## Lesson Plan 8

# The Biggest Plates on Earth

### Focus
Plate tectonics

### Focus Question
How do tectonic plates move, what are some consequences of this motion, and how do magnetic anomalies document the motion at spreading centers?

### Learning Objectives
Students will describe the motion of tectonic plates and differentiate between three typical boundary types between tectonic plates.

Students will infer what type of boundary exists between two tectonic plates, given information on earthquakes and volcanism in the vicinity of the boundary.

Students will infer the direction of motion between two tectonic plates given information on magnetic anomalies surrounding the spreading ridge between the plates.

### Additional Information for Teachers of Deaf Students
In addition to the words listed as Key Words, the following word should be part of the vocabulary list:
Crust

The words listed as Key Words are integral to the unit but will be difficult to introduce prior to the activity. They are really the material of the lesson. There are no formal signs in American Sign Language for any of these words and many are difficult to lipread. Having the vocabulary list on the board as a reference during the lesson will be extremely helpful. You may also give the list as a handout to the students to refer to after the lesson.

The Background Information has important information for use during the initial step of the learning procedure when you are explaining concepts of plate tectonics and drift. It may also be helpful to gather several flat rocks to demonstrate the motion of tectonic plates. It is important to demonstrate how small the movement is annually (several centimeters).

### Materials
- ❒ One copy each per student group - *Pacific Basin Tectonic Plates* and *Magnetic Anomalies on the Juan de Fuca Plate*

### Audio/Visual Materials
- ❒ Overhead transparency of cross section illustrating the main types of plate boundaries (download from U.S. Geological Survey web site: http://pubs.usgs.gov/publications/text/Vigil.html)
- ❒ Overhead transparency of map illustrating the Ring of Fire (from U.S. Geological Survey web site: http://pubs.usgs.gov/publications/text/fire.html)
- ❒ Overhead projector

### Teaching Time
Two or three 45-minute class periods

### Seating Arrangement
Groups of two to four students

### Key Words
Basalt
Ring of Fire

Asthenosphere
Lithosphere
Magma
Fault
Transform boundary
Convergent boundary
Divergent boundary
Subduction
Magnetic anomaly
Tectonic plate
Spreading center

## Background Information

This lesson is divided into two parts. First, students will infer whether plate boundaries associated with the Pacific Ring of Fire are divergent, convergent, or transform based on information about earthquakes and volcanic activity in the vicinity of the boundaries. In the second part, students will use magnetic anomaly data to draw inferences about the spreading center system on the divergent boundary of the Juan de Fuca plate.

Measurements of magnetic variations on the ocean floor have provided critical evidence for theories of continental drift and plate tectonics. When magma erupts along oceanic spreading ridges, it has high mineral content, including magnetic minerals, such as iron and magnetite that align with the Earth's magnetic field like compass needles. As the magma cools to form solid rock (basalt), particles of magnetite become immobilized, providing a record of the position of the Earth's magnetic field when the magma was extruded.

The Earth's magnetic field reverses at irregular intervals of an average of 400,000 years. The alignment of magnetic particles in the crust that was formed during periods of reversal is opposite to that of particles produced when the Earth's magnetic field is oriented similarly to the present. Scientists have found that the intensity of the Earth's magnetic field varies around spreading centers. In some locations it is stronger than normal, in other locations it is weaker. These variations, called magnetic anomalies, are the result of magnetic minerals in the basalt rocks. If the minerals' alignment was "locked" into the rocks when the Earth's magnetic field was similar to its present magnetic field, then the magnetism of the minerals is added to the Earth's magnetic field. Thus the total magnetic intensity is greater than normal and is called a positive magnetic anomaly. On the other hand, if the minerals' alignment occurred when the Earth's magnetic field was opposite to the present, then the magnetism of the minerals is opposite the Earth's current magnetic field. The total magnetic intensity is less than normal when measured above this negative magnetic anomaly.

When positive and negative magnetic anomalies are measured on either side of an oceanic spreading center, they form a zebra-striped pattern with the stripes running parallel to the spreading center ridge. Scientists have reconstructed the history of magnetic reversals for the past 4 million years using a dating technique based on isotopes of potassium and argon (see http://oceanexplorer.noaa.gov/explorations/02alaska/background/edu/media/mapping7_8.pdf.) They have calculated the age of the magnetic anomaly stripes and the rate at which tectonic plates are moving away from the spreading centers.

## Learning Procedure

1. Review plate tectonics and continental drift. Be sure students understand the idea of convergent, divergent, and transform boundaries, as well as the types of earthquakes and volcanic activity associated with each kind of boundary: strong earthquakes and explosive volcanoes at convergent boundaries; slow-flowing volcanoes, weaker earthquakes at divergent boundaries; strong earthquakes and rare volcanoes at transform boundaries. You may want to use materials from "This Dynamic Earth" and/or "This Dynamic Planet" (see Resources section), but do not give away the answers to the predictive exercise on the Pacific Basin Tectonic Plates.

2. Distribute copies of the *Pacific Basin Tectonic Plates*. Using the overhead of the Ring of Fire (see materials list) have each group decide what type of boundary exists at the indicated sites, based on the direction of plate movement. Tabulate each group's results, and lead a discussion of the reasoning behind their conclusions. If you want to use this exercise for evaluation, collect the worksheets before discussion.

3. Explain the origins of magnetic anomalies, and draw the students' attention to the area around the Juan de Fuca plate. Do not give too much detail on the plate; just talk about where it is in relation to the United States and Canada. Be sure the students realize that the small size of the plate brings convergent and divergent boundaries relatively close together. The fact that subduction at the convergent boundary with the North American plate caused the Mount St. Helen's eruption should spark students' interest.

4. Distribute copies of *Magnetic Anomalies on the Juan de Fuca Plate* to each student or student group. Have each group discuss the handout, and write its conclusions about the location of the spreading site on the ridge on the worksheet. Lead a discussion of the reasoning behind these conclusions. Students should infer that the magnetic anomalies occur on either side of a divergent plate boundary between the Juan de Fuca and Pacific plates with the youngest rocks closest to the spreading center at the boundary of the two plates. How do they account for the interruption in the continuity of the anomaly stripes? There is a transverse fault across the ridge.

## The BRIDGE Connection

www.vims.edu/bridge/geology.html

## The "ME" Connection

Have students write a first-hand account of a visit to a plate boundary, describing where the boundary occurs and what conditions are found there.

## Connection To Other Subjects

English/Language Arts, Geography

## Evaluation

Both worksheets may be used to evaluate students' understanding of the concepts presented. Alternatively or additionally, students may be asked to define key words, and/or identify the type of boundaries and expected conditions at the junctions of other tectonic plates.

## Extensions

Have students visit http://oceanexplorer.noaa.gov to study the Ring of Fire Expedition discoveries.

## Resources

http://oceanexplorer.noaa.gov – The Ring of Fire expedition documentaries and discoveries

http://pubs.usgs.gov/publications/text/dynamic.html#anchor19309449 – On-line version of "This Dynamic Earth," a thorough publication of the U.S. Geological Survey on plate tectonics written for a non-technical audience

http://pubs.usgs.gov/pdf/planet.html – "This Dynamic Planet," map and explanatory text showing Earth's physiographic features, plate movements, and locations of volcanoes, earthquakes, and impact craters

## National Science Education Standards

**Content Standard A: Science as Inquiry**
- Abilities necessary to do scientific inquiry
- Understanding about scientific inquiry

