



2005 Submarine Ring of Fire Expedition

What's the Difference?

FOCUS

Volcanic processes at convergent and divergent tectonic plate boundaries

GRADE LEVEL

9-12 (Earth Science)

FOCUS QUESTION

How do volcanic processes differ at convergent and divergent tectonic plate boundaries?

LEARNING OBJECTIVES

Students will be able to compare and contrast volcanoes at convergent and divergent plate boundaries.

Students will be able to identify three geologic features that are associated with most volcanoes on Earth.

Students will be able to explain why some volcanoes erupt explosively while others do not.

MATERIALS

- Copies of "Submarine Volcanism Worksheet," one copy for each student or student group

AUDIO/VISUAL MATERIALS

- (Optional) computer projection equipment to show downloaded video materials

TEACHING TIME

One 45-minute class period, 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
Hot spot
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

sphere 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 centers” or “mid-ocean 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 that surrounds the Pacific Ocean basin.

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.

In this lesson, students will investigate the characteristics of volcanoes at mid-ocean ridges and convergent plate boundaries, and make inferences to account for observed differences between volcanoes at these locations.

LEARNING PROCEDURE

1. To prepare for this lesson, read the Submarine Ring of Fire 2004 background essay, “Submarine Volcanism 2004” (<http://oceanexplorer.noaa.gov/explorations/04fire/background/volcanism/volcanism.html>). If students do not have internet access, you will also need to download diagrams of the structure of mid-ocean ridges and subduction zones (<http://oceanexplorer.noaa.gov/explorations/03fire/logs/ridge.html> and <http://oceanexplorer.noaa.gov/explorations/03fire/logs/subduction.html>), as well as reference materials cited on the “Submarine Volcanism Worksheet.” You may also want to visit the Magic Mountain Web

pages (<http://oceanexplorer.noaa.gov/explorations/02fire/logs/magicmountain/welcome.html>) to see the “landscape” around an active hydrothermal site.

2. Briefly review the concepts of plate tectonics and continental drift. Be sure students understand the distinction between mid-ocean ridges and subduction zones.
3. Provide each student or student group with a copy of the “Submarine Volcanism Worksheet,” and have students answer the worksheet questions.
4. Lead a discussion of students’ responses to questions on the worksheet. The correct responses are:
 - (1) What are three geologic features that account for most volcanoes on Earth?
Oceanic spreading centers at divergent plate boundaries (e.g., the Atlantic mid-ocean ridge), subduction zones at convergent plate boundaries (e.g., Pacific Ring of Fire), and “hot spots” which are believed to be relatively small regions in the Earth’s mantle that are especially hot (e.g., volcanoes of the Hawaiian Islands and Yellowstone Park); you may want to point out that more than half of the world’s volcanoes are located on the Pacific Ring of Fire, but that more than three-fourths of all lava produced on Earth comes from mid-ocean ridges.
 - (2) How is the shape of volcanoes at mid-ocean ridges different from the shape of volcanoes at subduction zones?
Mid-ocean ridge volcanoes tend to be linear and look like long, low ridges, while volcanoes at subduction zones tend to be cone-shaped and isolated.
 - (3) What causes a volcano to erupt explosively?
Stiff, viscous magma that traps gases and allows pressure to build up until an explosive eruption occurs.

(4) What are two primary factors that affect the viscosity of magma?
Silica (SiO₂) content and temperature of the magma.

(5) What is the difference between sheet lavas and pillow lavas?
Sheet lavas resemble broad blankets and are formed by lava that is very fluid and flows quickly (high effusion rate), while pillow lavas are bulbous mounds formed by slow-flowing lava (low effusion rate).

(6) Do volcanoes at mid-ocean ridges and subduction zones erupt explosively?
Volcanoes at subduction zones often erupt explosively; volcanoes at mid-ocean ridges usually do not.

(7) What is a caldera?
A large depression on the summit of a volcano caused by the downward collapse of the summit when large amounts of magma are suddenly removed from the magma chamber beneath the summit; this removal is often the result of a large explosive eruption.

(8) Are calderas more likely to occur at mid-ocean ridges or subduction zones? Why?
Calderas are more likely to occur at subduction zones, because subduction zone volcanoes are more likely to erupt explosively.

(9) Would you expect to find more primitive lava composition at mid-ocean ridges or subduction zones? Why?
More primitive lava would be expected at mid-ocean ridges, because this lava is produced by magma directly from the Earth’s interior, in contrast to the magma at subduction zone volcanoes which includes material from the surface of the subducted plate.

(10) How quickly do biological organisms colonize newly-erupted lava?

Biological colonization occurs rapidly, often within a few months of the lava's eruption.

THE BRIDGE CONNECTION

www.vims.edu/bridge/ – Click on “Ocean Science Topics” then “Marine Geology” for links to resources about plate tectonics and volcanoes

THE “ME” CONNECTION

Have students write a brief essay describing how exploration of deep-sea volcanoes could be of personal importance.

CONNECTIONS TO OTHER SUBJECTS

English/Language Arts, Chemistry

ASSESSMENT

Worksheets and class discussions provide opportunities for assessment.

EXTENSIONS

Have students visit <http://oceanexplorer.noaa.gov> to keep up to date with the latest Ring of Fire 2005 Expedition discoveries.

RESOURCES

<http://oceanexplorer.noaa.gov/explorations/04fire/background/volcanism/volcanism.html> – Ocean Explorer Ring of Fire 2004 Expedition essay on volcanism

<http://volcano.und.nodak.edu/> – Volcano World Web site

<http://pmel.noaa.gov/vents/nemo/explorer/concepts/mor.html>
– New Millennium Observatory (NeMO) Web site

<http://oceanexplorer.noaa.gov> – Follow the Ring of Fire Expedition daily as documentaries and discoveries are posted each day for your classroom use.

<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://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

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
- Interactions of energy and matter

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 and human-induced hazards

FOR MORE INFORMATION

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<http://oceanexplorer.noaa.gov>

Student Worksheet

The following Web sites provide extensive information on volcanoes and processes that produce them, including all the information you will need to answer these questions.

- Ocean Explorer Ring of Fire Expedition essay on volcanism
– <http://oceanexplorer.noaa.gov/explorations/04fire/background/volcanism/volcanism.html>
- Volcano World Web site – <http://volcano.und.nodak.edu/>
- New Millennium Observatory (NeMO) Web site –
<http://pmel.noaa.gov/vents/nemo/explorer/concepts/mor.html>

1. What are three geologic features that account for most volcanoes on Earth?

2. How is the shape of volcanoes at mid-ocean ridges different from the shape of volcanoes at subduction zones?

3. What causes a volcano to erupt explosively?

4. What are two primary factors that affect the viscosity of magma?

5. What is the difference between sheet lavas and pillow lavas?

6. Do volcanoes at mid-ocean ridges and subduction zones erupt explosively?

7. What is a caldera?

8. Are calderas more likely to occur at mid-ocean ridges or subduction zones? Why?

9. Would you expect to find more primitive lava composition at mid-ocean ridges or subduction zones? Why?

10. How quickly do biological organisms colonize newly-erupted lava?
