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2006 Submarine Ring of Fire

What's for Dinner?

(adapted from the 2005 New Zealand American Submarine Ring of Fire Expedition)

Focus

Sources of nutrition for biological communities associated with volcanoes of the Marianas Arc

Grade Level

7-8 (Life Science)

Focus Question

What does the presence of molten sulfur reveal about physical and chemical conditions at hydrothermal vents?

Learning Objectives

Students will be able to compare and contrast photosynthesis and chemosynthesis as sources of primary production for biological communities.

Students will be able to give at least three examples of organisms that live near hydrothermal vent systems.

Students will be able to describe two sources of primary production observed in biological communities associated with volcanoes of the Marianas Arc.

Materials

- ❒ If students do not have access to the internet, you will need to make copies of "Life without Light: Discoveries from the Abyss" (see "Resources"), and logs specified in "Learning Procedure" one copy for each student or student group

Audio/Visual Materials

- ❒ None

Teaching Time

At least two 45-minute class periods, plus time for student research

Seating Arrangement

Classroom style if students are working individually, or groups of two to four students

Maximum Number of Students

30

Key Words

Photosynthesis
Chemosynthesis
Primary production
Ring of Fire
Asthenosphere
Lithosphere
Magma
Fault
Transform boundary
Convergent boundary
Divergent boundary
Subduction
Tectonic plate
Mariana Arc

Background Information

The Submarine Ring of Fire is an arc of active volcanoes that partially encircles the Pacific Ocean Basin and results from the motion of large pieces of the Earth's crust known as tectonic plates.

These plates 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. The 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) that cause the tectonic plates to move several centimeters per year relative to each other.

If tectonic plates are moving apart their junction is called a divergent plate boundary; if they slide horizontally past each other they form a transform plate boundary; and if they collide more or less head-on they form a convergent plate boundary. The Pacific Ocean Basin lies on top of the Pacific Plate. To the east, new crust is formed by magma rising from deep within the Earth and erupting at divergent plate boundaries between the Pacific Plate and the North American and South American Plates. These eruptions form submarine mountain ranges called oceanic spreading ridges. While the process is volcanic, volcanoes and earthquakes along oceanic spreading ridges are not as violent as they are at convergent plate boundaries.

To the west, the Pacific Plate converges against the Philippine Plate. The Pacific Plate is forced beneath the Philippine Plate, creating the Marianas Trench (which includes the Challenger Deep, the deepest known area of the Earth's ocean). As the sinking plate moves deeper into the mantle, fluids are released from the rock causing the overlying mantle to partially melt. The new magma (molten rock) rises and may erupt violently to form volcanoes, often forming arcs of islands along the convergent boundary. The Mariana Islands are the result of this volcanic activity, which frequently causes earthquakes as well. The movement of the Pacific Ocean tectonic plate has been likened to a huge conveyor belt on which new crust is formed at the oceanic spreading ridges off the western coasts of North and South America, and older crust is recycled to the lower mantle at the convergent plate boundaries of the western Pacific.

Underwater volcanism produces hot springs in the middle of cold, deep ocean waters. These springs (known as hydrothermal vents) were first discovered in 1977 when scientists in the submersible Alvin visited an oceanic spreading ridge near the Galapagos Islands, and made one of the most exciting discoveries in 20th century biology. Here they found warm springs surrounded by large numbers of animals that had never been seen before. Since they were first discovered, sea-floor hot springs around spreading ridges have been intensively studied. In contrast, the hydrothermal systems around convergent plate boundaries are relatively unexplored.

The 2003 Ocean Exploration Ring of Fire expedition surveyed more than 50 volcanoes along the Mariana Arc, and discovered that ten of these had active hydrothermal systems (visit http://oceanexplorer.noaa.gov/explorations/03fire/welcome.html for more information on these discoveries). The 2004 Submarine Ring of Fire Expedition focussed specifically on hydrothermal systems of the Mariana Arc volcanoes, and found that these systems are very different from those found along mid-ocean ridges (visit http://oceanexplorer.noaa.gov/explorations/04fire/welcome.html for more information). The 2006 Submarine Ring of Fire Expedition is focussed on interdisciplinary investigations of the hydrothermal and volcanic processes on the submarine volcanoes of the Mariana Arc. In this lesson, students will explore some results from the Submarine Ring of Fire Expeditions, and how food webs may operate in hydrothermal vent communities.

Learning Procedure

NOTE: This lesson makes use of written logs, video, and photographic imagery from the 2004 Submarine Ring of Fire Web site, as well as a background article from the Smithsonian National

Zoological Park's Zoogoer Magazine. Depending upon the extent of internet access in your classroom, you may want to download and possibly duplicate some of these materials for student use. The activities described below may be undertaken as a single collaborative project involving all the students in the class, or as a series of projects undertaken by smaller groups of students. The optimal approach will depend upon the time available and student capabilities.

