Galapagos Rift Expedition

# The Galapagos Spreading Center

## Focus
Mid-Ocean Ridges

## Grade Level
9-12

## Focus Question
How does new ocean floor form?

## Learning Objectives
Students will learn the basic concept of seafloor spreading.

Students will be able to describe the processes involved in creating new seafloor at a mid-ocean ridge.

Students will investigate the Galapagos Spreading Center system.

Students will understand the different types of plate motion associated with ridge segments and transform faults.

## 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 lip-read. 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 teach some of the background 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
Per student
- ❒ Copy of Student Sheet - Map of the Galapagos Spreading Center

For the teacher:
- ❒ (Optional): Physiographic map of the Pacific Ocean (with seafloor features depicted)
- ❒ One overhead transparency copy of Figure 1 - Map of the Galapagos Spreading Center
- ❒ Pair of scissors
- ❒ One paper copy of Figure 1, cut into two pieces, along the ridge segments and transform fault
- ❒ Red overhead transparency pen
- ❒ One overhead transparency with large area colored red
- ❒ Overhead projector

## Audio/Visual Materials
None

## Teaching Time
20 minutes

## Seating Arrangement
Individual, or in groups of 2

## Maximum Number of Students
As many as are in the class

## Key Words

Ridge
Basalt
Fissure
Seafloor spreading
Tensional forces
Transform fault
Divergent
Molten
Translational
Plate
Magma
Extrude
Lithosphere
Hydrothermal vent
Convergent

## Background Information

(excerpt from *Of Sand and Sea*, by P. Keener-Chavis and L. Sautter, 2000)

In many areas, the Earth's 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 will erupt under water and cool 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 escaped—or extruded—fissure lava continually add material to the plates being pulled apart. The result is that at divergent boundaries, new lithosphere is produced and lithospheric plates "grow."

In regions of extensive and repeated fissure eruptions, ridges are formed. Often these underwater ridges have substantial height (as much as 2,000 to 3,000 meters) and are considered to include 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 seafloor spreading. For this reason, we often refer to divergent boundaries as spreading boundaries. As the new oceanic crustal rock moves away from the heated ridge, it cools and contracts, decreasing the ridge height (i.e., increasing the water depth) of the ridge flanks.

Recently, the use of undersea submersibles has provided a window to view the mid-ocean ridges. Scientists have actually observed new ocean floor being produced as red-hot lava extrudes from active fissures, instantly "freezing," or cooling, in the 2°C bottom water. Associated with the ridges are hydrothermal vents, where super-heated water, gases, and minerals escape from deep within the Earth.

The process of seafloor spreading not only forms ocean ridges, but over millions of years of seafloor spreading, also creates entire ocean basins. The modern oceans have all been formed by the divergence of two plates and the creation of newer oceanic crust. Examination of a map of the seafloor reveals 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

a. Teacher Preparation of the Overhead Model:

1. Cut a paper copy of Figure 1 along the Galapagos Spreading Center, which consists of ridge segments and a transform fault.
2. Reassemble the figure and put one piece of tape on the "ridge" to hold the two pieces together. This piece of tape will be removed during the demonstration (Step #1 in the Classroom Procedure), so be careful to not stick the tape on too securely.
3. Lay the red-colored overhead transparency under the paper.

