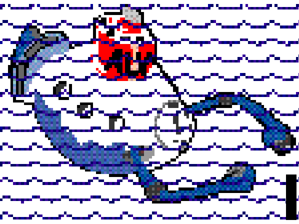


It's A Gas!

Focus:

Gas Hydrates on the ocean floor

Note: Dry ice is used in Part I of this activity as well as in Part II of the Hudson Canyon Slump Activity. These activities could be performed on the same day to make the best use of the dry ice.

Grade Level

9-12

Learning Objectives

Students will understand the importance of carbon, where carbon is stored on the Earth, and that the largest reservoir of carbon is gas hydrates.

Students will comprehend that Earth's climate changes, and how the greenhouse effect works.

Students will understand the potential of hydrates as a major new energy resource.

Students will understand the use of acoustics for mapping the seafloor and sub-seafloor.

Students will explore the conditions under which hydrates form.

Adaptations for Deaf Students

Conduct the Web Quest activity first to give the students background information. This will provide them with pre-knowledge they will need to better understand the demonstration.

Materials Provided by Teacher

Part I: Materials needed by each student group (for groups of 3-5 students)

- ❒ Large test tube (at least large enough for a #4 Stopper, and as long as possible)
- ❒ #4 stopper with hole, with glass tubing inserted into hole (this should be done by the teacher prior to the activity)
- ❒ 25 ml dilute coffee solution (no cream or sugar!) to simulate color of water
- ❒ Dry ice pellets (3-5 depending on size)
- ❒ Tongs for handling dry ice

Materials for teacher demonstration

- ❒ 600 ml beaker or larger
- ❒ Styrofoam cup
- ❒ Large test tube (at least large enough for a #4 Stopper, and as long as possible)
- ❒ #4 stopper with hole, with glass tubing inserted into hole
- ❒ Rubber tubing (at least 15 inches long)
- ❒ Tongs to handle dry ice
- ❒ Dry ice pellets (about 500 ml dry ice pellets)
- ❒ Scissors

Part II. Web site list and questions

Teaching Time

Part I: One 45-minute period
Part II: Two to three 45-minute periods

Seating Arrangement

Part I: Groups of 2-3 for lab work
Part II: Groups that will work in your computer situation for a Web Quest

Maximum Number of Students

35

Key Words

Hydrate
Hydrocarbons
Methane
Chemosynthesis
Cold seeps
Sublimation

Background Information

(For the teacher; students will be searching for some of this information in Part II in the Web-Quest)

Gas hydrate is an ice-like substance that forms in deep sea sediments when gas molecules, primarily methane, and other hydrocarbon gases such as propane, are trapped in a lattice of water molecules. The resulting solid is stable at temperatures above 0° C when pressure exceeds 1 atmosphere (33 feet of seawater). Gas hydrate reserves found along ocean margins are estimated to exceed presently-known petroleum reserves by approximately a factor of three. There is at least twice as much carbon locked up in hydrates than all other fossil fuels on the Earth. Japan, Korea, Norway, India and Canada are now developing the technologies needed to mine methane from hydrates.

Hydrates are known to substantially influence ocean carbon cycling, global warming, and coastal sediment stability. Localized meltdowns have been implicated in significant events of massive slope failure and are considered a geohazard by oil and gas production companies (Bagirov and Lerche, 1997). Massive hydrate dissolution events have been implicated as the cause of past greenhouse gas emissions that resulted in major climate swings evident in the geologic record (Dickens et al., 1997). Vast hydrate deposits exist below 1,000 meters depth all along the U.S. east coast.

Gas hydrate beds constantly leak gases up through the seafloor into the water, forming cold seeps on the ocean floor. Hydrocarbon seepage is common on continental margins around the world. Chemosynthetic communities similar to those found at hydrothermal vents inhabit cold seeps and use hydrocarbons or hydrogen sulfide for carbon and energy. Seep tubeworms, mussels, and clams form 2-meter high bushes and kilometer-sized beds. Most seeps are also characterized by high microbial productivity.

