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2005 Lost City Expedition

Animals of the Lost City

Focus
Biological communities at the Lost City Hydrothermal Field

Grade Level
5-6 (Life Science)

Focus Question
What organisms are found at the Lost City Hydrothermal Field, and how are they different from organisms found at hydrothermal vents associated with volcanic activity?

Learning Objectives
Students will be able to compare and contrast living organisms typically found at hydrothermal vent communities associated with volcanic activity with those found at vent communities of the Lost City Hydrothermal Field.

Students will be able to explain the difference between geologic processes that produce the Lost City Hydrothermal Field and processes that produce previously-discovered hydrothermal vents.

Materials
❒ Copies of background material on biological communities associated with the Lost City Hydrothermal Field and communities associated with hydrothermal vent fields based on volcanic activity, or references to appropriate materials (see Learning Procedure, Step 1)

❒ Materials for constructing murals (Bristol board, foamcore, etc; colored markers or pencils); if the "What's That?" lesson is to be completed, finished murals should measure approximately 76 cm x 85 cm (30 in x 36 in)

❒ (Optional, for demonstrating exothermic reactions) (a) chemical handwarmers (available from camping supply stores); or (b) polyester resin, catalyst, and disposable mixing container (available from hardware stores)

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

Teaching Time
Two 45-minute class periods, plus time for student research and work on murals and written reports

Seating Arrangement
Groups of four to six students

Maximum Number of Students
30

Key Words
Lost City
Hydrothermal vent
Peridotite
Hydrothermal fluid
Chemosynthesis
Autotrophic

Background Information
In 1977, scientists in the deep-diving submersible Alvin made the first visit to an oceanic spread-

ing 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 spe-

cies (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.

In this lesson, students will create murals to compare and contrast biological communities of LCHF and hydrothermal vent fields based on reactions of seawater with molten magma. These murals may also be used in the accompanying lesson, "What's That?"

Learning Procedure

1. To prepare for this lesson:
   (a) 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.

   (b) If you want to provide student groups with background information needed to construct murals, make copies of relevant essays from sites listed in (a) above, as well as from one or more sites that provide information on hydrothermal vent fields based on volcanic activity (http://www.oceanexplorer.noaa.gov/explorations/02fire/logs/magicmountain/welcome.html and http://www.bio.psu.edu/hotvents offer virtual tours of hydrothermal vent communities; http://seawifs.gsfc.nasa.gov/OCEAN_PLANET/HTML.ps_vents.html has links to many other Web sites with information about hydrothermal vents). Alternatively, depending upon students' research skills, you may want to simply provide students with these links and allow them to research relevant information on their own.

2. Briefly review the concepts of plate tectonics, being sure that students understand the processes that take place at convergent and divergent boundaries, and why these boundaries are often the site of volcanic activity. Briefly review the discovery of hydrothermal vents, and describe the general appearance of hot fluids venting from chimneys or cracks in the seafloor. You may want to show video clips from some of the sites referenced in Step 1 to supplement this discussion. Be sure students understand that these vent communities were produced by seawater reacting with molten magma.

   Tell students that in the year 2000 a different type of vent community was discovered in which heat results from reactions between seawater and solid rock (peridotite) that is brought close to the surface by faulting. Be sure students understand the difference between the two type of vents communities, and that the reactions that form the LCHF occur because the rock was originally formed deep inside the Earth's mantle, and has a chemical structure that is not stable in the presence of seawater.

   You can demonstrate an exothermic reaction with chemical handwarmers (follow directions on the package), or by catalyzing a small amount (100-200 ml) of polyester resin (follow directions on the resin container) in a disposable mixing cup (usually supplied with the resin). As the resin polymerizes, heat produced by the exothermic polymerization reaction is easily detectable by gently touching the container [NOTE: Be careful! Mix the resin and catalyst only in a suitable container, because enough heat is produced to melt ordinary plastic drinking cups].

   Discuss chemosynthesis, and contrast this process with photosynthesis. (See the Entering the Twilight Lesson Plan: http://oceanexplorer.noaa.gov/explorations/02mexico/background/edu/media/gom_twilight.pdf). Be sure students recognize that energy is required to synthesize essential compounds needed by living organisms; and that the key difference between photosynthesis and chemosynthesis is where the energy comes from.

