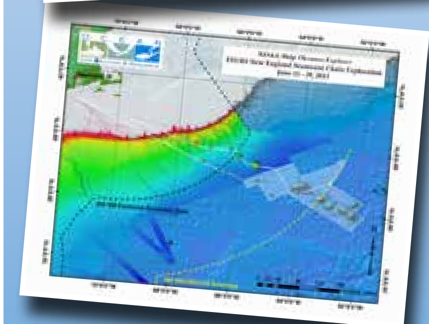
Northeast U.S. Canyons Expedition 2013

Strange Life



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lesson plan

Focus
Biological organisms in cold-seep communities

Grade Level
Middle School

Focus Questions
How does a system of living and non-living things operate to meet the needs of the organisms in cold-seep communities?

How do atomic and molecular interactions explain the properties of methane hydrates?

Learning Objectives
- Students will obtain, evaluate, and communicate information about flows and cycles of energy in cold-seep ecosystems.
- Students will develop a model that describes some of the interdependent relationships in cold-seep ecosystems.
- Students will develop and use a model to explain states and changes between states of methane hydrates.

Materials
For Part I, Developing a Model of Cold-Seep Ecosystems
- 5 x 7 index cards
- Drawing materials
- Corkboard, flip chart, or large poster board
- Colored yarn or string (see Learning Procedure Step 4)

For Part II, Constructing a Methane Hydrate Model
- *Methane Hydrate Model Construction Guide*, one for each student group
- Paper, unlined 8-1/2" X 11"
- Pencil
- Protractor or compass
- Scissors
- Cardboard or card stock (enough to make 13 pentagons)
- Ruler, 12-inch
- 11 - Bamboo skewers, 12" long
- 20 - Styrofoam balls, 1/2" to 1" diameter

- 4 - Styrofoam balls, 1” diameter
- 1 - Styrofoam ball, 1-1/2” diameter
- Tape, wrapping or strapping
- Spray paint, water-based latex; dark blue, light blue, red, and black (colored markers can also be used for a simpler version)
- Fishing line, 8 lb test; or light colored thread
- (Optional) Glue gun

Audio-Visual Materials

- (Optional) Interactive white board

Teaching Time

Part I: Two 45-minute class periods, plus time for student research;
Part II: Two or three 45-minute class periods, or may be sent home as an enrichment activity

Seating Arrangement

Groups of two or three students

Maximum Number of Students

30

Key Words

NOAA Ship *Okeanos Explorer*
Atlantic canyon
Cold seep
Methane hydrate
Chemosynthesis
Continental slope

Background Information

[NOTE: Explanations and procedures in this lesson are written at a level appropriate to professional educators. In presenting and discussing this material with students, educators may need to adapt the language and instructional approach to styles that are best suited to specific student groups.]

Deepwater canyons are among the most striking features of the continental slope off the east coast of the United States. There are more than 70 of these canyons in depths ranging from about 100 m to about 3,500 m, with steep, narrow walls that make exploration difficult. Research during the 1970’s and 1980’s (Hecker *et al.*, 1980; Hecker and Blechschmidt, 1979) showed that submarine canyons along the Atlantic continental slope could contain unique hard bottom communities, many of which include high densities of deepwater corals.

Images from Page 1 top to bottom:
The new 6,000-meter ROV has more sophisticated capabilities than the previous ROV used aboard the *Okeanos Explorer*, *Little Hercules*, and the increased capabilities will enable innovation through research and development of new sensors and systems. The new ROV currently includes hydraulic manipulator arms for deploying oceanographic sensors, an inertial navigation system, a Doppler velocity navigation system, and a system for dynamic lighting control. Image credit: NOAA *Okeanos Explorer* Program.
http://oceanexplorer.noaa.gov/okeanos/explorations/ex1302/welcome.htm

Map showing the area where the *Okeanos Explorer* has been conducting exploration operations along the Northeast Atlantic continental slope. Image courtesy of GEBCO, the U.S. Extended Continental Shelf Project, and NOAA *Okeanos Explorer* Program.
http://oceanexplorer.noaa.gov/okeanos/explorations/ex1303/media/ex1303map-hires.jpg

Methane hydrate looks like ice, but as the “ice” melts it releases methane gas which can be a fuel source. Image credit: Gary Klinkhammer, OSU-COAS.

