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## 2004 Ring of Fire Expedition

# Friendly Volcanos

### Focus
Ecological impacts of volcanism in the Mariana Islands

### Grade Level
7-8 (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.

### Materials
❒ Copies of "Mariana 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 45-minute class periods

### 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 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 the large plates (tectonic plates) that make up the outer shell of the Earth (the lithosphere). These plates consist of a crust about 5 km thick, and the upper 60 - 75 km of the Earth's mantle. The plates that make up the lithosphere 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.

Where tectonic plates slide horizontally past each

other, the boundary between the plates 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.

A convergent plate boundary is formed when tectonic plates collide more or less head-on. Usually one of the converging plates moves beneath the other (a process called 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 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.

Where tectonic plates are moving apart, they form a divergent plate boundary. At divergent plate 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. While the process is volcanic, volcanoes and earthquakes along oceanic spreading ridges are not as violent as they are at convergent plate boundaries.

The 2004 Ring of Fire Expedition continues exploration of the submarine volcanoes of the Mariana Arc, part of the Ring of Fire that lies to the north of Guam in the western Pacific. Here, the fast-moving Pacific Plate converges against the slower-moving Philippine Plate. The Pacific Plate is subducted beneath the Philippine Plate, creating the Mariana Trench (which includes the Challenger Deep, the deepest known area of the Earth's oceans). The Mariana Islands are the result of volcanoes caused by this subduction, 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 along the underwater volcanoes and island arcs of the western Pacific. While many volcanoes in the Mariana Arc have been mapped and sampled in recent years, the Ring of Fire Expeditions are the first explorations focused specifically on submarine hydrothermal systems of the Arc.

Soon after the 2003 Ring of Fire Expedition left the Mariana, 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.

Refer to the 2002 Ring of Fire Expedition for additional lesson plans developed for Grades 7-8 at www.oceanexplorer.noaa.gov.

## Learning Procedure

1. 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). Introduce the Ring of Fire, 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 of 2003 completed its mission in the area. Have students read "Mariana eruption killed Anatahan's corals," and briefly discuss the events reported in the article.

2. 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/home.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.

3. Lead a discussion of students' research results. Students should identify underwater volcanism as the source of hot springs that often occur 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).

Chemosynthetic bacteria form 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 mollusks. 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 limit 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

## Evaluation

Student reports and group discussions provide opportunities for assessment.

## Extensions

Have students visit http://oceanexplorer.noaa.gov to keep up to date with the latest Ring of Fire Expedition discoveries.

Have students visit http://www.pmel.noaa.gov/vents/nemo/explorer/bio_gallery/biogallery1.html for a gallery of animals found around hydrothermal vents

## Resources

http://oceanexplorer.noaa.gov – Follow the Ring of Fire Expedition daily as documentaries and discoveries are posted each day for your classroom use. A wealth of information can also be found at both of these sites.

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://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://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://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

## For More Information

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