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2005 Hidden Ocean Expedition

Burp Under the Ice

Focus
Potential role of Arctic methane deposits in climate change

Grade Level
9-12 (Earth Science)

Focus Question
How may warmer climates affect Arctic methane deposits, and what role may these deposits play in global climate change?

Learning Objectives
Students will be able to identify the natural processes that produce methane, and describe where methane deposits are located in the Arctic region.

Students will be able to explain how warmer climates may affect Arctic methane deposits.

Students will be able to explain how the release of large volumes of methane might affect Earth's climate.

Students will be able to describe how methane releases may have contributed to mass extinction events in Earth's geologic history.

Materials
❒ Research library and/or computers with internet access

Audio/Visual Materials
❒ None

Teaching Time
One 45-minute class period, plus time for student research

Seating Arrangement
Classroom style if students are working individually, or groups of two to four students

Maximum Number of Students
30

Key Words
Arctic Ocean
Canada Basin
Methane hydrate
Climate change
Permafrost
Mass extinction

Background Information
The Arctic Ocean is the most inaccessible and least-studied of all the Earth's major oceans. Although it is the smallest of the world's four ocean basins, the Arctic Ocean has a total area of about 14 million square kilometers (5.4 million square miles); roughly 1.5 times the size of the United States. The deepest parts of the Arctic Ocean (5,441 m; 17,850 ft), known as the Canada Basin, are particularly isolated and unexplored because of year-round ice cover. To a large extent, the Canada Basin is also geographically isolated by the largest continental shelf of any ocean (average depth about 50 meters) bordering Eurasia and North American. The Chukchi Sea provides a connection with the Pacific Ocean

via the Bering Strait, but this connection is very narrow and shallow, so most water exchange is with the Atlantic Ocean via the Greenland Sea. This isolation makes it likely that unique species have evolved in the Canada Basin.

Exploration of the Arctic Ocean, especially the Canada Basin, has become increasingly urgent because the Arctic environment is changing at a dramatic rate. A 2004 report from the Arctic Council states that temperature in the Arctic is increasing at nearly twice the rate of increase as the rest of the world. One visible result is rapid loss of glaciers and sea ice. Less visible are the impacts on living organisms that depend upon glaciers and sea ice for their habitat. Melting sea ice can also have direct effects on human communities. The Greenland Ice Sheet, for example, holds enough water to raise global sea levels by as much as 7 meters. Sea level increases at this magnitude would be sufficient to flood many coastal cities, including most of the city of London. A key objective of the 2005 Ocean Exploration Hidden Ocean Expedition is to help establish a marine life inventory and map the physical and chemical environment of the sea-ice, pelagic, and benthic ecosystems of the Canada Basin.

This lesson focuses on another potential problem associated with Arctic warming: sudden release of methane contained in permafrost and deep ocean ices. Methane is produced in many environments by a group of Archaea known as the methanogenic Archaeobacteria. These Archaeobacteria break down the organic material contained in once-living plants and animals to obtain energy by anaerobic metabolism. This process occurs throughout the world, including deep ocean sediments and beneath the permafrost of the Arctic tundra. In the deep ocean, methane molecules are surrounded by water molecules, and conditions of low temperature and high pressure allow stable ice-like structures called methane hydrates to form. In recent years, methane hydrates have received increased attention as a potential energy source, since the U.S. Geological Survey has estimated that Earth's methane hydrates may contain roughly twice the carbon contained in all reserves of coal, oil, and conventional natural gas combined. In addition, the 2001 NOAA Ocean Exploration Deep East Expedition found that biological communities associated with methane hydrates contained previously unknown species that may be sources of beneficial pharmaceutical materials.

But along with potential benefits, methane hydrates may also be the source of major 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 methane hydrates 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 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 or thawed permafrost could have a similar

effect, since methane has more than 30 times the heat-trapping ability of carbon dioxide. Some scientists have suggested that mass extinctions during the Paleocene epoch, the Jurassic period, and the Permian period (55 million years ago, 183 million years ago, and 251 million years ago respectively) may have been caused by a sudden release of methane from submarine sediments resulting in greenhouse effects that raised temperatures in the deep ocean by about six degrees Celsius.

In this lesson, students will investigate the potential mechanisms and consequences of sudden methane releases from deposits in the Arctic.

Learning Procedure

1. To become more familiar with the Hidden Ocean expedition, you may want to visit the expedition's Web page (http://oceanexplorer.noaa.gov/explorations/05arctic/welcome.html) for an overview of the expedition and background essays.

2. Briefly review the geography of the Arctic Ocean, highlighting the location of the Canada Basin and that much of this area is virtually unexplored because of year-round ice cover. Do not discuss recent decrease in ice cover or the implications of this decrease at this point.