Iceworms (*Hesiocaeca methanicola*) infest a piece of orange methane hydrate at 540 m depth in the Gulf of Mexico. During the Paleocene epoch, lower sea levels could have led to huge releases of methane from frozen hydrates and contributed to global warming. Today, methane hydrates may be growing unstable due to warmer ocean temperatures. Image credit: Ian MacDonald.
http://oceanexplorer.noaa.gov/explorations/06mexico/background/plan/media/iceworms_600.jpg

Habitat complexity in submarine canyons results from a combination of geological and biological features. Steep canyon walls, rocky outcrops, hard clay formations, boulders, rock rubble, and soft sediments all provide surfaces upon and within which various benthic organisms may grow. Sessile (non-moving) species such as sponges and cnidarians increase the surface complexity and provide additional habitat for other species. Soft sediment is the major substrate type, and most Atlantic canyons have extensive holes and tunnels produced by crabs, tilefish, burrowing anemones, and other animals that further extend the range of available habitats.

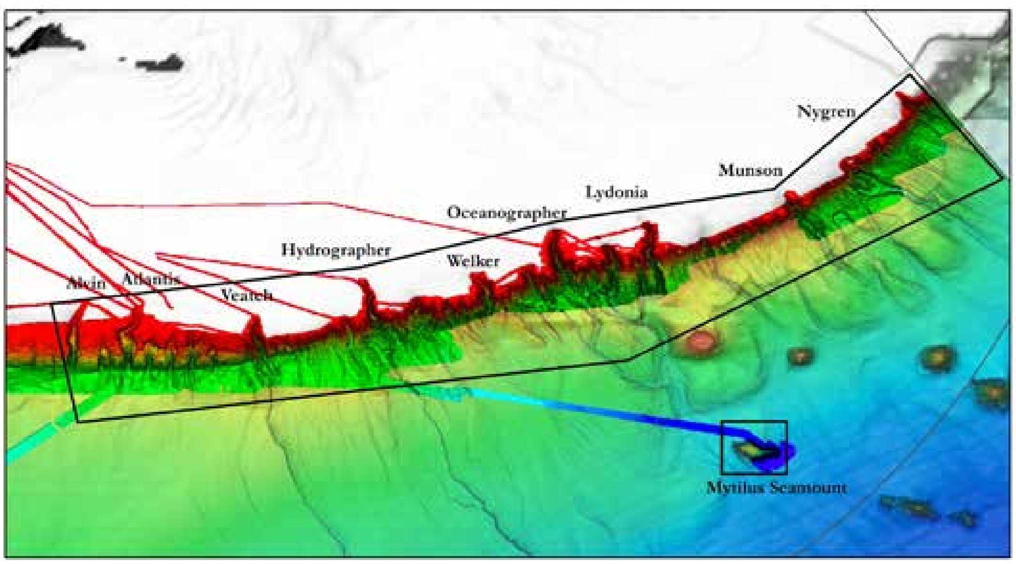
Atlantic canyons may also include chemosynthetic communities whose food webs are based on the energy of chemical compounds, in contrast to photosynthetic communities whose food webs are based on photosynthesis that uses energy from the sun. The first chemosynthetic communities were discovered in 1977 near the Galapagos Islands in the vicinity of underwater volcanic hot springs called hydrothermal vents, which usually occur along ridges separating the Earth's tectonic plates. Hydrogen sulfide is abundant in the water erupting from hydrothermal vents, and is used by chemosynthetic bacteria that are the base of the vent community food web. Another type of chemosynthetic community is found in areas where gases (such as methane) and liquid hydrocarbons seep out of sediments. These areas, known as cold seeps, are commonly found along continental margins, and (like hydrothermal vents) are home to many species of organisms that have not been found anywhere else on Earth.

Cold-seep communities have been found at two locations on the east coast continental slope. These communities may signal the presence of other unusual ecosystems, potentially important energy resources and areas that may be susceptible to submarine landslides that can trigger tsunamis. An historic example of this hazard was the 1929 Grand Banks submarine landslide, which produced a tsunami 3 to 8 m high. That tsunami killed 28 people along the Newfoundland coast, even though this area was sparsely populated at the time. A similar tsunami along the present-day Atlantic coast might be much more devastating.

