Bermuda: Search for Deep Water Caves 2009

To Make a Cave

Image captions/credits on Page 2.

lesson plan

Focus
Geologic processes that form caves

Grade Level
7-8 (Earth Science)

Focus Question
What are geologic processes that form caves?

Learning Objectives
- Students will be able to describe four geologic processes that form caves.
- Students will be able to explain why Bermuda has an unusually large number of caves.
- Students will be able to compare and contrast solutional and volcanic caves.
- Students will be able to describe at least five features that are typical of solutional caves.

Materials
- ❑ Copies of *Cave Formation Inquiry Guide,* one for each student group

Materials for royal icing (See Learning Procedure Step 1c):
- ❑ Whites of 3 large eggs
- ❑ Cream of tartar, 1/2 teaspoon
- ❑ Confectioner's sugar, 1 lb
- ❑ Electric hand mixer
- ❑ Mixing bowl, approximately 3 quart capacity

Materials for student mountain models, one for each student group:
- ❑ 12 sugar cubes
- ❑ Approximately 4 oz royal icing (see Learning Procedure Step 1c)
- ❑ Rubber bulb pipette (medicine droppers)
- ❑ Approximately 8 oz colored water (see Learning Procedure Step 1c)
- ❑ Aluminum foil pie pan
- ❑ Food coloring (see Learning Procedure Step 1c)
- ❑ 3 popsicle sticks

Audio-Visual Materials

- ❑ (Optional) Computer projector or other equipment for showing images of underwater caves

Teaching Time

Two or three 45-minute class periods, depending upon whether student research is completed in class or assigned as homework

Seating Arrangement

Groups of 3-4 students

Maximum Number of Students

32

Key Words

Anchialine cave
Bermuda
Solutional cave
Volcanic tube cave
Sea cave
Erosional cave
Speleothem

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.

Anchialine caves are partially or totally submerged caves in coastal areas. Anchialine (pronounced "AN-key-ah-lin") is a Greek term meaning "near the sea," and anchialine caves often contain freshwater and/or brackish water in addition to seawater. These caves may be formed in karst landscapes as well as in rock tubes produced by volcanic activity. Karst landscapes are areas where limestone is the major rock underlying the land surface, and often contain caves and sinkholes formed when acidic rainwater dissolves portions of the limestone rock. Volcanic caves are formed when the surface of flowing volcanic lava cools and hardens, while molten lava continue to flow underneath. If the molten lava continues to flow away from the hardened surface, a hollow tube will be formed that becomes a lava tube cave.

Water in anchialine caves tends to stratify according to salinity, with the heavier seawater below the level of fresh and brackish water. This stratification produces distinctive habitats occupied by a variety of species that are endemic to these locations. (Endemic means that these species are not found anywhere else). Some of these species are "living

Images from Page 1 top to bottom:
Water in inland tidal cave pools in Bermuda is brackish at the surface, but reaches fully marine salinity by a depth of several meters. Image credit: NOAA, Bermuda: Search for Deep Water Caves 2009.
http://oceanexplorer.noaa.gov/explorations/09bermuda/background/bermudaorigin/media/bermudaorigin_5.html

Divers swim between massive submerged stalagmites in Crystal Cave, Bermuda. Such stalactites and stalagmites were formed during glacial periods of lowered sea level when the caves were dry and air-filled. Image credit: NOAA, Bermuda: Search for Deep Water Caves 2009.
http://oceanexplorer.noaa.gov/explorations/09bermuda/background/bermudaorigin/media/bermudaorigin_3.html

Ostracods are small, bivalve crustaceans that can inhabit underwater caves. The ostracod genus *Spelaeoecia* is know only from marine caves and occurs in Bermuda, the Bahamas, Cuba, Jamaica and Yucatan (Mexico). Image credit: Tom Iliffe, NOAA, Bermuda: Search for Deep Water Caves 2009.
http://oceanexplorer.noaa.gov/explorations/09bermuda/background/plan/media/spelaeoecia.html

Prof. Tom Iliffe, diving with a Megalodon closed-circuit rebreather, tows a plankton net through an underwater cave to collect small animals. Image credit: Jill Heinerth, NOAA, Bermuda: Search for Deep Water Caves 2009.
http://oceanexplorer.noaa.gov/explorations/09bermuda/background/plan/media/plankton.html

fossils" known as relict species, which means that they have survived while other related species have become extinct.

