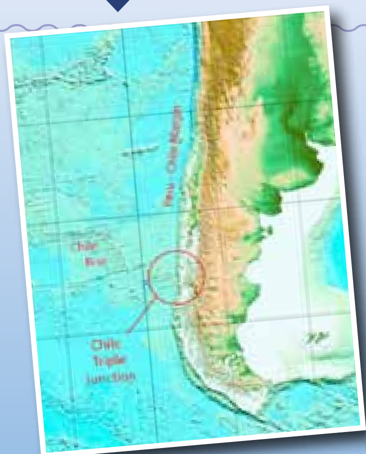
ocean explorer

www.oceanexplorer.noaa.gov



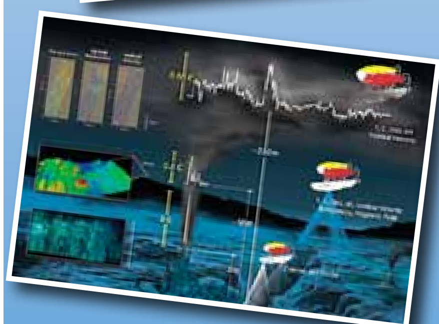


Image captions/credits on Page 2.

lesson plan

INSPIRE: Chile Margin 2010

The Tell-Tale Plume

Focus
Hydrothermal vent chemistry

Grade Level
9-12 (Earth Science/Chemistry/Mathematics)

Focus Question
How do ocean explorers use chemical and physical clues to locate hydrothermal vents in the deep ocean?

Learning Objectives
- Students will describe hydrothermal vents.
- Students will identify changes to the physical and chemical properties of seawater that are caused by hydrothermal vents.
- Students will use oceanographic data to recognize a probable plume from hydrothermal activity.

Materials
- Copies of *Hydrothermal Vent Plume Inquiry Guide* and *Hydrothermal Plume Plotting Sheet*, one for each student group
- Colored pencils or markers

Audio-Visual Materials
- (Optional) video or computer projection equipment to show images from the INSPIRE: Chile Margin 2010 Web page (http://oceanexplorer.noaa.gov/explorations/10chile/welcome.html)

Teaching Time
Two 45-minute class periods, plus time for student assignments

Seating Arrangement
Groups of 3-4 students

Maximum Number of Students
32

Key Words
Hydrothermal vent
Hydrothermal plume
Temperature anomaly

Particle anomaly
Chile Triple Junction

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.

Earthquakes and volcanoes are among Earth's most spectacular and terrifying geological events. The Mount St. Helens eruption of 1980 and the Haiti (7.0 magnitude) and Chile (8.8 magnitude) earthquakes of 2010 are recent and memorable examples of the extreme power that often accompanies these events. The Indian Ocean tsunami of 2004 was caused by an underwater earthquake that is estimated to have released the energy of 23,000 Hiroshima-type atomic bombs, and caused the deaths of more than 150,000 people.

Volcanoes and earthquakes are both linked to movements of 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

Images from Page 1 top to bottom:
Map of the Southeast Pacific Ocean and South American continent showing the Chile Rise spreading center, the Peru-Chile Margin, and the location of the Chile Triple Junction. *Photo credit: INSPIRE: Chile Margin 2010.*
http://oceanexplorer.noaa.gov/explorations/10chile/background/geology/media/geology1.html

Our 3-phased approach to ocean exploration with ABE. First, guided by chemical measurements made aboard ship, we program ABE to fly around within the water column "sniffing" for where the chemical signals are strongest using specialized in situ sensors. Second, once we know where the strongest chemical signals from a hydrothermal vent are, we program ABE to fly closer to the seafloor, making detailed maps of the seabed and, ideally, also intercepting the stems of hot buoyant hydrothermal plumes of water rising up above the seafloor. Third, and finally, we program ABE up once more to descend to right above the seabed and drive to and fro, very carefully – using obstacle avoidance techniques to stop it from crashing into the rough rocky terrain it finds – while taking photographs of whatever it is we have found: hydrothermal vents, cold seeps, and whatever new and unique animals they might host. *Photo credit: Christopher German.*
http://oceanexplorer.noaa.gov/explorations/10chile/background/exploration/media/exploration2.html