When methane is produced in deep ocean sediments, water molecules surround methane molecules, and conditions of low temperature and high pressure allow stable ice-like methane hydrates to form. Scientists are interested in methane hydrates for a variety of reasons, including their potential as an energy source, their association with unusual biological communities, and their possible role in tsunamis and climate change (for more information, see Appendix A, "More About Methane Hydrates").

The purpose of the Northeast U.S. Canyons Expedition 2013 is to extend exploration and investigations begun in 2011 of deepwater coral and hard bottom communities to canyons and inter-canyon areas on the continental slope off the New England coast. These studies are expected to discover new coral areas and other significant canyon habitats and provide information about processes that control their distribution, abundance, and ecological functions. For more information about exploration techniques, please see the Expedition Education Module Expedition Purpose for the Northeast U.S. Canyons Expedition 2013 at http://oceanexplorer.noaa.gov/okeanos/explorations/ex1304/edu.html.

In Part I of this lesson, students will investigate some of the organisms that are typically found in cold-seep communities, and how these organisms interact. In Part II, students investigate methane hydrates and develop a model to help explain some of the unusual properties of these substances.



Map showing submarine canyon and seamount areas expected to be be explored during the *Okeanos Explorer* 2013 Northeast U.S. Canyons Expedition. Nantucket and Martha's Vineyard are shown in northwest (top left) corner. Underlying seafloor bathymetry shows the northern portion of the U.S. continental margin to the abyss with shallow areas in red to the deepest areas shown in blue. Bathymetry data acquired during surveys conducted from 2004-2013. Image Credit NOAA *Okeanos Explorer* Program (2011-2013 surveys), Sandwell and Smith (1997), UNH CCOM (2004-2012 surveys).

Learning Procedure

Parts I and II of this lesson are intended to address, respectively, performance expectations MS-LS2-3 and MS-PS1-1 specified in the Next Generation Science Standards:

- MS-LS2-3. Develop a model to describe the cycling of matter and flow of energy among living and nonliving parts of an ecosystem.
- MS-PS1-1. Develop models to describe the atomic composition of simple molecules and extended structures.

1. To prepare for this lesson:
   (a) Review the background essays for the Northeast U.S. Canyons Expedition 2013 (http://oceanexplorer.noaa.gov/okeanos/explorations/ex1304/welcome.html).

(b) Review procedures on the *Methane Hydrate Model Construction Guide (Educator's Version)*, and gather necessary materials. This activity may be done as a cross-curricular mathematics lesson using student-constructed pentagons and dodecahedrons. Alignment to Common Core State Standards are listed as they are associated with specific Next Generation Science Standards performance expectations below. Alternatively, this activity may be done as a briefer demonstration using dodecahedrons constructed by the educator, but this approach will not fulfill performance expectation MS-PS1-1. In either case, you will need to complete Step 2 in advance. If you plan to construct the model as a demonstration, you should also complete Part 1 of the Methane Hydrate Model Construction Guide (page 16).

2. Briefly introduce the Northeast U.S. Canyons Expedition 2013, including the general location of deepwater canyons on the continental slope off the east coast of the United States. If necessary, review the concept of habitats, and discuss how habitat complexity affects the variety of organisms found in specific habitats (more complex habitats tend to support a greater variety of organisms). Be sure students understand that habitat complexity can result from geological features (such as rocky outcrops, hard clay formations, boulders, rock rubble, or sediments), as well as from living organisms (such as sponges and corals). Point out that the activities of certain organisms can also increase the variety of habitats, such as the creation of tunnels in soft sediments by burrowing activities of crabs, fishes, worms, and burrowing anemones.

   Engage students in a discussion of their existing knowledge of chemosynthetic communities, which should include the following elements:
   - Contrast chemosynthesis with photosynthesis.
   - In both processes, organisms build sugars from carbon dioxide and water.
   - This process requires energy; photosynthesizers obtain this energy from the sun, while chemosynthesizers obtain energy from chemical reactions.
   - Review the concepts of food chains and food webs, including the concept of trophic levels (primary producer, primary consumer, secondary consumer, and tertiary consumer).
   - Describe hydrothermal vents and cold-seeps as examples of chemosynthetic communities (you may want to refer to http://www.pmel.noaa.gov/vents, and http://www.divediscover.whoi.edu/vents/index.html, for images and more information).

