ocean explorer
oceanexplorer.noaa.gov

2004 Estuaries to the Abyss Expedition

Look at That Bump!

Focus

Physical and chemical processes associated with the Charleston Bump

Grade Level

7-8 (Physical Science)

Focus Questions

How does the Charleston Bump affect water flow in the Gulf Stream, what is the impact of these effects on biological communities, and what processes produce the rock-like surface of the Charleston Bump?

Learning Objectives

Students will be able to describe how the Charleston Bump affects the flow of water in the Gulf Stream.

Students will be able to describe the potential biological significance of effects induced by the Charleston Bump on the Gulf Stream.

Students will be able to use satellite imagery to obtain information on chlorophyll concentration at selected locations in the Earth's oceans.

Students will be able to describe the chemical processes that produce the rock-like surface of the Charleston Bump.

Materials

For Part 1 (see Learning Procedure)
- ❑ Computers with Internet access
- ❑ Copies of "Investigating the Blake Plateau and Charleston Bump" one copy for each student group

For Part 2 (see Learning Procedure)
- ❑ Modeling clay
- ❑ 19-liter (5 gallon) glass or plastic containers, one or more for each student group
- ❑ Plastic or rubber tubing to construct a siphon, approximately 6 mm internal diameter; one for each of the 19-liter containers; should be long enough to reach from the 19-liter container to the food storage container or tray
- ❑ 1-inch binder clamps, one for each siphon
- ❑ Flow-control clamps, one for each siphon
- ❑ Clear food storage containers or trays, approximately 8 cm x 12 cm x 25 cm, one or more for each student group
- ❑ Plastic tubing, approximately 12 mm internal diameter, and plastic fitting to attach the tubing to the food storage container or tray
- ❑ Sink or bucket for collecting and disposing of water flowing out of the trays
- ❑ 100 ml graduated cylinder
- ❑ Colored sugar solution (dissolve 100 grams sugar in 1 liter of water, and add food dye to make a brightly colored solution); approximately 250 ml for each student group
- ❑ Pasteur pipets with rubber bulbs or small (1 – 5 cc) syringes (glass "medicine droppers" can also be used if the glass is heated in a gas flame and drawn out to a length of about 10 cm); two for each student group

For Part 3 (see Learning Procedure)
- ❑ Copies of "Worksheet for Part 3 – Experiments

with Precipitation Reactions" one copy for each student group (unless Part 3 is done as a demonstration)

- ❑ Clean, dry 125 ml flask
- ❑ Approximately 50 g solid sodium acetate trihydrate, $CH_3C00Na•3H_20$
- ❑ Balance accurate to 1.0 gram
- ❑ Hot plate
- ❑ Stopper to fit the flask
- ❑ 0.3% lead nitrate solution, approximately 2 ml per demonstration
- ❑ 0.3% potassium iodide solution, approximately 2 ml per demonstration
- ❑ Two 10 ml test tubes
- ❑ Graduated cylinder or pipet for measuring 1.0 ml volumes

Audio/Visual Materials

None

Teaching Time

At least two 45-minute class periods, plus time for student research

Seating Arrangement

Classroom style or groups of 3-4 students

Maximum Number of Students

30

Key Words

Charleston Bump
Blake Plateau
Charleston Gyre
Precipitation
Supersaturated

Background Information

The Blake Plateau is a large sediment deposit located on the continental slope of the United States off the coasts of Florida, Georgia, South Carolina, and North Carolina. Depths on the plateau range from 400 to 1250 meters. On the eastern edge of the Plateau, the Blake Ridge extends in a direction roughly perpendicular to the continental rise for more than 500 km to the southwest. To the east of the Ridge, water depths increase sharply to more than 4,000 m. The Blake Ridge has been extensively studied over the past 30 years because of the large deposits of methane hydrate found in the area, (visit http://198.99.247.24/scng/hydrate/about-hydrates/about_hydrates.htm for more information about methane hydrates and why they are important).

About 130 km east of the Georgia-South Carolina coast, a series of rocky scarps, mounds, overhangs, and flat pavements rise from more than 700 m at the surface of the Blake Plateau to within 400 m of the sea surface. This hard-bottom feature is known as the Charleston Bump.