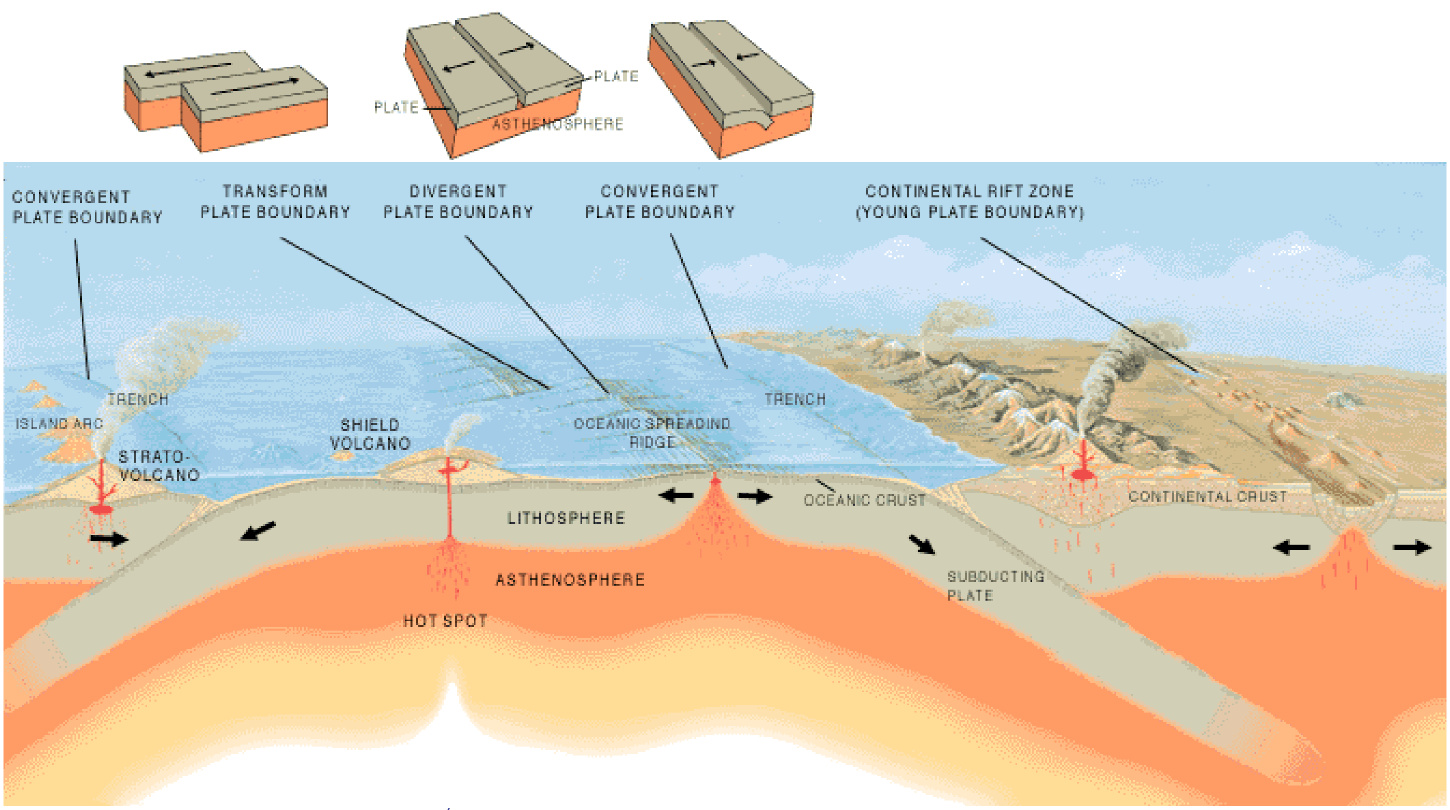
The ABE (Autonomous Benthic Explorer) autonomous underwater vehicle (free-swimming robot) about to be set loose to explore the bottom of the SW Indian Ocean from aboard the Chinese research ship RV Da Yang Yi Hao in Spring 2007. Over the past 5 years, ABE has been used on multiple expeditions to find new hydrothermal vents in the deep ocean all over the world, from New Zealand to South Africa and from Brazil to Ecuador. *Photo credit: Christopher German.*
http://oceanexplorer.noaa.gov/explorations/10chile/background/plan/media/missionplan3.html

A methane hydrate mound on the seafloor; bubbles show that methane is continuously leaking out of features like this. If bottom waters warmed, this entire feature may be destabilized and leak methane at a higher rate. *Photo credit: INSPIRE: Chile Margin 2010.*
http://oceanexplorer.noaa.gov/explorations/10chile/background/methane/media/methane4.html

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 3-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 3-dimensional structure of a mid-ocean ridge at:
http://oceanexplorer.noaa.gov/explorations/03fire/logs/ridge.html.

