



LESSON TITLE

High School

Plate Tectonics

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BIG IDEAS

Students will be required to use phenomena to build models, ask questions, make predictions, and analyze and interpret data to explain the theory of plate tectonics.

EDUCATION STANDARDS

HS-ESS1 -5 *Evaluate evidence of the past and current movements of continental and oceanic crust and the theory of plate tectonics to explain the ages of crustal rocks.*

[Clarification Statement: Emphasis is on the ability of plate tectonics to explain the ages of crustal rocks. Examples include evidence of the age of oceanic crust increasing with distance from mid-ocean ridges (a result of plate spreading) and the ages of North American continental crust decreasing with distance away from a central ancient core of the continental plate (a result of past plate interactions).]

NGSS Performance Expectation(s)

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts:
<p>Engaging in Argument from Evidence <i>Engaging in argument from evidence in 9–12 builds on K–8 experiences and progresses to using appropriate and sufficient evidence and scientific reasoning to defend and critique claims and explanations about the natural and designed world(s). Arguments may also come from current scientific or historical episodes in science.</i></p> <ul style="list-style-type: none"> • Evaluate evidence behind currently accepted explanations or solutions to determine the merits of arguments. 	<p>ESS1.C: The History of Planet Earth</p> <ul style="list-style-type: none"> • Continental rocks, which can be older than 4 billion years, are generally much older than the rocks of the ocean floor, which are less than 200 million years old. <p>ESS2.B: Plate Tectonics and Large-Scale System Interactions</p> <ul style="list-style-type: none"> • Plate tectonics is the unifying theory that explains the past and current movements of the rocks at Earth’s surface and provides a framework for understanding its geologic history. <i>(ESS2.B Grade 8 GBE) (secondary)</i> <p>PS1.C: Nuclear Processes</p> <ul style="list-style-type: none"> • Spontaneous radioactive decays follow a characteristic exponential decay law. Nuclear lifetimes allow radiometric dating to be used to determine the ages of rocks and other materials. <i>(secondary)</i> 	<p>Patterns</p> <ul style="list-style-type: none"> • Empirical evidence is needed to identify patterns.
<p align="center">Common Core State Standards:</p> <p>Math:</p> <p>MP.2 Reason abstractly and quantitatively. (HS-ESS1-5)</p> <p>HSN-Q.A.1 Use units as a way to understand problems and to guide the solution of multi-step problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data displays. (HS-ESS1-5)</p>		

HSN-Q.A.2 Define appropriate quantities for the purpose of descriptive modeling. *(HS-ESS1-5)*

HSN-Q.A.3 Choose a level of accuracy appropriate to limitations on measurement when reporting quantities. *(HS-ESS1-5)*

ELA:

RST.11-12.1 Cite specific textual evidence to support analysis of science and technical texts, attending to important distinctions the author makes and to any gaps or inconsistencies in the account. *(HS-ESS1-5)*

RST.11-12.8 Evaluate the hypotheses, data, analysis, and conclusions in a science or technical text, verifying the data when possible and corroborating or challenging conclusions with other sources of information. *(HS-ESS1-5)*

WHST.9-12.2 Write informative/explanatory texts, including the narration of historical events, scientific procedures/ experiments, or technical processes. *(HS-ESS1-5)*

MEASURABLE STUDENT LEARNING OBJECTIVES

Students will be able to:

- Explain the difference between continental drift and plate tectonics and the evidence for both
- Show why plates shift
- Show resultant features of the three crustal stresses
- Explain why we see different features at different plate boundaries

STEM INTEGRATION

Students will be exploring and learning about how the plates of earth move. Using data to observe evidence to understand the science of plate tectonics. Students will also be looking at technology that has been developed to measure the movement of the plates. Lastly, students will be learning the history of how the theory of plate tectonics was developed.

