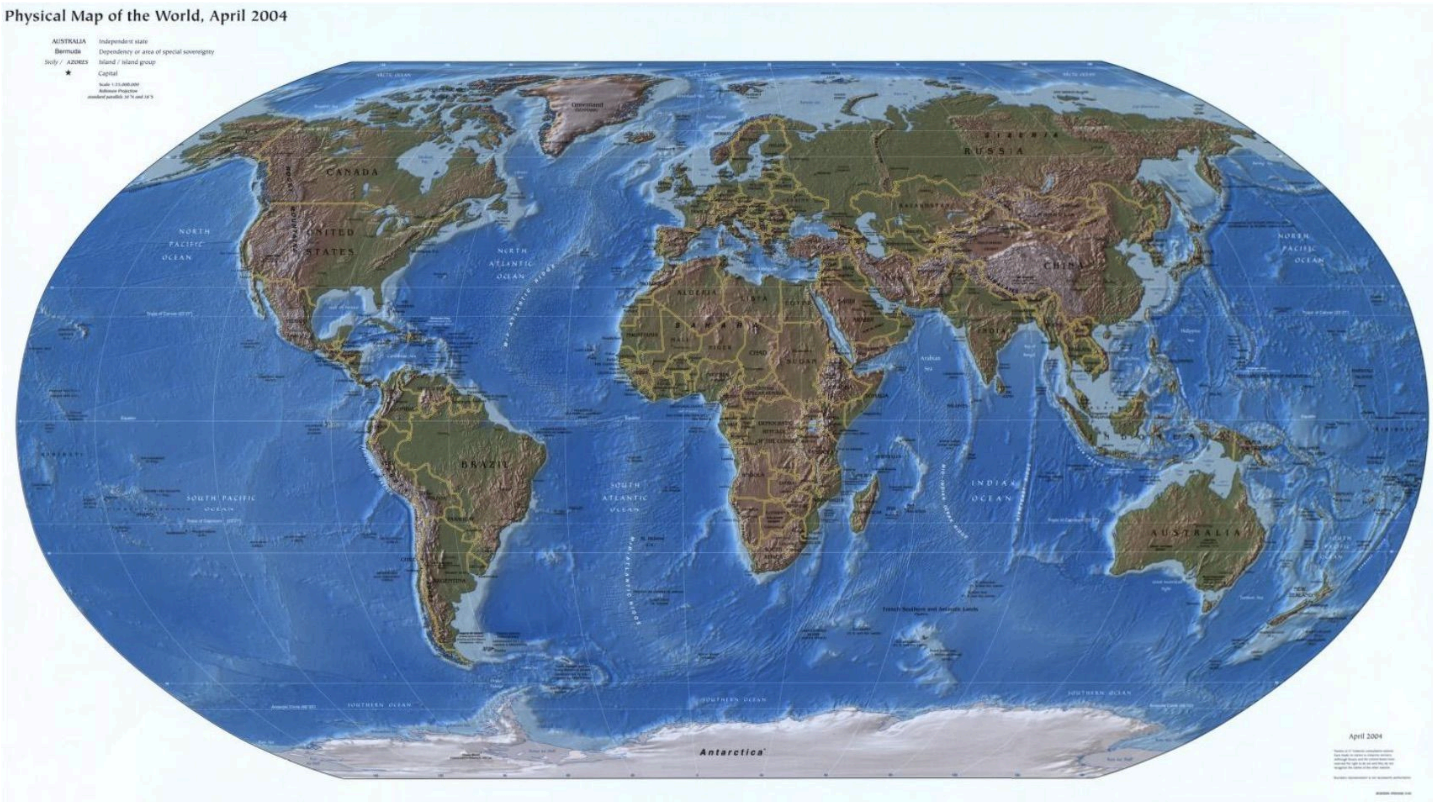
4. One idea that I contributed to my group or my class:

Explain what you know about the following question, based on what we discussed today:

1. Describe how empirical evidence helped you identify patterns and how those patterns, in turn, supported your analysis of the evidence that supports the theory of plate tectonics.

Constructing New York State

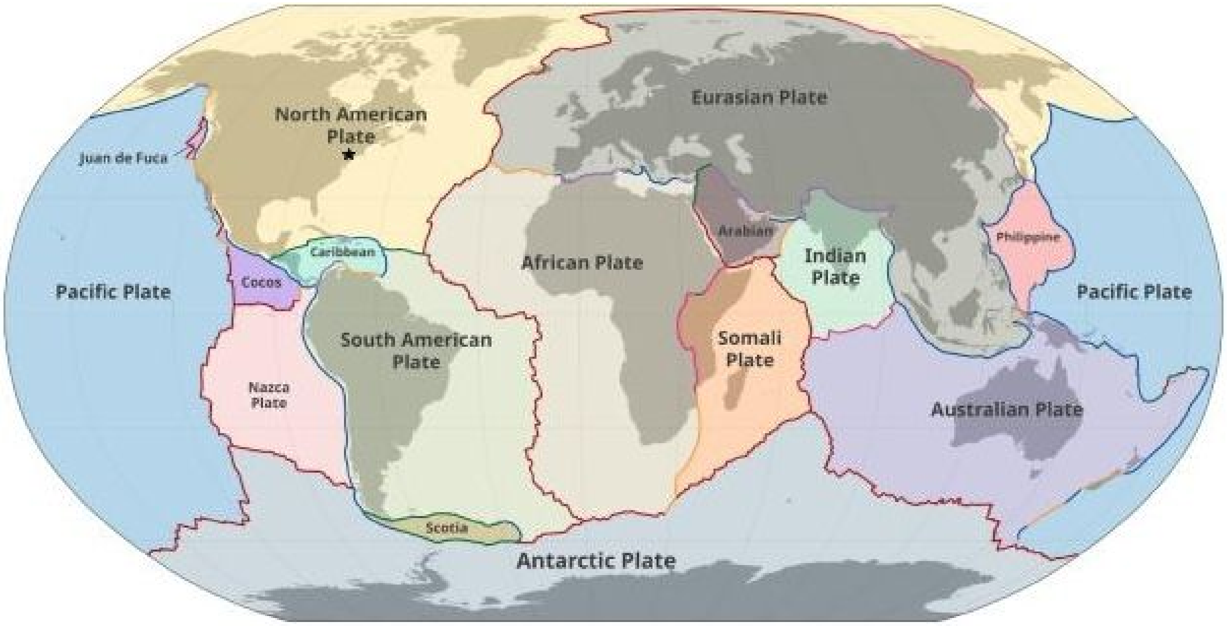
It has taken 4 billion years for the planet to look like this, with all of its oceans, continents, islands, and mountains.



Based on everything you have learned so far, from this unit and others, complete the table below by describing the factors that have changed the configuration of islands, continents, mountains, and oceans.

Factor	Describe the Mechanism of how that factor causes change	Describe the types of changes it causes	Timescale on which it causes change
Volcanic Eruption			
Tectonic Plate Motion			
Erosion			

Mountains and other surface features can form far from plate boundaries. For example, despite New York State's position in the middle of the North American Plate, it has mountains, rivers, and dramatic cliffs.




The adirondack mountains in New York State


The palisades in New York State

In this activity, you will examine the processes that created the unique landforms in New York State.

Step 1. Examine the ages of New York Bedrock

Use colored pencils to color in the Generalized Surface Bedrock Geology of New York State map by assigning a color to each pattern in the key and coloring in the map to match. Try to assign colors in an order that shows a changing scale (like rainbow order), as shown in the image to the right, to make the relationships easier to see.

Step 2. Analyzing Rock Types

1. Looking at the bolded rock types in the key of the Generalized Surface Bedrock Geology of New York State map, what trend do you notice about the relationship between rock type (sedimentary or

metamorphic) and the ages of the rocks in New York?

2. Turn to the Rock Cycle Infographic. Using a highlighter or colored pen, circle or highlight every rock name (eg. limestone) that is listed in the key of the Generalized Surface Bedrock Geology of New York State map.
3. Look at the arrows of the Rock Cycle Infographic that lead to or from the rock types you circled. Using a different colored pen or highlighter, box or highlight the processes (words ending in “ing,” “tion,” or “sion”) that show how the rock types change over time.
    - What types of processes seem to be involved in rock formation in New York State?

    - What types of processes that we’ve already learned about are not involved in the formation of rock over the past billion years in New York State?

4. Using evidence about the ages of the rocks in New York State, their types, and the processes that relate them, explain how you think the bedrock of New York formed.

5. Based on the *Rock Cycle Infographic*, which types of rocks would you expect to find closer to the surface or at higher elevations, and which rock types would you expect to find at lower elevations or further beneath the surface? Support your answer with evidence from the *Rock Cycle Infographic*.

Step 3. Determining the Ages of Surface Features

1. Compare your color-coded Generalized Surface Bedrock Geology of New York State map with the Geographic Province and Landscape Regions of New York State.
2. Using the information from the Generalized Surface Bedrock Geology of New York State map, annotate the Geographic Province and Landscape Regions of New York State map with the ages and rock types (sedimentary or metamorphic) in each region.
3. Do the rock types, ages, and landforms match your predictions above? Explain your answer using specific evidence from each map.

Step 4. Understanding New York's Landforms

As we've learned, the motion of the tectonic plates over millions of years has separated our continents and created the oceans between them. As plates separate, rising magma breaks through (a form of volcanic activity), very slowly producing new ocean crust. As plates converge, some crust is reabsorbed into Earth's mantle while other crust is pushed upwards, forming mountains through the process of tectonic uplift. We also know that volcanic eruptions can create and destroy islands over short periods of time, like in the example of Krakatoa.

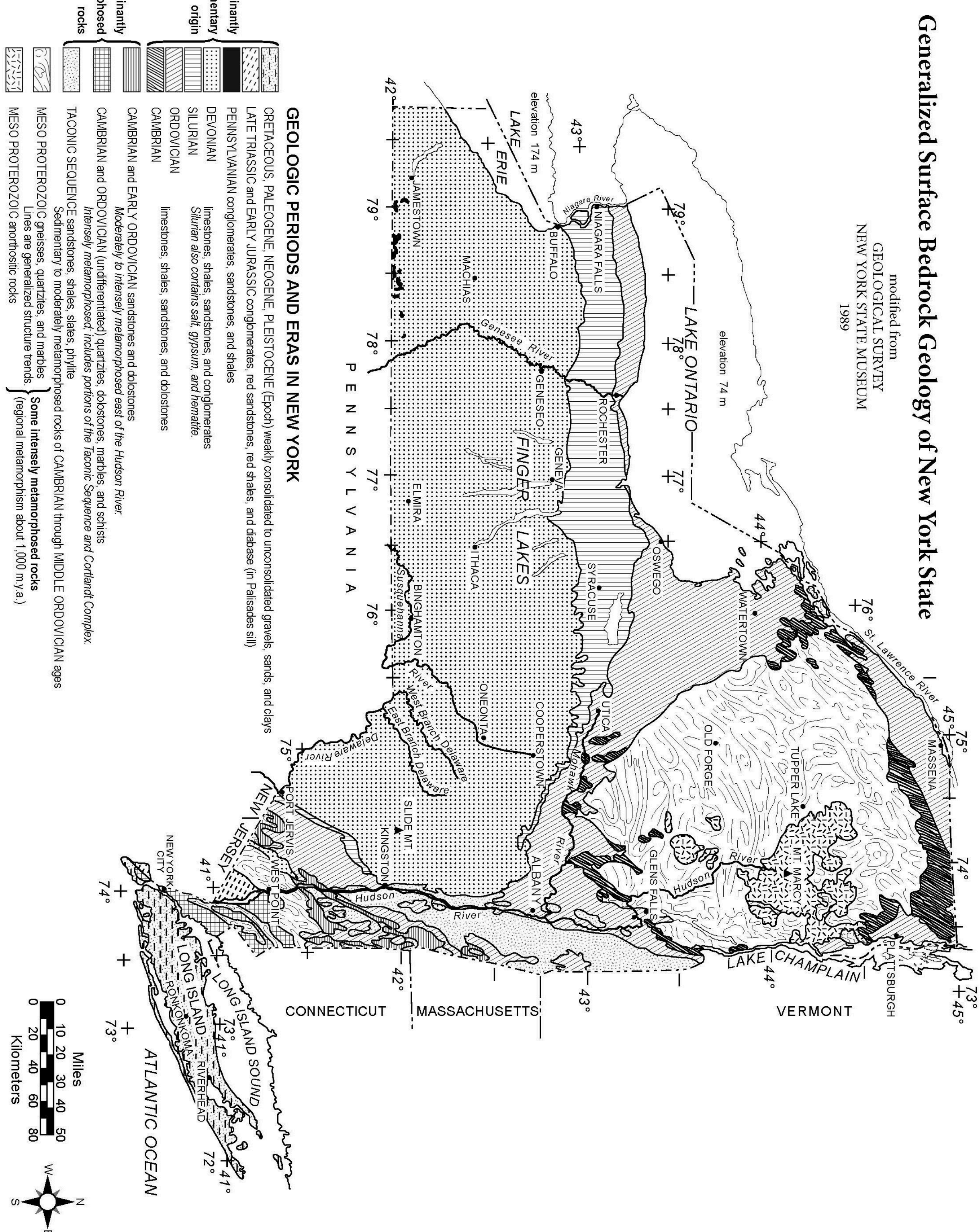
New York State, which sits in the middle of the North Atlantic Plate, has not been subject to volcanic activity for at least 1 billion years, and the rock types and topography seen in the state are not due to divergent or convergent plate boundaries or to volcanic activity.

