ocean explorer
oceanexplorer.noaa.gov

2005 Submarine Ring of Fire Expedition

It's Going to Blow Up!

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

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.

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
   - the background article on "Arc Volcanism" (http://oceanexplorer.noaa.gov/explorations/05fire/background/volcanism/volcanism.htm); 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 and the Submarine Ring of Fire 2005 background page on the Kermadec Arc (http://oceanexplorer.noaa.gov/explorations/05fire/background/kermadecarc/kermadecarc.html) to supplement this discussion. Introduce the Ring of Fire, and describe the processes that produce the island arcs.

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 want 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. What two features are associated with the most violent volcanic eruptions?
felsic magmas and the formation of big calderas

2. Why are magmas with high silica content dangerous?
Silica molecules make magmas very viscous, and the high viscosity traps gasses, producing pressures that result in explosive eruptions.

3. What is a caldera?
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. What volcanos in the Kermadec Arc are scheduled for exploration by the Submarine Ring of Fire 2005 expedition?
Macauley, Brothers, Monowai, W, Healy, Rumble-III, Rumble-V, Tangaroa, Clark

5. Why were these volcanoes selected for exploration?
because they show evidence of having active hydrothermal systems

6. Which of these volcanoes have conspicuous calderas?
Macauley, Brothers, Monowai, W, and Healy

7. What is mafic lava?
lava having high concentrations of magnesium and iron

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

9. How much of the Earth's surface, including the ocean floor, is volcanic?
more than 80 percent of the Earth's surface is of volcanic origin

10. What are some benefits that result from volcanoes?
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. What was the most destructive volcanic eruption in the history of the United States?
the May 18, 1980 eruption of Mount St. Helens, Washington

12. Where is the largest active volcano in the world?
Mauna Loa, Hawaii

13. Which three countries have the most historically active volcanoes?
Indonesia, Japan and the United States

14. How often do volcanoes erupt in the Cascade Range?
Eruptions in the Cascades occur at an average rate of 1-2 per century.

15. Which Cascade Range volcano erupted through a glacier?
Mount Garibaldi in British Columbia, Canada

16. Which volcano in the Cascade Range is considered most dangerous? Why?
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. What is the greatest hazard presented by the most dangerous volcano in the Cascades?
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. How much of the Mount St. Helens cone was blown away during the May 18, 1980 eruption?
The volcano lost an estimated 3.4 billion cubic yards (0.63 cubic mile) of its cone.

19. What is "composite" or "strato" volcano?
volcanoes with large, steep-sided, symmetrical cones built of alternating layers of lava flows, volcanic ash, cinders, blocks, and bombs

20. What is a "shield" volcano?
volcanoes built almost entirely of fluid lava flows

21. How rapidly did the debris avalanche move down the slope of Mount St. Helens during the May 18, 1980 eruption?
The debris avalanche moved at speeds of 110 to 155 miles per hour.

22. What is a "pyroclastic flow"?
hot mixtures of volcanic fragments and gases that sweep along close to the ground with velocities that can approach 450 miles per hour

23. What is the difference between "magma" and "lava"?
Magma refers to molten rock underground, while lava is molten rock that has broken through the Earth's surface.

24. What is "volcanic ash"?
fragments of lava or rock blasted into the air by volcanic eruptions

25. What is a "lahar"?
mudflows and debris flows that originate 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 an 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. Have students visit http://oceanexplorer.noaa.gov to keep up to date with the latest Ring of Fire Expedition discoveries.

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

http://oceanexplorer.noaa.gov – Web site for NOAA's Ocean Explorer program, including the Submarine Ring of Fire expeditions

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://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

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

For More Information

Paula Keener-Chavis, Director, Education Programs
NOAA Office of Ocean Exploration
Hollings Marine Laboratory
331 Fort Johnson Road, Charleston SC 29412
843.762.8818
843.762.8737 (fax)
paula.keener-chavis@noaa.gov

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

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 2005 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 "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?

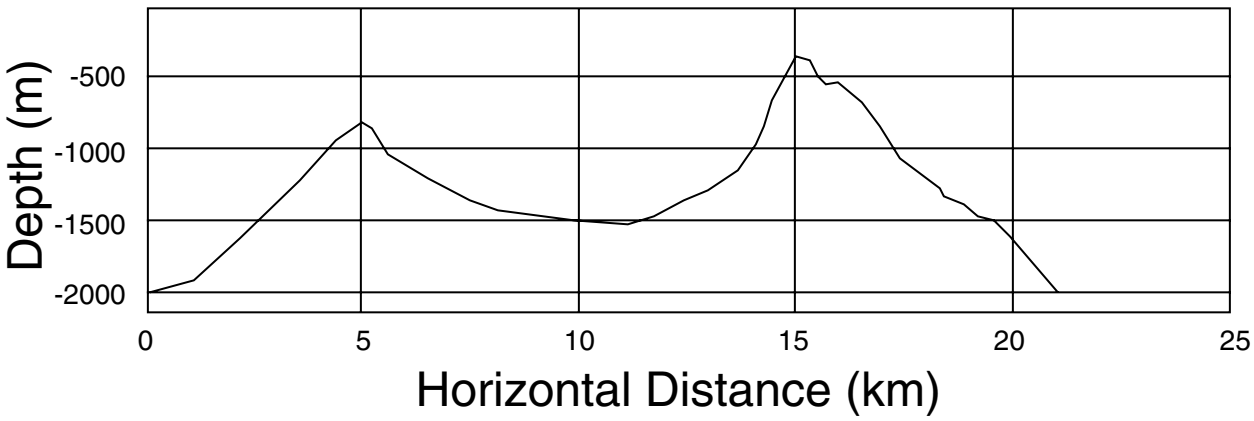
22. What is a "pyroclastic flow"?

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