NATURE OF STEM

The theory of plate tectonics was not a linear development. When Alfred Wegener originally started thinking about why it looks like South America and Africa fit together, most scientists had never put much thought into it. He came up with several pieces of evidence that supported his hypothesis; however, he couldn't explain how the plates moved. It wasn't until years after his death scientists found evidence that proves the movement of the plates. The theory of plate tectonics was then developed by putting all of the information together.

MATERIALS NEEDED

- [Seismology Map](#)
- [Volcanology](#)
- [Seafloor Age](#)
- [Topography/Bathymetry](#)
- [Plate Boundary Map](#) - Print 11 X 17
- Computer and a projector (instructor), computers (students for extension)
- Gumdrops
- Toothpicks
- Modeling clay
- Transparencies (cut into 4 squares each)
- 3 ring stands (or student volunteers)
- 3 satellite representations (e.g. Double Bubble gum)
- String

ENGAGING CONTEXT/PHENOMENON

Students will observe four different types of maps, seismic, volcanic, topographic, and seafloor age.

DATA INTEGRATION

Students will analyze and interpret GPS data, using time series plots in order to develop total horizontal velocity vector data around the world to identify other divergent zones and other plate motions.

TEACHER BACKGROUND KNOWLEDGE

A variety of geologic phenomena including earthquakes, volcanic eruptions, and mountain building occur at plate boundaries, all of which cause the Earth's surface, the crust, to deform. When deformation occurs, points on Earth's surface change location (north-south, east-west, up-down). Precise GPS instruments can measure the change in position. Earth scientists use this data to record how much and how quickly Earth's crust is moving due to plate tectonics and to better understand the underlying processes of the deformation.

Before starting the lesson, review these videos on how to demonstrate how GPS works: o In addition to following the steps below, watch this video

(<http://bit.ly/HowGPSworks-demo>) on YouTube to inform your instruction. The first segment demonstrates how to build a monument while the second half suggests ways to demonstrate how a GPS monument gathers location information. This video is meant to inform the instruction of teachers, not to be shown to students.

o A second video (<http://bit.ly/GPSdemo-part3>) on YouTube provides background for teachers about time series plots. (On YouTube search for "GPS gumdrop activity 3-5.") . Key points for the demonstration

- Satellites are in orbit above Earth's surface at an altitude of 20,200 km (12,600 mi)
- Each satellite sends a signal many times a second and 'talks' to the GPS; the GPS calculates how long it takes for the signal to reach the GPS and then calculates the distance between them.

o The string represents the distance between the satellite and a monument after this distance is calculated.

- The GPS needs 3 satellites to find its position on Earth.

- o With one satellite, the GPS could be anywhere on the surface of a sphere with a radius equal to the distance between the GPS and the satellite.
- o With two satellites, the monument could be anywhere on the circle of the two intersecting spheres.
- o With three satellites, the GPS could be at one of the two points where three spheres intersect. The Earth is the fourth sphere (the satellites know where the Earth is).
- o Since time is part of the calculation to find a position, a 4th satellite provides even more precision in location to correct position errors caused by clocks on the satellite and GPS.
 - These measurements are being made while satellites are moving at 2 kilometers/second!
 - Review this video for teaching: NASA's Brief History of Geodesy (<http://bit.ly/nasawhatisgeodesy>).

DIFFERENTIATION OF INSTRUCTION

When making groups, be sure to put students together with varying levels or you can pair lower students to travel together. On day 1, descriptions of boundaries can be given or leading questions to help with description of boundaries.

REAL-WORLD CONNECTIONS FOR STUDENTS

This lesson is about the plates of the earth moving. Students are also familiar with earthquakes and volcanoes.