**Content Standard B: Physical Science**
- Transfer of energy

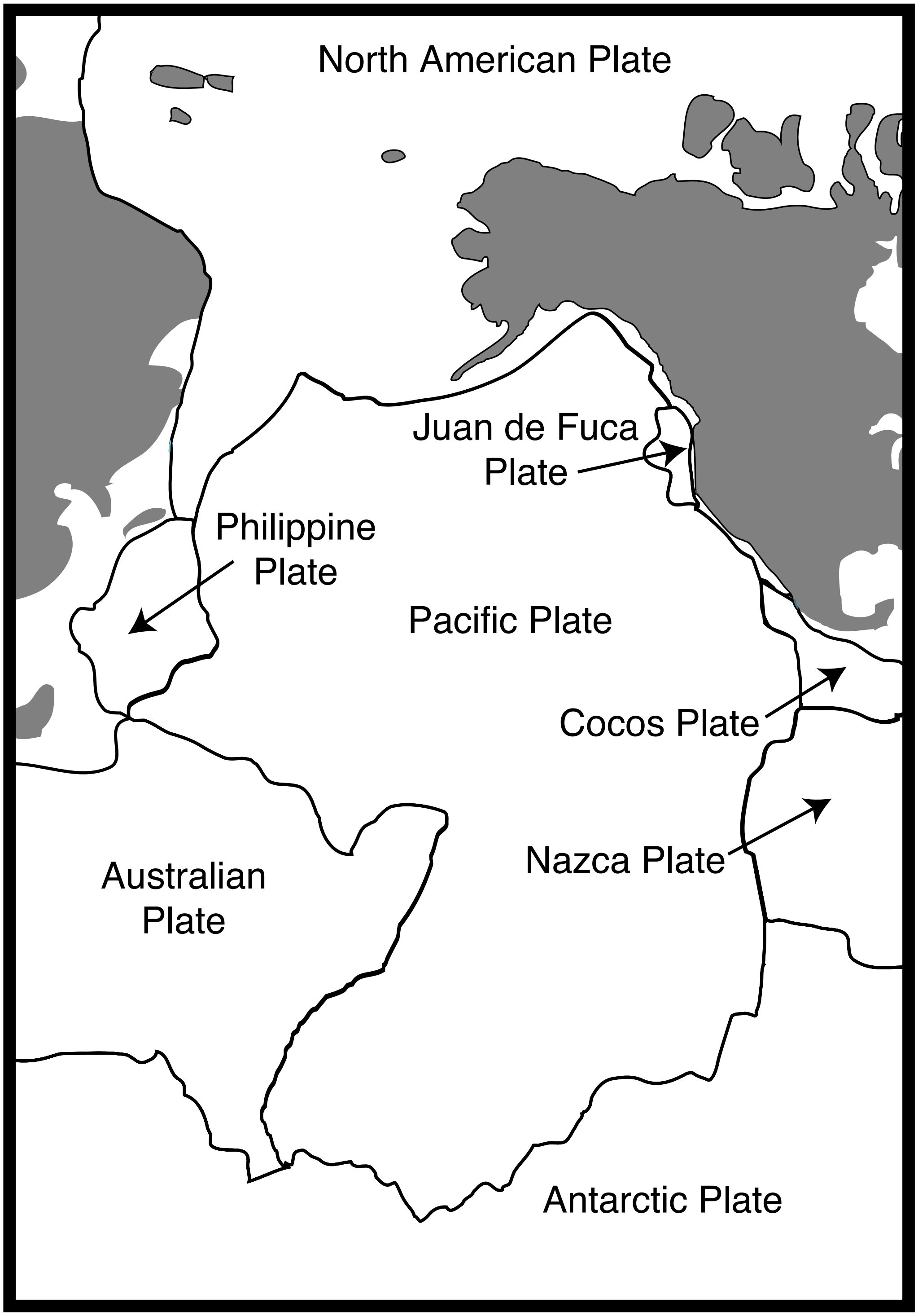
**Content Standard D: Earth and Space Science**
- Structure of the Earth system

*Activity developed by Mel Goodwin, PhD, The Harmony Project, Charleston, SC*

*Additional information for teachers of deaf students developed by Denise Monte, Teacher of the Deaf and Audiologist, American School for the Deaf, West Hartford, Connecticut*

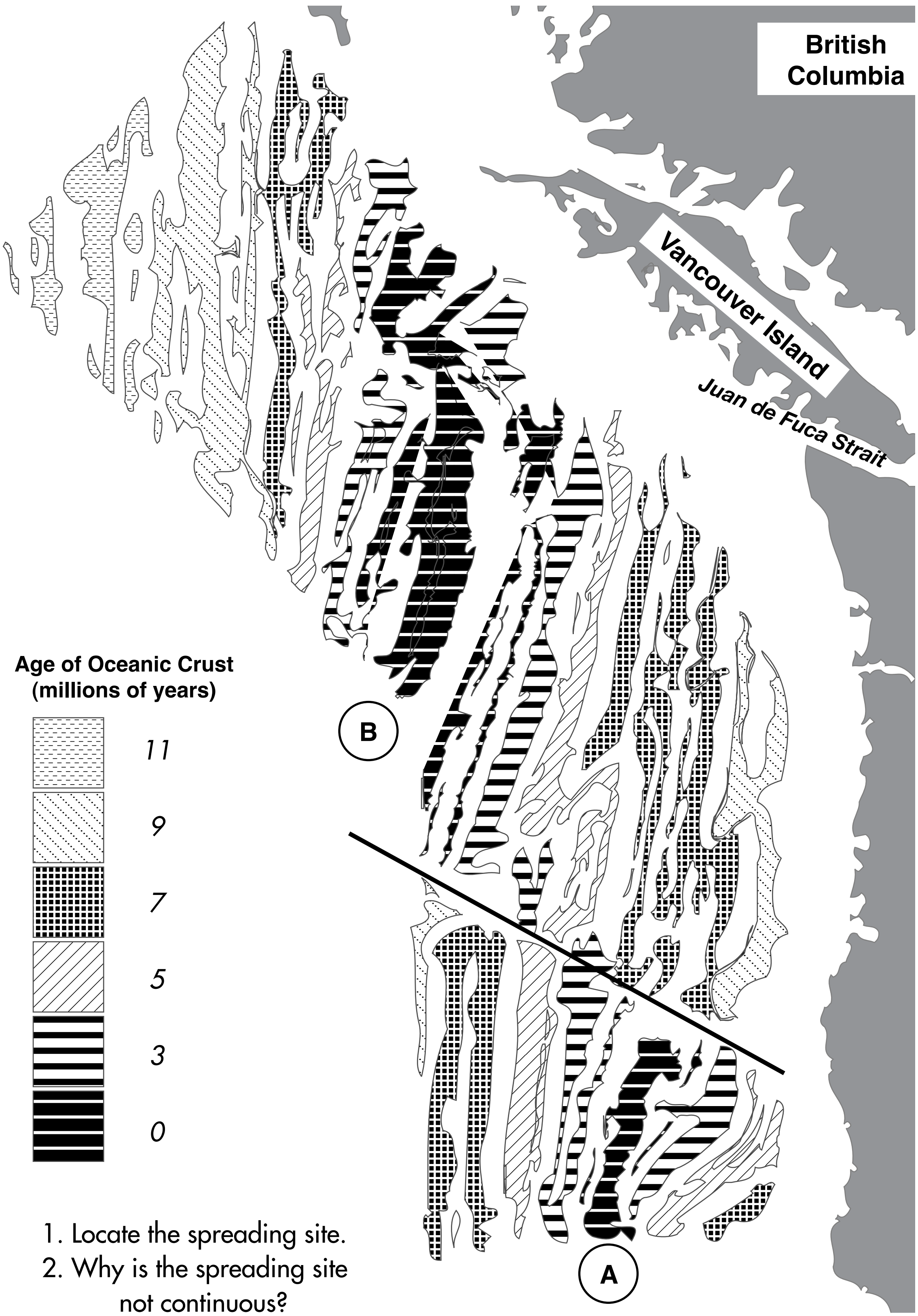
## Student Handout

Tectonic Plates Bordering the Pacific Basin



## Student Handout

Magnetic Anomalies on the Juan de Fuca Plate




1. Locate the spreading site.
2. Why is the spreading site not continuous?

Source: http://pubs.usgs.gov/publications/text/dynamic.html#anchor19309449

## Lesson Plan 9

# The Galapagos Spreading Center

### Focus
Mid-Ocean Ridges

### Focus Question
How does new ocean floor form?

### Learning Objectives
Students will model sea floor spreading, using the Galapagos Spreading Center system as an example.

Students will describe the processes that create new sea floor at a mid-ocean ridge.

### Additional Information for Teachers of Deaf Students
The words listed as Key Words should be introduced prior to the activity. There are no formal signs in American Sign Language for any of these words and many are difficult to lipread. If some of these topics have not already been covered in your class, you may need to add an additional class period to teach vocabulary and to teach some of the backround information to the students prior to the activity. This is very important if you intend to use the written evaluation at the end of the activity. The activity itself is very visual and is easily followed by most deaf students.

### Materials
For each student:
- ❒ Copy of *Map of the Galapagos Spreading Center*
- ❒ Copy of the *Galapagos Spreading Center Student Worksheet*

For the teacher:
- ❒ Physiographic map of the Pacific Ocean with sea floor features if available
- ❒ Overhead transparency of Figure 1
- ❒ Map of the *Galapagos Spreading Center*
- ❒ Scissors
- ❒ Paper copy of Figure 1, cut in two along the ridge segments and transform fault
- ❒ Red overhead transparency pen
- ❒ Overhead transparency with large area colored red

### Audio/Visual Materials
- ❒ Overhead projector

### Teaching Time
20 minutes

### Seating Arrangement
Individuals or in groups of 2

### Key Words
Ridge
Basalt
Fissure
Sea floor spreading
Tensional forces
Transform fault
Divergent
Molten
Translational
Plate
Magma
Extrude
Lithosphere
Hydrothermal vent
Convergent

## Background Information

In many areas, the Earth's tectonic plates are being pulled apart by tensional forces. Enormous elongate cracks, or fissures, in the lithosphere allow molten rock from deep within the Earth to rise and escape as lava. If a fissure occurs in oceanic lithosphere, the lava erupts under water, cooling very rapidly. The solid rock that is formed (called basalt) is oriented in elongate bands parallel to the fissure. Repeated events of tensional forces and extruded fissure lava continually add material to the plates being pulled apart. As a result, divergent boundaries produce new lithosphere, and lithospheric plates grow. Ridges form in regions of extensive and repeated fissure eruptions. Often these underwater ridges have substantial height—as much as 2,000 to 3,000 meters. They are regarded as the longest mountain chains in the world. As new oceanic crust forms at the ridges, older crust is progressively moved farther and farther from the ridge, creeping along at a rate of a few centimeters per year. This process is referred to as sea floor spreading. Hence, divergent boundaries are referred to as spreading boundaries. As the new oceanic crust rock moves away from the heated ridge, it cools and contracts, decreasing the ridge height on its flanks.