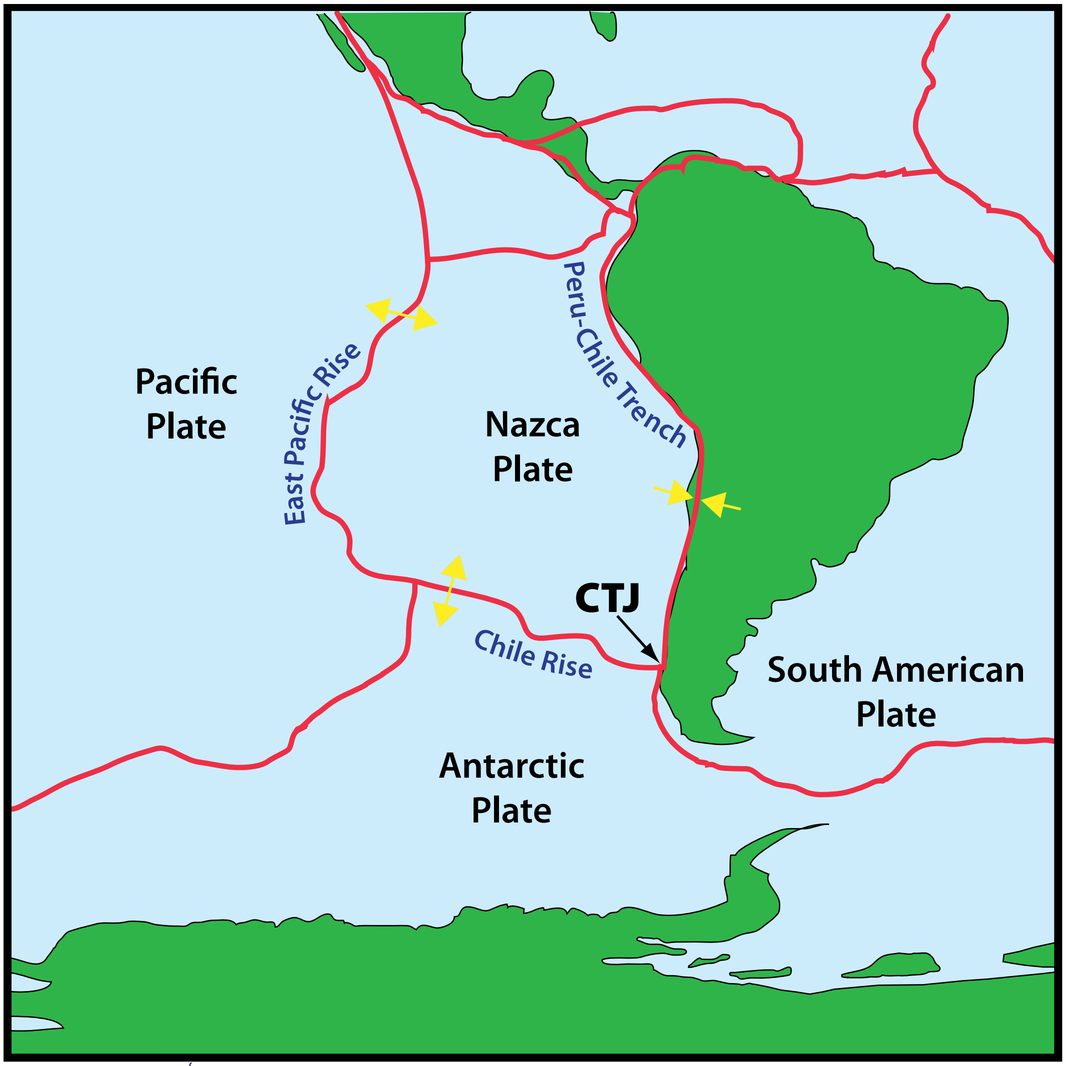
Figure 1: Types of Plate Boundaries



Artist's cross section illustrating the main types of plate boundaries. (*Cross section by José F. Vigil from This Dynamic Planet -- a wall map produced jointly by the U.S. Geological Survey, the Smithsonian Institution, and the U.S. Naval Research Laboratory.*)
http://pubs.usgs.gov/gip/dynamic/Vigil.html

Along the western coast of Chile, three of Earth's tectonic plates intersect in a way that does not occur anywhere else on the planet (see Figure 2). Chile, and the other countries of South America, lie on top of the South American tectonic plate. To the west of Chile, the Nazca Plate extends beneath the Pacific Ocean and meets the Pacific Plate along a divergent plate boundary called the East Pacific Rise. The southern edge of the Nazca Plate adjoins the Antarctic Plate along another

Figure 2: Chile Triple Junction



divergent plate boundary called the Chile Rise. The eastern edge of the Chile Rise is being subducted beneath the South American plate at the Chile Triple Junction (CTJ), which is unique because it consists of a mid-oceanic ridge being subducted under a continental tectonic plate. The eastern portion of the Nazca Plate is also being subducted along the Peru-Chile Trench, and the Andes mountains are one consequence of this process. Not surprisingly, complex movements of three tectonic plates at the CTJ result in numerous earthquakes. In fact, the largest earthquake ever recorded (magnitude 9.5) occurred along the Peru-Chile Trench in 1960. While earthquakes and volcanoes are often associated with massive destruction and loss of human life, the same processes that cause these events are also responsible for producing unique habitats for very different life forms.

One of the most exciting and significant scientific discoveries in the history of ocean science was made in 1977 at a divergent plate boundary near the Galapagos Islands. Here, researchers found large numbers of animals that had never been seen before clustered around underwater hot springs flowing from cracks in the lava seafloor. Similar hot springs, known as hydrothermal vents, have since been found in many other locations where underwater volcanic processes are active. Hydrothermal vents are formed when the movement of tectonic plates causes deep cracks to form in the ocean floor. Seawater flows into these cracks, is heated by magma, and then rises back to the surface of the seafloor. The water does not boil because of the high pressure in the deep ocean, but may reach temperatures higher than 350° C. This superheated water dissolves minerals in Earth's crust. Hydrothermal vents are locations where the superheated water erupts through the seafloor. The temperature of the surrounding water is near-freezing, which causes some of the dissolved minerals to precipitate from the solution. This makes the hot water plume look like black smoke, and in some cases the precipitated minerals form chimneys or towers.

