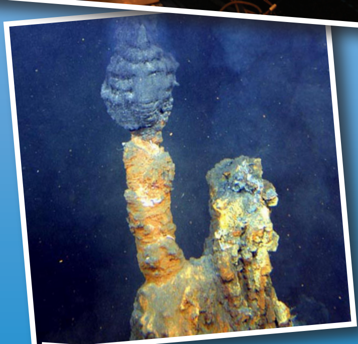
DEEP SEA EXPLORATION
INDEX2010
Sangihe Talaud
Indonesia-USA

INDEX/SATAL 2010

The Tectonic Challenge



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lesson plan

Focus

Plate tectonics

Grade Level

7-8 (Earth Science)

Focus Question

How do tectonic plates move, and how is this motion related to earthquakes, volcanoes, and tsunamis?

Learning Objectives

- Students will be able to describe the motion of tectonic plates
- Students will be able to differentiate between three typical boundary types that occur between tectonic plates
- Students will be able to infer the type of boundary that exists between two tectonic plates given information on earthquakes and volcanism in the vicinity of the boundary
- Students will be able to explain the relationship between tectonic plate movements and earthquakes, volcanoes, and tsunamis.

Materials

- ❑ Copies of Figures 1 and 2 on cover stock or glued onto poster board for jigsaw puzzles (see Learning Procedure, Steps 1 and 2)
- ❑ (Optional) Food coloring and container of hot water to demonstrate convection currents (see Learning Procedure, Step 3)
- ❑ Materials to make oobleck (see Learning Procedure, Step 4 and Appendix A); about 1.5 cups for each student group
- ❑ Pieces of rigid foam insulation or foamcore, approximately 3" x 3"; two for each student group
- ❑ Ceramic tiles or pieces of hardboard, approximately 3" x 3"; two for each student group
- ❑ Serving trays or cake pans (to contain oobleck during Learning Procedure Step 4); one for each student group

Audio-Visual Materials

- ❑ (Optional) Video or computer projection equipment; see Learning Procedure Step 1(b).

The NOAA Ship *Okeanos Explorer*
Formerly: USNS *Capable*
Launched: October 28, 1988
Transferred to NOAA: September 10, 2004
Commissioned: August 13, 2008
Class: T-AGOS
Length: 224 feet
Breadth: 43 feet
Draft: 15 feet
Displacement: 2,298.3 metric tons
Berthing: 46 (19 Mission/science)
Speed: 10 knots
Range: 9600 nm
Endurance: 40 days

Systems and Instumentation:
Kongsberg EM302 Multibeam rated to 7,000 m
SBE 911 Plus CTD
ROVs -
Little Hercules - 4,000 m depth rating; USBL tracking; depth, altitude, attitude/heading sensors; Seabird SBE 49 FastCat CTD; HD camera and HMI lights
Camera platform with depth/altitude/heading sensors, HD cameraand HMI lights.
Telepresence

Operations:
Ship crewed by NOAA Commissioned Officer Corps and civilians through NOAA's Office of Marine and Aviation; Mission equipment operated by NOAA's Office of Ocean Exploration and Research

For more information, visit http://oceanexplorer.noaa.gov/okeanos/welcome.html.

Images from Page 1 top to bottom:
The ROV Hercules being lowered into the water from the NOAA Ship *Okeanos Explorer*. Image credit: NOAA OER.

NOAA scientists examining live video feed from the ROV Hercules. Image credit: NOAA OER.

Mussels, shrimp, limpets, and crabs cover the slope of an underwater volcano near a hydrothermal vent. Image credit NOAA
http://www.photolib.noaa.gov/bigs/expl0071.jpg

Black smokers on the Kermadec Arc. Image courtesy of New Zealand American Submarine Ring of Fire 2007 Exploration, NOAA Vents Program, the Institute of Geological & Nuclear Sciences and NOAA-OE.
http://oceanexplorer.noaa.gov/explorations/07fire/logs/july31/media/brothers_blacksmoker_600.jpg

Teaching Time
One or two 45-minute class periods

Seating Arrangement
Groups of 3-4 students

Maximum Number of Students
30

Key Words
Core
Magma
Mantle
Crust
Tectonic plate
Plate boundaries
Volcano
Earthquake
Tsunami

Background Information
NOTE: Explanations and procedures in this lesson are written at a level appropriate to professional educators. In presenting and discussing this material with students, educators may need to adapt the language and instructional approach to styles that are best suited to specific student groups.

