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Windows to the Deep Exploration

The Big Burp: A Bad Day in the Paleocene

Focus
Global warming and the Paleocene extinction

Grade Level
5-6 (Earth Science)

Focus Question
How could global warming have been responsible for the Paleocene extinction event 55 million years ago?

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

Students will be able to describe the processes that are believed to result in global warming.

Students will be able to infer how a global warming event could have contributed to the Paleocene extinction event.

Materials
❒ Drawing materials (for students constructing geological timeline

Audio/Visual Materials
❒ None (illustrations from http://www.uky.edu/KGS/education/activities.html#time and/or http://www.palaeos.com may be used for the student-constructed geological timeline, but are optional)

Teaching Time
One or two 45-minute class periods, 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 radiated 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, global warming, and the Paleocene extinction event.

Learning Procedure

1. Lead an introductory discussion of 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 scientists often find that events and processes that at first seem completely unrelated turn out to be closely connected, and that this is particularly true for processes that operate on a global scale or over long periods of time. Say that they are going to investigate the possible connections between methane hydrates, global warming, and a mass extinction event that took place about 55 million years ago.

2. Assign one or more groups to research the following topics:
   - methane hydrates (What are they? Where are they found? Why are they important?)
   - global warming (What is it? What do scientists think may cause it?)
   - the Paleocene extinction event (What happened? What are possible causes?)
   - a summary of geological history (This group should create a timeline showing when the Paleocene occurred, and some of the other major events in geological history; http://www.uky.edu/KGS/education/geologictimescale.pdf and http://www.uky.edu/KGS/education/activities.html#time have lots of good information and resources for this activity … so much, in fact, that you may want to make this a separate activity involving the entire class).

   You may want to direct students to some or all of the information sources listed under "Resources," or you may want to have students discover these (or other) information sources on their own.

3. 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 (particularly in the case of the Paleocene extinction event). Have students discuss whether these events are always bad. You may want to point out that some scientists believe that a global warming event led to the emergence of many new groups of animals, possibly including our own distant ancestors. Students should recognize that "bad" depends upon your perspective: if your species becomes extinct, you probably think that's bad; but if a warming event makes it possible for your species to exist, then you'll probably think that's good. The point is, global warming in our time may have major negative consequences for human populations (and probably for many other species); but other species may benefit from such an event.

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 from two viewpoints, one describing how a global extinction event is "good," the other describing how the same event is "bad."

Connections to Other Subjects

English/Language Arts, Biology, Chemistry

Evaluation

One or both of the following products provide opportunity for assessment:
- Results and presentation of the research component of the activity;
- 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 researchers 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

Paull, C.K., B. Hecker, C. Commeau, R.P. Feeman-Lynde, C. Nuemann, W.P. Corso, G. Golubic, J. Hook, E. Sikes, and J. Curray. 1984. Biological communities at Florida Escarpment resemble hydrothermal vent communities. Science 226:965-967 – early report on cold seep communities.

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
- Understanding 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
- Earth's history

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 hazards
- Risks and benefits

- Science and technology in society

For More Information

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