Although 30 years have passed since the discovery of the first hydrothermal vents, more than 90% of the global ridge crest still has not been explored for the presence or absence of hydrothermal activity (German *et al.*, 2008). A primary purpose of the INSPIRE: Chile Margin 2010 expedition is to locate new chemosynthetic ecosystems near the CTJ. Because hydrothermal vents and cold-seeps cause changes to the chemistry and physical characteristics of surrounding seawater, these geologic features 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 these clues, scientists use a package of electronic instruments called a CTD, which stands for conductivity, temperature, and depth. Often, CTDs are attached to a much larger metal frame called a rosette, which also holds water sampling bottles that are used to collect water at different depths, and may also carry other instruments that can measure additional physical or chemical properties. Plumes are usually found within a few hundred meters of the ocean floor. Since many hydrothermal vent locations are several thousand meters deep, ocean explorers usually raise and lower a CTD rosette 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 may resemble the movement of a yo-yo; a resemblance that has led to the nickname "tow-yo" for this type of CTD sampling. See http://oceanexplorer.noaa.gov/technology/tools/sonde_ctd/sondectd.html and http://www.pmel.noaa.gov/vents/PlumeStudies/WhatIsACTD/CTDMethods.html for more information.

Learning Procedure

1. To prepare for this lesson:
   (a) Review introductory essays for the INSPIRE: Chile Margin 2010 Expedition at http://oceanexplorer.noaa.gov/explorations/10chile/welcome.html.
   (b) Review questions on the *Hydrothermal Vent Plume Inquiry Guide*, and procedures for plotting optical back-scatter data.

2. Introduce the the INSPIRE: Chile Margin 2010 Expedition. If students are not familiar with hydrothermal vents, provide a brief overview, highlighting the processes that lead to their formation, and that vent fluids are extremely hot and are enriched with minerals dissolved from rock in Earth's crust. You may want to show images or video of vents from http://www.pmel.noaa.gov/vents/multimedia.html. Tell students that a primary objective of the INSPIRE: Chile Margin 2010 Expedition is to locate previously undiscovered hydrothermal vents in the vicinity of the Chile Triple Junction. Briefly describe a CTD, emphasizing that these devices are often capable of measuring many other parameters in addition to conductivity, temperature, and depth. You may want to use information and/or images from http://www.pmel.noaa.gov/vents/PlumeStudies/WhatIsACTD/CTDMethods.html.

   Say that their assignment is to investigate some of the methods used to prospect for new vent systems, and analyze oceanographic data from a hydrothermal vent site on the Mid-Atlantic Ridge.

3. Provide each student group with a copy of the *Hydrothermal Vent Plume Inquiry Guide*. You may need to explain the graphing technique involved in the data analysis portion of the Guide, since students may not have previously encountered this technique.

4. When students have completed the *Inquiry Guide*, lead a discussion of their results. This following points should be included:
   - A hydrothermal vent is a hot spring on the ocean floor caused by magma heating seawater that has entered cracks in the seafloor.
   - A hydrothermal fluid is seawater that has been heated and altered by interaction with rock in Earth's crust.
   - A hydrothermal plume is hydrothermal fluid that has been injected into the ocean at hydrothermal vent fields.
   - Hydrothermal plumes are often colored white or black by mineral particles that precipitate as hot hydrothermal fluids mix with cold seawater.

- Hydrothermal plumes can be detected in seawater surrounding hydrothermal vent fields because the plumes have a distinctly different physical and chemical properties from the surrounding seawater.

- Heat, particle content, and concentration of chemicals contained in vent fluids are some of the physical or chemical properties that may be used to detect hydrothermal plumes.

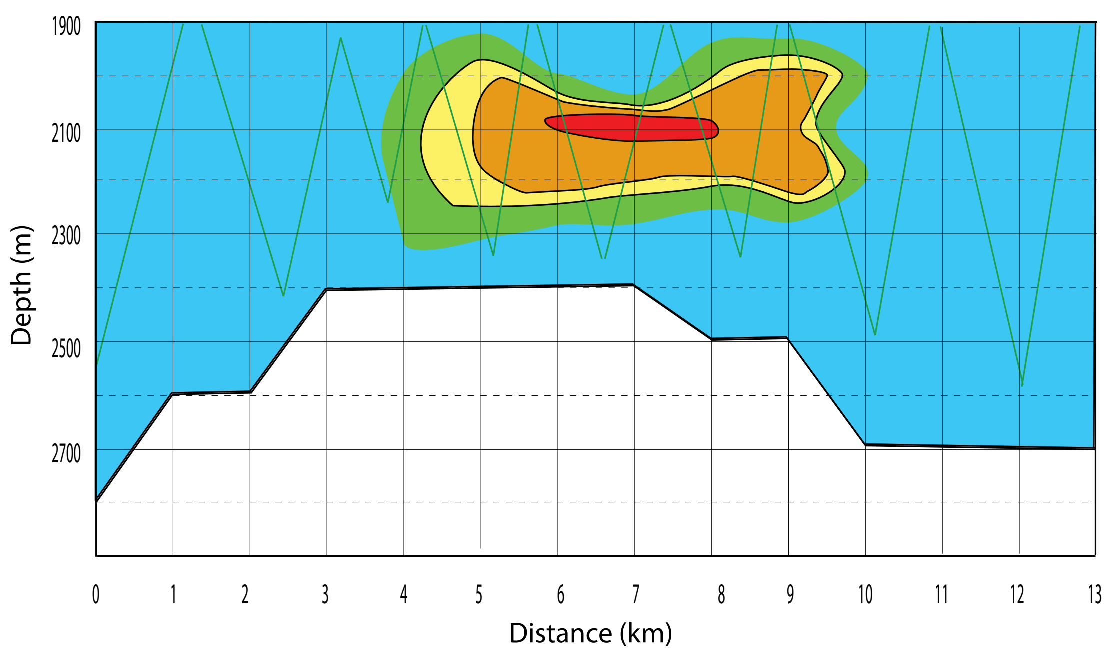
- A Temperature Anomaly is a difference in temperature between a hydrothermal plume and the surrounding seawater.