Recent use of undersea submersibles provides a window to view the mid-ocean ridges. Scientists have actually watched new ocean floor being produced as red-hot lava extrudes from active fissures, instantly hardening in the cold 2°C bottom water. Hydrothermal vents form on ridges where superheated water, gases, and minerals escape from deep within the Earth.

Sea floor spreading not only forms ocean ridges, but over millions of years creates entire ocean basins. The modern oceans were formed by the divergence of two plates creating new oceanic crust in between. Sea floor maps reveal a crooked, but continuous mountain chain that divides the Atlantic Ocean, known as the Mid-Atlantic Ridge. Like the seams of a baseball, the ridge system continues around the globe, connecting with the Indian Ocean ridge system. Eventually the "seam" travels across the southern Pacific and appears to end as it runs into Central America.

## Learning Procedure

1. Prepare the Spreading Center Overhead Model:
   a. Cut a paper copy of Figure 1 along the Galapagos Spreading Center of ridge segments and a transform fault.
   b. Reassemble the figure with a piece of tape on the "ridge" to hold the two pieces together, but able to be removed during the demonstration.
   c. Put the red-colored overhead transparency under the paper.

### Classroom Procedure

1. Give each student or group a paper copy of Figure 1, the *Galapagos Spreading Center*. Have them locate the ridge segments, the transform fault, and the Galapagos Islands. Lead a discussion of these sea floor features using the overhead of Figure 1.

2. Compare Figure 1 to a large scale sea floor map to see where the Galapagos Spreading Center is located relative to the rest of the Pacific Ocean. What plates lie to the north and south of the spreading center? (the Cocos Plate to the north, the Nazca Plate to the south.)

3. Using the overhead projector and the overhead model prepared in advance, demonstrate how magma extrudes at the ridge. Place the red overhead transparency and cut and taped paper copy of Figure 1 on the overhead projector. The paper blocks the light. The shadow represents the oceanic sea floor crust.

4. Remove the tape carefully so that the "fissure" does not open.

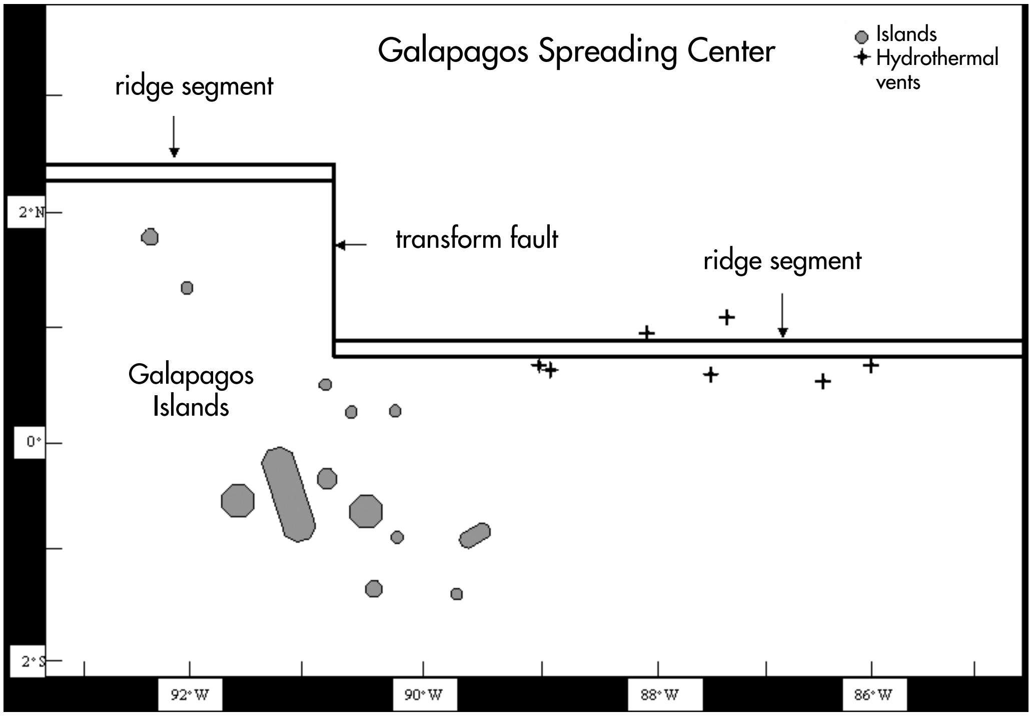



Figure 1. Schematic of the Galapagos Spreading Center. Ridge segments are shown as double lines, whereas a transform fault is shown as a single line. The Cocos Plate lies to the north of the ridge system, and the Nazca Plate lies to the south.

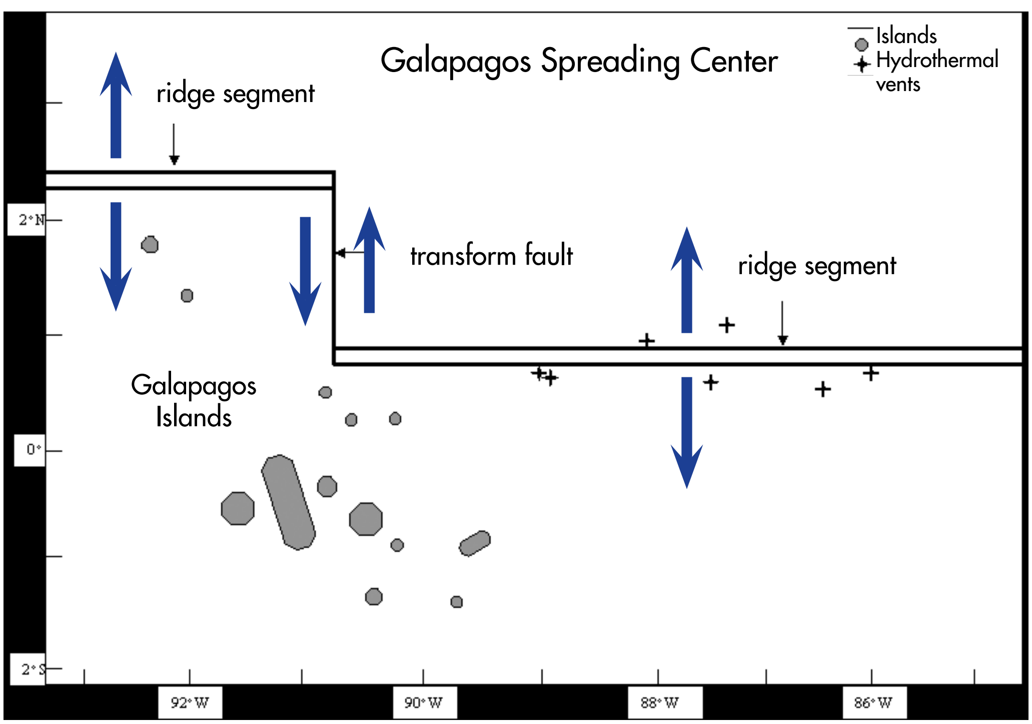



Figure 2. Schematic of the Galapagos Spreading Center with arrows on each side of ridge segments and transform fault, indicating relative motion of the Cocos plate (north) and Nazca Plate (south).

5. Describe how tensional forces in nearly opposite directions to the north and to the south of the Galapagos Spreading Center have, over time, caused fracturing of the oceanic crust. Fissures—or elongate breaks in the crust—have formed and the oceanic crust has diverged or moved away from the fissures. The double lines on Figure 1 represent two ridge segments that began as fissures.

6. At this point, pull the parts away from each other about an inch, revealing the underlying red transparency "glowing" as though it were molten (or melted) rock.

7. Ask students what the red represents—magma or molten rock—and to suggest what happens to the magma when the overlying pressure of the oceanic crust is released. Remind them that the seawater is about 2°C. The magma rises with the release of pressure as the two plates diverge. It solidifies quickly in the cold ocean water and forms new sea floor. This new sea floor is a long band of rock that has solidified between two bands of older rock.

8. Repeat the overhead model demonstration with the Figure 1 transparency, asking the students to focus on the type of motion observed at the transform fault (single line, north-south), across the two ridge segments.

9. Students should draw arrows on their paper copy of Figure 1 to illustrate the direction of relative motion on either side of each ridge segment and on either side of the transform fault. Their figure should have arrows like those on Figure 2.

10. Have students note the locations of potential hydrothermal vents - areas where superheated water, gases, and minerals are released from beneath the oceanic crust. Ask students why hydrothermal vents are so closely associated with ridge systems. Hydrothermal vents form where high temperatures and fractured Earth enable hot water, minerals, and gases to escape from the sea floor. The ridges are fractures in the crust.

## The BRIDGE Connection

http://web.vims.edu/bridge/ – Scroll over "Ocean Science Topics," then "Habitats," and click on "Deep Sea"

http://www.vims.edu/bridge/technology.html

## The "Me" Connection

Have students find out which plate they live on and what kind of activity is currently occurring along the boundaries of that plate near their home or near a city of their choice.

## Connections to Other Subjects

Geography, Technology, and Mathematics

## Evaluation

Use the *Galapagos Spreading Center Student Worksheet*. Students may either complete this individually or in groups, sharing their answers with the class as a whole. Explanations for the teacher are in italics, in parentheses, below.

