OCEAN EXPLORATION & RESEARCH

Section 4: Water Column Investigations for Volume 2: How Do We Explore?

NOAA Ship *Okeanos Explorer:* America's Ship for Ocean Exploration. Image credit: NOAA. For more information, see the following Web site: *http://oceanexplorer.noaa.gov/okeanos/welcome.html*

The Oceanographic Yo-yo

Focus

CTD (conductivity, temperature, depth profiler), ocean chemistry and hydrothermal vents

Grade Level

7-8 (Physical Science)

Focus Question

How do ocean explorers aboard the *Okeanos Explorer* use chemical clues to locate hydrothermal vents in the deep ocean?

Learning Objectives

- Students will explain the effects of hydrothermal vents on chemical and physical parameters of seawater.
- Students will describe instruments aboard the *Okeanos Explorer* that detect these effects.
- Students will analyze data from the *Okeanos Explorer* to find chemical clues that suggest the presence of hydrothermal vents.

Materials

- One gallon of water, chilled in a refrigerator
- Vinegar; 1 tablespoon for each student group
- A heat source (microwave oven or hot plate)
- One eyedropper
- One tablespoon
- For each student group:
  - Copy of *CTD Sample Analysis Worksheet*
  - Two thermometers
  - 20 strips pH paper
  - pH color indicator chart
  - Five 100ml beakers or plastic cups labeled A, B, C, D, and E

Audio Visual Materials

- Video projector or large screen monitor for showing downloaded videos (see Learning Procedure, Step 2)

Teaching Time

Two 45-minute class periods

Seating Arrangement
Groups of three to four students

Maximum Number of Students
30

Key Words and Concepts
Ocean Exploration
Okeanos Explorer
CTD
Conductivity
pH
Hydrothermal vent
Plume

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

On August 13, 2008, the NOAA Ship *Okeanos Explorer* was commissioned as "America's Ship for Ocean Exploration;" the only U.S. ship whose sole assignment is to systematically explore Earth's largely unknown ocean. The strategy for accomplishing this mission is to use state-of-the-art technologies to search the ocean for anomalies; things that are unusual and unexpected. When an anomaly is found, the exploration strategy shifts to obtaining more detailed information about the anomaly and the surrounding area. An important concept underlying this strategy is the distinction between exploration and research. As a ship of discovery, the role of *Okeanos Explorer* is to locate new features in the deep ocean, and conduct preliminary investigations that provide enough data to justify follow-up by future expeditions.

The *Okeanos Explorer* strategy 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.

In addition to state-of-the-art navigation and ship operation equipment, this strategy depends upon four types of technology:

- Telepresence;

NOAA Ship *Okeanos Explorer:* America's Ship for Ocean Exploration. Image credit: NOAA. For more information, see the following Web site: *http://oceanexplorer.noaa.gov/okeanos/welcome.html*

Okeanos Explorer Vital Statistics:
Commissioned: August 13, 2008; Seattle, Washington
Length: 224 feet
Breadth: 43 feet
Draft: 15 feet
Displacement: 2,298.3 metric tons
Berthing: 46, including crew and mission support
Operations: Ship crewed by NOAA Commissioned Officer Corps and civilians through NOAA's Office of Marine and Aviation Operations (OMAO); Mission equipment operated by NOAA's Office of Ocean Exploration and Research

For more information, visit *http://oceanexplorer.noaa.gov/okeanos/welcome.html*.
Follow voyages of America's ship for ocean exploration with the *Okeanos Explorer* Atlas at *http://www.ncddc.noaa.gov/website/google_maps/OkeanosExplorer/mapsOkeanos.htm*

- Multibeam sonar mapping;
- CTD (an instrument that measures conductivity, temperature, and depth) 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 4,000 meters.

In many ways, telepresence is the key to the *Okeanos Explorer*'s exploration strategy. This technology allows people to observe and interact with events at a remote location. The *Okeanos Explorer*'s telepresence capability is based on advanced broadband satellite communication through which live images can be transmitted from the seafloor to scientists ashore, classrooms, and newsrooms, and opens new educational opportunities that are a major part of *Okeanos Explorer*'s mission for advancement of knowledge.

