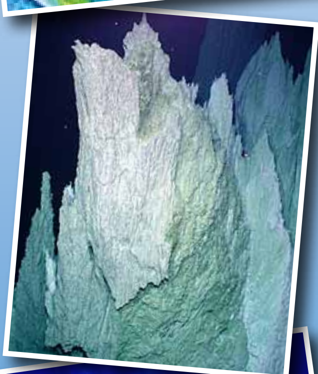
The Mid-Cayman Rise Expedition 2011

Tracking Down the Vents



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lesson plan

Focus

Plumes from hydrothermal vents

Grade Level

7-8 (Physical Science)

Focus Question

How does the principle of buoyancy help ocean explorers find hydrothermal vents?

Learning Objectives

- Students will be able to compare and contrast buoyant and nonbuoyant hydrothermal vent plumes.
- Students will be able to explain how buoyant plumes become neutrally buoyant.
- Students will be able to explain how ocean explorers can predict the source of a hydrothermal vent plume if they know the altitude of a plume above the seafloor.
- Students will be able to demonstrate how hydrothermal vent plumes can be detected from chemical clues.

Materials

- *Technical Reading – Notes on Hydrothermal Vent Plumes Worksheet*; one copy for each student
- *Hydrothermal Vent Plume Inquiry Guide* and *Plume Sniffer Challenge Guided Design Portfolio Sheet*; one copy for each student group

Audio-Visual Materials

- 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
Hydrothermal vent
Plume
Buoyant Plume
CTD

Background Information
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.

One of the most exciting and significant scientific discoveries in the history of ocean science was made in 1977, deep on the ocean floor near the Galápagos 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 seawater flows into deep cracks in the ocean floor, is heated by molten rock to temperatures that may be higher than 350° C, and then rises back to the surface to form hydrothermal vents where the superheated water erupts through the seafloor. The presence of thriving biological communities in the deep ocean was a complete surprise, because it was assumed that food energy resources would be scarce in an environment without sunlight to support photosynthesis. 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. Photosynthesis and chemosynthesis both require a source of energy that is transferred through a series of chemical reactions into organic molecules that living organisms may use as food. In photosynthesis, light provides this energy. In chemosynthesis, the energy comes from other chemical reactions.

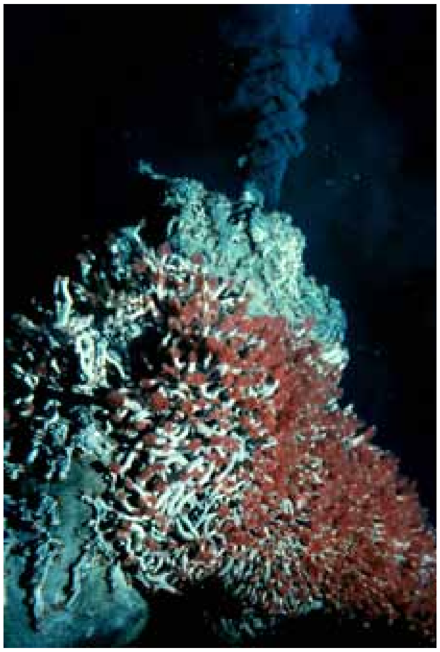
Deepwater biological communities associated with hydrothermal vents are fundamentally different from other biological systems, and there are many unanswered questions about the individual species and interactions between species found in these communities. These species include some of the most primitive living organisms (Archaea) that some scientists believe may have been the first life forms on Earth. Many species are new to science, and may prove to be important sources of unique drugs for the treatment of human diseases. Although much remains to be learned, new drugs and other useful products have already been discovered in hydrothermal vent organisms. At present, almost

Images from Page 1 top to bottom:
The Mid Cayman Rise (MCR) is an undersea ridge deep in the Caribbean Sea at the tectonic boundary where the North American Plate and the Caribbean Plate are spreading apart. (Map courtesy of NOAA)
http://www.whoi.edu/oceanus/viewImage.do?id=125232&aid=86988

Typical morphology of active chimney at Lost City on the Mid Cayman Rise showing multiple, delicate pinnacles of young carbonate material. The tall, white, carbonate structures emit clear, warm fluids that form no particles in the water. The fluids coming out of these chimneys have very high pH (10-11) and maximum temperatures of less than 100°C. Image courtesy of Lost City 2003, University of Washington.
http://oceanexplorer.noaa.gov/explorations/05lostcity/background/chem/media/active.html

Colonies of microbes are attached to carbonate material from within the chimney walls. There are microbes that eat methane and help to counter-balance the methane production of the methanogens (organisms that generate methane). Some colonies form filamentous strands, such as the one shown in the far right of this microphotograph. Each small dot (microbe) that makes up the strand is about 1 micron in size. Image courtesy of University of Washington.
http://oceanexplorer.noaa.gov/explorations/05lostcity/background/overview/media/fig8microbe.jpg

Black smokers are formed when volcanic action emits metal sulfides. The calcium carbonate white chimneys at Lost City were formed when fluids with a very high pH and calcium content mixed with seawater. This vigorously venting black smoker, called Sully, emits jets of particle-laden fluids that create the "black smoke". The particles are predominantly very fine-grained sulfide minerals formed when the hot hydrothermal fluids mix with near freezing seawater. Image courtesy of University of Washington.
http://oceanexplorer.noaa.gov/explorations/05lostcity/background/chem/media/sully2.html



Part of a 360°C black smoker chimney in the Main Endeavour hydrothermal field on the Juan de Fuca Ridge in the N.E. Pacific Ocean. Black smokers have now been found throughout the mid-ocean ridge spreading system. Since their discovery, the billowing 360°C jets of metal sulfide- and gas-laden fluids were believed to typify submarine hot spring systems. They are oases for colonies of animals such as tubeworms, giant clams, and spider crabs whose symbionts depend on volcanic gases such as carbon dioxide (CO_2) for survival. Vibrant colonies of tube worms with red gills thrive on this large edifice, which is predominantly composed of iron- and sulfur-bearing minerals. Image courtesy of University of Washington.
http://oceanexplorer.noaa.gov/explorations/05lostcity/background/overview/media/fig2strawberry.jpg

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 *Thermus thermophylus*, a microorganism that is adapted to live under extremely high temperature conditions near hydrothermal vents. One of these adaptations is a 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.