The Charleston Bump was first discovered in the 1970's when scientists noticed an eastward deflection in the Gulf Stream off the coast of South Carolina. The cause of this deflection turned out to be the Charleston Bump, which also produces wave-like oscillations that roll northward toward Cape Hatteras. These waves produce another circulatory feature known as the Charleston Gyre. The Gyre is a reverse circulation that forms in the trough of the first wave downstream of the Charleston Bump, and resembles the dangerous hydraulics that form beneath waterfalls and river rapids (see "Eddies, Gyres, and Drowning Machines" at http://oceanexplorer.noaa.gov/explorations/03bump/background/edu/edu.html for more information).

In 1979, scientists correlated satellite observations of the Gyre with measurements made from a research ship that showed elevated phytoplankton pigment concentrations within the Gyre, suggesting that this circulation was associated with upwelling currents that bring nutrients to the surface and enhance phytoplankton growth. Despite these observations, and even though waters over the Charleston Bump have been important to commercial fishing for many years, the ecology of the Bump was not studied until very recently. Prior to these studies, it was generally assumed that fisheries were the result of migrations from other areas and/or nutrients carried in from deeper or coastal waters. And although no one had actually looked at the surface of the Charleston Bump, it was assumed that benthic communities were scattered and relatively unproductive. Once scientists actually began exploring the area more thoroughly, they found many diverse and thriving benthic communities.

The 2001 "Islands in the Stream" and 2003 "Investigating the Charleston Bump" Ocean Exploration expeditions found a series of very complex habitats on the Charleston Bump with numerous fishes and invertebrate species involved in communities that we are just beginning to understand. Scientists also discovered that the surface of the Bump is an unusual type of rock that is not formed by cooled volcanic magma or cemented sand particles. Instead, the rock is formed chemically by manganese and phosphate precipitated directly from seawater. This type of rock forms when seawater becomes supersaturated with phosphate ions. The excess phosphate ions bind with other ions (such as manganese) to form a solid. Visit http://oceanexplorer.noaa.gov/explorations/islands01/log/sab_summary/sab_summary.html, and http://oceanexplorer.noaa.gov/explorations/03bump/welcome.html for more information.

In this activity, students will re-trace some of the discoveries about the Charleston Bump that provide the foundation for the 2004 "Estuary to the Abyss" Expedition to study how biological communities of the Charleston Bump are linked to other coastal and oceanic habitats, and how these communities are affected by habitat, terrestrial runoff, oceanographic factors, and physical features.

Learning Procedure

This activity is organized into three parts: (1) features of the Charleston Bump revealed in satellite imagery; (2) modeling water flow over and around the Charleston Bump; and (3) experiments with precipitation reactions. You may discuss results of each part as the respective activities are completed, or have a single comprehensive discussion after all activities have been completed.

Part 1 – Features of the Charleston Bump revealed in satellite imagery.

1. Review the general geographic location and form of the Gulf Stream and the continental shelf adjacent to the U.S. Atlantic coast. Tell students that their assignment is to investigate some features of the continental shelf known as the Blake Plateau and Charleston Bump, but do not discuss these features further at this point.

   Tell students that they will be using satellite data as part of their investigation. Explain that these data are collected by Sea-viewing Wide Field-of-view Sensor (SeaWiFS) satellite which measures the color of the world's oceans. Color is directly related to photosynthetic activity, because the visible color in most of the world's oceans varies with the concentration of chlorophyll and other plant pigments present in the water, so the oceans appear greener where more phytoplankton are present. The SeaWiFS satellite can view all of the Earth's oceans (except where the oceans are obscured by clouds) every 48 hours. Data are available via the internet for education and research purposes.

2. Provide each student group with a copy of "Investigating the Blake Plateau and Charleston Bump." Each group should prepare a written report that includes answers to questions on the worksheet as well as any satellite images used in their investigation. You may want to direct students to the following websites, or allow them to discover suitable resources on their own:
   oceanexplorer.noaa.gov/explorations/islands01/background/islands/sup11_bump.html
   http://daac.gsfc.nasa.gov/CAMPAIGN_DOCS/OCDST/charleston_bump.html

3. Lead a discussion of students' research results. In addition to accurately locating the Blake Plateau and Charleston Bump, students should realize that the Charleston Bump appears to induce a significant alteration in the flow of the Gulf Stream, and that the referenced satellite image shows increased chlorophyll concentrations in this area as well. Students should understand the implications of increased chlorophyll: a potential increase in photosynthetic activity and primary production, a consequently larger food source for secondary consumers, and an overall increase in biological productivity. If students have not completed Part 2, have them do so before discussing upwelling.

Part 2 – Modeling Water Flow Over and Around the Charleston Bump

[NOTE: Portions of this activity were adapted from "Form and Function in the Marine Environment" by Jeffrey Miller on the Access Excellence Web site at http://www.accessexcellence.org/AE/AEC/AEF/1995/miller_marine.html]

1. Prepare experimental flumes by attaching a plastic hose barb fitting to one end of each food storage container or tray by drilling a hole near the top of the container or tray that will provide a snug fit for the fitting. Glue the fitting in place with silicone adhesive so that the pointed end of the fitting extends outward. When the adhesive has set, attach a piece of plastic tubing (about 12 mm inside diameter) to provide a way to channel outflow from the flume to a sink or bucket.

2. Tell students that detailed surveys of the Charleston Bump are just beginning, but we can have a general idea of what to expect based on explorations in other deep-water, hard-bottom habitats. Explain that underwater features like the Charleston Bump alter the flow of ocean currents, and these alterations often have a significant influence on biological communities in the area.

Tell students that their assignment is to investigate how an object such as the Charleston Bump might affect water flowing past the object, and to make inferences about how the observed effects might be significant to organisms on the Charleston Bump.

3. Have student groups prepare experimental flumes for use:
   a. Fill a 19-liter (5 gallon) container with plain water.
   b. Connect a siphon from the water container to the flume. Use a 1-inch binder clamp to hold the siphon tubing onto the side of the flume. Attach a flow-control clamp to the tubing.
   c. Connect a piece of tubing to the outflow connector on the flume, and place the open end of tubing in a sink or bucket.
   d. Loosen the clamp on the siphon tubing. Allow water to flow into the flume until it begins to flow out of the outflow tubing, then tighten the clamp.

4. Have students use modeling clay to construct a boulder-like shape that can be completely submerged in the flume and whose width will be about one-third the total width of the flume.

5. To study water flow around the shape, place the object in the middle of the flume. Using a graduated cylinder to measure the volume of water flowing from the outflow tubing, adjust the clamp on the siphon until the outflow is about 100 ml per minute. Use a Pasteur pipette to inject a small amount of colored sugar solution into the water near the upstream side of the object. Observe the sugar solution as it moves over and around the object. The optimum flow rate and amount of injected sugar solution depend upon the volume of the flume and size of the object. Students should experiment with these parameters until they are able to see definite flow patterns in the sugar solution.

Have students test each object with at least two different flow rates (e.g., 100 ml and 200 ml). Students should prepare written reports of their results, including simple diagrams illustrating the observed flow around each of the objects tested.

6. Have each group present their results. Lead a group discussion of what happens when water flows around the kinds of shapes tested, and how alteration of water flow might be important to benthic organisms on the Charleston Bump. Typically, water becomes turbulent as it flows past an obstruction, and gyres ("swirls") and eddies (reverse currents) develop downstream of the obstruction. These disturbances to the overall direction of flow can have important benefits to benthic organisms. Eddies and gyres can create small regions where water movement is significantly reduced, making it easier for organisms to maintain position in the water and for filter feeding organisms to use delicate anatomical structures (such as tentacles) to obtain food. Remind students that eddies can occur in a vertical dimension as well as a horizontal dimension. These flow modifications can concentrate nutrients, plankton and particulate matter, increasing the feeding efficiency of organisms that consume these materials. Upwellings can be produced in a similar way when a deep current encounters an obstruction that "steers" the water in an upward direction. The flumes in this lesson are too shallow to simulate upwelling conditions, but students may see some upward deflection as the colored sugar solution passes over boulder-like objects.

Part 3 – Experiments with Precipitation Reactions [NOTE: To save time and supplies, you may do this part of the activity as a demonstration. If you elect to have each group do the activity, multiply the quantities shown in "Materials" by the number of student groups. Portions of this activity were adapted from the Siraze Chemistry Club Web site: www.siraze.net/chemistry/sezennur/experiments.htm

1. Prepare lead nitrate and potassium iodide solutions: Dissolve 3 g lead nitrate, $Pb(NO_3)_2$, in 1.0 l distilled water. Dissolve 3 g potassium iodide, KI, in 1.0 l distilled water. Caution: The lead nitrate solution is toxic.

2. Tell students that the surface of the Charleston Bump is an unusual type of rock that is not formed by cooled volcanic magma or cemented sand particles. Instead, the rock is formed chemically by certain ions that are precipitated directly from seawater. If each group is doing Part 3, have groups follow procedures and answer questions on "Worksheet for Part 3 – Experiments with Precipitation Reactions." If you are doing Part 3 as a demonstration, proceed as follows.

3. Fill a clean, dry 125-ml flask with 40 g solid sodium acetate tri-hydrate, $CH_3C00Na•3H_20$. Slowly heat the flask on a hot plate until the material completely liquifies. Continue heating for 1 - 2 minutes, but do not allow the material to boil. Remove the flask from the hot plate, insert a stopper, and allow the material to cool without jarring or disturbing the flask. Note: It is important that the flask be clean and without scratches or other imperfections on the inside of the glass as these imperfections could act as a nucleus for crystal growth.

4. Have one or two students place their hand against the flask to test the temperature. Carefully remove the stopper from the flask and add one tiny crystal of solid sodium acetate. Stopper the flask again, and observe as the liquid in the top part of the flask begins to crystallize. Have the same students test the flask temperature again.

5. Measure 1 ml lead nitrate and 1 ml potassium iodide into separate 10 ml test tubes. Pour the contents of one of the test tubes into the other test tube, and observe the results.
6. Lead a discussion of these results. Students

should realize that when the the sodium acetate trihydrate is heated, a portion of the sodium acetate is dissolved into an aqueous solution, and the remainder of the sodium acetate changes from the solid to liquid phase. As the solution cools, a supersaturated state is created in which more of the sodium acetate in the liquid phase is greater than the amount that could be dissolved in the available water. When a small crystal of sodium acetate is introduced into the solution, the crystal provides a nucleus for growth of many more crystals that are formed as the sodium acetate changes from the liquid phase to the solid phase. As is typical of this kind of phase transition, the solid phase contains less thermal energy than the liquid phase, so heat is released and the flask becomes warmer as crystalization proceeds.

When lead nitrate and potassium iodide solutions are combined, lead ions react with iodide ions to form lead iodide which is relatively insoluble in water and precipitates out of solution. Potassium nitrate formed by reactions between the remaining potassium and nitrate ions is quite soluble, and these ions and their reactions product remain in solution.

Be sure students understand that these same processes are involved in the formation of manganese phosphide rock. Seawater normally contains both manganese and phosphate ions. When the seawater becomes supersaturated with phosphate ions (possibly from terrestrial runoff) the excess phosphate reacts with other ions (such as manganese) to produce a precipitate that becomes a rock-like solid.

The BRIDGE Connection

www.vims.edu/bridge/ – Click on "Ocean Science" in the navigation menu to the left, then "Physics," then "Currents" for resources on the Gulf Stream.

The "Me" Connection

Have students write a short essay on how knowledge about relatively unexplored features like the Charleston Bump could be of direct benefit to their own lives.

Connections to Other Subjects

English/Language Arts, Mathematics, Earth Science, Life Science

Evaluation

Written reports prepared in Steps 1.2, 2.5, and discussions in Step 3.6 provide opportunities for assessment.

Extensions

1. Have students visit http://oceanexplorer.noaa.gov to find out more about the 2004 Estuary to the Abyss Expedition and about opportunities for real-time interaction with scientists on current Ocean Exploration expeditions.

2. Visit http://oceanexplorer.noaa.gov/explorations/03bump/background/edu/edu.html for additional education activities related to exploration of the Charleston Bump.

Resources

oceanexplorer.noaa.gov/explorations/03bump/background/plan/plan.html – Simulated flyover of the Charleston Bump

http://www.bigelow.org/virtual/index_bath.html – Web resources for information and classroom activities on ocean bottom topography

http://oceanexplorer.noaa.gov/gallery/livingocean/livingocean_coral.html – Ocean Explorer photograph gallery

http://oceanica.cofc.edu/activities.htm – Project Oceanica Web site, with a variety of resources on ocean exploration topics

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 C: Life Science
- Populations and ecosystems

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

Content Standard F: Science in Personal and Social Perspectives
- Populations, resources, and environments

For More Information

Paula Keener-Chavis, National Education Coordinator/Marine Biologist
NOAA Office of Exploration
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 plan was produced by Mel Goodwin, PhD, The Harmony Project, Charleston, SC for the National Oceanic and Atmospheric Administration. If reproducing this lesson, please cite NOAA as the source, and provide the following URL:
http://oceanexplorer.noaa.gov

Student Handout

Investigating the Blake Plateau and Charleston Bump

A. Download or trace a map of the East Coast of the United States. Research the following features. Provide a brief explanation of each feature, and locate the feature on your map:

Blake Plateau ____

Charleston Bump ____

Gulf Stream ____

B. Obtain satellite images showing these features using information from the Sea-viewing Wide Field-of-view Sensor (SeaWiFS) satellite which measures the color of the world's ocean:

1. Go to the SeaWiFS browser page at http://seawifs.gsfc.nasa.gov/cgi/seawifs_browse.pl. You will see a global map displaying recent sea surface temperature information. Beneath the map are links to navigate to sea surface temperature images for other dates.

2. Click repeatedly on the "Previous Year" link until "1998" appears in the middle of the navigation arrows. Click on the "Apr" link. A new set of links will appear for the month of April. Click on the "Apr 23 - Apr 30" link.

3. Click on a portion of the global map to retrieve records from a specific geographic location. For this lesson, click near the southeastern coast of the United States. A new page will open headed "Multiple Hits," and a series of thumbnail maps will be displayed for the month specified. The earliest dates are on the left.

4. Click on the third thumbnail map from the left that corresponds to April 25, 1998, which provides exceptionally good coverage of the sea surface along the east coast of the United States (white areas have no data, usually because of cloud cover). The entire map will be displayed on the left side of the screen. The date is

Student Handout (continued)

shown near the middle of the screen, on top of a small global map that shows the path of the satellite that provided the data for the image on the left.

Notice the band of light blue-green that parallels the east coast of Florida, and how this band bulges toward the east off the coast of South Carolina. This band corresponds to the path of the Gulf Stream, and the eastward deflection is caused by the Charleston Bump.

5. Use your Web browser to copy the map, then paste it into a word processing program for use in your report. Be sure to label the pasted map with the correct date.

6. Click on the rainbow-colored scale to show the chlorophyll concentration that corresponds to the various colors on the map. Copy this scale and paste it into your word processing document as well.

7. You can click on the "Display level-1A browse" button to change the map to a true color image. On April 25, 1998, thin clouds obscured some of the image over the Charleston Bump. But if you click on "Monthly" and repeat Steps 2 through 4 to retrieve a map for May 15, 1998, you can see a much clearer true color image (in this case, choose the thumbnail on the right in Step 4, which corresponds to the desired date). In the true color image for May 15, 1998, you can see the Charleston Gyre as a dark oval south of Cape Fear.

8. You can explore the movement of the Gulf Stream further by repeating Steps 2 through 4 to retrieve images for other dates.

Student Handout

Worksheet for Part 3 – Experiments with Precipitation Reactions

1. Weigh 40 g solid sodium acetate tri-hydrate, $CH_3C00Na \bullet 3H_20$, and transfer the chemical into a clean, dry 125-ml flask with.

2. Slowly heat the flask on a hot plate until the material completely liquifies. Continue heating for 1 - 2 minutes, but do not allow the material to boil.

3. Remove the flask from the hot plate, insert a stopper, and allow the material to cool without jarring or disturbing the flask.

4. Place your hand against the flask to test the temperature.

5. Carefully remove the stopper from the flask and add one tiny crystal of solid sodium acetate. Stopper the flask again, and observe as the liquid in the top part of the flask begins to crystallize. Place your hand against the flask again to test the temperature. Record your observations.

6. Measure 1 ml lead nitrate solution and 1 ml potassium iodide solution into separate 10-ml test tubes. Pour the contents of one of the test tubes into the other test tube, and observe the results. Record your observations.