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2005 Submarine Ring of Fire Expedition

Unexplored!

Focus
Scientific exploration of deep-sea volcanoes

Grade Level
5-6 (Life Science/Physical Science/Earth Science)

Focus Question
How do scientists prepare to explore ares of the ocean that are virtually unknown?

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

Students will be able to infer the kinds of living organisms that may be found around hydrothermal vents.

Students will be able to describe three ways in which scientists may prepare to explore areas that are practically unknown.

Students will be able to explain two types of primary production that may be important to biological communities around hydrothermal vents in the Mariana Arc.

Materials
- ❒ Copies of "Unexplored! Worksheet," one copy for each student or student group
- ❒ If students do not have internet access: copies of "Biological Studies 2004" (http://oceanexplorer.noaa.gov/explorations/04fire/background/biology/biology.html) and "Submarine Volcanism 2004" (http://oceanexplorer.noaa.gov/explorations/04fire/background/volcanism/volcanism.html), one copy for each student or student group

Audio/Visual Materials
- ❒ Chalkboard, marker board, or overhead projector with transparencies

Teaching Time
One or 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
Chemosynthetic

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 coin-

cides 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.

Underwater volcanism produces hot springs in the middle of cold, deep ocean waters. These springs (known as hydrothermal vents) were first discovered in 1977 when scientists in the submersible Alvin visited an oceanic spreading ridge near the Galapagos Islands, and made one of the most exciting discoveries in 20th century biology. Here they found warm springs surrounded by large numbers of animals that had never been seen before. Since they were first discovered, sea-floor hot springs around spreading ridges have been intensively studied. In contrast, the hydrothermal systems around convergent plate boundaries are relatively unexplored.

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.

Learning Procedure

1. To prepare for this lesson, read the background essays by Verena Tunnicliffe ("Biological Studies 2004;" http://oceanexplorer.noaa.gov/explorations/04fire/background/biology/biology.html) and Kim Juniper ("Ecothoughts: Figuring Out Vent Ecosystems on the Fly;" http://oceanexplorer.noaa.gov/explorations/04fire/logs/april08/april08.html).

2. Briefly 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). Briefly discuss the discovery of new life forms and ecosystems at hydrothermal vent systems that result from tectonic processes (you may want to use resources from NOAA's hydrothermal vent Web site (http://www.pmel.noaa.gov/vents/home.html) to supplement this discussion). Be sure students understand the concept of primary production, and the distinction between chemosynthetic primary production and photosynthetic primary production. Introduce the Ring of Fire, and describe the processes that produce the Mariana Arc.

   Tell students that the 2004 Ring of Fire Expedition explored hydrothermal systems of the Mariana Arc, and that the mission of the 2005 Submarine Ring of Fire Expedition is to explore hydrothermally active volcanoes in the Kermadec Arc where tectonic plates are converging more rapidly than any other subduction zone in the world.

   Point out that these expeditions are studying places that have been explored very little or not at all. Lead a brief discussion of students' ideas about how they might prepare for this type of expedition, and record their ideas on a marker board or overhead projector transparency.

3. Provide each student or student group with a copy of "Unexplored! Worksheet" (and copies of "Biological Studies 2004" by Verena Tunnicliffe and "Submarine Volcanism 2004" by Bill Chadwick if students do not have access to the internet). Have students study the background materials and answer the questions on the worksheet.

4. Review students' answers to the worksheet questions. The correct answers are:

   (1) What processes form submarine volcanoes at mid-ocean ridges and along the Pacific Ring of Fire?

   At mid-ocean ridges, tectonic plates are moving apart and magma rises to fill the gap between the spreading plates. Along the Pacific Ring of Fire, tectonic plates are colliding, with one plate forced under the other causing the lower plate to move into the Earth where it is melted and recycled. This process also causes melting above the collision zone, and the molten rock rises back to the surface creating chains of volcanoes.

   (2) How are the volcanoes produced at mid-ocean ridges different from the volcanoes along the Pacific Ring of Fire?

   Volcanoes at mid-ocean ridges look like long ridges and are usually nonexplosive, while volcanoes along the Pacific Ring of Fire are cone-shaped and often erupt explosively.

   (3) What are hydrothermal vents?

   Hydrothermal vents are hot springs on the ocean floor.

   (4) What produces "black smokers?"

"Black smokers" are produced by hydrothermal vent fluid which contains high concentrations of dissolved minerals. When the fluid enters the cold water of the deep ocean, some of these minerals precipitate giving the appearance of black smoke.

(5) How do hydrothermal vent fluids influence the kinds of living organisms are found around hydrothermal vents?

Some of the chemicals dissolved in the hydrothermal vent fluid provide an energy source for microorganisms that is not dependent on sunlight.

(6) To plan biological explorations in areas that are practically unknown, biologists build their study plans around what three pieces of information?

- *Prior biological work in similar areas*
- *Known geological and chemical conditions*
- *Experience with similar systems elsewhere in the world*

(7) What kinds of animals might be expected around hydrothermal vents in the Mariana Arc?

shrimps, crabs, anemones, snails, barnacles, mussels, vestimentiferans (tubeworms)

(8) What are two types of primary production that may be important to biological communities around hydrothermal vents in the Mariana Arc?

Chemosynthetic bacteria and photosynthetic plankton

(9) Filamentous bacterial mats are an example of what type of primary production?

Chemosynthesis

(10) Scientists exploring the slope of a volcano named East Diamante found that the surface of the slope in deep water was covered with dense mats formed by chemosynthetic bacteria, but as the slope rose toward the sea surface encrusting red algae appeared and the bacterial mats gradually disappeared. What does the appearance of encrusting red algae on the slope of a volcano signify?

Transition from chemosynthetic primary production to photosynthetic primary production

The Bridge Connection

www.vims.edu/bridge/ – Click on "Ocean Science Topics" then "Habitats," then "Deep Sea" for links to information and activities about hydrothermal vents.

The "Me" Connection

Identify a geographic area that is completely unfamiliar to your students. Have students write a brief essay describing how they would prepare to learn as much as they could about this area in a specified period of time (one day or less).

Connections to Other Subjects

English/Language Arts, Geography

Assessment

Worksheets and class discussions provide opportunities for assessment.

Extensions

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

2. Visit http://oceanexplorer.noaa.gov/explorations/04fire/background/edu/edu.html for more activities and lesson plans related to the Ring of Fire expeditions.

Resources

http://oceanexplorer.noaa.gov – Follow the 2005 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, volcanoes, and earthquake locations

http://www.pbs.org/wgbh/nova/teachers/activities/2609_abyss.html – Nova Teachers Web site, Volcanoes of the Deep Classroom Activity to research and classify symbiotic relationships between individual organisms of different species.

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
- 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 E: Science and Technology
- Understandings about science and technology

Content Standard F: Science in Personal and Social Perspectives
- Science and technology in society

Content Standard G: History and Nature of Science
- Nature of science

For More Information

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http://oceanexplorer.noaa.gov

Student Worksheet

Read the background essays by Verena Tunnicliffe ("Biological Studies 2004;" http://oceanexplorer.noaa.gov/explorations/04fire/background/biology/biology.html) and Bill Chadwick ("Submarine Volcanism 2004;" http://oceanexplorer.noaa.gov/explorations/04fire/background/ volcanism/volcanism.html).

1. What processes form submarine volcanoes at mid-ocean ridges and along the Pacific Ring of Fire?

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2. How are the volcanoes produced at mid-ocean ridges different from the volcanoes along the Pacific Ring of Fire?

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3. What are hydrothermal vents?

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4. What produces "black smokers?"

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5. How do hydrothermal vent fluids influence the kinds of living organisms that are found around hydrothermal vents?

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6. To plan biological explorations in areas that are practically unknown, biologists build their study plans around what three pieces of information?

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7. What kinds of animals might be expected around hydrothermal vents in the Mariana Arc?

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8. What are two types of primary production that may be important to biological communities around hydrothermal vents in the Mariana Arc?

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9. Filamentous bacterial mats are an example of what type of primary production?

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10. Scientists exploring the slope of a volcano named East Diamante found that the surface of the slope in deep water was covered with dense mats formed by chemosynthetic bacteria, but as the slope rose toward the sea surface encrusting red algae appeared and the bacterial mats gradually disappeared. What does the appearance of encrusting red algae on the slope of a volcano signify?

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