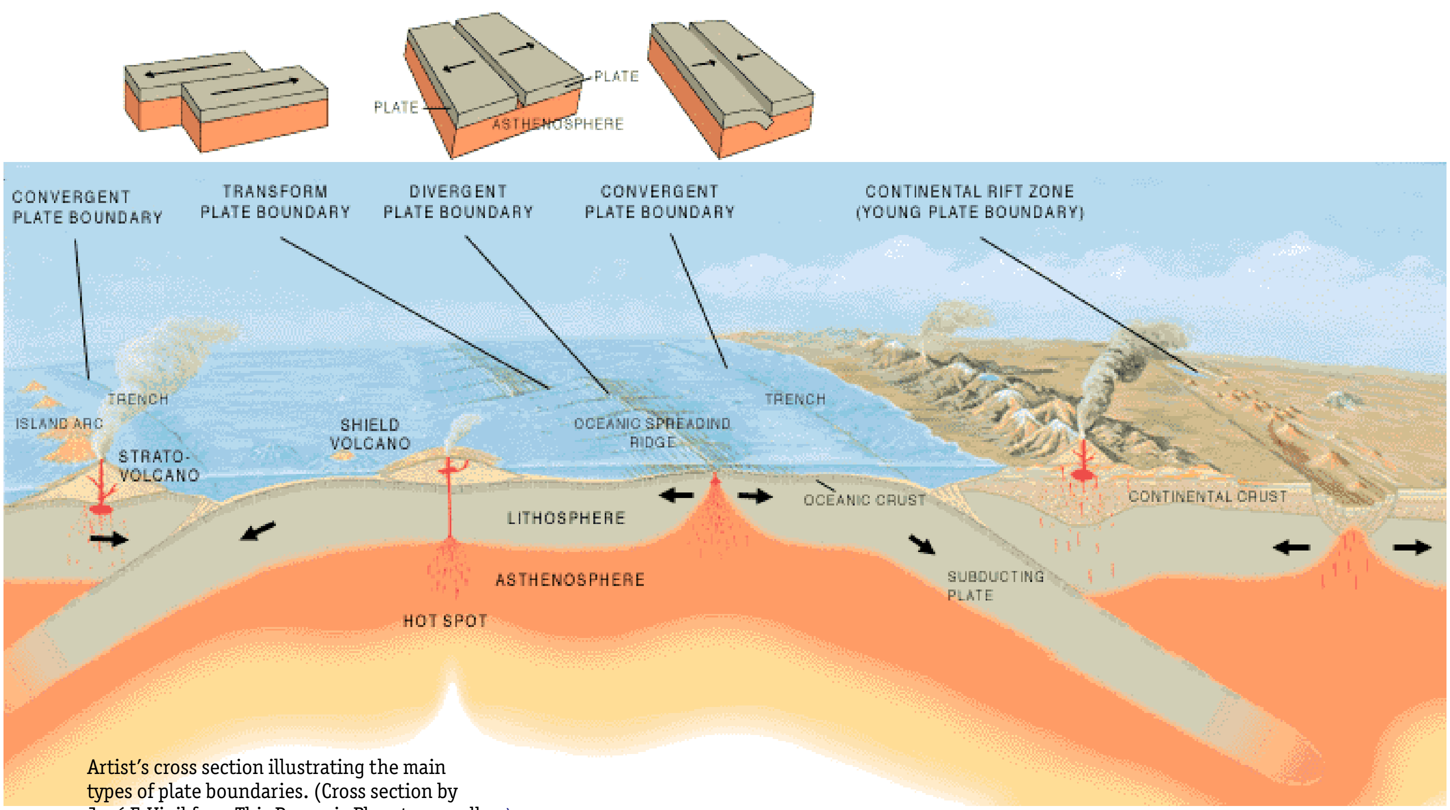
The geologic processes that produce hydrothermal vents are linked to movements of tectonic plates, which are portions of the Earth's outer crust (the lithosphere) about 5 km thick, as well as the upper 60 - 75 km of the underlying mantle. These plates move on a hot flowing mantle layer called the asthenosphere, 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; when tectonic plates collide more or less head-on, convergent plate boundary is formed; where tectonic plates are moving apart, they form a divergent plate boundary. At divergent plate boundaries, magma (molten rock) 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. A rift valley is typically present along the top of the ridge. While the process is volcanic, volcanoes and earthquakes along oceanic spreading ridges are not as violent as they are at convergent plate boundaries. You can view the three-dimensional structure of a mid-ocean ridge at: http://oceanexplorer.noaa.gov/explorations/03fire/logs/ridge.html. For additional discussion about convergent and transform plate boundaries, see the Galapagos Rift 2011 Expedition Purpose: http://oceanexplorer.noaa.gov/okeanos/explorations/ex1103/background/edu/purpose.html.

On a global scale Earth's oceanic spreading ridges are connected and form a single mid-ocean ridge system that is part of every ocean. This mid-ocean ridge system is about 50,000 km long, and is the longest mountain range in the world. Although they are connected, the ridges that make up the global mid-ocean ridge system are not all the same. This is because tectonic plates adjacent to different ridges may move apart at different rates. Plates that are part of fast-spreading ridge systems may move apart at rates of 20 cm/yr or more, while plates that are part of ultraslow-spreading ridge systems may move at rates of 2 cm/yr or less. In general, hydrothermal vents are most common along fast-spreading ridge systems; but about 50% of the global mid-ocean ridge system consists of slow- or ultraslow spreading ridges, and there is greater variety in the types of hydrothermal vents founds along these ridges.

