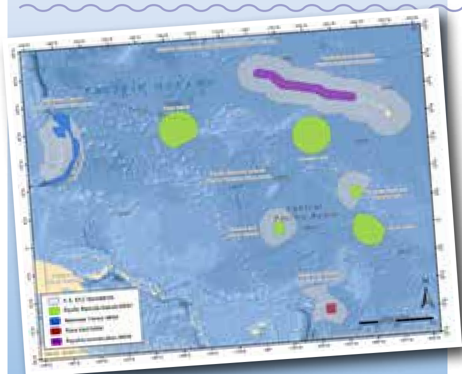
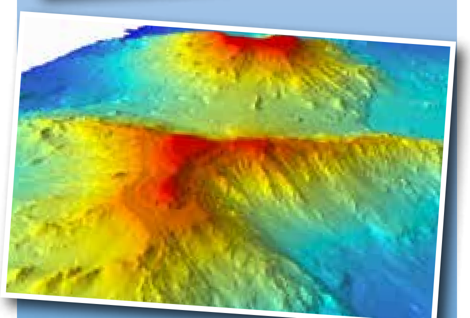
Hohonu Moana:
Exploring Deep Waters Off Hawaii Expedition 2015

To Make an Archipelago!





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lesson plan

Grade Level

6-8 (Earth Science)

Focus

Formation of the Hawaiian Archipelago

Focus Question

What geological processes produced the different physical forms seen among islands in the Hawaiian Archipelago?

Learning Objectives

- Students will describe eight stages in the formation of islands in the Hawaiian Archipelago, and will describe how a combination of hotspot activity and tectonic plate movement could produce the arrangement of seamounts observed in the Hawaiian Archipelago.

- Students will construct a scientific explanation based on evidence for how a combination of hotspot activity and tectonic plate movement could produce the distributions of cobalt-rich ferromanganese resources found in the Hawaiian Archipelago.

Materials

- ❑ Diagram of "The Hawaiian Archipelago" (Download from http://www.soest.hawaii.edu/GG/HCV/haw_formation.html)

- ❑ Map of the Hawaiian Archipelago (e.g., http://sanctuaries.noaa.gov/science/condition/pmnm/images/fig1_lg.jpg)

- ❑ Materials for constructing island models OR drawing materials OR student Internet access, depending upon option chosen for Learning Procedure Step #4

- ❑ Brief description of selected islands (see Learning Procedure step #4; http://www.bishopmuseum.org/research/nwhi/geograph.html is a useful source for this information)

Audio-Visual Materials

- ❑ (Optional) Interactive white board

Teaching Time

Two to three 45-minute class periods

Seating Arrangement

Groups of two to four students

Maximum Number of Students

30

Key Words

archipelago
atoll
Marine National Monument
cobalt
ferromanganese crust
seamount
lithosphere
hotspot
tectonic plate

Background Information

Marine protected areas (MPAs) are areas of the marine environment where there is legal protection for natural and cultural resources. In the United States, marine national monuments are marine protected areas that are created by Presidential Proclamation (this is a different creation process than for national marine sanctuaries, which are designated by NOAA or Congress and require extensive public process, local community engagement, stakeholder involvement, and citizen participation for designation and management).

The two largest U.S. Marine National Monuments of the United States are Papahänaumokuäkea Marine National Monument (PMNM) northwest of the inhabited main Hawaiian Islands, and Pacific Remote Islands Marine National Monument (PRIMNM) which consists of Wake, Howland, Baker and Jarvis Islands, Johnston Atoll, Kingman Reef and Palmyra Atoll. Besides being the two largest Marine National Monuments, they are also among the world's most remote MPAs. Many of the species found in these MPAs are found nowhere else on Earth (species that are found in only one specific location are said to be "endemic" to that location). The marine habitats of PMNM, for example, are home to over 7,000 species, 25% of which are endemic. For additional information about PMNM and PRIMNM, please see the essay, "Exploration of the two largest marine protected areas of the United States," by Daniel Wagner and Samantha Brooke. [http://oceanexplorer.noaa.gov/okeanos/explorations/ex1504/background/mpas/welcome.html]

