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## 2005 Galapagos Spreading Center

# And Now for Something Completely Different...

### Focus
Biological communities at hydrothermal vents

### Grade Level
5-6 (Life Science)

### Focus Question
What organisms are typical of hydrothermal vents near the Galapagos Spreading Center?

### Learning Objectives
Students will be able to identify and describe at least three organisms that are typical of hydrothermal vent communities near the Galapagos Spreading Center.

Students will be able to identify and discuss at least three lines of evidence that suggested the existence of hydrothermal vents before they were actually discovered.

Students will be able to explain why hydrothermal vent communities are apt to be short-lived.

### Materials
- ❒ A variety of art supplies, including construction paper, markers, pipe cleaners, glue, tape, scissors, etc.
- ❒ Copies of "Guidelines for Murals and Reports on Hydrothermal Vent Organisms," one copy for each student or student group

### Audio/Visual Materials
None

### Teaching Time
Four to five 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

### 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. Where the plates move apart, a rift is formed that allows magma (molten rock) to escape from deep within the Earth and harden into solid rock known as basalt. Areas where this happens are known as spreading centers, and are a well-known feature of mid-ocean ridges (MORs) such as the East Pacific Rise and Mid-Atlantic Ridge. Spreading centers are also called "divergent plate boundaries," because the plates are moving apart. Convergent plate boundaries, on the other hand, occur where tectonic motion causes plates to collide. When one plate descends beneath the other, the process is called subduction and high temperatures and pressures are generated 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.

Volcanic activity can also occur in the middle of a tectonic plate, at areas known as hotspots, which are thought to be 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 there is further volcanic activity (or a drop in sea level) the islands 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.

The tectonic setting of the Galapagos Islands is more complex. The Galapagos were also formed by a hotspot called the Galapagos mantle plume (GMP), which continues to produce active volcanoes (the Sierra Negra volcano erupted on October 22, 2005). These islands are formed on the Nazca Plate, which is moving east-southeast. On the western side of the Nazca Plate, this motion produces a divergent plate boundary 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. This subduction has caused some of the oldest seamounts formed by the GMP to disappear beneath the South American and Caribbean Plates, so it is not certain exactly how long the GMP has been active in its present position (for illustrations of these boundaries and plates, as well as detailed discussion of tectonic processes, see "This Dynamic Earth" available online from the U.S. Geological Survey at http://pubs.usgs.gov/publications/text/dynamic.pdf).

This tectonic setting means hydrothermal systems along the GSC may receive magma from the

GMP as well as from rifts associated with the spreading center itself. 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. Because the Galapagos mantle plume is known to provide an increased supply of magma to nearby hydrothermal vent systems, the GSC is an ideal "natural experiment" 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 learn about the first exploration of hydrothermal vents, and investigate some of the vent animals that had never been seen before vent systems were discovered.

## 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)

   In addition, visit the Dive and Discover Web site (http://www.divediscover.whoi.edu/expedition9/; linked from the 2005 Rift Expedition Web page) for a complete chronicle of the 2005 Galapagos Rift Expedition, as well as the Dive and Discover presentation on the 25th anniversary of the discovery of hydrothermal vents (http://www.divediscover.whoi.edu/ventcd/vent_discovery). You may also want to obtain the CD-ROM of this presentation or download selected images to accompany your narrative about the discovery of hydrothermal vents in the following step.

2. Briefly review the concepts of plate tectonics, being sure that students understand the processes that take place at convergent and divergent boundaries, why these boundaries are often the site of volcanic activity, and the distinction between volcanic activity at hotspots and at plate boundaries. Hotspots are believed to originate deep inside the Earth, far below the tectonic plates that are floating on the asthenosphere. Thus, hotspots are essentially stationary, while the plates are in constant motion; so "chains" of islands and seamounts are formed by hotspot lava as a plate moves over a hotspot location. Scientists have found that the distance between hotspots remains constant over periods of time in which the distance between features on tectonic plates changes by thousands of kilometers. This observation provides further evidence that hotspots are relatively stationary.

   Tell students that the idea of plate tectonics (like many important scientific concepts) took a long time to become accepted. The idea of continents moving across the surface of the Earth was first suggested by Abraham Ortelius (a Dutch mapmaker) in 1596, but it was not until 1912 that the idea was developed as an actual scientific theory by a German meteorologist named Alfred Wegener. Even then, the theory was not generally accepted until the 1960's (see "This Dynamic Earth," http://pubs.usgs.gov/publications/text/dynamic.pdf for more details about the history of plate tectonics theory).

   Once accepted, plate tectonics theory helped explain many different observations about Earth's biology, geography, and geology; but also raised many new questions as well. One of these concerned the possible existence of hot springs in the deep ocean. The idea was that lava erupting onto the seafloor at divergent plate boundaries would cool and solidify to form new crust. Because the cooling lava would contract, cracks would be expected to form in the solidified surface. Seawater entering these cracks could come into contact with hot rocks below the seafloor where the water would become heated and rise back to the surface, possibly forming geysers or other features similar to those seen on land (such as in Yellowstone National Park).