1. To prepare for this lesson, review:
   - Introductory essays for the 2006 Submarine Ring of Fire Expedition at http://oceanexplorer.noaa.gov/explorations/06fire/welcome.html
   - NOAA Learning Object on Hydrothermal Vent Life at http://www.learningdemo.com/noaa/; and
   - References listed in Step 4, below.

2. Briefly review the concepts of plate tectonics and continental drift. Be sure students understand the idea of convergent, divergent, and transform boundaries, as well as the overall type of earthquake and volcanic activity associated with each type of boundary (strong earthquakes and explosive volcanoes at convergent boundaries; slow-flowing volcanoes, weaker earthquakes at divergent boundaries; strong earthquakes, rare volcanoes at transform boundaries). You may want to use materials from "This Dynamic Earth" and/or "This Dynamic Planet" (see Resources section). Briefly discuss the discovery of new life forms and ecosystems at hydrothermal vent systems that result from tectonic processes (you may want to use resources from NOAA's hydrothermal vent Web site (http://www.pmel.noaa.gov/vents/home.html) to supplement this discussion). Introduce the Ring of Fire, and describe the processes that produce the Mariana Arc.

3. Tell students that the 2004 Ring of Fire Expedition explored hydrothermal systems of the Mariana Arc, including the biological communities associated with these systems. Point out that these expeditions are studying places that have been explored very little or not at all, so it is very likely that scientist will find species that have never been seen before. Review (or introduce) the concepts of a food web and primary production, emphasizing that the primary source of energy for most familiar food webs is the sun. Lead a brief "brainstorming" session about what the primary energy source might be for biological communities that live in the deep ocean, where sunlight is absent. Students may hypothesize that these communities depend upon dead organisms and detritus that sink from shallower waters; and in fact, this is true for some deep-sea communities. For these communities, the sun is still the primary energy source, since the dead organisms and detritus were part of food webs based on photosynthesis. Some students may already be somewhat familiar with hydrothermal vents and may suggest chemosynthesis as a potential energy source for deep-sea communities. If chemosynthesis is not suggested, do not introduce the concept just yet.

4. Tell students that their assignment is to prepare a report on the major types of organisms found in deep-sea communities on two of the volcanoes explored by the 2004 Ring of Fire Expedition, and to decide what the primary energy source probably is for these communities. Reports should include:
   - A list the organisms reported from the East Diamante and NW Rota 1 volcanoes;
   - The approximate depth at which these organisms were found;
   - How each organism obtains its food;
   - Inferences about the primary energy source for these communities, and evidence to support these inferences.

   You may want to divide the sites and organisms among several students or student groups to reduce the time needed to complete the assignment. Another approach is to have the entire class work together to build a list of organisms, divide the list among the students for purposes of researching how these organisms obtain their food, then brainstorm probable primary energy sources after students have presented the results of their research.

You may also want to have students construct a model or diagram of one of these volcanoes to help visualize where the organisms were found. Three dimensional animations of several volcanoes can be found at http://oceanexplorer.noaa.gov/explorations/04fire/background/marianaarc/media/diamante_vr.html.

Direct students to (or provide copies of) the following resources to begin their assignment:
- "Life without Light: Discoveries from the Abyss" (see "Resources")
- Logs from April 15, 2004; April 14, 2004; April 12, 2004; April 11, 2004; April 5, 2004; and April 2, 2004 (links at http://oceanexplorer.noaa.gov/explorations/04fire/welcome.html)
- Videos from the "Aquarium" and hydrothermal vent sites at East Diamante volcano (April 5 and April 8; see the Expedition photo log at http://oceanexplorer.noaa.gov/explorations/04fire/logs/photolog/photolog.html)
- The Tree of Life project (http://tolweb.org/tree/phylogeny.html) is a good starting point for research into feeding habits

You may also want to suggest that students include photographs of representative species from the Expedition photo log page.

5. Have students present the results of their research. The following points should emerge during these presentations:

Four organisms were observed in the vicinity of hydrothermal vents on NW Rota 1 (whose summit is 600 m deep):
- small white crab;
- shrimp;
- large limpets; and
- scale worms.

In the daily logs, scientists speculated that the crabs might feed on the shrimp, since the shrimp reacted violently when crabs approached, and that bacterial mats were probably the main food of the shrimp. Limpets were seen grazing near fluid seeps, possibly on bacterial films. Students should infer that the primary energy source for these species is probably chemosynthetic bacteria that are able to utilize sulfur compounds released through the hydrothermal vents, and that form extensive mats on which several organisms were seen grazing.