3. Tell students that their assignment is to:
   (a) Write a brief research report describing the physical and biological features of a LCHF-type vent community or a vent community based on reactions of seawater with molten magma; and

   (b) Construct a mural that illustrates the features that would be seen by an observer inside a deep-diving submarine from a distance of about ten feet.

   Assign each student group either a volcanic activity-based vent community or a LCHF-type activity-based vent community, and provide background information or references to sources of this information.

   If you plan to use these murals for the "What's That?" lesson, emphasize that each group should keep their information to themselves, and not share ideas for their illustrations with other groups. In addition, murals should include a reasonable amount of open space (that is, a mural of a LCHF community should have more than one carbonate chimney, and these should occupy no more than half of the total area of the mural). Viewing one or more of the virtual tours referenced in step 1 should give a reasonably good idea about how the overall mural should appear.

   NOTE: It is particularly important that students working on murals of the LCHF understand that many of the organisms in these communities would not be visible at a distance of ten feet (which is why scientists initially thought there were very few animals at Lost City); so their murals will illustrate tall chimneys and hot fluids, but not much else. Their written reports, however, should contain a complete account of what is presently known about the organisms that inhabit these communities. Stress that studies of the LCHF are only beginning, while vent communities based on volcanic activity have been studied for more than 30 years. To provide an opportunity to make these points, you may want to require each group to discuss plans for their mural prior to actually preparing their illustration.

4. Proceed to the Learning Procedure for "What's That" if you want to students to complete that lesson.

5. Have each student group make an oral presentation of their research report, then lead a discussion of these results. The following points should be included:

   - The most prominent feature of LCHF communities are the tall chimneys of carbonate rock that may be 20 or 30 meters high.

   - Chimneys in hydrothermal vent fields formed by volcanic activity are much shorter that those found at LCHF, and are made of metallic rocks, particularly iron sulfide.

   - Hydrothermal fluids at vent fields formed by volcanic activity have temperatures as high as 403°C, are rich in dissolved metals and hydrogen sulfide, are highly acidic, and form "black smokers."

   - Hydrothermal fluids at LCHF have temperatures between 40° – 90°C, contain high concentrations of methane and hydrogen, are highly alkaline (basic), and do not form "black smokers."

   - Autotrophic bacteria are the base of the food web in both communities, but bacteria at vent fields formed by volcanic activity use hydrogen sulfide and metals, while bacteria at LCHF use methane and hydrogen.

   - Typical fauna at vents formed by volcanic activity include tubeworms (vestimentiferans) up to 3 meters in length, large clams and mussels (up to 30 cm long), limpets, poly-

chaete worms, shrimps, and crabs; suspension feeders (barnacles, anemones, "feather duster" worms, bivalves) dominate the benthic fauna a short distance away from the vent.

- Microorganisms are abundant in the LCHF biological community, as well as gastropods, amphipods, polychaete worms, nematodes, bivalves, and sponges; although the overall biomass of these communities is less than at vents formed by volcanic activity, the diversity (number of different species) appears to be just as high.

Briefly discuss the visibility, size, and habits of animals that initially led scientists to believe that there was very little fauna at LCHF. The important point here is that our powers of direct observation are not powerful enough to detect every organism that may be present. Many beaches, for example, appear to have very few species; but if we dig into the sand, use a microscope, and make observations at different times of day and night we are likely to see much more.

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 real or imaginary example of how our limited powers of direct observation led (or might have led) to erroneous conclusions based on an initial set of observations.

Connections to Other Subjects

English/Language Arts, Geography, Physical Science

Evaluation

Groups' murals, written reports, and oral presentations provide opportunities for assessment.

Extensions

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

Have students diagram a hypothetical food web for the LCHF, beginning with chemosynthetic bacteria that use hydrogen and/or methane from vent fluids.

Discuss the idea that chemosynthetic bacteria were the first life forms on Earth (see Rock Eaters of the Gulf of Alaska at http://oceanexplorer.noaa.gov/explorations/02alaska/background/edu/media/rock_eaters9_12.pdf for more information).

Resources

http://oceanexplorer.noaa.gov/explorations/explorations.html – Index page for Ocean Explorer expeditions, including the 2005 Lost City expedition

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

- Structure and function in living systems
- 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

- Abilities of technological design
- Understandings about science and technology

Content Standard F: Science in Personal and Social Perspectives

- Populations, resources, and environments

Content Standard G: History and Nature of Science

- Nature of science

For More Information

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