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Northwestern Hawaiian Islands Exploration

Islands, Reefs and a Hotspot

Focus
Formation of the Hawaiian archipelago

Grade Level
5-6 Earth Science

Focus Question
What geological processes produced the different physical forms seen among the Hawaiian Islands?

Learning Objectives
Students will be able to describe eight stages in the formation of islands in the Hawaiian archipelago.

Students will be able to describe the movement of tectonic plates in the Hawaiian archipelago region.

Students will be able to describe how a combination of hotspot activity and tectonic plate movement could produce the arrangement of seamounts observed in the Hawaiian archipelago.

Additional Information for Teachers of Deaf Students
In addition to the words listed as key words, the following words should be part of the vocabulary list.
Atoll
Nautical
SCUBA
Exploration
ROV
Corals
Archipelago
Tectonic plate
Lithosphere
Crust
Mantle
Asthenosphere
Convection current
Faults
Magma
Basalt
Subduction
Eruption
Crater
Summit
Caldera

There are no formal signs in American Sign Language for any of these words listed as key words and many are difficult to lipread. Having the vocabulary list on the board as a reference during the lesson will be extremely helpful. It may also be helpful to have a list of the key words as a handout for the students.

Convection currents are explained in the Background Information. A brief demonstration of a convection current can be conducted by adding food coloring to a heated container of water. This will be helpful to demonstrate the concept. It would also be helpful to make an overhead transparency in addition to the handout of the "Location and Age of Some Islands in the Hawaii Archipelago" listed in Step 2. The activity should be conducted as a group rather than individually.

The eight stages of growth and erosion in the islands of the Hawaiian Archipelago are listed in the Background Information and discussed in Step 4 of the Learning Procedure. This should be copied and given as a handout to the students to assist during the activity. It can also be reviewed as homework after the first day. Depending on the level of your students, you may prefer using the second part of the activity.

Substitute the following for Step 5 in the Learning Procedure: Select several islands from the Northwestern Hawaiian Islands group, and provide a brief description of these islands. Construct a model or diagram of the appropriate development stage and provide an explanation for their classification.

Materials

- ❒ Copies of the "Central Pacific Map Grid" and "Location and Age of Some Islands in the Hawaii Archipelago," one for each student group (or an overhead transparency of the latter data sheet).
- ❒ Diagram of "The Hawaiian Archipelago" (Download from http://www.soest.hawaii.edu/GGHCV/haw_formation.html)
- ❒ 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 #5; http://www.hawaiireef.noaa.gov/maps/maps.html is a useful source for this information)

Audio/Visual Materials

None, unless an overhead transparency is used instead of individual handouts of "Location and Age of Some Islands in the Hawaii Archipelago"

Teaching Time

One or two 45-minute class periods

Seating Arrangement

Groups of four students

Maximum Number of Students

32

Key Words

Archipelago
Tectonic plate
Mantle
Asthenosphere
Lithosphere
Magma
Rift
Subduction
Hotspots
Caldera

Background Information

Nearly 70% of all coral reefs in U.S. waters are found around the Northwestern Hawaiian Islands, a chain of small islands and atolls that stretches for more than 1,000 nautical miles (nm) northwest of the main Hawaiian Islands. While scientists have studied shallow portions of the area for many years, almost nothing is known about deeper ocean habitats below the range of SCUBA divers. Only a few explorations have been made with deep-diving submersibles and remotely-operated vehicles (ROVs), but these have found new species and species previously unreported in Hawaiian waters. These islands are regularly visited by Hawaiian monk seals, one of only two species of monk seals remaining in the world (the Caribbean monk seal was declared extinct in 1994). Waters around the Northwestern Hawaiian Islands may be an important feeding area for the seals, which appear to feed on fishes that find shelter among colonies of deep-water corals. These corals are also of interest, because they include several species that are commercially valuable for jewelry. The possibility of discovering new species also has commercial importance as well as scientific interest, since some of these species may produce materials of importance to

medicine or industry.

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 the tectonic plates that make up the Earth's crust. The outer shell of the Earth (called the lithosphere) consists of about a dozen large plates of rock (called 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. 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. Plates may slide horizontally past each other at 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.

Where tectonic plates move apart (for example, along the mid-ocean ridge in the middle of the Atlantic Ocean) a rift is formed, which allows magma (molten rock) to escape from deep within the Earth and harden into solid rock known as basalt. Where tectonic plates come together, 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). 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.

Scientists recognize eight stages of growth and erosion in the islands of the Hawaiian archipelago:

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**, in which lava 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**, in which 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 stage of reef growth** 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 a coral growth to keep pace with the sinking so that reefs can form (French Frigate Shoals is in this stage);
7. **The stage of post-erosional eruptions** 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);
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).

This activity focuses on the role of plate tectonic movement and hotspot activity on the formation of island in the Hawaiian archipelago, and on the stages in island development that can be seen throughout the island chain.

Learning Procedure

1. Introduce the location of the Northwestern Hawaiian Islands, and point out some of the features that make this area important (discussed above). Introduce (or review) the concept of plate tectonics and the processes (subduction and hotspots) that result in volcanic activity. Tell students that the hotspot associated with formation of the Hawaiian Islands is located beneath the Big Island of Hawaii, but do not discuss the motion of the Pacific plate or the relative age of islands in the archipelago. Be sure students understand that the hotspot remains more or less stationary relative to movement of the tectonic plate.

2. Distribute copies of the "Central Pacific Map Grid" and "Location and Age of Some Islands in the Hawaii Archipelago" to each group (or display an overhead projection of the latter data sheet). Have students plot the location of each island on the Map Grid, and label each island with its name and age. You may need to review the concept of the latitude and longitude coordinate system prior to plotting. Have students infer the direction of motion of the Pacific plate, and calculate its approximate velocity. You may need to help students deal with large numbers and decimal places. The basic calculation is velocity = distance ÷ time, which in the case of Midway is 2,432 km ÷ 27,700,000 yr = 0.0000877 km/yr = 0.0877 m/yr = 8.77 cm/yr; the same calculation for Nihoa is 780 km ÷ 7,200,000 yr = 10.8 cm/yr

3. Show the students the diagram of "The Hawaiian Archipelago." Discuss why the older islands (to the left of the diagram) have different profiles from those on the right side of the profile. Students should recognize that islands near or below the sea surface are older than those that have conspicuous mountains, and infer that erosion is a probable reason for this. Students should also recognize that volcanic activity can be expected to subside as an island is carried away from the hotspot by motion of the Pacific

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. Assign each 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.hawaiireef.noaa.gov/maps/maps.html has information that will help with the latter assignment).

5. Select several islands from the Northwestern Hawaiian Islands group, and provide a brief description of these islands. Have students prepare a written report that assigns each island to an appropriate development stage and provides an explanation for their classification.

The BRIDGE Connection

www.vims.edu/bridge/pacific.html

The "Me" Connection

Have students write a short essay about an imaginary personal visit to islands at each of the eight stages of development, describing the physical conditions, plant and animal life that they encounter on each island.

Connections to Other Subjects

English/Language Arts, Geography, Biology

Evaluation

Develop a grading rubric that includes calculations of Pacific plate movement (Step #2, oral participation in Step #3, modeling or research activity in Step #4, and the written report in Step #5.

Extensions

Visit http://explorers.bishopmuseum.org/nwhi/geoact.shtml for others activities relevant to the Northwestern Hawaiian Islands.

Resources

http://oceanexplorer.noaa.gov – Follow the Northwestern Hawaiian Islands Expedition as documentaries and discoveries are posted each day for your classroom use.

http://www.soest.hawaii.edu/GG/HCV/haw_formation.html – Hawaii Center for Volcanology Web site about the formation of the Hawaiian Islands

http://www.hawaiireef.noaa.gov/maps/maps.html – Information about the Northwestern Hawaiian Islands region

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 C: Earth and Space Science

- Structure of the Earth system
- Earth's history

For More Information

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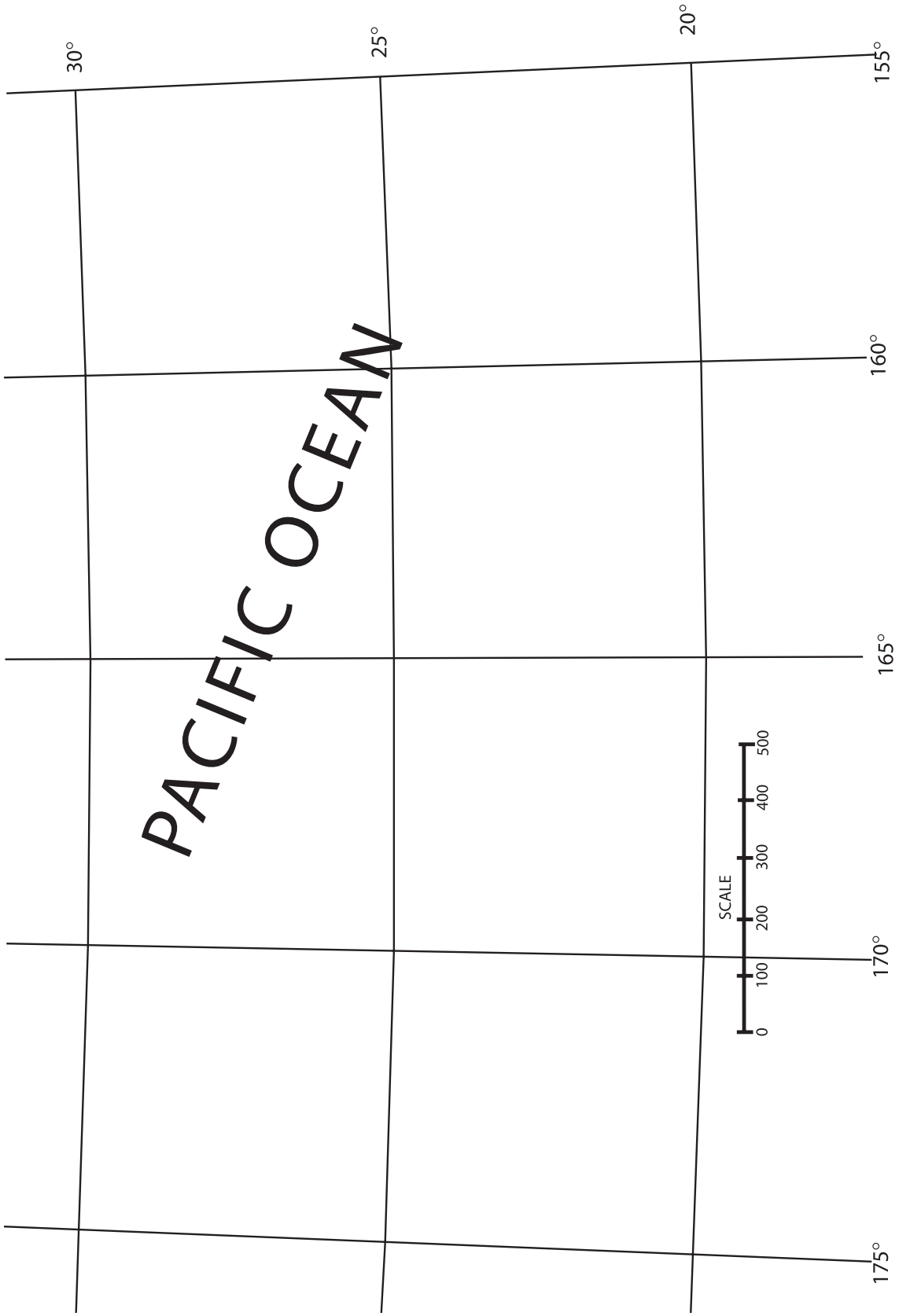
Student Handout

Central Pacific Map Grid



Student Handout

Location and Age of Some Islands in the Hawaii Archipelago

(from http://www.soest.hawaii.edu/GGHCV/haw_formation.html)

Volcano/Island Name	Distance from Kilauea (km)	Age (million years)	Location (latitude, longitude) (approximate)
Kilauea (Hawaii)	0	0-0.4	19.3°N, 155.4°W
Mauna Kea (Hawaii)	54	0.375	19.9°N, 155.4°W
Haleakala (Maui)	182	0.75	20.9°N, 156.2°W
Kahoolawe	185	1.03	20.7°N, 156.5°W
West Maui	221	1.32	21.0°N, 156.7°W
Lanai	226	1.28	21.0°N, 156.9°W
West Molokai	280	1.90	21.2°N, 157.2°W
Waianae (Oahu)	374	3.7	21.6°N, 158.1°W
Kauai	519	5.1	22.2°N, 159.5°W
Niihau	565	4.89	22.0°N, 160.2°W
Nihoa	780	7.2	23.1°N, 161.8°W
Necker	1,058	10.3	23.6°N, 164.6°W
Gardner Pinnacles	1,435	12.3	25.0°N, 168.0°W
Laysan	1,818	19.9	25.7°N, 171.7°W
Pearl & Hermes Reef	2,281	20.6	28.0°N, 175.6°W
Midway	2,432	27.7	28.3°N, 177.0°W