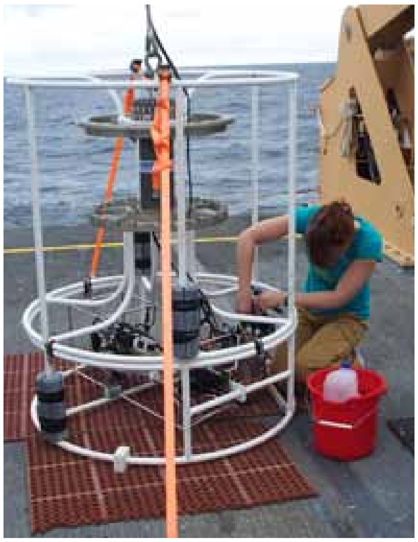
The Mid-Cayman Rise (MCR) is the world's deepest and slowest-spreading mid-ocean ridge. Exploration of the MCR was underway in the 1970's, but the discovery of the first hydrothermal vents on the Galápagos Spreading Center caused deep-sea researchers to change the focus of their investigations...until recently. In 2009, a systematic exploration along the MCR found evidence of three different types of hydrothermal vents within 100 km of each other. For more discussion about different vent types, see the Mid-Cayman Rise Expedition 2011 Exploration Purpose: http://oceanexplorer.noaa.gov/okeanos/explorations/ex1104/background/edu/purpose.html.

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

Hydrothermal vent communities on the MCR are interesting to biologists because they probably contain species that are new to



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.

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

science, some of which may provide useful bioproducts. In addition, the MCR is isolated from the rest of the global mid-ocean ridge system, though it was connected to the Galápagos Spreading Center until about 5 million years ago when the Isthmus of Panama closed the seaway connecting the Caribbean Sea and Pacific Ocean. This raises intriguing questions about MCR vent organisms: Do they resemble vent biota on other ocean ridges such as the Galápagos Spreading Center or the Mid-Atlantic Ridge? How similar are they to organisms in chemosynthetic communities of the Gulf of Mexico? Answers to these questions can provide new insights about how new hydrothermal vent systems are colonized, and whether vent organisms move between widely separated vent systems. It is also possible that some MCR hydrothermal vent systems produce organic molecules by processes that do not involve living organisms. These processes are potentially relevant to the origins of life on Earth, as well as exploration for similar systems that support living organisms in other parts of our solar system.

The Mid-Cayman Rise Expedition 2011 is focused on locating new hydrothermal vent sites on the Mid-Cayman Rise, and exploring these sites with the *Little Hercules* remotely operated vehicle which will capture video images of biological and geological features of these sites. To find new vent sites, ocean explorers will take advantage of the fact that hydrothermal vents cause changes to the physical and chemical properties of seawater. These changes can be detected with a CTD, which stands for conductivity, temperature, and depth, and refers to a package of electronic instruments that measure these properties.

Conductivity is a measure of how well a solution conducts electricity and is directly related to salinity, which is the concentration of salt and other inorganic compounds in seawater. Salinity is one of the most basic measurements used by ocean scientists. When combined with temperature data, salinity measurements can be used to determine seawater density which is a primary driving force for major ocean currents. Often, CTDs are attached to a much larger metal frame called a rosette, which may hold water sampling bottles that are used to collect water at different depths, as well as other instruments that can measure additional physical or chemical properties.

Masses of changed seawater are called plumes, and are usually found within a few hundred meters of the ocean floor. Since underwater volcanoes and hydrothermal vents may be 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.

In this activity, students will investigate properties of hydrothermal vent plumes, and how ocean explorers use these properties to locate undiscovered hydrothermal vents.

Learning Procedure

1. To prepare for this lesson:
   (a) Review introductory essays for the Mid-Cayman Rise Expedition 2011 at http://oceanexplorer.noaa.gov/okeanos/explorations/ex1104/welcome.html.
   (b) Review background information on hydrothermal vents from Web sites that will be provided for student research. The following sites provide sufficient information to complete the *Hydrothermal Vent Plume Inquiry Guide*:
      - http://www.pmel.noaa.gov/vents/about.html – Web page for the Vents Program at NOAA's Pacific Marine Environmental Laboratory.
      - http://www.pmel.noaa.gov/vents/nemo/explorer/concepts/hydrothermal.html
      - http://www.pmel.noaa.gov/vents/PlumeStudies/plumes-whystudy.html
      - http://www.pmel.noaa.gov/vents/PlumeStudies/WhatIsACTD/CTDMethods.html
      - 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. Useful information relevant to questions on the *Inquiry Guide* can be found by clicking the "Vent Basics" link, and by clicking "Hot Topics on Vent Science" then "The Hydrothermal Vent Prospecting Team."

      If an interactive white board or computer projection facilities are available, you may also want to bookmark one or more of these Web pages or download some images from these sites to show your students. Visit http://oceanexplorer.noaa.gov/explorations/02fire/logs/magicmountain/welcome.html for 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.
   (c) Review the *Plume Sniffer Challenge Guided Design Portfolio Sheet*.

2. Briefly introduce the Mid-Cayman Rise 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. If necessary, review the basic concept of plate tectonics and the three ways that Earth's tectonic plates may move relative to each other (these are discussed, with links to illustrations, in the Galapagos Rift 2011 Expedition Purpose: http://oceanexplorer.noaa.gov/okeanos/explorations/ex1103/background/edu/purpose.html). Briefly describe hydrothermal vents, but do not go into detail about vent plumes. If you have bookmarked Web pages or downloaded imagery, show these materials at this point. 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.