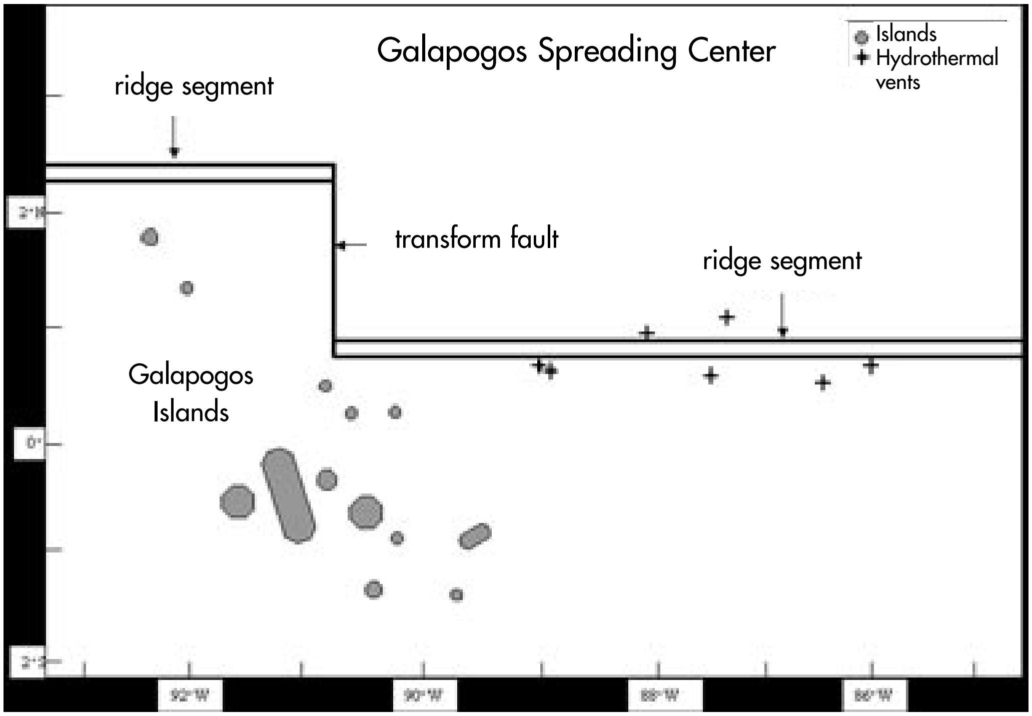


Figure 1. Schematic of the Galapagos Spreading Center. Ridge segments are shown as double lines, whereas a transform fault is shown as a single line. The Cocos Plate lies to the north of the ridge system, and the Nazca Plate lies to the south.

