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2005 Galapagos Spreading Center

How Does Your Magma Grow?

Focus
Hotspots and mid-ocean ridges

Grade Level
7-8 (Physical Science)

Focus Question
What geological processes produce island chains and hydrothermal vents?

Learning Objectives
Students will be able to identify three types of plate boundaries that are associated with movement of Earth's tectonic plates.

Students will be able to compare and contrast volcanic activity associated with spreading centers and hotspots.

Students will be able to describe the processes that resulted in the formation of the Galapagos Islands.

Students will be able to describe the processes that produce hydrothermal vents.

Materials
Copies of "Guidance Questions for Research on the Formation of the Galapagos Islands and their Hydrothermal Vents," one copy for each student or student group

Audio/Visual Materials
None

Teaching Time
One or two 45-minute class periods, plus time for student research

Seating Arrangement
Classroom style or groups of 3-4 students

Maximum Number of Students
30

Key Words
Hydrothermal vent
Galapagos Spreading Center
Mid-ocean ridge
Plate tectonics
Plate boundary
Hotspot

Background Information
On February 17, 1977, scientists exploring the seafloor near the Galapagos Islands made one of the most significant discoveries in modern science: large numbers of animals that had never been seen before were clustered around underwater hot springs flowing from cracks in the lava seafloor. Similar hot springs, known as hydrothermal vents, have since been discovered in many other locations where underwater volcanic processes are active.

These processes are often associated with movement of the tectonic plates that make up the Earth's crust. The outer shell of the Earth (called the lithosphere) consists of about a dozen large plates of rock (called tectonic plates) that move

several centimeters per year relative to each other. These plates consist of a crust about 5 km thick, and the upper 60 - 75 km of the Earth's mantle. The plates that make up the lithosphere move on a hot flowing mantle layer called the asthenosphere, which is several hundred kilometers thick. Heat within the asthenosphere creates convection currents (similar to the currents that can be seen if food coloring is added to a heated container of water). These convection currents cause the tectonic plates to move.

The Galapagos Islands and their hydrothermal vents are the result of tectonic activity and other processes that allow molten rock (magma) to escape from deep within the Earth onto the seafloor. One of the key questions about hydrothermal systems is how their biological and geological processes are affected by variations in the supply of magma and thickness of the Earth's crust. The geologic setting of the Galapagos region provides an ideal "natural laboratory" to study this question. Ironically, despite the importance of hydrothermal vents, the Galapagos Spreading Center (GSC) where they were first discovered has received very little exploration. This is the primary purpose of the 2005 Galapagos Spreading Center Expedition.

In this lesson, students will research information about the formation of the Galapagos Islands and the processes that produced the first hydrothermal vents known to science.

Learning Procedure

1. To prepare for this lesson, review background essays for the 2005 Galapagos Spreading Center Expedition, the 2005 Galapagos Rift Expedition, and the 2002 Ocean Exploration Galapagos Rift Expedition (http://oceanexplorer.noaa.gov/explorations/05galapagos/welcome.html; http://oceanexplorer.noaa.gov/explorations/05galapagosrift/welcome.html; and http://oceanexplorer.noaa.gov/explorations/02galapagos/galapagos.html, respectively)

   You may also want to visit the Dive and Discover presentation on the 25th anniversary of the discovery of hydrothermal vents (http://www.divediscover.whoi.edu/ventcd/vent_discovery), and obtain the CD-ROM or download selected images to enhance group discussions in Step 4.

2. Briefly review the concepts of plate tectonics, being sure that students understand the overall process, but do not go into detail about types of plate boundaries or associated volcanic activity at this point.

3. Tell students that their assignment is to research the formation of the Galapagos Islands and their hydrothermal vents, and prepare a written report that includes answers to questions on the "Guidance Questions for Research on the Formation of the Galapagos Islands and their Hydrothermal Vents" worksheet. Information needed to answer questions on the worksheet can be found on the Web sites referenced in Step 1, as well as many other sources. You may want to provide these references to your students, or allow them to discover them (and others) on their own.

4. Lead a discussion of students' reports. The following points should be included:
   - When tectonic plates move apart they form divergent plate boundaries. This movement causes a rift to form that allows magma (molten rock) to escape from deep within the Earth and harden into solid rock (basalt), which becomes new crust material. Areas where this happens are known as spreading centers, and are a well-known feature of mid-ocean ridges such as the East Pacific Rise and Mid-Atlantic Ridge.

   - When tectonic plates collide, one plate may slide beneath the other, or the two plates may slide horizontally past each other. When one plate descends beneath the other, the process is called subduction and a conver-

gent plate boundary is formed. Subduction generates high temperatures and pressures that can lead to explosive volcanic eruptions (such as the Mount St. Helens eruption which resulted from subduction of the Juan de Fuca tectonic plate beneath the North American tectonic plate). Transform plate boundaries occur where plates slide horizontally past each other. At these boundaries, the motion of plates rubbing against each other sets up huge stresses that can cause breaks (faults) in the rock that can result in earthquakes. A well-known example of a transform plate boundary is the San Andreas fault in California.

- Hotspots are sources of magma that are associated with volcanic eruptions at the Earth's surface (usually under the ocean, but sometimes on land). Hotspots are thought to be formed by natural pipelines to reservoirs of magma in the upper portion of the Earth's mantle. The volcanic features at Yellowstone National Park are the result of hotspots, as are the Hawaiian Islands. As the Pacific tectonic plate moves over the Hawaiian hotspot, magma periodically erupts to form volcanoes that 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, 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, islands are carried farther away from the hot spot, and the crust cools and subsides. At the same time, erosion gradually shrinks the islands, and unless these is further volcanic activity (or a drop in sea level) the island eventually submerge below the ocean surface. To the northwest of Kure, the Emperor Seamounts are the submerged remains of former islands that are even older than Kure.