3. Provide students with the *Technical Reading, Notes on Hydrothermal Vent Plumes Worksheet*, which is from the NOAA Pacific Marine Environmental Laboratory Web site (http://www.pmel.noaa.gov/vents/PlumeStudies/plumes-whystudy.html), and tell students to answer the questions at the end of the reading. Most students will encounter some unfamiliar terms in this reading. These may be discussed with the entire class, or students may be required to find definitions on their own. When students have completed this assignment, discuss their results:
   - A hydrothermal vent plume is a mass of seawater that has been changed by mixing with the fluid from a hydrothermal vent.
   - A buoyant hydrothermal vent plume is less dense than the surrounding seawater; a neutrally buoyant plume has the same density as the surrounding seawater.
   - Buoyant hydrothermal vent plumes become neutrally buoyant because the surrounding seawater becomes mixed into the plume as the plume rises.
   - If the temperature in a plume is rapidly increasing, an ocean explorer might conclude that the hydrothermal vent that produced the plume is relatively nearby.
   - When the density of a hydrothermal plume matches the density of the surrounding seawater, the plume stops rising and begins to disperse laterally (sideways).
   - A neutrally buoyant plume is moved by ocean currents at the depth where the plume is neutrally buoyant.

4. Provide each student group with a copy of the *Hydrothermal Vent Plume Inquiry Guide*, and say that their assignment is to find out more about hydrothermal vent plumes, and then design a Plume Sniffer that ocean explorers could use to find hydrothermal vents. Caution students that they should not assume that a CTD is the best tool, but should start with what clues they think are most likely to appear in a vent plume and go from there. Remind students that they should

Engineering Design Process

The Engineering Design Process is a series of steps that engineers use to create solutions to problems. There are many versions of the Process, but the basic steps include:

- Define the problem.
- Gather relevant information.
- Brainstorm possible solutions.
- Analyze possible solutions and select the most promising.
- Test the solution by building a prototype.
- Revise and improve the solution.
- Repeat previous steps until results are acceptable.
- Report the design process and results.

These steps involve several key skills:

- Obtaining, evaluating, and communicating information;
- Analyzing and interpreting data;
- Using mathematics, information and computer technology, and computational thinking; and
- Using evidence to discuss the strengths and weaknesses of ideas and designs.

Most problems will include certain constraints that may relate to cost, size, environmental conditions, or other specific requirements. Some constraints may be identified in the statement of the problem, but most problems need additional analysis to be certain that all constraints are understood. Often, constraints will force designers to make trade-offs in their solutions. For example the strongest material may be too expensive, or too heavy to meet cost and size constraints. Identifying the solution that meets all of the constraints with the best combination of trade-offs is called optimization. Models are frequently used to help designers visualize possible solutions, and may be two-dimensional illustrations, three-dimensional physical shapes, or mathematical calculations that predict how well a potential solution will do what is necessary to solve the problem. Each step of the Engineering Design Process involves systematically examining information that is needed to move to the next step. This kind of examination is called analysis.

follow the steps in the Engineering Design Process, and record their work on the *Plume Sniffer Challenge Guided Design Portfolio Sheet*.

Students may be unfamiliar with the nanomole/l units of concentration used for data in Part B, but it isn't necessary for students to understand the concept of molar concentration to complete this activity. All they really need to understand is that when these numbers increase it means that there is an increased quantity of the chemical being measured.

5. When students have completed their research and Plume Sniffer designs, lead a discussion of answers to questions on the *Inquiry Guide*:

Part A:

- The vent fluid from black smokers looks like smoke because tiny mineral grains form when the hot vent fluid mixes with cold seawater.
- White smoker fluid is usually cooler (250-300°C) and flows more slowly than black smoker fluid. The fluid contains dissolved minerals that precipitate when the fluid enters cooler seawater, but these minerals do not contain metals which cause the color of black smokers.
- A "diffuse hydrothermal vent" forms when hot fluids rising from depth are mixed with cold seawater and spread out below the surface of the seafloor. The temperature of diffuse vents is usually only a few tens of degrees above the surrounding seawater, but the vent fluid still contains high levels of hydrogen sulfide and other compounds that can support complex chemosynthetic ecosystems.
- Hydrothermal vent plumes can be extremely hot, and are rich in dissolved chemicals. Ocean explorers use these characteristics to locate undiscovered hydrothermal vents.
- Ocean explorers use CTDs to detect increased temperatures or concentrations of chemicals that may signal the presence of hydrothermal vent plumes that can help locate undiscovered hydrothermal vents.
- A tow-yo is a CTD that is raised and lowered through several hundred meters near the bottom as the ship slowly cruises over the area being surveyed.

Part B:

Students' graphs of data in Table 1 should resemble Figures 1 – 9. Each of these graphs except Figure 9 includes one or more spikes that signal the possible presence of a hydrothermal vent plume. At the Picard site, the plume is 3900 – 4200 m deep; at the Walsh site the plume is 3700 – 4200 m deep; at the Europa site the plume is about 2100 m deep.