In the summer of 2010, years of planning, field trials, and state-of-the-art technology came together for the first time on the the ship's maiden voyage as part of the INDEX-SATAL 2010 Expedition. This expedition was an international collaboration between scientists from the United States and Indonesia to explore the deep ocean in the Sangihe Talaud Region. This region is located in the 'Coral Triangle', which is the global heart of shallow-water marine biodiversity. A major objective of the expedition was to advance our understanding of undersea ecosystems, particularly those associated with submarine volcanoes and hydrothermal vents. Among the Expedition's many "firsts," this was the first time scientists have been able to use an underwater robot to get a first-hand look at deepwater biodiversity in the waters of the Sangihe Talaud Region. For more information about the INDEX-SATAL 2010 Expedition, see *http://oceanexplorer.noaa.gov/okeanos/explorations/10index/welcome.html*.

Map showing the Coral Triangle region – the most diverse and biologically complex marine ecosystem on the planet. The Coral Triangle covers 5.7 million square km, and matches the species richness and diversity of the Amazon rainforest. Although much of the diversity within the Coral Triangle is known, most still remains unknown and undocumented. Image courtesy of *www.reefbase.org*. *http://oceanexplorer.noaa.gov/okeanos/explorations/10index/background/hires/coral_triangle_hires.jpg*

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.

The presence of thriving biological communities in the deep ocean was a complete surprise, because it had been 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. Energy for chemosynthesis in the vicinity of hydrothermal vents often comes from hydrogen sulfide.

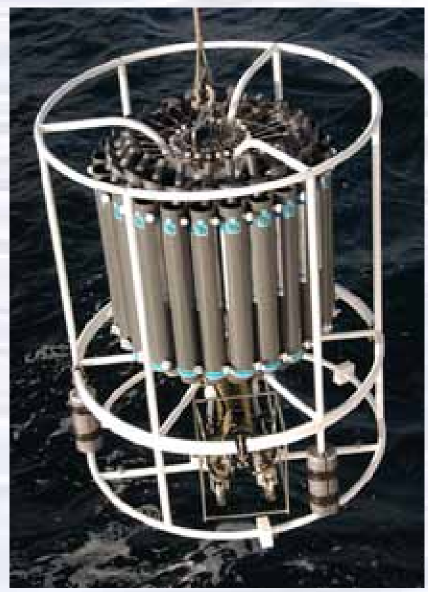
Hydrothermal vents and chemosynthetic communities are often associated with changes in the chemical properties of seawater. To look for these changes, ocean explorers use an instrument known as a CTD, which stands for conductivity, temperature, and depth. A CTD is a package of electronic instruments 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 sensors that can measure additional physical or chemical properties.

Temperature measurements from CTD sensors can be used to detect changes in water temperature that may indicate the presence of volcanoes or hydrothermal vents. Masses of seawater with unusual characteristics are called plumes, and are usually found within a few hundred meters of the ocean floor. Since underwater volcanoes

CTD Systems Aboard *Okeanos Explorer*

The *Okeanos Explorer* is equipped with a Seabird Electronics Model 9/11+ CTD system mounted on an SBE 32 rosette frame. This rosette includes 24 sampling bottles that can be individually triggered to collect samples at various depths. On many CTD casts, additional sensors to measure oxidation reduction potential and optical backscatter are added to the instrument package, because these parameters can also signal the presence of hydrothermal vents and reducing communities.

The SBE 9+ CTD unit has a depth rating of 6,800 meters. The ship also carries an expendable bathythermograph (XBT) that is used to measure the velocity of sound in the ocean at various depths. This information is needed by the multibeam sonar system to collect accurate bathymetric data.
Note: Mention of proprietary names does not imply endorsement by NOAA.