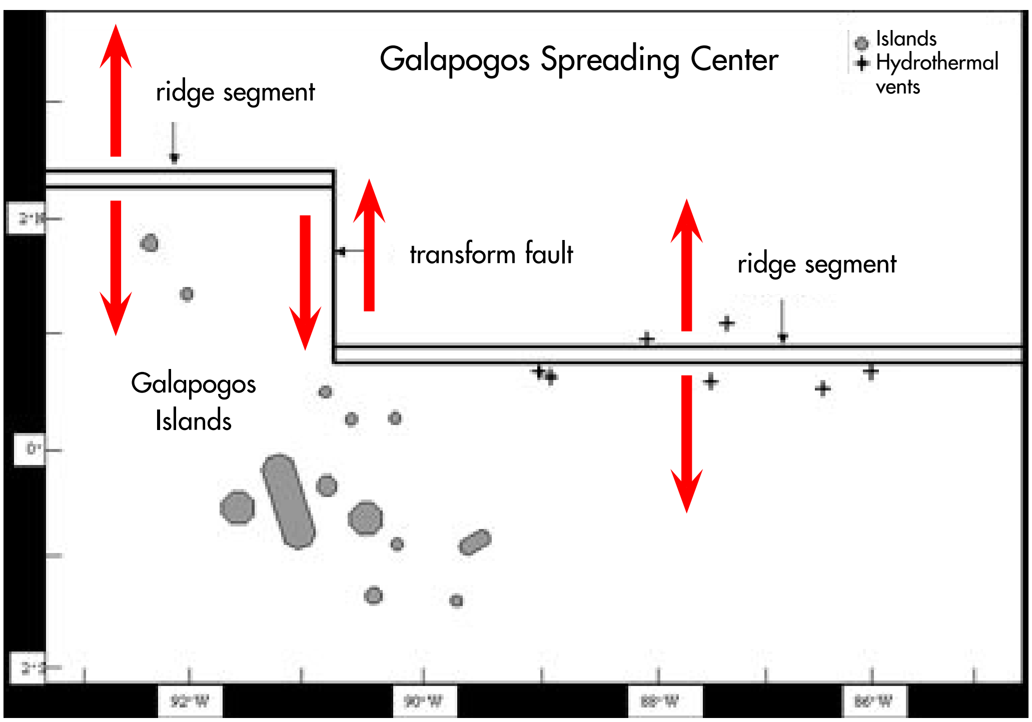


Figure 2. Schematic of the Galapagos Spreading Center with arrows on each side of ridge segments and transform fault, indicating relative motion of the Cocos plate (north) and Nazca Plate (south).

b. Classroom Procedure:

1. Provide each student group with a paper copy of Figure 1, the map of the Galapagos Spreading Center region. Have each group locate the ridge segments, transform fault, and Galapagos Islands. The teacher should lead a discussion of these various seafloor features, using the overhead transparency of Figure 1.
2. Compare this figure to a larger scale seafloor map to see where the Galapagos Spreading Center is located relative to the rest of the Pacific Ocean. Have students determine what plates lie to the north and south of the spreading center (Cocos Plate to the north, Nazca Plate to the south).
3. Using the overhead projector and the overhead model that was prepared in advance, demonstrate how magma extrudes at the ridge. Place the red overhead transparency and paper copy of Figure 1 (that has been cut and taped) on the overhead projector. The paper will block out the light. Describe the large shadow as representing the oceanic crust of the sea floor.
4. Remove the tape carefully so that the "fissure" does not open.
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, diverge the paper about an inch, revealing the underlying red transparency that will "glow" as though it were molten (or melted) rock.
7. Ask students what the red represents (magma, which is molten rock) and to determine what will happen to the "magma" once the overlying pressure from the oceanic crust is released. Remind them that the overlying seawater is close to or less than 2°C. The magma rises with the release of pressure as the two plates diverge. The magma solidifies quickly in the cold ocean water and forms new seafloor. This new seafloor is a long, tabular band of rock that has solidified between two bands of older rock.
8. Repeat the overhead model demonstration, but ask the students to focus on the type of motion observed at the transform fault (single line, north-south), that connects 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 show arrows like those on Figure 2.
10. Have students note the locations of potential hydrothermal vent activity, indicated on Figure 1. Vents are 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 require high temperatures and fractured Earth to enable hot water, minerals, and gases to escape from the seafloor.

## The Bridge Connection

http://educate.si.edu/lessons/currkits/ocean/secrets/essay.html
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 at the end of this activity. Students can 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 seafloor 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.
*(Along ridge segments, the motion is divergent, in opposite directions, i.e., 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 release 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 that heats and fractures the oceanic crust.)*

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 with a member of their family each day to keep up to date with the latest 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
- Follow the Galapagos Rift Expedition daily as documentaries and discoveries are posted each day for your classroom use. A wealth of resource information can also be found at both of these sites.

http://volcano.und.nodak.edu/vwdocs/vwlessons/volcano_types/spread.htm

http://newport.pmel.noaa.gov/~chadwick/galapagos.html

"Exploring Plate Tectonics: a Hands-On Approach" Dr. Leslie Sautter, College of Charleston, Charleston, SC.

*Of Sand and Sea: Teachings from the Southeastern Shoreline*, by Paula Keener-Chavis and Leslie Reynolds Sautter, 2000, special publication of the South Carolina Sea Grant Consortium, Charleston, SC, 140 pp.

