Windows to the Deep Exploration

The Big Burp: Where's the Proof?

Focus
Potential role of methane hydrates in global warming

Grade Level
9-12 (Earth Science)

Focus Question
What evidence exists to suggest that methane hydrates played a part in the Cambrian explosion and Paleocene extinction events?

Learning Objectives
Students will be able to describe the overall events that occurred during the Cambrian explosion and Paleocene extinction events.

Students will be able to define methane hydrates, and hypothesize how these substances could contribute to global warming.

Students will be able to describe and explain evidence to support the hypothesis that methane hydrates contributed to the Cambrian explosion and Paleocene extinction events.

Materials
❒ Drawing materials (optional, depending upon whether you decide to have students construct a geological timeline)

Audio/Visual Materials
None

Teaching Time
Three to four 45-minute class periods (depending upon whether students research and construct a geological timeline), plus time for group research

Seating Arrangement
Groups of 4-6 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

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 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 the possible release of methane from methane hydrates to the atmosphere and the potential impact of these releases on global warming. This activity focuses on methane hydrates might be involved with the Cambrian explosion and the Paleocene extinction event.

Learning Procedure

1. Lead an introductory overview discussion of the geological timescale. You may want to have student groups research major events in an assigned group of geologic periods, then combine their results to construct the timescale. Direct students to http://www.uky.edu/KGS/education/geologictimescale.pdf, http://www.uky.edu/KGS/education/activities.html#time, and http://www.palaeos.com for background information for this activity. Have students speculate on the events that mark the end of one period and the beginning of another. Often these events involve mass extinctions of the majority of species alive at a particular point in the Earth's history. A variety of causes have been proposed for these extinctions, including the evolution of oxygen-producing (i.e., photosynthetic) plants, impact of extra-terrestrial objects (e.g., asteroids) and climate change (e.g., global warming or ice ages). If you have students construct their own geological timescale, you may want to have them include possible explanations for the end of one period and the beginning of the next.

2. Briefly introduce the 2003 Windows to the Deep Ocean Exploration expedition. At this point tell students only that the expedition is investigating areas of the Blake Ridge that contain substances called methane hydrates. Tell students that they are going to investigate the possible connections between methane hydrates, and some of the major events on the geological timescale.

3. Assign one or more groups to research the following topics and related questions:

Topic 1: Methane Hydrates

- What are they? (Students should include a model of a methane hydrate molecule; see http://198.99.247.24/scng/hydrate/about-hydrates/about_hydrates.htm).
- Where are they found?
- Why are they important?

Topic 2: Global Warming

- What is it?
- What evidence suggests that global warming has or could occur?
- What chemicals are believed to be involved in global warming, and how do they cause this effect?
- Critique: Students may choose to refute the concept of global warming as long as they provide a balanced presentation of credible evidence on both sides of the question.

Topic 3: The Cambrian Explosion

Students can obtain a professional journal article on this subject at www.gps.caltech.edu/users/jkirschvink/pdfs/KirschvinkRaubComptesRendus.pdf. They may not understand all of the language, but should be able to obtain a sense of the hypothesis and evidence involved.

- What appears to have happened?
- What are possible causes of the event?

Topic 4: The Paleocene Extinction Event There are many articles on the web about this subject; you may also want to direct students to the articles by S. Simpson, and M. Katz listed in "Resources;" or you may decide to let them discover these by themselves!

- What appears to have happened?
- What are possible causes of the event?

4. Have each group present results of their research. After presentations are completed, lead a discussion of how these topics may be related. Be sure students understand what methane hydrates are, why they are of practical interest and importance to us, how they may periodically release large quantities of methane gas to the atmosphere, and what the consequences of such releases might be. This is a classic example of "good news/bad news": a possible source of new energy that may also be a time bomb. Have students discuss what scientific and political priorities

should be concerning exploration of areas where methane hydrates occur.

Encourage students to consider the significance of mass extinction events. These obviously are a disadvantage to the species that become extinct, but often the absence of these species has allowed others to evolve. As a result of their research, students may also want to comment on the potential role of humans in mass extinction (some scientists believe that our species has caused many other species to disappear or to be on the verge of disappearing. Ironically, many of the conditions that are bad for endangered species are also bad for humans. On the other hand, spontaneous release of large quantities of methane from deep-sea sediments could happen regardless of human activity, could have major impacts on presently-living species (including our own), and could be beyond our ability to influence the outcome.

The BRIDGE Connection

www.vims.edu/bridge/ – Enter "greenhouse" in the "Search" box, then click "Search" to display entries on the BRIDGE website for global warming and the greenhouse effect.

The "Me" Connection

Have students write a short essay describing what should be done if there were a sudden release of methane from deep-sea sediments into the atmosphere.

Connections to Other Subjects

English/Language Arts, Biology, Chemistry

Evaluation

One or more of the following products provide opportunity for assessment:

- The geological timescale (if you decide to have students do this activity);
- Results and presentation of individual research topics;
- Individual or group written reports interpreting the combined research results of all groups prior to group discussion.

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 explorers are learning about cold-seep communities.

Log onto http://oceanography.geol.ucsb.edu/Ocean_Materials/Mini_Studies/Greenhouse_gases/Greenhouse_gases.html for more information and activities related to the greenhouse effect.

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.uky.edu/KGS/education/geologictimescale.pdf and http://www.uky.edu/KGS/education/activities.html#time – Great resources on geological time and major events in Earth's history

http://www.rps.psu.edu/deep/ – Notes from another expeditions exploring deep-sea communities

http://ridge2000.bio.psu.edu/nonsciencelinks.htm – Links to other deep ocean exploration web sites

http://www-ocean.tamu.edu/education/oceanworld/resources/ – Links to other ocean-related web sites

http://www.geol.ucsb.edu/faculty/valentine/Valentine%202002.pdf – Review of methane-based chemosynthetic processes

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

Katz, M, E., D. K. Pak, G. R. Dickens, and K. G. Miller. 1999. The source and fate of massive carbon input during the latest Paleocene thermal maximum. Science 286: 1531-1533.

Kirschvink, J. L. and T. D. Raub. 2003. A methane fuse for the Cambrian explosion: carbon cycles and true polar wander. Comptes Rendus Geoscience 335:65-78. Journal article on the possible role of methane release in rapid diversification of animal groups. Also available on-line at www.gps.caltech.edu/users/jkirschvink/ pdfs/KirschvinkRaubComptesRendus.pdf

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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