My Friend, The Volcano

(adapted from the 2004 Submarine Ring of Fire Expedition)

Focus
Ecological impacts of volcanism in the Mariana and Kermadec Islands

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

Focus Question
What are the ecological impacts of volcanic eruptions on tropical island arcs?

Learning Objectives
Students will be able to describe at least three beneficial impacts of volcanic activity on marine ecosystems.

Students will be able to explain the overall tectonic processes that cause volcanic activity along the Mariana Arc and Kermadec Arc.

Materials
- ❒ Copies of "Marianas eruption killed Anatahan's corals," one copy per student or student group (from http://www.cdnn.info/eco/e030920/e030920.html)

Audio/Visual Materials
None

Teaching Time
Two or three 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
Ring of Fire
Asthenosphere
Lithosphere
Magma
Fault
Transform boundary
Convergent boundary
Divergent boundary
Subduction
Tectonic plate

Background Information
The Submarine Ring of Fire is an arc of active volcanoes that partially encircles the Pacific Ocean Basin, including the Kermadec and Mariana Islands in the western Pacific, the Aleutian Islands between the Pacific and Bering Sea, the Cascade Mountains in western North America, and numerous volcanoes on the western coasts of Central America and South America. These volcanoes result from the motion of large pieces of the Earth's crust known as tectonic plates.

Tectonic 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). These convection currents cause the tectonic plates to move several centimeters per year relative to each other.

The junction of two tectonic plates is called a "plate boundary." Three major types of plate boundaries are produced by tectonic plate movements. If two tectonic plates collide more or less head-on they form a convergent plate boundary. Usually, one of the converging plates will move beneath the other, which is known as subduction. Deep trenches are often formed where tectonic plates are being subducted, and earthquakes are common. 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. These island arcs are always landward of the neighboring trenches. For a 3-dimensional view of a subduction zone, visit: http://oceanexplorer.noaa.gov/explorations/03fire/logs/subduction.html.

The junction of two tectonic plates that are moving apart is called a divergent plate boundary. Magma 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. While the process is volcanic, volcanoes and earthquakes along oceanic spreading ridges are not as violent as they are at convergent plate boundaries. View the 3-dimensional structure of a mid-ocean ridge at: http://oceanexplorer.noaa.gov/explorations/03fire/logs/ridge.html.

The third type of plate boundary occurs where tectonic plates slide horizontally past each other, and is known as a transform plate boundary. As the plates rub against each other, huge stresses are set up that can cause portions of the rock to break, resulting in 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. See animations of different types of plate boundaries at: http://www.seed.slb.com/en/scictr/watch/living_planet/plate_boundaries/plate_move.htm.

The volcanoes of the Submarine Ring of Fire result from the motion of several major tectonic plates. The Pacific Ocean Basin lies on top of the Pacific Plate. To the east, along the East Pacific Rise, new crust is formed at the oceanic spreading center between the Pacific Plate and the western side of the Nazca Plate. Farther to the east, the eastern side of the Nazca Plate is being subducted beneath the South American Plate, giving rise to active volcanoes in the Andes. Similarly, convergence of the Cocos and Caribbean Plates produces active volcanoes on the western coast of Central America, and convergence of the North American and Juan de Fuca Plates causes the volcanoes of the Cascades in the Pacific Northwest.

On the western side of the Pacific Ocean, the Pacific Plate converges against the Philippine Plate and Australian Plate. Subduction of the Pacific Plate creates the Mariana Trench (which includes the Challenger Deep, the deepest known area of the Earth's ocean) and the Kermadec Trench. As the sinking plate moves deeper into the mantle, new magma is formed as described above, and erupts along the convergent boundary to form volcanoes. The Mariana and Kermadec 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, and older crust is recycled to the lower mantle at the convergent plate boundaries of the western Pacific. For more information on plate tectonics, visit the NOAA Learning Objects Web site (http://www.learningdemo.com/noaa/). Click on the links to Lessons 1, 2 and 4 for interactive multimedia presentations and

Learning Activities on Plate Tectonics, Mid-Ocean Ridges, and Subduction Zones. See the satellite and sonar survey animation of the Mariana Arc Volcanic Chain at:
http://oceanexplorer.noaa.gov/explorations/04fire/background/marianaarc/media/sat_em_islands_video.html.

Beginning in 2002, Ocean Exploration expeditions have undertaken systematic mapping and study in previously-unexplored areas of the Submarine Ring of Fire. Visit

- http://oceanexplorer.noaa.gov/explorations/02fire/logs/magicmountain/;
- http://www.oceanexplorer.noaa.gov/explorations/03fire/;
- http://www.oceanexplorer.noaa.gov/explorations/04fire/;
- http://www.oceanexplorer.noaa.gov/explorations/05fire/; and
- http://oceanexplorer.noaa.gov/explorations/06fire/welcome.html

for more information about the many discoveries, as well as still and video imagery, from these expeditions. The New Zealand American Submarine Ring of Fire 2007 Expedition is focused on detailed exploration of hydrothermal systems at Brothers Volcano in the Kermadec Arc, an area where tectonic plates are converging more rapidly than any other subduction zone in the world.

