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2005 Lost City Expedition

What's That?

Focus
Investigating Lost City Hydrothermal Field ecosystems by remotely operated vehicles

Grade Level
5-6 (Life Science/Physical Science)

Focus Question
What are some of the decisions that scientists must make when deciding how to investigate an unexplored area of the deep ocean?

Learning Objectives
Students will be able to describe a sampling strategy for investigating an unknown area, and will be able to explain why this strategy is appropriate for such an investigation.

Students will be able to identify and discuss some of the limitations faced by scientists investigating unexplored areas of the deep ocean.

Students will be able to discuss how an autonomous underwater vehicle such as the Autonomous Benthic Explorer can contribute to discoveries such as the Lost City Hydrothermal Field.

Materials
- ❒ Murals constructed in the "Animals of the Lost City" lesson
- ❒ Removable "sticky notes," 7.6 cm x 7.6 cm (3 in x 3 in); 120 for each mural

Audio/Visual Materials
- ❒ (Optional) equipment for viewing online or downloaded video of vent communities

Teaching Time
One or two 45-minute class periods, plus time for completion of the "Animals of the Lost City" lesson

Seating Arrangement
Groups of four to six students

Maximum Number of Students
30

Key Words
Lost City
Hydrothermal vent community
Autonomous underwater vehicle
Autonomous Benthic Explorer

Background Information
In 1977, scientists in the deep-diving submersible Alvin made the first visit to an oceanic spreading ridge near the Galapagos Islands, and made one of the most exciting discoveries in 20th century biology. In the middle of deep, cold ocean waters, they found hot springs and observed black smoke-like clouds billowing from chimneys of rock; and nearby were communities of animals that no one had ever seen before.

These hot springs came to be known as hydrothermal vents, and since that first discovery, more than 200 similar vent fields have been documented in the world's ocean. These systems are formed when seawater flowing through cracks in the seafloor crust enters magma-containing chambers beneath a spreading ridge. Intense heat from the molten rock causes a variety of chemical changes and many substances from the rocks become dissolved in the fluid. The heated fluid becomes less dense, rises upward, and emerges onto the sea floor to form a hydrothermal vent. When the heated fluid is cooled by cold water of the deep ocean, many of the dissolved materials precipitate, creating black clouds and chimneys of rock-like deposits. The hydrothermal fluid emerging from the vents is rich in sulfide, which is used as an energy source by chemosynthetic bacteria to produce essential organic substances. These autotrophic bacteria are the base of a diverse food web that includes large tubeworms (vestimentiferans), clams, mussels, limpets, polychaete worms, shrimp, and crabs.

In 2000, a different sort of vent field was serendipitously discovered on an underwater mountain called the Atlantis Massif near the Mid-Atlantic Ridge. This new field also had hot fluids venting from rocky chimneys. But these chimneys towered as much as 200 feet above the seafloor, much larger than chimneys found in other vent fields. In fact, the vent field was located 15 kilometers away from the spreading axis of the Mid-Atlantic Ridge and the chimneys looked so much like towers and spires of a fantastic city that the new vent field was named "Lost City." And the fluids emerging from the chimneys, as well as the surrounding biological communities, were unlike any other known hydrothermal system. Subsequent investigations have shown that the newly-discovered hydrothermal fields are not formed by seawater reacting with molten magma. Instead, these fields are formed when seawater reacts with solid mantle rocks. These rocks, called peridotites, are formed deep inside the Earth, but a unique type of faulting can bring them close to the seafloor. Cracks in the seafloor can allow seawater to percolate down to the up-lifted peridotites. When this happens, numerous chemical reactions occur between seawater and minerals in the rock (a process called serpentinization). These reactions produce a large amount of heat that causes the fluids to rise and eventually vent at the surface of the seafloor. Mixing between the heated fluids and cold surrounding seawater causes additional reactions that include precipitation of calcium carbonate (limestone), which forms the towering chimneys of Lost City. Because the reactions of seawater with peridotites are essential to these formations, the Lost City is called a "peridotite-hosted ecosystem."