3. Tell students that their assignment is to investigate and prepare a written report on the potential effects of a warmer climate on Arctic methane deposits, and what consequences might result from these effects. Reports should include:
   - What evidence exists of warmer Arctic climates during recent years;
   - Sources of Arctic methane;
   - Where Arctic methane deposits are found;
   - Why short periods of rapid global warming in the geologic past are more likely to have been caused by methane releases than by carbon dioxide;
   - What effects warmer climates might have on methane deposits; and
   - How methane releases might produce a "chain reaction" of climate warming.

   There are extensive internet resources on this subject, and students should have little difficulty finding adequate resources to complete this assignment. If you want to help them get started, provide one or more of the links listed under "Resources."

4. Lead a discussion of students' reports, which should include the following points:
   - Evidence of warmer Arctic climates during recent years includes rising temperatures of surface air and upper soils; decreasing extent and thickness of Arctic sea ice; retreating glaciers across the Arctic region; permafrost thaw resulting in damage to buildings, roads, airport runways, and pipelines; and increased freshwater input to the Arctic Ocean due to accelerated snowmelt.
   - Methane is a natural product of the anaerobic decay of the remains of animals and plants.
   - Methane deposits in the Arctic are found beneath permafrost that overlays layers of decaying materials that produce methane, as well as in methane hydrates in the deeper portions of the Arctic Ocean.
   - Short periods of rapid global warming are most likely due to methane release because methane is a much more powerful greenhouse gas than carbon dioxide, but only remains in the atmosphere for ten years compared to a residence time of about 100 years for carbon dioxide. Global warming caused by carbon dioxide would be expected to last much longer than warming caused by methane.
   - Warmer climates could cause thawing of permafrost layers, releasing methane from deeper layers of decaying organic material. Warmer temperatures could also result in methane release from methane hydrates. Methane added to the atmosphere could

increase the "greenhouse effect," resulting in additional warming which in turn could trigger additional methane releases in a sort of "chain reaction."

Be sure students understand that most current models of the potential impacts of global climate change do not include potential impacts of releases from methane deposits. Point out that global warming that may have triggered methane releases leading to prior extinction events is thought to have been caused by increased volcanic activity, but that greenhouse gas emissions from human activities are likely to be at least partially responsible for current warming trends. Regardless of whether such emissions are solely responsible for present trends, the fact that these emissions result from human activities means that humans could change these activities in ways that reduced emissions of greenhouse gases.

The BRIDGE Connection

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

The "Me" Connection

Have students write a brief essay explaining how improved knowledge of unexplored areas such as the Canada Basin could help predict potential consequences of climate change in the Arctic region, and how such predictions might be of personal benefit. If students have trouble getting started, suggest they consider where methane hydrates are likely to be found and how sudden releases of large volumes of methane might affect them personally.

Connections to Other Subjects

Biology, Chemistry, English/Language Arts, Geography

Evaluation

Student reports prepared in Learning Procedure Step 2 and group discussion in Step 3 provide opportunities for assessment.

Extensions

1. Have students visit http://oceanexplorer.noaa.gov/explorations/05arctic/welcome.html to keep up to date with the latest 2005 Hidden Ocean Expedition discoveries.
2. Visit http://oceanexplorer.noaa.gov/explorations/02arctic/background/education/media/arctic_lessonplans.html for more lesson plans and activities related to the 2002 Hidden Ocean expedition.
3. Log onto http://earthednet.org/Ocean_Materials/Mini_Studies/Greenhouse_gases/Greenhouse_gases.html for more information and activities related to the greenhouse effect.

Resources

http://oceanexplorer.noaa.gov/explorations/05arctic/welcome.html – Follow the 2005 Hidden Ocean Expedition daily as documentaries and discoveries are posted each day for your classroom use.

http://www.scribd.com/doc/42980/Arctic – Synopsis of a conference on "Climate Change, the Arctic and the United Kingdom: directions for future research;" 8 May 2002, University of East Anglia

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 http://www.gps.caltech.edu/~timraub/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.

http://www.coastalpost.com/05/01/08.htm – "Methane Burps: Ticking Time Bomb," by John Atcheson; from Baltimore Sun, Dec 16, 2004

http://www.netl.doe.gov/technologies/oil-gas/FutureSupply/MethaneHydrates/about-hydrates/about_hydrates.htm – Web site for the National Methane Hydrate R & D Program

http://www.giss.nasa.gov/research/features/200409_methane/ – Article and links to additional resources about methane, methane hydrates, and their influence on climate

http://www.uky.edu/KGS/education/index.htm – Great resources on geological time and major events in Earth's history

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
- Chemical reactions

Content Standard C: Life Science

- Interdependence of organisms

Content Standard D: Earth and Space Science

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

Content Standard E: Science and Technology

- Understandings about science and technology

Content Standard F: Science in Personal and Social Perspectives

- Personal and community health
- 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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