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2005 Submarine Ring of Fire Expedition

What's for Dinner?

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

Grade Level
5-6 (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

Background Information
The Ring of Fire is an arc of active volcanoes and earthquake sites that partially encircles the Pacific Ocean Basin.The location of the Ring of Fire coincides with the location of oceanic trenches and volcanic island arcs that result from the motion of large pieces of the Earth's crust (tectonic plates). Tectonic plates consist of 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). These convection currents cause the tectonic plates to move several centimeters per year relative to each other.

The junction of two tectonic plates is known as a plate boundary. Where two plates slide horizontally past each other, the junction is known as a transform plate boundary. Movement of the plates causes huge stresses that break portions of the rock and produce earthquakes. Places where these breaks occur are called faults. A well-known example of a transform plate boundary is the San Andreas fault in California.

Where tectonic plates are moving apart, they form a divergent plate boundary. At these boundaries, magma (molten rock) rises from deep within the Earth and erupts to form new crust on the lithosphere. Most divergent plate boundaries are underwater (Iceland is an exception), and form submarine mountain ranges called oceanic spreading ridges.

If two tectonic plates collide more or less head-on, they produce a convergent plate boundary. Usually, one of the converging plates moves beneath the other in a process called subduction. Subduction produces deep trenches, and earthquakes are common. As the sinking plate moves deeper into the mantle, increasing pressure and heat release fluids from the rock causing the overlying mantle to partially melt. The new magma rises and may erupt violently to form volcanoes that often form arcs of islands along the convergent boundary. These island arcs are always landward of the neighboring trenches. This process can be visualized as a huge conveyor belt on which new crust is formed at the oceanic spreading ridges and older crust is recycled to the lower mantle at the convergent plate boundaries. The Ring of Fire marks the location of a series of convergent plate boundaries in the western Pacific Ocean.

The Mariana Arc is part of the Ring of Fire that lies to the north of Guam in the western Pacific. Here, the fast-moving Pacific Plate is subducted beneath the slower-moving Philippine Plate, creating the Marianas Trench (which includes the Challenger Deep, the deepest known area of the Earth's oceans). The Marianas Islands are the result of volcanoes caused by this subduction, which frequently causes earthquakes as well. In 2003, the 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 2005 Submarine Ring of Fire Expedition will explore hydrothermally active volcanoes in the Kermadec Arc, an area where tectonic plates are converging more rapidly than any other subduction zone in the world.

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, seafloor hot springs around spreading ridges have been intensively studied. In contrast, the hydrothermal systems around convergent plate boundaries are relatively unexplored.

The 2004 Submarine Ring of Fire Expedition provided intriguing reports and spectacular images of biological communities around volcanoes of the Mariana Arc. In this lesson, students will explore some of these results and how food webs may operate in these 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. 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.

2. 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 deepsea 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 deepsea communities. If chemosynthesis is not suggested, do not introduce the concept just yet.

3. Tell students that their assignment is to prepare a report on the major types of organisms found in deepsea 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.

4. 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
  - 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. These bacteria 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
  - 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
  - hydrozoa

- The video from a hydrothermal vent site on the same volcano includes
  - a spider crab (seen but not named)
  - basket stars
  - anemone
  - barnacles
  - 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. Have students visit http://oceanexplorer.noaa.gov to keep up to date with the latest Ring of Fire Expedition discoveries.

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

http://oceanexplorer.noaa.gov – Follow the Ring of Fire Expedition daily as documentaries and discoveries are posted each day for your classroom use.

http://nationalzoo.si.edu/publications/zoogoer/1996/3/lifewithoutlight.cfm – "Life without Light: Discoveries from the Abyss," by Robin Meadows; Smithsonian National Zoological Park, *Zoogoer* Magazine, May/June 1996

http://pubs.usgs.gov/publications/text/dynamic.html#anchor19309449 – Online 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://oceanexplorer.noaa.gov/explorations/03fire/logs/subduction_vr.html – 3-dimensional "subduction zone" plate boundary video.

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

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

For More Information

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