While no one had actually seen a seafloor hot spring, there were several pieces of evidence that supported the idea:

- In certain parts of the Red Sea, deep waters are known to have unusually high temperatures, and abnormally high concentrations of salt. Investigations of this phenomenon in the 1960s found that seafloor sediments from the same area were unusually rich in copper, iron, manganese, zinc and other metals.

- Because the Red Sea has a mid-ocean ridge running through it, scientists speculated that hot brines and metal-rich sediments might be related to the divergent plate boundary, and that similar conditions might exist at other spreading centers. Deep-sea drilling expeditions to spreading centers in the Atlantic, Pacific, and Indian Oceans found that sediments from these sites also contained high concentrations of metals. In addition, metal-rich sediments were also found on top of volcanic ocean crust at sites far away from active spreading centers, suggesting that these deposits had been formed at mid-ocean ridges and then transported away by seafloor spreading.

- Deep-sea drilling expeditions also recovered rocks from midocean ridge sites that were different from the generally black rocks found in the deep ocean. Analysis of minerals in these unusual rocks suggested that they could have been formed from typical black rocks by chemical reactions that can only take place in the presence of hot water.

- Plate tectonics theory led some scientists to realize that large deposits of metal-rich ores on land were pieces of the seafloor (called ophiolites) that had been thrust on top of continents by collisions between tectonic plates. The minerals in ophiolites were found to have many similarities with the minerals found in rocks near mid-ocean ridges.

- Scientists expected that the seafloor near midocean ridges would be heated by hot mantle material rising to the surface at divergent plate boundaries. But measurements of actual temperature in these areas were cooler than expected. One of the proposed explanations was that seawater entering cracks in the seafloor could absorb heat and then carry it away as the heated fluid rose back to the seafloor surface and dispersed into the ocean.

Seafloor hot springs offered an explanation for many different observations; an important characteristic of a good scientific theory. Since the ultimate test of this theory was to find one of these springs, a series of expeditions was launched to study midocean ridges in greater detail than had ever been attempted before. For the first time, these expeditions made extensive use of deep-diving submersibles. Expeditions to the mid-Atlantic ridge made many important observations, but did not find a hot spring. Finally, in 1977, an expedition studying the Galapagos Rift found an important clue: an area of seafloor where the water temperature was noticeably higher than normal, and where the lava bottom was covered with hundreds of clam and mussel shells. When scientists descended onto the site in the submersible Alvin, they saw shimmering water flowing out of small cracks in the lava, then turning cloudy as minerals began to precipitate out of the warm fluid. The first hydrothermal vent had been discovered.

But the biggest surprise was that the clams and mussels were not alone: dense biological communities that included crabs, octopi, bright red tubeworms, and orange animals resembling dandelions were found around the Galapagos hydrothermal vents—and scientific ideas about life on Earth were changed forever.

3. Tell students that they will be working in small groups to create a class mural of a hydrothermal vent ecosystem. They will then prepare, as a group, oral and written reports describing the component of the class mural they created. Students should be divided into one of the following groups:
   - Tubeworms/Microbes
   - Mussels/Clams
   - Hydrothermal Vent Geology [focusing on the physical structure of the vent(s) itself]
   - Vent Shrimp/Dandelion Animals
   - Octopi/Zoarcid Fish

   Using the "Guidelines for Murals and Reports on Hydrothermal Vent Organisms" worksheet, guide students to use the Web sites referenced in Step 1 and others that they may discover to learn how to construct their group component of the class mural and group reports.

4. Lead a discussion of students' reports. The following points should be included:

   - Often, mussels are among the first organisms to colonize hydrothermal vent sites.

   - Tubeworms can grow up to two meters long and ten centimeters in diameter.

   - Tubeworms obtain their nutrition from symbiotic bacteria that live inside the tubeworms. The bacteria use carbon dioxide, hydrogen sulfide, and oxygen to produce sugars that the tubeworms use as food. The tubeworms use their red plumes to extract hydrogen sulfide and oxygen from the surrounding water, and make these chemicals available to the symbiotic bacteria.

   - Mussels obtain food from symbiotic microbes living in their gills, as well as from food filtered from the surrounding water

   - Dandelion animals belong to the phylum Cnidaria, which also includes jellyfish, anemones, and corals. The "dandelions" are actually colonies made of many individual animals.

   - Dandelion animals are scavengers, and are among the last animals to colonize vent sites. If there are a lot of dandelions around a vent site, it usually means that the vents are no longer active and most of the other organisms in the area are dying.

   - Shrimp eat microbes and may also eat mussels.

   - Hydrothermal vent microbes include bacteria and Archaea.

   - Vent microbes are the base of the vent system food chain.

   - Vent microbes are chemoautotrophic, and are the base of the vent system food chain.

   - Vent microbes grow on every surface. Some live inside tubeworms, clams, and mussels and have symbiotic relationships with these animals.

   - Vent clams depend on symbiotic bacteria that live in the their gills and produce sugars from chemicals in the hydrothermal fluid.

   - Octopi and zoarcid fish are top predators. Octopi eat crabs, clams, and mussels. Zoarcid fish eat everything from tubeworms to shrimp.

- Vent crabs include species like the Galatheid crab (squat lobster) that are scavengers, as well as species like the brachyuran crabs that are fierce predators. Predatory crabs eat bacteria, shrimp, mussels, clams, tubeworms, and other crabs.

- The Rose Garden was the hydrothermal vent site where vent tubeworms were first observed.

- Between 1977 and 2005, the Rose Garden 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

Remind students that new scientific theories, and sometimes actual discoveries, often are met with skepticism before they are accepted; particularly if they challenge a widely accepted belief or theory. Have students write a brief essay in which they discuss whether this a a good thing, or is an obstacle to better understanding.

## Connections to Other Subjects

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

## Evaluation

Class mural, 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**

- Properties and changes of properties in matter
- Transfer of energy

**Content Standard C: Life Science**

- Structure and function in living systems
- Populations and ecosystems
- Diversity and adaptations of organisms

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

- Structure 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**
- Populations, resources, and environments
- Science and technology in society

**Content Standard G: History and Nature of Science**
- Science as a human endeavor
- Nature of science

## For More Information

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## Student Handout
## Guidelines for Murals and Reports on Hydrothermal Vent Organisms

1. Which group of animals is often the first to colonize a hydrothermal vent site?

2. How big do tubeworms grow?

3. How do tubeworms obtain their food? What are their red plumes for?

4. How do mussels obtain their food?

5. What phylum includes the "dandelion animals?"

6. What do "dandelion animals" eat? What do large numbers of "dandelion animals" usually indicate about a biological community near a hydrothermal vent?

7. How do vent shrimp obtain their food?

8. What kinds of microbes are found at hydrothermal vents? Where are they in hydrothermal vent food chains? How do they obtain their food?

9. Where do vent microbes grow?

10. How do vent clams obtain their food?

11. Where are octopi and zoarcid fish in hydrothermal vent food chains? What do they eat?

12. How do vent crabs obtain their food?

13. What is the Rose Garden?

14. What happened to the Rose Garden between 1977 and 2005?

## Teacher Answers
## Guidelines for Murals and Reports on Hydrothermal Vent Organisms

1. Which group of animals is often the first to colonize a hydrothermal vent site?
   - Often, mussels are among the first organisms to colonize hydrothermal vent sites.

2. How big do tubeworms grow?
   - Tubeworms can grow up to two meters long and ten centimeters in diameter.

3. How do tubeworms obtain their food? What are their red plumes for?
   - Tubeworms obtain their nutrition from symbiotic bacteria that live inside the tubeworms. The bacteria use carbon dioxide, hydrogen sulfide, and oxygen to produce sugars that the tubeworms use as food. The tubeworms use their red plumes to extract hydrogen sulfide and oxygen from the surrounding water, and make these chemicals available to the symbiotic bacteria.

4. How do mussels obtain their food?
   - Mussels obtain food from symbiotic microbes living in their gills, as well as from food filtered from the surrounding water

5. What phylum includes the "dandelion animals?"
   - Dandelion animals belong to the phylum Cnidaria, which also includes jellyfish, anemones, and corals. The "dandelions" are actually colonies made of many individual animals.

6. What do "dandelion animals" eat? What do large numbers of "dandelion animals" usually indicate about a biological community near a hydrothermal vent?
   - Dandelion animals are scavengers, and are among the last animals to colonize vent sites. If there are a lot of dandelions around a vent site, it usually means that the vents are no longer active and most of the other organisms in the area are dying.

7. How do vent shrimp obtain their food?
   - Shrimp eat microbes and may also eat mussels.

8. What kinds of microbes are found at hydrothermal vents? Where are they in hydrothermal vent food chains? How do they obtain their food?
   - Hydrothermal vent microbes include bacteria and Archaea.
   - Vent microbes are the base of the vent system food chain.
   - Vent microbes are chemo-autotrophic, and are the base of the vent system food chain.

9. Where do vent microbes grow?
   - Vent microbes grow on every surface. Some live inside tubeworms, clams, and mussels and have symbiotic relationships with these animals.

10. How do vent clams obtain their food?
    - Vent clams depend on symbiotic bacteria that live in the their gills and produce sugars from chemicals in the hydrothermal fluid.

## Teacher Answers (Continued)

11. Where are octopi and zoarcid fish in hydrothermal vent food chains? What do they eat?
    - Octopi and zoarcid fish are top predators. Octopi eat crabs, clams, and mussels. Zoarcid fish eat everything from tubeworms to shrimp.

12. How do vent crabs obtain their food?
    - Vent crabs include species like the Galatheid crab (squat lobster) that are scavengers, as well as species like the brachyuran crabs that are fierce predators. Predatory crabs eat bacteria, shrimp, mussels, clams, tubeworms, and other crabs.

13. What is the Rose Garden?
    - The Rose Garden was the hydrothermal vent site where vent tubeworms were first observed

14. What happened to the Rose Garden between 1977 and 2005?
    - Between 1977 and 2005, the Rose Garden vanished, possibly due to a volcanic eruption nearby