- Hotspots are believed be relatively stationary compared to tectonic plates, because hotspots are thought to originate deep inside the Earth, far below the tectonic plates that are floating on the asthenosphere. The combination of comparatively stationary hotspots and plates that are in constant motion produces "chains" of islands and seamounts formed from hotspot lava as a plate moves over a hotspot location.

- The Galapagos Islands were formed by a hotspot called the Galapagos mantle plume (GMP). These islands are formed on the Nazca Plate, which is moving east-southeast. On the western side of the Nazca Plate, a divergent plate boundary is formed with the Pacific Plate. This boundary is called the East Pacific Rise. On the northern side of the Nazca Plate, just north of the Galapagos archipelago, another divergent boundary exists with the Cocos Plate. This boundary is known as the Galapagos Spreading Center (GSC). A convergent boundary exists on the eastern side of the Nazca Plate, which is being subducted beneath the South American and Caribbean Plates. On the southern portion of the Nazca Plate there is a transform plate boundary between the Nazca and Antarctic Plates.

- The Sierra Negra volcano in the Galapagos Islands erupted on October 22, 2005.

- Some of the oldest seamounts formed by the Galapagos Mantle Plume have been subducted beneath the South American and Caribbean Plates and have disappeared.

- Hydrothermal vents are formed where newly-erupted lava at divergent plate boundaries cools and contracts, forming cracks in the solidified surface. Seawater entering these cracks comes into contact with hot rocks below the seafloor where the water becomes

heated and rises back to the surface. Along the way, the heated water reacts with the basalt rock and dissolves minerals out of the crust. When the heated fluid rises out of the seafloor into cold ocean water, the dissolved minerals precipitate out of solution, causing the appearance of a "black smoker."

- Hydrothermal systems along the Galapagos Spreading Center may receive magma from the Galapagos Mantle Plume as well as from rifts associated with the spreading center itself.

- The Rose Garden hydrothermal vent site apparently has vanished, possibly due to a volcanic eruption nearby.

The Bridge Connection

www.vims.edu/bridge – Select Ocean Science Topics, then select Ecology, then Deep Sea

The "Me" Connection

Have students write a brief essay describing how knowledge of plate tectonic processes could be directly beneficial to humans. If they have trouble getting started, you may want to suggest that they consider whether there is any potential connection with natural disasters (such as tsunamis . . .).

Connections to Other Subjects

English/Language Arts; Life Science; Geography; Earth Science

Evaluation

Reports and discussions in Steps 3 and 4 provide opportunities for assessment.

Extensions

Visit these sites for many more activities and links related to plate tectonics, earthquakes and seismology:
http://www.ldeo.columbia.edu/~mwest/WS4instructors/primer.html

Resources

http://oceanexplorer.noaa.gov/explorations/05galapagos/welcome.html – Web page for the 2005 Galapagos Spreading Center Expedition

http://www.divediscover.whoi.edu/ventcd/vent_discovery – Dive and Discover presentation on the 25th anniversary of the discovery of hydrothermal vents

http://seawifs.gsfc.nasa.gov/OCEAN_PLANET/HTML/ps_vents.html – Article, "Creatures of the Thermal Vents" by Dawn Stover

http://www.oceansonline.com/hydrothe.htm – "Black Smokers and Giant Worms," article on hydrothermal vent organisms

Tunnicliffe, V., 1992. Hydrothermal-vent communities of the deep sea. American Scientist 80: 336-349.

Corliss, J. B., J. Dymond, L.I. Gordon, J.M. Edmond, R.P. von Herzen, R.D. Ballard, K. Green, D. Williams, A. Bainbridge, K. Crane, and T.H. Andel, 1979. Submarine thermal springs on the Galapagos Rift. Science 203:1073-1083. – Scientific journal article describing the first submersible visit to a hydrothermal vent community

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

- Structure and properties of matter
- Chemical reactions
- Motions and forces

Content Standard D: Earth and Space Science

- Energy in the Earth system
- Geochemical cycles
- Origin and evolution of the Earth system

Content Standard E: Science and Technology

- Abilities of technological design
- Understandings about science and technology

Content Standard F: Science in Personal and Social Perspectives

- Natural resources
- Natural and human-induced hazards

Content Standard G: History and Nature of Science

- Nature of scientific knowledge
- Historical perspectives

For More Information

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Student Handout

Guidance Questions for Research on the Formation of the Galapagos Islands and their Hydrothermal Vents

1. What kind of boundary is formed where tectonic plates are moving apart? What happens as a result of the plates moving apart? What are areas called where this occurs?

2. What kind of boundaries are formed where tectonic plates collide? What happens as a result of this collision? What is subduction?

3. What is a hotspot? What is the relationship between hotspots and Yellowstone National Park and the Hawaiian Islands?

4. Why do scientists think that hotspots are relatively stationary when compared to the Earth's tectonic plates?

5. How were the Galapagos Islands formed? Which tectonic plate includes these islands? Describe the motion of this plate, and the types of boundaries that it forms with adjacent plates. Locate the East Pacific Rise and the Galapagos Spreading Center.

6. Is there any recent evidence of volcanic activity in the Galapagos Islands?

7. What has happened to some of the oldest seamounts formed by the Galapagos Mantle Plume?

8. What causes hydrothermal vents and "black smokers?"

9. What are two sources of magma to hydrothermal systems along the Galapagos Spreading Center?

10. What has happened to the hydrothermal vent site known as the Rose Garden, discovered in 1977?