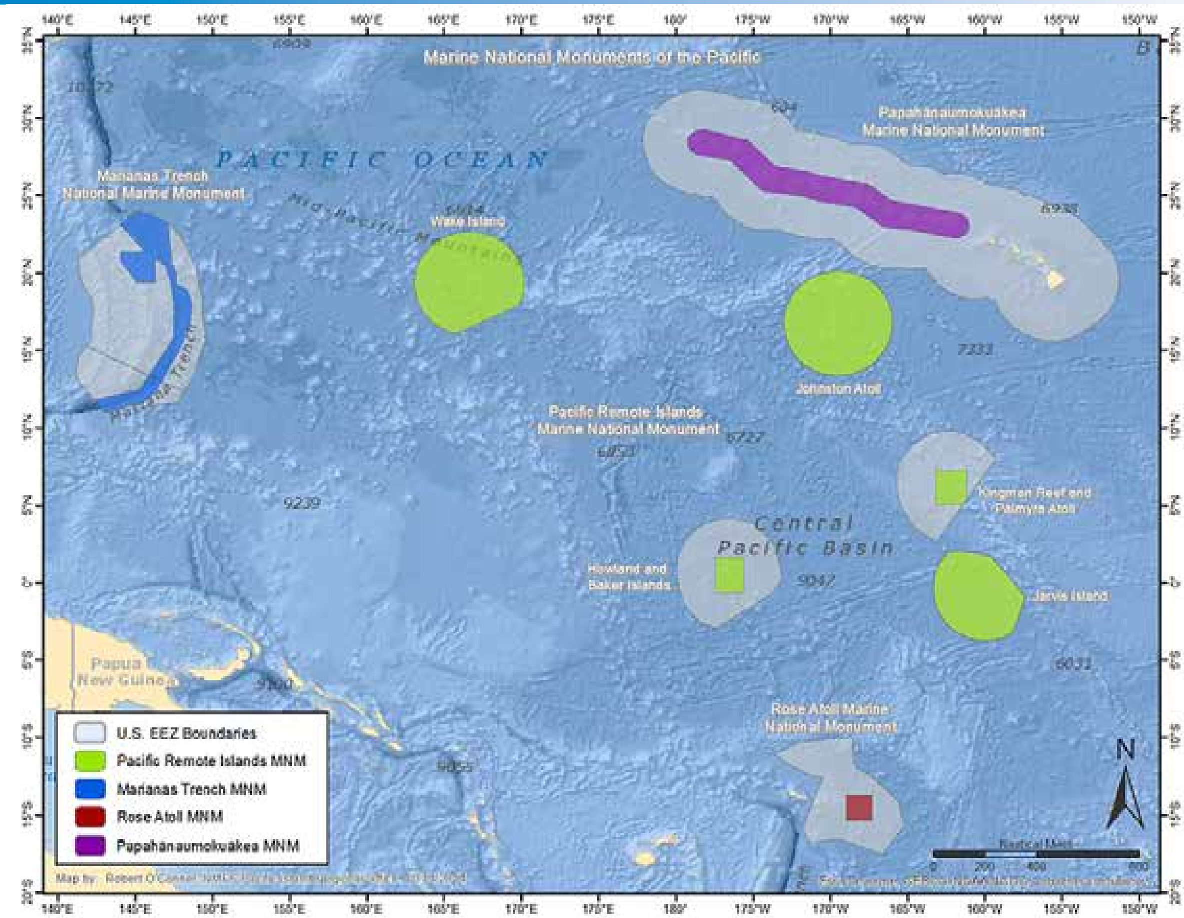
The islands of the Hawaiian archipelago were formed by a series of volcanic eruptions that began more than 80 million years ago. Volcanoes are often associated with movement of large plates of rock (called tectonic plates) that make up the Earth's crust. The outer shell

Images from Page 1 top to bottom:
Marine National Monuments of the Pacific. Image credit: Robert O'Conner, NMFS, Pacific Island Regional Office (PIRO)
http://www.fpir.noaa.gov/Graphics/MNM/Pacific_MNM_DRAFT_10_14_2014.jpg

3D image of Academician Berg seamount in the Papahanaumokuakea Marine National Monument. Image credit: C. Kelley (created from data obtained by the Schmidt Ocean Institute).

A Hawaiian species of gorgonian called *Rhodaniridogorgia* bending in the current. Image credit: NOAA-HURL archives.