Soon after the 2003 Ring of Fire Expedition left the Marianas, a major volcanic eruption on the island of Anatahan buried the island in ash and dropped tons of sediment into nearby waters, resulting in massive coral deaths. Volcanic eruptions are often viewed as disasters; but while these events are obviously destructive, volcanism may also have ecological benefits. In this activity, students will explore some ways in which these terrifying events may be helpful to life on Earth.

Learning Procedure

1. To prepare for this lesson, review the introductory essays for the New Zealand American Submarine Ring of Fire 2007 Expedition at http://oceanexplorer.noaa.gov/explorations/07fire/welcome.html. You may also want to review portions of "This Dynamic Earth" and/or "This Dynamic Planet" (see Resources section).

2. 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). Introduce the Ring of Fire and the New Zealand American Submarine Ring of Fire 2007 Expedition, and describe the processes that produce the Mariana Arc. Tell students that there was a major volcanic eruption on the Mariana Island of Anatahan in 2003, a few months after the Ring of Fire Expedition completed its mission in the area. Have students read "Marianas eruption killed Anatahan's corals," and briefly discuss the events reported in the article.

3. Tell students that their assignment is to find at least three ways in which volcanic activity like that on Anatahan could be beneficial to nearby ecosystems. Depending upon students' internet research skills and available time, you may want to direct them to one or more of the following sites:

   http://www.pmel.noaa.gov/vents/index.html (NOAA's hydrothermal vent Web site);
   http://www.cdnn.info/eco/e030910/e030910.html (article about volcanic activity associated with the most developed reefs in the Northern Mariana Islands);
   http://communications.uvic.ca/ring/98oct02/tunnicliffe.html (article about an eruption of the Axial underwater volcano);
   http://www.the-conference.com/JConfAbs/5/415.pdf (article about the fertilization potential of volcanic ash in ocean waters)

Have each group write a report describing three ways that volcanic activity may benefit marine ecosystems.

4. Lead a discussion of students' research results. Students should identify underwater volcanism as the source of hot springs that often occur in the middle of cold, deep ocean waters. These hydrothermal vents were first discovered in 1977 when scientists in the submersible Alvin visited an oceanic spreading ridge near the Galapagos Islands—and found warm springs surrounded by large numbers of animals that had never been seen before. Since that discovery, many other hydrothermal vent systems have been discovered in deep waters.

   While high temperatures are a conspicuous feature of these systems (and of volcanoes), it is the chemicals (particularly hydrogen sulfide and methane) released from cracks in the seafloor crust that provide the foundation for hydrothermal vent communities. Bacteria that are specially adapted to life in hydrothermal plumes use these chemicals to produce simple sugars in a process called chemosynthesis. This process closely resembles photosynthesis in which green plants use energy from sunlight to combine carbon dioxide and water to form simple sugars that are the basis for most familiar food chains. The key difference is that in chemosynthesis, energy to produce the sugars is obtained from chemical bonds in hydrogen sulfide (or another compound, such as methane) instead of from sunlight. Both green plants and chemosynthetic organisms are called autotrophs (meaning they feed themselves). See the "Lesson" portion of Lesson 5 at http://www.learningdemo.com/noaa/ for a comparison of photosynthesis and chemosynthesis.

   Chemosynthetic bacteria are the base of a food web that includes many types of animals. In one of the most direct relationships, the bacteria live inside the tissues of giant tubeworms and clams. The animals' blood carries carbon dioxide, oxygen, and hydrogen sulfide to the bacteria and receives nourishment from the sugars produced by the bacteria. This is a true symbiosis (a mutually beneficial relationship between organisms) because the bacteria also benefit from having a sheltered environment inside the clams and tubeworms that provides protection from sudden changes in temperature and chemical composition of the vent fluid. Tubeworms have no mouth or gut; they depend entirely upon their symbiotic bacteria for survival.

   Other pathways in vent food webs do not involve this type of symbiosis. Some chemosynthetic bacteria float freely in the vent plume, and provide a food source for plankton. Organic materials, including the remains of bacteria and plankton, float in the cooler water beneath the plume and are a food source for filter-feeding organisms such as mussels and other molluscs. Other chemosynthetic bacteria form mats on hard surfaces, and are grazed by snails. All of these animals may become food for predators such as polychaete worms, crabs, fishes, and octopi. Some of these predators may spend most of their time outside the vent community, and visit only briefly to find food. Most species found in vent communities, though, are not found anywhere else. Many new species of animals have been found as more hydrothermal vents are explored. In fact, every time a new vent is explored, there is a good chance of finding animals that have previously been unknown to science.