Watch this video How Earth Recycled a Mountain Range in order to see how the Adirondack mountains formed. After you are done watching, arrange the *Adirondack Mountain Cards* along the *Adirondack Mountain Timeline*. Sketch your completed model in the space below:

Using the model and what you've learned throughout this unit, answer the following questions:

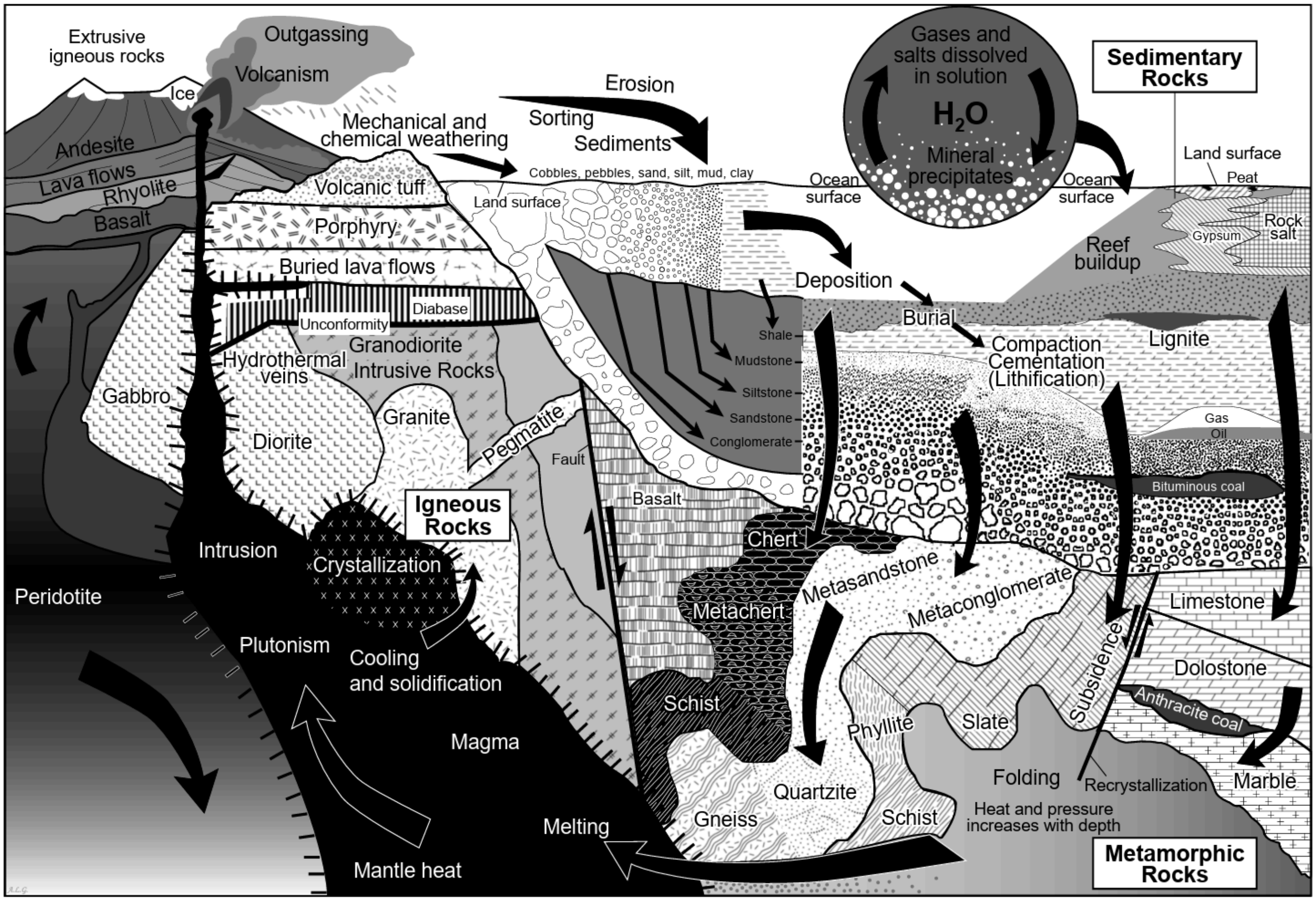
1. How does this model explain the observations of rock ages and types found in New York State?

2. Name the constructive and destructive processes that formed the Adirondacks and Krakatoa. Compare and contrast the timescales on which these processes operate.

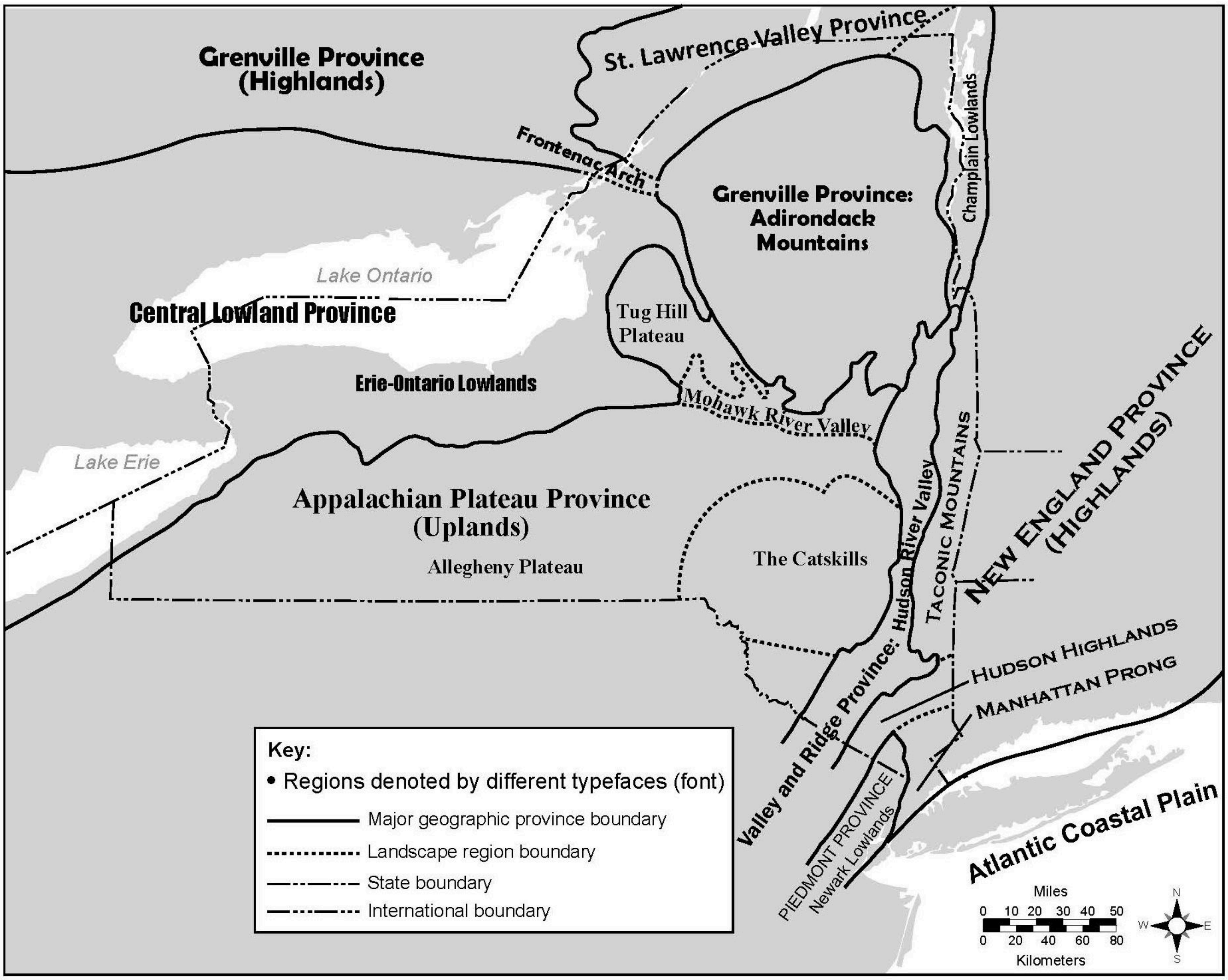


Generalized Surface Bedrock Geology of New York State
modified from
GEOLOGICAL SURVEY
NEW YORK STATE MUSEUM
1989
GEOLOGIC PERIODS AND ERAS IN NEW YORK
Dominantly sedimentary origin
Dominantly metamorphosed rocks
CRETACEOUS, PALEOGENE, NEOGENE, PLEISTOCENE (Epoch) weakly consolidated to unconsolidated gravels, sands, and clays
LATE TRIASSIC and EARLY JURASSIC conglomerates, red sandstones, red shales, and diabase (in Palisades sill)
PENNSYLVANIAN conglomerates, sandstones, and shales
DEVONIAN limestones, shales, sandstones, and conglomerates
SILURIAN Silurian also contains salt, gypsum, and hematite.
ORDOVICIAN limestones, shales, sandstones, and dolostones
CAMBRIAN
CAMBRIAN and EARLY ORDOVICIAN sandstones and dolostones
Moderately to intensely metamorphosed east of the Hudson River.
CAMBRIAN and ORDOVICIAN (undifferentiated) quartzites, dolostones, marbles, and schists
Intensely metamorphosed; includes portions of the Taconic Sequence and Cortlandt Complex.
TACONIC SEQUENCE sandstones, shales, slates, phyllite
Sedimentary to moderately metamorphosed rocks of CAMBRIAN through MIDDLE ORDOVICIAN ages
MESO PROTEROZOIC gneisses, quartzites, and marbles
Lines are generalized structure trends.
MESO PROTEROZOIC anorthositic rocks
Some intensely metamorphosed rocks
(regional metamorphism about 1,000 m.y.a.)
LAKE ONTARIO
elevation 74 m
LAKE ERIE
elevation 174 m
Niagara River
NIAGARA FALLS
BUFFALO
JAMESTOWN
MACHIAS
Genesee River
GENESEO
ROCHESTER
GENEVA
FINGER LAKES
ELMIRA
ITHACA
OSWEGO
SYRACUSE
WATERTOWN
BINGHAMTON
Susquehanna River
ONEONTA
West Branch Delaware
East Branch Delaware
Delaware River
COOPERSTOWN
UTICA
Mohawk River
OLD FORGE
TUPPER LAKE
MT. MARCY
MASSENA
St. Lawrence River
PLATTSBURGH
LAKE CHAMPLAIN
GLENS FALLS
ALBANY
Hudson River
SLIDE MT.
KINGSTON
PORT JERVIS
WEST POINT
NEW YORK CITY
LONG ISLAND SOUND
LONG ISLAND
RONKONKOMA
RIVERHEAD
ATLANTIC OCEAN
PENNSYLVANIA
NEW JERSEY
CONNECTICUT
MASSACHUSETTS
VERMONT
Miles
0 10 20 30 40 50
0 20 40 60 80
Kilometers
N
S
E
W

Rock Cycle Infographic



GEOGRAPHIC PROVINCE AND LANDSCAPE REGIONS OF NEW YORK STATE



Who is Most at Risk?

1. Brainstorm what characteristics distinguish areas with high levels of tectonic activity from areas with low levels of tectonic activity

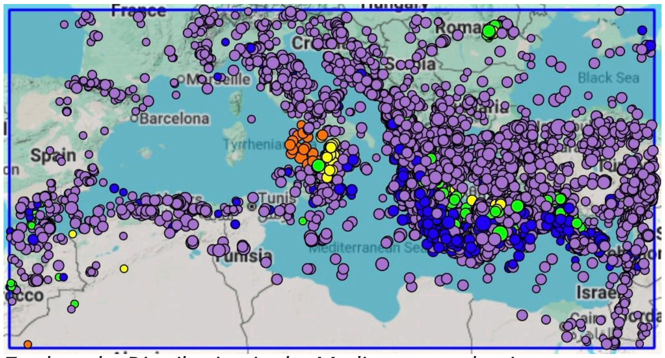
2. Brainstorm what characteristics affect how earthquake activity affect people in different areas with high levels of tectonic activity

Deaths from Earthquakes in the Key 5 Regions

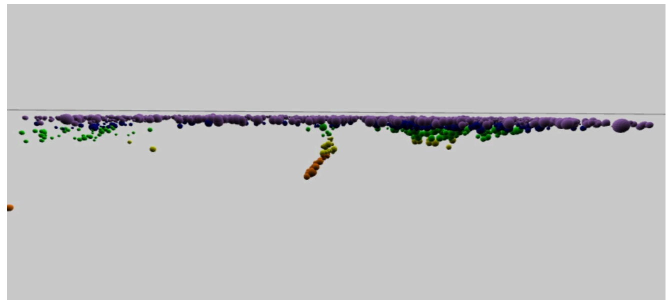
	Mediterranean Basin	Great Rift Valley	Mainland Southeast Asia	Japanese Archipelago	Andes Region
Deaths since 1900	186234	302	12251	185929	130151
Deaths since 1990	87403	75	6091	27460	6336

Mediterranean Basin

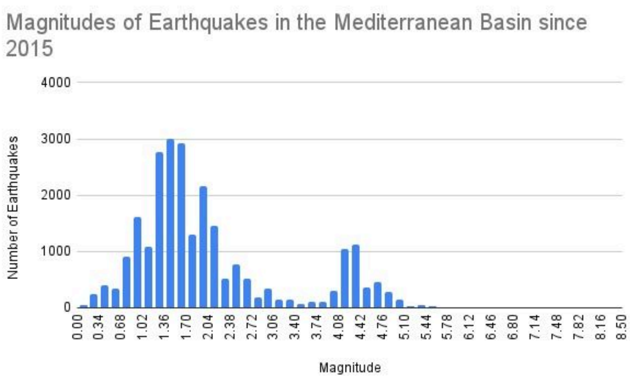
The mediterranean basin has many plates moving in different directions; small plates collide here, and others move apart, forming the earthquake patterns shown below. It is characterized by frequent earthquakes of varying depths and volcanic activity.



