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Aegean and Black Sea 2006 Expedition

My Friend, the Volcano

(adapted from the 2004 Submarine Ring of Fire Expedition)

Focus
Ecological impacts of volcanism

Grade Level
7-8 (Life Science/Earth Science)

Focus Question
What are the ecological impacts of volcanic eruptions on nearby ecosystems?

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.

Materials
Computers with internet access, or suitable library resources

Audio/Visual Materials
None

Teaching Time
One 45-minute class period

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

Maximum Number of Students
30

Key Words
Thera
Asthenosphere
Lithosphere
Magma
Fault
Transform boundary
Convergent boundary
Divergent boundary
Subduction
Tectonic plate

Background Information
The geographic region surrounding the Aegean and Black Seas has been the stage for many spectacular performances in Earth's geologic and human history. Human activities on the region's stage began during Paleolithic times; artifacts discovered near Istanbul are believed to be at least 100,000 years old. Well-known Aegean cultures include the Minoans (ca 2,600 – 1,450 BC), Mycenaeans (ca 1,600 – 1,100 BC), Ancient Greeks (776 – 323 BC), and Hellenistic Greeks (323 – 146 BC). Istanbul—"the only city that spans two continents"—has been a crossroads of travel and trade for more than 26 centuries. Mariners have traveled the Aegean and Black Seas since Neolithic ("Stone Age" times; 6,500 – 3,200 BC), probably for a combination of purposes, including trading, exploration, and warfare.

Interactions between these cultures and many others were often violent and destructive. So, too, were interactions with geological processes.

One of the most dramatic and destructive events was the eruption of a volcano in a small group of Aegean islands called Thera (also known as Santorini), sometime between 1,650 and 1,450 BC. Estimated to be four times more powerful than the Krakatoa volcano of 1883, the eruption left a crater 18 miles in diameter, spewed volcanic ash throughout the Eastern Mediterranean, and may have resulted in global climactic impacts. Accompanied by earthquakes and a tsunami, the volcano destroyed human settlements, fleets of ships, and may have contributed to the collapse of the Minoan civilization on the island of Crete, 110 km to the south.

Many volcanoes, including the one near Thera, are caused by movement of tectonic plates. These plates are portions of Earth's outer crust (lithosphere) about 5 km thick, as well as the upper 60 - 75 km of the underlying mantle. Tectonic 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.

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, breaks portions of the rock, and produces 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 tectonic setting of the Aegean/Black/Mediterranean Sea area is complex, and includes two major plates (the Eurasian and African Plates) as well as several minor ones (including the Hellenic, Turkish, Arabian, and Van Plates). Boundaries between these plates are not always clear, but motion at plate boundaries is undoubtedly responsible for earthquakes and volcanoes throughout the region. This is not considered a highly volcanic area, but even one Thera-type volcano can do plenty of damage!

Thera and its neighboring islands are the most active volcanic center in the Aegean Arc, and are part of a single volcano that has erupted many times. At one time, there were fewer than the five islands visible today. In fact, one of its older names is "Strongyle," which means circular or rounded, suggesting that the overall appearance was different in the past. During some of its eruptions, the floor of the volcano's crater collapsed into the magma chamber below, forming a caldera. Over time, the caldera was partially re-filled by other volcanic activity. Before the eruption during Minoan times, the rim of the caldera was an almost-continuous ring, with only a single entrance. The floor of the caldera collapsed again during the Minoan eruption, destroying part of the above-water ring, thereby creating two new channels.

Studies of volcanic ash deposits suggest that the Minoan eruption happened in at least five stages. The first was a series of precursory volcanic events that took place over several months and may have provided the inhabitants with a warning of things to follow, perhaps accounting for the absence of human remains at Akrotiri. The next stage should have left no doubt about what was coming: An eruption column 36 km high was ejected into the atmosphere, blanketing the Eastern Mediterranean with hot pumice and ash. Then came an even more violent stage. Cracks in the crater floor allowed seawater to contact hot magma, producing explosions of steam that hurled large blocks of rock and clouds of steam and ash over the islands and adjacent ocean. These explosions were followed by a classic "pyroclastic flow;" a river of ash, pumice, gases, and possibly mud that flowed down the sides of the volcano at speeds of 60 miles per hour or more. In the final and most violent stage of all, the pyroclastic flow reached the coast with temperatures approaching 400°C. Visit http://www.immersionpresents.org/ for more information about the Minoan eruption, including photographs of other volcanoes in similar eruptive stages.

Volcanic eruptions are often viewed as disasters; 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 background essays for the Aegean and Black Sea 2006 Expedition at http://oceanexplorer.noaa.gov/explorations/06blacksea/, as well as information on the Theran volcano at http://www.immersionpresents.org/.

   If students will not have access to the internet for research, you will also need to download suitable materials, or confirm that such materials are available in libraries to which students have access.

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). You may want to use materials from "This Dynamic Earth" and/or "This Dynamic Planet" (see Resources section).

3. Introduce the Aegean and Black Sea 2006 Expedition, emphasizing events surrounding the Bronze Age eruption of the Theran volcano. You may want to have students visit the Immersion Presents Web site cited above or download images of volcanic eruptions. 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://communications.uvic.ca/ring/98oct02/tunnicliffe.html (article about from an eruption of the Axial underwater volcano); and/or
   - 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).

   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/06blacksea to keep up to date with the latest Aegean and Black Sea 2006 Expedition discoveries.

Resources

NOAA Learning Objects

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.

Other Relevant Lessons 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.

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.

It's Going to Blow Up!

http://oceanexplorer.noaa.gov/explorations/05fire/background/edu/media/rof05_explosive.pdf
(10 pages, 1.6Mb) (from the New Zealand American Submarine Ring of Fire 2005 Expedition)

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

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

Come on Down!

http://oceanexplorer.noaa.gov/explorations/02galapagos/background/education/media/gal_gr7_8_l1.pdf
(6 pages, 464k) (from the 2002 Galapagos Rift Expedition)

Focus: Ocean Exploration

In this activity, students will research the development and use of research vessels/vehicles used for deep ocean exploration; calculate the density of objects by determining the mass and volume; and construct a device that exhibits neutral buoyancy.

Other Resources and Links

http://oceanexplorer.noaa.gov/explorations/06blacksea – Web site for the Aegean and Black Sea 2006 Expedition

http://www.immersionpresents.org/ – Immersion Presents Web site; click on "Ancient Eruptions!" for more information about the Aegean and Black Sea 2006 Expedition, images, and educational activities

http://www.ngdc.noaa.gov/paleo/ctl/clihis10k.html –Timeline for last 10,000 years from NOAA's Paleoclimatology Web site

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://disc.gsfc.nasa.gov/oceancolor/scifocus/oceanColor/dead_zones.shtml – Web page from NASA about "Creeping Dead Zones," including SeaWIFS satellite imagery

http://news.nationalgeographic.com/news/2000/12/122800blacksea.html – National Geographic Web site, "Ballard Finds Traces of Ancient Habitation Beneath Black Sea"

http://blacksea.orlyonok.ru/blacksea.shtml – Web site of the Living Black Sea Marine Environmental Education Program in the Russian Federal Children Center Orlyonok

Friedrich, W. L.. 2000. Fire in the Sea. The Santorini Volcano: Natural History and the Legend of Atlantis. Translated by Alexander R. McBirney. Cambridge University Press. 258 pp.

Ryan, W. and W. Pitman. 1999. Noah's Flood: The New Scientific Discoveries About the Event That Changed History. Simon and Schuster. New York.

Yanko-Hombach, V. 2003. "Noah's Flood" and the late quaternary history of the Black Sea and its adjacent basins: A critical overview of the flood hypotheses. Paper presented at the Geological Society of America Annual Meeting, November 2–5, 2003, Seattle, WA (abstract available online at http://gsa.confex.com/gsa/2003AM/finalprogram/abstract_58733.htm).

http://ina.tamu.edu/ub_main.htm – Web site with information about the excavation of a Bronze Age shipwreck at Uluburun, Turkey

http://projectsx.dartmouth.edu/history/bronze_age/ – Dartmouth University Web site, "Prehistoric Archaeology of the Aegean," with texts, links to other online resources, and numerous bibliographic references

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

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. G'slason, and N. îskarsson. 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
- Understanding 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 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.
- *Fundamental Concept d.* Sea level is the average height of the ocean relative to the land, taking into account the differences caused by tides. Sea level changes as plate tectonics cause the volume of ocean basins and the height of the land to change. It changes as ice caps on land melt or grow. It also changes as sea water expands and contracts when ocean water warms and cools.

Essential Principle 2.
The ocean and life in the ocean shape the features of the Earth.
- *Fundamental Concept b.* Sea level changes over time have expanded and contracted continental shelves, created and destroyed inland seas, and shaped the surface of land.
- *Fundamental Concept e.* Tectonic activity, sea level changes, and force of waves influence the physical structure and landforms of the coast.

Essential Principle 5.
The ocean supports a great diversity of life and ecosystems.
- *Fundamental Concept e.* The ocean is three-dimensional, offering vast living space and diverse habitats from the surface through the water column to the seafloor. Most of the living space on Earth is in the ocean.

- *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 6.
The ocean and humans are inextricably interconnected.

- *Fundamental Concept b.* From the ocean we get foods, medicines, and mineral and energy resources. In addition, it provides jobs, supports our nation's economy, serves as a highway for transportation of goods and people, and plays a role in national security.
- *Fundamental Concept c.* The ocean is a source of inspiration, recreation, rejuvenation and discovery. It is also an important element in the heritage of many cultures.
- *Fundamental Concept f.* Coastal regions are susceptible to natural hazards (such as tsunamis, hurricanes, cyclones, sea level change, and storm surges).

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.

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