Animals that live only in anchialine habitats are called stygofauna or stygobites. Investigations of these species have revealed some puzzling relationships, including:

- Some stygobite species appear to have been in existence longer than the caves they inhabit, which implies that these species must have arrived in the caves from somewhere else; but how could this happen if these species are only found in caves?
- Some stygobite species are found in caves that are widely separated, such as crustacean species found in caves on opposite sides of the Atlantic Ocean and species in Australian anchialine caves that are also found Atlantic and Caribbean caves.
- Geographic distribution of some species suggests a possible connection with mid-ocean ridges. For example, shrimps belonging to the genus *Procaris* are only known from anchialine habitats in the Hawaiian Islands, Ascension Island in the South Atlantic, and Bermuda in the North Atlantic.
- Some anchialine species are most closely related to organisms that live in the very deep ocean.
- Some anchialine species are most closely related to organisms that live in deep sea hydrothermal vent habitats.
- An unusually large proportion of anchialine cave species in Bermuda are endemic to these caves, suggesting that these habitats have been stable for a long period of time.

Most investigations of anchialine caves have been confined to relatively shallow depths; yet, the observations described above suggest that connections with deeper habitats may also be important to understanding the distribution of stygobite species. Bermuda is a group of mid-ocean islands composed of limestone lying on top of a volcanic seamount. Because they are karst landscapes, the islands of Bermuda have one of the highest concentrations of cave systems in the world. Typical Bermuda caves have inland entrances, interior cave pools, underwater passages, and tidal spring outlets to the ocean. Bermuda's underwater caves contain an exceptional variety of endemic species, most of which are crustaceans. Most of these organisms are relict species with distinctive morphological, physiological, and behavioral adaptations to the cave environment that suggest these species have been living in caves for many millions of years. Yet, all known anchialine caves in Bermuda were completely dry only 18,000 years ago when sea levels were at least 100 m lower than present because of water contained in glaciers. Such observations suggest the possibility of additional caves in deeper water that would have provided habitat for anchialine species when presently-known caves were dry.

In this activity, students will investigate geologic processes that form caves.

Learning Procedure

1. To prepare for this lesson:
   (a) Review introductory essays for the Bermuda: Search for Deep Water Caves 2009 expedition at http://oceanexplorer.noaa.gov/explorations/09bermuda/welcome.html. You may also want to visit http://oceanexplorer.noaa.gov/technology/subs/rov/rov.html for images and discussions of various types of ROVs used in ocean exploration. If you want to explain multibeam sonar, you may also want to review information and images at http://oceanexplorer.noaa.gov/technology/tools/sonar/sonar.html.
   (b) Download a few images of anchialine caves from http://www.tamug.edu/cavebiology/index2.html
   (c) Review the *Cave Formation Inquiry Guide*, and prepare materials for students' cave models:
   - Make royal icing by beating the whites of 3 large eggs with 1/2 teaspoon cream of tartar in a large bowl with an electric mixer. When the mixture is frothy, set the mixer on low speed and gradually beat in 1 pound confectioner's sugar. Increase the mixer speed to high and beat 5 - 7 minutes until stiff glossy peaks form when beaters are lifted. Keep icing tightly covered and refrigerated until ready to use. Yield: approximately 20 oz.
   - Color enough tap water with blue food coloring so that each group will have approximately 8 oz of colored water.

   NOTE: While the icing and sugar cubes are edible, contamination is likely and students should be discouraged from eating anything in a laboratory setting. With this in mind, you may want to use food coloring to give the icing an unappetizing appearance, and should call the mixture something like "sealing compound" instead of "icing."

2. Day 1—Briefly introduce the Bermuda: Search for Deep Water Caves 2009 expedition, and show some images of anchialine caves. Emphasize that some species living in these caves are not found anywhere else, and that some are called living fossils because they have survived while other related species have become extinct. Point out that very little is known about deep water anchialine caves, and discuss why scientists might want to find and explore these caves.

3. Provide each student group with a copy of the *Cave Formation Inquiry Guide* and access to materials needed for Part I. Have students complete Step 1 of Part I. If there is still time remaining, students may begin work on Part II.

4. Day 2—Provide students with colored water and popsicle sticks, and have them finish Part I of the *Inquiry Guide*. If additional time is needed for Part II, this may be assigned as homework or completed during the next class period.

5. Lead a discussion of students' answers to questions on the *Inquiry Guide*. The following points should be included:
   - Caves may be formed by:
     - Flowing lava (volcanic tube caves);
     - Acidic water flowing over limestone (solutional caves);
     - Wave erosion of coastal cliffs (sea caves); and
     - Erosion of rocks and ice by water- and wind-borne particles (erosional and glacier caves).

   - Bermuda has an unusually large number of caves because the island is composed of limestone lying on top of a volcanic seamount, and limestone is easily dissolved by acidic rainwater to form caves.

   - A speleothem is a mineral deposit formed in a cave.

   - A stalactite is an icicle-shaped formation that hangs from the ceiling of a cave, and is produced by precipitation of minerals from water dripping through the cave ceiling. Most stalactites have pointed tips.

   - A stalagmite is an upward-growing mound of mineral deposits that have precipitated from water dripping onto the floor of a cave. Most stalagmites have rounded or flattened tips.

   - Splattermite is an informal name for a type of stalagmite that has plate-shaped upright protrusions that arc around a central axis. The formation is the result of drops that splash off of a stalagmite's growing tip. Splattermites only form where conditions are favorable for rapid deposition of calcite.

   - Flowstone is a deposit of minerals from water flowing over the floor or walls of a cave. As layers of flowstone become thicker, their shape becomes rounded.

   - A drapery is a sheet-like deposit of minerals from water flowing along a slope cave ceiling. Surface tension allows the water to cling to the overhanging surface as it flows slowly downward.

   - Spar is a general term that refers to crystals that have clearly visible crystal faces.

- Pool spar are well-defined crystals that grow underwater in cave pools.

- Shelfstone is a ledge or projection extending from the edge of a cave pool usually formed when minerals precipitate on top of a cave pool and attach to the side of the pool. For this reason, shelfstones are indicators of past pool levels.

- A showerhead is a hollow cone-shaped formation, narrow above and broad below, and is generally only found in tropical caves.

- A coralloid is a mineral formation shaped like knobs, globs, buttons, corals, or bunches of grapes.

- A conulite is a "splash cup" that forms when water dripping rapidly through the cave ceiling flings aside loose particles on the cave floor.

- A pearl is a mineral deposit that forms in shallow cave pools around a nucleus of sand or other substance. Pearls are usually spherical but may also have other shapes, and range in size from barely larger than a sand grain up to the size of golf balls.

- A raft is a thin sheet-like mineral deposit that forms on the surface of cave pools.

- Boxwork is a network of thin blade-shaped mineral deposits protruding from the walls, ceiling, or floor of a cave.

- A baldacchino canopy is a rounded deposit of minerals that forms when the surface of a cave pool recedes beneath a growing stalagmite or flowstone.

- A rimstone dam is a barrier of deposited minerals that forms on the edge of a stream or shallow pool in a cave.

- A shield is a mineral deposit that forms where water is forced through a tiny crack in a cave wall, ceiling or floor. As the water sprays through the crack, minerals are deposited into parallel extensions on either side of the crack.

- A helictite is a twisted filament-shaped mineral deposit formed when water seeps through tiny pores in the rock ceiling, walls, or floor of a cave. Helictites may resemble tiny threads or may be as large as deer antlers.

The "Me" Connection

Have students write a brief essay describing why they would, or would not, like to explore an underwater cave.

Connections to Other Subjects

English/Language Arts, Life Science, Physical Science

Assessment

Written reports and class discussions provide opportunities for assessment.

Extensions

1. Visit http://oceanexplorer.noaa.gov/explorations/09bermuda/welcome.html for more about the Bermuda: Search for Deep Water Caves 2009 expedition.

Other Relevant Lesson Plans from NOAA's Ocean Exploration Program

(The following Lesson Plans are targeted toward grades 7-8 unless otherwise noted.)

Entering the Twilight Zone
(5 pages, 108k) (from the Exploring Alaska's Seamounts 2002 Expedition)
http://oceanexplorer.noaa.gov/explorations/02alaska/background/edu/media/biocomm7_8.pdf

Focus: Biological communities of Alaska seamounts (Life Science)

In this activity, students will be able to infer why biological communities on seamounts are likely to contain unique or endemic species, calculate an index of similarity between two biological communities given species occurrence data, make inferences about reproductive strategies in species that are endemic to seamounts, and explain the implications of endemic species on seamounts to conservation and extinction of these species.

Food Web Mystery
(4 pages, 1Mb) (from the Mountains in the Sea 2003 Expedition)
http://oceanexplorer.noaa.gov/explorations/03mountains/background/education/media/mts_foodweb.pdf

Focus: Food webs in the vicinity of seamounts (Life Science)

In this activity, students will be able to describe typical marine food webs, explain why food is generally scarce in the deep-ocean environment, and discuss reasons that seamounts may be able to support a higher density of biological organisms than would appear to be possible considering food available from primary production at the ocean's surface.

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/explorations/09bermuda/welcome.html – Web site for the for the Bermuda: Search for Deep Water Caves 2009 expedition

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://www.caves.org/committee/education/learnmoreaboutcaves.htm – National Speleological Society Web page with links to education materials

http://teacher.scholastic.com/lessonrepro/lessonplans/theme/caves01.htm – An online theme unit introduction to "The Science of Caves" presented by Scholastic, Inc.

http://teacher.scholastic.com/lessonrepro/lessonplans/theme/caves04.htm – An online theme unit "Sea Caves" presented by Scholastic, Inc.

http://www.eduref.org/cgi-bin/printlessons.cgi/Virtual/Lessons/Science/Geology/GLG0001.html – Educator's Reference Desk Lesson Plan, "Karst Topography"

http://www.nature.nps.gov/geology/caves/program.htm – Web page for the Cave and Karst Program of the U. S. National Park Service

http://edc2.usgs.gov/pubslists/teachers-packets/exploringcaves/index.php – "Exploring Caves" teaching packet for grades K-3 from the U.S. Geological Survey

National Science Education Standards

Content Standard A: Science As Inquiry

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

Content Standard D: Earth and Space Science

- Structure of the Earth system

Ocean Literacy Essential Principles and Fundamental Concepts

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 c. Erosion—the wearing away of rock, soil and other biotic and abiotic earth materials—occurs in coastal areas as wind, waves, and currents in rivers and the ocean move sediments.

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 d. Ocean biology provides many unique examples of life cycles, adaptations and important relationships among organisms (such as symbiosis, predator-prey dynamics and energy transfer) that do not occur on land.

Fundamental Concept e. The ocean is three-dimensional, offering vast living space and diverse habitats from the surface through the water column to the seafloor. Most of the living space on Earth is in the ocean.

Fundamental Concept f. Ocean habitats are defined by environmental factors. Due to interactions of abiotic factors such as salinity, temperature, oxygen, pH, light, nutrients, pressure, substrate and circulation, ocean life is not evenly distributed temporally or spatially, i.e., it is "patchy". Some regions of the ocean support more diverse and abundant life than anywhere on Earth, while much of the ocean is considered a desert.

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.

Send Us Your Feedback

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Please send your comments to:
oceanexeducation@noaa.gov

For More Information

Paula Keener-Chavis, Director, Education Programs
NOAA Ocean Exploration and Research Program
Hollings Marine Laboratory
331 Fort Johnson Road, Charleston SC 29412
843.762.8818
843.762.8737 (fax)
paula.keener-chavis@noaa.gov

Acknowledgements

This lesson was developed by Mel Goodwin, PhD, Marine Biologist and Science Writer. Layout and design by Coastal Images Graphic Design, Charleston, SC. If reproducing this lesson, please cite NOAA as the source, and provide the following URL: http://oceanexplorer.noaa.gov/

To Make a Cave

Cave Formation Inquiry Guide

Part I – Make a Cave!

1. You should have a supply of sugar cubes, sealing compound, popsicle sticks, and an aluminum pie pan. Use the popsicle sticks to spread a small amount of sealing compound onto the sugar cubes so you can glue them together to form a rectangular block. Put the block on the pie pan, and use the remaining sealing compound to cover the block as completely as possible. Allow your model mountain to harden overnight.

2. You should have your model mountain, some colored water, and a rubber bulb pipette (medicine dropper). Slowly drip water onto the mountain and observe what happens. Record your observations.

3. Before your mountain is completely eroded, use the popsicle sticks to gently break it in half. What has happened inside the model mountain?

Part II – Research

1. What are four ways that caves can be formed?

2. Why does Bermuda have an unusually large number of caves?

To Make a Cave

Cave Formation Inquiry Guide – 2

3. Describe the following features found in solutional caves:

Speleothem

Stalactite

Stalagmite

Splattermite

Flowstone

Drapery

Spar

Pool spar

To Make a Cave

Cave Formation Inquiry Guide – 3

Shelfstone

Showerhead

Coralloid

Conulite

Pearl

Raft

Boxwork

Baldacchino canopy

Rimstone dam

To Make a Cave
Cave Formation Inquiry Guide – 4

Shield

Helictite