Hawaiian bubblegum coral at 350 m depth with anemones, brittlestars, and other animals living in their colonies. Image credit: NOAA-HURL archives.



Marine National Monuments of the Pacific.
Image credit: Robert O'Conner, NMFS, Pacific Island Regional Office (PIRO)
http://www.fpir.noaa.gov/Graphics/MNM/Pacific_MNM_DRAFT_10_14_2014.jpg

of the Earth (called the lithosphere) consists of about a dozen large tectonic plates (there are many more smaller tectonic plates) that move several centimeters per year relative to each other. These plates consist of a crust about 5 km thick, and the upper 60 - 75 km of the Earth's mantle. Tectonic 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. Places where two or more tectonic plates collide are called plate boundaries, which are classified according to the relative motion of the colliding plates. Boundaries where tectonic plates slide horizontally past each other are called transform plate boundaries. The motion of the plates rubbing against each other sets up huge stresses 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.

Boundaries where tectonic plates move apart (for example, along the mid-ocean ridge in the middle of the Atlantic Ocean) are called divergent plate boundaries. Typically, a rift is formed that allows magma (molten rock) to escape from deep within the Earth and harden into solid rock known as basalt.

The *Okeanos Explorer* Exploration Strategy

The overall *Okeanos Explorer* strategy is based on finding anomalies; conditions or features that are different from the surrounding environment. This is because anomalies may point the way to new discoveries, which are part of the ship's mission. Changes in chemical properties of seawater, for example, can indicate the presence of underwater volcanic activity, hydrothermal vents, and chemosynthetic communities. Once an anomaly is detected, the exploration strategy shifts to obtaining more detailed information about the anomaly and the surrounding area. An important concept underlying this strategy is a distinction between exploration and research. As a ship of discovery, the role of *Okeanos Explorer* is to locate new features in the deep ocean, and conduct preliminary characterizations of the site that provide enough data to justify potential follow-up by future expeditions.

This strategy involves three major activities:

- Underway reconnaissance;
- Water column exploration; and
- Site characterization.

Underway reconnaissance involves mapping the ocean floor and water column while the ship is underway, and using other sensors to measure chemical and physical properties of seawater. Water column exploration involves making measurements of chemical and physical properties "from top to bottom" while the ship is stopped. In some cases these measurements may be made routinely at pre-selected locations, while in other cases they may be made to decide whether an area with suspected anomalies should be more thoroughly investigated. Site characterization involves more detailed exploration of a specific region, including obtaining high quality imagery, making measurements of chemical and physical seawater properties, and obtaining other appropriate types of data.

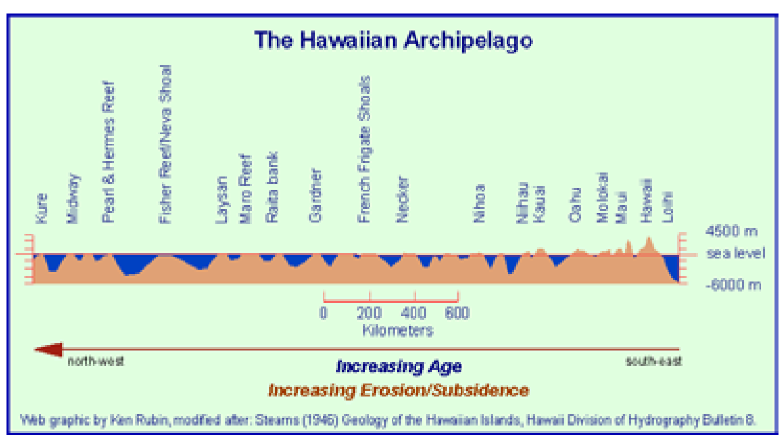
In addition to state-of-the-art navigation and ship operation equipment, this strategy depends upon four key technologies:

- Telepresence;
- Multibeam sonar mapping system;
- CTD (an instrument that measures conductivity, temperature, and depth) and other electronic sensors to measure chemical and physical seawater properties; and
- A Remotely Operated Vehicle (ROV) capable of obtaining high-quality imagery in depths as great as 6,000 meters).

Convergent plate boundaries exist where tectonic plates collide more or less head-on. At convergent plate boundaries, one plate may descend beneath the other in a process called subduction, which generates high temperatures and pressures that can lead to explosive volcanic eruptions (such as the Mount St. Helens eruption which resulted from subduction of the Juan de Fuca tectonic plate beneath the North American tectonic plate). For images of different types of plate boundaries, see http://oceanexplorer.noaa.gov/facts/plate-boundaries.html.

