Lesson 5:
Plate Tectonics and Volcanism

Students explore plate movement and the relationship between plate tectonics and volcanoes.

Main Lesson Concept: The Earth's solid crust is composed of separate sections that constantly move on a partially molten layer of the upper mantle. Major geologic events such as volcanic eruptions result from these plate motions.

Scientific Question: What is plate tectonics? What is the relationship between plate tectonics and volcanoes?

Objectives	Standards
• Students will describe where volcanoes occur and why they occur at those locations. • Students will explain the theory of plate tectonics and the relationship between plate tectonics and volcanoes. • Students will draw and explain a model of plate tectonics.	**Meets**: 2061: 4E (3-5) #2 NSES: B (5-8) #3.2 2061: 4E (6-8) #3 **Partially Meets**: 2061: 4C (6-8) #1

Assessment	Abstract of Lesson
Responses to Astro Journal questions and design of a model of plate tectonics.	Students predict where volcanoes occur on a blank map of the Earth's plates. They observe a map of volcanoes and conclude that volcanoes occur where plates collide, move apart, and at hot spots. They discuss the theory of plate tectonics and design a model of plate tectonics. The class makes and discusses one or two of the selected model designs.

Prerequisite Concepts

- Heating and cooling may cause changes in the properties of materials. Many kinds of changes occur faster under hotter conditions. (2061: 4D (3-5) #1)
- Atoms and molecules are perpetually in motion. Increased temperature means greater average energy of motion, so most substances expand when heated. In solids, the atoms are closely locked in position and can only vibrate. In liquids, the atoms or molecules have higher energy, are more loosely connected, and can slide past one another; some molecules may get enough energy to escape into a gas. In gases, the atoms or molecules have still more energy and are free of one another except during occasional collisions. (2061: 4D (6-8) #3, Astronomy Lessons 4 and 5)
- Humans need the following geologic conditions (Geology Lesson 1):
  - Liquid outer core (coupled with the planet's rotation and a thick atmosphere)
  - Viscous mantle (slow motion)
  - Slow motion of crust and upper mantle (lithosphere) of 3-5 cm/year
- Substances of greater density will sink below those of lesser density. (Geology Lesson 3)
- The mantle moves in convection cells. Convection cells are circular currents formed when heated material rises and cooler material sinks. (Geology Lesson 4)
- The crust and top part of the upper mantle that is solid is called the lithosphere (sphere of rock). (Geology Lesson 4)
- The lower part of the upper mantle composed of some molten or melted rock is called the asthenosphere. (Geology Lesson 4)
- Below the asthenosphere is the rest of the mantle, which is solid and extends all the way to the outer core. (Geology Lesson 4)
- Because the continental plates fit well together, and similar animal and plant fossils have been found on separate continents, scientists theorize that in the past the continental plates formed a supercontinent at least once. (see suggested activity below if your students have no previous experience with the evidence for plate tectonics.)

Major Concepts

- The solid crust and upper mantle of the Earth—including both continental and oceanic crust—consist of separate sections that overlie a hot, partially molten area.
- The separate crustal plates move on this molten layer at rates of centimeters per year, colliding in some places, pulling apart in others.
- The Earth's crust and upper mantle (together called the lithosphere) move at the same rate as mantle convection.
- Volcanoes occur where plates collide or move apart, and in areas known as "hot spots."
- Plate tectonics involves the lithosphere moving over the asthenosphere.

Suggested Prerequisite Activity on the Evidence for Plate Tectonics:

1. Draw on students' prior knowledge about the Earth.

- Ask the students to think of a jigsaw puzzle.

- Question: How would you describe the pieces of a jigsaw puzzle?
- *Answer: The pieces of a jigsaw puzzle are unique sizes and shapes. The pieces fit together in only one way in order to create a picture.*

  Note to Teacher: If you have pieces to a jigsaw puzzle available, show students pieces connected together to help reinforce this idea.

- Question: What continent do we live on?
- *Answer: We live on the continent of North America.*

- Have the students look at a world map.

  Note to Teacher: There is a world map provided at the end of this lesson.