- A Particle Anomaly is a difference in the concentration of suspended particles in a hydrothermal plume compared to the surrounding seawater.

- Temperature and particle anomalies are created when seawater is heated by magma to temperatures that are much higher than normal deep ocean temperatures. The heated water dissolves minerals from rocks in Earth's crust. When hydrothermal fluid emerges into the ocean at hydrothermal vents, many of these minerals precipitate out of solution. Some of these precipitates remain suspended in hydrothermal plumes and may be transported tens of kilometers away from the vent site.

Have each group present and discuss their plots of LSS data. Students should infer that the data suggest that a hydrothermal plume was present between depths of about 2000 to 2300 m. The probable location of the hydrothermal vent that produced this plume is between 6 and 8 km along the survey track. Figure 1 illustrates a plot of data in Table 1.

Figure 1.



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 short essay discussing how studies of plate tectonics and hydrothermal vents might be of personal benefit.

Connections to Other Subjects

English/Language Arts

Assessment

Written reports and class discussions provide opportunities for assessment.

Extensions

1. Visit http://oceanexplorer.noaa.gov/explorations/10chile/welcome.html for the latest activities and discoveries by the INSPIRE: Chile Margin 2010 Expedition.
2. Visit http://oceanexplorer.noaa.gov/edu/learning/welcome.html for interactive multimedia presentations and Learning Activities on Plate Tectonics, Mid-Ocean Ridges, Subduction Zones, and Chemosynthesis and Hydrothermal Vent Life. Click on links to Lessons 1, 2, 4, and 5 respectively.

Other Relevant Lesson Plans from NOAA's Ocean Exploration Program

My Wet Robot

(PDF, 300 kb) (from the Bonaire 2008: Exploring Coral Reef Sustainability with New Technologies Expedition)

http://oceanexplorer.noaa.gov/explorations/08bonaire/background/edu/media/wetrobot.pdf

Focus: Underwater Robotic Vehicles (Physical Science)

Students will be able to discuss the advantages and disadvantages of using underwater robots in scientific explorations, identify key design requirements for a robotic vehicle that is capable of carrying out specific exploration tasks, describe practical approaches to meet identified design requirements, and (optionally) construct a robotic vehicle capable of carrying out an assigned task.

Sound Pictures
(PDF, 1 Mb) (from the *Lophelia* II 2009: Deepwater Coral Expedition: Reefs, Rigs, and Wrecks)
http://oceanexplorer.noaa.gov/explorations/09lophelia/welcome.html

Focus: Sonar (Physical Science)

In this activity, students will explain the concept of sonar, describe the major components of a sonar system, explain how multibeam and sidescan sonar systems are useful to ocean explorers, and simulate sonar operation using a motion detector and a graphing calculator.

Chemosynthesis for the Classroom
(PDF, 274 kb) (from the 2002 Gulf of Mexico Expedition)
http://oceanexplorer.noaa.gov/explorations/02mexico/background/edu/media/gom_chemo_gr912.pdf

Focus: Chemosynthetic bacteria and succession in chemosynthetic communities (Chemistry/Biology)

Students will observe the development of chemosynthetic bacterial communities and will recognize that organisms modify their environment in ways that create opportunities for other organisms to thrive. Students will also be able to explain the process of chemosynthesis and the relevance of chemosynthesis to biological communities in the vicinity of cold seeps.

Hydrothermal Vent Challenge
(PDF, 412 kb) (from the Submarine Ring of Fire 2004 Expedition)
http://oceanexplorer.noaa.gov/explorations/04fire/background/edu/media/RoF.ventchall.pdf

Focus: Chemistry of hydrothermal vents (Chemistry)

Students will be able to define hydrothermal vents and explain the overall processes that lead to their formation. Students will be able to explain the origin of mineral-rich fluids associated with hydrothermal vents. Students will be able to explain how black smokers and white smokers are formed. Students will be able to hypothesize how properties of hydrothermal fluids might be used to locate undiscovered hydrothermal vents.

Lost City Chemistry Detectives
(PDF, 326 kb) (from the Lost City 2005 Expedition)
http://oceanexplorer.noaa.gov/explorations/05lostcity/background/edu/media/lostcity05_chemdetect.pdf

Focus: Chemistry of the Lost City Hydrothermal Field (Chemistry/Earth Science)

Students will be able to compare and contrast the formation processes that produce black smokers and the Lost City hydrothermal field, describe the process of serpentinization and how this process contributes to formation of chimneys at the Lost City hydrothermal field, and describe and explain the chemical reactions that produce hydrogen and methane in Lost City hydrothermal vent fluids.