1. Summarize, in a paragraph, how new sea floor is formed at a divergent ridge. *(See above.)*

2. Summarize, in a paragraph, the differences in motion of the two plates at ridge segments as compared to motion at the transform fault. *(Along ridge segments, the motion is divergent, in opposite directions, moving apart, and the direction of motion is perpendicular to the trend of the ridge segment; along transform faults and transform plate boundaries, motion is translational, meaning that the plates slide past one another and the direction of motion is parallel to the transform fault line.)*

3. Where would you expect to find the most earthquakes in the region depicted in Figure 1? Explain your answer. *(The greatest amount of*

*friction would occur along the transform fault/ transform plate boundary, as the two plates are sliding past each other. Therefore, one would expect the highest frequency of earthquakes to occur here.)*

4. Why do you think oceanographers selected the sites indicated on Figure 1 as potential hydrothermal vent sites? Why might vents be concentrated along a mid-ocean ridge? *(Hydrothermal vents occur where tremendous heat and pressure are released from the Earth's crust. Areas with significant fracturing and an underlying magma chamber would be potential sites for such vents. Mid-ocean ridges are formed by rising magma.)*

5. At the ridge segments, motion is:
   a) divergent
   b) convergent
   c) translational
   d) in the same direction
   *(answer a is correct)*

6. At the fracture between the two ridge segments the motion is:
   a) divergent
   b) convergent
   c) translational
   d) in the same direction
   *(answer c is correct)*

7. Would you expect to find earthquakes anywhere in this modeled ocean? Why or why not? If so, where? *(Because plates of solid lithosphere are in motion, tremendous friction occurs and energy, in the form of earthquakes, is released throughout the divergent plate boundary system. Most earthquakes occur along the transform faults, as plates slide past each other.)*

## Extensions

Have your students visit http://oceanexplorer.noaa.gov and www.divediscover.whoi.edu to read about the Galapagos Rift Expedition discoveries.

What is the origin of the Galapagos Islands? Research the composition of the Galapagos Islands. Are they made of coral, sand, or volcanic material? Infer how they may have formed, based on what you have learned from this activity.

## Resources

http://oceanexplorer.noaa.gov and www.divediscover.whoi.edu - Galapagos Rift Expedition documentaries and discoveries.

http://volcano.oregonstate.edu/types-volcanoes

http://www.pmel.noaa.gov/vents/staff/chadwick/galapagos.html

## National Science Education Standards

**Content Standard A - Science as Inquiry**
- Formulate and revise scientific explanations and models using logic and evidence.
- Understandings about scientific inquiry

**Content Standard D - Earth and Space Science**
- Energy in the Earth system
- The origin and evolution of the Earth system

*Activity developed by Rachel McEvers, College of Charleston and Leslie Sautter, PhD, College of Charleston*

*Additional information for teachers of deaf students developed by Denise Monte, Teacher of the Deaf and Audiologist, American School for the Deaf, West Hartford, Connecticut*

## Student Handout

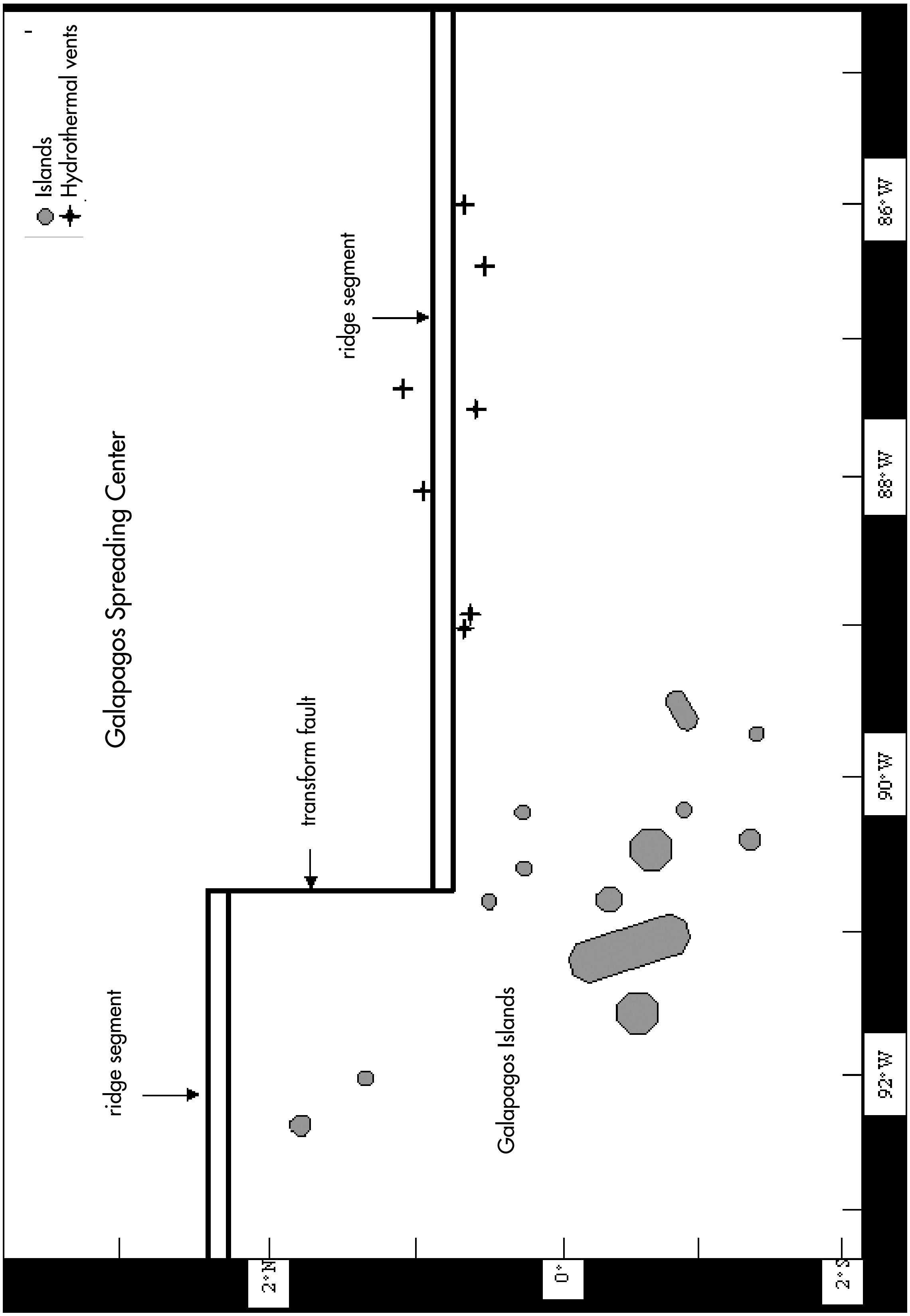



Figure 1. Schematic of the Galapagos Spreading Center. Ridge segments are shown as double lines at A and C, whereas a transform fault is shown as a single line at B.

# Galapagos Spreading Center Student Work Sheet

1. Summarize, in a paragraph, how new sea floor is formed at a divergent ridge.

2. Summarize, in a paragraph, the differences in motion of the two plates at ridge segments as compared to motion at the transform fault.

3. Where would you expect to find the most earthquakes in the region depicted in Figure 1? Explain your answer.

4. Why do you think oceanographers selected the sites indicated on Figure 1 as potential hydrothermal vent sites? Why might vents be concentrated along a mid-ocean ridge?

5. At the ridge segments, motion is:
   a) divergent b) convergent c) translational d) in the same direction
6. At the fracture between the two ridge segments the motion is:
   a) divergent b) convergent c) translational d) in the same direction
7. Would you expect to find earthquakes anywhere in this modeled ocean? Why or why not? If so, where?

## Lesson Plan 10

# AdVENTurous Findings on the Deep-Sea Floor

### Focus
Vent development along the Galapagos Rift

### Focus Question
How do hydrothermal vents form and build structures?

### Learning Objectives
Students will observe formation of precipitates in a model hydrothermal vent.

Students will compare the model hydrothermal vent with an actual hydrothermal vent on the Galapagos Rift.

### Additional Information for Teachers of Deaf Students
The words listed as Key Words should be introduced prior to the activity. There are no formal signs in American Sign Language for any of these words and many are difficult to lipread. If some of these topics have not already been covered in your class, you may need to add an additional class period to teach vocabulary and to teach some of the backround information to the students prior to the activity.

The steps of activities for both days can be written on the board and covered with paper. As each step is done then they can be revealed. This is a very visual activity and represents the concept well to the students.

### Materials
**Part I—For each group:**
- ❒ Several pictures of hydrothermal vents downloaded from the NeMo Explorer web site at http://www.pmel.noaa.gov/vents/nemo/explorer.html and www.divediscover.whoi.edu
- ❒ One *Make Your Own Deep-sea Vent!* instruction page
- ❒ Large clear plastic or glass container, about 1 gallon
- ❒ Small bottle, 8 oz or less
- ❒ 5 drops of red food coloring
- ❒ 1m piece of cotton string
- ❒ Cold tap or ice water to fill large container
- ❒ Hot water about 80 degrees C to fill the small bottle.