INTEGRATION POSSIBLE MISCONCEPTIONS

- *Earth's crust being one piece*
- *Plates move fast enough for us to see a difference or don't move because we can't see the change.*

LESSON PROCEDURE

5E	Details of 5E Lesson Implementation
<p><u>Engage</u></p> <p><i>Students are observing different specialty maps of the Earth.</i></p>	<p>Procedure: <i>Watch a video of Earthquakes of the 20th century</i></p> <p>Modifications Use captions</p> <p>Standards Addressed HS-ESS1-5</p> <p>Formative/Summative Assessments None</p> <p>Resources Video</p>

Explore

Students are observing different specialty maps of the Earth, creating a description of boundaries

Procedure: Students assemble with their specialty (Seismic, Volcanic, Seafloor age, topographic)

Task 1. Look at your group's map and talk about what you see. What you look for will vary with data type. For the point data (volcanoes and earthquakes) you are looking for distribution patterns. For surface data (topography and seafloor age) you are looking for where the surface is high and where it is low, where it is old and where it is young. Work as a group. Let everyone talk about what they see. During this period concentrate on the whole world, not just your assigned plate (if you know what it is).

Task 2 . Now focus your attention on the plate boundaries. Identify the nature of your data near the plate boundaries. Is it high or low, symmetric or asymmetric, missing or not missing, varying along the boundary or constant along the boundary, and etc. As a group, classify the plate boundaries based on your observations of your group's data. Restrict yourselves to about 4-5 boundary types. At this point, do not try to explain the data; just observe!

Task 3 . Assign a colored pencil color to each boundary type in your classification scheme. Color your first Plate Boundary Map to locate your group's boundary types. If the data are asymmetric at a particular boundary type, devise a way of indicating that on your plate boundary map. Each person should mark the boundary types identified by the group on their own map. Each person should write down descriptions of the group's plate boundary classifications on the back of their map. These maps and descriptions will be turned in at the end of the exercise.

Modifications: Intentional grouping, boundary descriptions or leading questions for boundary descriptions

Standards Addressed *HS-ESS1-5*

Formative/Summative Assessments Descriptions of the boundaries

	<p>Resources</p> <ul style="list-style-type: none"> • Seismology Map • Volcanology • Seafloor Age • Topography/Bathymetry • Plate Boundary Map - Print 11 X 17
<p><u>Explain</u></p> <p><i>Facilitate opportunities for students to explain their understanding of concepts and processes and make sense of new concepts.</i></p>	<p>Procedure: Students will assemble in the groups with their plates</p> <p>Task 1. Each person should make a brief presentation to the rest of their group about their Scientific Specialty's data and classification scheme. Your group may move to each map in turn while doing this or you may have smaller maps for each group to use.</p> <p>Task 2. Compare the classifications of boundary type for your plate based on each type of data. Are there common extents (along the boundaries) between the different classifications? Can your plate group come up with a new classification scheme that now includes data from all four Scientific Specialties? As above, assign a color to each of your plate boundary types. If a boundary is asymmetric, be sure to devise a way to represent the asymmetry. Mark the boundaries of your plate or plate grouping using your color scheme on your second Plate Boundary Map. Also write a description of the plate boundary classes you have used. The map and description should be turned in at the end of the exercise.</p> <p>Task 3. The student group spokes-people make their presentations. If needed, ask them to describe their plate boundary classifications and then to give us a tour around their plate. Sometimes there are questions from other students; ask questions to draw out some feature they have on their map, but have not talked about.</p> <p>Modifications <i>Be intentional with the groups that you make, have a script ready</i></p>