During the summer of 2010, scientists from Indonesia and the United States will work together on an expedition to explore the deep ocean surrounding Indonesia. This mission is called INDEX/SATAL 2010, since the expedition is focussed on INDonesia, EXploration, and the Sangihe Talaud (SATAL) region. Working from the Indonesian Research Vessel *Baruna Jaya IV* and the NOAA Ship *Okeanos Explorer*, these ocean explorers expect to find new deep-sea ecosystems, undiscovered geological features, and living organisms that have never been seen before. New discoveries are always exciting to scientists; but information from ocean exploration is important to everyone, because:
- Biodiversity in deep-sea ecosystems includes new species that can provide important drugs and other useful products;
- Some deep-sea ecosystems include organisms that can be used for human food;
- Information from deep ocean exploration can help predict earthquakes and tsunamis; and
- Human benefits from deep ocean systems are being affected by changes in Earth's climate and atmosphere.

The geology of the seafloor around Indonesia is very complex and active. Active geology means that the land and seafloor of Indonesia frequently experience volcanoes, earthquakes, and tsunamis.

Indonesia's Research Vessel
Baruna Jaya IV

Port of Registry - Jakarta, Indonesia
Purpose - Oceanography, Fishery
Launched - 1995
Length - 60.4 m
Width - 12.10 m
Draft - 4.15 m
Draft mean - 4.15m
Cruising speed - 10 kts
BPPT Indonesia - owner
17 crew, 33 scientists, and engineers

Deck Gear:
6 ton A-Frame
3 ton Crane
2 - Gilson Winches
2 - Otter Trawl Winches
Hydrographic Winch

Oceanographic Equipment:
Seabeam ELAXC1050D Multibeam
Seabeam ELAC 1190 Multibeam
ELAC 4700
Acoustic Doppler Current Profiler RDI Broadband
Sea Bird SBE-911 CTD with Rosette
Aanderaa, MORS, RDI current meters
Gravity Core Sediment Sampler
Oretech 3000 Subbottom Profiler
Edge Tech 4200-MP Sidescan Sonar

Fishery Equipment:
Mid- and Deep-water Fisheries Trawl
Koden Fish Finder
Simrad EK 500
Plankton Net

Volcanoes in Indonesia have caused more human fatalities and generated more tsunamis than any other volcanic region on Earth. The reason for this geologic activity is that Indonesia is located at the junction of several tectonic plates that make up Earth's crust. Collisions between these plates cause volcanoes and earthquakes, and may also cause tsunamis. 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. These plates move on a hot flowing mantle layer called the asthenosphere, which is several hundred kilometers thick. Heat within the asthenosphere creates convection currents that cause 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. View animations of different types of plate boundaries at: http://www.seed.slb.com/flash/science/features/earth/livingplanet/plate_boundaries/en/index.html.

A convergent plate boundary is formed when tectonic plates collide more or less head-on. When two continental plates collide, they may cause rock to be thrust upward at the point of collision, resulting in mountain-building (the Himalayas were formed by the collision of the Indo-Australian Plate with the Eurasian Plate). When an oceanic plate and a continental plate collide, the oceanic plate moves beneath the continental plate in a process 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. View the 3-dimensional structure of a subduction zone at: http://oceanexplorer.noaa.gov/explorations/03fire/logs/subduction.html.

Where tectonic plates are moving apart, they form a divergent plate boundary. At divergent plate boundaries, 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