**Part II—For each group:**
- ❒ 50 ml water
- ❒ 5 ml calcium chloride (Damp Rid, used to remove moisture from closets is widely available or salt used to melt ice from walks in winter)
- ❒ 5 ml baking soda
- ❒ 8 oz clear plastic cup

### Audio/Visual Materials
None

### Teaching Time
One or two periods 45 minute periods

### Seating Arrangement
Groups of 3 or 4 students

### Key Words
Hydrothermal vent
Magma
Precipitate
Chemical reaction

Continental plates
Geysers
Rift
Mantle
Molten

## Background Information

Rifts and hydrothermal vents are examples of how energy transfer affects solids and liquids. Rifts occur on the ocean floor where drifting continental plates are separating. The rift creates an opening in the crust. The cold deep ocean water comes in contact with materials rising from the Earth's mantle at temperatures of 1000 degrees as molten rock. When the continental plates separate, mantle magma rises into the gap in the crust. When molten rock comes in contact with cold ocean water, at 2 degrees Celsius, the magma's heat energy is transferred to the water. The magma cools, forming new solid rock sea floor crust.

Hydrothermal deep vents are underwater hot springs, but they differ from the geysers and hot springs associated with volcanic areas on land. Ocean water seeps down to the hot mantle through cracks in the thin ocean crust. As is comes in contact with mantle magma, heat energy is transferred to the water, and it becomes superheated. When released to the sea, the heated water is less dense than the cold ocean water, so it rises. High deep sea pressure keeps the heated water from boiling. Great pressure also speeds up chemical reactions. Deep hydrothermal vents form superheated plumes of water that are laced with minerals. These minerals give the hot water plumes color. They also help build the vent structure and feed the vent organisms. In contact with cold water, the dissolved minerals precipitate out and settle. They aggregate to form structures that resemble chimneys around the vent.

## Learning Procedure

### Part I

1. Using the Background Information, discuss what hydrothermal vents are and where they are found. Distribute hydrothermal vent pictures downloaded from the NeMo Explorer website:http://www.pmel.noaa.gov/vents/nemo/explorer.html and www.divediscover.whoi.edu

2. Challenge your students to experiment with several aspects of deep vent physical science by modeling the release of hot water in cold water and the formation of a precipitate from minerals in solution.

3. Distribute copies of *Make Your Own Deep-sea Vent*. Ask the students: "How can you model the action of the heated water rising from the cracks of hydrothermal vents as it mixes with the surrounding cold water?"

4. Provide the materials listed in Part I and let the student groups work independently, following the instructions.

5. Ask the students what each part of their model represents in a deep vent. What can they conclude about the movement of water around a deep vent?

### Part II

1. Provide the student groups with the materials listed under Part II.

2. Ask them to observe the calcium chloride and baking soda separately, recording their observations.

3. Put the calcium chloride and baking soda into the 8 oz. cup and continue to make and record observations. Are there any changes when the solids are combined?

4. Add the water to the solids. What happens? Make sure they understand that they are watching a chemical reaction. The bubbles are carbon dioxide gas given off during this reaction.

5. Do you see anything developing in the bottom of the cup? Students should describe seeing a white substance. Explain that the white substance is calcium carbonate. Because it formed from two chemicals in solution and settled out of solution, it is called a precipitate. A similar process causes hydrothermal vent chimneys to form around deep-sea vents. Heated minerals dissolved in hot water released from the vent come in contact with cooler water. As this water loses its heat to the cold deep seawater, minerals precipitate and settle. They form structures that resemble chimneys with the hydrothermal vent geyser in the middle. Thus, the transfer of energy between magma and water creates new ocean floor structures.

## The BRIDGE Connection

http://www.vims.edu/bridge/vents.html Go to this site for a BRIDGE Ocean AdVENTure on hydrothermal vents.

## The "Me" Connection

Have the students explore possible uses by humans for the precipitates found around a hydrothermal vent site.

## Connections to Other Subjects

English/Language Arts

## Evaluation

Written responses in a science notebook may be evaluated for understanding how precipitates and vent chimneys are formed, if students record these findings individually.

## Extensions

Have your students visit http://oceanexplorer.noaa.gov and www.divediscover.whoi.edu for Galapagos Rift Expedition discoveries.

## Resources

http://oceanexplorer.noaa.gov and www.divediscover.whoi.edu

http://www.pmel.noaa.gov/vents/nemo/explorer.html - A wealth of information on hydrothermal vents

http://pubs.usgs.gov/publications/text/exploring.html "Exploring the deep ocean floor: Hot springs and strange creatures"

http://seawifs.gsfc.nasa.gov/OCEAN_PLANET/HTML/ps_vents.html "Creatures of the Thermal Vents"

## National Science Education Standards

**Content Standard A: Science as Inquiry**
- Abilities necessary to do scientific inquiry
- Understandings about scientific inquiry

**Content Standard B: Physical Science**
- Properties and changes of properties in matter

**Content Standard D: Earth and Space Science**
- Structures of the Earth system
- Earth's history

*Activity developed by Barbara Eager, Springfield Elementary School, Charleston County School District*

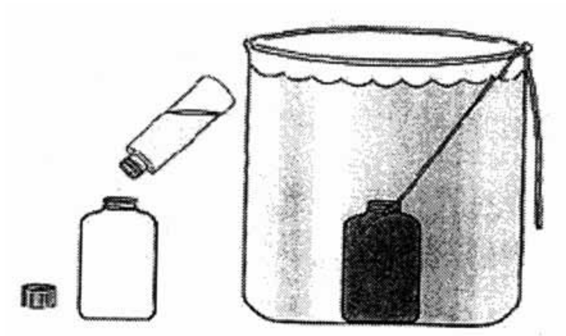
*Additional information for teachers of deaf students developed by Denise Monte, Teacher of the Deaf and Audiologist, American School for the Deaf, West Hartford, Connecticut*

**Student Handout**

# Make Your Own Deep-Sea Vent!

**Materials:**
1 large glass container
1 small bottle
Food coloring
A piece of string
Hot and cold water

**Directions:**
1. Fill the large glass container with very cold water.
2. Tie one end of the piece of string around the neck of the small bottle.
3. Fill the small bottle with hot water and add a few drops of food coloring.
4. Keeping the small bottle upright, carefully lower it into the glass container until it rests on the bottom.
5. Watch what happens!



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Central Wharf
Boston, MA 02110
617.973.5200
http://www.neaq.org/education_and_activities/games_and_activities/activities/make_your_own_deep-sea_vent.php

## Lesson Plan 11

# Volcanoes, Plates, Seamounts and Island Chains

### Focus
Role of volcanism in the formation of chains of islands and seamounts

### Focus Question
How do volcanic hotspots in the Earth's crust and the movement of tectonic plates form island chains?

### Learning Objectives
Students will describe the processes that form seamount and island chains.

Students will describe tectonic plate movement and types of volcanic activity associated with these movements.

Students will describe how a combination of hotspot activity and tectonic plate movement produces the arrangement of seamounts observed in the Axial-Cobb-Eikelberg-Patton chain of Alaska.

### Additional Information for Teachers of Deaf Students
This activity is very visual and easy for students to follow. The difficulty is in explaning the activity while the teacher's hands are busy. You may wish to have students do the entire activity, controlling both the screen and the spray can. This will allow you to explain and direct the activity.

### Materials
❒ Framed window screen
❒ Small can of shaving foam (not gel)
❒ Newspapers
❒ Overhead transparency Gulf of Alaska Seamounts
❒ Overhead transparency of Patton seamount 3-D bathymetric model downloaded from http://geo.oregonstate.edu/~kellerr/GofAseamounts.html

### Audio/visual Materials
❒ Overhead projector
❒ Optional computer video of simulated fly-around of the Patton Seamount; download from http://geo.oregonstate.edu/~kellerr/Fly_around.mov

### Teaching Time
One class period

### Seating Arrangement
Classroom style or in cooperative groups

### Key Words
Basalt
Rift
Subduction
Hotspot
Seamount
Magma

### Background Information
This exercise combines a teacher-led demonstration with students working with actual data. Both address the sources of seamounts. It assumes students have learned about plate tectonics.

Seamounts are undersea mountains rising above the ocean floor to heights as great as 3,000 m (10,000 ft) or more. Compared to the surrounding ocean waters, seamounts have high biological productivity and provide habitats for a variety of organisms. There are also seamounts that break the surface of the water forming islands. Numerous seamounts have been discovered worldwide. Many of these seamounts occur in long chains that parallel the west coast of the U.S. and Canada. One of the longest chains, known as the Axial-Cobb-Eikelberg-Patton chain, was studied in the Ocean Exploration Expedition Exploring Alaska's Seamounts. The OE Northwest Hawaiian Islands Exploration as well as other OE expeditions focused on seamounts and island chains because of their geological and biological interests.

What formed these underwater mountains and islands, and why are they arranged in chains? Seamounts and island chains are probably the products of underwater volcanoes. These volcanoes may have several origins.

First, in places where tectonic plates collide, one plate descends beneath the other in a process called subduction. This generates high temperatures and pressures that lead to explosive volcanic eruptions such as Mount St. Helens' eruption caused by subduction of the Juan de Fuca plate beneath the North American plate. What produced the seamounts in the Alaskan Axial-Cobb-Eikelberg-Patton chain along this junction of two plates? One hypothesis is that they were formed over the Cobb Hotspot, which is currently located off the coast of Oregon near the ridge between the Juan de Fuca and Pacific tectonic plates. As the Pacific plate moved laterally, different parts of the Pacific plate were over the Cobb Hotspot through time. Volcanoes produced by the hotspot are aligned in the same direction as the plate moves.

