Exploring Alaska's Seamounts

Mystery of the Alaskan Seamounts

Focus
Formation of seamounts in the Gulf of Alaska

Grade Level
9-12 (Earth Science)

Focus Question
How were seamounts in the Axial-Cobb-Eikelberg-Patton chain formed?

Learning Objectives
Students will be able to describe the processes that form seamounts.

Students will learn how isotope ratios can be used to determine the age of volcanic rock.

Students will interpret basalt rock age data from seamounts in the Gulf of Alaska to investigate a hypothesis for the origin of these seamounts.

Additional Information for teachers of Deaf Students
In addition to the words listed as Key Words, the following words should be part of the list.

Magnets	Tectonic
Polarity	Hypothesis
Latitude	Aligns
Longitude	Expedition
Magnetic North	Glaciers
Habitats	

The words listed as Key Words should be introduced prior to the activity. There are no formal signs in American Sign Language for many of these words and many are difficult to lip-read.

If some of this information has not already been covered in your class, you may need to add an additional class period to teach vocabulary and teach some of the Background Information to the students prior to the activity. The activity itself is very visual and is easily followed by most deaf students.

An additional assessment tool is to give a TV-style report about the events rather than a written report. This could be more like a report for the Discovery Channel so it could be a bit more in depth. They can hand in their notes as written work.

Materials
- ❒ Copies of the "Seamount Age Data Sheet," one for each student group
- ❒ Outline map of the Gulf of Alaska
- ❒ Rulers and pencils or markers to aid in plotting locations on the outline map
- ❒ Overhead transparency "Gulf of Alaska Seamounts"
- ❒ Overhead transparency "Basalt Age Data from the Patton-Murray Platform"
- ❒ (Optional) overhead transparency of Patton seamount 3-D bathymetric model (Can be downloaded from http://ridge.coas.oregonstate.edu/rkeller/seamounts.html

Audio/Visual Materials
- ❒ Overhead projector
- ❒ (Optional) computer video of simulated fly-around of the Patton seamount; download from http://ridge.coas.oregonstate.edu/rkeller/Fly_around.mov

Teaching Time

30 – 45 minutes

Seating Arrangement

Four groups of students

Maximum Number of Students

24

Key Words

Basalt
Rift
Subduction
Hotspot
Seamount
Magma
Isotope
Radioactive decay
$^{40}Ar/^{39}Ar$ dating

Background Information

Seamounts are undersea mountains that rise from the ocean floor, often with heights of 3,000 m (10,000 ft) or more. Compared to the surrounding ocean waters, seamounts have high biological productivity, and provide habitats for a variety of plant, animal, and microbial species. Numerous seamounts have been discovered in the Gulf of Alaska. Many of these seamounts occur in long chains that parallel the west coast of the U.S. and Canada. One of the longest chains, known as the Axial-Cobb-Eikelberg-Patton chain, is being intensively studied by the Ocean Exploration 2002 Gulf of Alaska Expedition. What formed these underwater mountains in the first place, and why are they arranged in chains? These are two of the questions that the Gulf of Alaska Expedition hopes to answer.

Seamounts are generally thought to be the remains of underwater volcanoes that can be formed in several ways. Many volcanoes are associated with the movement of the tectonic plates that make up the Earth's crust. At spreading centers where these 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 sort of natural pipelines to reservoirs of magma in the upper portion of the Earth's mantle. Hotspots appear to remain stationary, while the tectonic plates gradually move across the hotspot location.

What produced the seamounts in the Axial-Cobb-Eikelberg-Patton chain? One hypothesis is that they were formed over the Cobb hotspot which is currently located off the coast of Oregon near the ridge between the Juan de Fuca and Pacific tectonic plates. As the Pacific plate moved away from the Juan de Fuca plate, different portions of the Pacific plate were exposed to the Cobb hotspot, causing volcanoes produced by the hotspot to be aligned in the same direction that the plate was moving.

One way to test this hypothesis is to determine the age of the basalt rocks that form the seamounts, and to use this age to calculate the distance that the Pacific plate moved since the rocks were formed from cooled magma (we make this calculation by multiplying the rate of plate movement (cm/yr) by the age (yr). This distance can then be subtracted from the present location of the seamounts ("backtracking") to determine where the plate was located when the seamounts were formed. If the hotspot hypothesis is correct, the calculated location should be close to the Cobb hotspot.

There are a variety of techniques used to determine the age of rocks, many of which rely on the decay of radioactive isotopes to provide a kind of "geological clock." As radioactive isotopes decay, they form other isotopes. If we are able to measure how much of these "decay products" have been produced, and know the rate of decay, we can determine how long the decay process has been underway. If radioactive isotopes are trapped inside rocks at the time the rocks are formed, the "decay products" will accumulate inside the rocks as well. This is the basis of some of the most widely used techniques for establishing the age of geological structures.

Researchers studying Gulf of Alaska seamounts have used a radioactive isotope of potassium (^{40}K), which is common in many rocks, to determine the age of the basalt rocks collected from the seamounts by dredging or by drilling. ^{40}K decays to produce ^{40}Ar (argon) and ^{40}Ca (calcium), so this dating system measures the amount of ^{40}Ar that has accumulated in the rocks, estimates the amount of ^{40}K in the rocks and calculates age from the decay rate for ^{40}K (half-life = 1.25 billion years). For technical reasons, it is more accurate to estimate potassium by irradiating the samples in a nuclear reactor to produce ^{39}Ar, so this technique is known as "$^{40}Ar/^{39}Ar$ dating."

Learning Procedure

1. Explain that seamounts are the remains of underwater volcanoes, and that they are islands of productivity compared to the surrounding ocean environment. You may want to use a color transparency of the 3-D bathymetric model of the Patton Seamount, and/or the video of the simulated fly-around during this discussion. DO NOT use the "Gulf of Alaska Seamounts" transparency at this point. Describe the general process of underwater volcano formation, the concept of isotopes and radioactive decay, and how radioactive decay can be used to determine the age of basalt rocks. You may need to review the concept of plate tectonics, if students are unfamiliar with the relevant terms.

2. Provide each student group with a "Seamount Age Data Sheet." Each group should use the latitude and longitude of the sampling points to locate their seamount on the outline map of the Gulf of Alaska. Using the information on the direction and drift rate of the Pacific Plate, they should calculate the distance their seamount has moved since it was formed, and backtrack this distance to locate the probable site of its formation. To aid this process, remind students that there are 60 minutes in one degree (60′ = 1°) of latitude or longitude, and that one degree of latitude is approximately 1,823 meters. With this information, they can use the latitude scale on the left side of the map to transfer their calculated plate motion distances to the map. (This is a good exercise in keeping track of the decimal point! You may want to suggest using scientific notation to assist with this.) When all groups have plotted the present location and probable formation site of their seamount, lead a discussion comparing their results to information shown on the overhead transparency "Gulf of Alaska Seamounts." This discussion should identify the Cobb hotspot as the probable origin of the four seamounts, and it should be clear that the Axial Seamount is still in an active stage of formation.

3. Show the students the overhead transparency, "Basalt Age Data from the Patton-Murray Platform." Data from early studies of these seamounts appear to show that they are too young to have been formed at the Cobb hotspot. But deep sea drilling later recovered basalt that was much older, and exactly fitted the theory of formation at the Cobb hotspot. Discuss possible reasons why the earlier studies found younger rocks. Two possible explanations being studied as part of the Gulf of Alaska Expedition are (1) that volcanic activity has continued periodically after the initial seamount formation; and (2) that glaciers could have dropped stones from other locations on the seamount during Ice Ages.

The Bridge Connection

www.vims.edu/bridge/geology.html

The "Me" Connection

Have students write a first-hand account of an exploratory dive to investigate formation of the Axial Seamount. You may want to have them do library or Internet research to back up their report.

Connections to Other Subjects

English/Language Arts, Geography, Mathematics

Evaluation

Have students write a newspaper-style report about events happening on the Juan de Fuca ridge. Tell them it is OK to include events that are happening slowly (such as tectonic plate movement) as well as events happening more quickly (such as volcanic eruptions). Their reports should include subduction beneath the North American plate (and possibly associated volcanic activity), seafloor spreading, and events associated with the Cobb hotspot (such as formation of the Axial seamount).

Extensions

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

Resources

http://oceanexplorer.noaa.gov – The Gulf of Alaska Expedition posted discoveries each day for your classroom use. A wealth of information can be found at both of these sites.

http://ridge.coas.oregonstate.edu/rkeller/seamounts.html – Background on seamount exploration and research in the Gulf of Alaska

http://volcano.und.nodak.edu/vwdocs/vwlessons.atg.html – Teacher's guide on plate tectonics, hot spots, and volcanoes

http://newton.physics.wwu.edu:8082/jstewart/scied/earth.html – Earth science education resources

http://www.sciencegems.com/earth2.html – Science education resources

http://earth.leeds.ac.uk/dynamic earth – Background on plate tectonics

http://www-sci.lib.uci.edu/HSG/Ref.html – References on just about everything

Dalrymple, G. B., D. A. Clague, T. Vallier, and H. W. Menard, 1987. 40Ar/ 39Ar age, petrology, and tectonic significance of some seamounts in the Gulf of Alaska. In Keating, B. H. and R. Batiza, eds., Seamounts, islands, and atolls. American Geophysical Union, Geophysical Monograph 43, p. 297-315.

Keller, R. A. M. R. Fisk, R. A. Duncan, and W. M. White,1997. 16 m.y. of hotspot and non-hotspot volcanism on the Patton-Murray seamount platform, Gulf of Alaska. Geology 25:511-514.

Keller, R. A., 2002. Exploration and origin of Gulf of Alaska seamounts. Proposal to NOAA Ocean Exploration Program.

National Science Education Standards

Content Standard A: Science as Inquiry

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

Content Standard D: Earth and Space Science

- Geochemical cycles
- Origin and evolution of the Earth system

For More Information

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Student Handout

Seamount Age Data Sheet

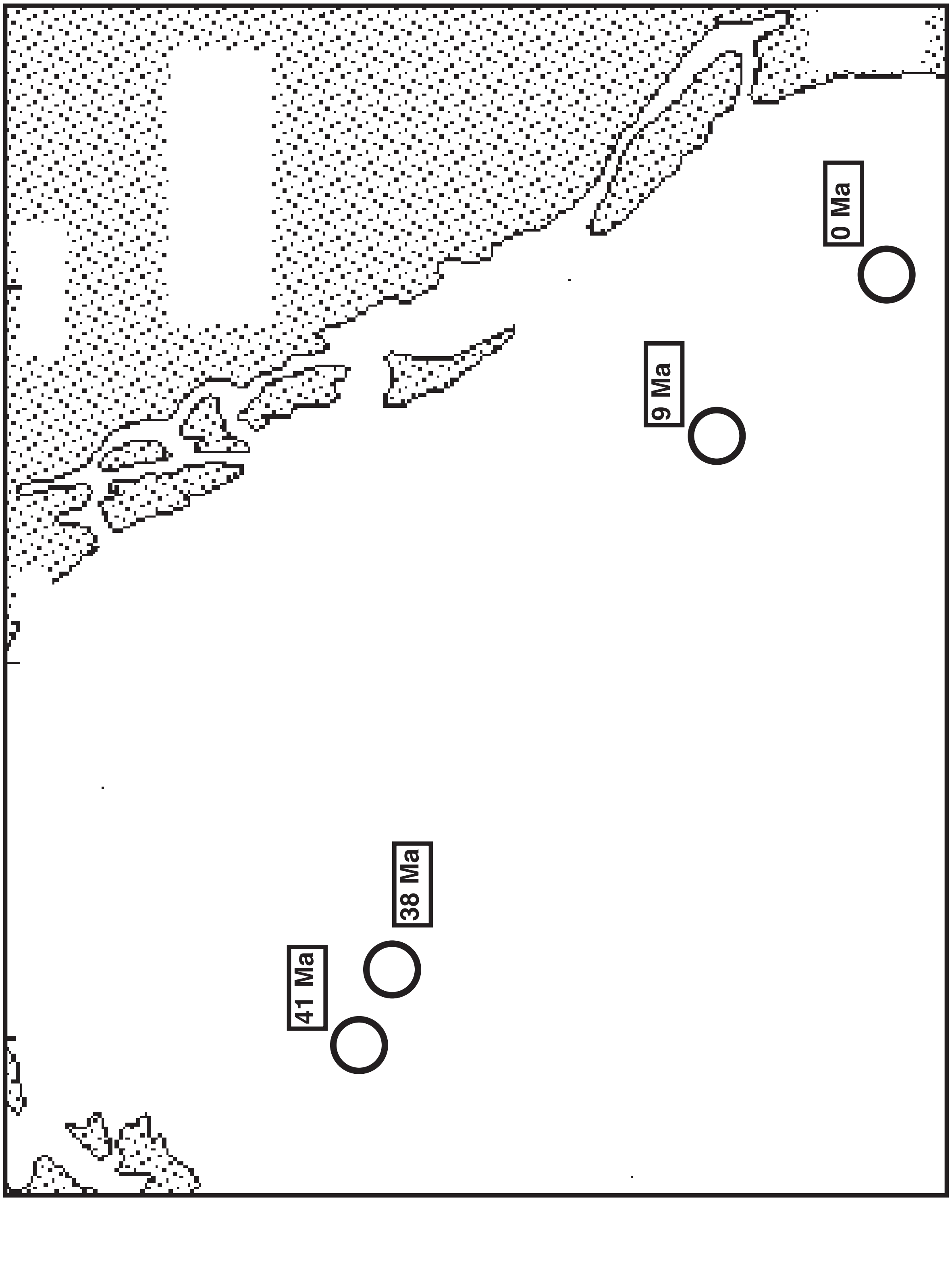
(adapted from Keller, 2002 and Keller *et al.*, 1997)

Seamount Dating	Latitude	Longitude	Age by $^{40}Ar/^{39}Ar$ 9 (Ma)
Patton	54°30'N	150°30'W	33
Murray	53°54'N	148°30'W	27
Warwick	48.0°N	132°30'W	7
Axial	45°54'N	130°0'W	0

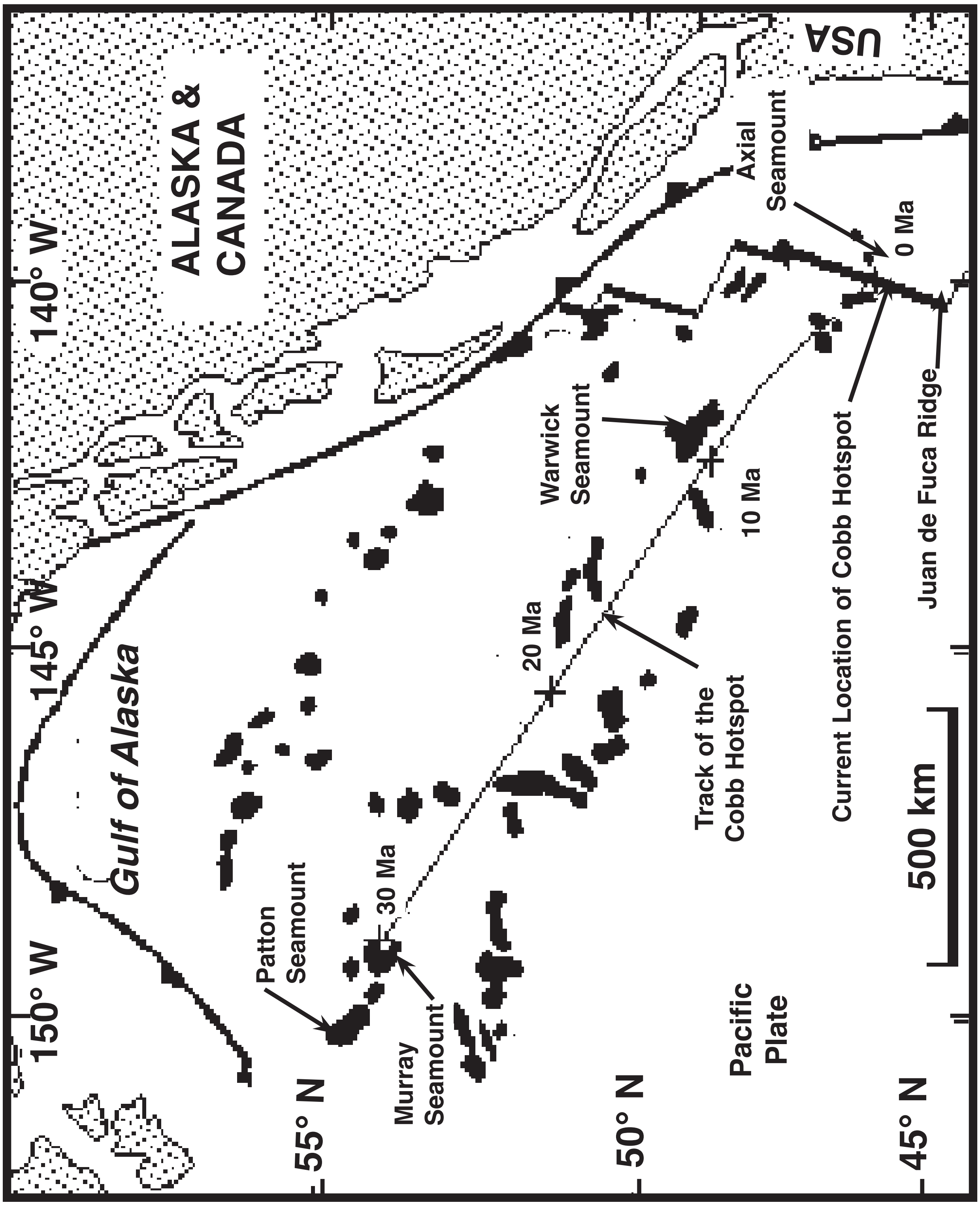
Plate Movement: The approximate average motion of the Pacific Plate for the last 30 million years is 5 cm/yr toward the northwest.

Student Handout

Outline Map of Gulf of Alaska



Gulf of Alaska Seamounts Map
(for overhead)



http://ridge.coas.oregonstate.edu/rkeller/seamounts.html
College of Oceanic and Atmospheric Sciences, Oregon State University

For Overhead

Basalt Age Data from the Patton-Murray Platform
(adapted from Dalrymple *et al.*, 1987, and Keller *et al.*, 1997)

Report Date Dating	Sample Source	Depth below Seamount Floor (m)	Age by $^{40}Ar/^{39}Ar$ (Ma)
1987	dredge	<100	28
1997	drill	292	17.1
1997	drill	307	27.3
1997	drill	375	33.0