A CTD rosette is lowered to measure the salinity, temperature, depth and concentration of particles in the water column. Scientists use particle concentration and oxygen reduction potential as the most sensitive indicators of hydrothermal plumes. Image courtesy of NOAA *Okeanos Explorer* Program, INDEX-SATAL 2010.
http://oceanexplorer.noaa.gov/okeanos/explorations/10index/logs/june27/media/ex_ctd.html

Plot showing light scattering (dNTU) sensor and oxygen reduction potential (ORP) data, versus time, acquired by the CTD/rosette as it passed through a plume overtop of Kawio Barat volcano. There was an intense particle anomaly and ORP decrease in the bottom 30 meters of the water column when the plume was encountered. A drop in the ORP, like you see here, means that there are more electron donor compounds in the water produced by enrichment of seawater in dissolved metals and chemicals billowing out of hydrothermal vents. The ORP values begin to increase again, recovering slowly, when the CTD leaves the plume. Image courtesy of Sharon Walker, PMEL.
http://oceanexplorer.noaa.gov/okeanos/explorations/10index/logs/hires/kawio_barat_hires.jpg

and hydrothermal vents may be several thousand meters deep, ocean explorers often 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.

This lesson introduces students to simple analysis of CTD data as a method for finding underwater volcanoes and hydrothermal vents.

Learning Procedure

NOTE: The water sample analysis activity described in Step 4 is adapted from the 2002 Galapagos Rift Expedition lesson, "Yo-Yos, Tow-Yos and pH, Oh My!" by Stacia Fletcher, South Carolina Aquarium, Charleston, SC.

1. To prepare for this lesson:
   a) Review:
      - Introductory essays for the INDEX-SATAL 2010 Expedition (*http://oceanexplorer.noaa.gov/okeanos/explorations/10index/welcome.html*);
      - Background information on CTD technology at *http://www.pmel.noaa.gov/vents/PlumeStudies/WhatIsACTD/CTDMethods.html*

   (b) Review background information about the *Okeanos Explorer* exploration strategy and technologies.

   (c) If students are not familiar with deep-sea chemosynthetic communities, you may want to use Multimedia Discovery Mission Lesson 5, Chemosynthesis and Hydrothermal Vent Life (*http://oceanexplorer.noaa.gov/edu/learning/welcome.html*), and/or information from *http://www.pmel.noaa.gov/vents/nemo/explorer.html*.

   (d) Review procedures for the simulated analysis of CTD samples (Step 4). Prepare materials for this activity:
      1) Chill one gallon of water overnight in a refrigerator.
      2) For each group of four students, fill five 100ml beakers with chilled water and label each with an A, B, C, D and E.
      (3) Heat the water in all beakers labeled D for 60 seconds in the microwave oven about 15 minutes before the start of class. The water should be above 50 C, but not boiling.
      4) Add 3 drops of vinegar to all beakers labeled C and E and stir.
      5) Add one tablespoon of vinegar to all beakers labeled D and stir.

   (e) If desired, download images referenced in Step 2.

2. Briefly introduce the NOAA Ship *Okeanos Explorer* and the INDEX-SATAL 2010 Expedition. Briefly discuss why this kind of exploration is important (for background information, please see the lesson, *Earth's Ocean is 95% Unexplored: So What?*; *http://oceanexplorer.noaa.gov/okeanos/explorations/10index/background/edu/media/so_what.pdf*). Highlight the overall exploration strategy used by *Okeanos Explorer*, including the following points:
   - The overall strategy is based on finding anomalies;
   - This strategy involves
     - Underway reconnaissance;
     - Water column exploration; and
     - Site characterization;

STEM Connections

Ocean exploration aboard the *Okeanos Explorer* is a real-world example of STEM concepts in action:

Science provides the overall objective – to better understand Earth's ocean – as well as a methodology for systematically acquiring this understanding;

Technology includes the tools, systems and processes that have been made to make deep-ocean exploration possible;

Engineering designs the technologies that can function in the deep-ocean environment;

Mathematics provides the basis for measurements, data analysis, and engineering design.