Endemic seep fauna vary in species composition and abundance, depending on the type and amount of seepage. Some species live exclusively with a particular form of hydrocarbon; such as the hydrate iceworms discovered during a 1997 submersible cruise (Desbruyeres and Toulmond, 1998). Others are common to a range of seepage, for example, *Beggiatoa* bacteria. Seep communities are ecologically important as sources of food and refuge for a vast array of background slope species, and economically important as they mark underlying oil and gas sources and potential reserves.

In an era when oil companies are pushing deeper in search of new resources, understanding the dynamics and ecology of seep communities will enhance NOAA's role as a steward of ocean environments. To date, the only U.S. cold seep communities to be explored and studied have been in the Pacific and Gulf of Mexico, although extensive hydrate beds and associated cold seeps exist off the U.S. east coast.

Our knowledge of where hydrates are located in the ocean is limited. Estimates are based primarily on seismic profiling done by oil companies to find new reserves. In the 1980s, geologists noted a line on many acoustic records below the seafloor, called a bottom-simulating reflector (BSR). Based on a few deep-sea cores, the line has been hypothesized to be the base of the hydrate beds. Many more samples and cores must be taken to verify this potentially massive store of carbon.

Off the southeastern United States, a small area (only 3,000 square kilometers) beneath the Blake Ridge, formed by rapidly-deposited sediments, appears to contain a volume of methane in hydrate that is equivalent to approximately 30 times the U.S. annual consumption of gas (Dillon, 1995). The bed was drilled during the Ocean Drilling Program Leg 164 in 1992. During site surveys with a photo sled, chemosynthetic mussel beds were discovered—the first cold seep community found along the U.S. east coast outside the Gulf of Mexico.

Learning Procedure

Part I: Simulation of gas hydrate formation.

1. **Teacher demonstration:** The teacher will set up a demonstration that will progress as the students perform their simulation. This demonstration is designed to cool water to freezing while trapping carbon dioxide bubbles within/below the ice. The experimental design is important to allow the ice to form at the top of the tube first instead of at the bottom. This will simulate the formation of a gas hydrate in the sediments just below the deep sea floor. The demonstration uses more water than the student activity and will take longer for the ice to form. It should be ready to observe when students are finishing their activity. To set up the demonstration, use the following instructions:
   a. Cut a Styrofoam cup in half (as shown in Figure 1) and make a hole in the bottom that is big enough for the test tube to fit through. Place this piece of cup "hole side up" in the bottom of the large beaker. This keeps the bottom of the test tube below the dry ice level.

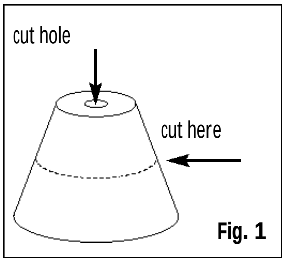
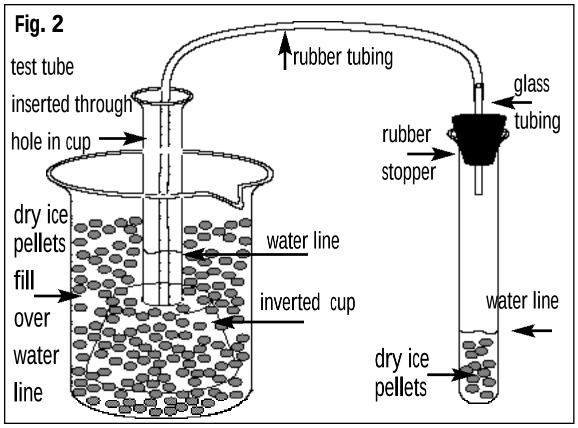


Fig. 1

   b. Pour 20 ml of water into one of the test tubes and place the test tube into the Styrofoam base. Fill the remainder of the beaker with dry ice pellets (Figure 2).
   c. Insert the loose end of the rubber into the test tube in the beaker so that the end is all the way at the bottom of the test tube. See Figure 2 for the entire set-up.
   d. Place a small piece of dry ice in the second test tube and cover it with water. Put

