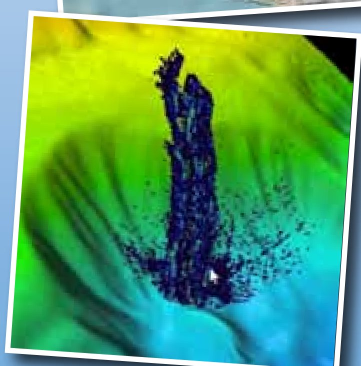
Galápagos Rift Expedition 2011

A Hydrothermal AdVENTure

(adapted from the INSPIRE: Chile Margin 2010 Expedition)



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lesson plan

Focus
Hydrothermal vents

Grade Level
5-6 (Physical Science)

Focus Question
What causes hydrothermal vents to form?

Learning Objectives
- Students will be able to describe the overall structure of hydrothermal vents.
- Students will be able to explain the relationship between hydrothermal vents and the motion of tectonic plates.
- (Optional) Students will create a model of a hydrothermal vent.

Materials
- Copies of *Hydrothermal Vent Inquiry Guide,* one for each student
- (Optional) Materials for demonstrating hydrothermal circulation; see Learning Procedure Step 4
- (Optional) Materials for modeling hydrothermal vents; poster materials, colored markers, modeling clay

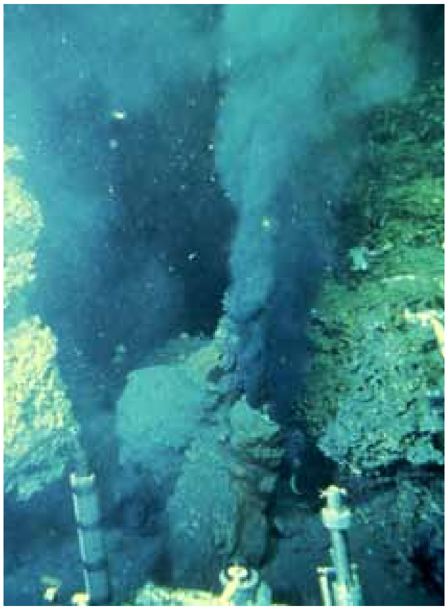
Audio-Visual Materials
- (Optional) Interactive white board or computer projection equipment; see Learning Procedure Step 1.

Teaching Time
One or two 45-minute class periods

Seating Arrangement
Classroom style

Maximum Number of Students
30

Key Words
Galápagos Rift
Galápagos Spreading Center
Hydrothermal vent



The first photograph of a black smoker vent published on the cover of *Science* magazine. The blackened water is jetting out at 1-5 meters per second and is 380°C, hotter than a pizza oven. Image courtesy Spiess, Macdonald, *et al*, 1980. http://oceanexplorer.noaa.gov/explorations/05galapagos/logs/hires/macdonald_hires.jpg

Images from Page 1 top to bottom:
An overview of the Galápagos Islands. They are produced by volcanic activity caused by magma upwelling at the Galápagos hotspot. Green to white indicates the coastline, outside this is below sea level. Image produced by Ken Macdonald using GeoMapApp courtesy of Lamont Doherty Earth Observatory.
http://oceanexplorer.noaa.gov/explorations/05galapagos/background/hotspots/media/Galapagos_IS_Topo_600.html

Multibeam image of Mendocino Ridge Plume taken with the Kongsberg EM302 multibeam bathymetric mapping system. Image courtesy INDEX-SATAL 2010 Expedition.
http://oceanexplorer.noaa.gov/okeanos/media/movies/mendocino_ridge_plume_video.html

Close-up imagery showing a type of gooseneck barnacle, shrimp and a scaleworm on Kawio Barat submarine volcano. Image captured more than 1,850 meters deep by the *Little Hercules* ROV on August 3, 2010. Image courtesy of NOAA *Okeanos Explorer* Program, INDEX-SATAL 2010.
http://oceanexplorer.noaa.gov/okeanos/explorations/10index/logs/slideshow/ex_july_highlights/gallery/hires/barnacle_zoom_hires.jpg

Doug Jongeward, a highly skilled IT Specialist, works in the control room of the *Okeanos Explorer* managing the enormous amounts of video and data that is collected each day on board the ship. Image courtesy of NOAA *Okeanos Explorer* Program.
http://oceanexplorer.noaa.gov/okeanos/explorations/10index/logs/hires/8_doug_jongeward_hires.jpg

Magma
Mantle
Tectonic plate

Background Information

NOTE: Explanations and procedures in this lesson are written at a level appropriate to professional educators. In presenting and discussing this material with students, educators may need to adapt the language and instructional approach to styles that are best suited to specific student groups.

On Feb. 17, 1977, scientists exploring the seafloor near the Galápagos 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, which are portions of the Earth's outer crust (the lithosphere) about 5 km thick, as well as the upper 60 - 75 km of the underlying mantle. These plates 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). Movement of convection currents causes tectonic plates to move several centimeters per year relative to each other.

Where tectonic plates slide horizontally past each other, the boundary between the plates is known as a transform plate boundary. As the plates rub against each other, huge stresses are set up that can cause portions of the rock to break, resulting in earthquakes. Places where these breaks occur are called faults. A well-known example of a transform plate boundary is the San Andreas Fault in California. View animations of different types of plate boundaries at: http://www.seed.slb.com/flash/science/features/earth/livingplanet/plate_boundaries/en/index.html.