Massif Mystery
(PDF, 327 kb) (from the Lost City 2005 Expedition)
http://oceanexplorer.noaa.gov/explorations/05lostcity/background/edu/media/lostcity05_massif.pdf

Focus: (Earth Science) Structure and Origin of the Atlantis Massif

Students will be able to compare and contrast basalt, gabbro, and peridotite; explain what the presence of these rocks may suggest about the origin of formations where they are found; and describe and interpret research data that suggest possible origins of the Atlantis Massif.

Where There's Smoke, There's...
(PDF, 248 kb) (from the New Zealand American Submarine Ring of Fire 2005 Expedition)
http://oceanexplorer.noaa.gov/explorations/05fire/background/edu/media/rof05_smoke.pdf

Focus: Hydrothermal vent chemistry at subduction volcanoes (Chemistry)

Students will be able to use fundamental relationships between melting points, boiling points, solubility, temperature, and pressure to develop plausible explanations for observed chemical phenomena in the vicinity of subduction volcanoes.

Where's My 'Bot?
(PDF, 492 kb) (from the Bonaire 2008: Exploring Coral Reef Sustainability with New Technologies Expedition)
http://oceanexplorer.noaa.gov/explorations/08bonaire/background/edu/media/wheresbot.pdf

Focus: Marine Navigation (Earth Science/Mathematics)

In this activity, students will estimate geographic position based on speed and direction of travel, and integrate these calculations with GPS data to estimate the set and drift of currents.

Thar She Blows!
(PDF, 456 kb) (from the 2002 Galapagos Rift Expedition)
http://oceanexplorer.noaa.gov/explorations/02galapagos/background/education/media/gal_gr9_12_l3.pdf

Focus: Hydrothermal vents

In this activity, students will demonstrate an understanding of how the processes that result in the formation of hydrothermal vents create new ocean floor; students will demonstrate an understanding of how the transfer of energy effects solids and liquids.

The Big Burp: Where's the Proof?
(PDF, 364 kb) (from the Expedition to the Deep Slope 2007 Expedition)
http://oceanexplorer.noaa.gov/explorations/07mexico/background/edu/media/burp.pdf

Focus: Potential role of methane hydrates in global warming (Earth Science)

In this activity, students will be able to describe the overall events that occurred during the Cambrian explosion and Paleocene extinction events and will be able to define methane hydrates and hypothesize how these substances could contribute to global warming. Students will also be able to describe and explain evidence to support the hypothesis that methane hydrates contributed to the Cambrian explosion and Paleocene extinction events.

The Census of Marine Life
(PDF, 300 kb) (from the 2007: Exploring the Inner Space of the Celebes Sea Expedition]
http://oceanexplorer.noaa.gov/explorations/07philippines/background/edu/media/census.pdf

Focus: The Census of Marine Life (Biology)

In this activity, students will be able to describe the Census of Marine Life (CoML) and explain in general terms the CoML strategy for assessing and explaining the changing diversity, distribution and abundance of marine species from the past to the present, and for projecting the future of marine life. Students will also be able to use the Ocean Biogeographic Information System to retrieve information about ocean species from specific geographic areas.

The Galapagos Spreading Center
(PDF, 480 kb) (from the 2002 Galapagos Rift Expedition)
http://oceanexplorer.noaa.gov/explorations/02galapagos/background/education/media/gal_gr9_12_l2.pdf

Focus: Mid-Ocean Ridges (Earth Science)

Students will be able to describe the processes involved in creating new seafloor at a mid-ocean ridge; students will investigate the Galapagos Spreading Center system; students will understand the different types of plate motion associated with ridge segments and transform faults.

The Roving Robotic Chemist
(PDF, 440 kb) (from the PHAEDRA 2006 Expedition)
http://oceanexplorer.noaa.gov/explorations/06greece/background/edu/media/robot_chemist.pdf

Focus: Mass Spectrometry (Physical Science)

In this lesson, students will be able to explain the basic principles underlying mass spectrometry, discuss the advantages of in-situ mass spectrometry, explain the concept of dynamic re-tasking as it applies to an autonomous underwater vehicle, and develop and justify a sampling strategy that could be incorporated into a program to guide an AUV searching for chemical clues to specific geologic features.

This Life Stinks
(PDF, 276 kb) (from the 2003 Windows to the Deep Expedition)
http://oceanexplorer.noaa.gov/explorations/03windows/background/education/media/03win_lifestinks.pdf
Focus: Methane-based chemosynthetic processes (Physical Science)

Students will be able to define the process of chemosynthesis, and contrast this process with photosynthesis. Students will also explain the process of methane-based chemosynthesis and explain the relevance of chemosynthesis to biological communities in the vicinity of cold seeps.

This Old Tubeworm
(PDF, 484 kb) (from the 2002 Gulf of Mexico Expedition)
http://oceanexplorer.noaa.gov/explorations/02mexico/background/edu/media/gom_oldtube.pdf

Focus: Growth rate and age of species in cold-seep communities

In this activity, 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 construct a graphic interpretation of age-specific growth, given data on incremental growth rates of different-sized individuals of the same species. Students will also be able to estimate the age of an individual of a specific size, given information on age-specific growth in individuals of the same species.