The scientists also reported seeing many animals that were not living at the vents, including
- sea anemones;
- soft corals;
- hydroids; and
- stalked crinoids.

Students may infer that the primary energy source for these organisms is also the chemosynthetic bacteria. Since these organisms are all particle feeders, it is also reasonable to infer that the primary energy source may be particulate matter generated near the sea surface, in which case the primary energy source would be the sun. A third possibility is that these organisms use particulate material produced in both chemosynthetic and photosynthetic food webs.

Logs reporting observations on the East Diamante volcano make it clear that both chemosynthetic and photosynthetic food webs are present. The slope of "Pinnacle Cone" was completely covered with a microbial mat, but red and green algae appeared at a depth of approximately 200 m, so that hydrothermal vent (chemosynthetic) and coral reef (photosynthetic) communities were overlapping at 190 m depth.

The video clip from the "Aquarium" site at East Diamante includes images of:

- tuna (a transient species; not part of the bottom community);
- tangs;
- squirrelfish;
- gorgonian coral;
- other soft corals; and
- hydrozoa.

The video from a hydrothermal vent site on the same volcano includes:

- a spider crab (seen but not named);
- basket stars;
- anemone;
- barnacles; and
- snails.

This list includes grazers (snails), suspension feeders (basket stars, anemone, barnacles), and omnivores (spider crab).

Be sure students understand the concept of primary production, and the distinction between chemosynthetic primary production and photosynthetic primary production. Students should also realize that it is possible for organisms to receive energy from both types of primary production. For example, many of the organisms reported by the 2004 Ring of Fire Expedition are suspension feeders, and probably receive a substantial portion of their nutrition from plankton. Plankton may include the larval forms of species found near vents (such as crabs, shrimp, worms and snails), as well as species in photosynthetic communities. You may want to point out that these larval forms may remain in the water column for days or months, and are the main means by which new vent sites are colonized.

The Bridge Connection

www.vims.edu/bridge/index_archive0503.html – Links to resources about hydrothermal vents

The "Me" Connection

Have students write a brief essay describing how chemosynthetic food webs might be personally important or beneficial.

Connections to Other Subjects

English/Language Arts, Geography

Assessment

Student reports and discussions provide opportunities for assessment.

Extensions

1. Visit http://oceanexplorer.noaa.gov/explorations/06fire/welcome.html for daily logs and updates about discoveries being made by the 2006 Submarine Ring of Fire Expedition.

2. Visit the MARVE (Marine Virtual Explorer) Web site of the Stanford University School of Earth Sciences (http://pangea.stanford.edu/projects/marve/) for a simulated research dive in the Alvin submersible to a hydrothermal vent field on the East Pacific Rise.

Resources

Multimedia Learning Objects

http://www.learningdemo.com/noaa/ – Click on the links to Lessons 1, 2, 4, and 5 for interactive multimedia presentations and Learning Activities on Plate Tectonics, Mid-Ocean Ridges, Subduction Zones, and Chemosynthesis and Hydrothermal Vent Life

Other Relevant Lesson Plans from the Ocean Exploration Program

Mapping Deep-sea Habitats in the Northwestern Hawaiian Islands

http://www.oceanexplorer.noaa.gov/explorations/02hawaii/background/education/media/nwhi_mapping.pdf (7 pages, 80kb) (from the 2002 Northwestern Hawaiian Islands Expedition)

Focus: Bathymetric mapping of deep-sea habitats (Earth Science - This activity can be easily modified for Grades 5-6)

In this activity, students will be able to create a two-dimensional topographic map given bathymetric survey data, will create a three-dimensional model of landforms from a two-dimensional topographic map, and will be able to interpret two- and three-dimensional topographic data.

It's a Gas! Or is it? http://www.oceanexplorer.noaa.gov/explorations/05fire/background/edu/media/rof05_gas.pdf (9 pages, 760k) (from the New Zealand American Submarine Ring of Fire 2005 Expedition)

Focus: Effects of temperature and pressure on solubility and phase state (Physical Science/ Earth Science)

Students will be able to describe the effect of temperature and pressure on solubility of gases and solid materials; describe the effect of temperature and pressure on the phase state of gases; and infer explanations for observed chemical phenomena around deep-sea volcanoes that are consistent with principles of solubility and phase state.

How Does Your Magma Grow? http://www.oceanexplorer.noaa.gov/explorations/05galapagos/background/edu/media/05galapagos_magma.pdf (6 pages, 224k) (from the 2005 Galapagos: Where Ridge Meets Hotspot Expedition)

Focus: Hot spots and midocean ridges (Physical Science)

In this activity, students will identify types of plate boundaries associated with movement of the Earth's tectonic plates, compare and contrast volcanic activity associated with spreading centers and hot spots, describe processes which resulted in the formation of the Galapagos Islands, and describe processes that produce hydrothermal vents.