With increasing attention to developing integrated approaches to STEM education and technological literacy, the How Do We Explore? theme offers an exciting context for educators who wish to bring more STEM content to their classrooms.

To assist with such efforts, most lessons developed for the *How Do We Explore?* theme identify opportunities to include specific benchmarks and standards for technological literacy that have been developed by the International Technology and Engineering Education Association (ITEA, 2007). While these standards have not been widely adopted, they provide useful guidance for efforts to enhance STEM content in advance of its inclusion in formal curricula.

In addition, the *How Do We Explore?* suite of lessons includes activities that are intended to provide opportunities to apply design processes, build technological devices, and develop some of the hands-on abilities that are an integral part of most concepts about STEM education. These activities are directly tied to the technologies and scientific methodologies used for ocean exploration aboard the *Okeanos Explorer*.

For more information, see: *http://www.iteaconnect.org/TAA/Publications/TAA_Publications.html*

- This strategy relies on four key technologies:
  - Multibeam sonar mapping system;
  - CTD and other electronic sensors to measure chemical and physical seawater properties;
  - A Remotely Operated Vehicle (ROV) capable of obtaining high-quality imagery and samples in depths as great as 4,000 meters; and
  - Telepresence technologies that allow people to observe and interact with events at a remote location.

You may want to show some or all of the images in the adjacent sidebar to accompany this review.

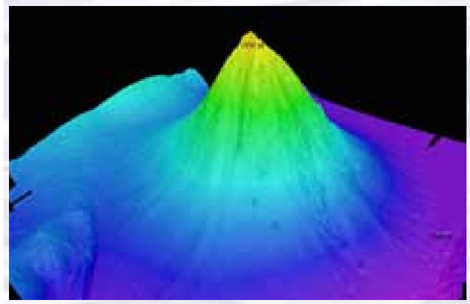
Show an image of a CTD, and explain that this is actually a collection of several electronic instruments that measure various things about seawater. The basic instruments measure temperature, depth, and conductivity. Most of the device seen in the image is a water sampling device called a rosette or carousel, that contains water sampling bottles that are used to collect water at different depths. Before the CTD is lowered into the ocean, the bottles are opened so that water flows freely through them. As the CTD travels through the water column, scientists can monitor readings from the sensors. If something unusual appears in the measurements, the scientists can send a signal through the CTD cable that closes one or more of the bottles to collect a water sample from the location where the unusual measurements appeared.

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 1c, present these now. Tell students that a major objective of the INDEX-SATAL 2010 Expedition was to locate submarine volcanoes, hydrothermal vents, chemosynthetic ecosystems, and seamounts associated with active geologic processes in Indonesia's deep sea.

3. Discuss some of the clues that might result from changes that hydrothermal vents might cause in seawater. Increased temperature is fairly obvious, since heat from Earth's core is the energy source that causes vents to form. Temperatures of hydrothermal fluids may be more than 300°C, since the high pressure of deep-sea environments prevents water from boiling. Fluids from hydrothermal vents are often highly acidic, in contrast to normal seawater which is slightly basic; so pH is another potential clue. You may need to explain that pH is a measure of the concentration of hydrogen ions (which actually exist as hydronium ions, H_3O^+). For a more detailed discussion about pH, please see the lesson, *Why Do We Explore?* (*http://oceanexplorer.noaa.gov/okeanos/edu/leadersguide/media/09whydoweexplore.pdf*). Hydrogen sulfide is often found in hydrothermal vent fluids, but is not normally found in seawater. So a chemical analysis that indicates its presence in a seawater sample would be another clue that signals vents may be nearby.