Where Did They Come From?
(PDF, 296 kb) (from the 2005 GalAPAGoS: Where Ridge Meets Hotspot Expedition)
http://oceanexplorer.noaa.gov/explorations/05galapagos/background/edu/media/05galapagos_biogeography.pdf

Focus: Species variation in hydrothermal vent communities (Life Science)

Students will define and describe biogeographic provinces of hydrothermal vent communities, identify and discuss processes contributing to isolation and species exchange between hydrothermal vent communities, and discuss characteristics which may contribute to the survival of species inhabiting hydrothermal vent communities.

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/explorations/10chile/welcome.html – Web site for the INSPIRE: Chile Margin 2010 Expedition

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

Yoerger, D., A. Bradley, M. Jakuba, M. Tivey, C. German, T. Shank, R. Embley. 2007. Mid-ocean ridge exploration with an autonomous underwater vehicle. Oceanography 20(4):52-61(available online at http://www.tos.org/oceanography/issues/issue_archive/issue_pdfs/20_4/20.4_yoerger_et_al.pdf)

German, C., D. Yoerger, M. Jakuba, T. Shank, C. Langmuir, K. Nakamura. 2008. Hydrothermal exploration with the Autonomous Benthic Explorer. Deep-Sea Research I 55:203-219

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
- Chemical reactions
- Motions and forces

Content Standard D: Earth and Space Science
- Energy in the Earth system
- Geochemical cycles

Content Standard E: Science and Technology
- Abilities of technological design

Content Standard F: Science in Personal and Social Perspectives
- Natural resources
- Natural and human-induced hazards

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. 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.

Essential Principle 5.
The ocean supports a great diversity of life and ecosystems.
Fundamental Concept e. Tectonic activity, sea level changes, and force of waves influence the physical structure and landforms of the coast.
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

We value your feedback on this lesson.
Please send your comments to:
oceanexeducation@noaa.gov

For More Information

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The Tell-Tale Plume

Hydrthermal Vent Plume Inquiry Guide

Background

These Web pages will help answer the following questions:

http://www.pmel.noaa.gov/vents/PlumeStudies/plumes-whatis.html – What is a Hydrothermal Plume?

http://www.pmel.noaa.gov/vents/PlumeStudies/AnomalyPage.html

1. What is a hydrothermal vent?

2. What is a hydrothermal fluid?

3. What is a hydrothermal plume?

4. Why are hydrothermal plumes often colored white or black?

5. Why is it possible to detect hydrothermal plumes in seawater surrounding hydrothermal vent fields?

6. What are some physical or chemical properties that may be used to detect hydrothermal plumes?

7. What is a Temperature Anomaly?

8. What is a Particle Anomaly?

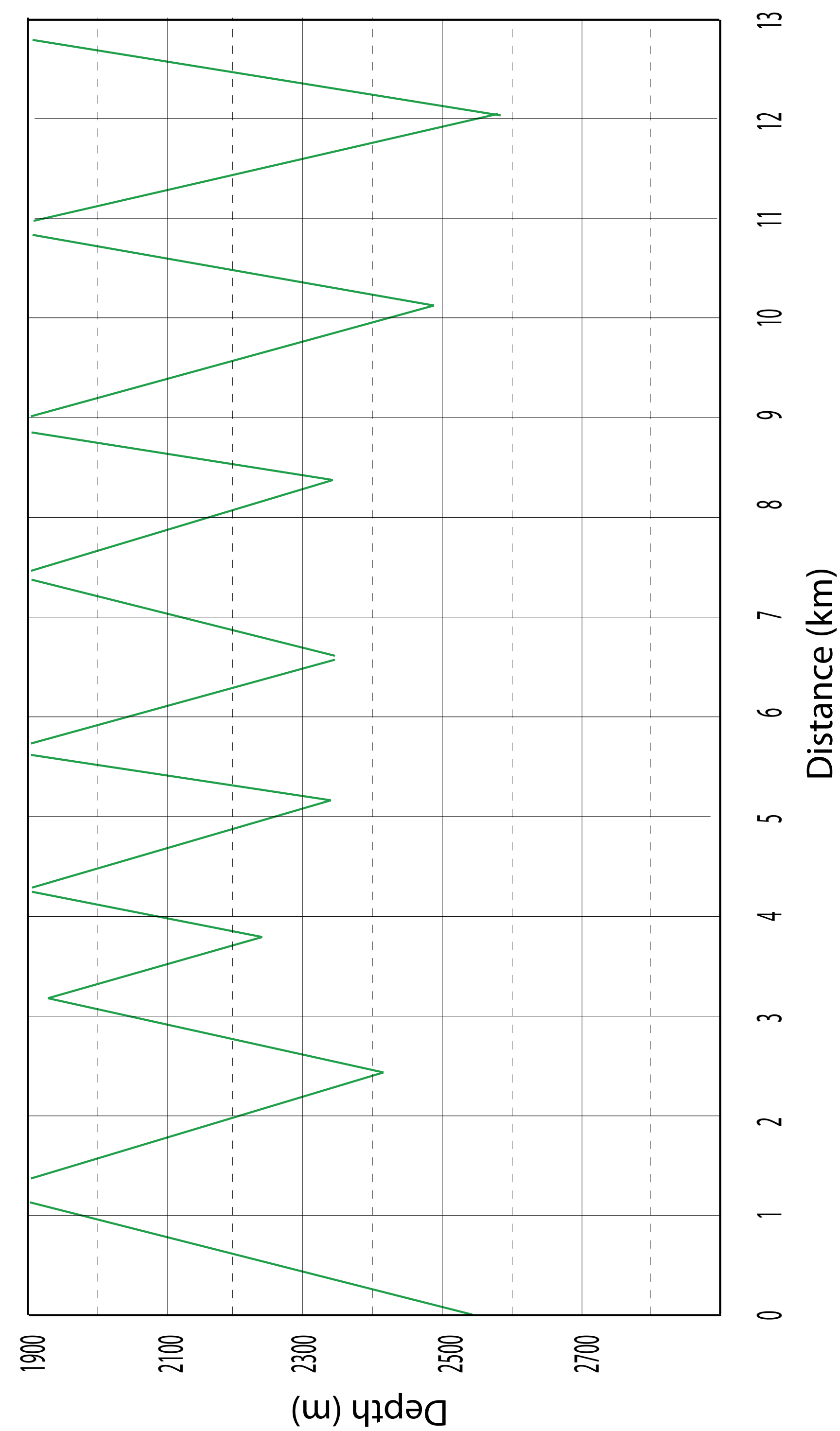
9. What happens at hydrothermal vent sites to cause temperature anomalies and particle anomalies?

