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2006 Submarine Ring of Fire

It's Going to Blow Up!

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

Focus
Volcanism on the Pacific Ring of Fire

Grade Level
7-8 (Earth Science)

Focus Question
What are major characteristics of volcanoes on the Pacific Ring of Fire?

Learning Objectives
Students will be able to describe the processes that produce the "Submarine Ring of Fire."

Students will be able to explain the factors that contribute to explosive volcanic eruptions.

Students will be able to identify at least three benefits that humans derive from volcanism.

Students 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.

Materials
❒ Copies of "Ring of Fire Volcanism Worksheet," one copy for each student or student group

Audio/Visual Materials
❒ (Optional) Equipment for viewing video clips from the Ocean Explorer Web site

Teaching Time
One or 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
Volcano
Caldera
Cascade Mountains
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.

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 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.

On April 1, 2004, scientists exploring the NW Rota #1 volcano reported the first-ever direct observations of a submarine volcanic eruption. In this lesson, students will investigate some characteristics of volcanoes associated with the Submarine Ring of Fire, including volcanoes present within the continental United States.

Learning Procedure

1. To prepare for this lesson, read
   - Introductory essays for the 2006 Submarine Ring of Fire Expedition at http://oceanexplorer.noaa.gov/explorations/06fire/welcome.html; and
   - Submarine Ring of Fire 2004 daily logs for April 1 and April 4 (http://oceanexplorer.noaa.gov/explorations/04fire/logs/april01/april01.html; and http://oceanexplorer.noaa.gov/explorations/04fire/logs/april04/april04.html).

   You may also want to visit the US Geological Survey's Cascades Volcano Observatory Web site (http://vulcan.wr.usgs.gov/) to become familiar with the resources available.

2. Briefly review the concepts of plate tectonics and continental drift and how they are related to underwater volcanic activity. You may want to use resources from NOAA's hydrothermal

vent Web site (http://www.pmel.noaa.gov/vents/home.html) and possibly the video clips linked to the Submarine Ring of Fire 2004 daily log for April 1 to supplement this discussion. Introduce the Submarine Ring of Fire, and describe the processes that produce the island arcs. Tell students that the 2006 Submarine Ring of Fire Expedition is focussed on more detailed investigations of Mariana Arc volcanoes.

3. Tell students that their assignment is to familiarize themselves with some basic concepts of volcanology and to investigate a portion of the Ring of Fire that is present within the continental United States. Provide each student or student group with a copy of "Ring of Fire Volcanism Worksheet," and direct students to research the answers to questions on the worksheet. You may also to provide formulas for the volume of a cone and volume of a sphere, or may let students find these on their own.

4. Lead a discussion of students' answers to worksheet questions. The correct answers are:

(1) Felsic magmas and the formation of big calderas are associated with the most violent volcanic eruptions.

(2) Magmas with high silica content are dangerous because silica molecules make magmas very viscous, and the high viscosity traps gasses, producing pressures that result in explosive eruptions.

(3) A caldera is a huge depression at the top of a volcano formed by explosive eruptions that remove large volumes of magma from beneath a volcano, causing the ground to collapse into the emptied space.

(4) The volcanos Macauley, Brothers, Monowai, W, Healy, Rumble-III, Rumble-V, Tangaroa, and Clark are scheduled for exploration by the Submarine Ring of Fire 2006 expedition.

(5) These volcanoes were selected for exploration because they show evidence of having active hydrothermal systems.

(6) Macauley, Brothers, Monowai, W, and Healy

(7) Mafic lavas have high concentrations of magnesium and iron.

(8) The Cascade mountains in the western United States are part of the Pacific Ring of Fire.

(9) More than 80 percent of the Earth's surface is of volcanic origin.

(10) Volcanic ash increases soil fertility by adding nutrients. Groundwater heated by hot magma can be used for geothermal energy. Volcanic processes concentrate valuable minerals into deposits that include most of the metallic minerals mined in the world.

(11) The May 18, 1980 eruption of Mount St. Helens, Washington was the most destructive volcanic eruption in the history of the United States.

(12) Mauna Loa, Hawaii is the largest active volcano in the world.

(13) Indonesia, Japan and the United States have the most historically active volcanoes.

(14) Eruptions in the Cascades occur at an average rate of 1-2 per century.

(15) Mount Garibaldi in British Columbia, Canada erupted through a glacier.

(16) Mount Rainier, Washington is potentially the most dangerous volcano in the Cascades because of its great height, frequent earthquakes, active hydrothermal system, and

extensive glacier mantle, although Mt. Ranier has not produced a significant eruption in the past 500 years.

(17) The greatest hazard presented by Mt. Ranier is a mixture of mud and rock debris known as a "debris flow," which looks and behaves like flowing concrete. Debris flows are unpredictable and may occur independently of a volcanic eruption, and could cover the distance between Mount Rainier and the Puget Sound lowland in as little as 30 minutes.

(18) Mount St. Helens lost an estimated 3.4 billion cubic yards (0.63 cubic mile) of its cone during the May 18, 1980 eruption.

(19) "Composite" or "strato" volcanoes have large, steep-sided, symmetrical cones built of alternating layers of lava flows, volcanic ash, cinders, blocks, and bombs.

(20) "Shield" volcanoes are built almost entirely of fluid lava flows.

(21) The debris avalanche on Mount St. Helens moved at speeds of 110 to 155 miles per hour during the May 18, 1980 eruption.

(22) A "pyroclastic flow" is a hot mixture of volcanic fragments and gases that sweeps along close to the ground with velocities that can approach 450 miles per hour.

(23) Magma refers to molten rock underground, while lava is molten rock that has broken through the Earth's surface.

(24) "Volcanic ash" is fragments of lava or rock blasted into the air by volcanic eruptions.

(25) A "lahar" is a mudflow or debris flow that originates from the slopes of a volcano. Lahars contain a high concentration of rock debris which gives them the internal strength to transport huge boulders, buildings and bridges. Lahars exert extremely high impact forces against objects in their paths.

To solve the "Geometry Challenge" students need to find the volume of material that would have been removed from the original West Rota volcano to produce the present form. This material can be represented as a cone resting on one half of a sphere. The base of the cone is 10 km across, and its height is approximately 1075 meters (the depths of the two sides of the caldera rim in the profile diagram are approximately -350 m and -800 m, so the average depth is -575 m; this depth added to the 500 m elevation above sea level equals 1075 m). The diameter of the sphere is about 10 km. So, the volume of the cone is equal to:

$1/3 \bullet \pi \bullet r^2 \bullet h = 1/3 \bullet \pi \bullet (5\ km)^2 \bullet (1075\ m) = 1/3 \bullet \pi \bullet 25\ km^2 \bullet 1.075\ km = 28.1\ km^3$

The volume of the sphere is:

$4/3\ \pi\ r^3 = 4/3 \bullet \pi \bullet (5\ km)^3 = 4/3 \bullet \pi \bullet 125\ km^3 = 523.3\ km^3$

The total volume of the cone and half of the sphere is:

$261.7\ km^3 + 28.1\ km^3 = 2898.8\ km^3$

The Bridge Connection

www.vims.edu/bridge – in the "Search" box in the upper right corner, type "volcano."

The "Me" Connection

Have students imagine that they are in the vicinity of a volcano that suddenly becomes active. Have them write a brief essay describing what indications they might observe that could precede and eruption, and what actions would be appropriate to this situation. You may want to suggest that

they visit http://vulcan.wr.usgs.gov/Hazards/Safety/framework.html for background information.

Connections to Other Subjects

English/Language Arts, Geography, Mathematics

Assessment

Students' answers to worksheet questions and participation in class 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 http://vulcan.wr.usgs.gov/Outreach/VolcanoMobiles/framework.html for a volcano mobile construction activity.

3. Visit http://vulcan.wr.usgs.gov/Hazards/RiskPosters/framework.html for three downloadable posters dealing with volcanic risk.

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/lifewithoutlight.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

Corliss, J. B., J. Dymond, L.I. Gordon, J.M. Edmond, R.P. von Herzen, R.D. Ballard, K. Green, D. Williams, A. Bainbridge, K.

Crane, and T. H. Andel, 1979. Submarine thermal springs on the Galapagos Rift. Science 203:1073-1083. – Scientific journal article describing the first submersible visit to a hydrothermal vent community

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.

Tunnicliffe, V., 1992. Hydrothermal-vent communities of the deep sea. American Scientist 80:336-349.

Van Dover, C. L. Hot Topics: Biogeography of deep-sea hydrothermal vent faunas; available online at http://www.divediscover.whoi.edu/hottopics/biogeo.html

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

- Motions and forces

Content Standard D: Earth and Space Science

- Energy in the Earth system
- Geochemical cycles
- Origin and evolution of the Earth system

Content Standard F: Science in Personal and Social Perspectives

- Natural resources
- Natural and human-induced hazards

Ocean Literacy Essential Principles and Fundamental Concepts

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 6.

The ocean and humans are inextricably interconnected.

- *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 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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Student Handout

Ring of Fire Volcanism Worksheet

Read the background articles, "Arc Volcanism" and "An Enormous 'Room for a Hot Bath' at West Rota Volcano" (http://oceanexplorer.noaa.gov/explorations/05fire/background/volcanism/volcanism.html and http://oceanexplorer.noaa.gov/explorations/04fire/logs/april04/april04.html, respectively). The following Web sites also have information that will be helpful in answering these questions:

- http://oceanexplorer.noaa.gov/explorations/05fire/welcome.html
- http://vulcan.wr.usgs.gov/

1. What two features are associated with the most violent volcanic eruptions?

2. Why are magmas with high silica content dangerous?

3. What is a caldera?

4. What volcanos in the Kermadec Arc are scheduled for exploration by the Submarine Ring of Fire 2006 expedition?

5. Why were these volcanoes selected for exploration?

6. Which of these volcanoes have conspicuous calderas?

7. What is mafic lava?

8. What mountain chain in the western United States is part of the Pacific Ring of Fire?

9. How much of the Earth's surface, including the ocean floor, is volcanic?

10. What are some benefits that result from volcanoes?

11. What was the most destructive volcanic eruption in the history of the United States?

12. Where is the largest active volcano in the world?

13. Which three countries have the most historically active volcanoes?

14. How often do volcanoes erupt in the Cascade Range?

15. Which Cascade Range volcano erupted through a glacier?

16. Which volcano in the Cascade Range is considered most dangerous? Why?

17. What is the greatest hazard presented by the most dangerous volcano in the Cascades?

18. How much of the Mount St. Helens cone was blown away during the May 18, 1980 eruption?

19. What is a "composite" or "strato" volcano?

20. What is a "shield" volcano?

21. How rapidly did the debris avalanche move down the slope of Mount St. Helens during the May 18, 1980 eruption?

22. What is a "pyroclastic flow"?

23. What is the difference between "magma" and "lava"?

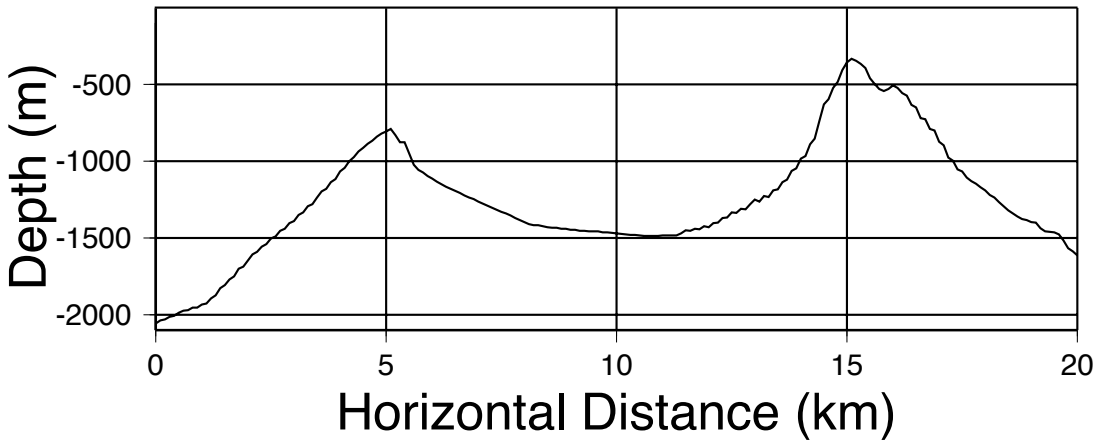
24. What is "volcanic ash"?

25. What is a "lahar"?

Geometry Challenge

Here is a profile of the West Rota volcano, visited by the Submarine Ring of Fire 2004 expedition. At one time, West Rota may have risen 500 m above sea level. How much material was blown away when the caldera was formed? Assume:

- the original shape of the volcano approximated a symmetrical cone
- the shape of the caldera approximates half of a symmetrical sphere



Student Handout
Teacher Answer Key

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   silica molecules make magmas very viscous, and the high viscosity traps gasses, producing pressures that result in explosive eruptions

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   a huge depression at the top of a volcano formed by explosive eruptions that remove large volumes of magma from beneath a volcano, causing the ground to collapse into the emptied space

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the Cascades

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more than 80 percent of the Earth's surface is of volcanic origin

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volcanic ash increases soil fertility by adding nutrients; groundwater heated by hot magma can be used for geothermal energy; volcanic processes concentrate valuable minerals into deposits that include most of the metallic minerals mined in the world

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