## 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

## For More Information

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## Acknowledgements

This lesson plan was developed by Rachel McEvers and Leslie Sautter, College of Charleston, Charleston, SC for the National Oceanic and Atmospheric Administration. If reproducing this lesson, please cite NOAA as the source, and provide the following URL:
http://oceanexplorer.noaa.gov

## Student Handout

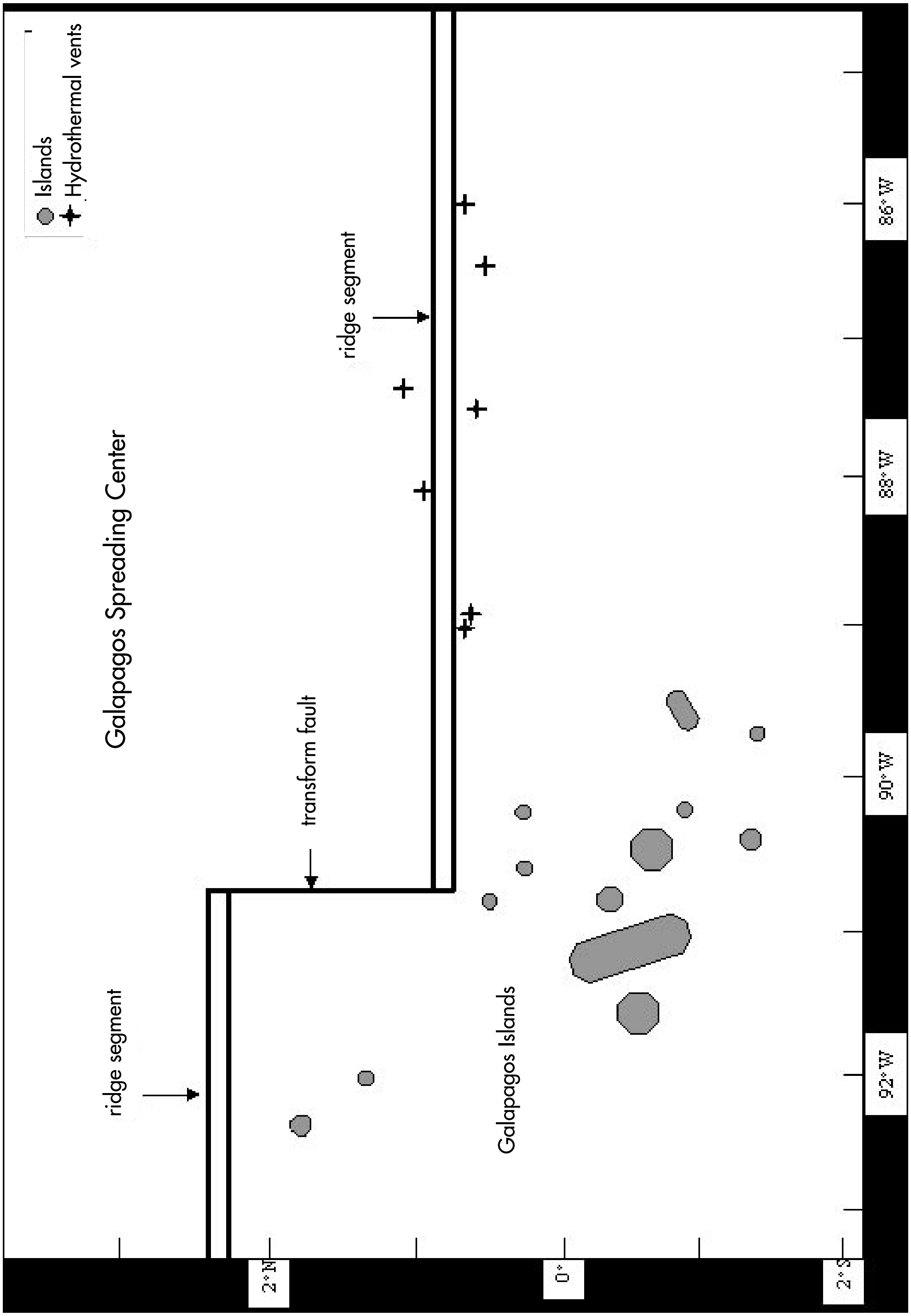


Figure 1. Schematic of the Galapagos Spreading Center. Ridge segments are shown as double lines at A and C, whereas a transform fault is shown as a single line at B.

## Student Handout

1. Summarize, in a paragraph, how new seafloor 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?