Analyze

Particle anomalies are often found with electronic instruments that measure the amount of light that is scattered by a solution (called optical back-scatter). The amount of scattering is proportional to the concentration of suspended particles in the solution. One such instrument is called a Light Scatter Sensor (LSS), whose output increases as light scattering increases. Table 1 contains data from a LSS survey of a section of the Mid-Atlantic Ridge (MAR). The Table gives LSS readings at 1 km intervals over a 13 km-long section of the MAR. For each interval, LSS readings were obtained in 100 m intervals beginning at a depth of 1900 m down to the ocean floor.

Plot these data by entering each LSS value on the *Hydrothermal Plume Plotting Sheet*. The green line on the Plotting Sheet shows the path of the tow-yo that was used to obtain the LSS data. When all values have been entered, draw a line that connects points where the LSS values equal 50 mv. You will have to estimate these points. If one of your plotted LSS values is 45, and it is next to a plotted value of 57, you would estimate that the point corresponding to an LSS value of 50 is about halfway between the two plotted points. Next, draw a line that connects points where the LSS values equal 60 mv. Again, you will need to interpolate. Continue this procedure to draw two more lines for LSS values of 90 mv and 110 mv. Finally, color the Plotting Sheet so that areas with LSS values of 50 mv or less are one color, areas with LSS values between 50 and 60 mv are another color, and so on for LSS values between 60 and 90 mv, 90 and 110 mv, and greater than 110 mv. What do these data suggest about the possible location of a hydrothermal vent?

Hydrothermal Plume Plotting Sheet



The Tell-Tale Plume

Hydrothermal Vent Plume Inquiry Guide

Table 1. Light Scatter Sensor Data from a Section of the Mid-Atlantic Ridge

Interval (km)	Depth (m)	LSS (mv)	Interval (km)	Depth (m)	LSS (mv)	Interval (km)	Depth (m)	LSS (mv)
0	1900	35	5	1900	40	10	2400	40
0	2000	40	5	2000	93	10	2500	40
0	2100	40	5	2100	105	10	2600	ND
0	2200	40	5	2200	81	10	2700	BOTTOM
0	2300	45	5	2300	57			
0	2400	40	5	2400	BOTTOM	11	1900	40
0	2500	45				11	2000	40
0	2600	40	6	1900	40	11	2100	45
0	2700	ND	6	2000	45	11	2200	40
0	2800	BOTTOM	6	2100	117	11	2300	40
			6	2200	105	11	2400	40
1	1900	35	6	2300	40	11	2500	40
1	2000	40	6	2400	BOTTOM	11	2600	40
1	2100	40				11	2700	BOTTOM
1	2200	40	7	1900	35			
1	2300	40	7	2000	40	12	1900	40
1	2400	40	7	2100	117	12	2000	45
1	2500	45	7	2200	81	12	2100	45
1	2600	BOTTOM	7	2300	45	12	2200	40
			7	2400	BOTTOM	12	2300	40
2	1900	40				12	2400	40
2	2000	40	8	1900	35	12	2500	40
2	2100	40	8	2000	69	12	2600	40
2	2200	40	8	2100	117	12	2700	BOTTOM
2	2300	40	8	2200	69			
2	2400	40	8	2300	45	13	1900	40
2	2500	ND	8	2400	40	13	2000	45
2	2600	BOTTOM	8	2500	BOTTOM	13	2100	45
						13	2200	40
3	1900	35	9	1900	40	13	2300	40
3	2000	35	9	2000	93	13	2400	40
3	2100	35	9	2100	57	13	2500	ND
3	2200	40	9	2200	81	13	2600	ND
3	2300	45	9	2300	40	13	2700	BOTTOM
3	2400	BOTTOM	9	2400	40			
			9	2500	BOTTOM			
4	1900	35						
4	2000	57	10	1900	40			
4	2100	69	10	2000	587			
4	2200	69	10	2100	45			
4	2300	57	10	2200	57			
4	2400	BOTTOM	10	2300	45			

ND = No data