Volcanoes also form at hotspots not associated with subduction—natural breaks in the Earth's crust that are pipelines releasing magma from the Earth's mantle. As the tectonic plate moves over the hotspot, volcanoes form in a chain along the direction of the plate movement. The Hawaiian Islands form this kind of chain on the Pacific plate.

The volcanoes may be sufficiently active to break the surface of the ocean, forming an island. The island may be so heavy that it eventually sinks —forming a seamount or the volcano may never be active enough to break the surface.

## Learning Procedure

1. Make or purchase the framed window screen. See directions.

2. Discuss with students the origins of seamounts described above. You may use the overheads and video to illustrate your teaching. You may need to review the concept of plate tectonics. Be sure to distinguish the volcanic activity at spreading ridges—typically a slow ooze of lava—from volcanoes near areas of subduction zones or hotspots—both of which can be quite active.

3. Demonstrate how periodic volcanic eruptions at a hotspot and the movement of a tectonic plate over that hotspot can produce a seamount chain similar to that found in the Gulf of Alaska. Let two students hold the framed screen above the can of shaving foam which you should control. Position the can so that the starting point is near the 41 Ma mark. Work over newspapers. Have the students move the screen very slowly. As the screen moves, gently release a small squirt of foam to produce a small mound on top of the screen—practice this in advance to get a feel for the trigger! Make 4 mounds.

4. Use the Gulf of Alaska Seamounts overhead transparency to show that the framed screen is a model for the edge of the Pacific plate with the four mounds representing the Patton, Murray, Warwick, and Axial Seamounts. What is the can of shaving foam? The Cobb Hotspot.

5. Ask the students how long they think this took to happen? Put the age data on the board. What does Ma mean? Millions of years. If the Axial Seamount has an age of 0, where is it located? Over the hotspot. It is still being formed.

## The BRIDGE Connection

www.vims.edu/bridge/geology.html

## The "ME" Connection

Have students write a first-hand account of an exploratory dive to investigate formation of the Axial Seamount. You may want to have them do library or internet research to back up their report.

## Connections To Other Subjects

English/Language Arts, Geography, Mathematics

## Evaluation

Have students write a newspaper style report about events happening on the Juan de Fuca Ridge. Tell them it is OK to include events that are happening slowly (such as tectonic plate movement) as well as events happening more quickly (such as volcanic eruptions). Their reports should include subduction beneath the North American plate (and possibly associated volcanic activity), sea floor spreading, and events associated with the Cobb Hotspot (such as formation of the Axial Seamount).

## Extensions

Have students visit http://oceanexplorer.noaa.gov to check out Exploring Alaska's Seamounts and the Northwest Hawaiian Islands Exploration as well as more recent seamount expeditions.

Get out a world map and ask the students to look for other island chains. Then search for information on their geological origins on the Internet.

## Resources

http://geo.oregonstate.edu/~kellerr/GofAseamounts.html - Background on seamount exploration and research in the Gulf of Alaska

http://volcano.oregonstate.edu/ – Volcano World Web site from Oregon State University

http://serc.carleton.edu/teacherprep/resources/activities.html – Teaching activities for earth science educators

http://www.sciencegems.com/earth2.html - Science education resources

http://www.see.leeds.ac.uk/structure/dynamicearth/ - Background on plate tectonics

http://www.martindalecenter.com/ - References on just about everything

## National Science Education Standards

**Content Standard A: Science as Inquiry**

- Abilities necessary to do scientific inquiry
- Understanding about scientific inquiry

**Content Standard D: Earth and Space Science**

- Structure of the Earth system

*Activity developed by Mel Goodwin, PhD, The Harmony Project, Charleston, SC*

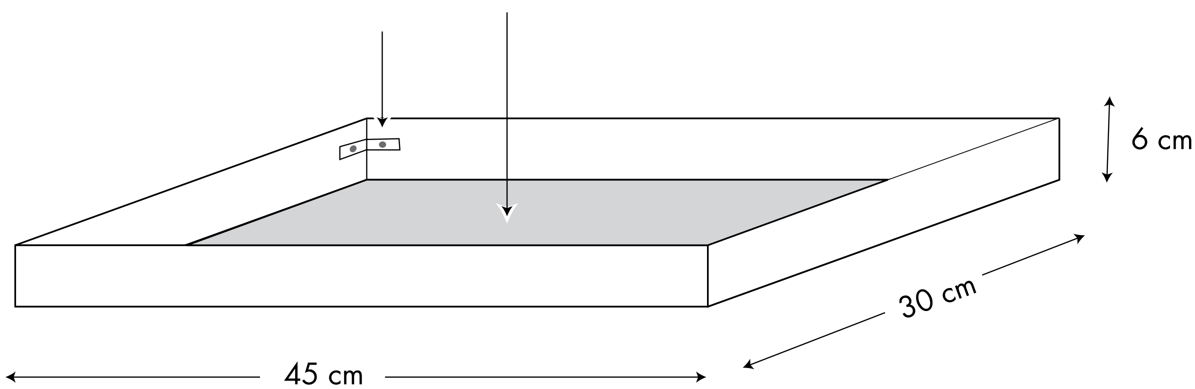
*Additional information for teachers of deaf students developed by Denise Monte, Teacher of the Deaf and Audiologist, American School for the Deaf, West Hartford, Connecticut*

## Teacher Demonstration

## Making a "Tectonic Plate"

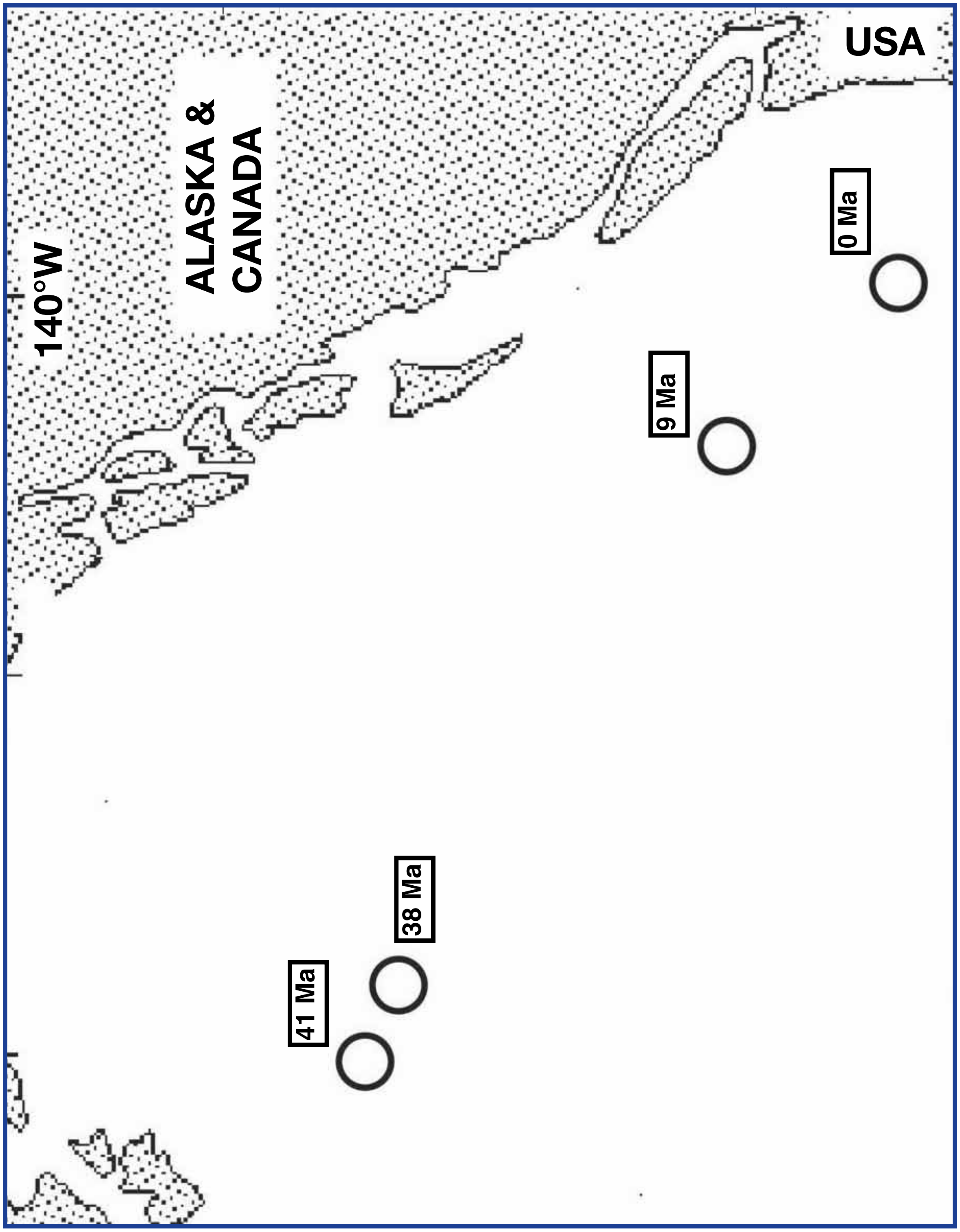
1. You will need a piece of window screen that is about 11″ x 17 ″ in a frame. You may get it by doing any one of the following:
   a. Buy an aluminum-framed replacement window screen, already put together at a hardware or home store.
   b. Buy a cheap picture frame and a piece of window screen and staple the screen to the frame.
   c. Cut the middle out of a soft plastic lid from a Rubber Maid tub. Use Goop adhesive to attach the screen.