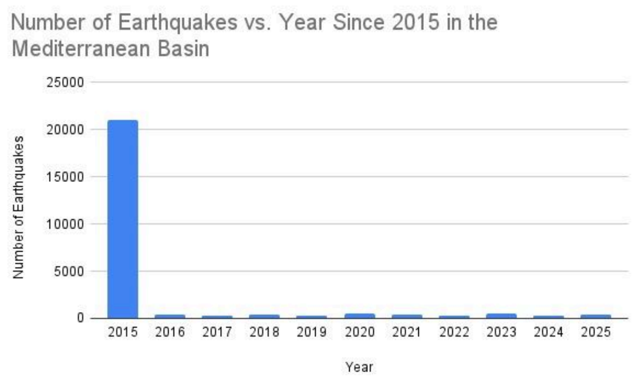
Earthquake Distribution in the Mediterranean basin



Earthquake Depth in the Mediterranean Basin

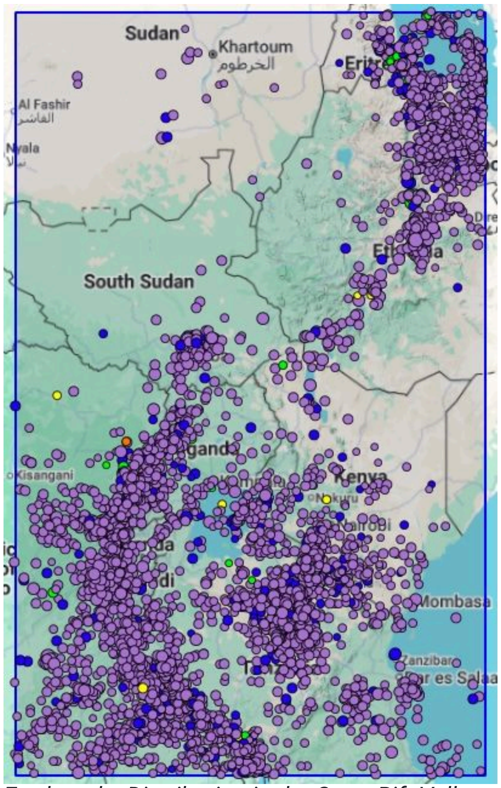


Magnitudes of Earthquakes in the Mediterranean Basin since 2015

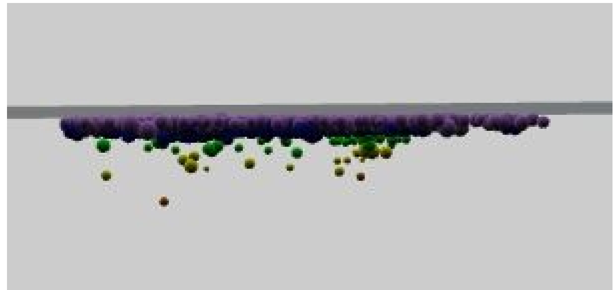


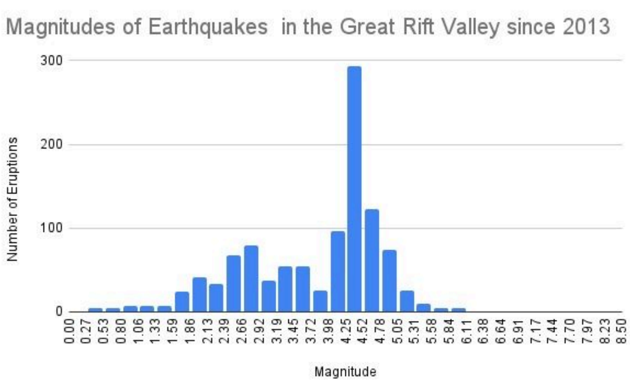
Number of Earthquakes vs. Year Since 2015 in the Mediterranean Basin

Rift Valley
The rift valley is on a divergent plate boundary where plates move apart. It is characterized by frequent shallow earthquakes and volcanic activity.

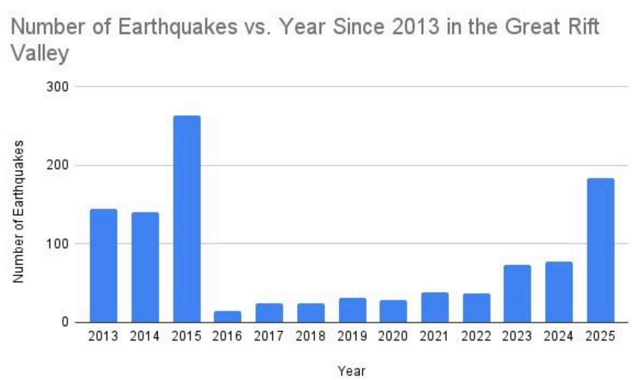


Earthquake Distribution in the Great Rift Valley


Earthquake Depth in the Great Rift Valley

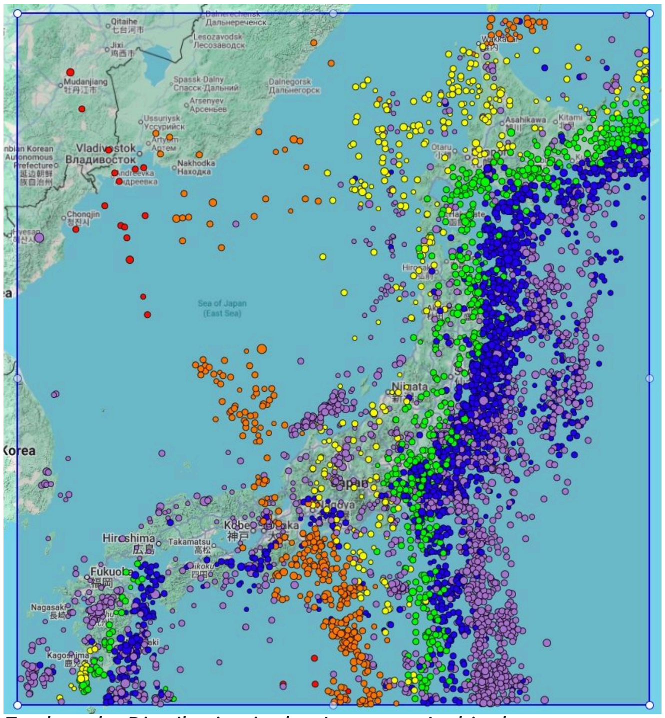


Magnitudes of Earthquakes in the Great Rift Valley since 2013

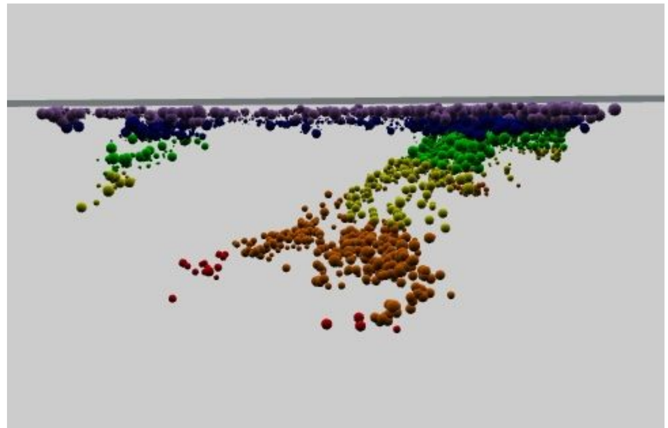


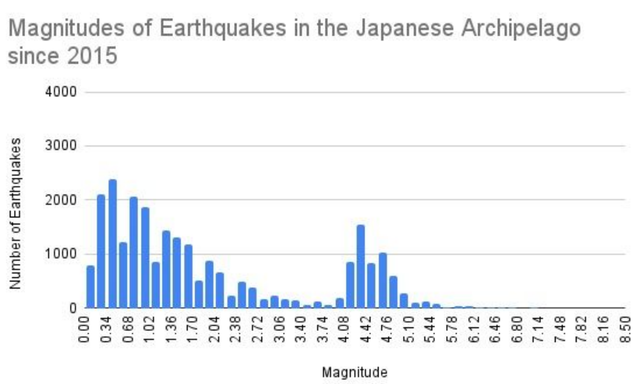
Number of Earthquakes vs. Year Since 2013 in the Great Rift Valley

The Japanese Archipelago
The Japanese Archipelago sits on a convergent plate boundary where plates are colliding. As one plate layers underneath another, weak spots in the crust form, and heat and friction create frequent deep earthquakes and volcanic eruptions.

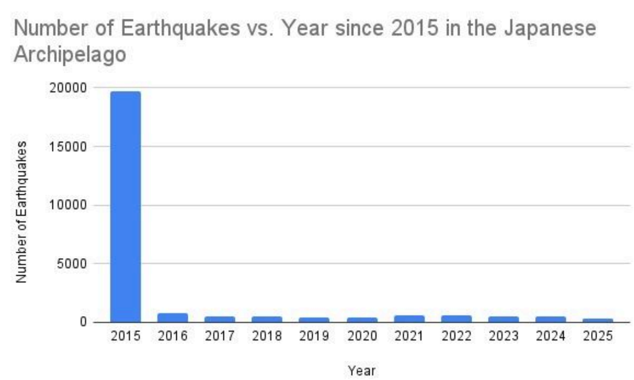


Earthquake Distribution in the Japanese Archipelago


Earthquake Depth in the Japanese Archipelago

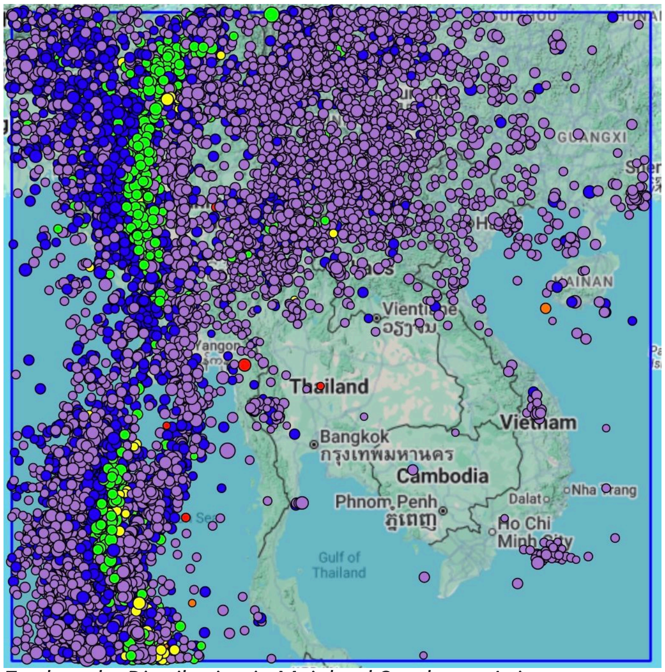


Magnitudes of Earthquakes in the Japanese Archipelago since 2015

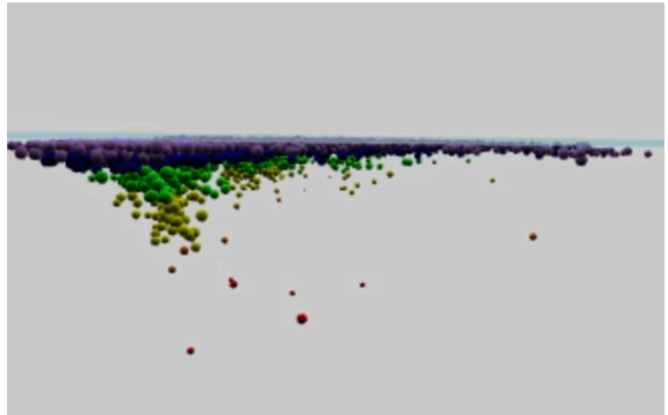


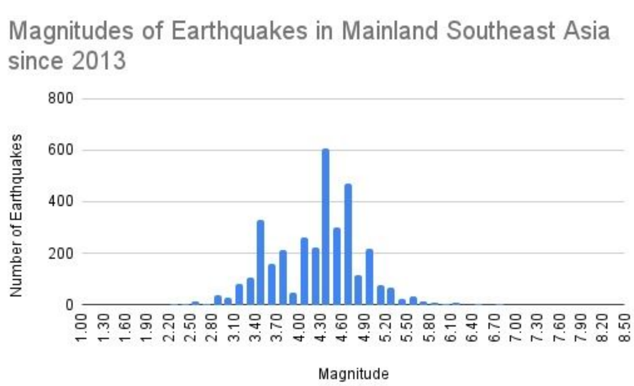
Number of Earthquakes vs. Year Since 2015 in the Japanese Archipelago

Mainland Southeast Asia
Mainland Southeast Asia sits at continental convergent plate boundaries. Here, tall mountains form as two plates collide and stack up. The earthquakes that happen here tend to be shallower, but can cause damage to these mountainous regions.