In contrast to the abundant biological communities of hydrothermal vents formed by volcanic activity, the Lost City Hydrothermal Field (LCHF) initially appeared to be devoid of living organisms. But when scientists took a closer look at the surface of the chimneys (they actually vacuumed the surface), they found large numbers of tiny shrimps and crabs. Because most of these animals are less than one centimeter in size, transparent or translucent, and tend to hide in small crevices, they were easily overlooked when the LCHF was first discovered. While the total biomass around the LCHF vents appears to be less than at other hydrothermal vents, scientists believe there is just as much diversity (variety of different species). Like previously discovered vent communities, the LCHF ecosystem is based on microorganisms that are able to use chemicals in the vent fluids as an energy source for producing complex organic compounds that are used as food by other species (chemosynthesis). But again, the LCHF differs in that the fluids emerging from the chimneys has very little of the hydrogen sulfide and metals that are typical in hydrothermal fluids of other vent. Instead, LCHF vent fluids contain high concentrations of methane and hydrogen, and these chemicals appear to provide the energy source for chemosynthetic microbes.

Discovery of the LCHF is a good example of how serendipity often enters scientific investigations.

Scientists who made the discovery were studying the Atlantis Massif, a formation unusual enough to justify its own investigation. In the words of Donna Blackman, a geophysicist from the Scripps Institution of Oceanography and chief scientist of the expedition, "As so often happens, we were pursuing one set of questions concerning building of the mountain and we stumbled onto a very important new discovery."

The scientists investigating the Atlantic Massif were using a robotic vehicle known as the Autonomous Benthic Explorer (ABE) that is designed to conduct underwater surveys without a pilot or tether to a ship or submersible. ABE operates entirely on its own, performing a predetermined set of maneuvers, taking photographs, and collecting data and samples over an area about the size of a city block. Currently, ABE follows a set of instructions placed in its memory before deployment and the data it collects are accessible only after the robot is recovered. When ABE gave scientists their first glimpse of the LCHF, they only had time for one dive in the deep submergence vehicle Alvin for a first-hand look. The fact that scientists initially thought there were very few animals at Lost City underscores some of the challenges faced by scientists who are studying unexplored areas with limited time for observations.

In this lesson, students will simulate an investigation of a hydrothermal vent community using an autonomous underwater vehicle.

Learning Procedure

1. To prepare for this lesson, review background information on the Autonomous Benthic Explorer (ABE) at http://oceanexplorer.noaa.gov/technology/subs/abe/abe.html.

2. Complete Steps 1, 2, and 3 of the "Animals of the Lost City" lesson. Be sure to stress that students should keep their work secret from other groups.

3. Have each group completely cover their mural with "sticky notes" placed edge-to-edge with the top row and left column of sticky notes labeled as illustrated in Figure 1(Found on Page 6).

4. Briefly discuss the Autonomous Benthic Explorer, highlighting the fact that instructions for an ABE mission must be programmed before the vehicle begins the investigation.

5. Tell students that their assignment is to simulate an investigation of an unexplored hydrothermal vent community using an ABE-type robot. The area of the investigation will be represented by a mural prepared by another group of students. Say that because of time and technical constraints, their robot can only obtain 40 images, each of which covers an area equal to a single sticky note.

   To prepare for their exploration, they need to decide which 40 images to obtain out of the total 99 possible images in the entire area of investigation (the labelled sticky notes in the top row and left hand column are not included in the area of investigation). The location of each image will be described by an "address" that uses the row and column labels (similar to the x, y coordinate system used in graphing data). So, the image in the upper left corner has address = A, 1; the image in the upper right corner has address = CC, 1; the image in the lower left corner has address = A, 35; the image in the lower right corner has address = CC, 35; etc.

   Have each group decide on an exploration strategy by selecting the 40 locations to be programmed into their robot. Some of the possible strategies are:
   - Random (scattered over the entire area of investigation);
   - Clustered (groups of two or more images spaced over the area of investigation);
   - Transect (locations selected to concentrate images in specific rows or columns);

- Checkerboard (image locations evenly spaced over the area of investigation

Have each group submit a written list of their selected image addresses (so the teacher can guard against changes in the address list as images are revealed in Step 7).

6. Assign each group to one of the murals prepared by another group. Groups that prepared murals illustrating LCHF-type vent communities should be assigned an "unknown" mural illustrating a vent community based on reactions of seawater, and vice versa.

7. Have one member of each group remove the sticky notes corresponding to the selected image addresses as these addresses are read aloud by another group member. When all 40 images have been revealed, all members of the groups should remain seated far enough away from the mural so that no additional sticky notes can be removed.