Sample frame and screen

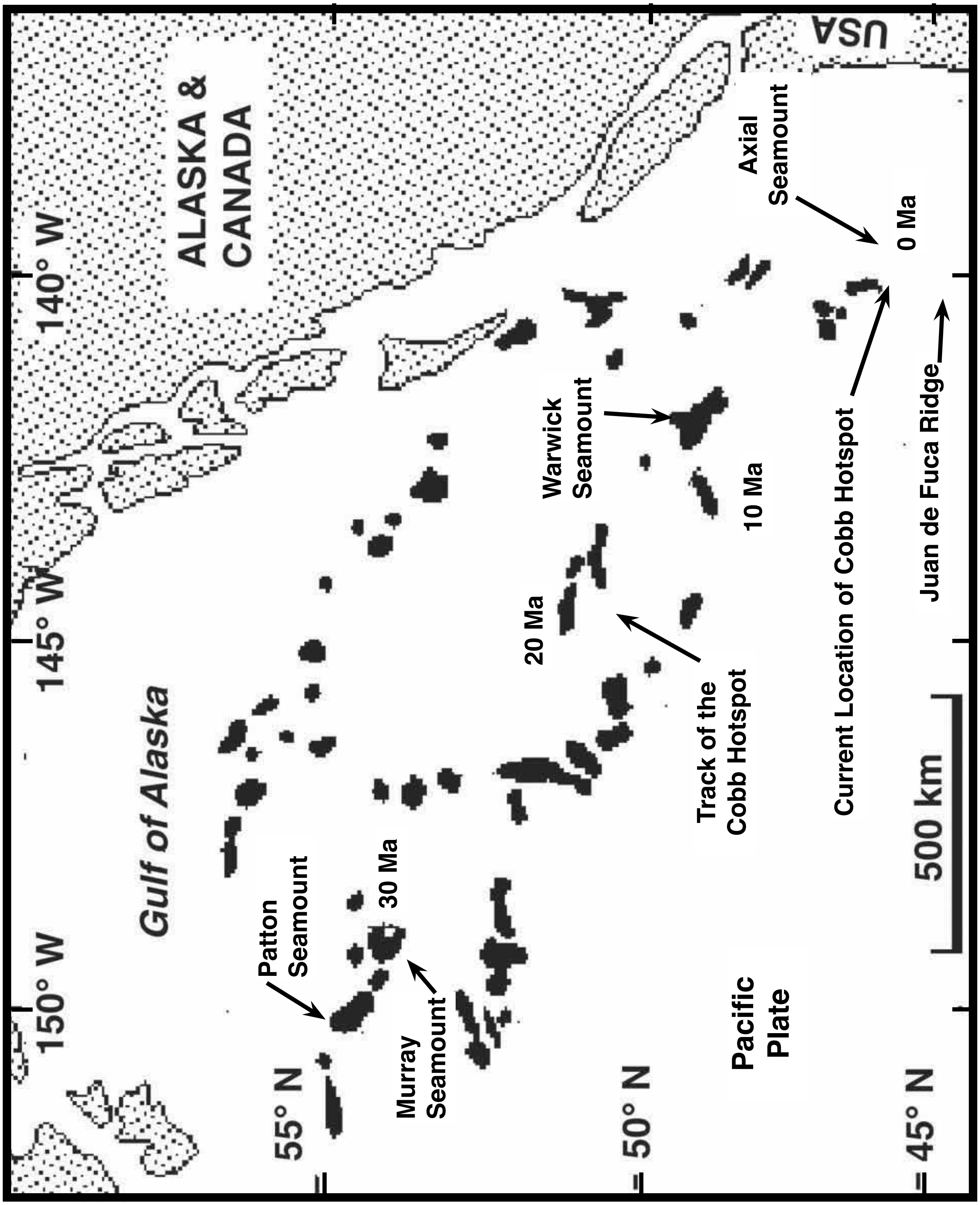



Window screen may be purchased by the foot at hardware stores.

**Map for use with framed screen and shaving foam (enlarge it to fit on an 11 x 17 sheet, if desired)**



# Gulf of Alaska Seamounts Map (for overhead)




http://geo.oregonstate.edu/~kellerr/GofAseamounts.html
College of Oceanic and Atmospheric Sciences, Oregon State University

## Lesson Plan 12

# Islands, Reefs and Hotspots

### Focus

Formation of the island chains through hotspots and plate movement

### Focus Question

What geological processes produced the island chain of Hawaii?

### Learning Objectives

Students will map and describe the stages of Hawaiian Island formation.

Students will describe how hotspot activity and tectonic plate movement produced the seamounts of the Hawaiian archipelago.

### Additional Information for Teachers of Deaf Students

In addition to the words listed as Key Words, the following words should be part of the vocabulary list:

Atoll
Coral
Crust
Convection current
Faults
Subduction
Eruption
Crator
Summit

There are no formal signs in American Sign Language for any of these words listed as Key Words and many are difficult to lipread. Having the vocabulary list on the board as a reference during the lesson will be extremely helpful. It may also be helpful to have a list of all the key words as a handout for the students.

A brief demonstration of a convection current can be conducted by adding food coloring to a heated container of water. This will be helpful to demonstrate the concept. It would also be helpful to make an overhead transparency in addition to the handout of the "Location and Age of Some Islands in the Hawaiian Archipelago" listed in Step 2. The activity should be conducted as a group rather than individually.

The eight stages of growth and erosion in the islands of the Hawaiian Archipelago are listed in the Background Information. This should be copied and given as a handout to the students to assist during the activity. It can also be reviewed as homework after the first day.

You may wish to substitute the following for Step 5 in the Learning Procedure: Select several islands from the Northwestern Hawaiian Islands group, and provide a brief description of these islands. Construct a model or diagram of the appropriate development stage and provide an explanation for their classification.

### Materials

For each student:

❒ Copy of *Central Pacific Map Grid* and *Location and Age of Some Islands in the Hawaii Archipelago*

For the teacher:

- ❒ Diagram of the Hawaiian Archipelago downloaded from http://www.soest.hawaii.edu/GG/HCV/haw_formation.html
- ❒ Brief description of selected islands (http://www.bishopmuseum.org/research/nwhi/geograph.html is a useful source for this information)

## Audio/visual Materials

- ❒ None

## Teaching Time

One or two 45-minute class periods

## Seating Arrangement

Groups of four students

## Key Words

Archipelago
Tectonic plate
Mantle
Asthenosphere
Lithosphere
Magma
Subduction
Hotspots
Caldera
Erosion

## Background Information

This activity examines a specific example of plate tectonic movement and hotspot activity currently forming an island chain: the Hawaiian archipelago. Students will learn about the stages in the formation and degradations of hotspot islands.

The Hawaiian archipelago has arisen from a series of volcanic eruptions starting more than 80 million years ago with the Hawaiian hotspot, thought of as a pipeline to magma in the upper Earth's mantle. It is presently located near the Big Island of Hawaii at the southeastern end of the archipelago. The Pacific tectonic plate moves over the asthenosphere toward the northwest at a rate of 5 to 10 cm per year. As it moves over the hotspot, magma periodically erupts, creating volcanoes that grow to become islands. The oldest island is Kure at the northwestern end of the archipelago. The youngest is the Big Island of Hawaii at the southeastern end. Loihi, just east of the Big Island, is the newest volcano in the chain and may eventually form another island. As the Pacific plate moves to the northwest and the island is carried away from the hotspot, the crust cools and subsides. At the same time, erosion gradually reduces the island which eventually sinks below the ocean surface. Northwest of Kure, the Emperor Seamounts are the submerged remnants of islands even older than Kure.

Scientists recognize eight stages of growth and erosion of the Hawaiian archipelago islands:

1. **The deep submarine stage** begins with submarine eruptions, which eventually reach the ocean surface. Loihi is in this stage.

2. **The shallow submarine stage** features an above-water crater, which spouts lava from rifts on the side of the cone.

3. **The subaerial shield-building stage** begins with collapse of the volcano summit, forming a caldera. The volcano continues to emit lava from the summit and from rifts in the side of the cone. Mauna Loa and Kilauea are in this stage.

4. **The post-caldera stage**, in which lava fills and overflows the caldera, forming a rounded summit. While overall volcanic activity may slow down, significant lava flow still continues: the Kohala Mountains, Mauna Kea, and Hualalai as well as Haleakala are in this stage.

5. **The erosional stage**, in which lava is no longer being added, and the volcanic cone is attacked by erosion from the ocean and rainfall. A sea bluff, deep valleys and sharp ridges are characteristic

features. Kauai, Oahu, and portions of all the major Hawaiian Islands are in this stage.

6. **The reef growth stage** occurs as volcanic mountains are eroded to rocks that barely break the ocean's surface. The volcanic island is slowly sinking, but coral growth keep paces with the sinking so that the rocks are fringed with a coral reef. French Frigate Shoals is in this stage.