A convergent plate boundary is formed when tectonic plates collide more or less head-on. When two continental plates collide, they may cause rock to be thrust upward at the point of collision, resulting in mountain-building (the Himalayas were formed by the collision of the Indo-Australian Plate with the Eurasian Plate). When an oceanic plate and a continental plate collide, the oceanic plate moves beneath the continental plate in a process known as subduction. Deep trenches are often formed where tectonic plates are being subducted, and earthquakes are common. As the sinking plate moves deeper into the mantle, fluids are released from the rock causing the overlying mantle to partially melt. The new magma (molten rock) rises and may erupt violently to form volcanoes, often forming arcs of islands along the convergent boundary. These island arcs are always landward of the neighboring trenches. View the three-dimensional structure of a subduction zone at: http://oceanexplorer.noaa.gov/explorations/03fire/logs/subduction.html.

Where tectonic plates are moving apart, they form a divergent plate boundary. At divergent plate boundaries, magma rises from deep within the Earth and erupts to form new crust on the lithosphere. Most divergent plate boundaries are underwater (Iceland is an exception), and form submarine mountain ranges called oceanic spreading ridges. While the process is volcanic, volcanoes and earthquakes along oceanic spreading ridges are not as violent as they are at convergent plate boundaries. View the three-dimensional structure of a mid-ocean ridge at: http://oceanexplorer.noaa.gov/explorations/03fire/logs/ridge.html.

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.

The Galápagos region is geologically complex (see Figure 1 on page 4). The Galápagos Islands were formed by a hotspot called the Galápagos 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 Galápagos archipelago, another divergent plate boundary exists with the Cocos Plate. This boundary is known as the Galápagos 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 additional discussion and illustrations about these processes, see "This Dynamic Earth" available online from the U.S. Geological Survey at http://pubs.usgs.gov/publications/text/dynamic.pdf).

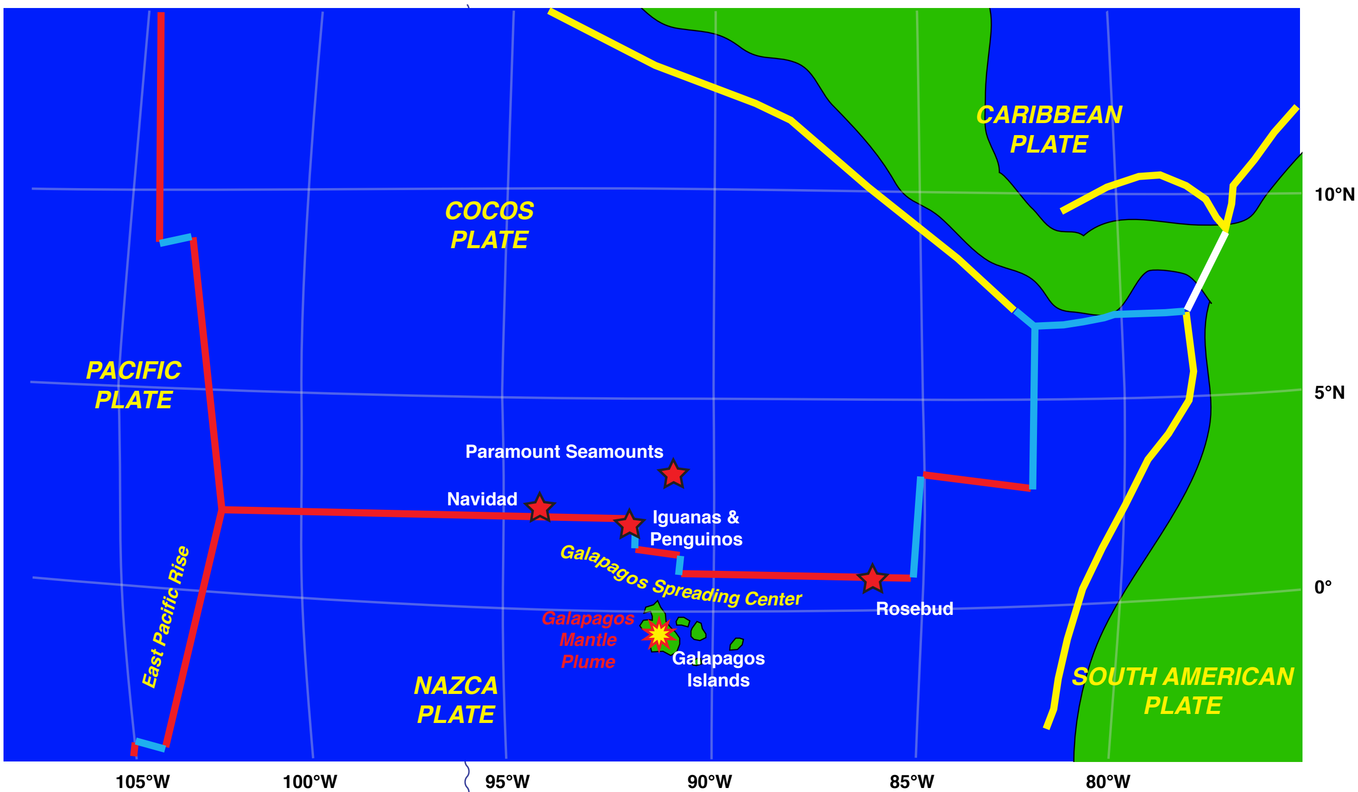


Figure 1. Galápagos Tectonic Setting. Red plate boundaries are divergent; yellow plate boundaries are convergent; blue plate boundaries are transform; white plate boundaries are undetermined. Navidad, Iguanas and Penguinos are locations where black smokers were discovered in 2005. Paramount Seamounts are an exploration target for Galápagos Rift Expedition 2011. For more information see the Galapagos Rift Expedition 2011 Expedition Education Module (http://oceanexplorer.noaa.gov/okeanos/explorations/ex1103/background/edu/edu.html. Credit: UNAVCO (tectonic boundaries); NOAA (hydrothermal sites)

When the movement of tectonic plates causes deep cracks to form in the ocean floor, seawater can flow into these cracks. As the seawater moves deeper into the crust, it is heated by molten rock. As the temperature increases, sulfur and metals such as copper, zinc, and iron dissolve from the surrounding rock into the hot fluid. Eventually, the mineral-rich fluid rises again and erupts from openings in the seafloor. The temperature of the erupting fluid may be as high as 400°C, and contains hydrogen sulfide, which is toxic to many species. When the hot hydrothermal fluid meets cold (nearly freezing) seawater, minerals in the fluid precipitate. The precipitated mineral particles give the fluid a smoke-like appearance, so these vents are often called black smokers or white smokers, depending upon the types of minerals in the fluid. Precipitated minerals may also form chimneys that can be several meters high.

Hydrothermal vent communities and other deepwater chemosynthetic ecosystems are fundamentally different from other biological systems on Earth, and there are plenty of unanswered questions about the individual species and interactions between species found in these communities. Many of these species are new to science, and include primitive living organisms (Archaea) that some scientists believe may have been the first life forms on Earth. Although much remains to be learned, useful products have already been discovered in hydrothermal vent organisms. At present, almost all drugs produced from natural sources come from terrestrial plants, but marine animals produce more

Aft view of the *Okeanos Explorer*.
http://oceanexplorer.noaa.gov/okeanos/media/slideshow/gallery/ex2010/hires/aft_view_hires.jpg

The NOAA Ship *Okeanos Explorer*
Formerly: USNS *Capable*
Launched: October 28, 1988
Transferred to NOAA: September 10, 2004
Commissioned: August 13, 2008
Class: T-AGOS
Length: 224 feet
Breadth: 43 feet
Draft: 15 feet
Displacement: 2,298.3 metric tons
Berthing: 46 (19 Mission/science)
Speed: 10 knots
Range: 9600 nm
Endurance: 40 days

Systems and Instrumentation:
Kongsberg EM302 Multibeam rated to 7,000 m
SBE 911plus CTD
ROVs -
Little Hercules - 4,000 m depth rating; USBL tracking; depth, altitude, attitude/heading sensors; Seabird SBE 49 FastCat CTD; HD camera and HMI lights
Camera platform with depth/altitude/heading sensors, HD camera and HMI lights.
Telepresence

Operations:
Ship crewed by NOAA Commissioned Officer Corps and civilians through NOAA's Office of Marine and Aviation Operations; Mission equipment operated by NOAA's Office of Ocean Exploration and Research

For more information, visit http://oceanexplorer.noaa.gov/okeanos/welcome.html.

drug-like substances than any group of organisms that live on land. Some chemicals from microorganisms found around hydrothermal vents (the exopolysaccharide HE 800 from *Vibrio diabolicus*) are promising for the treatment of bone injuries and diseases, while similar chemicals may be useful for treating cardiovascular disease. Other examples of useful products include a protein from *Thermus thermophylus,* which is a microorganism that is adapted to live under extremely high temperature conditions near hydrothermal vents. One of these adaptations is the protein Tth DNA polymerase that can be used to make billions of copies of DNA for scientific studies and crime scene investigations. Another microorganism (genus *Thermococcus*) produces a type of protein (an enzyme called pullulanase) that can be used to make sweeteners for food additives.

In 2002 and 2005, NOAA's Office of Ocean Exploration and Research sponsored expeditions to the Galápagos Rift (see http://oceanexplorer.noaa.gov/explorations/02galapagos/welcome.html and http://oceanexplorer.noaa.gov/explorations/05galapagos/welcome.html for more information about these expeditions). A major objective of the 2002 expedition was to revisit a hydrothermal vent site named Rose Garden to investigate changes that might have occurred in the community of living organisms around the vent since it was discovered in 1977. Scientists found that significant changes had indeed taken place: Rose Garden had completely disappeared! In its place was a fresh sheet of lava that had apparently buried the vent and all of the surrounding organisms. About 300 meters away, a new vent field (which the scientists named Rosebud) was discovered with typical hydrothermal vent species beginning to colonize cracks in recently-formed lava. These discoveries underscored a growing awareness that the deep ocean environment can change much more quickly than was previously believed. The 2005 expedition focused on a portion of the GSC that had never been explored for hydrothermal vents. Scientists hoped that they would find black smokers, because at that time high temperature (several hundred degrees C) vents had not been found in the Galápagos region; only vents whose temperatures were less than 50°C. Using chemical and physical clues, explorers eventually made the first discovery of black smokers on the Galápagos Rift!

Port view of the Okeanos Explorer.
http://oceanexplorer.noaa.gov/okeanos/media/slideshow/gallery/ex2010/hires/port_view_hires.jpg

These discoveries set the stage for the Galápagos Rift Expedition 2011, which will use the state-of-the-art exploration capabilities of the NOAA Ship *Okeanos Explorer* to obtain detailed information about the biology and geology of Galápagos hydrothermal ecosystems, and determine whether different ecosystems are found at different vent fields within the Galápagos region. A major objective of this Expedition is to survey and map known hydrothermal vent sites and to search for new hydrothermal vents in unexplored regions of the Galápagos Rift.

In this activity, students will investigate hydrothermal vents. Optionally, students will also create models of hydrothermal vents, and use these models to explain the overall structure of hydrothermal vents as well as the relationship between hydrothermal vents and the motion of tectonic plates.

Learning Procedure

[NOTE: Because the discovery of hydrothermal vents was so significant and exciting, there is a wealth of information available on the geology and ecology of vent ecosystems. Several sources and potential activities are highlighted below, and educators are encouraged to investigate these, and select combinations that are most appropriate to their own students and specific curriculum needs.]

1. To prepare for this lesson:
   (a) Review introductory essays for the Galápagos Rift Expedition 2011 at http://oceanexplorer.noaa.gov/okeanos/explorations/ex1103/welcome.html.
   (b) Review background information on hydrothermal vents from one or more of these Web sites:
   - http://oceanexplorer.noaa.gov/explorations/02fire/logs/magicmountain/welcome.html – This site links to virtual fly-throughs and panoramas of the Magic Mountain hydrothermal vent site on Explorer Ridge in the NE Pacific Ocean, about 150 miles west of Vancouver Island, British Columbia, Canada. Explorer Ridge is a spreading center where two tectonic plates are spreading apart and there is active eruption of submarine volcanoes.
   - http://www.pmel.noaa.gov/vents/nemo/index.html – Web site for NOAA's New Millennium Observatory (NeMO), a seafloor observatory at an active underwater volcano near the spreading center between the Juan de Fuca and Pacific tectonic plates. The "Explore" section of the site offers images and essays that include mid-ocean ridges, hydrothermal vents, and seafloor animals. The "Education" section of the site provides Powerpoint® presentations and curriculum materials.
   - http://www.nationalgeographic.com/xpeditions/lessons/07/g35/seasvents.html – National Geographic Xpeditions lesson plan, *We're in Hot Water Now: Hydrothermal Vents*, includes links to *National Geographic* magazine articles and video with an emphasis on geography and geographic skills.

- http://www.divediscover.whoi.edu/vents/index.html – Woods Hole Oceanographic Institution's Dive and Discover Web site about hydrothermal vents includes details about vent formation, education resources, and the story of the discovery of the first hydrothermal vent in 1977.

If an interactive white board or a computer projection facility is available, you may also want to bookmark selected Web pages or download some images from these sites to show your students.

(c) Review Multimedia Discovery Missions [http://oceanexplorer.noaa.gov/edu/learning/welcome.html] Lessons 1, 2, 4, and 5 on Plate Tectonics, Mid-Ocean Ridges, Subduction Zones, and Chemosynthesis and Hydrothermal Vent Life. Decide how much of this material to use with your students.

(d) Review the *Hydrothermal Vent Inquiry Guide*, and note any vocabulary in the background reading that may require additional explanation.

(e) Review optional hydrothermal modeling activities in Step 4, and decide whether you will use these, either as demonstrations or student activities.

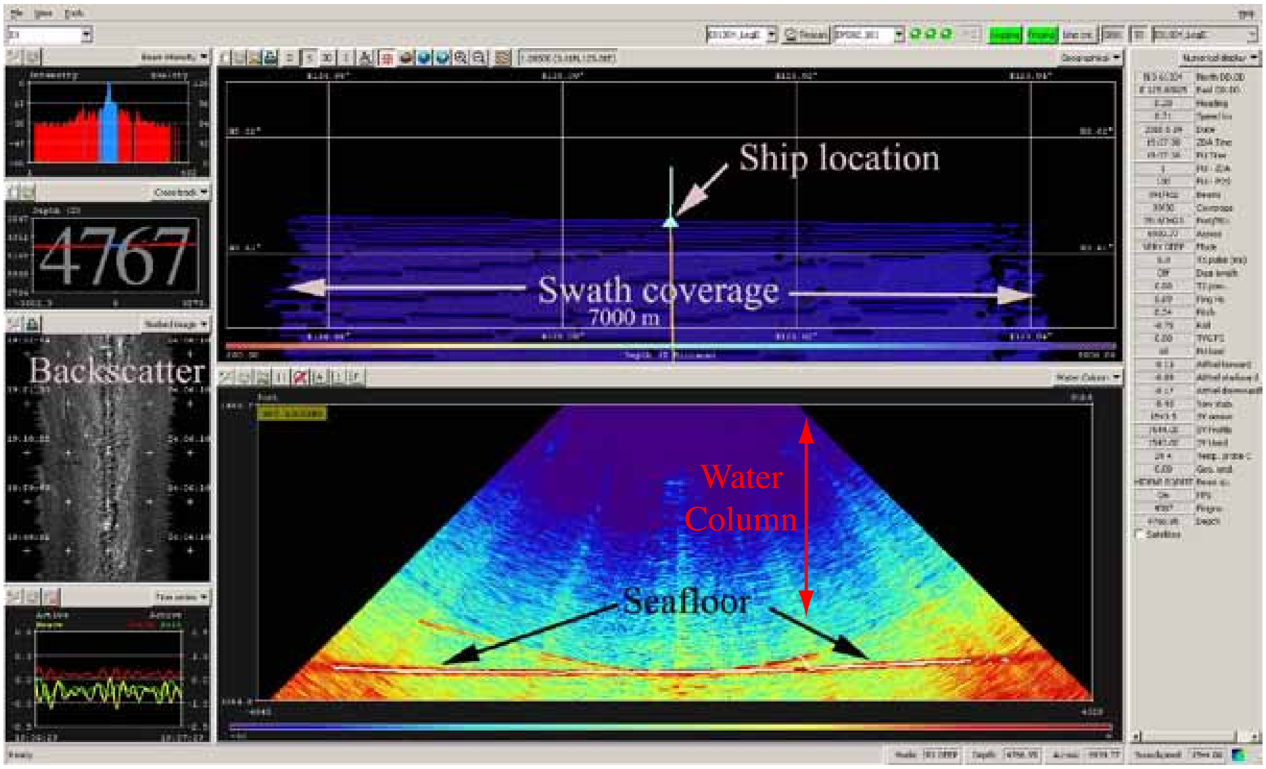
2. If students are not familiar with the concept of plate tectonics, complete part or all of the *When Plates Collide* lesson (http://oceanexplorer.noaa.gov/explorations/10chile/background/edu/media/whenplates.pdf).

Briefly introduce the Galápagos Rift Expedition 2011, and the NOAA Ship *Okeanos Explorer*, which is the only U.S. ship whose sole assignment is to systematically explore Earth's largely unknown ocean for the purposes of discovery and the advancement of knowledge. Be sure students understand that discoveries of deep sea chemosynthetic communities during the last 30 years are major scientific events that have changed many assumptions about life in the ocean and have opened up many new fields of scientific investigation.

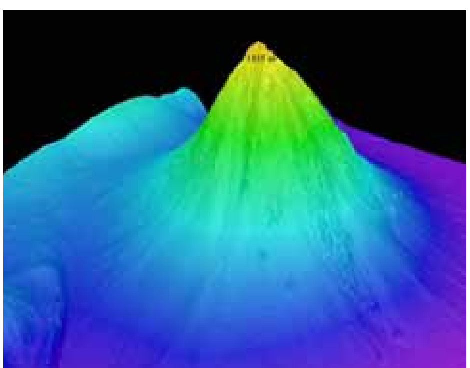
Mention the overall exploration strategy used by the *Okeanos Explorer*, which involves three major activities:

- Underway reconnaissance;
- Water column exploration; and
- Site characterization.

Underway reconnaissance involves mapping the ocean floor and water column while the ship is underway, and using other sensors to measure chemical and physical properties of seawater. Water column exploration involves making measurements of chemical and physical properties "from top to bottom" while the ship is



Data acquisition screen: There is a lot of information to keep track of when standing watch at the multibeam acquisition station. Each piece of information provides unique and valuable details about the seafloor, which are used in the exploration decision-making process: swath coverage is used to determine the spacing of consecutive passes of the ship over an area being surveyed to ensure that the area is completely mapped; the water column allows us to visualize the detected seafloor and water mass above it in order to identify features on the seafloor or above; and the backscatter imagery shows the relative hardness or softness of the seafloor, which helps identify targets such as shipwrecks and deep water coral reefs. Image courtesy of NOAA *Okeanos Explorer* Program, INDEX-SATAL 2010. http://oceanexplorer.noaa.gov/okeanos/explorations/10index/logs/hires/june26fig3_hires.jpg



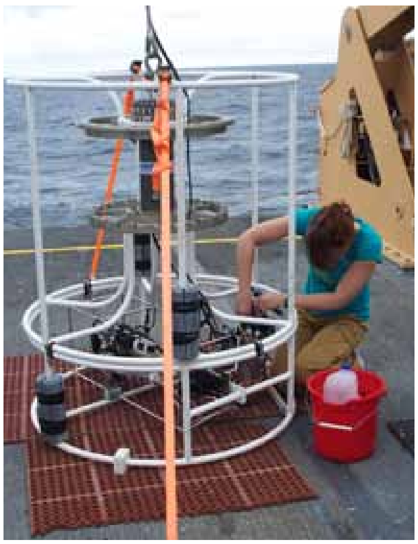
This is a perspective view of the Kawio Barat (West Kawio) seamount looking from the northwest acquired with multibeam sonar. The underwater volcano rises around 3800 meters from the seafloor. Image courtesy of NOAA *Okeanos Explorer* Program, INDEX-SATAL 2010. http://oceanexplorer.noaa.gov/okeanos/explorations/10index/logs/hires/june26fig1_hires.jpg

stopped. In some cases these measurements may be made routinely at pre-selected locations, while in other cases they may be made to decide whether an area with suspected anomalies should be more thoroughly investigated. Site characterization involves more detailed exploration of a specific region, including obtaining high quality imagery, making measurements of chemical and physical seawater properties, and obtaining appropriate samples.

Key technologies involved with this strategy include:
- Multibeam sonar mapping system;
- CTD and other electronic sensors to measure chemical and physical seawater properties; and
- A Remotely Operated Vehicle (ROV) capable of obtaining high-quality imagery and samples in depths as great as 6,000 meters.

A fourth technological capability that is essential to the *Okeanos Explorer* exploration strategy is advanced broadband satellite communication. This capability provides the foundation for "telepresence" technologies that allow people to observe and interact with events at a remote location. Telepresence allows live images to be transmitted from the seafloor to scientists ashore, classrooms, newsrooms and living rooms, and opens new educational

Scientists and spectators located at the Seattle ECC watch as a thriving hydrothermal ecosystem unfolds before them in video footage streaming live from the seafloor. Image courtesy of NOAA *Okeanos Explorer* Program, INDEX-SATAL 2010.
http://oceanexplorer.noaa.gov/okeanos/explorations/10index/logs/hires/seattle_command_center_hires.jpg



Senior Survey Technician Elaine Stuart works on the CTD while the altimeter battery recharges. Water sampling bottles, which are often attached to the rosette frame, have been removed for tow-yo operations. Sensors are mounted in the lower part of the frame where SST Stuart is working. Image courtesy of NOAA *Okeanos Explorer* Program.
http://tethys.gso.uri.edu/OkeanosExplorerPortal/ex1103l1/news-articles/update-for-june-25-2011/image/image_view_fullscreen

Okeanos Explorer crew launch the ROV *Little Hercules*. Image courtesy of NOAA *Okeanos Explorer* Program, INDEX-SATAL 2010.
http://oceanexplorer.noaa.gov/okeanos/explorations/10index/background/rov/media/launch.html

opportunities that are a major part of the *Okeanos Explorer's* mission for advancement of knowledge. In addition, telepresence makes it possible for shipboard equipment to be controlled by scientists in shore-based Exploration Command Centers(ECCs). In this way, scientific expertise can be brought to the exploration team as soon as discoveries are made, and at a fraction of the cost of traditional oceanographic expeditions.

Tell students that a major objective of the Galápagos Rift Expedition 2011 is to survey and map known hydrothermal vent sites, and to search for new hydrothermal vents in unexplored regions of the Galápagos Rift. Review the geologic setting of the Galápagos summarized in Figure 1. Be sure students understand the distinction between a hotspot (which is an unusually hot part of Earth's mantle, is more or less stationary, and may occur anywhere underneath tectonic plates) and a spreading center (which occurs at the boundary between two tectonic plates that are moving apart). If possible, show some images of hydrothermal vents, and explain that hydrothermal vents are often found at the junction between two of Earth's tectonic plates. Tell students that their assignment is to investigate how hydrothermal vents are formed, and how they are related to the motion of tectonic plates.

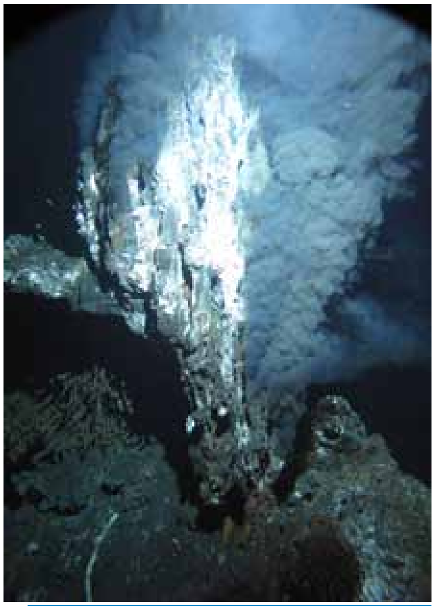
3. Provide each student with a copy of the *Hydrothermal Vents Inquiry Guide*, and selected Web addresses or downloaded reference materials. When students have answered questions on the *Inquiry Guide*, lead a discussion of their results. The following points should be included:
   - Hydrothermal vents are underwater hot springs that form when seawater flows into cracks in the ocean floor and is heated by hot magma beneath Earth's crust.
   - The temperature of hydrothermal vent fluid may be as high as 300°C and 400°C, but much cooler hydrothermal vents also exist (the first vents discovered in 1977 had fluid temperatures less than 50°C).
   - Hot hydrothermal vent fluid is capable of dissolving elements and minerals from rock beneath the ocean floor, so this fluid often contains large amounts of substances such as sulfur, copper, zinc, gold, and iron, and is very acidic.

- Seawater in hydrothermal vents does not boil because of the high pressure in the deep ocean.
- Vent chimneys are chimney-like structures formed by minerals that precipitate when hydrothermal vent fluids are cooled by surrounding seawater, because the solubility of many dissolved materials is reduced when temperature decreases.
- "Black smokers" are vent chimneys formed from deposits of iron sulfide, which is black.
- "White smokers" are vent chimneys formed from deposits of barium, calcium, and silicon, which are white.
- Hydrothermal vents, volcanoes, and earthquakes often happen at the junction of two of Earth's tectonic plates because movement of the plates causes cracks that allow molten rock to rise through Earth's crust and allow seawater to flow through heated rock beneath the ocean floor.

4. (Optional) Several activities have been described to model the dispersion of hot hydrothermal fluid in cold seawater. Two of these are:
AdVENTurous Findings on the Deep Sea Floor
(http://oceanexplorer.noaa.gov/explorations/02galapagos/background/education/media/gal_gr5_6_l2.pdf; from the Ocean Explorer 2002 Galápagos Rift Expedition); and
Cold Water, Hot Water and Super-heated Water!
(http://www.ridge2000.org/SEAS/downloads/curriculum/seas_unit3_activity1.pdf; from the Student Experiments At Sea program of the Ridge 2000 initiative)

Both activities involve placing a container of hot colored water in a larger container of cold water and observing the dispersal of the colored fluid. *AdVENTurous Findings on the Deep Sea Floor* also includes an activity to demonstrate the formation of precipitates. These activities are written as student activities, but may also be done as demonstrations if this is more appropriate to available time and facilities.

5. (Optional) Have students create a poster or three-dimensional model of a hydrothermal vent. Key features that should be included are:
   - Ocean floor
   - Cracks in the ocean floor
   - Rock in Earth's crust
   - Seawater
   - Magma
   - Superheated water
   - Precipitating minerals ("smoke")
   - Vent chimney



A black smoker chimney named 'Boardwalk' emitting 644°F (340°C) hydrothermal fluids in the northeastern Pacific Ocean at a depth of 7,260 feet (2,200 m). Microbes grow within and on the surface of such mineral formations. Image courtesy of James F. Holden, University of Massachusetts, Amherst.
http://oceanexplorer.noaa.gov/okeanos/explorations/10index/background/hires/boardwalk_black_smoker_hires.jpg

Hydrothermal vents on Kawio Barat submarine volcano spew white smoke. Image captured more than 1,850 meters deep by the *Little Hercules* ROV on August 3, 2010. Image courtesy of NOAA *Okeanos Explorer* Program, INDEX-SATAL 2010.
http://oceanexplorer.noaa.gov/okeanos/explorations/10index/logs/slideshow/ex_july_highlights/gallery/hires/white_plumes_hires.jpg

The BRIDGE Connection

www.vims.edu/bridge/ – Click on "Ocean Science Topics" in the menu on the left side of the page, then select "Geology" or "Habitats" for activities and links about hydrothermal vent formation and ecology.

The "Me" Connection

Have students write a brief essay discussing how hydrothermal vents might be useful to humans.

Connections to Other Subjects

English/Language Arts, Earth Science

Assessment

Written reports and class discussions provide opportunities for assessment.

Extensions

1. Visit http://oceanexplorer.noaa.gov/okeanos/explorations/ex1103/welcome.html for the latest activities and discoveries by the Galápagos Rift Expedition 2011.
2. Visit the education sections of Web sites provided in Step 1 for additional activities about hydrothermal vents.

Multimedia Discovery Missions

http://oceanexplorer.noaa.gov/edu/learning/welcome.html – Click on the links to Lessons 1, 2, 4, 5, 6, and 12 on Plate Tectonics, Mid-Ocean Ridges, Subduction Zones, Chemosynthesis and Hydrothermal Vent Life, Deep-Sea Benthos, and Food, Water, and Medicine from the Sea.

Other Relevant Lesson Plans from NOAA's Ocean Exploration Program

And Now for Something Completely Different...
(from the 2005 GalAPAGos: Where Ridge Meets Hotspot Expedition)
http://oceanexplorer.noaa.gov/explorations/05galapagos/background/edu/media/05galapagos_dfferent.pdf

Focus: Biological communities at hydrothermal vents (Life Science)

In this activity, students will identify and describe organisms typical of hydrothermal vent communities near the Galápagos Spreading Center, explain why hydrothermal vent communities tend to be short-lived, and identify and discuss lines of evidence which suggested the existence of hydrothermal vents before they were actually discovered.

Earth's Ocean is 95% Unexplored: So What?
(from the INDEX-SATAL 2010 Expedition)
http://oceanexplorer.noaa.gov/okeanos/explorations/10index/background/edu/media/so_what.pdf

Focus: Importance of deep ocean exploration (Life Science/Earth Science)

Students describe at least three different deep ocean ecosystems, explain at least three reasons for exploring Earth's deep ocean, and explain at least three ways that deep ocean ecosystems may benefit humans.

Let's Make a Tubeworm!
(from the INDEX-SATAL 2010 Expedition)
http://oceanexplorer.noaa.gov/okeanos/explorations/10index/background/edu/media/tubeworm.pdf

Focus: Hydrothermal vent ecosystems (Life Science)

Students explain the overall structure of hydrothermal vents and how they are related to the motion of tectonic plates; describe the process of chemosynthesis in general terms; contrast chemosynthesis and photosynthesis; describe the anatomy of vestimentiferans; and explain how these organisms obtain their food.

To Explore Strange New Worlds
(Grades 7-8; adaptations for Grades 5-6 & 9-12) (from the *Okeanos Explorer Education Materials Collection, Volume 2: How Do We Explore?*)
http://oceanexplorer.noaa.gov/okeanos/edu/lessonplans/media/hdwe_78_toexplore.pdf

Focus: Strategies for exploring unknown areas on Earth (Life Science/Physical Science/Earth Science)

Students describe requirements for explorations of unknown areas on Earth; discuss factors that influenced exploration strategies of the Lewis and Clark and *Challenger* Expeditions; describe the overall exploration strategy used aboard the NOAA Ship *Okeanos Explorer*; and describe how fractal geometry models natural systems, and how scale influences exploration strategy and results.

A Day in the Life of an Ocean Explorer
(from the *Okeanos Explorer Education Materials Collection, Volume 2: How Do We Explore?*)
http://oceanexplorer.noaa.gov/okeanos/edu/lessonplans/media/hdwe_56_dayinlife.pdf

Focus: Telepresence and communications for ocean exploration (Physical Science)

Students identify the basic requirements for human communication; describe at least three ways in which humans communicate; discuss the importance of scientific communication; and explain the concept of telepresence, how it is implemented aboard NOAA Ship *Okeanos Explorer*, and how it is used to increase the pace, efficiency, and scope of ocean exploration.

When Plates Collide
(from the INSPIRE: Chile Margin 2010 Expedition)
http://oceanexplorer.noaa.gov/explorations/10chile/background/edu/media/whenplates.pdf

Focus: Plate Tectonics – Movement of plates, results of plate movement, and the Chile Triple Junction (Earth Science)

Students describe the motion of tectonic plates; compare and contrast three typical boundary types that occur between tectonic plates; describe the plate boundaries that occur and the Chile Triple Junction; and explain why a variety of chemosynthetic communities are expected to occur in this area.

Living With the Heat
(from the Submarine Ring of Fire 2006 Expedition
http://oceanexplorer.noaa.gov/explorations/06fire/background/edu/media/ROF06.LivingHeat.pdf

Focus: Hydrothermal vent ecology and transfer of energy among organisms that live near vents. (Life Science/Earth Science)

Students describe how hydrothermal vents are formed and characterize the physical conditions at these sites; explain what chemosynthesis is and contrast this process with photosynthesis; identify autotrophic bacteria as the basis for food webs in hydrothermal vent communities; and describe common food pathways between organisms typically found in hydrothermal vent communities.

InVENT a Deep-Sea Invertebrate
(from the 2002 Galápagos Rift Expedition)
http://oceanexplorer.noaa.gov/explorations/02galapagos/background/education/media/gal_gr5_6_l3.pdf

Focus: Galápagos Rift Ecosystem - Structure and Function in Living Systems (Life Science)

Students design an invertebrate capable of living near deep-sea hydrothermal vents, and learn about the unique adaptations that organisms must have in order to survive in the extreme environments of the deep sea.

Other Resources

The Web links below are provided for informational purposes only. Links outside of Ocean Explorer have been checked at the time of this page's publication, but the linking sites may become outdated or non-operational over time.

http://oceanexplorer.noaa.gov/okeanos/explorations/ex1103/welcome.html – Web site for the Galápagos Rift Expedition 2011, with links to lesson plans, career connections, and other resources

http://oceanexplorer.noaa.gov/okeanos/edu/welcome.html – Web page for the *NOAA Ship Okeanos Explorer Education Materials Collection*

http://celebrating200years.noaa.gov/edufun/book/welcome.html#book - A free printable book for home and school use introduced in 2004 to celebrate the 200th anniversary of NOAA; nearly 200 pages of lessons focusing on the exploration, understanding, and protection of Earth as a whole system

http://oceanexplorer.noaa.gov/explorations/02galapagos/welcome.html – Web site for the 2002 Galápagos Rift Expedition

http://oceanexplorer.noaa.gov/explorations/05galapagos/welcome.html – Web site for the 2005 GalAPAGoS: Where Ridge Meets Hotspot Expedition

http://oceanexplorer.noaa.gov/explorations/02fire/logs/magicmountain/welcome.html – Links to virtual fly-throughs and panoramas of the Magic Mountain hydrothermal vent site on Explorer Ridge in the NE Pacific Ocean, where two tectonic plates are spreading apart and there is active eruption of submarine volcanoes

http://www.pmel.noaa.gov/vents/nemo/index.html – Web site for NOAA's New Millennium Observatory (NeMO), a seafloor observatory at an active underwater volcano near the spreading center between the Juan de Fuca and Pacific tectonic plates

http://www.nationalgeographic.com/xpeditions/lessons/07/g35/seasvents.html – National Geographic Xpeditions lesson plan, *We're in Hot Water Now: Hydrothermal Vents*, includes links to *National Geographic* magazine articles and video with an emphasis on geography and geographic skills

http://www.divediscover.whoi.edu/vents/index.html – Woods Hole Oceanographic Institution's Dive and Discover Web site about hydrothermal vents includes details about vent formation, education resources, and the story of the discovery of the first hydrothermal vent in 1977.

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
- Motions and forces
- Transfer of energy

Content Standard D: Earth and Space Science

- Structure of the Earth system
- Earth's history

Content Standard F: Science in Personal and Social Perspectives

- Natural hazards

Ocean Literacy Essential Principles and Fundamental Concepts

Essential Principle 1.
The Earth has one big ocean with many features.
Fundamental Concept b. An ocean basin's size, shape and features (such as islands, trenches, mid-ocean ridges, rift valleys) vary due to the movement of Earth's lithospheric plates. Earth's highest peaks, deepest valleys and flattest vast plains are all in the ocean.

Essential Principle 2.
The ocean and life in the ocean shape the features of the Earth.
Fundamental Concept a. Many earth materials and geochemical cycles originate in the ocean. Many of the sedimentary rocks now exposed on land were formed in the ocean. Ocean life laid down the vast volume of siliceous and carbonate rocks.
Fundamental Concept e. Tectonic activity, sea level changes, and force of waves influence the physical structure and landforms of the coast.

Essential Principle 5.
The ocean supports a great diversity of life and ecosystems.
Fundamental Concept g. There are deep ocean ecosystems that are independent of energy from sunlight and photosynthetic organisms. Hydrothermal vents, submarine hot springs, and methane cold seeps rely only on chemical energy and chemosynthetic organisms to support life.

Essential Principle 7.
The ocean is largely unexplored.
Fundamental Concept a. The ocean is the last and largest unexplored place on Earth—less than 5% of it has been explored. This is the great frontier for the next generation's explorers and researchers, where they will find great opportunities for inquiry and investigation.

Fundamental Concept b. Understanding the ocean is more than a matter of curiosity. Exploration, inquiry and study are required to better understand ocean systems and processes.
Fundamental Concept d. New technologies, sensors and tools are expanding our ability to explore the ocean. Ocean scientists are relying more and more on satellites, drifters, buoys, subsea observatories and unmanned submersibles.
Fundamental Concept f. Ocean exploration is truly interdisciplinary. It requires close collaboration among biologists, chemists, climatologists, computer programmers, engineers, geologists, meteorologists, and physicists, and new ways of thinking.

Send Us Your Feedback

In addition to consultation with expedition scientists, the development of lesson plans and other education products is guided by comments and suggestions from educators and others who use these materials. Please send questions and comments about these materials to: oceanexeducation@noaa.gov.

For More Information

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Credit

A Hydrothermal AdVENTure

Hydrothermal Vents Inquiry Guide

Visit the Web sites or other materials provided by your teacher, and answer the following questions:

1. What are hydrothermal vents and how are they formed?

2. How hot is hydrothermal vent fluid?

3. How does the temperature affect the chemical composition of hydrothermal vent fluid?

4. Does seawater boil in hydrothermal vents? Why?

5. What are vent chimneys, and how are they formed?

6. What are "black smokers," and why are they black?

7. What are "white smokers," and why are they white?

8. Hydrothermal vents, volcanoes, and earthquakes often happen at the junction of two of Earth's tectonic plates. Why?