4. The following activity simulates an analysis of water samples collected by a CTD to identify samples that may have been collected near a hydrothermal vent site. Tell students that their assignment is to analyze several samples collected by a CTD to determine whether any of the samples suggest that they might have been collected from a location near a hydrothermal vent. Demonstrate the correct way to measure pH with a pH strip if students are not already familiar with this

The ROV Little Hercules descends through deep water to an undersea volcano in the Celebes Sea to search for hydrothermal vents and associated ecosystems. Image courtesy of NOAA *Okeanos Explorer* Program, INDEX-SATAL 2010
http://oceanexplorer.noaa.gov/okeanos/explorations/10index/logs/hires/1june29_hires.jpg



Okeanos Explorer's EM302 multibeam sonar mapping system produced this detailed image of the Kawio Barat seamount, which rises around 3800 meters from the seafloor. Image courtesy of NOAA *Okeanos Explorer* Program, INDEX-SATAL 2010
http://oceanexplorer.noaa.gov/okeanos/explorations/10index/logs/hires/june26fig1_hires.jpg

Scientists in the Exploration Command Center at NOAA's Pacific Marine Environmental Laboratory in Seattle view live video from the *Okeanos Explorer's* ROV. Image courtesy NOAA
http://www.pmel.noaa.gov/images/headlines/ecc.jpg

Senior Survey Technician Elaine Stuart holds onto the CTD as it comes aboard the *Okeanos Explorer*. Image courtesy NOAA
http://www.moc.noaa.gov/oe/visitor/photos/photospage-b/CAP%20015.jpg

Figure 1.

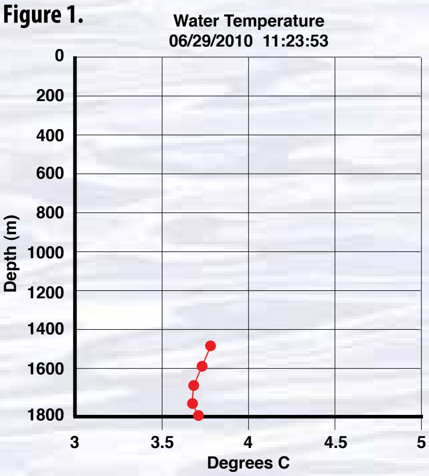


Figure 2.

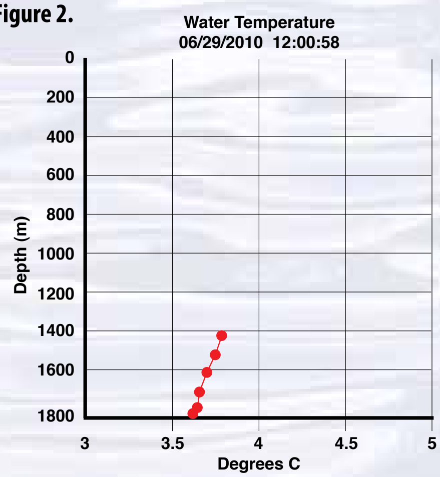
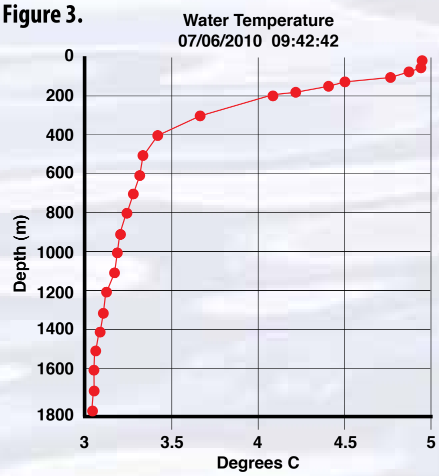


Figure 3.



procedure.
Provide each student group with two thermometers, 20 strips of pH paper, a pH color indicator chart, a *CTD Sample Analysis Worksheet*, and samples A, B, C, D and E. Tell students to make measurements needed to complete the worksheet.

Be sure students understand that the grids provided for their graphs have zero at the TOP of the Y-axis. This is because oceanographers like to plot CTD data with depth on the y-axis and the greatest depths at the bottom of the plot, since that is the way we usually think about a profile of the water column.