7. **The post-erosional eruption stage** is marked by minor renewal of volcanism with a few small cones or lava flows. Portions of West Maui are in this stage.

8. **The atoll stage** occurs as the rocks erode or sink below sea level so that only the coral reef remains at the surface. Pearl and Hermes Reefs and Kure are in this stage.

## Learning Procedure

1. This activity should follow Volcanoes, Plates, Seamounts and Island Chains. Ask the students to locate the Hawaiian Islands on a world or Pacific Ocean map. Challenge them to figure out how they were formed based on what they learned in the above activity.

2. Distribute copies of the *Central Pacific Map Grid* and *Location and Age of Some Islands in the Hawaii Archipelago* to each group. Working independently or in pairs, have the students plot the location of each island on the Map Grid, then label each island with its name and age. You may need to review the concept of the latitude and longitude coordinate system prior to plotting.

3. Have the students discuss with their partner or group what they think accounts for the observed ages and locations of the islands. Each student should write a paragraph describing the process he/she thinks was responsible. Then hold a class discussion in which the above information is addressed.

4. Having done a previous hotspot exercise, they should get part of the idea, but may not remember erosion. Show the students the Hawaiian Archipelago diagram. Discuss why the older islands (to the left of the diagram) have different profiles from those on the right side of the diagram. Students should recognize that islands near or below the sea surface are older than those that have conspicuous mountains, and infer that erosion is a probable reason for this. Students should also recognize that volcanic activity subsides as an island is carried away from the hotspot by motion of the Pacific plate. The three currently active volcanoes in Hawaii are Kilauea, Mauna Loa, and Loihi—all relatively close to the Hawaiian hotspot.

4. Have students infer the direction of motion of the Pacific plate, and calculate its approximate velocity. You may need to help students deal with large numbers and decimal places. The basic calculation is velocity = distance ÷ time, which in the case of Midway is 2,432 km ÷ 27,700,000 yr = 0.0000877 km/yr = 0.0877 m/yr = 8.77 cm/yr; the same calculation for Nihoa is 780 km ÷ 7,200,000 yr = 10.8 cm/yr

5. Describe the stages of volcanic island formation. Have the students identify islands that are examples of each stage as you list and describe the stages.

## The BRIDGE Connection

www.vims.edu/bridge/pacific.html

## The "Me" Connection

Have students write a travel brochure encouraging tourists to visit one island, describing the physical conditions as well as plant and animal life that they encounter.

## Connections to Other Subjects

English/Language Arts, Geography, Biology

## Evaluation

Develop a grading rubric that includes calculations of Pacific plate movement, quality of the paragraph written and participation in discussion.

## Extensions

Visit http://www.bishopmuseum.org/research/nwhi/index.html for others activities relevant to the Northwestern Hawaiian Islands.

## Resources

http://oceanexplorer.noaa.gov – See the Northwestern Hawaiian Islands Expedition documentaries and discoveries posted there.

http://www.soest.hawaii.edu/GG/HCV/haw_formation.html – Hawaii Center for Volcanology web site about the formation of the Hawaiian Islands

http://www.bishopmuseum.org/research/nwhi/geograph.html – Information about the Northwestern Hawaiian Islands region

## National Science Education Standards

**Content Standard A: Science As Inquiry**

- Abilities necessary to do scientific inquiry
- Understanding about scientific inquiry

**Content Standard B: Physical Science**

- Transfer of energy

**Content Standard C: Earth and Space Science**

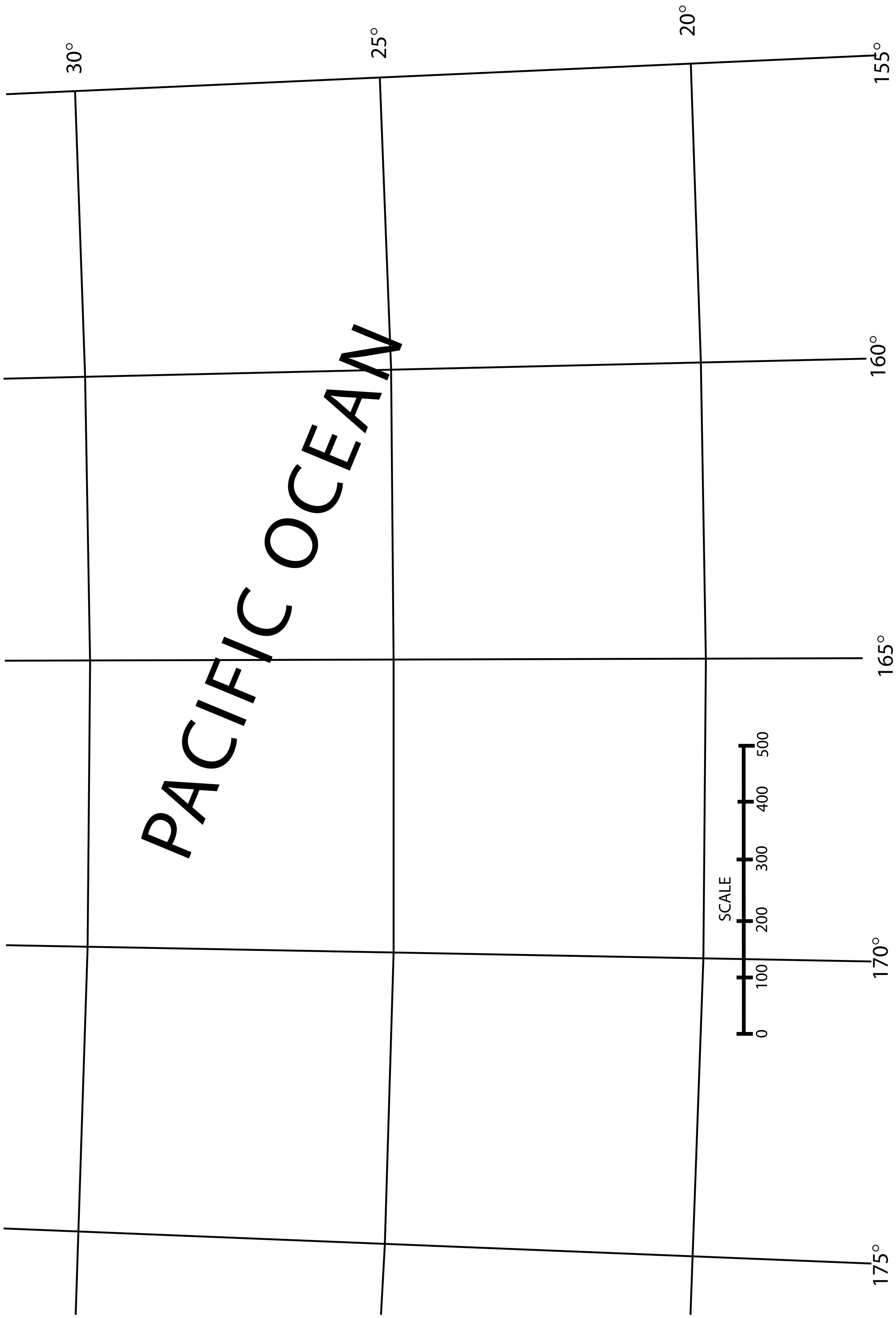
- Structure of the Earth system
- Earth's history

*Activity developed by Mel Goodwin, PhD, The Harmony Project, Charleston, SC*

*Additional information for teachers of deaf students developed by Denise Monte, Teacher of the Deaf and Audiologist, American School for the Deaf, West Hartford, Connecticut*

## Student Handout

# Central Pacific Map Grid



**Student Handout**

## Location and Age of Some Islands in the Hawaii Archipelago

(from http://www.soest.hawaii.edu/GG/HCV/haw_formation.html)

| Volcano/Island Name | Distance from Kilauea (km) | Age (million years) | Location (latitude, longitude) (approximate) |
|---|---|---|---|
| Kilauea (Hawaii) | 0 | 0-0.4 | 19.3°N, 155.4°W |
| Mauna Kea (Hawaii) | 54 | 0.375 | 19.9°N, 155.4°W |
| Haleakala (Maui) | 182 | 0.75 | 20.9°N, 156.2°W |
| Kahoolawe | 185 | 1.03 | 20.7°N, 156.5°W |
| West Maui | 221 | 1.32 | 21.0°N, 156.7°W |
| Lanai | 226 | 1.28 | 21.0°N, 156.9°W |
| West Molokai | 280 | 1.90 | 21.2°N, 157.2°W |
| Waianae (Oahu) | 374 | 3.7 | 21.6°N, 158.1°W |
| Kauai | 519 | 5.1 | 22.2°N, 159.5°W |
| Niihau | 565 | 4.89 | 22.0°N, 160.2°W |
| Nihoa | 780 | 7.2 | 23.1°N, 161.8°W |
| Necker | 1,058 | 10.3 | 23.6°N, 164.6°W |
| Gardner Pinnacles | 1,435 | 12.3 | 25.0°N, 168.0°W |
| Laysan | 1,818 | 19.9 | 25.7°N, 171.7°W |
| Pearl & Hermes Reef | 2,281 | 20.6 | 28.0°N, 175.6°W |
| Midway | 2,432 | 27.7 | 28.3°N, 177.0°W |