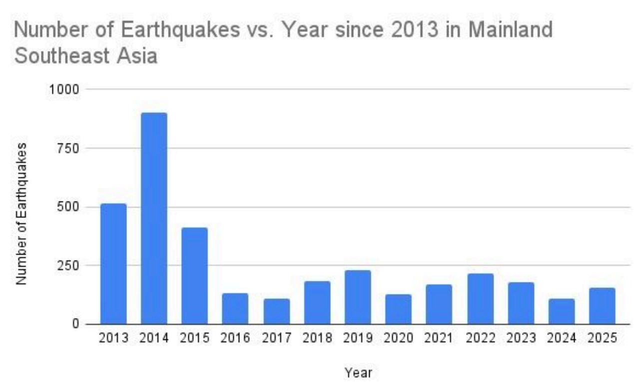


Earthquake Distribution in Mainland Southeast Asia


Earthquake Depth in Mainland Southeast Asia

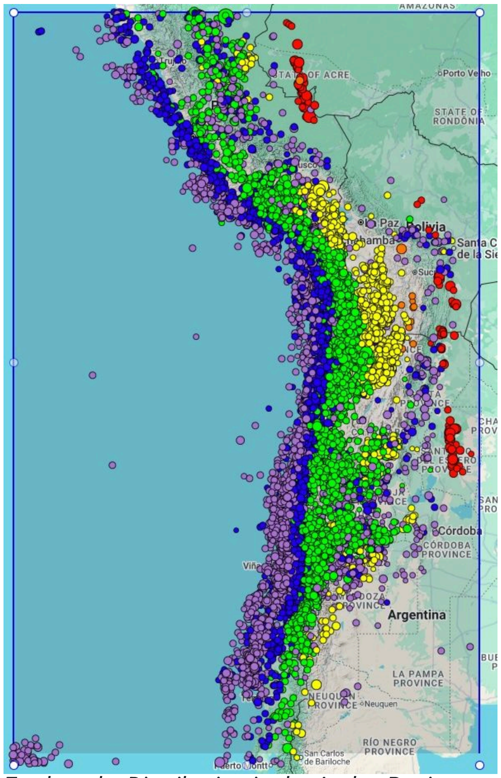


Magnitudes of Earthquakes in Mainland Southeast Asia since 2013

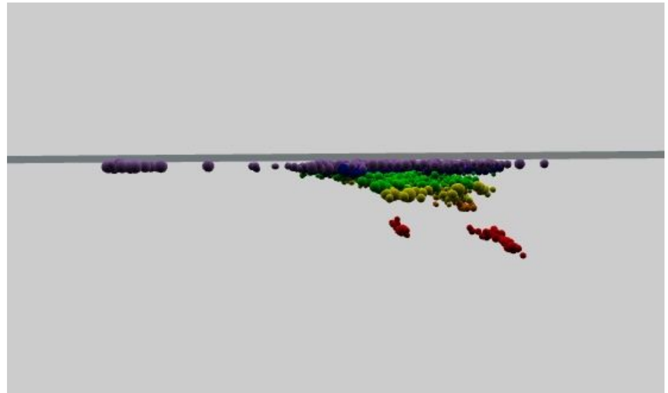


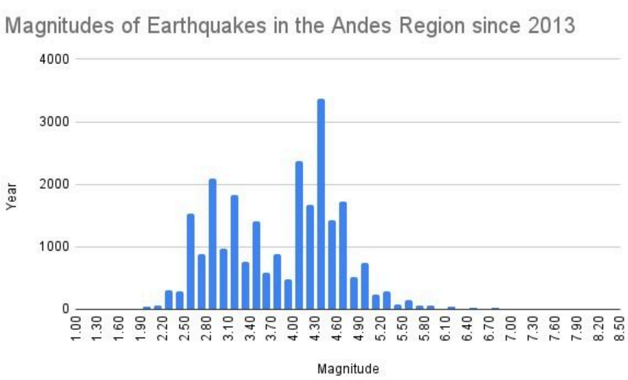
Number of Earthquakes vs. Year Since 2013 in Mainland Southeast Asia

Andes Region
The Andes Region sits on convergent plate boundaries where an oceanic plate meets a continental plate. As a result, this region is mountainous and prone to frequent deep earthquakes. The strongest earthquake ever recorded occurred here.

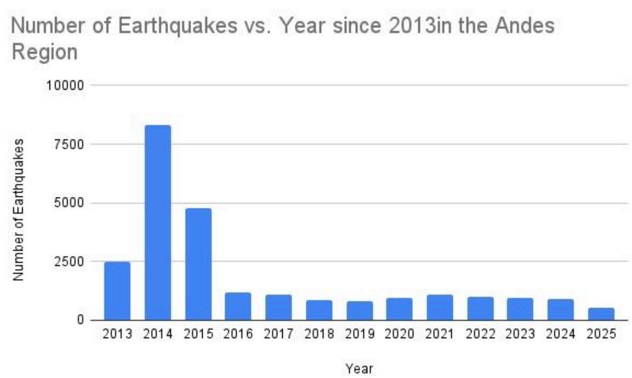


Earthquake Distribution in the Andes Region


Earthquake Depth in the Andes Region



Magnitudes of Earthquakes in the Andes Region since 2013



Number of Earthquakes vs. Year Since 2013 in the Andes Region

Plate Boundaries & Surface Features Model Rubric

Surface Features & Plate Boundaries	Proficient	Developing
Model based on Surface Features & Plate Boundaries	The model effectively and accurately represents the types and mechanisms of hazards that are produced at different plate boundaries and includes all of the components below: • Type / structure of plate boundaries at each performance task location. • The direction of plate movement at each performance task location. • The surface features / hazards at each performance task location The components of the model "speak for themselves" for the most part. **OR** There are legends, keys, or written captions to clarify the components. Relevant evidence is identified for changes to the model and scientific reasoning to link the evidence to each change to the model is provided.	The model is incomplete in showing the types and mechanisms of hazards that are produced at different plate boundaries, **missing one or more** of the components below: • Type / structure of plate boundary at each performance task location. • The direction of plate movement at each performance task location. • The surface features / hazards at each performance task location The components of the model do not really "speak for themselves." **OR** Legends, keys, or written components are insufficient to clarify the model. Some evidence identified for changes to the model is not relevant and / or scientific reasoning to link the evidence to each change to the model is not provided.
Stability & Change	Response to reflection prompt 2 clearly articulates how mathematical calculations of data were used to determine rates of change in seafloor spreading and /or frequency of volcanic eruptions and tsunamis.	Response to reflection prompt 2 does not clearly articulate how mathematical calculations of data were used to determine rates of change in seafloor spreading and /or frequency of volcanic eruptions and tsunamis.
Student Self- Score	**Circle One** **Proficient** **Developing**	**Glow**: **Grow**:
Teacher Score	**Circle One** **Proficient** **Developing**	**Glow**: **Grow**:

Plate Boundaries & Surface Features Argument Rubric

<table>
<tr><th>Surface Features & Plate Boundaries</th><th>Proficient</th><th>Developing</th></tr>
<tr><td>Argument based on the unit</td><td>The argument makes a claim identifying which location they think is most at risk of an earthquake, volcanic eruption, and / or tsunami.

The claim is supported with relevant/accurate evidence from the earthquake, volcanic eruptions and tsunami data sets for each location, including:
frequency of earthquakes, volcanic eruptions and tsunamis.
magnitude of earthquakes, volcanic explosivity and tsunami wave height.
Reasoning is provided to support the claim, including:
connections between type plate interaction and the hazards that can occur due to these interactions.
connections between level of risk and frequency and magnitude of earthquakes.
connections between level of risk and frequency and volcanic eruption explosivity.
connections between level of risk and frequency and wave height of tsunamis.</td><td>The argument makes a claim identifying which location they think is most at risk of an earthquake, volcanic eruption, and / or tsunami.

The claim is weakly supported with evidence from the earthquake, volcanic eruption and tsunami data sets, investigations, or readings.

Reasoning is not provided to support the claim.</td></tr>
<tr><td>Stability & Change</td><td>Argument includes rates at which volcanic eruptions and tsunamis occur at different performance task locations.</td><td>Argument includes rates at which volcanic eruptions and tsunamis occur at different performance task locations.</td></tr>
<tr><td>Student Self- Score</td><td>Circle One

Proficient   Developing</td><td>Glow:

Grow:</td></tr>
<tr><td>Teacher Score</td><td>Circle One

Proficient   Developing</td><td>Glow:

Grow:</td></tr>
</table>

Relevance to your life: Think about everything that you have learned throughout this unit so far.

1. What is one idea and/or skill you learned that you think is important to teach someone in your family or community?

____

____

2. To whom do you intend to teach this idea and/or skill? Why do you think it is important for this person to learn this idea and/or skill?

____

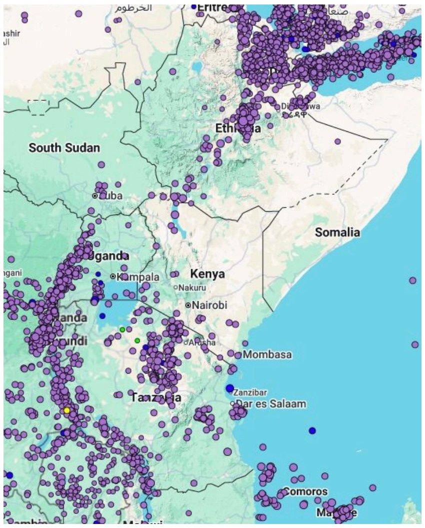
____

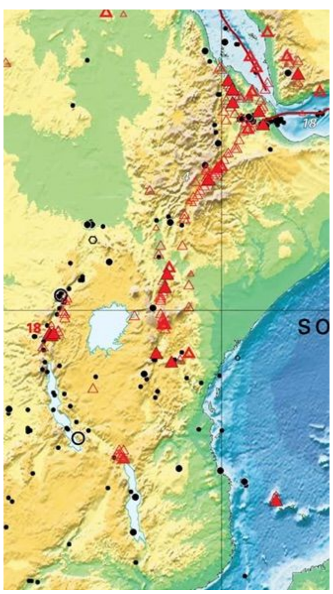
Energy and Matter 5E

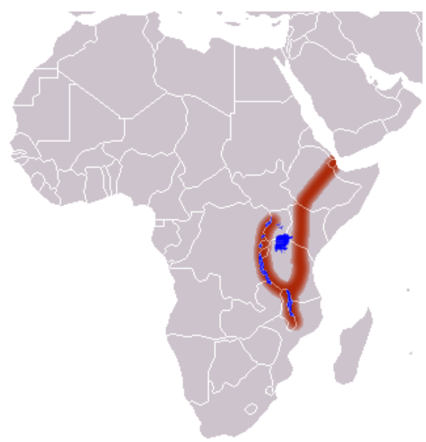
Unit 3 Earthquakes, Tsunamis, and Volcanoes: Who's at Risk?	Earth and Space Science

Student Name:

Africa's Great Rift Valley, a set of rifts at diverging plate boundaries stretching from the Middle East down to Malawi, is a geologically active region that frequently experiences seismic activity from tectonic forces.







Modeling Earth’s Interior Processes

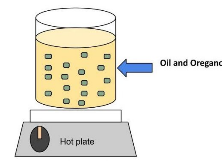
Introduction: In this activity you will be investigating patterns in the **movement of matter** when it is heated and cooled. Keep in mind, the patterns you observe in these models may provide insight that will help you explain where the energy that caused the movement of matter you observed from the Tonga volcanic eruption.

Set up the three models by following the directions below. Be sure to be detailed when recording your observations.

Model 1

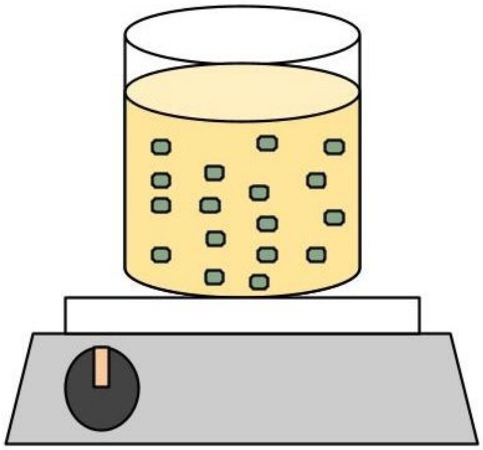
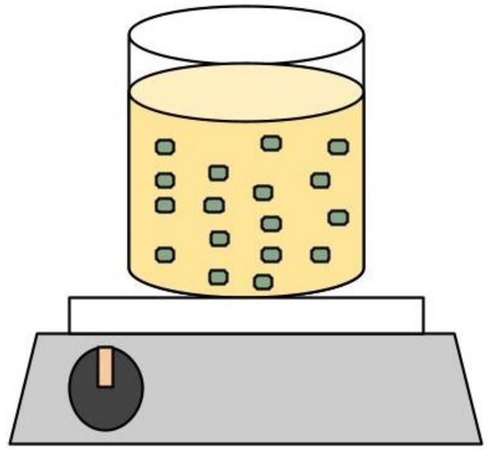
Set-up Directions:

1. Look at the set-up for **Model 1** to the right, then make predictions about the movement of the oregano and oil when the hot plate heats it up. Draw and describe your predictions in the **Prediction** column of **Table 1**.
2. Add the oregano to the oil in the beaker, if it has not already been added.
3. Have a timer ready. Place the beaker on the hot plate, and **after about 30-45 sec** draw and describe your observations in the **Observations** column of Table **1**.



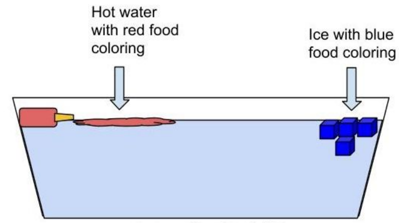
Set-up for Model 1

Table 1
In the boxes below, draw the beaker of water with the oregano in it. Be sure to label the beaker, oil, oregano, heat source, and use arrows to draw the path of the movement of the oregano and oil.