5. Discuss students' results. Students should infer that sample D may have been collected in the vicinity of a hydrothermal vent, since its temperature is noticeably higher than that of the other samples, and its pH is noticeably lower. Ask students what other measurements might be made to support this inference. These might include chemical analysis to detect the presence of substances associated with hydrothermal vents, such as hydrogen sulfide.

   Students' graphs of CTD data should resemble Figures 1, 2, and 3. Students should recognize that Figure 1 is different from the others, in that water temperature increases near the bottom (even a small increase is significant). Since this is not what would ordinarily be expected, it is an anomaly! In fact, this CTD cast was made in the vicinity of an active hydrothermal vent. The next day, *Okeanos Explorer*'s ROV *Little Hercules* visited the site and found an active hydrothermal vent "surrounded by yellow and black molten sulfur, multiple species of hot-vent shrimp, a 10cm scale worm, and a small patch of stalked barnacles. After departing from the vent, the ROV ascended the summit ridge and encountered fields of sulfide chimneys with vast aggregations of stalked barnacles at their base. The chimneys varied in terms of age and venting characteristics. Some chimneys were fairly oxidized and others covered in white sulfide. Some chimneys were venting clear fluid while others were venting black smoke." You can read more about the site, and see images from *Little Hercules* here: *http://oceanexplorer.noaa.gov/okeanos/explorations/10index/logs/june30/june30.html*.

6. Discussion of CTD technology may also include the following components of technological literacy (ITEA, 2007):
   - **Scope of technology –** Development of CTD instrumentation allows many chemical and physical characteristics to be measured in the ocean, some of which could not be measured in deep water before this technology was created.
   - **Core concepts of technology –** A CTD is an example of several technological systems connected together; including different systems to measure various chemical and physical characteristics of seawater, and equipment for collecting water samples from very deep areas in Earth's ocean.
   - **Relationships between technologies and other fields of study –** Improvements to each of the technologies listed above improves the overall capability of water column investigations; and this information is useful to geologists, biologists, and many other branches of science.

The BRIDGE Connection

www.vims.edu/bridge/ – Scroll over "Ocean Science Topics" in the menu on the left side of the page, then "Habitats" then select "Deep Ocean" for activities and links about deep-ocean ecosystems.

The "Me" Connection

Have students read the daily log entry for July 29, 2010 from the INDEX-SATAL 2010 Expedition (*http://oceanexplorer.noaa.gov/okeanos/explorations/10index/logs/july29/july29.html*), and write a brief essay discussing whose job they would like to have if they were personally aboard the ship.

Connections to Other Subjects

English/Language Arts, Social Studies, Mathematics

Assessment

Class discussions and students' work with the charting activity provide opportunities for assessment.

Extensions

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, 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

And Now for Something Completely Different…

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

Focus: Biological communities at hydrothermal vents (Grades 5-6; Life Science)

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

A Hydrothermal AdVENTure

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

Focus: Hydrothermal vents (Grades 5-6; Earth Science)

Students explain the overall structure of hydrothermal vents and how they are related to the motion of tectonic plates, and will create a model of a hydrothermal vent.

The Volcano Factory

(from the 2004 Submarine Ring of Fire expedition)
http://oceanexplorer.noaa.gov/explorations/04fire/background/edu/media/RoF.volcanism.pdf

Focus: Volcanism on the Mariana Arc (Grades 5-6; Earth Science)

Students explain the tectonic processes that result in the formation of the

Mariana Arc and the Mariana Trench, and explain why the Mariana Arc is one of the most volcanically-active regions on Earth.

Unexplored

(from the New Zealand American Submarine Ring of Fire 2005 expedition)
http://oceanexplorer.noaa.gov/explorations/05fire/background/edu/media/rof05_unexplored.pdf

Focus: Scientific exploration of deep-sea volcanoes (Grades 5-6; Life Science/Physical Science/Earth Science)

Students compare and contrast submarine volcanoes at convergent and divergent plate boundaries, infer the kinds of living organisms that may be found around hydrothermal vents, describe three ways in which scientists may prepare to explore areas that are practically unknown, and explain two types of primary production that may be important to biological communities around hydrothermal vents in the Mariana Arc.