Fig. 2


the stopper into the test tube and attach the rubber tubing to the glass tubing in the test tube stopper.

e. After the student activity, or when the ice has formed at the top of the water in the test tube, discuss with the students how this simulates the trapping of methane within gas hydrates on the sea floor. As the ice melts, have students observe the release of CO_2 bubbles from the ice. This simulates the release of methane from melting hydrates.

f. Safety note: When the water forms an ice cap in the test tube and the liquid water can no longer dissolve carbon dioxide, the carbon dioxide will begin to back up into the "gas generating" test tube. The stopper may actually pop out of the test tube at this time. Be sure to set up this demonstration in an area away from the student activity in case this happens.

2. Student Activity: The students will perform a smaller version of the demonstration that will simulate formation of gas hydrates within the sea floor. SAFETY PRECAUTIONS: Students should never touch dry ice with their hands. Tongs should be used to transfer the dry ice to the test tubes. Students should wear safety goggles.

a. Using tongs, place several small pieces of dry ice into the bottom of the test tube. These pieces should almost fill the diameter of the test tube. They should take up about 1 inch of the height of the test tube. The number of pellets needed will depend on the size of pellets obtained.

b. Add enough dilute coffee to just completely cover the dry ice. Place the rubber stopper (with the glass tubing already inserted through it) into the stopper.

c. If liquid begins to bubble up through the tubing, remove some of the water. If bubbling stops while dry ice is still present in the tube, add a small amount of additional water.

d. Answer the questions on the student page.

Part II: Web-Quest Research of Gas Hydrates and Related Information. This will link students to the Deep East web site (http://oceanexplorer.noaa.gov) for updated information about the discovery of gas hydrates and related seep communities.

1. Separate students into small groups for Internet research (depending on the size of the class and the number of available computers. Students could even be assigned specific questions to research and then report back to the whole group.)
2. Provide students with a copy of the web sites and the questions. The number at the end of the question refers to the site(s) with information to answer that question. (You may remove these numbers to make the search more interesting and challenging.)

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The "Me" Connection:

Ask students to brainstorm ways in which petroleum and natural gas products affect their daily lives (cars, heat, gas grills, plastics…). Have students make a list of alternatives fuels for each of the items that they list.

Evaluation

Ask students to write a paragraph based on what they have learned in this lesson and how their new knowledge might make a difference in their lives 10 years from now.

THE BRIDGE CONNECTION

www.vims.edu/bridge

EXTENSIONS

- Ask students to investigate older technologies used in previous ocean exploration initiatives.
- Ask students to generate a list of reasons why new energy resources need to be utilized.
- Ask students to investigate career opportunities as ocean explorers, ocean scientists, and others whose careers support ocean science research and exploration. Visit www.marinecareers.net
- Perform a Boyle's Law Demonstration: Place a marshmallow bunny in a vacuum flask and use a hand pump to change the pressure within the flask. The chemistry teacher at your school should have this equipment if you do not. This demonstrates pressure/volume relationships (as pressure increases, volume decreases and visa versa) and illustrates compressed gas within the gas hydrates.Gas hydrates compressed within the sea floor expand tremendously when brought up to atmospheric pressures. For example, 1cubic cm of hydrate (within the sea floor) produces 158 cubic cm of methane at 1 atmosphere).
- Imploding Soda Can Demonstration: Take an empty soft drink can and place about 3 ml of tap water in the can. Heat the can on a hot plate until steam emerges from the opening. Quickly (using tongs) flip the can over into a bin with ice water. The can "implodes" with a loud noise. This demonstrates relationship between temperature, volume, and pressure of a gas.
- Using the following information, determine the amount of gas that could be squeezed into a scuba tank that is 8L (or 8000 cubic centimeters) if the gas was pressurized to the same degree as it is on the sea floor. Hydrates form at depths of about 400m. Pressure changes 1 atm for each 10 meters of depth. Research Boyle's Law and use the formula to determine the answer. (Answer: 240 L or 240,000 cubic centimeters)
- Visit the Ocean Explorer Web Site at www.oceanexplorer.noaa.gov