Figure 1

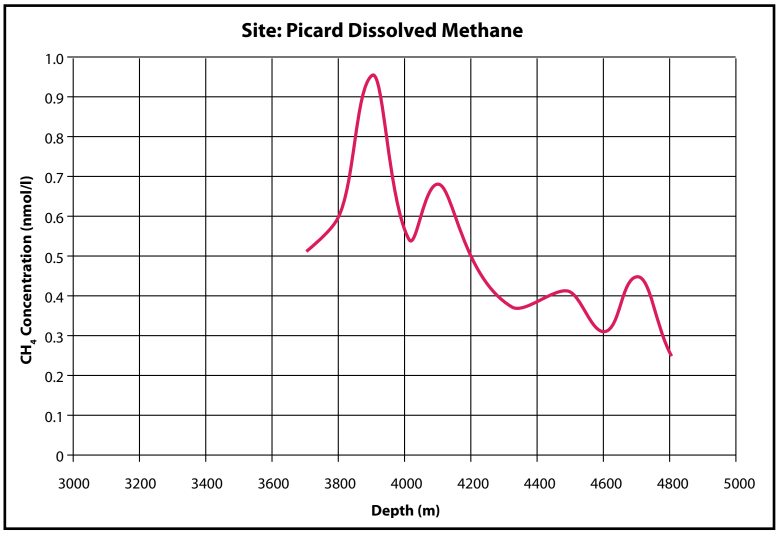


Figure 2

Figure 3

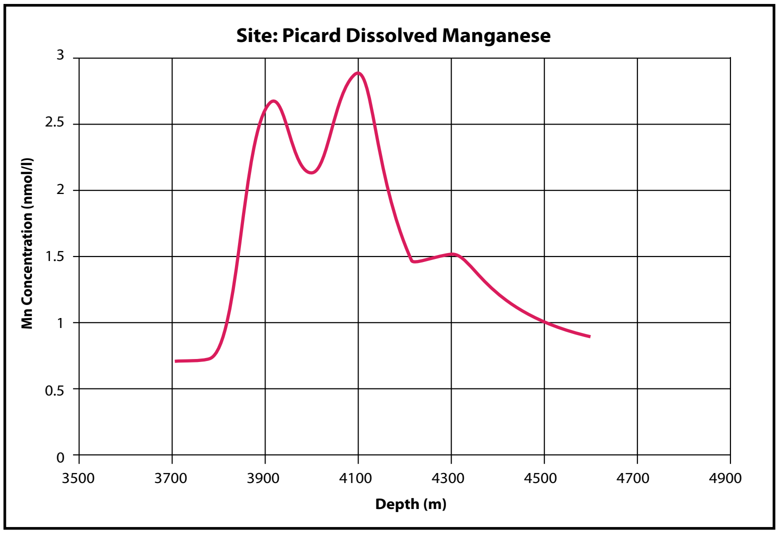


Figure 4

Figure 5

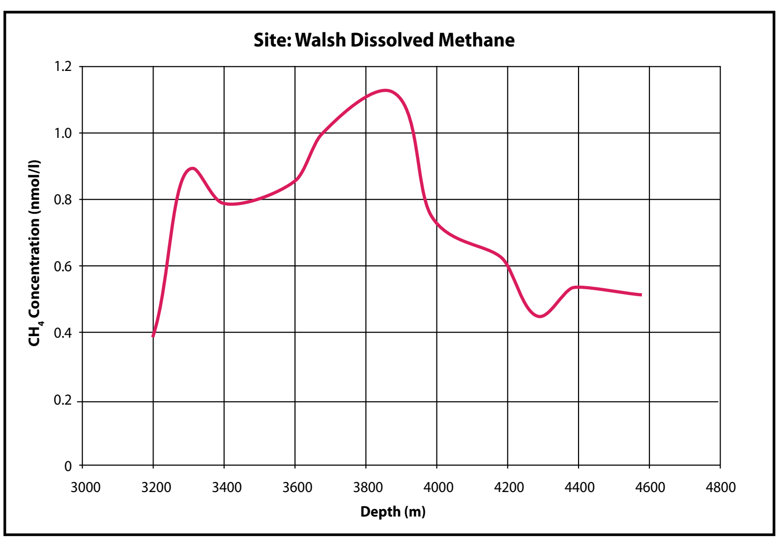


Figure 6

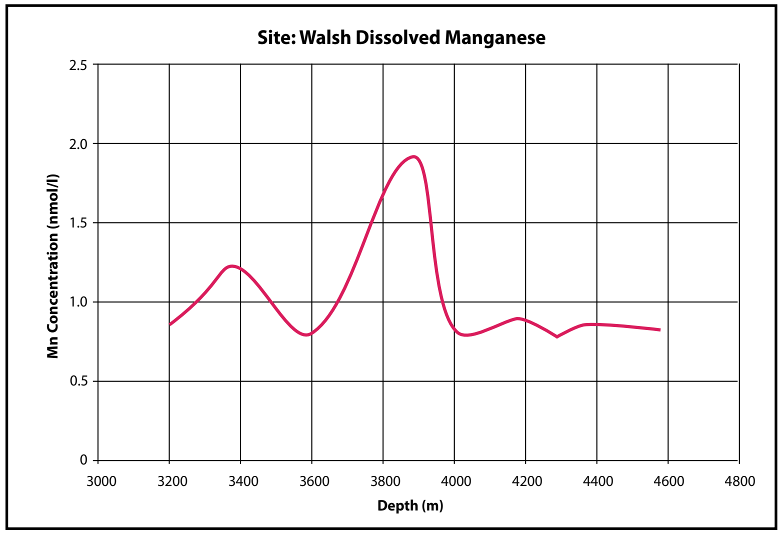


Figure 7

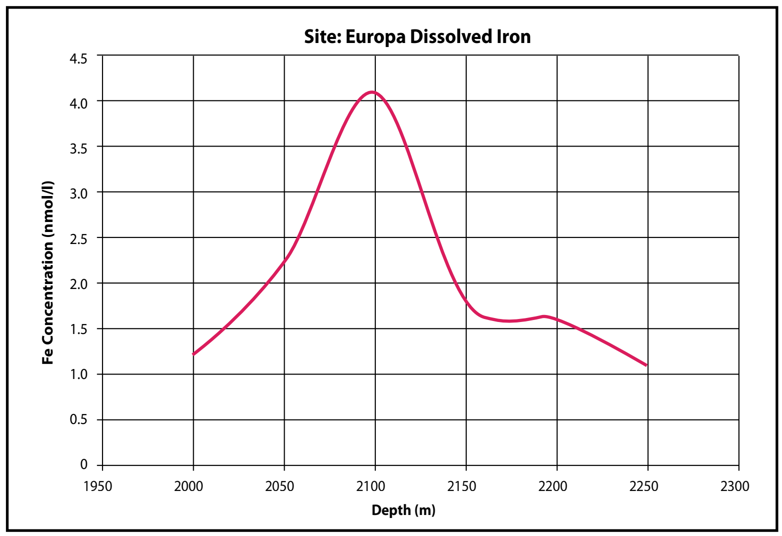


Figure 8

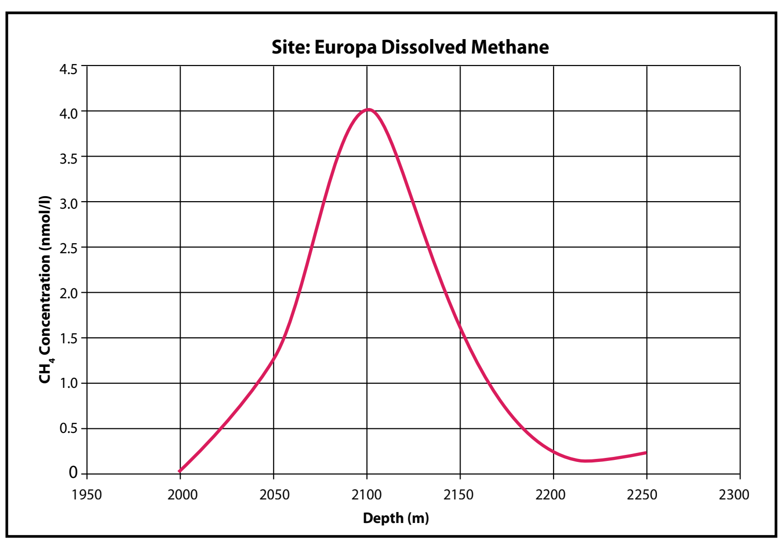
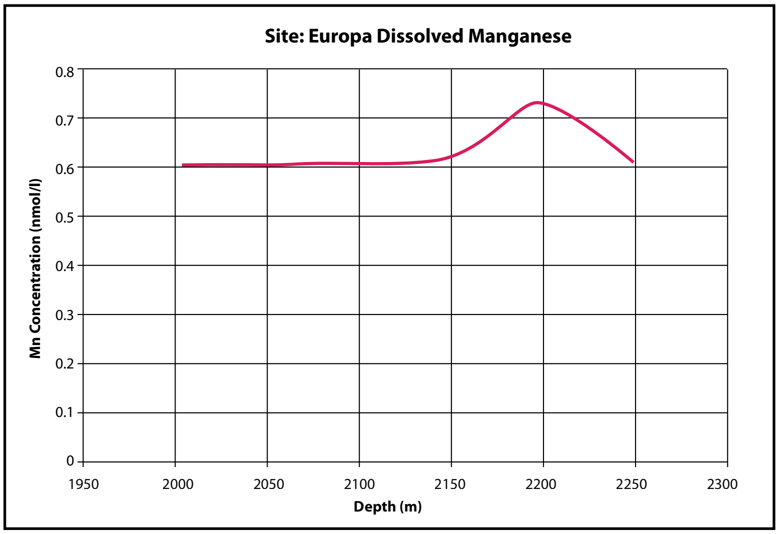


Figure 9



Part C:

Students' designs will vary. At a minimum, they should include some way to detect changes in temperature, and several chemicals typical of hydrothermal vent fluids such as dissolved iron, methane, manganese, or hydrogen. Designs should also include a way to measure depth, a mechanism for raising and lowering the Sniffer, and, if the Sniffer is to be towed (as for a tow-yo), some way to determine where the Sniffer is behind the towing vessel. The latter point is likely to be overlooked, but this is a serious issue for actual tow-yo operations where the CTD may be far astern of the towing vessel on a long cable. See the Hot Maps lesson (http://oceanexplorer.noaa.gov/okeanos/explorations/ex1103/background/edu/media/ex1103_hotmaps.pdf) for more discussion about how to deal with this problem and a mathematical exercise that demonstrates one solution. Following discussion of each group's design, students should revise their *Guided Design Portfolio Sheets* (Step 6) and record their conclusions (Step 7).

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 describing some other type of "Sniffer" that uses physical or chemical clues to detect processes that may be of personal importance (e.g., smoke, carbon monoxide).

Connections to Other Subjects

English/Language Arts; Social Studies (Geography); Mathematics