Living With the Heat

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

Focus: Hydrothermal vent ecology and transfer of energy among organisms that live near vents (Grades 5-6; Life Science/Earth Science)

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

Anonymous. 2010. Web site for the INDEX-SATAL 2010 Expedition [Internet]. Office of Ocean Exploration and Research, NOAA [cited January 7, 2011]. Available from *http://oceanexplorer.noaa.gov/okeanos/explorations/10index/welcome.html* – Includes links to lesson plans, career connections, and other resources

Anonymous. Ocean Explorer [Internet]. NOAA Office of Ocean Exploration and Research [cited January 4, 2011]. Available from: *http://oceanexplorer.noaa.gov*.

Anonymous. 2011. *Okeanos Explorer* Education Materials Collection [Internet]. NOAA Office of Ocean Exploration and Research [cited January 4, 2011]. Available from: *http://oceanexplorer.noaa.gov*

Anonymous. *Okeanos Explorer* America's Ship For Ocean Exploration [Internet]. NOAA Office of Ocean Exploration and Research [cited January 24, 2011]. Available from: *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 *Okeanos Explorer*

Anonymous. CTD and Tow Methods [Internet]. NOAA Pacific Marine Environmental Laboratory [cited January 4, 2011]. Available from: *http://www.pmel.noaa.gov/vents/PlumeStudies/WhatIsACTD/CTDMethods.html*

International Technology Education Association. 2007. Standards for Technological Literacy: Content for the Study of Technology. Reston, VA. 260 pp.

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
- Transfer of energy

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

Content Standard D: Earth and Space Science
- Structure of the Earth system

Content Standard E: Science and Technology
- Understandings about science and technology

Content Standard F: Science in Personal and Social Perspectives
- Personal health
- Populations, resources, and environments

Ocean Literacy Essential Principles and Fundamental Concepts

Because most Fundamental Concepts are broad in scope, some aspects of some Concepts may not be explicitly addressed in this lesson. Such aspects, however, can be easily included at the discretion of the individual educator.

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 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 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 6.
The ocean and humans are inextricably interconnected.

Fundamental Concept b. From the ocean we get foods, medicines, and mineral and energy resources. In addition, it provides jobs, supports our nation's economy, serves as a highway for transportation of goods and people, and plays a role in national security.

Fundamental Concept g. Everyone is responsible for caring for the ocean. The ocean sustains life on Earth and humans must live in ways that sustain the ocean. Individual and collective actions are needed to effectively manage ocean resources for all.

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 c. Over the last 40 years, use of ocean resources has increased significantly, therefore the future sustainability of ocean resources depends on our understanding of those resources and their potential and limitations.

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, including how you use it in your formal/informal education settings.
Please send your comments to:
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For More Information

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CTD Sample Analysis Worksheet

Group Name: ______________________

Sample	Temperature	pH
A		
B		
C		
D		
E		

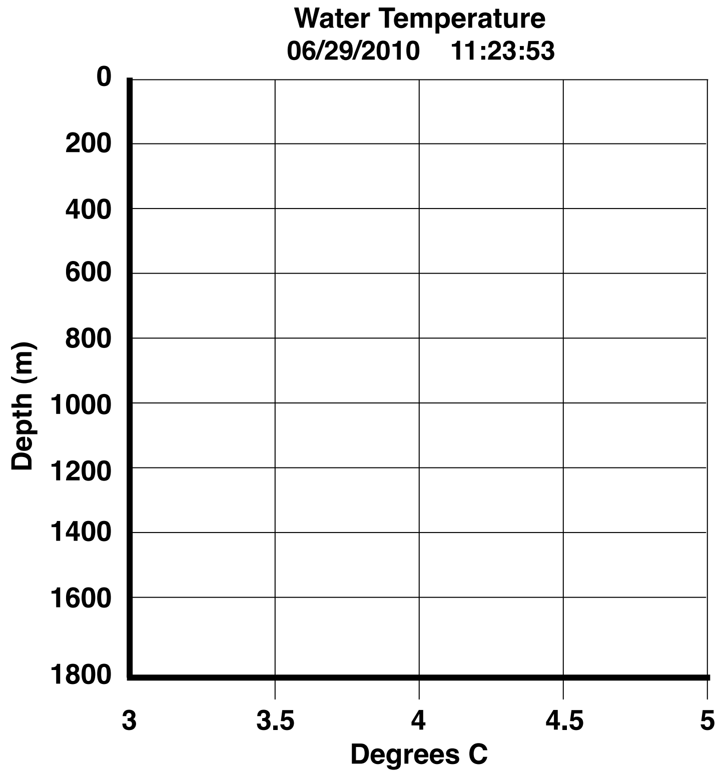
1. Do the data in the table above suggest that any of these samples might have been collected near a hydrothermal vent?