NATIONAL SCIENCE EDUCATION STANDARDS:

Content Standard A - Science as Inquiry
- Abilities necessary to do scientific inquiry

Content Standard B - Physical Science
- Understand properties and changes of properties in matter
- Understand transfer of energy

Content Standard C - Life Science
- Populations and ecosystems
- Diversity and adaptations of organisms

Content Standard D - Earth and Space Science
- Understand structure of the Earth system
- Understand Earth's history

Content Standard E - Science and Technology
- Develop abilities of technical design
- Develop understandings about science and technology

Student Activity Sheet

Part I: Simulation of Gas Hydrate Formation

You will perform a smaller version of the teacher demonstration that will simulate formation of gas hydrates within the sea floor.

Procedures:

SAFETY PRECAUTIONS: Students should never touch dry ice with their hands. Tongs should be used to transfer the dry ice to the test tubes. Students should wear safety goggles.

1. Using tongs, place several small pieces of dry ice into the bottom of the test tube. These pieces should almost fill the diameter of the test tube. The pellets should take up about 1 inch of the height of the test tube. The number of pellets needed will depend on the size of pellets obtained.
2. Add enough dilute coffee to just completely cover the dry ice. Place the rubber stopper (with the glass tubing already inserted through it) into the stopper. Write your observations in the space provided in the question section below.
3. If liquid begins to bubble up through the tubing, remove some of the water. If bubbling stops while dry ice is still present in the tube, add a small amount of additional water.

Questions:

1. What did you observe when the water was added to the dry ice in the test tube?

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2. If you have never seen dry ice before, the smoke-like gas is carbon dioxide that is sublimating from the "ice." Define sublimation from your observations.

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3. As the water freezes within the test tube, some carbon dioxide bubbles should become trapped within or below the water ice. This simulates the formation of gas hydrates, an ice-like substance that forms when natural gas molecules are trapped in a cage of water molecules. Try to find areas with trapped CO^2 gas bubbles and describe them.

4. Describe the crystals of water that form as water freezes.

5. Continue to watch the test tube as the water ice begins to melt. What happens to the bubbles of carbon dioxide as the water melts?

6. In order for water to freeze it must loose heat energy. Where is the heat energy going when it leaves the water? What evidence do you have to support this?

7. Carbon dioxide (like methane) is not very soluble in water. What evidence do you see to support this?

8. Compare carbon dioxide's density to that of water. Support your answer.

9. Gas hydrates form on the sea floor where the pressure is much greater than it is at the surface. If you could increase the pressure on your test tube "system," how might your results differ? Support your answer.

10. Methane gas, CH^4 ("natural gas"), is a fossil fuel and it is the most common gas found in gas hydrates. Why were you unable to use it in this activity?

11. If methane is not soluble in water and is less dense than water, what will happen to methane from the gas hydrates on the seafloor if the temperature increases enough for the ice to melt? Support your answer.

12. Methane, as a fossil fuel, is obviously a good source of energy. Hypothesize ways that this energy might be used directly by organisms on the deep sea floor.

13. Most gas hydrates that form on the sea floor actually form beneath the sediments. From your observations in this activity, hypothesize how the melting of gas hydrates could affect the sediments above them.

Summary:

Summarize what you have learned about gas hydrates from this activity.