Assessment

Written reports and class discussions provide opportunities for assessment.

Extensions

1. Visit http://oceanexplorer.noaa.gov/okeanos/explorations/ex1104/welcome.html for the latest activities and discoveries by the Mid-Cayman Rise Expedition 2011.
2. Visit the education sections of Web sites provided in Step 1 for additional activities about hydrothermal vents.
3. Visit the *Okeanos Explorer* Digital Atlas (http://www.ncddc.noaa.gov/website/google_maps/OkeanosExplorer/mapsOkeanos.htm) and Web page (http://oceanexplorer.noaa.gov/okeanos/welcome.html) for reports, images, and other products from *Okeanos Explorer* cruises.

Multimedia Discovery Missions

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

Other Relevant Lesson Plans from NOAA's Ocean Exploration Program

But Why Is It Important to ME?
(from the Galapagos Rift 2011 Expedition)
http://oceanexplorer.noaa.gov/okeanos/explorations/ex1103/background/edu/media/ex1103_important.pdf

Focus: Human benefits from exploration of hydrothermal vent ecosystems (Life Science/Physical Science)

Students will explain at least three ways in which exploration of hydrothermal vent ecosystems can provide direct benefits to humans, and will create presentations to present this information to school audiences.

The Oceanographic Yo-Yo
(from the Galapagos Rift 2011 Expedition)
http://oceanexplorer.noaa.gov/okeanos/explorations/ex1103/background/edu/media/ex1103_oceanyoyo.pdf

Focus: Using ocean chemistry to locate hydrothermal vents (Physical Science)

Students explain the effects of hydrothermal vents on chemical and physical parameters of seawater, and how oceanographers can use these effects to locate hydrothermal vents.