	<p>Standards Addressed <i>HS-ESS1-5</i></p> <p>Formative/Summative Assessments <i>Listen to presentations</i></p> <p>Resources <i>Same as Explain</i></p>
<p>Elaborate</p> <p><i>Provide applications of concepts and opportunities to challenge and deep ideas; build on or extend understanding and skills.</i></p>	<p>Procedure: <i>Teacher will wrap up this portion with a presentation on the plate boundary process. Making sure to introduce divergent, convergent, and transform plates boundaries.</i></p> <p>Modifications <i>Notes can be made into fill in the blank</i></p> <p>Standards Addressed <i>HS-ESS1-5</i></p> <p>Formative/Summative Assessments <i>None</i></p> <p>Resources</p> <p><i>Plate Tectonic Slides</i></p> <p><i>Plate Tectonic Notes</i></p>
<p>Evaluate</p> <p><i>Assess students knowledge, skills and abilities.</i></p>	<p>Procedure:</p> <p><i>Activation of Prior Knowledge: Assess students' level of prior knowledge by facilitating a preliminary discussion of GPS technology. Some questions to launch a discussion may include: What is GPS technology? What does GPS stand for? How does GPS technology work? What is GPS technology used for? Who uses GPS technology?</i></p> <p><i>Procedure (Pinpoint location with GPS):</i></p> <p><i>In advance, mark locations of ring stands such that all three strings meet in one location. Launch the PowerPoint presentation, Measuring plate motion with GPS: Introducing GPS to study tectonic plates as they move, twist, and crumple. Show the video, NASA's Brief History of Geodesy (http://bit.ly/nasawhatisgeodesy), Engage the class in a brief discussion about geodesy and uses of GPS. Ask a volunteer to provide an explanation of Geodesy and remind your students that Geodesy is the study of the Earth's size,</i></p>

shape, orientation, gravitational field, and variations of these with time. Pose the question, “How can GPS data be used in the field of Geodesy and geology?” before advancing to the next slide. At the “GPS Basics” slide, stop and model how satellites pinpoint the location of a GPS station.

For the demonstration you will need 3 ring stands (or 3 volunteers), 3 ‘satellites’ (e.g. Double Bubble gum) to place at the top of the stand to represent satellites, 3 lengths of string of different lengths (all longer than the height of the stand), and 1 gumdrop monument. Explain satellites are flying above Earth’s surface at an altitude of 20,200 km (12,600 mi); the ring stands represent that altitude. The bubble gum represents the satellites. The pieces of the GPS “gumdrop” monument: The gumdrop is the GPS antenna; Each toothpick is a leg of the monument – the legs are cemented up to 30 feet into the ground. The putty is the cement holding the GPS monument in place. The “place marker” of the monument is the slightly shorter toothpick sticking straight down from the middle of the gumdrop so that the tip of this toothpick is barely above the surface. Gumdrop ‘GPS’ monument and the satellites relationship. The satellite ‘talks’ (broadcasts) to the GPS its satellite name and current position in space; the GPS receiver calculates how long it takes for the signal to reach the GPS and then calculates the distance between them. Measuring the distance is called trilateration. The string represents the distance between the satellite and a monument after this distance is calculated. This calculation is happening every second, sometimes 10 times a second! Demonstrate how the location of the GPS becomes more pinpointed with one, then two, then three satellites.

One satellite (GPS could be anywhere on the surface of the sphere with the satellite in the center). Ask a student to move one string (held tautly) in all directions to indicate that the distance (approximately 20,000 km) is known, but the direction isn’t. The GPS could be anywhere on the surface of the sphere with the satellite (at least where the satellite had been at that moment since it is moving) at its center. o Two satellites (GPS could be anywhere on the circle of the two intersecting spheres):

Ask another student to hold the string taut and move the 2nd string in the shape of the sphere. Then move the 1st and 2nd strings together, so that the strings stay taut and ask what shape is made by this movement (a circle). Emphasize again that the only known

entity is the distance between the monument and satellite.

Three satellites (The GPS could be at one of the two points where three spheres intersect.) Ask a third student to move the 3rd string along with 1st and 2nd strings to show where all three strings intersect. The Earth is the fourth sphere (the satellites know where the Earth is). A 4th satellite provides even more location precision by correcting the tiny errors in the clocks on the satellite and GPS. IV. Place the gumdrop GPS monument where the three strings intersect. V. Remind students that the GPS measures the time it takes for the signal to go from the Satellite to the GPS monument then calculates the distance - this happens while satellites are moving at 2 kilometers/second! VI. Ask your students to complete the questions 1 - 5 in Part 1 of the worksheet.

Part 2: What can GPS tell us about Iceland? Introduction: Measuring GPS Movement with Time Series Plots: Display the “Measuring GPS Movement...” slide. Inform students that they are viewing data collected from a single GPS station. Explain that the data from the GPS stations in the Plate Boundary Observatory operated by UNAVCO (which is one of the EarthScope projects) is freely available to the public. Each GPS station has a data file which contains the daily change in position. Ask students to flip to page 2 of their student worksheets. Display the “GPS Time Series Plots” slide. Explain to your students that time series plots show the position of a monument as time passes. There are three components: north-south, east-west, and up-down movement. We are not using the vertical motion in this exercise.

Walk through the slides to help students learn how to read the time series plots. Discuss the slides as your students fill in the box on their worksheets as a reference. On the “Time Series Plots” slide, discuss the relationship between time series plots and direction with your students, asking questions to assess for comprehension. On the “Gaps in Data” slide, discuss the gaps that may occur in data with your students.

Procedure:

Orient the students by showing the slide with the world map and perhaps having students use a large wall map or globe to find Iceland.

Display the “Iceland’s GPS data: REYK and HOFN” slide. Explain to students that they will be analyzing data collected from two GPS stations on Iceland, REYK (in the town of Reykjavik) and HOFN (in the town of Hofn) to see how the tectonic plates underlying the monuments are moving.

Show students the next slide that shows both the plots for both GPS stations. Allow students to complete questions 1-3 on their worksheets either independently or in pairs.

Display the “Units on time series plots” slide and discuss the answers for 1 – 3.

Drawing vectors to show velocity:

Procedure

I. Ask your students, “If you were geologists, how would you represent this information so that it could be easily interpreted by others?”

II. Display the “Mapping plate movement” slide and explain how vectors can be used to show the velocity of motion.

III. Explain that they will be making a map like this one, zoomed into Iceland. IV. Ask students to look at the steps for creating a vector in their packets and display the “What is a vector?” slide. (The map of Iceland and graphs included in the lab worksheets may be used for graphing. However, you may also wish to distribute extra graph paper at this time for students to create a “rough copy” as they practice drawing vectors.)

VI. Explain that all vectors have magnitude and direction. With GPS monuments, the magnitude is the speed at which it moves. The direction is the direction the GPS moves, or its azimuth. • Vector’s tail = starting location of the GPS monument. • Direction the vector points = direction the GPS station is moving. • Length of the vector = how fast the GPS station is moving. • See the What is a vector in the Student Worksheet

VII. Continue through the PowerPoint as students draw the vectors on the map on their worksheets and illustrate vectors on their graph paper. Monitor students as they simulate the motion of both

GPS stations with their models.

VIII. With the “Mapping Vectors” slide displayed, tell students that after collecting and displaying data, it is now time to analyze and synthesize data in order to draw scientific conclusions. Allow students time to work through the “Interpreting the data and maps” section of their worksheets with a partner. Pace among students as they work, providing clarification and support where necessary.

Modifications Arrange students in either pairs or groups of three for this activity, pairing students with different strengths and challenges together. Consider assigning group roles to facilitate active participation in all students. Group roles may include: Scribe, Group Leader, Artist, Discussion Director, etc.

Standards Addressed *HS-ESS1-5*

Formative/Summative Assessments The worksheet that goes with the lesson

Resources

[Measuring plate motion Slides](#)

[Measuring plate motion worksheet - Teacher](#)

[Measuring plate motion worksheet - Student](#)

[Measuring plate motion guide pdf](#)

REFERENCES

<https://plateboundary.rice.edu/downloads.html>

<https://www.unavco.org/education/resources/modules-and-activities/gps-measuring-plate-motion/gps-measuring-plate-motion.html>