Gas Hydrates Web-Quest

Procedure:

You are a part of the Deep East Exploration scientific team that will be investigating gas hydrates on the seafloor of the Hudson River Canyon and Blake Ridge. Before devising a research plan and designing equipment to obtain your samples, you must first learn as much as possible about gas hydrates and their importance in the biology, ecology, and geology of the ocean floor. Remember that much of the Hudson River Canyon and Blake Ridge have not been explored before by manned submersibles, and that you (as the scientists) may discover new information about gas hydrates and the communities that they support. You may even discover new species of organisms. This Web-Quest activity is designed to provide only an overview of gas hydrates, their formation, and their significance in these areas of the ocean floor being explored. Although much of the information can be found on one site, you are encouraged to visit all sites since each site has its own strengths and focuses. Numbers in () after each question indicate the number of the site from the list below:

Web Sites:

1. www.hydrate.org
2. http://woodshole.er.usgs.gov/project-pages/hydrates/
3. http://woodshole.er.usgs.gov/projectpages/hydrates/factsheets.html
4. www.nrlssc.navy.mil/~hydrates/index.htm
5. www.bio.psu.edu/people/faculty/fisher/cold_seeps/
6. www.oceanexplorer.noaa.gov

1. What is a gas hydrate (or methane hydrate)? (1, 2, 6)
2. Describe its structure (try to draw a model of its structure). (1)
3. Under what conditions do they form? (1, 2)
4. Where are methane hydrates found, in general? (1, 2, 4, 6)
5. There are two different processes by which the methane gas found within the hydrates forms. Describe them. (1, 2)
6. What must be present for biogenic methane to form? (1)
7. How much methane gas can be obtained from one cubic centimeter of methane hydrate? (Remember that the gas in the hydrate is compressed by pressure of the deep ocean and it is at a colder temperature. It will take up more space at the surface of the ocean.) (1)

8. How are gas hydrate deposits located and what technology is used to collect the samples? (1, 2, 4)
9. What does BSR stand for? Describe the BSR. How does it “distort” the scientists’ view of the seafloor? (1, 2)
10. What problems are associated with getting samples of gas hydrates to the surface ship? (1)
11. Why is it important to study gas hydrates? (At least 3 reasons) (2, 4)
12. Looking at a map of worldwide distribution of known methane hydrate reserves, why is the US interested in explorations to learn more about these resources? (4)
13. From a Navy perspective, why is knowledge about methane hydrates important? (4)
14. How are gas hydrates related to or connected to biology? (1, 5, 6)
15. What role do chemosynthetic bacteria play in the communities that form where methane seeps up through the ocean floor? (5, 6)
16. Describe the community that forms around the methane seeps on the sea floor. Go to site 5 and take the Tour of animals/ecosystem in the Gulf of Mexico.
17. How could the knowledge of these communities be useful to scientists seeking to discover new reserves of methane hydrates on the ocean floor?
18. Methane, along with carbon dioxide, has been related to the Greenhouse Effect. (1, 2, 6)
19. What are some ways that methane is released into the atmosphere?
20. How do methane and carbon dioxide affect climate?
21. Why is methane of such great concern in the global warming picture?
22. What amount of methane do scientists predict is available from gas hydrates compared with other sources of fossil fuels? (Sources such as petroleum and non-hydrate natural gas) (1, 2, 3)

Deep East Internet Connection:

Go to www.oceanexplorer.noaa.gov and find the Deep East pages. Scientists will be studying gas hydrates and seep communities at two locations, Leg 2 in the Hudson Bay Canyon and Leg 3 at Blake Ridge. Scientists will be studying gas hydrates in core samples of sediments and will also study the assemblages of organisms found at sites where methane seeps form the basis of chemosynthetic communities. Scientists will be posting information on organisms found at these sites, many of which may never have been seen before.

1. Find out more about the specific scientists working with gas hydrates and the communities. Check out the site information and choose one scientist who is concentrating on these areas and write a short biography. If you could ask this scientist one question about his/her research, what would your question be?

2. From information on the web site, determine how core samples are taken to obtain gas hydrates.

3. Beginning with Leg 2, at Hudson Bay Canyon, keep a log of new information posted on the website about hydrates or cold seep communities and organisms discovered or documented.

Gas Hydrates Web-Quest

(Teacher's Answer Page!)