Other Links and Resources

http://www.oceanexplorer.noaa.gov/explorations/04fire/background/marianaarc/marianaarc.html – Virtual fly-throughs and panoramas of eight sites in the Mariana Arc

http://www.oceanexplorer.noaa.gov/explorations/02fire/logs/magic-mountain/welcome.html – Magic Mountain Virtual Web site, featuring animations and videos of the Magic Mountain hydrothermal field

http://oceanexplorer.noaa.gov/explorations/03fire/logs/subduction.html and http://oceanexplorer.noaa.gov/explorations/03fire/logs/ridge.html – Animations of the 3-dimensional structure of a mid-ocean ridge and subduction zone

http://pubs.usgs.gov/publications/text/dynamic.html#anchor19309449 – On-line version of "This Dynamic Earth," a thorough publication of the U.S. Geological Survey on plate tectonics written for a non-technical audience

http://pubs.usgs.gov/pdf/planet.html – "This Dynamic Planet," map and explanatory text showing Earth's physiographic features, plate movements, and locations of volcanoes, earthquakes, and impact craters

http://www.pmel.noaa.gov/vents/nemo/education.html – Web site for the New Millennium Observatory Project, a long-term study of the interactions between geology, chemistry, and biology on Axial Seamount, an active volcano on the Juan de Fuca Ridge that is part of the mid-ocean ridge system

http://vulcan.wr.usgs.gov/ – USGS Cascades Volcano Observatory, with extensive educational and technical resources

http://volcano.und.edu/ – Volcano World Web site at the University of North Dakota http://nationalzoo.si.edu/publications/zoogoer/1996/3/lifewithout-light.cfm – "Life without Light: Discoveries from the Abyss," by Robin Meadows; Smithsonian National Zoological Park, Zoogoer Magazine, May/June 1996

http://www.ngdc.noaa.gov/mgg/image/2minrelief.html – Index page for NOAA's National Geophysical Data Center combined global elevation and bathymetry images (http://www.ngdc.noaa.gov/mgg/image/2minsurface/45N135E.html includes the Mariana Arc)

http://www.guam.net/pub/sshs/depart/science/mancuso/marianas/intromar.htm – Web site with background information on 15 of the Mariana Islands.

http://volcano.und.nodak.edu/vwdocs/volc_models/models.html – U of N. Dakota volcano Web site, directions for making various volcano models

http://volcano.und.nodak.edu/vw.html – Volcano World Web site

http://www.extremescience.com/DeepestOcean.htm – Extreme Science Web page on the Challenger Deep

http://oceanexplorer.noaa.gov/explorations/05galapagos/welcome.html – Web page for the 2005 Galapagos Spreading Center Expedition

http://www.divediscover.whoi.edu/ventcd/vent_discovery – Dive and Discover presentation on the 25th anniversary of the discovery of hydrothermal vents

http://seawifs.gsfc.nasa.gov/OCEAN_PLANET/HTML/ps_vents.html – Article, "Creatures of the Thermal Vents" by Dawn Stover

http://www.oceansonline.com/hydrothe.htm – "Black Smokers and Giant Worms," article on hydrothermal vent organisms

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Shank, T. M. 2004. The evolutionary puzzle of seafloor life. Oceanus 42(2):1-8; available online at http://www.whoi.edu/cms/files/dfino/2005/4/v42n2-shank_2276.pdf.

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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
- Understandings about science and technology

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

Ocean Literacy Essential Principles and Fundamental Concepts

Essential Priniciple 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 e.* Tectonic activity, sea level changes, and force of waves influence the physical structure and landforms of the coast.

Essential Principle 4.
The ocean makes Earth habitable.

- *Fundamental Concept b.* The first life is thought to have started in the ocean. The earliest evidence of life is found in the ocean.

Essential Priniciple 5.
The ocean supports a great diversity of life and ecosystems.

- *Fundamental Concept b.* Most life in the ocean exists as microbes. Microbes are the most important primary producers in the ocean. Not only are they the most abundant life form in the ocean, they have extremely fast growth rates and life cycles.
- *Fundamental Concept c.* Some major groups are found exclusively in the ocean. The diversity of major groups of organisms is much greater in the ocean than on land.
- *Fundamental Concept d.* Ocean biology provides many unique examples of life cycles, adaptations and important relationships among organisms (such as symbiosis, predator-prey dynamics and energy transfer) that do not occur on land.
- *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 Priniciple 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.

For More Information

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