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

Please Pass the Remote
(from the *Okeanos Explorer Education Materials Collection, Volume 2: How Do We Explore?*)
http://oceanexplorer.noaa.gov/okeanos/edu/lessonplans/media/hdwe_78_remote.pdf

Focus: Wireless communications (Physical Science)

Students identify and discuss at least five ways in which they use wireless technology in their daily lives; discuss the importance of communication to our culture, and describe some of the factors that contribute to the complexity of human communication; discuss factors that influence the effectiveness of human communication; identify the major components of wireless communications systems used aboard the *Okeanos Explorer*; and explain how these components support telepresence and scientific communication.

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.

What *Little Herc* Saw
(from the *Okeanos Explorer Education Materials Collection, Volume 2: How Do We Explore?*)
http://oceanexplorer.noaa.gov/okeanos/edu/lessonplans/media/hdwe_78_littleherc.pdf

Focus: Use of Robotics for Ocean Exploration (Physical Science/Technology)

Students discuss the importance of robotic vehicle technology to the ocean exploration strategy used aboard the *Okeanos Explorer*; discuss how information from underwater robots about biological and geological features is relevant to the concept of biodiversity; and demonstrate a process for analyzing video data from the *Okeanos Explorer's* underwater robot.

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/ex1104/welcome.html – Web site for the Mid-Cayman Rise Expedition 2011 Expedition

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

http://www.ncddc.noaa.gov/website/google_maps/OkeanosExplorer/mapsOkeanos.htm – Web site for the *Okeanos Explorer* Atlas, which provides a map-based link to information about current and previous ocean exploration expeditions conducted aboard the NOAA Ship *Okeanos Explorer* 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://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.

http://explore.noaa.gov/special-projects/indonesia-u-s-scientific-and-technical-cooperation-in-ocean-exploration/files/Okeanos_Explorer_for_WOC_-_FINAL.pdf – NOAA Fact Sheet about the *Okeanos Explorer*

German, C. R., A. Bowen, M. L. Coleman, D. L. Honig, J. A. Huber, M. V. Jakuba, J. C. Kinsey, M. D. Kurz, S. Leroy, J. M. McDermott, B. Mercier de Lépinay, K. Nakamura, J. S. Seewald, J. L. Smith, S. P. Sylva, C. L. Van Dover, L. L. Whitcomb, and D. R. Yoerger. 2010. Diverse styles of submarine venting on the ultraslow spreading Mid-Cayman Rise. Proceedings of the National Academy of Sciences 107(32):14020–14025. www.pnas.org/content/early/2010/07/13/1009205107.full.pdf

Correlations

Framework for K-12 Science Education

A. Scientific and Engineering Practices
1. Asking questions and defining problems
4. Analyzing and interpreting data
5. Using mathematics and computational thinking
6. Constructing explanations and designing solutions
7. Engaging in argument from evidence
8. Obtaining, evaluating, and communicating information

B. Crosscutting Concepts
1. Patterns
2. Cause and effect: Mechanism and explanation
4. Systems and system models

C. Disciplinary Core Ideas

Physical Sciences

Core Idea PS1: Matter and Its Interactions

PS1.A: Structure and Properties of Matter
Core Idea PS2: Motion and Stability: Forces and Interactions
PS2.A: Forces and Motion
PS2.C: Stability and Instability in Physical Systems
Life Sciences
Core Idea LS2: Ecosystems: Interactions, Energy, and Dynamics
LS2.A: Interdependent Relationships in Ecosystems
Earth and Space Sciences
Core Idea ESS2: Earth's Systems
ESS2.B: Plate Tectonics and Large-Scale System Interactions
Engineering, Technology, and the Applications of Science
Core Idea ETS1: Engineering Design
ETS1.A: Defining and Delimiting an Engineering Problem
ETS1.B: Developing Possible Solutions
ETS1.C: Optimizing the Design Solution

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.

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.

Common Core State Standards for Mathematics

Grade 5

Geometric measurement: understand concepts of volume and relate volume to multiplication and to addition.

Grade 6

Solve real-world and mathematical problems involving area, surface area, and volume.

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.

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Credit

To Sink, To Rise, or To Float
Technical Reading

Notes on Hydrothermal Vent Plumes

from NOAA Pacific Marine Environmental Laboratory Web site:
http://www.pmel.noaa.gov/vents/PlumeStudies/plumes-whystudy.html

Hydrothermal fluids mix rapidly with seawater. Entrainment of ambient seawater dilutes the rising plume and causes temperatures and particle concentrations within the plume to decrease within a short distance from a vent orifice. Hydrothermal plumes continue to rise through seawater as long as plume fluids are less dense (more buoyant) than the surrounding seawater. Once the density of the hydrothermal plume matches the density of the ambient seawater, the hydrothermal plume stops rising and begins to disperse laterally. This "neutrally buoyant plume" gets distributed by being "blown" by ocean currents at that density level. The greatest change in intensity of heat or particles within the plume occurs relatively near the source (within a few kilometers). Throughout the processes of rising, mixing with ambient seawater and subsequent advection away from the area of the source, the plume undergoes changes. The evolution of vent fluids and particles can only be studied by finding the plume and sampling it at various times and distances from the sources.

Questions:

1. What is a hydrothermal vent plume?

2. What is the difference between a buoyant hydrothermal vent plume and a neutrally buoyant plume?

3. How do buoyant hydrothermal vent plumes become neutrally buoyant?

4. If you were an ocean explorer, and found that the temperature in a plume was rapidly increasing, what might you conclude about the location of the hydrothermal vent that produced the plume?

