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2004 Ring of Fire Expedition

The Volcano Factory

Focus
Volcanism on the Mariana Arc

Grade Level
5-6 (Earth Science)

Focus Question
What processes are responsible for the formation of the Mariana Arc?

Learning Objectives
Students will be able to explain the tectonic processes that result in the formation of the Mariana Arc and the Mariana Trench.

Students will be able to explain why the Mariana Arc is one of the most volcanically-active regions on Earth.

Materials
- ❒ Foam core or heavy cardboard; one piece approximately 20 cm x 50 cm for each student group modeling the Mariana Arc
- ❒ Modeling clay
- ❒ Additional modeling materials, depending upon techniques chosen (see Learning Procedure, Step 2).

Audio/Visual Materials
- ❒ (Optional) Overhead projector and transparencies

Teaching Time
One or two 45-minute class periods, plus time to complete models and written reports

Seating Arrangement
Groups of two to four students

Maximum Number of Students
30

Key Words
Basalt
Ring of Fire
Asthenosphere
Lithosphere
Magma
Fault
Transform boundary
Convergent boundary
Divergent boundary
Subduction
Tectonic plate
Pyroclastic
Lava flow

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 the large plates (tectonic plates) that make up the outer shell of the Earth (the lithosphere). These plates consist of a crust about 5 km thick, and the upper 60 - 75 km of the Earth's mantle. The plates that make up the lithosphere 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.

Where tectonic plates slide horizontally past each other, the boundary between the plates is known as a transform plate boundary. As the plates rub against each other, huge stresses are set up that can cause portions of the rock to break, resulting in 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.

A convergent plate boundary is formed when tectonic plates collide more or less head-on. Usually one of the converging plates moves beneath the other (a process called subduction). Deep trenches are often formed where tectonic plates are being subducted, and earthquakes are common. 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 rises and may erupt violently to form volcanoes, often forming arcs of islands along the convergent boundary. These island arcs are always landward of the neighboring trenches.

Where tectonic plates are moving apart, they form a divergent plate boundary. At divergent plate 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. While the process is volcanic, volcanoes and earthquakes along oceanic spreading ridges are not as violent as they are at convergent plate boundaries.

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.

The 2004 Ring of Fire Expedition continues exploration of the submarine volcanoes of the Mariana Arc, part of the Ring of Fire that lies to the north of Guam in the western Pacific. Here, the fast-moving Pacific Plate converges against the slower-moving Philippine Plate. The Pacific Plate is subducted beneath the Philippine Plate, creating the Mariana Trench (which includes the Challenger Deep, the deepest known area of the Earth's oceans). The Mariana Islands are the result of volcanoes caused by this subduction, which frequently causes the 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 along the underwater volcanoes and island arcs of the western Pacific. While many volcanoes in the Mariana Arc have been mapped and sampled in recent years, the Ring of Fire Expeditions are the first explorations focused specifically on submarine hydrothermal systems of the Arc.

Refer to the 2002 Ring of Fire Expedition for additional lesson plans for Grades 5-6 at http://oceanexplorer.noaa.gov

Learning Procedure

1. 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. Introduce the Ring of Fire, and describe the processes that produce the Mariana Arc. Tell students that the mission of the 2004 Ring of Fire Expedition is to explore the hydrothermal systems of the Mariana Arc.

2. Have students review information about volcanoes of the Mariana Arc at http://volcano.und.nodak.edu/vwdocs/volc_images/southeast_asia/mariana/basic_geology.html Assign each student group to prepare a three-dimensional relief map of the Mariana Arc, or a model of a typical volcano of the Mariana Islands.

   Students making relief maps should obtain a combined elevation and bathymetry image of the Mariana Arc from NOAA's National Geophysical Data Center web page http://www.ngdc.noaa.gov/mgg/image/2minrelief.html. Clicking on the image at http://www.ngdc.noaa.gov/mgg/image/2minsurface/45N135E.html will produce a high resolution surface relief image of the Mariana Arc. This image should be printed and enlarged to approximately 20 x 50 cm. One way to do this is to copy the image onto an overhead transparency, project the image onto a wall at the desired size, and then trace the projected image onto a piece of cardboard or foam core. The island arcs can be constructed with modeling clay. Students should identify the following locations on their models: Uracas (Farallon de Pajaros), Maug, Ascuncion, Agrihan, Pagan, Alamagan, Guguan, Sarigan, Anatahan, Medinilla, Saipan, Tinian, Aguihan, Rota, Guam, West Mariana Ridge, Backarc Basin, Forearc, and Mariana Trench. The 2003 Ring of Fire Mission Plan on the Ocean Explorer Web site (www.oceanexplorer.noaa.gov) and information at http://www.guam.net/pub/sshs/depart/science/mancuso/Mariana/intromar.html will help students locate these areas.

   Explain to students that they will have to exaggerate the vertical scale of their models to adequately show the topography. If the Mariana Arc is about 1200 km long, fitting this area onto a surface that is 50 cm long means that each cm on the model will be equal to 24 km. At this scale , the maximum depth of the Mariana Trench (a little less than 11 km) would only be less than 5 mm. A vertical scale of 1 cm = 1,000 m will allow students to model the vertical relief reasonably well.

   Students who are assigned to make volcano models should visit http://volcano.und.nodak.edu/vwdocs/volc_images/southeast_asia/mariana/basic_geology.html and model one of the volcanic islands described (Agrigan, Alamagan, Anatahan, Asuncion, Farallon de Pajaros, Guguan, Maug, Pagan, or Sarigan). Once they have selected a volcano, students should select one of the modeling techniques described at http://volcano.und.nodak.edu/vwdocs/volc_models/models.html. The Play Dough, Paper and Cardboard, Three-dimensional Cardboard, and Simple Clay techniques are most appropriate for this assignment. Depending upon available time and your tolerance for chaos, you may decide to allow students to include eruptions in their models.

   Each student group should prepare a brief written report describing the volcanic processes that formed the Mariana Arc. Be sure students explain the terms stratovolcano, pyroclastic, and lava flow. You may want to direct them to http://volcano.und.nodak.edu/vwdocs/vwlessons/volcano_types/strato.htm and http://volcano.und.nodak.edu/vwdocs/Submarine/plates/converg/ for additional background information.

3. After each student group has presented their models, lead a discussion about the Mariana Arc. Students should realize that the processes

that formed these islands and volcanoes are ongoing, and that new (and existing) volcanoes may erupt at any time. Point out that soon after the 2003 Ring of Fire Expedition, there was a major eruption of the Anatahan volcano. Be sure students also realize that the visible volcanoes that form the Mariana Islands are only a small fraction of the volcanoes that have been produced by subduction along the island arc. Because of the extreme depths of the Mariana Trench, there are almost certainly many volcanoes that have not been discovered, and most have not been studied in any detail. Have students use their models to discuss discoveries made by the 2004 Ring of Fire Expedition (http://oceanexplorer.noaa.gov).

The BRIDGE Connection

www.vims.edu/bridge/ – Click on "Ocean Science Topics" then "Marine Geology." Enter http://www.vims.edu/bridge/archive0799.html for directions for preparing a three-dimensional plot of any part of the Earth's surface.

The "Me" Connection

Have students imagine that they live on one of the Mariana Islands. Have each student write a short essay describing life on the island, and how they feel about living over one of the most volcanically-active places on Earth.

Connections to Other Subjects

English/Language Arts, Geography, Mathematics, Life Science

Evaluation

Models and written reports provide opportunities for assessment.

Extensions

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

Have students visit http://www.guam.net/pub/sshs/depart/science/mancuso/Mariana/intromar.htm and prepare a brief report on one of the 15 Mariana Islands listed, including wildlife, ecosystems, and economic importance.

Resources

http://oceanexplorer.noaa.gov – Follow the Ring of Fire Expedition daily as documentaries and discoveries are posted each day for your classroom use. A wealth of information can also be found at both of these sites.

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

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/Mariana/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://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.extremescience.com/DeepestOcean.htm – Extreme Science web page on the Challenger Deep

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

- Transfer of energy

Content Standard D: Earth and Space Science

- Structure of the Earth system

Content Standard F: Science in Personal and Social Perspectives

- Natural hazards
- Risks and benefits

For More Information

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