Prediction	Observations
Draw what you think will happen. *Use arrows to indicate any movement.* 	*Draw what you observe.* *Use arrows to indicate any movement.* 
In the space below, describe what you think will happen in words.	*In the space below, describe what you observe in words.*

Model 2

Set-up Directions:



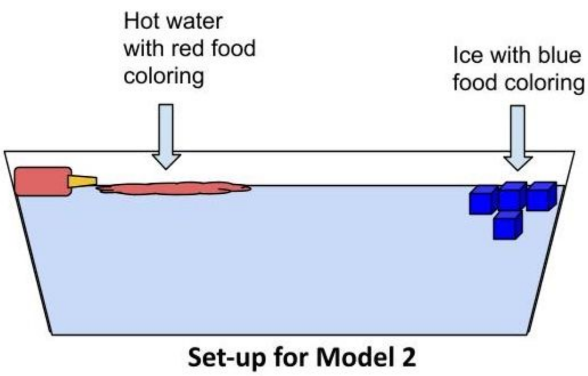
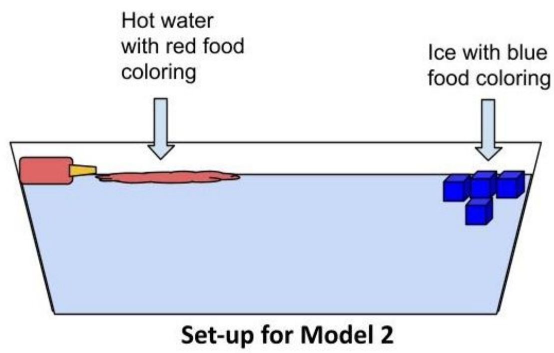
Set-up for Model 2

1. Look at the set-up for **Model 2** to the right, then make predictions about the movement of the hot red food coloring and the cold blue food coloring. Draw and describe your predictions in the **Prediction** column of **Table 2**.

2. The container is filled approximately halfway with room temperature water. Be sure that the water is completely still before proceeding. Try not to bump the table!

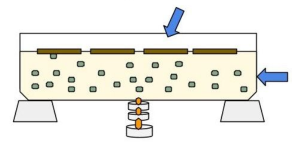
3. Very gently add 3-4 blue colored ice cubes to the left side of the bin, then gently lay the bottle with red colored hot water on the other side as shown in the set-up for **Model 2** above. Draw and describe your observations in the **Observations** column of **Table 2**.

Table 2
In the boxes below, draw and describe your observations. Be sure to label the container, water, ice cube, and use arrows to draw the path of the movement of the food coloring and ice cubes.

Prediction	Observations
Draw what you think will happen. *Use arrows to indicate any movement.* 	*Draw what you observe.* *Use arrows to indicate any movement.* 
In the space below, describe what you think will happen in words.	*In the space below, describe what you observe in words.*

Model 3

Set-up Directions:



Set up for Model 3

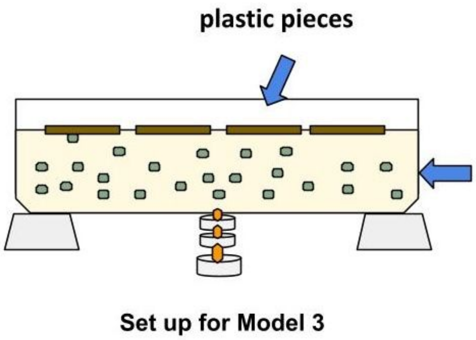
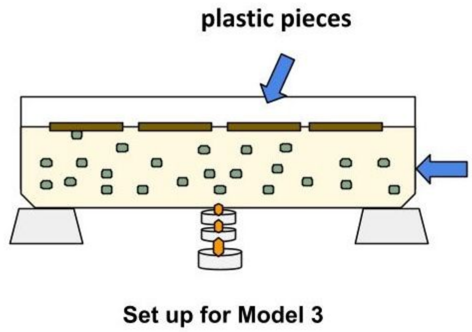
1. Look at the set-up for **Model 3** to the right, then make predictions about the movement of the oregano and oil after the candles are lit. What do you think will happen to the plastic pieces? Draw and describe your predictions in the **Prediction** column of **Table 3**. oil and oregano

2. Gently place the four pieces of plastic on top of the cooking oil in the middle of the glass dish. Be sure that the pieces of plastic are touching each other or very close together.

3. Place 3-4 small lit candles underneath the glass dish so that they are in a row along the center of the dish as seen in the set-up for **Model 3** above. **After about 30 seconds**, draw and describe your observations in the **Observations** column of **Table 3**.

BLOW OUT THE CANDLES BEFORE MOVING ON!

Table 3
In the boxes below, draw and describe your observations. Be sure to label the oregano, oil, and plastic pieces. Use arrows to draw the path of the movement of the oregano and oil and the 4 plastic pieces.

Prediction	Observations
Draw what you think will happen. *Use arrows to indicate any movement.* 	*Draw what you observe.* *Use arrows to indicate any movement.* 
In the space below, describe what you think will happen in words.	*In the space below, describe what you observe in words.*

Modeling Earth's Interior Processes

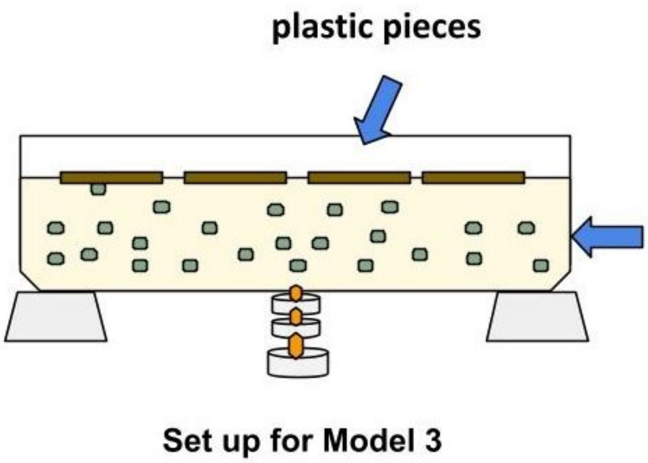
See	Think	Wonder
What patterns did you observe related to matter (stuff) rising?	What do you think is causing the matter to move?	What questions do you still have?
What patterns did you observe related to matter (stuff) sinking?	What do you think is causing the matter to move?	What questions do you still have?
What else did you observe in the models?	How might what you're observing explain plate motion associated with the formation and eruption of the Tonga volcano you observed?	What questions do you still have?

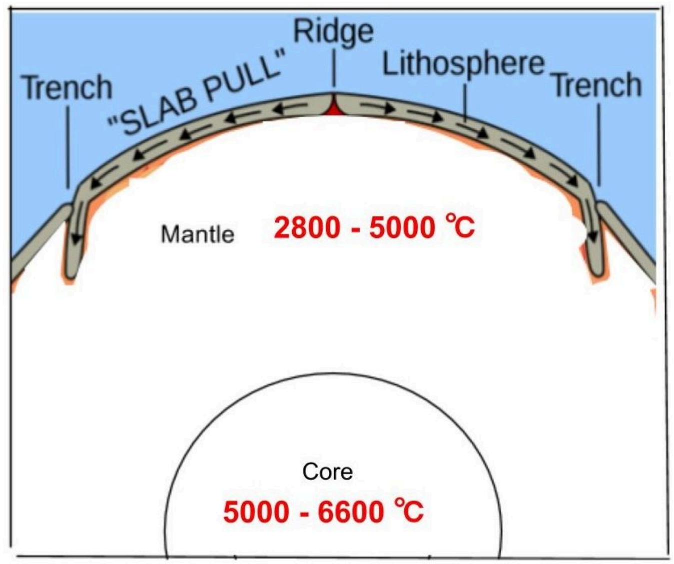
Explaining the Great Rift Valley

Part 1: What did the investigation tell us about how energy from Earth's interior causes plate motion?

Directions:

1. Examine the models below. Using words and annotations, make connections between the classroom demonstration and the model of the Earth. Which parts of each model are equivalent? Be sure to find the matching parts for the tea candles, oil, and floating plastic.

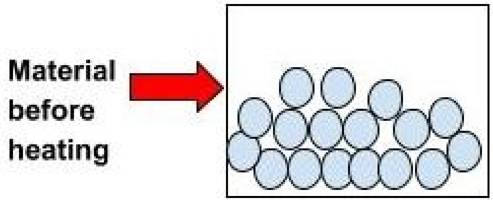


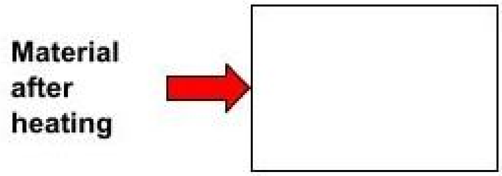


The Role of Density

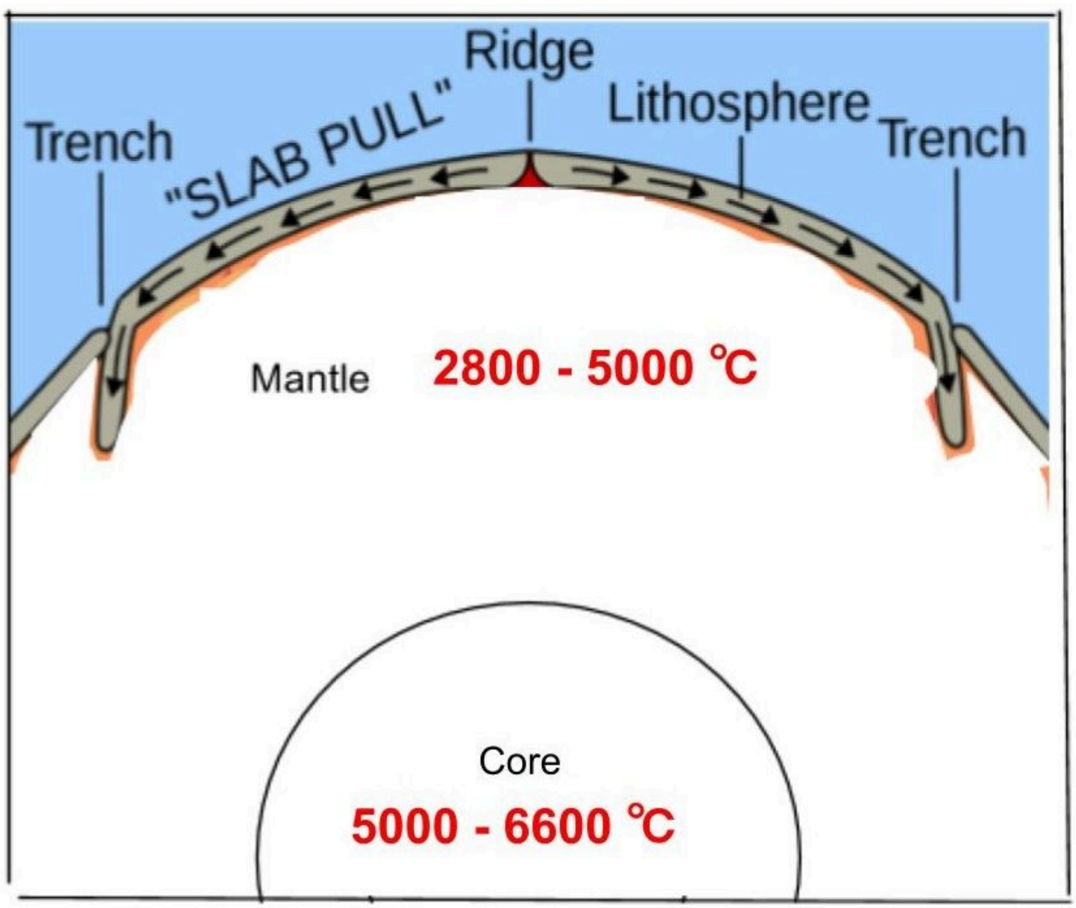
1. Recall what you learned from the density column activity during the Earth's Interior Investigation. How do layers of different substances form?

2. How do you think temperature and density of a material are related? In other words, **how does a change in temperature of a material affect its density?** Show your thinking by drawing the particles of the material below after it is heated.





3. Using what you observed during the investigation, annotate the model below to show how energy and matter are moving in Earth's interior to drive tectonic plate motion



Where does the heat come from?

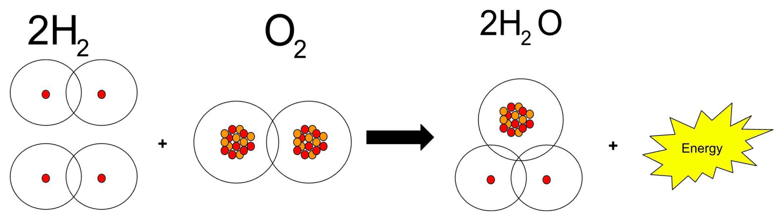
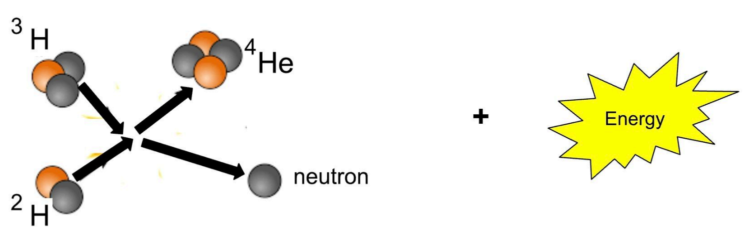
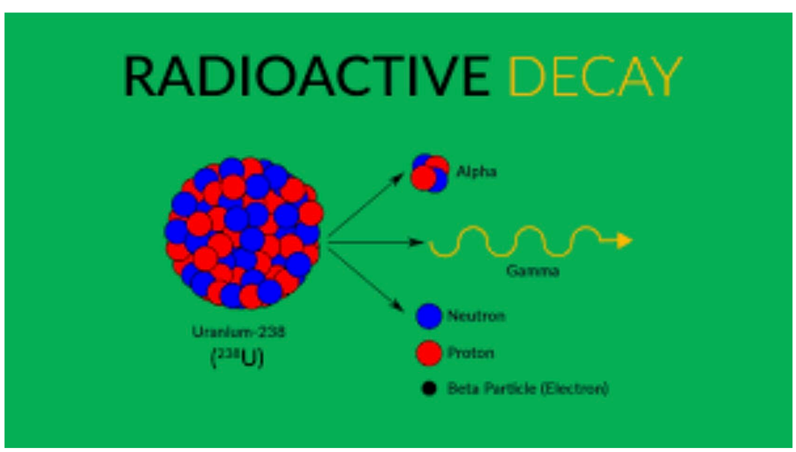
The motion of the mantle is what drives plate tectonics. Earth's crustal plates float on the hot mantle, and magma from the mantle and crust rise in weak parts of the crust to generate the ocean floor and volcanic activity. This process requires motion due to heat, like the heat from the candles in the model. But where does that heat come from?

Based on temperatures found at the bottom of deep boreholes into the planet's crust, scientists have calculated an estimation of the total amount of heat Earth's interior releases is roughly 44 trillion joules of energy per second or 44,000,000,000,000. That's about six times as much energy as the United States consumes per year!

It is widely agreed that the core's reservoir of heat from the Earth's formation may contribute between 20% and 50% of all the internal heat that ultimately flows to the surface of Earth. This heat was generated when the violent collisions of smaller bodies forced them together into clumps, and kinetic energy was transformed into heat energy. As Earth grew, it exerted more gravity on the matter making it up, pulling denser materials like iron into the center while less dense materials rose to the surface. The friction produced by that movement generated even more heat. This heat is slowly lost from Earth, moving from the core into the mantle and out through the crust, where it is dissipated into space.

That residual heat, which is radiating primarily from the core, causes approximately 20-50% of the heating in the mantle. Where is the rest of the heat coming from?

Possible Energy-Releasing Processes in the Earth's Interior

Type of reaction	Equation	Conditions required for process to occur
Chemical		Requires free Oxygen gas (oxygen not bonded to another element, as it is in the air)
Nuclear Fusion		• Does not happen in solid form • Lighter elements in gas or liquid form • Temperatures of at least 4 million degrees celsius • A suitable ion density is 4.9833887e-13 g/ml
Radioactive Decay		Spontaneously occurs in rocks

4. Based on the evidence above, which process is most likely responsible for heat in the mantle? Support your answer with evidence from the data.

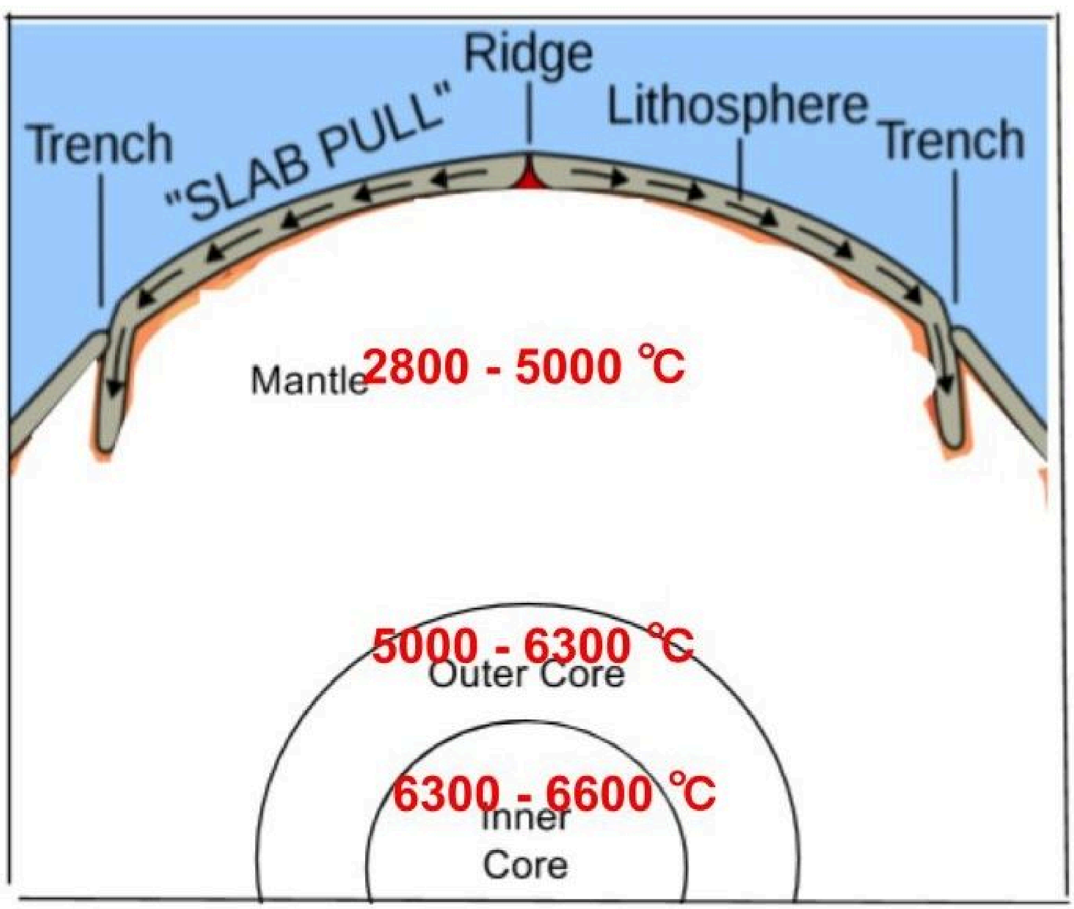
Part 2: Modeling the Movement of Energy and the Motion of the Great Rift Valley

Convection in the outer core: The energy dissipated by the solid inner core drives convection currents in the liquid outer core. This motion is what generates Earth's magnetic field.

Convection in the mantle: convection in the mantle is generated both by the heat dissipated from the core and from spontaneous radioactive decay scattered throughout the mantle.

Use the information above and everything you've learned in this investigation to construct an annotated model demonstrating the movement of energy in different layers of the Earth and how the movement in the mantle results in the Great Rift Valley.
In your model, be sure to include:

- Temperature/heating
- Density
- Rising and sinking
- Convection in the outer core
- Convection in the mantle from residual heat **and** radioactive decay



Summary Task

We recently completed a class consensus discussion. How did it go?

1. One thing that went well in the discussion:

2. One thing we can improve the next time we have a discussion:

3. One person who helped me learn today:

What did you learn from this person?

4. One idea that I contributed to my group or my class:

Explain what you know about the following questions, based on what we discussed today:

1. What did you figure out what causes the motion of matter within Earth's interior?

2. Describe how energy within Earth's interior drives the cycling of matter.

3. Review model 1 that you developed in part 1 of the Explain phase of the Plate Boundaries and Surface Features investigation. Use what you have learned during this investigation to describe how energy was transferred from Earth's interior to Earth's surface, causing the eruption and aftermath of the Tonga volcano.

4. Summarize what you have learned about how energy drives the movement of matter within and between systems.

5. Describe how you used multiple lines of evidence to determine the cause of the unique features of the Great Rift Valley.

How do energy and minerals impact human populations?

Directions for Read-Generate-Sort-Solve:

1. Read: Read the *Minerals, Energy, and Human Populations* silently.
2. Generate: On your group's chart paper, generate ideas about concepts that are connected to the reading.
3. Sort: Have everyone in the group star one idea that they think is most relevant to the question.
4. Solve: As a group, discuss the ideas you deemed most important, and come up with a response to the question.

How has resource availability guided the development of human populations and societies?
Generate Ideas.

Name:	**Name:**
Name:	**Name:**

How has resource availability guided the development of human populations and societies?

Record your group's answer.

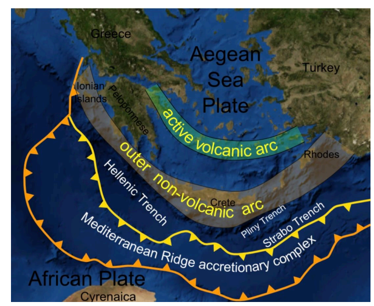
Human History in Seismically Active Areas

Despite (or perhaps because of) those hazards, the Great Rift Valley is the birthplace of humanity. Though Homo sapiens (humans) may have evolved elsewhere, every living person can be traced back to a small population of humans who lived 200,000 years ago in this region.

Humans have lived here ever since, coping with the risks, but also reaping the benefits of the energy and minerals present in the rift system. In this valley, hot springs bubble through hydrothermal vents, and some scientists believe that human ancestors may have begun cooking by boiling food in these springs 1.8 million years ago, long before we'd harnessed the power of fire. If true, that would mean that the volcanic nature of this area is what made human ancestors able to extract more calories from their food and begin to grow the big brains that set us apart.

Active tectonism creates varied landscapes, including valleys, mountains, lakes, and highlands. This range of topography creates different weather patterns and varied ecosystems, paving the way for high volumes of biodiversity and supporting increasing populations.

Volcanic activity also helps create fertile soil by cycling minerals to the surface. One type of volcanic ash, called andisol, was a key factor in the availability of pasture land for domesticating large animals 10,000 years ago, and then adoption of agriculture in the Great Rift Valley a few thousand years later, which supported growing populations. Now, this same fertile land allows for the cultivation of coffee, tea, and corn.



As technology has improved and needs have changed, different resources from the region have been exploited. The circulation of hot fluids concentrates scattered trace elements, resulting in high concentrations of gold, diamonds, nickel, copper, iron, tin, cobalt, coal, oil, natural gas, gemstones, and rare earth elements in volcanic regions. In the 1800s, the resource richness of the rift valley region drove colonialism as European powers tried to harness the wealth of this area. Germans mined gold in Tanzania, Belgium brutalized the DRC for rubber and diamonds, then for copper. Today, the same region is being exploited for its cobalt and rare earth element reserves, which are critical for batteries and electric technologies.

This pattern is not unique to the Great Rift Valley. Some very early civilizations, including the Greeks, Romans, and Etruscans, were built on top of fertile volcanic soils in the Mediterranean-Aegean region. Volcanically active regions of Indonesia have excellent rice growing conditions, supporting populations in those areas. Valuable veins of minerals are often found near subduction zones, providing materials that human populations used for tools and other innovations as societies blossomed. Other tectonic processes create areas with high heat and pressure within the crust, which transforms decaying organic matter into oil, coal, and natural gas, key resources since the Industrial Revolution.

Beyond the valuable materials available in areas of high seismic activity, plate boundaries often form areas where land meets sea. These connections are important for fishing, trade, and transportation.

Sources:
https://news.mit.edu/2020/early-human-hot-springs-food-0915

The History of the Lake Victoria Goldfield.

https://pubs.usgs.gov/gip/dynamic/tectonics.html

Tectonically Active Region Resources

Japanese Archipelago	Mainland Southeast Asia	Mediterranean Basin	Great Rift Valley	Andes Region
- volcanic islands contain of rich, fertile soil - diverse landscapes and ecosystem resources from varied topography due to tectonic activity - position surrounded by water but near the continent, provided abundant sea food and trade resources - limestone and coal resources - precious metals like gold	- mountainous region with high rainfall and rivers allowed for wet rice cultivation - diverse landscapes and ecosystem resources from varied topography due to tectonic activity - coastal position gave access to ocean trade - copper, tin, iron, precious metals like gold and silver - precious minerals like rubies and sapphires	- volcanic lands with rich, fertile soil - diverse landscapes and ecosystem resources from varied topography due to tectonic activity - central sea gave access to trade and food resources - mineral resources like salt - energy resources like oil and gas	- volcanic lands with rich, fertile soil - diverse landscapes and ecosystem resources due to tectonic activity - precious metals like gold, nickel, copper, iron, tin, cobalt - precious minerals like diamonds and gemstones - energy resource like coal, oil, and natural gas, gemstones	- volcanic lands with rich, fertile soil - mountainous region with high rainfall and rivers - diverse landscapes and ecosystem resources from varied topography due to tectonic activity - coastal position provides abundant seafood resources - precious metals like copper, silver, gold, zinc, and tin

Energy Transfer Model Rubric

Energy Transfer	Proficient	Developing
Model based on Energy Transfer	The model effectively and accurately shows how and where energy is produced in the Earth's interior, how energy drives the motion of plates, and risk at the performance task locations and includes all of the components below: • Radioactive decay in the mantle as a major source of energy within Earth's interior. • convection currents and how they transfer energy from Earth's interior to the surface to cause earthquakes, volcanic eruptions, and tsunamis at different performance task locations. • vulnerability of the populations at each performance task location. The components of the model "speak for themselves" for the most part. **OR** There are legends, keys, or written captions to clarify the components. Relevant evidence is identified for changes to the model and scientific reasoning to link the evidence to each change to the model is provided.	The model is incomplete in showing how and where energy is produced in the Earth's interior, how energy drives the motion of plates, **missing one or more** of the components below: • Radioactive decay in the mantle as a major source of energy within Earth's interior. • convection currents and how they transfer energy from Earth's interior to the surface to cause earthquakes, volcanic eruptions, and tsunamis at different performance task locations. • vulnerability of the populations at each performance task location. The components of the model do not really "speak for themselves." **OR** Legends, keys, or written components are insufficient to clarify the model. Some evidence identified for changes to the model is not relevant and / or scientific reasoning to link the evidence to each change to the model is not provided.
Energy and Matter	Model shows how energy drives the motion of matter between Earth's interior and surface as a result of differences in temperature / density caused by energy produced in the mantle. Response to reflection prompt 1 clearly articulates how tracking the flow of energy and matter in models of Earth's interior and surface from the Explore phase allowed them to see how energy produced in the mantle can lead to the movement of matter on Earth's surface.	Model does not show how energy drives the motion of matter between Earth's interior and surface as a result of differences in temperature / density caused by energy produced in the mantle. Response to reflection prompt 1 does not clearly articulate how tracking the flow of energy and matter in models of Earth's interior and surface from the Explore phase allowed them to see how energy produced in the mantle can lead to the movement of matter on Earth's surface.
Student Self-Score	**Circle One** **Proficient** **Developing**	**Glow**: **Grow**:
Teacher Score	**Circle One** **Proficient** **Developing**	**Glow**: **Grow**:

Energy and Matter Explanation Rubric

Energy Transfer	Proficient	Developing
Argument based on the unit	The argument makes a claim identifying which location they think is most at risk of an earthquake, volcanic eruption, and / or tsunami. The claim is supported with relevant/accurate evidence from the earthquake, volcanic eruptions and tsunami data sets for each location, including: • Frequency of earthquakes, volcanic eruptions and tsunamis. • Magnitude of earthquakes, volcanic explosivity and tsunami wave height. • Vulnerability of populations at each performance task location. Reasoning is provided to support the claim, including: • connections between type plate interaction and the hazards that can occur due to these interactions. • connections between level of risk and frequency and magnitude of earthquakes. • connections between level of risk and frequency and volcanic eruption explosivity. • connections between level of risk and frequency and wave height of tsunamis. • connections between vulnerability factors and risk at each performance task location.	The argument makes a claim identifying which location they think is most at risk of an earthquake, volcanic eruption, and / or tsunami. The claim is weakly supported with evidence from the earthquake, volcanic eruption and tsunami data sets, investigations, or readings. Reasoning is not provided to support the claim.
Stability & Change	Argument includes rates at which volcanic eruptions and tsunamis occur at different performance task locations.	Argument includes rates at which volcanic eruptions and tsunamis occur at different performance task locations.
Student Self- Score	**Circle One** **Proficient** **Developing**	**Glow**: **Grow**:
Teacher Score	**Circle One** **Proficient** **Developing**	**Glow**: **Grow**:

Relevance to your life: Think about everything that you have learned throughout this unit so far.

1. What is one idea and/or skill you learned that you think is important to teach someone in your family or community?

____

____

2. To whom do you intend to teach this idea and/or skill? Why do you think it is important for this person to learn this idea and/or skill?

____

____

Unit Closing

Unit 3 Earthquakes, Tsunamis, and Volcanoes: Who's at Risk?	**Earth and Space Science**
Student Name:	

Tectonic Hazard Vulnerability Profile: The Mediterranean Basin

Building Construction and Infrastructure:

A key vulnerability across the Mediterranean Basin is the quality and age of building infrastructure. While seismic building codes exist in countries like Italy, Greece, and Turkey, a large percentage of existing buildings were constructed before these regulations were in place. A 2020 European seismic risk model estimated that approximately 130 million people in Italy, Turkey, Greece, and Romania live in buildings designed with no or low-level seismic provisions. Additionally, rapid urbanization in coastal and less developed regions can lead to the construction of buildings that do not meet safety standards.

Population Density:

More than a third of the Mediterranean's population lives in coastal areas, which account for less than 12% of the total land area. This results in high population density in these areas. Cities like Istanbul and Izmir in Turkey, Athens in Greece, and Naples and Catania in Italy are located in areas of high seismic risk. The concentration of people and economic activity in these cities makes them particularly vulnerable to a major earthquake. Istanbul, with a population of over 15 million, is situated near the active North Anatolian Fault, making it one of the most at-risk cities in Europe. Densely populated coastal areas are at risk not only from earthquakes but also from tsunamis, which can be triggered by seismic events or submarine landslides. The Mediterranean is the second most tsunami-prone region in the world, and many coastal cities lack adequate preparedness for such a rapid-onset hazard.

Emergency Preparedness and Response:

The Mediterranean basin comprises many countries with varying levels of development. There is a mediterranean-wide tsunami early warning system (ICG/NEAMTWS), but response to the warning depends on the rapid spread of information and a prepared public. Turkey has a functional, government-supported earthquake early warning system that can provide a few seconds of warning, allowing for automated actions like stopping trains and opening fire station doors. In contrast, Italy and Greece do not have national, operational early warning systems, although research has shown that they would be feasible and beneficial.

Public Awareness and Education:

Education and awareness campaigns vary by country within the region. Italy, for example, has a standardized public education campaign around seismic hazards, but these types of efforts are not coordinated across the Mediterranean basin. Despite a history of significant seismic activity, a culture of preparedness is not as ingrained in the Mediterranean as in other seismically active regions of the world. This can lead to a false sense of security and a lack of household-level preparedness, such as having an emergency plan or a disaster kit. Public perception of risk is often low, partly due to the infrequency of major events.

Tectonic Hazard Vulnerability Profile: The Great Rift Valley

Building Construction and Infrastructure

The most significant vulnerability in the Great Rift Valley is the widespread use of vulnerable building construction. A large portion of the housing, particularly for the urban poor and in rural areas, consists of informal or non-engineered structures made of materials like adobe, mud, and unburnt bricks. These buildings are highly susceptible to collapse even during moderate seismic shaking. A 1989 magnitude 6.2 earthquake in Malawi, for example, killed 10 people and caused $28 million in economic losses. A similar event today could result in up to 1,500 fatalities and $250 million in losses, highlighting the increasing risk due to expanding cities and vulnerable construction.

Population Density

The Great Rift Valley is home to a growing population, with over 30 million urban poor living in the region. This number is projected to double to 60 million by 2050. The rapid urbanization, often in unsafe settlements, concentrates large numbers of people in seismically active areas. This high population density, combined with the vulnerability of the built environment, creates a scenario where even a moderate earthquake could have catastrophic consequences. The risk is further compounded by the fact that many of these urban centers are located directly along fault lines.

Emergency Preparedness and Response

While there have been some improvements in regional cooperation, emergency preparedness and response capabilities vary significantly across the countries in the Great Rift Valley. Some countries, like Kenya, have established a national disaster response plan and a National Disaster Operation Centre (NDOC) to coordinate efforts. However, in other countries, such as Burundi and Tanzania, emergency operation centers have yet to be fully established. A key challenge is the lack of resources to implement and enforce building regulations and to train government and local agencies on effective response strategies.

Public Awareness and Education

Public awareness of seismic risk in the Great Rift Valley is often low. Because large, high-magnitude earthquakes are infrequent, many residents may assume the risk is low or nonexistent. This can lead to a lack of individual and community-level preparedness, such as not having a family emergency plan or a disaster kit. While educational activities have been shown to be effective in raising awareness and preparedness among children and communities, there is a need for more consistent and widespread campaigns. A focus on public education is crucial to increase awareness around emergency preparedness and risk.

Tectonic Hazard Vulnerability Profile: the Japanese Archipelago

Building Construction and Infrastructure:
Japan's vulnerability to tectonic hazards is influenced by the quality of building construction and infrastructure. Strict building codes and advanced engineering techniques have led to the construction of tectonic hazards-resistant buildings and infrastructure in many urban areas. However, older structures and buildings in rural or coastal regions may be more vulnerable, particularly those constructed before modern seismic standards were established.

Population Density:
Japan's high population density exacerbates vulnerability to tectonic hazards, particularly in urban areas such as Tokyo and Osaka. Densely populated cities are at greater risk of casualties and damage during seismic events, with millions of residents living in high-rise buildings and densely packed neighborhoods. Coastal communities are also vulnerable due to the concentration of population along the Pacific Ring of Fire.

Emergency Preparedness and Response:
Japan maintains a comprehensive emergency preparedness and response framework to mitigate the impacts of tectonic hazards. The Japan Meteorological Agency (JMA) operates an advanced tectonic hazards early warning system, providing rapid alerts to the public and emergency responders. Evacuation plans, disaster drills, and community-based disaster preparedness initiatives enhance readiness and resilience.

Public Awareness and Education:
Public awareness of tectonic hazards risks and preparedness measures in Japan is high, supported by extensive education and outreach initiatives. Educational campaigns, school programs, and community engagement activities promote tectonic hazards awareness and safety procedures. Japan's history of seismic events and cultural emphasis on disaster resilience contribute to a proactive approach to public education and awareness.

Tectonic Hazard Vulnerability Profile: Mainland Southeast Asia

Building Construction and Infrastructure

The region's building and infrastructure vulnerability varies greatly. Many new infrastructure projects, particularly in countries like Indonesia, are beginning to incorporate advanced seismic resilience techniques such as fiber-reinforced cement, base isolation systems, and seismic dampers. However, a significant challenge remains with older buildings, which may not have been constructed to withstand seismic events. In highly populated cities like Bangkok or Hanoi, the presence of older structures with irregular designs and close proximity to each other can increase the risk of damage from building collisions. The rapid pace of urbanization also means that new developments may not always have the most stringent seismic requirements, further amplifying the risk.

Population Density

The rapid population growth and urbanization in mainland Southeast Asia have a direct impact on its seismic vulnerability. A study found that the population in Asia's most seismically hazardous areas increased rapidly between 2000 and 2015, with urban population growth being a major contributing factor. This includes a significant increase in vulnerable populations, such as children and the elderly. With cities becoming more densely populated and a concentration of infrastructure in these areas, the potential for severe consequences from an earthquake is heightened.

Emergency Preparedness and Response

Emergency preparedness and response in the region have seen significant improvements, particularly through regional cooperation. The ASEAN Agreement on Disaster Management and Emergency Response (AADMER), established after the 2004 tsunami, serves as a blueprint for coordinated action. The ASEAN Coordinating Centre for Humanitarian Assistance on Disaster Management (AHA Centre) supports member states with emergency relief and maintains a regional stockpile of goods. Countries like Thailand have developed and trained Medical Emergency Response Teams (MERTs). However, despite these advancements, challenges remain in governance, institutional capacity, and securing adequate funding for disaster preparedness.

Public Awareness and Education

Public awareness and education are critical for reducing casualties and property damage. While efforts have been made, there is a recognized gap in scientific education regarding earthquake hazards. Some projects, such as the "Building Urban Resilience in Southeast Asia" initiative, have focused on school safety and public education campaigns. The World Risk Poll noted that the population in Southeast Asia is more prepared to face disasters and feels a greater sense of agency in protecting themselves, a sentiment attributed to the region's focus on disaster response. However, the lack of earthquake-related topics in official school curricula in some areas, such as Nepal, highlights a need for more consistent and comprehensive educational programs.

Tectonic Hazard Vulnerability Profile: The Andes Region

Building Construction and Infrastructure

A significant portion of the population in the Andes region, as high as 83% in some countries, lives in zones with a moderate to high seismic hazard. The vulnerability of building construction is a major concern, as a large percentage of buildings, particularly older ones, were built before modern seismic design codes were implemented. Many structures are made of unreinforced masonry, a material that is highly susceptible to collapse during an earthquake. However, there are ongoing efforts to improve building safety. In a case study in Peru's Colca Valley, research has explored the use of reinforced adobe techniques for sustainable reconstruction, demonstrating a viable option for improving the seismic resistance of traditional housing.

Population Density

Population density is a critical factor in the region's seismic risk. Rapid urbanization has led to a concentration of people and assets in cities, which are often located in seismically active areas. This rapid growth has created pressure for housing, and in many cases, this has resulted in the construction of vulnerable, non-seismic-resistant buildings for the poorest segments of the population. The high population density, especially in urban centers, means that a single major seismic event could have devastating consequences in terms of loss of life and economic damage. The Global Earthquake Model (GEM) Foundation's South America Risk Assessment (SARA) Project has focused on creating city-specific scenarios to help with risk management strategies in these densely populated areas.

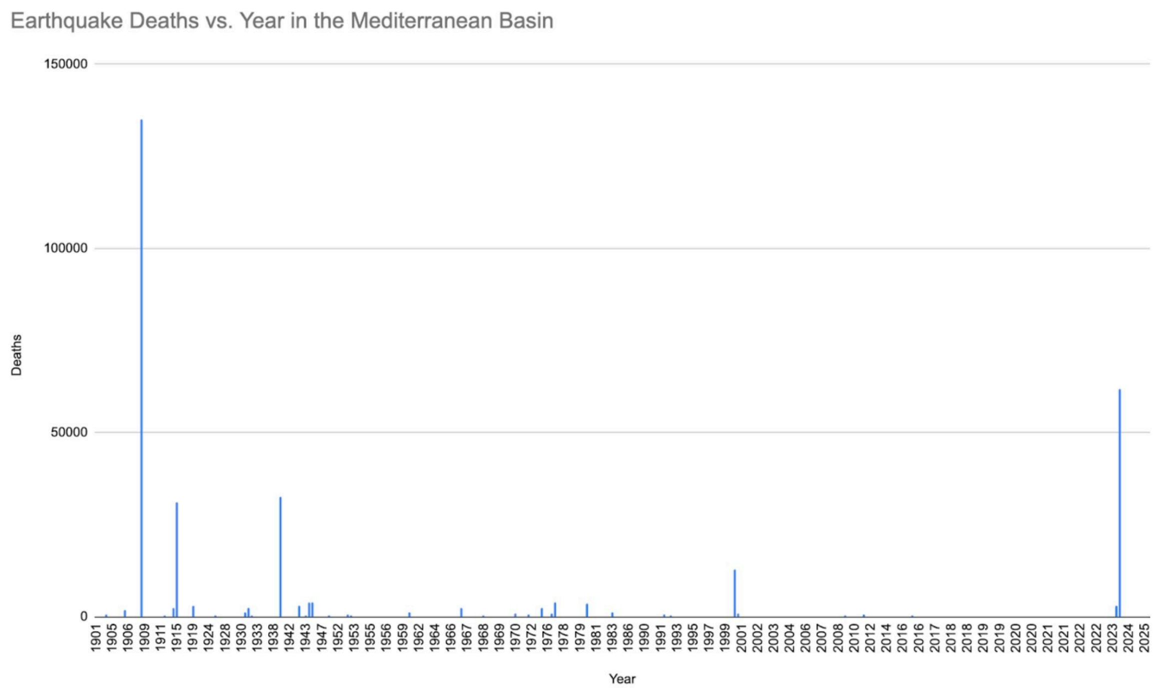
Emergency Preparedness and Response

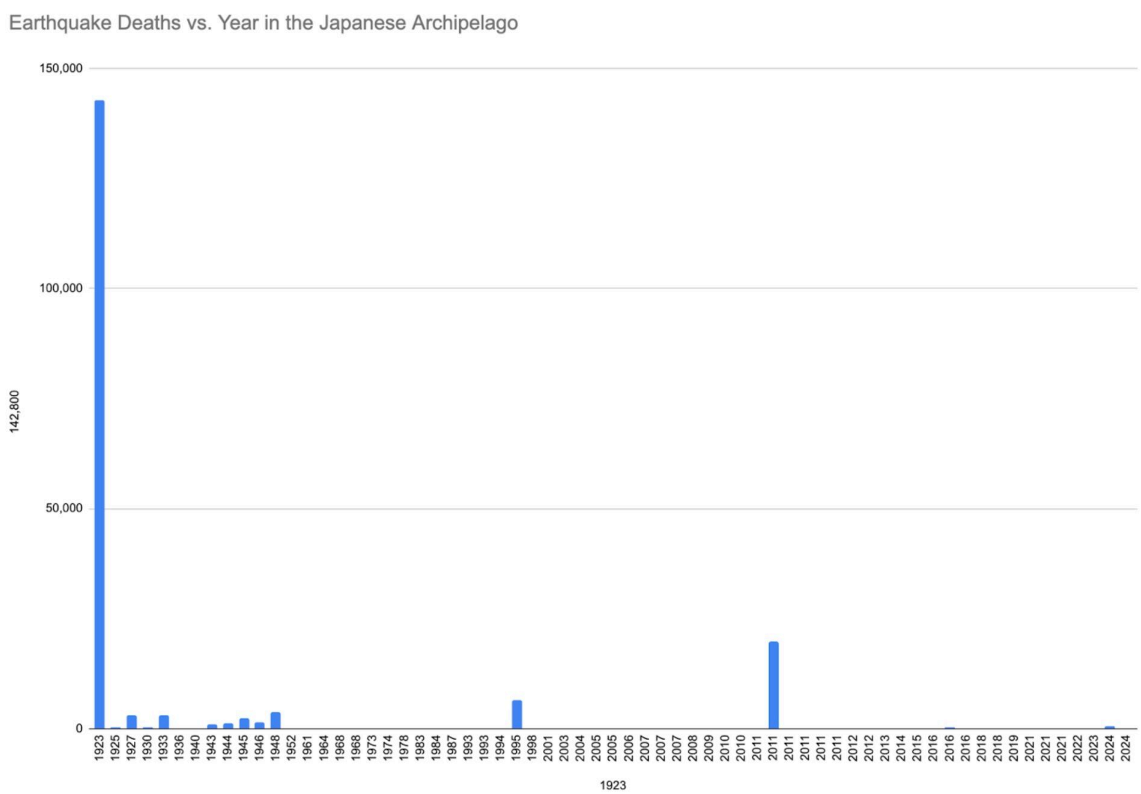
Emergency preparedness and response efforts are underway, but they face significant challenges. Public awareness and education are recognized as key to reducing risk. The Andes region, with its diverse geography and population, requires a comprehensive and tailored approach to disaster risk reduction. The Andean Community of Nations (CAN) has an Andean Strategy for Disaster Risk Management to address these issues. This strategy aims to improve disaster risk management by focusing on everything from the development of exposure datasets to social vulnerability indicators. However, the effectiveness of these strategies can be hampered by factors like the limited availability of resources, especially for the most vulnerable populations.

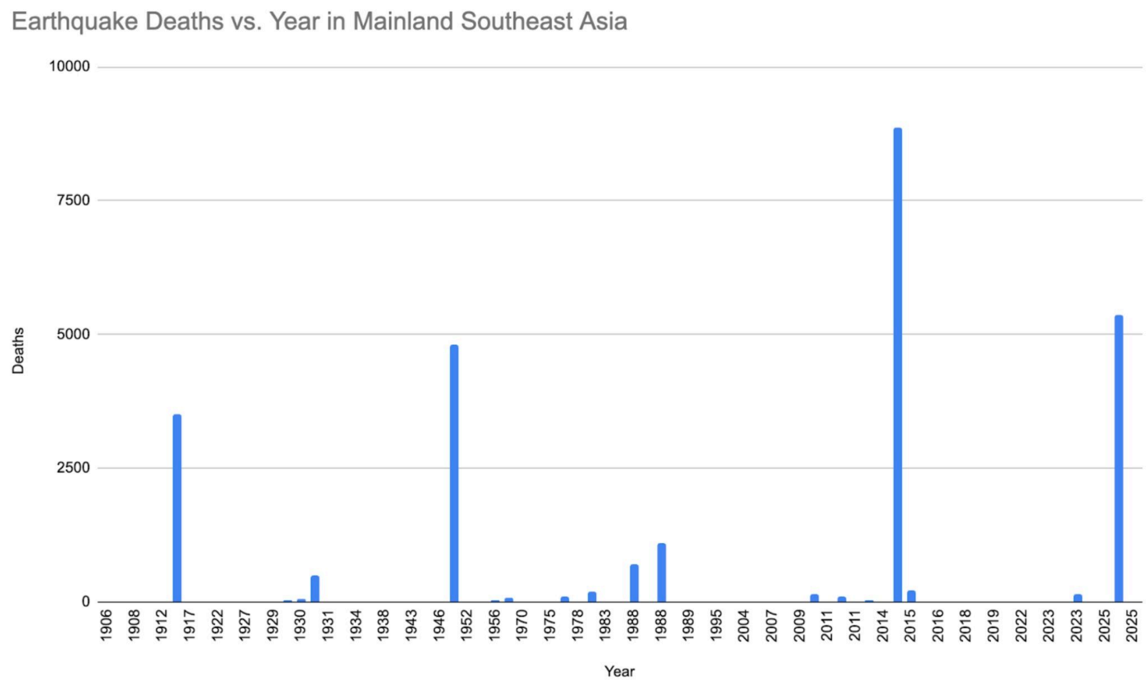
Public Awareness and Education

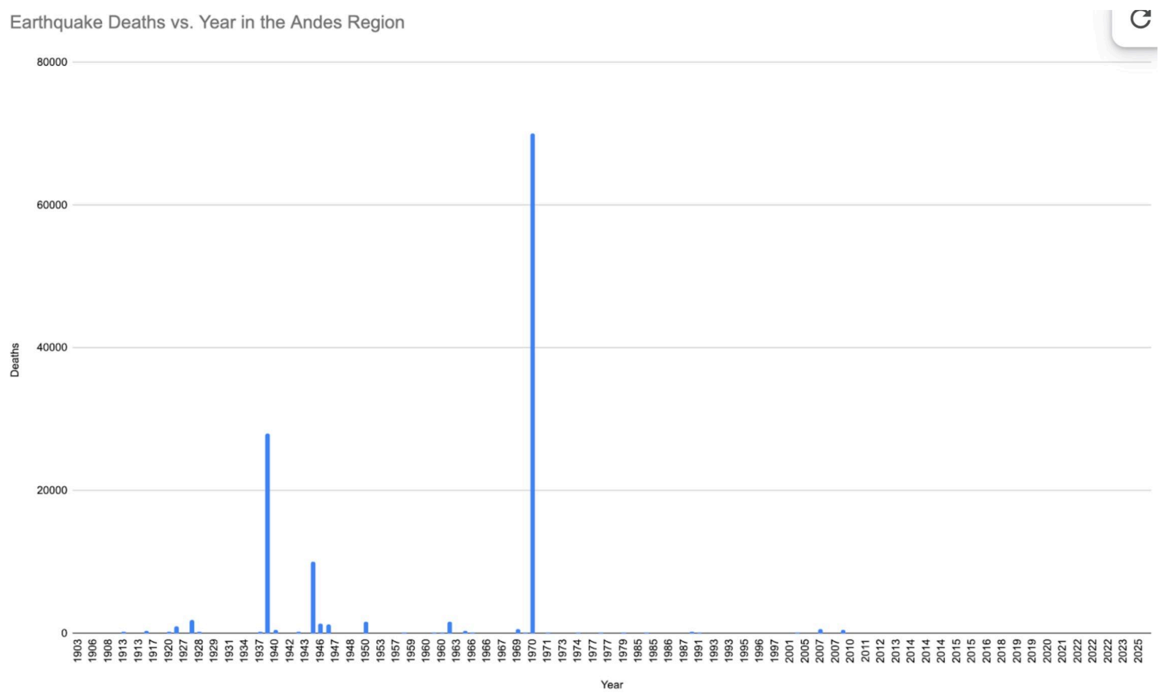
Public awareness and education are fundamental to mitigating the impact of tectonic hazards. Although it is impossible to predict when an earthquake will occur, education can help people prepare for the event and respond appropriately. Initiatives by organizations like the Red Cross and Red Crescent Societies focus on creating and disseminating educational materials for communities and schools. These programs aim to promote a "culture of safety" by teaching people about risk, encouraging the development of family preparedness plans, and promoting actions such as "Drop, Cover, and Hold On" during an earthquake. However, gaps in scientific education about seismic hazards still exist.

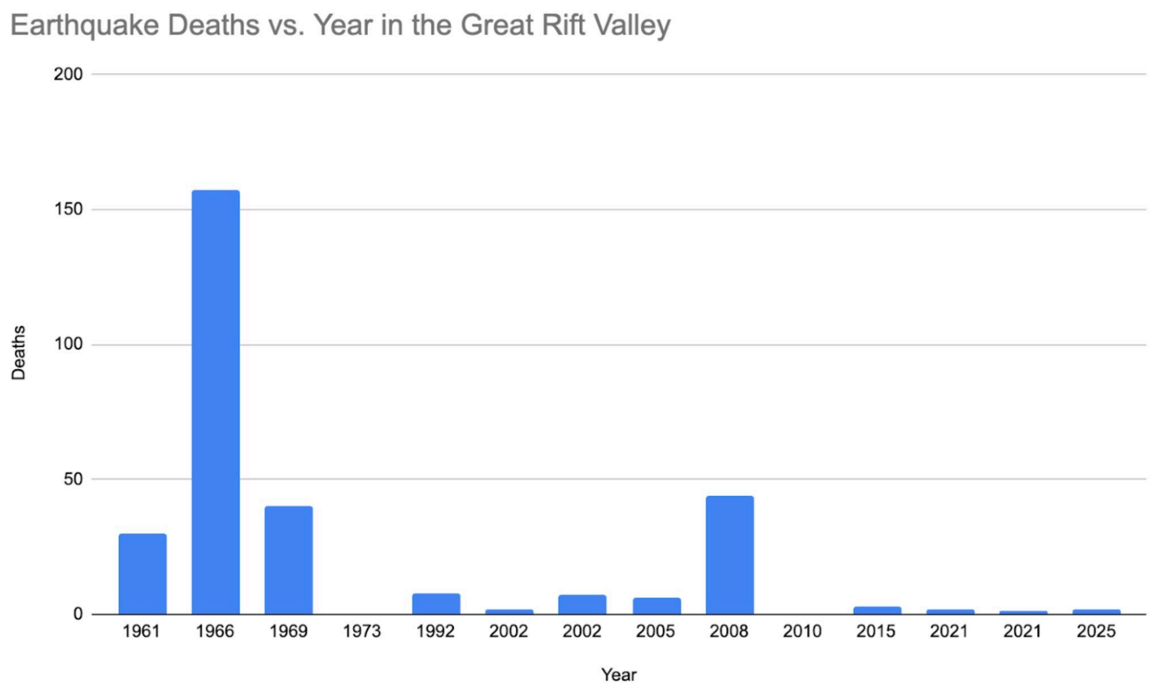
Earthquake Deaths Over Time






Earthquake Deaths vs. Year in Mainland Southeast Asia
10000
7500
5000
2500
0
Deaths
1906 1908 1912 1917 1922 1927 1929 1930 1931 1934 1938 1943 1946 1952 1956 1970 1975 1978 1983 1988 1988 1989 1995 2004 2007 2009 2011 2011 2014 2015 2016 2018 2019 2022 2023 2023 2025 2025
Year


Earthquake Deaths vs. Year in the Andes Region
80000
60000
40000
20000
0
Deaths
1903 1906 1908 1913 1913 1917 1920 1927 1928 1929 1931 1934 1937 1940 1942 1943 1946 1947 1948 1950 1953 1957 1959 1960 1960 1963 1966 1966 1967 1969 1970 1971 1973 1974 1977 1977 1979 1985 1986 1987 1991 1993 1993 1995 1996 1997 2001 2005 2007 2007 2010 2011 2012 2013 2014 2014 2015 2015 2016 2018 2019 2019 2020 2021 2022 2022 2022 2023 2025
Year


Earthquake Deaths vs. Year in the Great Rift Valley
200
150
100
50
0
Deaths
1961
1966
1969
1973
1992
2002
2002
2005
2008
2010
2015
2021
2021
2025
Year