   Volcanic eruptions in shallow water can also bring a variety of chemicals into marine ecosystems and may provide nutrients to food webs that support highly diverse communities. In the case of reef communities at Maug Island, it is not certain whether the high diversity and development of these communities is primarily due to nutrient enrichment or habitat variety;

but volcanic activity contributes to both.

A different type of benefit has been suggested by scientists in Iceland. These researchers noticed that the continuing increase in atmospheric carbon dioxide slowed significantly after the two largest volcanic aerosol eruptions of the twentieth century (Agung, Bali and Pinatubo, Philippines). Since volcanoes are known to release enormous quantities of carbon dioxide when they erupt, the scientists reasoned that there must have been some simultaneous event that increased the removal of carbon dioxide from the atmosphere, and hypothesized that this was due to fertilization of phytoplankton in ocean surface waters by volcanic ash. According to this hypothesis, fertilization of phytoplankton would have led to an increase in photosynthesis, and consequently an increased uptake of carbon dioxide. Experiments to test this hypothesis showed that volcanic ash released significant amounts of phosphorus, silica, iron, and manganese. In areas of the ocean where low concentrations of these nutrients limits photosynthesis, fertilization by volcanic ash could increase photosynthesis and biological uptake of carbon dioxide.

The Bridge Connection

www.vims.edu/bridge/ – Click on "Ocean Science Topics" then "Marine Geology."

The "Me" Connection

Have students write a short essay on how volcanoes might directly affect their own lives.

Connections to Other Subjects

English/Language Arts, Geography, Earth Science

Assessment

Student reports and group discussions provide opportunities for assessment.

Extensions

Have students visit http://oceanexplorer.noaa.gov/explorations/07fire/welcome.html to keep up to date with the latest New Zealand American Submarine Ring of Fire 2007 Expedition discoveries, and find out what scientists are learning about hydrothermal systems in the vicinity of Brothers Volcano.

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 NOAA's Ocean Exploration Program

It's Going to Blow Up! [http://www.oceanexplorer.noaa.gov/explorations/06fire/background/edu/media/ROF06.BlowUp.pdf] (15 pages; 332k) (from the Submarine Ring of Fire 2006 Expedition)

Focus: Volcanism on the Pacific Ring of Fire (Earth Science)

Students will be able to describe the processes that produce the Submarine Ring of Fire; explain the factors that contribute to explosive volcanic eruptions; identify at least three benefits that humans derive from volcanism; describe the primary risks posed by volcanic activity in the United States; and identify the volcano within the continental U.S. that is considered most dangerous.

What's for Dinner? [http://www.oceanexplorer.noaa.gov/explorations/06fire/background/edu/media/ROF06.Dinner.pdf] (8 pages; 288k) (from the Submarine Ring of Fire 2006 Expedition)

Focus: Sources of nutrition for biological communities associated with volcanoes of the Mariana Arc (Life Science)

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

give at least three examples of organisms that live near hydrothermal vent systems; and describe two sources of primary production observed in biological communities associated with volcanoes of the Mariana Arc.

Other Links and 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.

oceanexplorer.noaa.gov – Web site for NOAA's Ocean Exploration program

http://www.pmel.noaa.gov/vents/index.html – NOAA's hydrothermal vent Web site

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.pbs.org/wgbh/nova/teachers/activities/2609_abyss.html – Nova Teachers Web site, Volcanoes of the Deep Classroom Activity to research and classify symbiotic relationships between individual organisms of different species.

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

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

http://www.pmel.noaa.gov/vents/nemo/explorer/bio_gallery/biogallery1.html – NeMO Explorer animal gallery

http://www.the-conference.com/JConfAbs/5/415.pdf – Online version of Frogner, P., S. Gíslason, and N. Óskarsson. 2000. Fertilization Potential of Volcanic Ash in Ocean Surface Waters . Journal of Conference Abstracts 5(2):415.

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 F: Science in Personal and Social Perspectives

- Populations, resources, and environments
- Natural hazards
- Risks and benefits

Ocean Literacy Essential Principles and Fundamental Concepts

Essential Principle 1.
The Earth has one big ocean with many features.

Fundamental Concept a. The ocean is the dominant physical feature on our planet Earth—covering approximately 70% of the planet's surface. There is one ocean with many ocean basins, such as the North Pacific, South Pacific, North Atlantic, South Atlantic, Indian and Arctic.

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 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 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 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.

Send Us Your Feedback

We value your feedback on this lesson.
Please send your comments to:
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Acknowledgements

This lesson plan was produced by Mel Goodwin, PhD, The Harmony Project, Charleston, SC for the National Oceanic and Atmospheric Administration. If reproducing this lesson, please cite NOAA as the source, and provide the following URL: http://oceanexplorer.noaa.gov