   When 40 images have been revealed on all of the murals, have each group prepare a description of their area of investigation based on their observations.

8. Have each group present an oral summary of their conclusions, then lead a discussion of the sampling strategies that appeared to provide the best information. Students should realize that scientists often have little or no information about the actual distribution of interesting features in an explored area, so a common strategy is to perform a broad survey that includes samples scattered over the entire survey area, then collect additional samples in areas that reveal interesting features.

   Because rare, widely scattered features may still be missed, scientists sometimes use a "cumulative species" graph to decide when they have collected enough samples. This is simply a graph in which the total number of species (or other features of interest) found is plotted on the y-axis against the number of samples collected plotted on the x-axis. Initially the cumulative number of species (y-axis) increased rapidly as more samples (x-axis) are collected, but the curve eventually begins to "flatten out" so that collecting more samples produces fewer and fewer new species. (See Figure 2 on page 7.) Students should realize that in almost all investigations, the number of samples collected is a compromise between the need to develop a complete picture of what is present and problems of time, sample capacity, ability to analyze large numbers of samples, and other technical constraints.

   When areas appear devoid of features of interest, other types of samples may be collected. For example, when scientists saw no evidence of animal life on Lost City chimneys by visual observation, they tried vacuuming the surface of the chimneys to collect small, hard-to-see organisms; and this strategy revealed that quite a bit more animal life was present than was believed initially!

9. Complete Step 5 of the "Animals of the Lost City" lesson.

The Bridge Connection

www.vims.edu/bridge/ – In the "Site Navigation" menu on the left, click "Ocean Science Topics," then "Habitats," then "Deep Sea" for links to resources about hydrothermal vents.

The "Me" Connection

Have students write a short essay describing a search strategy that they might personally use to locate a "feature of interest" such as a friend in a shopping mall, lost pet, or interesting book in an airport bookstore.

Connections to Other Subjects

English/Language Arts, Geography, Physical Science, Mathematics

Evaluation

Reports and discussions in Step 8 provide opportunities for assessment.

Extensions

1. Visit http://oceanexplorer.noaa.gov/explorations/05lostcity/welcome.html to keep up to date with the latest Lost City Expedition discoveries.

2. Visit http://oceanexplorer.noaa.gov/technology/subs to investigate how other underwater research vehicles are used in deep sea explorations.

Resources

Visit the Lost City expedition's Web pages (http://oceanexplorer.noaa.gov/explorations/05lostcity/welcome.html; http://www.lostcity.washington.edu/; and http://www.immersionpresents.org) for an overview of the expedition and background essays.

http://www.oceanexplorer.noaa.gov/explorations/02fire/logs/magicmountain/welcome.html – Virtual tour of Magic Mountain, a hydrothermal vent site located on Explorer Ridge in the NE Pacific Ocean, about 150 miles west of Vancouver Island, British Columbia, Canada.

http://oceanexplorer.noaa.gov/explorations/03fire/logs/ridge.html – 3-dimensional structure of a "mid-ocean ridge," where two of the Earth's tectonic plates are spreading apart

http://www.bio.psu.edu/hotvents – Virtual tour of hydrothermal vent communities

http://seawifs.gsfc.nasa.gov/OCEAN_PLANET/HTML.ps_vents.html – Links to many other Web sites with information about hydrothermal vents

Tunnicliffe, V., 1992. Hydrothermal-vent communities of the deep sea. American Scientist 80: 336-349.

Corliss, J. B., J. Dymond, L.I. Gordon, J.M. Edmond, R.P. von Herzen, R.D. Ballard, K. Green, D. Williams, A. Bainbridge, K. Crane, and T.H. Andel, 1979. Submarine thermal springs on the Galapagos Rift. Science 203:1073-1083. – Scientific journal article describing the first submersible visit to a hydrothermal vent community

National Science Education Standards

Content Standard A: Science As Inquiry
- Abilities necessary to do scientific inquiry
- Understandings about scientific inquiry

Content Standard C: Life Science
- Populations and ecosystems

Content Standard E: Science and Technology
- Abilities of technological design
- Understandings about science and technology

Content Standard F: Science in Personal and Social Perspectives
- Science and technology in society

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

For More Information

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Figure 1.

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	AA	BB	CC
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Figure 2.