Volcanoes can also be formed at hotspots, which are thought to be natural pipelines to reservoirs of magma in the upper portion of the Earth's mantle. The Hawaiian islands are the result of volcanic activity associated with a hotspot that appears to deeply penetrate the mantle to the boundary between the mantle and the Earth's metallic core. The Hawaiian hotspot is presently located beneath the Big Island of Hawaii at the southeastern end of the archipelago.

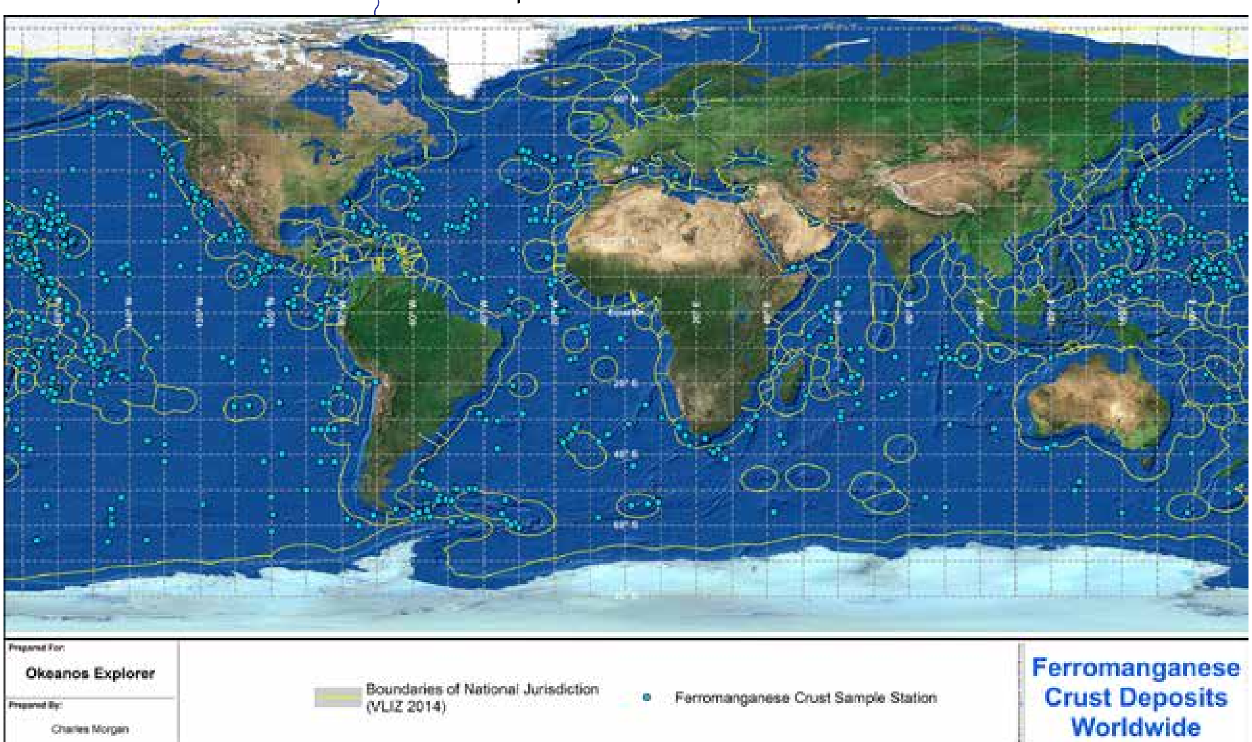
The Pacific tectonic plate is presently moving over the asthenosphere toward the northwest at a rate of 5 to 10 cm per year. As the plate moves over the Hawaiian hotspot, magma periodically erupts to form volcanoes that become islands. The oldest island is Kure at the northwestern end of the archipelago. The youngest is the Big Island of Hawaii at the southeastern end. Loihi, east of the Big Island, is the newest volcano in the chain and may eventually form another island. As the Pacific plate moves to the northwest, islands are carried farther away from the hot spot, and the crust cools and subsides. At the same time, erosion gradually shrinks the islands, and unless there is further volcanic activity (or a drop in sea level) the island eventually submerges below the ocean surface. To the northwest of Kure, the Emperor Seamounts are the submerged remains of former islands that are even older than Kure.



In addition to containing unique biological, geological, and cultural resources, PMNM and PRIMNM also contain significant mineral resources including cobalt-rich ferromanganese crusts. (Other mineral resources discussed in this lesson include manganese nodules and massive sulfide deposits.) These minerals are presently the focus of seafloor mining interests. Although these monument areas are rich in deep seabed minerals, mining cannot occur due to the protected status of the areas. The study of these protected areas will provide data and information that can be used as an environmental baseline for understanding the marine environment and ecology where these types of mineral resources are found.

Cobalt-rich ferromanganese crusts have unusually high concentrations of certain metals, particularly cobalt, manganese, and nickel, that are used to add properties such as hardness, strength and corrosion resistance to steel and super alloys used in the aerospace industry. These metals are also used in products such as photovoltaic and solar cells, superconductors, advanced laser systems, catalysts, fuel cells, powerful magnets, and cutting tools.

Deep-sea ferromanganese crusts form on submerged rock surfaces in sites around the world. They are most common on the flanks of seamounts, which are underwater mountains (often remnants of extinct volcanoes) that rise 1,000 meters or more above the surrounding seafloor. The thickest and most cobalt-rich crusts are found on the flanks and summits of seamounts at depths of 800-2,500 meters. The thickest crusts found to date are within the boundary of the PMNM. For more information about cobalt-rich ferromanganese crusts, please see the essay, "Cobalt-Rich Ferromanganese Deep-Sea Crust Deposits in the Hawaiian and Johnston Island Exclusive Economic



Zone," by Charles Morgan.[http://oceanexplorer.noaa.gov/okeanos/explorations/ex1504/background/crusts/welcome.html] For more information about seamounts, please see the essay, "Seamounts: underwater islands of the Pacific," by Les Watling. [http://oceanexplorer.noaa.gov/okeanos/explorations/ex1504/background/seamounts/welcome.html]

Whether mining becomes reality in various locations in the Pacific depends upon decisions that must consider how the process of extracting these resources will affect all of the other resources in the same area. Answering this question depends upon knowing what resources presently exist in an area of potential mineral extraction, and how these resources interact with other marine ecosystems. Providing habitat information on seamounts with cobalt-rich crusts is a key focus of the Hohonu Moana: Exploring Deep Waters Off Hawaii Expedition 2015, aboard the NOAA Ship *Okeanos Explorer*. This is the first expedition of a planned three year effort called the Campaign to Address Pacific monument Science, Technology, and Ocean NEeds (CAPSTONE).

CAPSTONE will focus on systematically collecting baseline information to support science and management needs within and around the U.S. Marine National Monuments and other protected places in the Pacific Ocean. Science priorities include:

- surveying habitats in areas that have recently been added or may soon be added to marine monuments and sanctuaries;
- identifying and characterizing vulnerable marine habitats, particularly deep-sea coral & sponge communities;
- characterizing seamounts within the Pacific Crust Zone (an area about 3,000 kilometers southwest of Japan that contains the world's oldest seamounts where many metallic compounds have been deposited over about 150 million years to form relatively thick crusts);
- collecting information on the geologic history of Central Pacific Seamounts, including those that may be relevant to our understanding of plate tectonics and subduction zone biology and geology; and
- providing a foundation of publicly accessible data and information products to spur further exploration, research, and management activities.

This expedition will use deepwater mapping, remotely operated vehicles, chemical and physical analytic tools, and high-bandwidth satellite communications to gather information about the region that will catalyze further exploration and research, and help guide future management activities.

For more information about NOAA Ship *Okeanos Explorer*, her expeditions and exploration strategies, please see http://oceanexplorer.noaa.gov/okeanos/about.html and the *NOAA Ship Okeanos Explorer Education Materials Collection* http://oceanexplorer.noaa.gov/okeanos/edu/welcome.html.

In this lesson, students will investigate the geologic processes that resulted in the formation of the Hawaiian Island archipelago, and how these processes are related to the distribution of cobalt-rich ferromanganese deposits.

Learning Procedure

1. To prepare for this lesson,
   a. review background information about the Hohonu Moana: Exploring Deep Waters Off Hawaii Expedition 2015 [http://oceanexplorer.noaa.gov/okeanos/explorations/ex1504/welcome.html].

   b. Review the Multimedia Discovery Mission, Plate Tectonics (Lesson 1) [http://oceanexplorer.noaa.gov/edu/learning/welcome.html#lesson1], and Seamounts (Lesson 14) [http://oceanexplorer.noaa.gov/edu/learning/welcome.html#lesson14]. Decide whether your students will be able to understand these presentations on their own, or whether you want to use the slides with your own narration and explanations. You may also want to keep track of new vocabulary to discuss with your students.

   c. Depending upon available time and specific learning objectives, you may also want to review "Exploration of the two largest marine protected areas of the United States," by Daniel Wagner and Samantha Brooke [http://oceanexplorer.noaa.gov/okeanos/explorations/ex1504/background/mpas/welcome.html], and/or "Cobalt-Rich Ferromanganese Deep-Sea Crust Deposits in the Hawaiian and Johnston Island Exclusive Economic Zone," by Charles Morgan [http://oceanexplorer.noaa.gov/okeanos/explorations/ex1504/background/crusts/welcome.html], and/or essays about seamounts, and/or the NOAA Ship *Okeanos Explorer* exploration strategy referenced above.

2. Briefly introduce
   - The NOAA Ship *Okeanos Explorer*, which is the only U.S. ship whose sole assignment is to systematically explore Earth's largely unknown ocean for the purposes of discovery and the advancement of knowledge;
   - Marine national monuments, and the variety of biological, geological, and cultural resources found in the PMNM and PRIMNM;

- Cobalt-rich ferromanganese crusts, why they are considered an important geological resource, and why there is concern about mining these crusts; and
- The Hohonu Moana: Exploring Deep Waters Off Hawaii Expedition 2015.

3. Show students video from the Multimedia Discovery Missions about Plate Tectonics (Lesson 1) and Seamounts (Lesson 14), or your own presentation about these topics.

   Be sure students understand:
   - The concept of tectonic plate movements;
   - The Hawaiian Archipelago is in the middle of the Pacific tectonic plate;
   - Volcanoes can be formed at hotspots, which are thought to be natural pipelines to reservoirs of magma in the upper portion of the Earth's mantle;
   - Hotspots remain more or less stationary relative to movement of the overlying tectonic plate;
   - The Hawaiian Archipelago is the result of volcanic activity associated with a hotspot that is presently located beneath the Big Island of Hawaii at the southeastern end of the archipelago;
   - The Pacific tectonic plate is presently moving over the asthenosphere toward the northwest at a rate of 5 to 10 cm per year;
   - As the Pacific tectonic plate moves over the Hawaiian hotspot, magma periodically erupts to form volcanoes that become islands;
   - The oldest island in the Hawaiian Archipelago is Kure at the northwestern end of the archipelago;
   - The youngest island in the Hawaiian Archipelago is the Big Island of Hawaii at the southeastern end; and
   - Volcanic activity subsides as islands are carried away from the hotspot by motion of the Pacific tectonic plate; the three currently active volcanoes in Hawaii are Kilauea, Mauna Loa, and Loihi; all relatively close to the Hawaiian hotspot.

4. Describe the stages of volcanic island formation.
   1) The deep submarine stage begins with submarine eruptions, which eventually reach the ocean surface (Loihi is in this stage);
   2) The shallow submarine stage features an above-water crater, which spouts lava from rifts on the side of the cone;
   3) The subaerial shield-building stage begins with collapse of the highest point (summit) on the volcanic cone to form a caldera. The volcano continues to emit lava from the summit and from rifts in the side of the cone (Mauna Loa and Kilauea are in this stage);

4) The post-caldera stage is whenlava fills and overflows the caldera to form a rounded summit. While overall volcanic activity may slow down, significant lava flow still continues (the Kohala Mountains, Mauna Kea, and Hualalai are in this stage; Haleakala is also in this stage, even though the caldera is not filled and still has a crater shape);
5) The erosional stage is when lava is no longer being added, and the volcanic cone is attacked by erosion from the ocean and rainfall. A sea bluff, deep valleys and sharp ridges are characteristic features of this stage (Kauai, Oahu, and portions of all the major Hawaiian Islands are in this stage);
6) The reef growth stage occurs when volcanic mountains are eroded to the point that they are only rocks that barely break the ocean's surface. The volcanic island is slowly sinking at this stage, but it is often possible for coral growth to keep pace with the sinking so that reefs can form (French Frigate Shoals is in this stage);
7) The post-erosional eruptions stage is marked by minor renewal of volcanism through which a few small cones or lava flows may be formed (portions of West Maui are in this stage); and
8) The atoll stage occurs when lava rock has been eroded below sea level, and only the coral reef remains at the surface (Pearl and Hermes Reef and Kure are in this stage).

Assign each student group one of the eight stages, and have students either construct a model or diagram of their assigned stage, or alternatively find an example of their assigned stage among the islands of the Hawaiian archipelago (http://www.bishopmuseum.org/research/nwhi/geograph.html has information that will help with the latter assignment).

5. Tell students that the richest cobalt-rich ferromanganese crusts are found where there is bare rock that is kept clear of sediments by strong currents, in depths between 800 meters and 2,500 meters. Ask students to explain the relationship between hotspot activity, tectonic plate movement, and distributions of cobalt-rich ferromanganese resources found in the Hawaiian Archipelago. This should be an easy, straightforward synthesis of information covered earlier in this lesson: Hotspot activity and tectonic plate movement have produced volcanic islands and seamounts of the Hawaiian Archipelago. These geologic structures provide conditions appropriate for the formation of cobalt-rich ferromanganese crusts.

The BRIDGE Connection

www.vims.edu/bridge/pacific.html – Activities and links about tectonic processes and the Hawaiian hotspot

The "Me" Connection

Have students write a brief essay discussing how plate tectonic processes might affect them personally.

Connections to Other Subjects

English/Language Arts, Social Studies

Assessment

Participation in class discussions provides opportunity for assessment.

Extensions

Visit http://oceanexplorer.noaa.gov/okeanos/explorations/explorations.html for links to individual voyages of discovery by NOAA Ship *Okeanos Explorer*.

Multimedia Discovery Missions

http://oceanexplorer.noaa.gov/edu/learning/welcome.html Click on the links to Lesson 14 for interactive multimedia presentations and Learning Activities on seamounts.

Other Relevant Lesson Plans from NOAA's Ocean Exploration Program

Roots of the Hawaiian Hotspot (grades 9-12)
from the 2002 Northwestern Hawaiian Islands expedition
[http://oceanexplorer.noaa.gov/explorations/02hawaii/background/education/media/nwhi_roots.pdf]

Focus: Seismology and geological origins of the Hawaiian Islands (Earth Science)

Students explain the processes of plate tectonics and volcanism that resulted in the formation of the Hawaiian Islands, describe, compare, and contrast S waves and P waves, explain how seismic data recorded at different locations can be used to determine the epicenter of an earthquake, infer a probable explanation for the existence of ultra-low velocity zones, and explain how these zones may be related to the Hawaiian hotspot.

How Does Your Magma Grow? (Grades 7-8)
from the 2005 GalAPAGoS: Where Ridge Meets Hotspot expedition
[http://oceanexplorer.noaa.gov/explorations/05galapagos/background/edu/media/05galapagos_magma.pdf]

Focus: Hot spots and midocean ridges (Physical Science)

Students identify types of plate boundaries associated with movement of the Earth's tectonic plates, compare and contrast volcanic activity associated with spreading centers and hot spots, describe processes which resulted in the formation of the Galapagos Islands, and describe processes that produce hydrothermal vents.

Other Resources

The Web links below are provided for informational purposes only. Links outside of the Ocean Explorer web site 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/edu/welcome.html – Web page for the *Okeanos Explorer Education Materials Collection*

http://oceanexplorer.noaa.gov/facts/seamounts.html – Seamount fact sheet

http://oceanexplorer.noaa.gov/edu/themes/seamounts/welcome.html -Ocean Explorer Seamount theme page

http://oceanexplorer.noaa.gov/edu/themes/vents-and-volcanoes/welcome.html - Ocean Explorer Vents and Volcanoes theme page

http://oceanexplorer.noaa.gov/explorations/05galapagos/background/hotspots/hotspots.html – essay, "What Is A Hotspot," by Ken MacDonald; from the 2005 GalAPAGoS: Where Ridge Meets Hotspot Expedition

Next Generation Science Standards

MS. Earth's Systems

Performance Expectation:

MS-ESS3-1. Construct a scientific explanation based on evidence for how the uneven distributions of Earth's mineral, energy, and groundwater resources are the result of past and current geoscience processes. [Clarification Statement: Emphasis is on how these resources are limited and typically non-renewable, and how their distributions are significantly changing as a result of removal by humans. Examples of uneven distributions of resources as a result of past processes include but are not limited to petroleum (locations of the burial of organic marine sediments and subsequent geologic traps), metal ores (locations of past volcanic and hydrothermal activity associated with subduction zones), and soil (locations of active weathering and/or deposition of rock).]

Science and Engineering Practices

Constructing Explanations and Designing Solutions

- Construct a scientific explanation based on valid and reliable evidence obtained from sources (including the students' own experiments) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future.

Disciplinary Core Ideas

ESS3.A: Natural Resources

- Humans depend on Earth's land, ocean, atmosphere, and biosphere for many different resources. Minerals, fresh water, and biosphere resources are limited, and many are not renewable or replaceable over human lifetimes. These resources are distributed unevenly around the planet as a result of past geologic processes.

Crosscutting Concepts

Cause and Effect

- Cause and effect relationships may be used to predict phenomena in natural or designed systems.

Connections to Engineering, Technology, and Applications of Science

Influence of Science, Engineering, and Technology on Society and the Natural World

- All human activity draws on natural resources and has both short and longterm consequences, positive as well as negative, for the health of people and the natural environment.

Common Core State Standards Connections:

ELA/Literacy -

RST.6-8.1 Cite specific textual evidence to support analysis of science and technical texts.

WHST.6-8.2 Write informative/explanatory texts to examine a topic and convey ideas, concepts, and information through the selection, organization, and analysis of relevant content.

WHST.6-8.9 Draw evidence from informational texts to support analysis, reflection, and research.

Mathematics -

6.EE.B.6 Use variables to represent numbers and write expressions when solving a real-world or mathematical problem; understand that a variable can represent an unknown number, or, depending on the purpose at hand, any number in a specified set.

7.EE.B.4 Use variables to represent quantities in a real-world or mathematical problem, and construct simple equations and inequalities to solve problems by reasoning about the quantities.

Ocean Literacy Essential Principles and Fundamental Concepts

Essential Principle 1.
The Earth has one big ocean with many features.

Fundamental Concept h. Although the ocean is large, it is finite and resources are limited.

Essential Principle 2.
The ocean and life in the ocean shape the features of Earth.

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

Essential Principle 6:
The ocean and humans are inextricably interconnected.

Fundamental Concept b. The ocean provides food, medicines, and mineral and energy resources. It supports jobs and national economies, serves as a highway for transportation of goods and people, and plays a role in national security.

Fundamental Concept d. Humans affect the ocean in a variety of ways. Laws, regulations, and resource management affect what is taken out and put into the ocean. Human development and activity leads to pollution (point source, nonpoint source, and noise pollution), changes to ocean chemistry (ocean acidification), and physical modifications (changes to beaches, shores, and rivers). In addition, humans have removed most of the large vertebrates from the ocean.

Fundamental Concept g. Everyone is responsible for caring for the ocean. The ocean sustains life on Earth and humans must live in ways that sustain the ocean. Individual and collective actions are needed to effectively manage ocean resources for all.

Essential Principle 7.
The ocean is largely unexplored.

Fundamental Concept b. Understanding the ocean is more than a matter of curiosity. Exploration, experimentation, and discovery are required to better understand ocean systems and processes. Our very survival hinges upon it.

Fundamental Concept c. Over the last 50 years, use of ocean resources has increased significantly; the future sustainability of ocean resources depends on our understanding of those resources and their potential.

Fundamental Concept f. Ocean exploration is truly interdisciplinary. It requires close collaboration among biologists, chemists, climatologists, computer programmers, engineers, geologists, meteorologists, physicists, animators, and illustrators. And these interactions foster new ideas and new perspectives for inquiries.

Send Us Your Feedback

In addition to consultation with expedition scientists, the development of lesson plans and other education products is guided by comments and suggestions from educators and others who use these materials. Please send questions and comments about these materials to: oceanexeducation@noaa.gov.

For More Information

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Credit