Briefly describe methane hydrates, and point out that cold-seep communities may signal the presence of methane hydrate deposits. Point out that if methane hydrates become unstable, they can trigger submarine landslides that can cause tsunamis. While we don't hear much about tsunamis on the U.S. east coast, you may want to mention the 1929 Grand Banks submarine landslide, which produced a tsunami 3 to 8 m high and killed 28 people along the Newfoundland coast.

Part I: Developing a Model of Cold-Seep Ecosystems

3. Assign each student group one or more of the following groups to research:

   Methanotrophic bacteria
   Thiotrophic bacteria
   Xenophyophores (see also genus *Syringammina*)
   Anthozoa (sea anemones)
   Turbellaria (a flatworm of the genus *Platyhelminthes*)
   Nautiliniella (a genus of polychaetes)
   Maldanidae (a family of polychaetes)
   Chaetopteridae (a family of polychaetes)
   Capitellidae (a family of polychaetes)
   Sipunculida (peanut worms)
   Bathymodiolus heckerae (a species of mussel)
   Vesicomya (a genus of clams)
   Octopoda (octopus)
   Munidopsis (a genus of crustacean)
   Alvinocaris (a genus of crustacean)
   Nematoda (a round worm)
   Sarsiaster greigi (a species of sea urchin)
   Chiridota (a genus of sea cucumber)
   Ophioctenella (a genus of brittle star)
   Brisingia (a genus of sea star)

   In addition to written reference materials (encyclopedia, periodicals, and books on the deep sea), the following Web sites contain useful information:

   http://biodidac.bio.uottawa.ca/
   http://eol.org

   Each student group should try to determine the energy (food) source(s) of their assigned organisms. It may not be possible to precisely determine specific foods for all groups, but students should be able to draw reasonable inferences from information about related organisms and anatomical features that may give clues about what the animals eat. Students should prepare a 5 x 7 index card for each organism with an illustration of the organism (photocopies from reference material, downloaded internet pictures, or their own sketches), notes on where the organism is found, approximate size of the organism, its trophic level (whether it is a primary producer, primary consumer, secondary consumer, or tertiary consumer), and whether it depends upon photosynthesis, chemosynthesis, or both.

4. Have each student group orally present their research results to the entire class. Temporarily attach the cards prepared by students to a corkboard, flip chart, or piece of poster board (painting tape, sticky notes, or thumbtacks can be used to temporarily anchor the cards). Tell students that their class assignment is to use the information on the cards to create a model that describes some of the interdependent relationships and energy flows in cold-seep ecosystems.

   Allow student groups to study the cards for 15 minutes and develop their ideas about interdependent relationships and energy flows. Then have groups take turns moving the cards so that they are arranged to show which organisms inhabit cold-seep communities and which organisms are from deep-sea environments outside cold-seep communities. Students should also indicate trophic (feeding) relationships between organisms using pieces of colored yarn or string. Depending upon available time, you may require student groups to move only one card at a time and make only one trophic connection, or allow them to move several cards at a time and make multiple trophic connections.

5. Lead a discussion of the food web(s) the students have created. During this discussion, consider the following guidance from the Next Generation Science Standards:
   (a) Performance expectations in LS2: Interactions, Energy, and Dynamics Relationships in Ecosystems are intended to help students formulate an answer to the question, "How does a system of living and non-living things operate to meet the needs of the organisms in an ecosystem?" and
   (b) Students who demonstrate understanding of performance expectation MS-LS2-3 can analyze and interpret data, develop models, and construct arguments and demonstrate a deeper understanding of resources and the cycling of matter and the flow of energy in ecosystems. They can also study patterns of the interactions among organisms within an ecosystem. They consider biotic and abiotic factors in an ecosystem and the effects these factors have on population.

   Leading questions that may be used to prompt appropriate discussion include, "Which groups show the greatest variety of anatomical types and feeding strategies?" and "Which groups are responsible for primary production?" Be sure students understand that since the bacteria, tubeworms, and mussels of the cold seeps obtain their nutrition through chemosynthesis, they take on the role of primary producers in this type of ecosystem since the food they make can be eaten by many other kinds of animals. At the same time, some primary production from photosynthesis also enters the system as dead plants settle to the bottom from shallower portions of the ocean above. The focus of this discussion should be on students' analyzing information and arguing from evidence, rather than specific details about individual organisms.