2. How do your data support this inference?

3. Here are some data from CTD casts made aboard the *Okeanos Explorer* during the INDEX-SATAL 2010 Expedition (these are just a few of the data points provided by the CTD instruments; the complete data sets contain thousands of points!). Plot these points on the grids. Do any of your graphs show any possible anomalies?

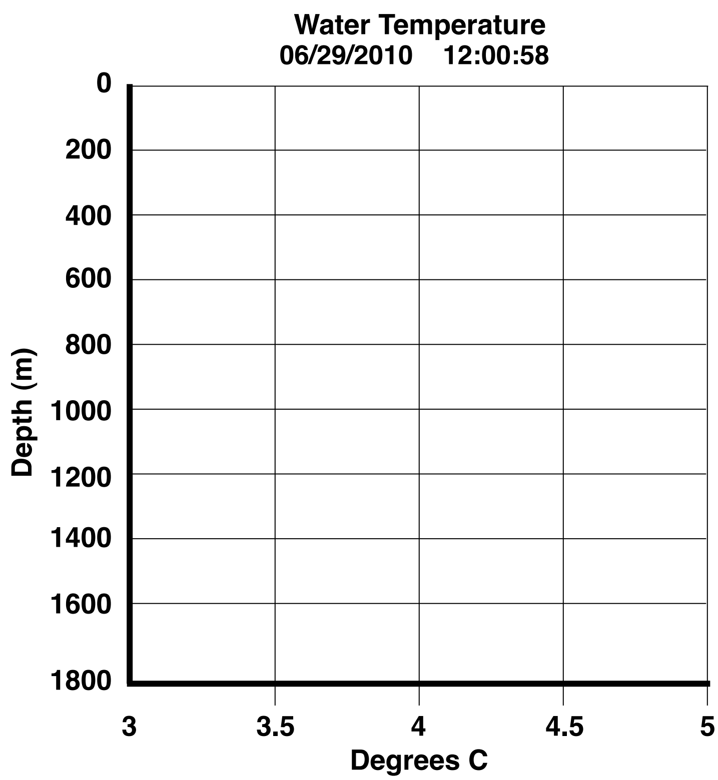
CTD Cast 06/29/2010 11:23:53

Depth (m)	Water Temperature (°C)
1450	3.8
1600	3.75
1680	3.6
1750	3.6
1800	3.7



CTD Cast 06/29/2010 12:00:58

Depth (m)	Water Temperature (°C)
1400	3.8
1500	3.75
1600	3.7
1700	3.67
1750	3.65
1800	3.6



CTD Cast 07/06/2010 09:42:42

Depth (m)	Water Temperature (°C)
10	4.95
50	4.9
80	4.85
100	4.8
150	4.5
175	4.4
190	4.2
200	4.1
300	3.7
400	3.4
500	3.35
600	3.32
700	3.30
800	3.25
900	3.20
1000	3.175
1100	3.16
1200	3.15
1300	3.12
1400	3.10
1500	3.08
1600	3.07
1700	3.06
1800	3.05