- Question: If you look at a world map and locate North America, what do you notice about the edges of the continent?
- *Answer: (Accept all reasonable answers. Student responses might include that the edges of North American are jagged, different shapes, some areas stick out, while other areas are indented.)*

- Question: Now look at other continents on the world map. What do you notice about the other continents?
- *Answer: (Accept all reasonable answers. Student responses might include that the edges of the other continents are similar to North America-jagged, different shapes, some areas stick out, while other areas are indented.)*

- Question: Looking at the world map, do you see any continents that you think South America would match up with like two jigsaw puzzle pieces? Explain your answer.
- *Answer: (Accept all reasonable answers. Students may respond that no two continents match up perfectly but that some do look like they could fit together, such as east South America and west Africa.)*

- Say: Scientists think that the continents were all joined together as one continent. Scientists call this a supercontinent.

Note to Teacher: The evidence scientists use for this theory is that the continental plates fit well together, the direction of the magnetic pole record preserved in rocks, corresponding rock formations, and similar animal and plant fossils that have been found on separate continents.

- Question: How do you think the continents might have been arranged when they were all one continent?
- *Answer: (Accept all reasonable answers.)*

Note to Teacher: If you photocopy the world map at the end of this lesson, you could provide each student or each pair of students with a world map. The students could then cut out a few of the continents and attempt to arrange them as one. This is a difficult activity to do with all of the continents, but the students can take as little or as long working on the activity as you want.

Suggested Timeline (45-minute periods):
Day 1: Engage and Explore sections
Day 2: Explain and Extend sections
Day 3: Evaluate section (20 minutes)

Materials and Equipment:
- A class set of Astro Journal Lesson 5
- A video of an earthquake (optional)
- Chart paper

Plate Tectonics Activity (materials may include the following for each group):
- 2 cups corn starch
- 2 cups water
- 1 bowl
- 1 spoon
- 1 plastic container
- A piece of plastic or plastic lid
- A thick piece of polystyrene (similar to Styrofoam™)
- Other materials will depend on the model designs students come up with (Make a list after the Extend section.)

Preparation
- Duplicate a class set of Astro Journal Lesson 5.
- Gather materials for the models.
- Prepare chart paper with major concept of the lesson to post at the end of the lesson.

Differentiation:

Accommodations
For students who may have special needs, have them work with a partner on their Astro Journal writing or report orally to the teacher.

Advanced Extensions
For students who have mastered the concept, research how volcanic eruptions occur and create an accurate model or demonstration. Explain why baking soda and vinegar is not an accurate model of volcanic eruptions.

Engage (approximately 15 minutes)

1. **Draw on students' prior knowledge of the Earth's interior.**
   - Question: What have you learned about the Earth so far?
   - *Answer: (Allow students to share their ideas.)*

   - Say: In Geology Lesson 4, you learned that scientists can describe the layers of the Earth based on composition or on movement.

   - Question: If you look at the interior of the Earth from a compositional viewpoint, what are the layers that make up the Earth?
   - *Answer: The layers that make up the interior of the Earth based on composition are the crust, mantle, and core.*

   - Question: If you look at the interior of the Earth from a mechanical viewpoint, what are the layers that make up the Earth?
   - *Answer: The layers that make up the Earth based on mechanics are the brittle, rigid lithosphere, partially molten asthenosphere, solid mantle, liquid outer core, and solid inner core.*

   - Say: In this lesson today, we will focus on the lithosphere and the asthenosphere.

   - Question: What is the lithosphere?
   - *Answer: The lithosphere is formed by the crust and the top part of the mantle.*

   - Say: Scientists have evidence that the lithosphere is broken up into sections. These sections of the lithosphere are called plates.

   - Question: What layer of the upper mantle is under the lithosphere?
   - *Answer: The asthenosphere is under the lithosphere.*

   - Question: How would you describe the asthenosphere?
   - *Answer: The asthenosphere is a partially molten part of the upper mantle that is below the lithosphere.*

   - Say: Because the asthenosphere is partially melted, the plates move on top of the asthenosphere.

2. **Draw on students' prior knowledge of the Earth's plates moving from their own experiences and from Geology lessons 1 and 4.**
   - Question: Have you ever seen evidence of Earth's plates moving? What observations did you make during this time?
   - *Answer: (Accept all reasonable answers. Students might respond that they have seen an earthquake in real life or on a video. Observations they might share are that the Earth shakes, objects move back and forth, and if the earthquake is severe enough, large objects may fall over.)*

     Note to Teacher: You might consider showing a clip from a video or movie of an earthquake for those students who may never have experienced one.

- Say: In the Geology Training module, you saw that movement inside the Earth causes the Earth to be habitable.

- Question: Where does movement inside the Earth occur?
- *Answer: There is movement in the lithosphere, the mantle, and the outer core.*

- Say: In Geology Lesson 4, you learned about movement inside the mantle.

- Question: How does the mantle move?
- *Answer: The mantle moves in convection cells.*

- Question: What is a convection cell?
- *Answer: A convection cells are circular currents formed when heated material rises and cooler material sinks.*

- Question: Why does the material rise or sink?
- *Answer: A change in density causes the material to rise or sink.*

- Question: What causes a change in density?
- *Answer: A change in temperature or pressure causes a change in density.*

3. Review Geology Lesson 1.

- Question: In the Geology Training module, what did you determine to be the geologic conditions required for human survival?
- *Answer: Humans need the following geologic conditions:*
  - *Liquid outer core (coupled with the planet's rotation and a thick atmosphere)*
  - *Viscous mantle (slow motion)*
  - *Slow motion of crust and upper mantle (lithosphere) of 3-5 cm/year*

4. Introduce the purpose of this lesson.

- Say: Today, we are going to learn how movement within the Earth can result in major geologic events, such as volcanic eruptions. In the next lesson, we will learn how this movement affects human survival.

5. Introduce the Scientific Questions.

- Say: The Scientific Questions we will be exploring are:
  - What is plate tectonics?
  - What is the relationship between plate tectonics and volcanoes?

Explore (approximately 30 minutes)

1. Introduce students to the Location of Volcanoes Activity.

- Say: We are going to focus on volcanoes during this lesson because volcanoes play an important role in human survival. In this activity, we will look at the location of volcanoes, and we will learn why volcanoes are located in these areas.

MISCONCEPTION: Middle school students taught by traditional means are not able to construct coherent explanations about the causes of volcanoes. Common misconceptions relating to volcanoes are that all mountains are volcanoes, volcanic eruptions are due to chemical reactions, and mountains don't move. The following discussion and activity about where volcanoes occur will help students with this misconception. Be sure to discuss with students that the baking soda and vinegar volcano that many of them have seen or made is not an accurate model. Explain to students that volcanoes do not erupt because of a chemical reaction, but rather they erupt because of pressure building up in the volcano. A great example is a soda bottle. Shake the soda bottle to cause an increase in pressure. You can then open the soda bottle, and the students can watch as the soda comes out of the bottle, similar to a volcano.

2. Discuss with students what plates are.

- Have students look at the plate map in their Astro Journals.

- Question: What observations can you make about this map?
- *Answer: (Allow students to share their observations. Student responses may include that there are lines on the map.)*

- Question: What do these lines represent?
- *Answer: (Allow students to share their ideas.)*

- Question: We learned that the lithosphere is broken up into sections. What are these sections of the lithosphere called?
- *Answer: These sections of the lithosphere are called plates.*

- Say: The lines on this map represent the boundaries of the plates.

- Question: What observations can you make about the plates from this map?
- *Answer: (Accept all reasonable answers. Student responses may include that the edges of the plates are jagged, that the plates include the oceans, and that the plates vary in size.)*

- Question: What observations can you make about the plates related to the continents?
- *Answer: (Accept all reasonable answers. Students should observe that the boundaries of the plates do not match up with the boundaries of the continents.)*

Note to Teacher: Students often find it difficult to distinguish between plates and continents. The use of a map like in this activity is helpful. To reinforce the idea that continents are not plates, you could have your students cut along the lines on the map. This will allow students to see that plates are made up of continents and ocean basins.

3. Discuss with students their hypotheses about where volcanoes occur.

- Question: Where do you think volcanoes occur?

- Have students predict where volcanoes occur on the blank plate map in their Astro Journals. Students should use a symbol to mark where they think volcanoes would be found.

- Have students explain in their Astro Journals why they think volcanoes will occur in the locations that they marked.

- Discuss with students why they think volcanoes will occur in the locations that they marked.

- Question: Why do you think volcanoes will occur in the locations that you marked?
- *Answer: (Allow students to share their ideas. Students may respond that they have learned or read about volcanoes occurring in the areas they marked.)*

4. Have students observe where volcanoes occur.

- For the Location of Volcanoes Activity, have students look at the plate map in their Astro Journal.

- Have students carefully study the map and answer the Part 1 Location of Volcanoes questions that follow.

5. Lead students in demonstrating the motion that occurs at plate boundaries.

- Say: Hold your hands out in front of you with the fingertips of each hand pointed in towards each other and touching.

- Say: Slowly push your fingertips together.

- Question: If you continued pushing your fingertips together, what do you think your fingertips would do?
- *Answer: (Allow students to share their ideas. Students may respond that the fingertips would collide with each other.)*

- Say: Imagine that your hands represent two plates.

- Explain to students that one of your hands/plates is denser than the other. The denser hand/plate represents oceanic crust, while the less dense hand/plate represents continental crust.

- Question: What is oceanic crust?
- *Answer: Oceanic crust is crust that has oceans located on it.*

- Question: What is continental crust?
- *Answer: Continental crust is crust that has continents located on it.*

- Question: If one of your hands/plates is denser than the other, what will happen when you push the two together?
- *Answer: (Allow students to share their ideas. Students should remember from Geology Lesson 4 that denser materials sink.)*

- Say: Remember in Geology Lesson 4, we learned that denser materials sink below less dense materials. As a result, your hand/plate that is denser will sink below your hand/plate that is less dense. We are going to repeat the activity we did at the beginning of this discussion.

- Have students hold their hands out in front of them with the fingertips of each hand pointed in towards each other and touching.

- Have the students repeat the process of slowly pushing their fingertips together. Students should show that one hand goes beneath the other hand as the two collide.

  Note to Teacher: Be sure that students are moving the fingers of one hand underneath the fingers of the other hand. Since one layer is denser than the other, it moves underneath the other layer, and doesn't collide head-on.

- Question: What do you think happens when two plates collide?
- *Answer: (Allow students to share their ideas. Student responses may include that a volcano would form when two plates collide.)*

Note to Teacher: At this type of boundary, the increase in pressure, temperature, and fluids during subduction of oceanic crust under another plate creates rising magma that forms volcanoes.

- Question: On the map, can you find a plate boundary where two plates collide?
- *Answer: (Students should be able to find an example of this. One example is the boundary between the Nazca Plate and the South American Plate.)*

- Question: Are there any volcanoes near this border?
- *Answer: Yes.*

- Say: One place that volcanoes occur is where two plates collide.

Note to Teacher: The place where two plates collide is called a convergent boundary. The convergent boundary that students demonstrated in this activity was oceanic-continental. A second type of convergent boundary that creates volcanoes is the oceanic-oceanic boundary. This is when two oceanic plates interact and form volcanoes. This is how Japan formed. Because both plates of oceanic crust have the same density, it is unpredictable which one will end up going under the other.

- Say: Hold your hands out in front of you again with the fingertips of each hand pointed in towards each other and touching.

- Say: Slowly pull your hands apart.

Note to Teacher: In a divergent boundary, where two plates move apart, the decrease in pressure causes the magma to rise, forming volcanoes.

- Question: What do you think this demonstration represents?
- *Answer: This demonstration represents two plates moving apart from each other.*

3. Have students complete the questions for Part 2 of Location of Volcanoes Activity.

- Explain to students that they will now use their knowledge of plate movement to answer questions about the location of volcanoes.

Explain (approximately 15 minutes)

1. Discuss student conclusions from the activity.

- Question: What observations can you make about the relationship between plate boundaries and volcanoes?
- *Answer: (Allow students to share their ideas. Students should observe that most of the volcanoes are located on plate boundaries.)*

- Question: Why do you think that most of the volcanoes occur at plate boundaries?
- *Answer: (Allow students to share their ideas. Students should respond that most volcanoes occur at plate boundaries because of the movement of the plates.)*

- Question: Explain where volcanoes are occurring on this map and why they are occurring at these locations in terms of plates and their movement.
- *Answer: Volcanoes occur where plates collide and where plates move apart.*

- Question: Do you see volcanoes on the map that are not at plate boundaries? If so, where are these volcanoes located?
- *Answer: Yes, there are volcanoes that are not on plate boundaries. An example is the Hawaiian Islands.*

- Say: These volcanoes occur in areas known as "hot spots." A hot spot is a place where part of the mantle with a very high temperature rises through the lithosphere causing volcanic eruptions. Scientists are not sure exactly why or how this happens.

- Say: At the beginning of this activity, you marked on a map in your Astro Journal where you thought volcanoes occurred. Look at your hypothesis/prediction.

- Question: Where do volcanoes occur?

- Have students answer this question in the Results section of their Astro Journals.

- Have students share their answers with the class. Student answers should state that volcanoes occur where plates collide, where plates move apart, and in areas known as hot spots.

2. Discuss plate movement with students.

- Say: Two of the places where volcanoes occur result from plates moving.

- Question: How do the plates move?
- *Answer: (Allow students to share their ideas. Use the following questions if students need more direction.)*

- Question: Plates are sections of what layer of the Earth?
- *Answer: Plates are sections of the lithosphere.*

- Question: What layer of the Earth is under the lithosphere?
- *Answer: The asthenosphere is under the lithosphere.*

- Question: How would you describe the asthenosphere?
- *Answer: The asthenosphere is a part of the upper mantle that is partially molten. It is what the lithosphere rides upon.*

- Say: Because the asthenosphere is partially melted and denser than the lithosphere, the plates move on top of the asthenosphere at the rate of centimeters per year. This theory of movement of the plates over the asthenosphere is called plate tectonics.

Note to Teacher: Students may ask what causes the plates to move. Scientists do not agree on the cause of plate tectonics. Some think that the convection of the mantle causes the plates to move, while others think that the lithosphere moves causing friction that heats up the mantle and causes the mantle to move.

Extend/Apply (approximately 30 minutes)

1. **Bridge to Plate Tectonics Activity.**
   - Say: In this lesson, you learned that the plates move on top of the asthenosphere. In this activity, you are going to design a model for plate tectonics.
   - Explain to students that they will work with their group to develop a design that represents the movement of the plates.
   - Say: When developing your designs, think about how to correctly represent the layers of the Earth that are involved in plate movements.
   - Say: Once the designs are complete, you will vote as a class to decide which two designs most correctly represent the movement of the plates. The two designs that are selected will then be demonstrated.

     Note to Teacher: Depending on time and availability of resources, all of the groups could prepare and demonstrate their models.
   - Explain to students that they should limit materials used in their designs to whatever they can acquire and bring in themselves.

     Note to Teacher: When developing this activity, we pictured students using a viscous material such as Ooblick (1 part cornstarch and 1 part water) to represent the asthenosphere. The model would be a plastic container with Ooblick poured in it. A piece of plastic (like a plastic lid or something else that is bendable) could serve as the oceanic crust, and a thick piece of polystyrene could serve as the continental crust. Students could use their hands or string to pull/push the polystyrene and plastic together across the Ooblick to show the plastic (oceanic crust) go underneath the polystyrene (continental crust). Encourage your students to be creative and use questioning to lead them to the best choices possible for their design. Questions might include: What do you know about the consistency of the asthenosphere? How viscous is the asthenosphere? You might also suggest that students brainstorm possible substances and then evaluate the pros and cons of each or rank them from best to worst with justifications.

2. **Put students into groups to develop their design.**
   - Explain to students that their designs need to include a labeled picture that shows the materials used and the layers of the Earth represented.
   - Have students complete their designs in their Astro Journals.

3. **Have students share their plate movement designs with the class.**

4. **Have the class vote on which two designs best represent the movement of the plates.**

5. **Have the groups that were voted as the two best prepare their models and present them to the class. Have students add volcanoes where appropriate in the model.**

Evaluate (approximately 20 minutes)

1. **Have students answer the Plate Tectonics Activity Questions in their Astro Journals.**

2. Discuss students' responses to their Astro Journals to ensure they have mastered the major concepts.

- Question: What is the theory of plate tectonics?
- *Answer: Plate tectonics is the movement of the solid lithosphere plates over the partially molten asthenosphere.*

- Question: What features of the models correctly represented plate tectonics?
- *Answer: (Allow students to share their ideas. Students may respond that the models correctly represented that the plates move on top of another surface that is partially fluid and that oceanic crust is denser than continental crust. The model also shows that plates move apart and together and that volcanoes occur at both locations.)*

- Question: What improvements could be made to the models to make them more accurate?
- *Answer: (Allow students to share their ideas. Students may respond that the models could be made to scale, materials that more accurately represent the lithosphere and asthenosphere could be used, a larger model could be made, and the model could be observed for a longer period of time.)*

- Question: How fast did plate tectonics occur in your model?
- *Answer: (Accept all reasonable answers. Plate tectonics in the students' models will most likely occur in a very short period of time.)*

- Question: In reality, how fast do the plates move on top of the asthenosphere?
- *Answer: The plates move at the rate of centimeters per year.*

- Say: This rate of centimeters per year is about the same rate as our fingernails grow and is the same rate as the rate of convection in the mantle.

- Question: What is the relationship between plate tectonics and volcanoes? Explain.
- *Answer: Volcanoes result from plate tectonics. Two of the places that volcanoes occur are where plates collide and where plates move apart.*

3. Collect students' Astro Journals and evaluate them to ensure they have each mastered the major concepts.

- The solid crust and upper mantle of the Earth—including both continental and oceanic crust—consist of separate sections that overlie a hot, partially molten area.

- The separate crustal plates move on this molten layer at rates of centimeters per year, colliding in some places, pulling apart in others.

- The Earth's crust and upper mantle (together called the lithosphere) move at the same rate as mantle convection. Volcanoes occur where plates collide, move apart and in areas known as "hot spots."

- Plate tectonics involves the lithosphere moving over the asthenosphere.

4. Bridge to next lesson.

- Say: Today, we learned how plates move and how this movement can result in volcanic eruptions. In the next lesson, we will learn how this movement affects human survival.

Note to Teacher: After each lesson, consider posting the main concept of the lesson some place in your classroom. As you move through the unit, you and the students can refer to the "conceptual flow" and reflect on the progression of the learning. This may be logistically difficult, but it is a powerful tool for building understanding.

Astro Journal Geology Lesson 5: Plate Tectonics and Volcanism | Name:

Class/Period: | Date:

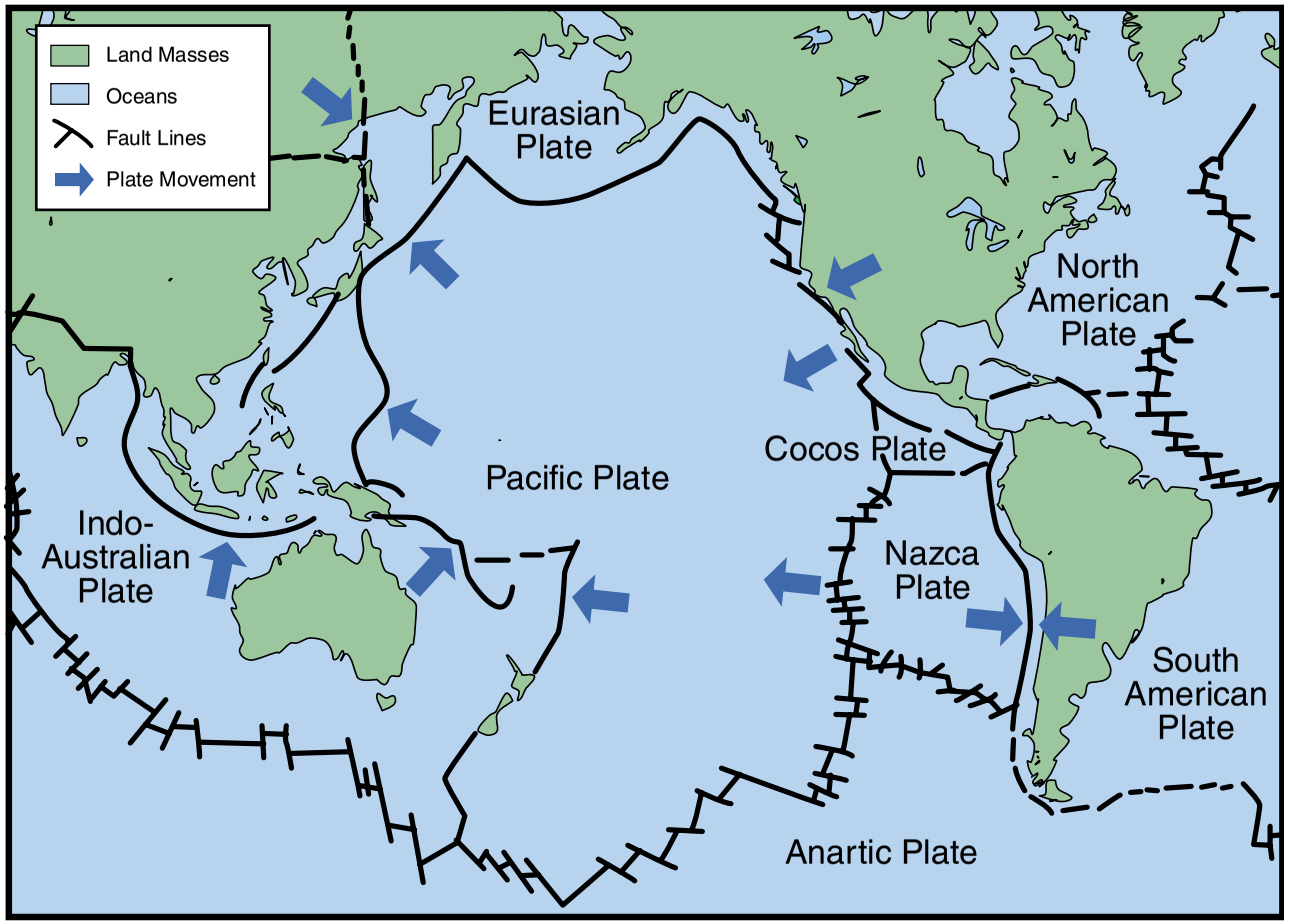
Location of Volcanoes Activity Part 1

Scientific Question:

What is plate tectonics? What is the relationship between plate tectonics and volcanoes?

1. **Hypothesis/Prediction**: Where do you think volcanoes occur?

2. **Directions:** Use a symbol to mark where you think volcanoes would be found on the map below



3. Why do you think volcanoes will occur in these locations?

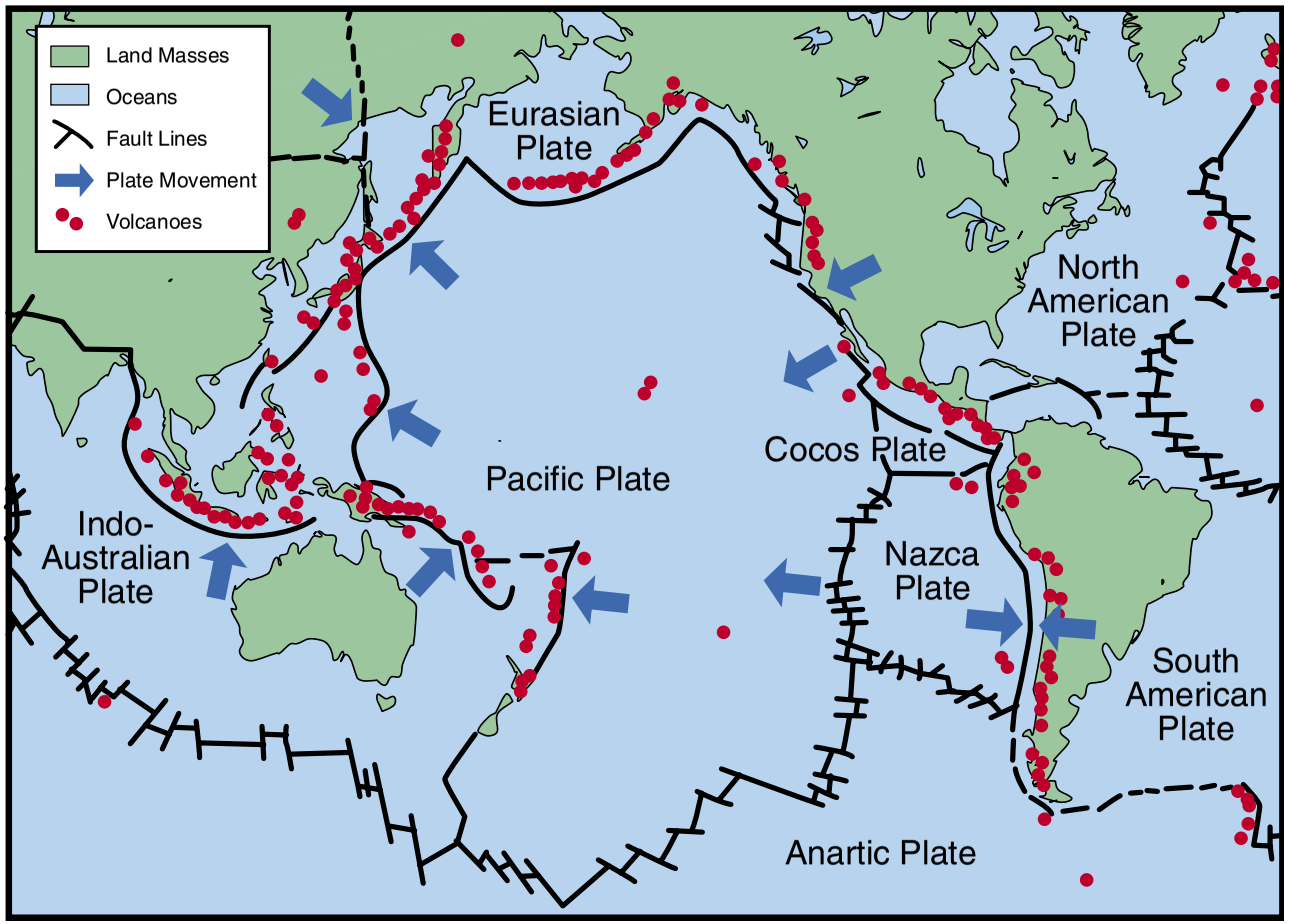
Astro Journal Geology Lesson 5: Plate Techtonics and Volcanism

Name:

Class/Period:

Date:

Plate Map Directions: Look at the map below to answer the questions.



4. What observations can you make about the location of volcanoes?

5. What observations can you make about the relationship between volcanoes and plate boundaries?

Astro Journal Geology Lesson 5: Plate Tectonics and Volcanism

Name:

Class/Period:

Date:

Part 2 Location of Volcanoes Activity

1. Explain where volcanoes are occurring on the Plate Map and why they are occurring at these locations in terms of plates and their movement.

2. Do you see volcanoes on the Plate Map that are not at plate boundaries? If so, where are these volcanoes located?

Results

3. Where do volcanoes occur?

Plate Tectonics Activity Question

4. What is plate tectonics?

2. Draw a picture of your model of plate tectonics in the space below. Include the following:
   1. Label the parts of the Earth that are represented.
   2. Use arrows to show where movement occurs.
   3. Use symbols for where volcanoes are most likely to be found and explain why.
   4. List the materials to be used in the model and explain why each is a good representation for the part it represents.

Name:

Class/Period:

Date:

3. What features of your model correctly represent plate tectonics?

4. What improvements could be made to your model to make it more accurately represent plate tectonics?

5. What is the relationship between plate tectonics and volcanoes? Explain.