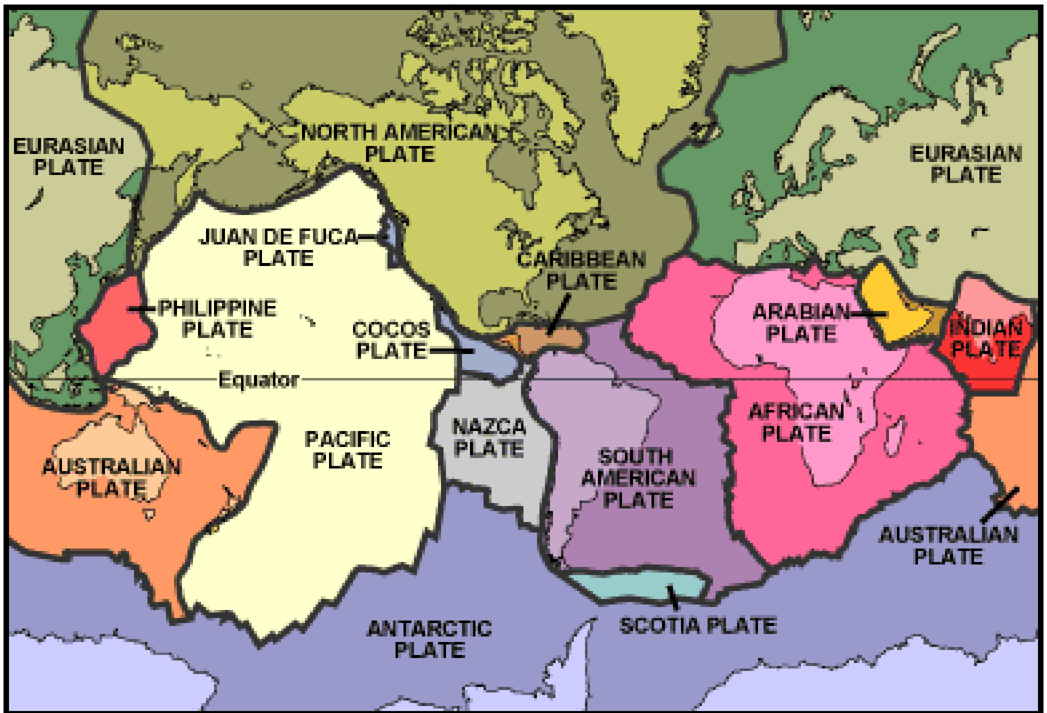
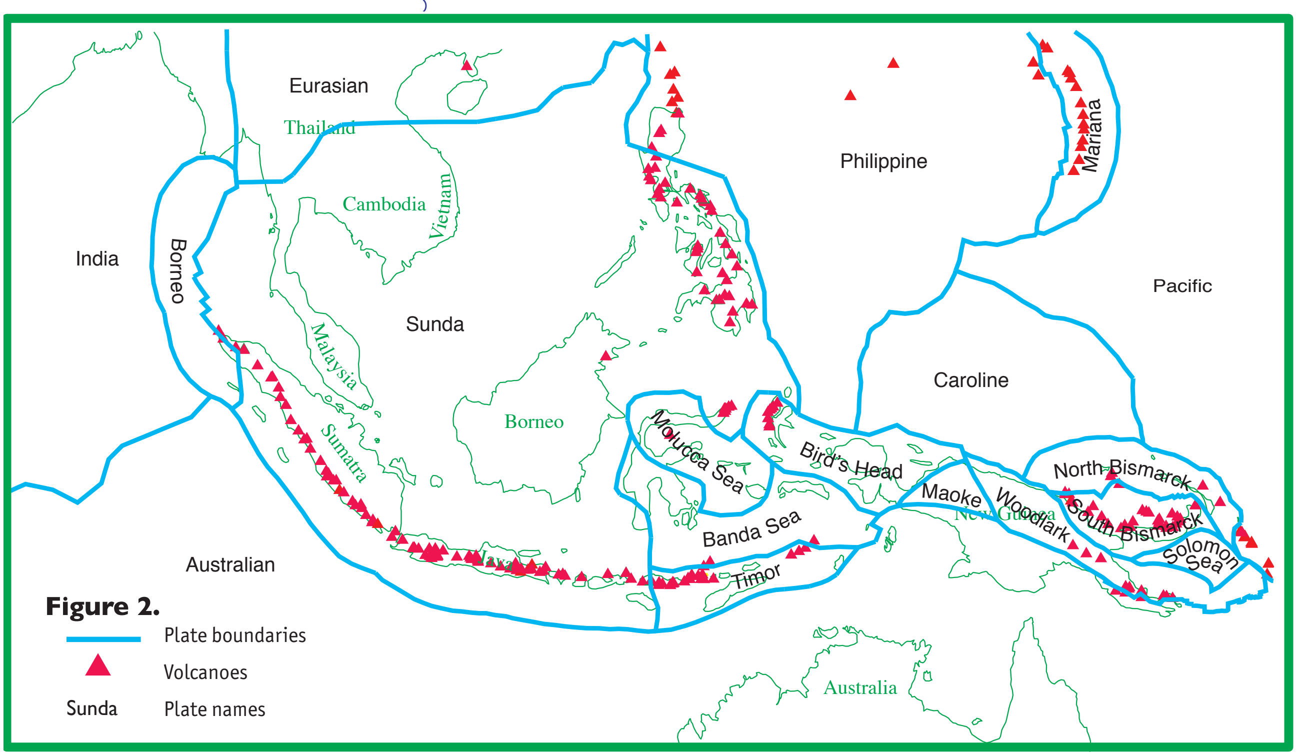


Figure 1. Major tectonic plates of the Earth's crust.

boundaries. View the 3-dimensional structure of a mid-ocean ridge at: http://oceanexplorer.noaa.gov/explorations/03fire/logs/ridge.html.

On a global scale, Earth's crust seems to be divided into 14 large plates (Figure 1). At this scale, Indonesia is located at the junction of the Eurasian, Pacific, India, and Australian Plates. In many places, including Indonesia, there are also many smaller plates that make the geology much more complex. Figure 2 illustrates some of these smaller plates. The India and Australian Plates are pushing underneath the Burma and Sunda Plates, forming an arc of volcanoes in western Indonesia. To the east, several smaller plates collide in various ways that also produce earthquakes and volcanoes.

Figure 2. Smaller plates around Indonesia.



Motion between these plates is not constant, because friction between the plates tends to keep them from moving. But while they are not moving, tectonic forces cause stresses to accumulate in the upper plate which gradually become deformed. Stresses may accumulate over centuries, until the deformation suddenly releases causing the plate to rebound. This plate motion produces an earthquake, as well as a giant underwater “kick” that generates a tsunami. The Banda Aceh earthquake and tsunami on December 26th, 2004 was caused by a sudden slip when the India Plate slid beneath the Burma Plate.

Deep ocean explorations in other areas have mapped deformation patterns in tectonic plates, and used these patterns to predict earthquake and tsunami hazards. Similar information from Indonesia’s deep ocean can be used to help prepare for these hazards.

This lesson guides student inquiries into plate tectonics.

Learning Procedure

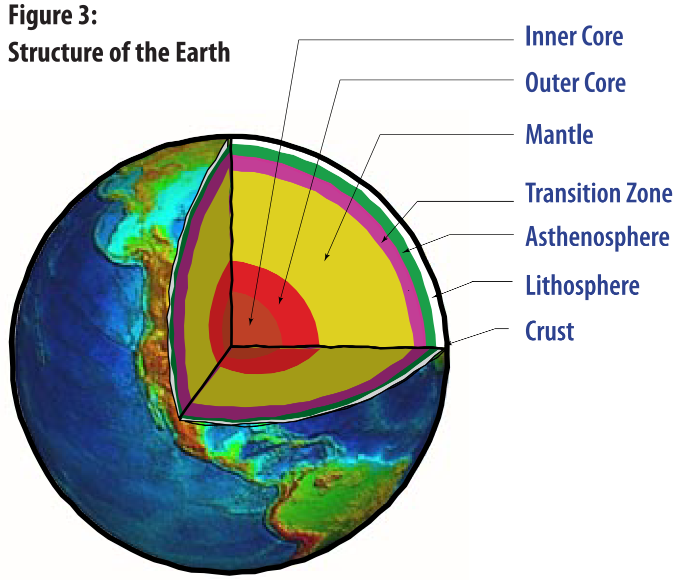
[NOTE: Portions of this activity are adapted from “When Plates Collide,” http://oceanexplorer.noaa.gov/explorations/10chile/background/edu/media/whenplates.pdf]

1. To prepare for this lesson:
   (a) Review introductory essays for the INDEX SATAL 2010 Expedition at http://oceanexplorer.noaa.gov/okeanos/explorations/10index/welcome.html
   (b) Review illustrations and explanations of plate tectonics in “This Dynamic Earth” and/or “This Dynamic Planet” (see Resources section) for possible use in Step 2. If video or computer projection facilities are available, you may also want to download some images from these materials to show your students.
   (c) Review Multimedia Discovery Missions [http://oceanexplorer.noaa.gov/edu/learning/welcome.html] Lessons 1, 2, and 4 on Plate Tectonics, Mid-Ocean Ridges, and Subduction Zones. Decide how much of this material to use with your students.
   (d) Make enlarged copies of Figures 1 and 2 and glue these onto poster board or stiff paper for constructing jigsaw puzzles (Step 2). Decide whether you will make the puzzles, or have students make them. Also, decide whether to have students research the motion of tectonic plates and add this information to the figures.
   (e) Experiment with oobleck recipes (Appendix A) and procedures in Step 4. Decide whether to prepare oobleck for this step in advance or to do this as part of student activities. Note that similar activities have been described using frosting, fruit rollups and graham crackers, but public health concerns and basic laboratory safety practices do not favor using edible materials in a classroom setting (though you may suggest that students might use such materials to repeat this demonstration at home).

2. Describe Earth's layered structure diagramed in Figure 3. Be sure students understand the spatial relationship of core, mantle, and crust. Explain the concept of plate tectonics, emphasizing that the plates are solid pieces of Earth's crust that float on a layer of the upper mantle that is partially-melted rock. Have student groups make jigsaw puzzles from enlarged copies of Figures 1 and 2 (or make these yourself in advance). Have contests to see which group can correctly assemble their puzzle in the shortest amount of time.

   Optional: Have students research the motion of tectonic plates and add this information to their puzzles by drawing arrows or colored lines to indicate convergent, divergent, and transform boundaries. See the essay on geology at http://oceanexplorer.noaa.gov/okeanos/explorations/10index/welcome.html.

Figure 3:
Structure of the Earth



3. Tell students that heat from Earth's core causes currents in the molten rock of the mantle (you can demonstrate similar currents by adding food coloring to a heated container of water), and these currents cause movement among Earth's tectonic plates. Introduce the concept of continental drift. Tell students that the junction of two tectonic plates is called a plate boundary, and describe the motion of plates at convergent, divergent, and transform boundaries. Remind students that these plates are huge pieces of rock, and ask them what they think happens when these plates collide. Explain the relationship of volcanoes and earthquakes to tectonic plate movements. You may want to point out that convergent, divergent, and transform boundaries are each associated with particular types of earthquake and volcanic activity: strong earthquakes and explosive volcanoes at convergent boundaries; slow-flowing volcanoes and weaker earthquakes at divergent boundaries; strong earthquakes, rare volcanoes at

transform boundaries. You may also want to discuss some of the energy transfers involved in plate motions, earthquakes, and volcanoes (e.g., heat energy from Earth's core; kinetic energy of plate movements and volcanic eruptions; heat of friction when plates collide with each other). Description and discussion of subduction at convergent plate boundaries also provides an opportunity to introduce the rock cycle.

4. Tell students that their assignment is to model convergent, divergent, and transform boundaries using oobleck, pieces of rigid foam insulation or foamcore, and tiles or pieces of hardboard. The lighter materials should be used to represent continental tectonic plates, which are less dense than oceanic tectonic plates that should be represented by pieces of tile or hardboard.

   A divergent boundary may be modeled by placing two pieces of heavier material side-by-side on a layer of oobleck, then moving them apart while pressing down slightly. This movement should cause the oobleck to be exposed and pushed up where the plates are separated, demonstrating how magma comes to the surface where tectonic plates are moving apart at divergent plate boundaries.

   A convergent boundary may be modeled by placing a piece of heavier material next to a piece of lighter material on a layer of oobleck, and gently pushing the two pieces together until they overlap so that the lighter material (continental plate) is on top and the heavier material (oceanic plate) has been subducted.

   A transform boundary may be modeled by placing two pieces of lighter (continental) material next to each other on a layer of oobleck, then pushing the pieces in opposite directions perpendicular to the direction of the junction.

The BRIDGE Connection

www.vims.edu/bridge/ – Scroll over "Ocean Science Topics" in the menu on the left side of the page, then select "Geology" for activities and links about plate tectonics.

The "Me" Connection

Have students write a first-hand account of a visit to a plate boundary, describing conditions at the boundary and what they might see in this area.

Connections to Other Subjects

English/Language Arts

Assessment

Tectonic plate puzzles, modeling activities and class discussions provide opportunities for assessment.

Extensions

1. Visit http://oceanexplorer.noaa.gov/okeanos/explorations/10index/welcome.html for the latest activities and discoveries by the INDEX/SATAL 2010 Expedition.

2. Create models of some deep ocean volcanoes (see http://celebrating200years.noaa.gov/edufun/book/MakeyourownVolcano.pdf).

Multimedia Discovery Missions

http://oceanexplorer.noaa.gov/edu/learning/welcome.html – Click on the links to Lessons 1 for interactive multimedia presentations and Learning Activities on Plate Tectonics.

Other Relevant Lesson Plans from NOAA's Ocean Exploration Program

Friendly Volcanos
(5 pages, 380k)) (from the 2004 Submarine Ring of Fire Expedition)
http://oceanexplorer.noaa.gov/explorations/04fire/background/edu/media/RoF.friendlyvol.pdf

Focus: Ecological impacts of volcanism in the Mariana Islands (Life Science/Earth Science)

Students will be able to describe at least three beneficial impacts of volcanic activity on marine ecosystems, and will be able to explain the overall tectonic processes that cause volcanic activity along the Mariana Arc.

It's Going to Blow Up!
(10 pages, 337Kb) (from the New Zealand American Submarine Ring of Fire 2005 Expedition)
http://oceanexplorer.noaa.gov/explorations/05fire/background/edu/media/rof05_explosive.pdf

Focus: Volcanism on the Pacific Ring of Fire (Earth Science)

Students will be able to describe the processes that produce the "Submarine Ring of Fire," explain the factors that contribute to explosive volcanic eruptions, describe the primary risks posed by volcanic activity in the United States, and identify the volcano within the continental U.S. that is considered most dangerous.

Other 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.

http://oceanexplorer.noaa.gov/okeanos/explorations/10index/welcome.html – Web site for the INDEX SATAL 2010 Expedition, with links to lesson plans, career connections, and other resources

http://oceanexplorer.noaa.gov/okeanos/edu/welcome.html – Web page for the NOAA Ship *Okeanos Explorer* Education Materials Collection

http://celebrating200years.noaa.gov/edufun/book/welcome.html#book - A free printable book for home and school use introduced in 2004 to celebrate the 200th anniversary of NOAA; nearly 200 pages of lessons focusing on the exploration, understanding, and protection of Earth as a whole system

http://oceanexplorer.noaa.gov/explorations/02fire/logs/magicmountain/welcome.html – Links to virtual fly-throughs and panoramas of the Magic Mountain hydrothermal vent site on Explorer Ridge in the NE Pacific Ocean, where two tectonic plates are spreading apart and there is active eruption of submarine volcanoes

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

Bird, P. (2003). "An updated digital model of plate boundaries". Geochemistry, Geophysics, Geosystems 4 (3): 1027. http://peterbird.name/publications/2003_PB2002/2003_PB2002.htm

http://explore.noaa.gov/special-projects/indonesia-u-s-scientific-and-technical-cooperation-in-ocean-exploration/files/Corals_for_WOC_-_FINAL.pdf – NOAA Fact Sheet about coral reefs

http://explore.noaa.gov/special-projects/indonesia-u-s-scientific-and-technical-cooperation-in-ocean-exploration/files/Okeanos_Explorer_for_WOC_-_FINAL.pdf – NOAA Fact Sheet about the NOAA Ship *Okeanos Explorer*

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
- Properties and changes of properties in matter
- Motions and forces
- Transfer of energy

Content Standard D: Earth and Space Science
- Structure of the Earth system
- Earth's history

Content Standard F: Science in Personal and Social Perspectives
- Natural hazards

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 e. Tectonic activity, sea level changes, and force of waves influence the physical structure and landforms of the coast.

Essential Principle 2.
The ocean and life in the ocean shape the features of the Earth.
Fundamental Concept b. Sea level changes over time have expanded and contracted continental shelves, created and destroyed inland seas, and shaped the surface of land.
Fundamental Concept e. Tectonic activity, sea level changes, and force of waves influence the physical structure and landforms of the coast.

Essential Principle 5.
The ocean supports a great diversity of life and ecosystems.
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 c. Over the last 40 years, use of ocean resources has increased significantly, therefore the future sustainability of ocean resources depends on our understanding of those resources and their potential and limitations.

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.

Send Us Your Feedback

We value your feedback on this lesson.
Please send your comments to:
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For More Information

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The Tectonic Challenge

Appendix A: Recipes for Oobleck

Oobleck is a non-Newtonian fluid whose name comes from the Dr. Seuss book, Bartholomew and the Oobleck. There are a variety of recipes for making oobleck, which include:

Option 1:
The simplest recipe is to slowly add approximately two cups of cornstarch to one cup of water, continuously mixing until the mixture is semi-solid (http://www.instructables.com/id/Oobleck/).

Option 2:
A less sticky version can be made from borax and glue (http://education.jlab.org/beamsactivity/6thgrade/oobleck/overview.html). Make a glue solution with equal volumes of white glue and water. Make a second solution by dissolving 60 ml of dry borax powder in one liter of water (the borax may not dissolve completely). Make oobleck by mixing 30 ml of the glue solution with 10 ml of the borax solution.

Option 3:
Mix 1/2 cup of liquid starch with 1 cup of white glue (http://www.ehow.com/how_2384117_create-oobleck-school-glue.html).

Food coloring may be added to any of these recipes if desired.