Ask students to make inferences about the relative abundance of each trophic level. In the simplest analysis, organisms at lower trophic levels (primary producers and primary consumers) must be more abundant than those on higher trophic levels. If this does not appear to be true, then there must be additional energy sources for the higher trophic levels.

Part II: Constructing a Methane Hydrate Model

6. Tell students that 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. Methane is produced in many environments by a group of Archaea known as methanogenic Archaea. These Archaea 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, water molecules surround methane molecules, and conditions of low temperature and high pressure allow stable ice-like methane hydrates to form.

   It is important that students understand that if temperature is increased or pressure is reduced, methane hydrate molecules may no longer be stable. If this happens, the "cage" of water molecules surrounding the methane molecules will disintegrate into individual water molecules, and the methane molecules will be released as a gas.

7. Briefly discuss how mathematical models help us understand science concepts. Tell students that they will use concepts and skills they have learned in mathematics to build a model of a methane hydrate molecule that will help them explain some of the properties of this unusual substance.

   Give each student group a copy of the *Methane Model Construction Guide*, and have them complete Parts 1 and 2.

8. When students have completed their models, have each group use their model to describe and explain one feature of methane hydrates. During these discussions, consider the following guidance from the Next Generation Science Standards:

(a) Performance expectations in PS1: Matter and its Interactions are intended to help students formulate an answer to the question, "How do atomic and molecular interactions explain the properties of matter that we see and feel?" and
(b) Students who demonstrate understanding of performance expectation MS-PS1-1 are able to provide molecular level accounts to explain states of matters and changes between states.

Also note that middle school students are not expected to discuss valence electrons, bonding energy, the ionic nature of subunits of complex structures, or to completely depict all of individual atoms in a complex molecule or extended structure.

The BRIDGE Connection

www.vims.edu/bridge/ - Click on "Ocean Science Topics," "Biology," "Plankton" in the navigation menu to the left for resources on ocean food webs. Click on "Ocean Science Topics," "Habitats," "Deep Sea" for resources on deep-sea communities.

The "Me" Connection

Have students write a short essay about how canyons on the continental slope might someday affect their own lives.

Connections to Other Subjects

English Language Arts, Mathematics

Assessment

Student presentations, answers to worksheet questions, and class discussions provide opportunities for assessment.

Extensions

1. Have students visit http://oceanexplorer.noaa.gov/okeanos/explorations/ex1304/edu.html to find out more about the Northeast U.S. Canyons Expedition 2013.

2. For additional relevant lesson plans, please see the Expedition Education Module for the Northeast U.S. Canyons Expedition.

Multimedia Discovery Missions

[http://oceanexplorer.noaa.gov/edu/learning/welcome.html]
Click on the links to Lessons 3, 5, 6, 8, and 14 for interactive multimedia presentations and Learning Activities on Deep-Sea Corals, Chemosynthesis and Hydrothermal Vent Life, Deep-Sea Benthos, Ocean Currents and Seamounts.

Other Resources

The Web links below are provided for informational purposes only. Links outside of Ocean Explorer have been checked at the time of this page's publication, but the linking sites may become outdated or non-operational over time.

http://oceanexplorer.noaa.gov/explorations/12midatlantic/welcome.html – Web site for the Deepwater Canyons 2012 - Pathways to the Abyss expedition

http://oceanexplorer.noaa.gov/okeanos/explorations/ex1206/welcome.html - Web site for the NOAA Ship *Okeanos Explorer* Northeast and Mid-Atlantic Canyons Expedition 2012.

De Leo, F. C., C. R. Smith, A. A. Rowden, D. A. Bowden, and M. R. Clark. 2010. Submarine canyons: hotspots of benthic biomass and productivity in the deep sea. *Proc. Biol. Sci.* 277(1695):2783-2792.

http://www.pmel.noaa.gov/vents – "Vents Program" Web page from NOAA's Pacific Marine Environmental Laboratory

http://www.divediscover.whoi.edu/vents/index.html for more information and activities on hydrothermal vent communities

Lesson Alignment to the Next Generation Science Standards Performance Expectations

Note: Alignment to Common Core State Standards are listed as they are associated with specific Next Generation Science Standards performance expectations below.

LS2: Interactions, Energy, and Dynamics Relationships in Ecosystems

Performance Expectation MS-LS2-3. Develop a model to describe the cycling of matter and flow of energy among living and nonliving parts of an ecosystem. [Clarification Statement: Emphasis is on describing the conservation of matter and flow of energy into and out of various ecosystems, and on defining the boundaries of the system.]

Science and Engineering Practices:

Developing and Using Models

- Develop a model to describe phenomena. (MS-LS2-3)

Disciplinary Core Idea:

LS2.B: Cycle of Matter and Energy Transfer in Ecosystems

- Food webs are models that demonstrate how matter and energy is transferred between producers, consumers, and decomposers as the three groups interact within an ecosystem. Transfers of matter into and out of the physical environment occur at every level. Decomposers recycle nutrients from dead plant or animal matter back to the soil in terrestrial environments or to the water in aquatic environments. The atoms that make up the organisms in an ecosystem are cycled repeatedly between the living and nonliving parts of the ecosystem. (MS-LS2-3)

Crosscutting Concepts:

Energy and Matter

- The transfer of energy can be tracked as energy flows through a natural system. (MS-LS2-3)

Connections to Nature of Science:

Scientific Knowledge Assumes an Order and Consistency in Natural Systems

- Science assumes that objects and events in natural systems occur in consistent patterns that are understandable through measurement and observation. (MS-LS2-3)

PS1: Matter and its Interactions

Performance Expectation MS-PS1-1. Develop models to describe the atomic composition of simple molecules and extended structures. [Clarification Statement: Emphasis is on developing models of molecules that vary in complexity. Examples of simple molecules could include ammonia and methanol. Examples of extended structures could include sodium chloride or diamonds. Examples of molecular-level models could include drawings, 3D ball and stick structures, or computer representations showing different molecules with different types of atoms.] [Assessment Boundary: Assessment does not include valence electrons and bonding energy, discussing the ionic nature of subunits of complex structures, or a complete depiction of all individual atoms in a complex molecule or extended structure.]

Science and Engineering Practices:

Developing and Using Models

- Develop a model to predict and/or describe phenomena. (MS-PS1-1),(MS-PS1-4)

Disciplinary Core Idea:

PS1.A: Structure and Properties of Matter

- Substances are made from different types of atoms, which combine with one another in various ways. Atoms form molecules that range in size from two to thousands of atoms. (MS-PS1-1)
- Solids may be formed from molecules, or they may be extended structures with repeating subunits (e.g., crystals). (MS-PS1-1)

Crosscutting Concepts:

Scale, Proportion and Quantity

- Time, space, and energy phenomena can be observed at various scales using models to study systems that are too large or too small. (MS-PS1-1)

Common Core State Standards Connections:

ELA/Literacy –

- RST.6-8.7 Integrate quantitative or technical information expressed in words in a text with a version of that information expressed visually (e.g., in a flowchart, diagram, model, graph, or table). (MS-PS1-1),(MS-PS1-2),(MS-PS1-4),(MS-PS1-5)

Mathematics –

- MP.2 Reason abstractly and quantitatively. (MS-PS1-1),(MS-PS1-2),(MS-PS1-5)
- MP.4 Model with mathematics. (MS-PS1-1),(MS-PS1-5)
- 8.EE.A.3 Use numbers expressed in the form of a single digit times an integer power of 10 to estimate very large or very small quantities, and to express how many times as much one is than the other. (MS-PS1-1)

Ocean Literacy Essential Principles and Fundamental Concepts

Essential Principle 1.

The Earth has one big ocean with many features.

Fundamental Concept b. Ocean basins are composed of the seafloor and all of its geological features (such as islands, trenches, mid-ocean ridges, and rift valleys) and vary in size, shape and features due to the movement of Earth's crust (lithosphere). Earth's highest peaks, deepest valleys and flattest plains are all in the ocean.

Essential Principle 5.

The ocean supports a great diversity of life and ecosystems.

Fundamental Concept e. The ocean provides a vast living space with diverse and unique ecosystems from the surface through the water column and down to, and below, the seafloor. Most of the living space on Earth is in the ocean.

Fundamental Concept f. