The Galápagos Rift Expedition 2011

But Why Is It Important to Me?

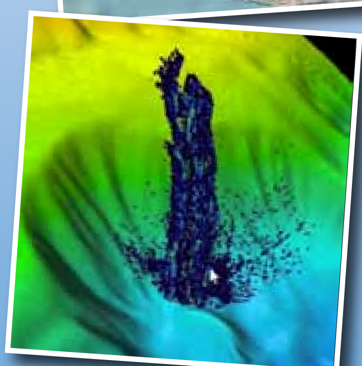


Image captions/credits on Page 2.

lesson plan

Focus

Human benefits from exploration of hydrothermal vent ecosystems

Grade Level

7-8 (Life Science/Physical Science)

Focus Question

How does exploration of deep-ocean ecosystems such as hydrothermal vents benefit humans?

Learning Objectives

- Students will explain at least three ways in which exploration of hydrothermal vent ecosystems can provide direct benefits to humans.

- Students will create presentations to present this information to school audiences.

Materials

- ❑ Copies of *Interview Questions About Ocean Exploration,* one for each student group

Audio-Visual Materials

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

Teaching Time

Two 45-minute class periods

Seating Arrangement

Groups of 3-4 students

Maximum Number of Students

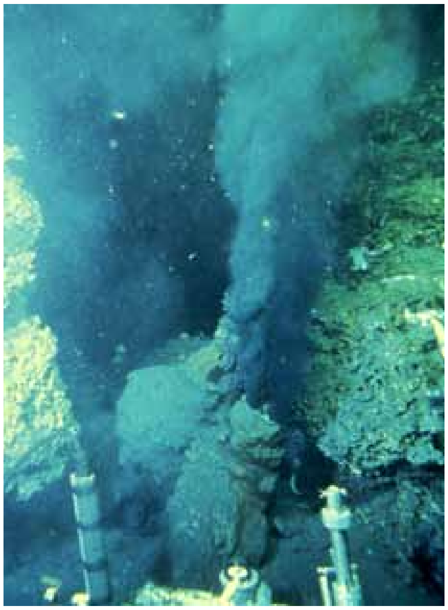
32

Key Words

Galápagos Rift
Hydrothermal vent
Ocean exploration

Background Information

NOTE: Explanations and procedures in this lesson are written at a level appropriate to professional educators. In presenting and discussing this



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

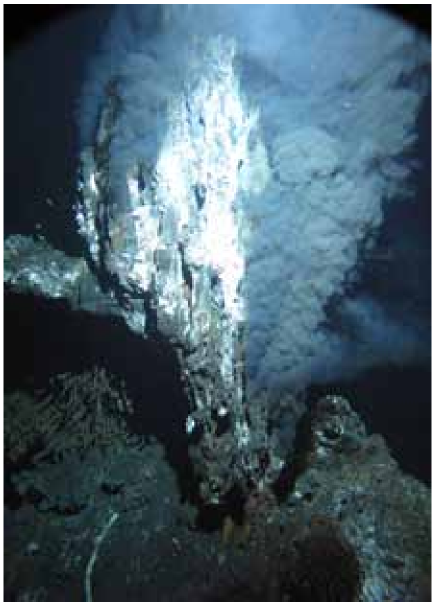
material with students, educators may need to adapt the language and instructional approach to styles that are best suited to specific student groups.

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.



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

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).

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.

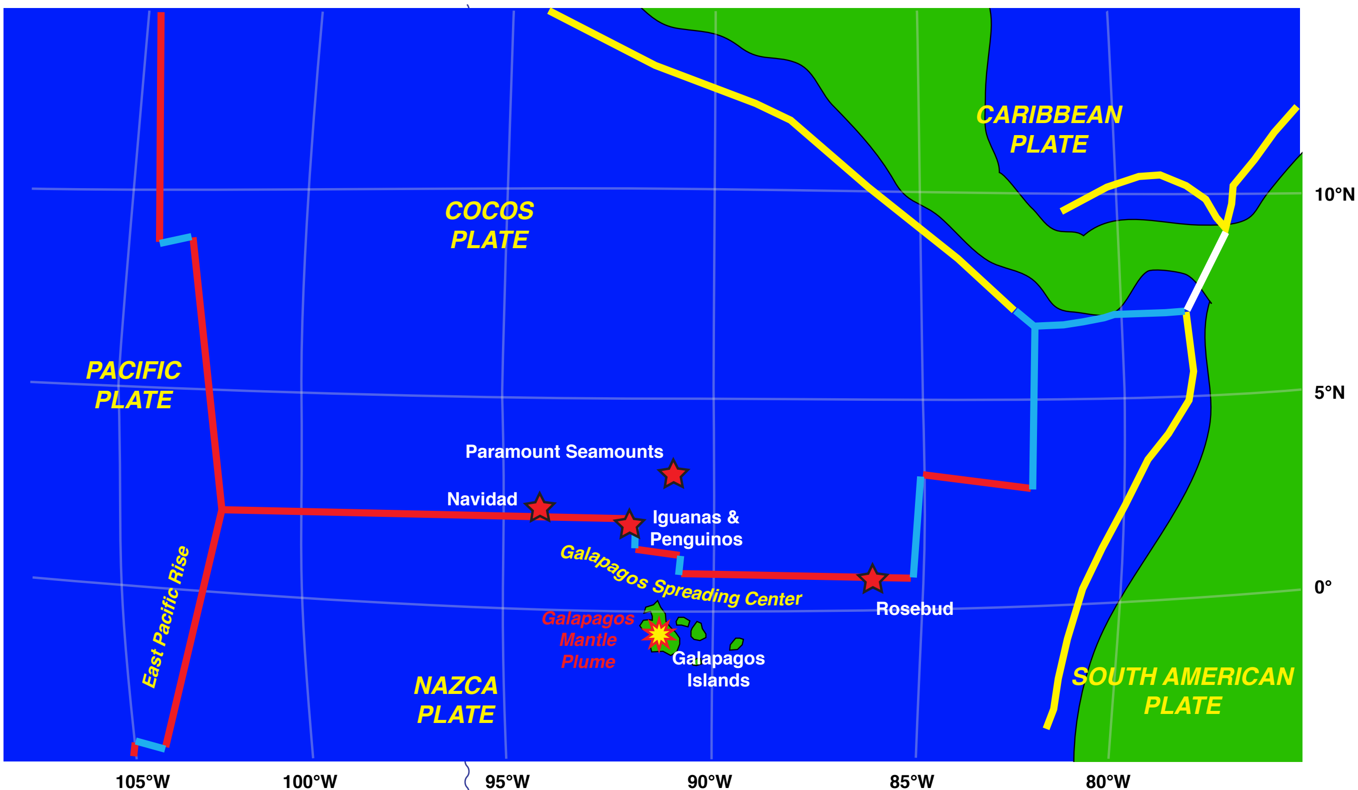


Figure 1. Galápagos Tectonic Setting. Red plate boundaries are divergent; yellow plate boundaries are convergent; blue plate boundaries are transform; white plate boundaries are undetermined. Navidad, Iguanas and Penguinos are locations where black smokers were discovered in 2005. Paramount Seamounts 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)

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.

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

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

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

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!

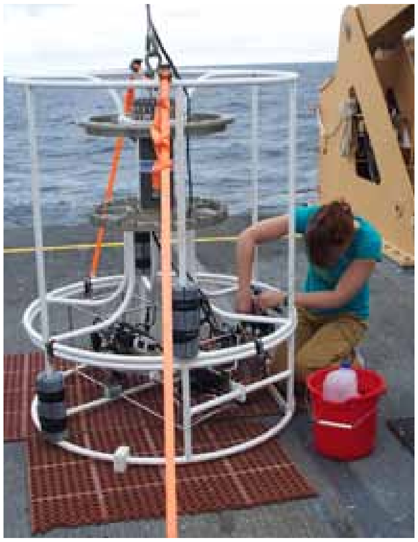
These discoveries set the stage for the Galápagos Rift Expedition 2011, which will use the state-of-the-art exploration capabilities of NOAA Ship *Okeanos Explorer* to obtain detailed information about the biology and geology of Galápagos hydrothermal ecosystems, and determine whether different ecosystems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

Ocean exploration and underlying reasons to explore Earth's ocean are not well-understood. In this lesson, students will investigate how and why scientists are exploring hydrothermal vents and other deep-ocean ecosystems, and will create presentations to communicate this information to school audiences.

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



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

A CTD with water sampling bottles attached to the rosette frame. Image courtesy of NOAA *Okeanos Explorer* Program.

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) (Optional) 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 *Interview Questions About Ocean Exploration* handout, and develop a list of potential audiences for student presentations. Questions 3 and 6 are based on several common misconceptions about science. You may want to review McComas (1996) for further discussion.

2. If students are not familiar with deep-sea chemosynthetic communities, briefly describe the concept of chemosynthesis, and contrast it with photosynthesis. Tell students that chemosynthetic ecosystems in the deep ocean are found where a source of chemical energy is emerging from the ocean floor. If you have decided to use materials referenced in Step 1b, present these now.

3. Briefly introduce the Galapagos Rift Expedition 2011, and the NOAA Ship *Okeanos Explorer*. Say that a primary purpose of the expedition is to search for new hydrothermal vents in unexplored regions of the Galapagos Rift. Ask students for their ideas about why this kind of exploration might be important. At this point, do not mention the reasons discussed in the Background section, but list students' ideas on a whiteboard or flip chart.

4. Say that few people think very much about the deep ocean or understand why its exploration is important. Explain that a very important part of science and exploration is communicating results to other people. For this reason, students have two assignments:
   - First, to find out about some of the reasons that it is important to explore deep-ocean systems such as hydrothermal vents; and

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

- Second, to communicate the results of their research to other people by participating in an interview in which students take on the role of experts who are answering questions asked by the host of a news program.

5. Provide each student group with a copy of the *Interview Questions About Ocean Exploration* handout. Tell students that these questions should guide their research into reasons for exploring deep-ocean systems, and how this exploration is done. You may want to provide some or all of the following resources to get started, but emphasize that there are many other sources of information, and that students should not limit their research to this list:

   NOAA Ship *Okeanos Explorer*, "America's Ship for Ocean Exploration" (http://oceanexplorer.noaa.gov/okeanos/welcome.html#)

   Multiple authors. 2006. Special Issue: The Oceans and Human Health. *Oceanography* 19(2); http://www.tos.org/oceanography/issues/issue_archive/19_2.html

   Multiple authors. 2007. Special Issue on Ocean Exploration. *Oceanography* 20(4); http://www.tos.org/oceanography/issues/issue_archive/20_4.html

   Exploration or Research Science - Where Do We Draw the Line? (http://oceanexplorer.noaa.gov/okeanos/explorations/10index/logs/july22/july22.html)

   McComas, W. 1996. Ten myths of science: Reexamining what we think we know..... School Science & Mathematics (96):10-16; http://www.newyorkscienceteacher.com/sci/files/user-submitted/Misconception1.pdf

6. When students have completed their research, have each group present its results. One way to do this is for the educator to play the role of Interviewer, then address one of the questions to one or more student groups. For evaluation purposes, you may want to have each group provide its answers in writing prior to the verbal interview. When one group has provided its answer to a question, ask other groups if they have anything to add. You may want to arrange to have an audience (other students, faculty, parents, etc) to give the interview more of the flavor of an actual performance.

   Answers to interview questions should include:
   - Hydrothermal vents are underwater hot springs flowing from cracks in the seafloor, in locations where underwater volcanic

processes are active. 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. 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.

When the first hydrothermal vents were discovered in 1977, scientists were surprised to find large numbers of animals that had never been seen before clustered around the vents. Researchers soon discovered that the organisms responsible for this biological abundance do not need photosynthesis, but instead are able to obtain energy from chemical reactions through processes known as chemosynthesis. The most conspicuous animals were large tubeworms, sometimes growing in clusters of millions of individuals. These unusual animals do not have a mouth, stomach, or gut. Instead, they have a large organ called a trophosome that contains chemosynthetic bacteria. The bacteria produce organic molecules that provide nutrition to the tubeworm. A similar symbiotic relationship is found in clams and mussels that have chemosynthetic bacteria living in their gills. Bacteria are also found living independently from other organisms in large bacterial mats. A variety of other organisms are also found in chemosynthetic communities, and probably use tubeworms, mussels, and bacterial mats as sources of food. These include snails, eels, sea stars, crabs, lobsters, isopods, sea cucumbers, and fishes.

- Ocean exploration involves discovering what lies beneath the surface of Earth's ocean. When an unusual feature (anomaly) is found, ocean explorers gather enough information to describe the anomaly and guide more detailed research by future expeditions. In a sense, *Okeanos Explorer* is a path-finding ship, creating a wake of discovery data for other scientists on other ships to conduct subsequent and more detailed investigations. Put another way, exploration is about discovery; research is about understanding.

- A common misconception about science is that experiments are the primary method used to make discoveries. Scientific experiments involve carefully planned procedures together with control and test groups, usually in an effort to establish cause and effect relationships. While experiments are a useful scientific tool, they are not the only way to gain knowledge. The discovery of hydrothermal vents is a good example. Other examples include many discoveries in astronomy that were made through extensive observations rather than experiments.

- The overall exploration strategy used by *Okeanos Explorer* 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 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.
  - Advanced broadband satellite communication that provides the foundation for "telepresence."

  Telepresence allows people to observe and interact with events at a remote location. Live images can be transmitted from the seafloor to scientists ashore, classrooms, newsrooms and living rooms, and opens new educational opportunities that are a major part of *Okeanos Explorer's* mission for the advancement of knowledge. 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.

- Because hydrothermal vents cause changes to the chemistry and physical characteristics of surrounding seawater, these vents are often surrounded by masses of seawater that are distinctly different from normal seawater. These water masses are called plumes, and provide ocean explorers with clues about the location of hydrothermal vents. To search for hydrothermal vents, scientists raise and lower a CTD through several hundred meters near the bottom as the ship slowly cruises over the area being surveyed. This repeated up-and-down motion of the towed CTD resembles the movement of a yo-yo, so this process is called tow-yo operations. During tow-yo operations, scientists may also make maps of the seafloor using multibeam sonar. Next, when CTD data show evidence of a possible plume from a hydrothermal vent, scientists use another type of sonar to look for bubbles and particles in the water column. Finally, when scientists feel they have strong evidence that a hydrothermal vent is in the area, Okeanos Explorer's remotely operated vehicle (ROV) is lowered to the bottom to gather video images of the area, and hopefully provide the first look at a newly discovered vent!

- 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 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.

Besides being a source of useful natural products, we know that
– Earth's ocean regulates our planet's climate and atmosphere;
– The ocean contains resources that can transform the way we obtain energy for human activities, and eliminate many of the negative consequences that result from the ways we presently obtain energy;
– The ocean can produce natural disasters that can wreak havoc on coastal communities and entire nations;
– Humans are now having a measurable impact on ocean life.
And yet, we know nearly nothing about 95% of Earth's ocean. Without exploration, we can't hope to enjoy the potential benefits the ocean has to offer, nor can we prepare for the problems the ocean may send our way.

- Another misconception about science is that scientific theories are inferior to "laws" of science, and don't merit serious attention. In fact, scientific theories and scientific laws are very different kinds of knowledge. Theories do not become laws, no matter how much evidence is assembled. Laws are generalizations about patterns of natural activity; theories are attempts to explain why these patterns exist.

  Confusion about laws and theories leads to another common misconception: that theories can be proven if scientists accumulate enough evidence. In fact, scientists almost never claim to have "proven" anything because they cannot observe every instance in which a theory may operate; and it only takes one exception to call a theory into serious doubt. Scientists' unwillingness to claim absolute proof for a theory does not mean the theory is distrusted; it is an admission that our understanding of nature is incomplete. Even so, well-supported theories can do a very good job of predicting the outcome of future events.

The BRIDGE Connection

www.vims.edu/bridge/ – Click on "Ocean Science Topics" in the menu on the left side of the page, then "Habitats" for activities and links about chemosynthetic ecosystems.

The "Me" Connection

Have students write a brief essay discussing how ocean exploration could be of personal benefit.

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. Take it on the air! If your school doesn't already have one, consider starting a low power broadcasting station. See http://www.hobbybroadcaster.net/index.html for resources and ideas.

Multimedia Discovery Missions

http://oceanexplorer.noaa.gov/edu/learning/welcome.html – Click on the links to Lessons 1, 5, and 6 for interactive multimedia presentations and Learning Activities on Plate Tectonics, Chemosynthesis and Hydrothermal Vent Life, and Deep-Sea Benthos.

Other Relevant Lesson Plans from NOAA's Ocean Exploration Program

How Does Your Magma Grow?
(from the 2005 GalAPAGos: Where Ridge Meets Hotspot Expedition)
http://oceanexplorer.noaa.gov/explorations/05galapagos/background/edu/media/05galapagos_magma.pdf

Focus: Hotspots and mid-ocean ridges (Physical Science)

Students will identify types of plate boundaries associated with movement of the Earth's tectonic plates; compare and contrast volcanic activity associated with spreading centers and hotspots; describe processes which resulted in the formation of the Galápagos Islands; and describe processes that produce hydrothermal vents.

One Tough Worm
(from the 2002 Gulf of Mexico Expedition)
http://oceanexplorer.noaa.gov/explorations/02mexico/background/edu/media/gom_toughworm.pdf

Focus: Physiological adaptations to toxic and hypoxic environments (Life Science)

Students will be able to explain the process of chemosynthesis; explain the relevance of chemosynthesis to biological communities in the vicinity of cold seeps; and describe three physiological adaptations that enhance an organism's ability to extract oxygen from its environment. Students will also be able to describe the problems posed by hydrogen sulfide for aerobic organisms, and explain three strategies for dealing with these problems.

The Tectonic Challenge
(from the INDEX-SATAL 2010 Expedition)
http://oceanexplorer.noaa.gov/okeanos/explorations/10index/background/edu/media/tectonics.pdf

Focus: Plate tectonics (Earth Science)

Students describe the motion of tectonic plates; differentiate between three typical boundary types that occur between tectonic plates; infer the type of boundary that exists between two tectonic plates given information on earthquakes and volcanism in the vicinity of the boundary; and explain the relationship between tectonic plate movements and earthquakes, volcanoes, and tsunamis.

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*; describe how fractal geometry models natural systems, and how scale influences exploration strategy and results.

Mapping the Deep Ocean Floor
(from the *Okeanos Explorer Education Materials Collection, Volume 2: How Do We Explore?*)
http://oceanexplorer.noaa.gov/okeanos/edu/lessonplans/media/hdwe_78_oceanfloor.pdf

Focus: Bathymetric mapping (Physical Science/Earth Science)

Students explain the advantages of multibeam sonar, and its role in the exploration strategy used aboard the *Okeanos Explorer*; and use data from the *Okeanos Explorer* to create a bathymetric map.

Who Promised You a Rose Garden?
(from the 2002 Galápagos Rift Expedition)
http://oceanexplorer.noaa.gov/explorations/02galapagos/background/education/media/gal_gr7_8_l3.pdf

Focus: Biological communities associated with hydrothermal vents along the Galápagos Rift and mapping (Life Science/Earth Science)

Students conduct independent research to discover what types of organisms can survive near hydrothermal vents; learn how organisms living along hydrothermal vents can survive in the absence of sunlight and photosynthesis; and use mapping skills to learn more about the Rose Garden at the Galápagos Rift.

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 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

McComas, W. 1996. Ten myths of science: Reexamining what we think we know..... School Science & Mathematics (96):10-16; http://www.newyorkscienceteacher.com/sci/files/user-submitted/Misconception1.pdf

http://www.hobbybroadcaster.net/index.html – Web site that provides information about the use of low power broadcasting for high school and college campus radio stations

http://sci-toys.com/scitoys/scitoys/radio/am_transmitter.html – Instructions for building a very inexpensive and very low-power radio transmitter

Multiple authors. 2006. Special Issue: The Oceans and Human Health. *Oceanography* 19(2); http://www.tos.org/oceanography/issues/issue_archive/19_2.html

Multiple authors. 2007. Special Issue on Ocean Exploration. *Oceanography* 20(4); http://www.tos.org/oceanography/issues/issue_archive/20_4.html

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
- Motions and forces

Content Standard C: Life Science
- Populations and ecosystems
- Diversity and adaptations of organisms

Content Standard D: Earth and Space Science
- Stucture 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
- Personal health
- Populations, resources, and environments
- Natural hazards
- Risks and benefits
- Science and technology in society

Content Standard G: History and Nature of Science
- Nature of science

Ocean Literacy Essential Principles and Fundamental Concepts

Essential Principle 2.
The ocean and life in the ocean shape the features of the Earth.
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 e. The ocean is three-dimensional, offering vast living space and diverse habitats from the surface through the water column to the seafloor. Most of the living space on Earth is in the ocean.
Fundamental Concept f. Ocean habitats are defined by environmental factors. Due to interactions of abiotic factors such as salinity, temperature, oxygen, pH, light, nutrients, pressure, substrate and circulation, ocean life is not evenly distributed temporally or spatially, i.e., it is "patchy". Some regions of the ocean support more diverse and abundant life than anywhere on Earth, while much of the ocean is considered a desert.
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

But Why Is It Important To Me?

Interview Questions About Ocean Exploration

1. Interviewer:
With me today are four ocean explorers who have recently returned from an expedition aboard the NOAA Ship *Okeanos Explorer* to study deep-sea hydrothermal vents near the Galápagos Islands. To get started, just what are hydrothermal vents anyway?

2. Interviewer:
I understand that the *Okeanos Explorer* is designed specifically for ocean exploration, and this is different from ocean research. Please explain the difference between exploration and research.

3. Interviewer:
So is "exploration" really science? I thought scientists always relied on experiments to make discoveries.

4. Interviewer:
What kinds of ocean exploration technologies are used aboard the *Okeanos Explorer*?

5. Interviewer:
So just how do you go about searching for hydrothermal vents?

6. Interviewer:
OK, you were all out there on the ship with state-of-the-art technology looking for these hydrothermal vents. It really sounds interesting, and I can understand why you are curious about places like this; but why is this kind of exploration important to average people?

7. Interviewer:
You mentioned that the ocean has an influence on our climate. Isn't this just a theory? I mean, scientists haven't actually proven this, have they?