Web Sites:

www.hydrate.org
http://woodshole.er.usgs.gov/project-pages/hydrates/why.html
http://woodshole.er.usgs.gov/project-pages/hydrates/factsheets.html
www.nrlssc.navy.mil/~hydrates/index.htm
www.bio.psu.edu/people/faculty/fisher/cold_seeps/
www.oceanexplorer.noaa.gov

1. What is a gas hydrate (or methane hydrate)? A type of natural formation that contains large amounts of methane and water in the form of ice; cages of water molecules that surround and trap methane
2. Describe its structure (try to draw a model of its structure). See diagram on site 1 (Chemistry Section)
3. Under what conditions do they form? Moderate pressure like that at 300m depth and low temperatures (but above freezing point of water); like those that exist on the sea floor between 300-500m
4. Where are methane hydrates found, in general? In sediments at ocean depths of 300-500m and in permafrost in high latitudes
5. There are two different processes by which the methane gas found within the hydrates forms. Describe them. Organic (biogenic) by bacterial decomposition of organic matter and thermogenic (venting) where natural gases are found in the Earth
6. What must be present for biogenic methane to form? Large, rapidly-accumulated dead organic material
7. How much methane gas can be obtained from one cubic centimeter of methane hydrate? (Remember that the gas in the hydrate is compressed by pressure of the deep ocean and it is at a colder temperature. It will take up more space at the surface of the ocean.) About 160 cubic cm of methane
8. How are gas hydrate deposits located and what technology is used to collect the samples? Seismic (sound/acoustic reflection), core samples of the ocean sediments and by looking for chemosynthetic communities
9. What does BSR stand for? Describe the BSR. How does it "distort" the scientist's view of the seafloor. Bottom Simulating Reflector; it "simulates" the bottom but is actually the bottom of the hydrate deposit.
10. What problems are associated with getting samples of gas hydrates to the surface ship? How was the problem solved? Samples with gas deteriorate before they get to the surface;

the gas bubbles out as the temperatures decrease; pressurized containers that seal immediately after the sample is taken

11. Why is it important to study gas hydrates? (at least 3 reasons) Large amount of methane as a future energy source; a source of atmospheric methane that affects global climate (Greenhouse Effect); affects sediment stability
12. Looking at a map of worldwide distribution of known methane hydrate reserves, why is the US interested in explorations to learn more about these resources? Many areas of hydrates exist along US continental shelf/offshore
13. From a Navy perspective, why is knowledge about methane hydrates important? Seafloor stability (important for safely hiding submarines) and sediments produce acoustic properties that adversely affect Navy acoustic systems.
14. How are gas hydrates related to or connected to biology? Much methane is produced by bacteria (biological processes) and it is the basis of the food chain for chemosynthetic communities at cold seep areas (it is an energy rich food).
15. What role do chemosynthetic bacteria play in the communities that form where methane seeps up through the ocean floor? They convert the methane into usable energy for other organisms; they are the producers (dark, no photosynthesis).
16. Describe the community that forms around the methane seeps on the sea floor. Bacteria to tubeworms and/or mussels to predators
17. How could the knowledge of these communities be useful to scientists seeking to discover new reserves of methane hydrates on the sea floor? Communities show locations of methane seeps, indicating methane hydrate locations.
18. Methane, along with carbon dioxide, has been related to the Greenhouse Effect.
    a. What are some ways that methane is released into the atmosphere? Swamps, termites, landfills, rice paddies, and cows!
    b. How do methane and carbon dioxide affect climate? Heat absorbing gases that absorb heat from the sun and influence climate
    c. Why is methane of such great concern in the global warming picture? Methane is 10 times more effective at absorbing heat than carbon dioxide.
19. What amount of methane do scientists predict is available from gas hydrates compared with other sources of fossil fuels? (Sources such as petroleum and non-hydrate natural gas) 100,000 TCF (trillion cubic feet) — 270,000,000 TCF estimates of methane in hydrates; 3 times more than other petroleum sources on Earth combined; in gigatons: gas hydrates 10,000, fossil fuels 5000, land sources 2790, ocean 983, atmosphere 3.6

Notes/Thoughts/Inspirations