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New Zealand American Submarine Ring of Fire 2007

The Biggest Plates on Earth
(adapted from the 2002 Ring of Fire Expedition)

Focus
Plate tectonics

Grade Level
5-6 (Earth Science)

Focus Question
How do tectonic plates move, and what are some consequences of this motion?

Learning Objectives
Students will be able to describe the motion of tectonic plates, and differentiate between three typical boundary types that occur between tectonic plates.

Students will be able to infer what type of boundary exists between two tectonic plates, given information on earthquakes and volcanism in the vicinity of the boundary.

Students will be able to describe plate boundaries and tectonic activity in the vicinity of the Kermadec Arc.

Materials
- ❒ Copies of "Active Volcanoes, Plate Tectonics, and the 'Ring of Fire'," one copy per student or student group (download from http://oceanexplorer.noaa.gov/explorations/05fire/background/volcanism/media/tectonics_world_map.html)

Audio/Visual Materials
- ❒ (Optional) Overhead transparency of cross section illustrating the main types of plate boundaries (download from U.S. Geological Survey Web site: http://pubs.usgs.gov/publications/text/Vigil.html)
- ❒ (Optional) Overhead transparency of map illustrating the Ring of Fire (from U.S. Geological Survey Web site: http://pubs.usgs.gov/publications/text/fire.html)
- ❒ (Optional) Overhead projector

Teaching Time
One or two 45-minute class periods

Seating Arrangement
Classroom 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
Spreading center

Background Information
The Submarine Ring of Fire is an arc of active volcanoes that partially encircles the Pacific Ocean Basin, including the Kermadec and Mariana Islands in the western Pacific, the Aleutian Islands

between the Pacific and Bering Sea, the Cascade Mountains in western North America, and numerous volcanoes on the western coasts of Central America and South America.

The location of the Ring of Fire coincides with the location of oceanic trenches and volcanic island arcs, and was one of the early clues that led to the theories of continental drift and plate tectonics. In 1940, Hugo Benioff, an American seismologist (a scientist who studies earthquakes) charted the location of deep earthquakes in the Pacific Ocean. He found that earthquake sites are distributed in an arc that spanned both sides of the ocean. Five years earlier, Japanese seismologist Kiyoo Wadati had noticed a similar pattern, and suspected that it was connected in some way to the idea of continental drift. He was right.

Today we know that the outer shell of the Earth consists of about a dozen large plates of rock (called tectonic plates) that move several centimeters per year relative to each other. Tectonic 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). These convection currents cause the tectonic plates to move several centimeters per year relative to each other.

The junction of two tectonic plates is called a "plate boundary." Three major types of plate boundaries are produced by tectonic plate movements. If two tectonic plates collide more or less head-on they form a convergent plate boundary. Usually, one of the converging plates will move beneath the other, which is known as 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 (molten rock) 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. For a 3-dimensional view of a subduction zone, visit: http://oceanexplorer.noaa.gov/explorations/03fire/logs/subduction.html.

The junction of two tectonic plates that are moving apart is called a divergent plate boundary. Magma 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. View the 3-dimensional structure of a mid-ocean ridge at: http://oceanexplorer.noaa.gov/explorations/03fire/logs/ridge.html.

The third type of plate boundary occurs where tectonic plates slide horizontally past each other, and 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. See animations of different types of plate boundaries at: http://www.seed.slb.com/en/scictr/watch/living_planet/plate_boundaries/plate_move.htm.

The volcanoes of the Submarine Ring of Fire result from the motion of several major tectonic plates. The Pacific Ocean Basin lies on top of the Pacific Plate. To the east, along the East Pacific Rise, new crust is formed at the oceanic spreading center between the Pacific Plate and the western side of the Nazca Plate. Farther to the east, the eastern side of the Nazca Plate is being subducted beneath the South American Plate, giving rise to active volcanoes in the Andes. Similarly, convergence of the Cocos and Caribbean Plates produces active volcanoes on the western coast of Central America, and convergence of the North American and Juan de Fuca Plates causes the volcanoes of the Cascades in the Pacific Northwest.

On the western side of the Pacific Ocean, the Pacific Plate converges against the Philippine Plate and Australian Plate. Subduction of the Pacific Plate creates the Mariana Trench (which includes the Challenger Deep, the deepest known area of the Earth's ocean) and the Kermadec Trench. As the sinking plate moves deeper into the mantle, new magma is formed as described above, and erupts along the convergent boundary to form volcanoes. The Mariana and Kermadec 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, and older crust is recycled to the lower mantle at the convergent plate boundaries of the western Pacific. For more information on plate tectonics, visit the NOAA Learning Objects Web site (http://www.learningdemo.com/noaa/). Click on the links to Lessons 1, 2 and 4 for interactive multimedia presentations and Learning Activities on Plate Tectonics, Mid-Ocean Ridges, and Subduction Zones.

Volcanoes at convergent plate boundaries along the Kermadec and Mariana Arcs often erupt as violent explosions, and form chains of isolated cone-shaped islands. In contrast, volcanoes found near the divergent plate boundaries of oceanic spreading ridges generally do not erupt explosively and look like long, low ridges. See the satellite and sonar survey animation of the Mariana Arc Volcanic Chain at: http://oceanexplorer.noaa.gov/explorations/04fire/background/marianaarc/media/sat_em_islands_video.html.

When seawater penetrates the permeable ocean crust in the vicinity of volcanoes, increased heat and pressure cause a variety of gases, metals and other materials to dissolve into the water from the surrounding rock. This process causes many metals to be concentrated by a thousand to a million times their concentration in normal seawater. When the fluid is vented into cold ocean water, some dissolved substances precipitate out of solution, forming metal deposits, "chimneys," and "black smokers." Dissolved gases may react to form other materials. At NW Rota Volcano, for example, dissolved sulfur dioxide forms sulfuric acid and elemental sulfur. At NW Eifuku Volcano, 1,600 meters below the sea surface, the 2004 Ring of Fire Expedition found buoyant droplets of liquid carbon dioxide, probably formed from degassing of a carbon-rich magma.

Hydrothermal fluids also provide an energy source for a variety of chemosynthetic microbes that in turn are the basis for unique food webs associated with hydrothermal vents. Many of these microbes have specific adaptations to extreme conditions; scientists found evidence for microbes living in hot spring fluids on NW Rota with a pH of 2.0 or less. Other new and unique microbes are expected to be found in association with extreme vent fluids as other sites are identified and explored along the Kermadec Arc.

Since they were discovered in 1977, hydrothermal vent communities associated with divergent plate boundaries have been extensively studied. In contrast, much less is known about hydrothermal systems near convergent plate boundaries like those of the Mariana and Kermadec Arcs. Beginning in 2002, Ocean Exploration expeditions have undertaken systematic mapping and study of hydrothermal systems in previously-unexplored areas of the Submarine Ring of Fire. Visit

- http://oceanexplorer.noaa.gov/explorations/02fire/logs/magicmountain/;
- http://www.oceanexplorer.noaa.gov/explorations/03fire/;
- http://www.oceanexplorer.noaa.gov/explorations/04fire/;

- http://www.oceanexplorer.noaa.gov/explorations/05fire/; and
- http://oceanexplorer.noaa.gov/explorations/06fire/welcome.html

for more information about the many discoveries, as well as still and video imagery, from these expeditions. The New Zealand American Submarine Ring of Fire 2007 Expedition is focused on detailed exploration of hydrothermal systems at Brothers Volcano, which is the most hydrothermally active submarine volcano on the Kermadec Arc.

In this lesson, students will infer whether plate boundaries associated with the Pacific Ring of Fire are divergent, convergent, or transform based on information about earthquakes and volcanic activity in the vicinity of the boundaries.

Learning Procedure

1. To prepare for this lesson, review the introductory essays for the New Zealand American Submarine Ring of Fire 2007 Expedition at http://oceanexplorer.noaa.gov/explorations/07fire/welcome.html, and "Arc Volcanism" at http://www.oceanexplorer.noaa.gov/explorations/05fire/background/volcanism/volcanism.html.

2. Explain the concept 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). Discuss energy transfers involved in plate motions, earthquakes, and volcanoes. You may want to use materials from "This Dynamic Earth" and/or "This Dynamic Planet" (see Resources section), but don't give away the answers to the predictive exercise on the Pacific Basin Tectonic Plates. Briefly review the major features of the "Ring of Fire," and purpose of the New Zealand American Submarine Ring of Fire 2007 Expedition. You may want to show still images or video of submarine volcanic activity from http://www.oceanexplorer.noaa.gov/explorations/06fire/logs/photolog/photolog.html.

3. Distribute copies of "Active Volcanoes, Plate Tectonics, and the 'Ring of Fire'" to each student or student group. Have each group decide what type of boundary exists at each of the four "Ring of Fire" sites indicated by the red arrows. The arcs of volcanoes in the two western Pacific sites and the site along the coast of South America should suggest that these are convergent boundaries. The fourth site in the northeastern Pacific is a little trickier, because five plates are involved: the Pacific Plate, the North American Plate, and the much smaller Juan de Fuca, Explorer, and Gorda Plates (the last three aren't labelled on the map). The three smaller plates have a divergent boundary with the Pacific Plate and a convergent boundary with the North American Plate. The active volcanoes of the Cascades on the western coast of North America are the result of these convergent boundaries. You may want to refer to the 2002 Ring of Fire Expedition (http://oceanexplorer.noaa.gov/explorations/02fire/background/plan/media/nepac.html), and possibly the "This Dynamic Planet" map (http://pubs.usgs.gov/pdf/planet.html) when discussing these boundaries with your students.

   Tabulate each group's results, and lead a discussion of the reasoning behind their conclusions. If you want to use this exercise for evaluation, collect the worksheets before discussion.

The Bridge Connection

www.vims.edu/bridge/geology.html

The "Me" Connection

Have students write a first-hand account of a visit to a plate boundary, describing where the boundary occurs and what conditions are found there

Connections to Other Subjects

English/Language Arts, Geography

Assessment

Worksheets may be used to evaluate students' understanding of the concepts presented. Alternatively or additionally, students may be asked to define key words, and/or identify the type of boundaries and expected conditions at the junctions of other tectonic plates.

Extensions

Have students visit http://oceanexplorer.noaa.gov/explorations/07fire/welcome.html to keep up to date with the latest New Zealand American Submarine Ring of Fire 2007 Expedition discoveries, and find out what scientists are learning about hydrothermal systems in the vicinity of Brothers Volcano.

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 NOAA's Ocean Exploration Program

The Volcano Factory [http://www.oceanexplorer.noaa.gov/explorations/06fire/background/edu/media/ROF06.VolFactory.pdf] (7 pages; 273 k)

Focus: Volcanism on the Mariana Arc (Earth Science)

Students will be able to explain the tectonic processes that result in the formation of the Mariana Arc and the Mariana Trench and explain why the Mariana Arc is one of the most volcanically-active regions on Earth.

Living With the Heat [http://www.oceanexplorer.noaa.gov/explorations/06fire/background/edu/media/ROF06.LivingHeat.pdf] (9 pages; 289 k) (from the Submarine Ring of Fire 2006 Expedition)

Focus: Hydrothermal vent ecology and transfer of energy among organisms that live near vents (Physical Science/Earth Science/Biology)

In this activity, students will be able to describe how hydrothermal vents are formed and characterize the physical conditions at these sites, explain what chemosynthesis is and contrast this process with photosynthesis, identify autotrophic bacteria as the basis for food webs in hydrothermal vent communities, and describe common food pathways between organisms typically found in hydrothermal vent communities.

Other Links and Resources

The Web links below are provided for informational purposes only. Links outside of Ocean Explorer have been checked at the time of this page's publication, but the linking sites may become outdated or non-operational over time.

oceanexplorer.noaa.gov – Web site for NOAA's Ocean Exploration program

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 http://www.pmel.noaa.gov/vents/index.html – NOAA's hydrothermal vent Web site

National Science Education Standards

Content Standard A: Science As Inquiry

- Abilities necessary to do scientific inquiry
- Understanding about scientific inquiry

Content Standard B: Physical Science

- Transfer of energy

Content Standard D: Earth and Space Science

- Structure of the Earth system

Ocean Literacy Essential Principles and Fundamental Concepts

Essential Principle 1.

The Earth has one big ocean with many features.

Fundamental Concept a. The ocean is the dominant physical feature on our planet Earth—covering approximately 70% of the planet's surface. There is one ocean with many ocean basins, such as the North Pacific, South Pacific, North Atlantic, South Atlantic, Indian and Arctic.

Fundamental Concept b. An ocean basin's size, shape and features (such as islands, trenches, mid-ocean ridges, rift valleys) vary due to the movement of Earth's lithospheric plates. Earth's highest peaks, deepest valleys and flattest vast plains are all in the ocean.

Essential Principle 5.

The ocean supports a great diversity of life and ecosystems.

Fundamental Concept b. Most life in the ocean exists as microbes. Microbes are the most important primary producers in the ocean. Not only are they the most abundant life form in the ocean, they have extremely fast growth rates and life cycles.

Fundamental Concept g. There are deep ocean ecosystems that are independent of energy from sunlight and photosynthetic organisms. Hydrothermal vents, submarine hot springs, and methane cold seeps rely only on chemical energy and chemosynthetic organisms to support life.

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 b. Understanding the ocean is more than a matter of curiosity. Exploration, inquiry and study are required to better understand ocean systems and processes.

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.

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Please send your comments to:
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For More Information

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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