5. When the density of a hydrothermal plume matches the density of the surrounding seawater, what happens to the plume?

6. What causes a neutrally buoyant plume to move?

Tracking Down the Vents

Hydrothemal Vent Plume Inquiry Guide

Part A. Find Out More About Hydrothermal Vent Plumes

Visit these Web sites to find answers to the following questions (these Web sites have a lot of interesting pages, so feel free to browse around!):

- http://www.pmel.noaa.gov/vents/about.html
- http://www.pmel.noaa.gov/vents/nemo/explorer/concepts/hydrothermal.html
- http://www.pmel.noaa.gov/vents/PlumeStudies/plumes-whystudy.html
- http://www.pmel.noaa.gov/vents/PlumeStudies/WhatIsACTD/CTDMethods.html
- http://www.divediscover.whoi.edu/vents/index.html

1. Some hydrothermal vents are called "black smokers" because the vent fluid resembles smoke. What causes the vent fluid to appear this way?

2. Some hydrothermal vents are called "white smokers." How are these vents different from black smokers (besides being white)?

3. What is a "diffuse hydrothermal vent"? Why do biologists like to find diffuse vents?

4. What are two characteristics of hydrothermal vent plumes that ocean explorers can use to locate undiscovered hydrothermal vents?

5. How do ocean explorers use CTDs to find hydrothermal vent plumes that help locate undiscovered hydrothermal vents?

6. What is a tow-yo?

Part B. Analyze Some Data

Table 1 lists data collected from three tow-yo operations during an expedition to locate new hydrothermal vents on the Mid-Cayman Rise. For each of the three sites, graph these data with depth on the x-axis and concentration of dissolved chemicals on the y-axis. Do any of these graphs show sudden changes ("spikes") that might signal the presence of a hydrothermal vent plume? If you think a plume is present, write the approximate depth at which the plume is located.

Table 1: Tow-Yo Data from Three Sites on the Mid Cayman Rise
(adapted from German *et al.*, 2010)

Depth (m)	Dissolved Iron (nmol/l)	Dissolved Methane (nmol/l)	Dissolved Manganese (nmol/l)
Site: Picard			
4800	2.1	0.25	0.8
4700	1.8	0.45	
4600	2.1	0.31	0.9
4500	2.5	0.41	1
4400	3.5	0.39	1.2
4300	3.6	0.38	1.5
4200	2.6	0.5	1.5
4100	12.5	0.68	2.82
4000	8.1	0.55	2.1
3900	13.1	0.95	2.6
3800	1.8	0.61	0.8
3700	2.2	0.51	0.7
Site: Walsh			
4600	2.5	0.51	0.81
4400	2	0.53	0.85
4300	2.2	0.45	0.79
4200	5.1	0.62	0.89
4000	4.9	0.75	0.85
3900	5.3	1.12	1.92
3700	5.1	1.01	1.06
3600	0.7	0.85	0.79
3400	2.5	0.79	1.21
3300	1.6	0.88	1.05
3200	1.5	0.38	0.85
Site: Europa			
2250	1.1	1.8	0.61
2200	1.6	1.8	0.73
2150	1.8	11.2	0.62
2100	4.1	31.1	0.61
2050	2.2	10	0.61
2000	1.2	0.1	0.6

Part C. Design a Plume Sniffer!

Suppose you are an ocean explorer who wants to find new hydrothermal vents. Luckily, you have just received a big grant to build a state-of-the-art Plume Sniffer. Use your knowledge about hydrothermal vents and vent plumes to decide what features you want the Sniffer to have. Use the Engineering Design Process (see Box) and the *Plume Sniffer Challenge Guided Design Portfolio Sheet* to help complete this assignment. WARNING: Do not assume that a CTD is the best tool, just because a lot of people use it! Start identifying the clues you think are most likely to appear in a vent plume and go from there.

Engineering Design Process

The Engineering Design Process is a series of steps that engineers use to create solutions to problems. There are many versions of the Process, but the basic steps include:

- Define the problem
- Gather relevant information
- Brainstorm possible solutions
- Analyze possible solutions and select the most promising
- Test the solution by building a prototype
- Revise and improve the solution
- Repeat previous steps until results are acceptable
- Report the design process and results

These steps involve several key skills:

- Obtaining, evaluating, and communicating information;
- Analyzing and interpreting data;
- Using mathematics, information and computer technology, and computational thinking; and
- Using evidence to discuss the strengths and weaknesses of ideas and designs.

Most problems will include certain constraints that may relate to cost, size, environmental conditions, or other specific requirements. Some constraints may be identified in the statement of the problem, but most problems need additional analysis to be certain that all constraints are understood. Often, constraints will force designers to make trade-offs in their solutions. For example the strongest material may be too expensive, or too heavy to meet cost and size constraints. Identifying the solution that meets all of the constraints with the best combination of trade-offs is called optimization. Models are frequently used to help designers visualize possible solutions, and may be two-dimensional illustrations, three-dimensional physical shapes, or mathematical calculations that predict how well a potential solution will do what is necessary to solve the problem. Each step of the Engineering Design Process involves systematically examining information that is needed to move to the next step. This kind of examination is called analysis.

Tracking Down the Vents
Plume Sniffer Challenge
Guided Design Portfolio Sheet

1. Define the problem.

State the problem in your own words:

2. Gather relevant information.

List the clues you think are most likely to appear in a vent plume:

3. Brainstorm possible solutions.

Use words or sketches to describe some possible solutions. Be sure to include a list of equipment necessary to operate your Plume Sniffer in addition to devices needed to detect the clues identified in Step 2:

4. Analyze possible solutions and select the most promising.

State which of the possible solutions is most promising and why:

5. Test the solution by building a prototype.

Unfortunately, you can't actually build your Sniffer, but describe how you would test it without having to go to a known hydrothermal vent plume:

6. Revise and improve the solution.

After discussing your design with the rest of the class, describe modifications that you think might improve your design:

7. Report the design process and results.

Summarize your conclusions: