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Windows to the Deep Exploration

What's the Big Deal?

Focus
Significance of methane hydrates

Grade Level
9-12 (Life Science)

Focus Question
Why should a NOAA Ocean Exploration expedition focus investigations on methane hydrates?

Learning Objectives
Students will be able to define methane hydrates and describe where these substances are typically found and how they are believed to be formed.

Students will be able to describe at least three ways in which methane hydrates could have a direct impact on their own lives.

Students will be able to describe how additional knowledge of methane hydrates expected to be found during the Blake Ridge expedition could provide human benefits.

Materials
❒ Copies of "Methane Hydrate Research Questions and Tips," one for each student group
❒ Materials to make molecular models (styrofoam balls, modeling clay, gumdrops, toothpicks, stiff wire, etc.)

Audio/Visual Materials
None

Teaching Time
One to one-and-a-half 45-minute class periods, plus time for research

Seating Arrangement
Five groups of 3-6 students

Maximum Number of Students
30

Key Words
Cold seeps
Methane hydrate ice
Clathrate
Methanogenic Archaeobacteria
Greenhouse gases
Greenhouse effect
Paleocene extinction event
Cambrian explosion
Alternative energy
Natural hazards

Background Information
The Blake Ridge is a large sediment deposit located approximately 400 km east of Charleston, South Carolina on the continental slope and rise of the United States. The crest of the ridge extends in a direction that is roughly perpendicular to the continental rise for more than 500 km to the southwest from water depths of 2,000 to 4,800 m. Over the past 30 years, the Blake Ridge has been extensively studied because of the large deposits of methane hydrate found in the area. Methane hydrate is a type of clathrate, a chemical substance in which the molecules of one material (water, in this case) form

an open lattice that encloses molecules of another material (methane) without actually forming chemical bonds between the two materials (visit http://198.99.247.24/scng/hydrate/about-hydrates/about_hydrates.htm to see a model of a methane hydrate clathrate).

Methane is produced in many environments by a group of Archaea known as the methanogenic Archaeobacteria. These Archaeobacteria obtain energy by anaerobic metabolism through which they break down the organic material contained in once-living plants and animals. When this process takes place in deep ocean sediments, methane molecules are surrounded by water molecules, and conditions of low temperature and high pressure allow stable ice-like methane hydrates to form. Scientists are interested in methane hydrates for several reasons. A major interest is the possibility of methane hydrates as an energy source. The U.S. Geological Survey has estimated that on a global scale, methane hydrates may contain roughly twice the carbon contained in all reserves of coal, oil, and conventional natural gas combined. In addition to their potential importance as an energy source, scientists have found that methane hydrates are associated with unusual and possibly unique biological communities. In September, 2001, the Ocean Exploration Deep East expedition explored the crest of the Blake Ridge at a depth of 2,154 m, and found methane hydrate-associated communities containing previously-unknown species that may be sources of beneficial pharmaceutical materials.

While such potential benefits are exciting, methane hydrates may also cause big problems. Although methane hydrates remain stable in deep-sea sediments for long periods of time, as the sediments become deeper and deeper they are heated by the Earth's core. Eventually, temperature within the sediments rises to a point at which the clathrates are no longer stable and free methane gas is released (at a water depth of 2 km, this point is reached at a sediment depth of about 500 m). The pressurized gas remains trapped beneath hundreds of meters of sediments that are cemented together by still-frozen methane hydrates. If the overlying sediments are disrupted by an earthquake or underwater landslide, the pressurized methane can escape suddenly, producing a violent underwater explosion that may result in disastrous tsunamis ("tidal waves").

The release of large quantities of methane gas can have other consequences as well. Methane is one of a group of the so-called "greenhouse gases." In the atmosphere, these gases allow solar radiation to pass through to the surface of the Earth, but absorb heat radiation that is reflected back from the Earth's surface, thus warming the atmosphere. Many scientists have suggested that increased carbon dioxide in the atmosphere produced by burning fossil fuels is causing a "greenhouse effect" that is gradually warming the atmosphere and the Earth's surface. A sudden release of methane from deep-sea sediments could have a similar effect, since methane has more than 30 times the heat-trapping ability of carbon dioxide.

In 1995, Australian paleoceanographer Gerald Dickens suggested that a sudden release of methane from submarine sediments during the Paleocene epoch (at the end of the Tertiary Period, about 55 million years ago) caused a greenhouse effect that raised the temperatures in the deep ocean by about 6° C. The result was the extinction of many deep-sea organisms known as the Paleocene extinction event. More recently, other scientists have suggested that similar events could have contributed to mass extinctions during the Jurassic period (183 million years ago), as well as to the sudden appearance of many new animal phyla during the Cambrian period (the "Cambrian explosion, about 520 million years ago).

A key objective of the 2003 Windows to the Deep Ocean Exploration expedition is to investigate methane hydrates and their associated biological communities. This activity focuses on the significance of methane hydrates.

Learning Procedure

1. Briefly introduce the 2003 Windows to the Deep Ocean Exploration expedition. At this point tell students only that the expedition is exploring areas of the Blake Ridge that contain substances called methane hydrates. Point out that these types of expeditions cost thousands of dollars, and ask students to speculate on why this kind of activity might be worthwhile. Most students will probably not be familiar with methane hydrates or their potential significance. Tell students that they are going to investigate methane hydrates, and that they may be surprised to find out how important these substances could be to their own lives.

2. Provide each student group with a "Methane Hydrate Research Questions and Tips" sheet. Tell students that they will be expected to present a written group report that addresses these questions, and participate in a class discussion of their results. Suggest that they divide the questions among the group members to simplify the research process.

3. Lead a discussion of students' research results. Begin by asking for one group that can explain what methane hydrates are, where they are found, and how they are formed. Next, ask for a group that can explain one way in which methane hydrates are significant to humans. Continue this process until all five groups have had a chance to present one piece of the whole story. Now, ask students what scientific research priorities and public policies should be established concerning methane hydrates. Encourage students to comment on the potential significance of global warming, alternative energy sources, useful biological products, and natural hazards.

4. Have each group submit their written report and model for evaluation.

The Bridge Connection

www.vims.edu/bridge/ – "methane hydrates" in the "search" box, then click "search" to display entries on the BRIDGE website for methane hydrates

The "Me" Connection

Have students write an essay describing why ocean exploration expeditions such as "Windows to the Deep" are, or are not, relevant and important to them personally.

Connections to Other Subjects

English/Language Arts, Biology, Chemistry

Evaluation

Group submissions should include the following:

1. Student models of a methane hydrate should include a methane molecule with one carbon atom bonded to four hydrogen atoms in a tetrahedral arrangement, and an outer lattice of water molecules. The water molecules may be represented by a single ball (or other structural element) or by oxygen atoms bonded to two hydrogen atoms.
2. Written reports should include the following:
   a. Accurate description of methane hydrate, explanation of how it is formed and where it is found;
   b. Discussion of the potential role of methane hydrates in global warming, including how methane is released from deep-sea sediments and the relative magnitude of the greenhouse effect of methane compared to other "greenhouse gases;"
   c. Discussion of methane hydrates as an alternative energy source and the relative magnitude of energy potentially available from methane hydrates compared to other energy sources;
   d. Discussion of natural hazards that may be associated with sudden release of methane gas from deep-sea sediments; and
   e. Discussion of potential benefits from new species that may be found in biological communities associated with methane hydrates.

Extensions

Log on to http://oceanexplorer.noaa.gov to keep up to date with the latest Blake Ridge Expedition discoveries, and to find out what researchers are learning about cold-seep communities.

Resources

http://oceanexplorer.noaa.gov – Follow the Blake Ridge Expedition daily as documentaries and discoveries are posted each day for your classroom use.

http://198.99.247.24/scng/hydrate/about-hydrates/about_hydrates.htm – Website for the National Methane Hydrate R&D Program

http://www.resa.net/nasa/ocean_methane.htm – Links to other sites with information about methane hydrates and associated communities

http://www.palaeos.com/ – Lots of information about life on Earth, geochronology, paleontology, etc., with many illustrations

http://calspace.ucsd.edu/virtualmuseum/climatechange2/cc2syllabus.shtml – University of California San Diego distance learning website's climate change course, with a good discussion in lesson 11 about methane and methane hydrates, with links to other resources

Simpson, S. 2000. Methane fever. Scientific American (Feb. 2000) pp 24-27. Article about role of methane release in the Paleocene extinction event.

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

- Structure and properties of matter
- Conservation of energy and increase in disorder
- Interactions of energy and matter

Content Standard C: Life Science

- Biological evolution

Content Standard D: Earth and Space Science

- Energy in the Earth system
- Origin and evolution of the Earth system

Content Standard E: Science and Technology

- Abilities of technological design
- Understandings about science and technology

Content Standard F: Science in Personal and Social Perspectives

- Natural resources
- Environmental quality
- Natural and human-induced hazards
- Science and technology in local, national, and global challenges

For More Information

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Student Handout

Methane Hydrate Research Questions and Tips

1. What is a clathrate?

2. What is methane hydrate? Include a model of a methane hydrate with your written report.

3. How are methane hydrates formed?

4. Where are methane hydrates found?

5. What is the effect of methane in the atmosphere? Is there any evidence of a direct effect on life on Earth in geological time?

6. In what ways can methane be released from methane hydrates?

7. Is there any practical use for methane hydrates?

8. Do methane hydrates pose any immediate danger to coastal areas?

9. Are any unusual biological organisms or communities associated with methane hydrates? If so, do these communities have any known or potential significance to humans?

Research Tips

1. Try a keyword search using the following terms, alone or in combination:
   cold seeps
   methane hydrate
   clathrate
   methanogenic Archaeobacteria
   Paleocene extinction
   energy hazard
   [be sure to use quotation marks or underlined spaces to tell your search engine to look for two-word phrases as a single term]

2. Check out the following websites:
   http://oceanexplorer.noaa.gov
   http://198.99.247.24/scng/hydrate/about-hydrates/about_hydrates.htm
   http://www.resa.net/nasa/ocean_methane.htm
   http://calspace.ucsd.edu/virtualmuseum/climatechange2/cc2syllabus.shtml
   (read lesson 11.3)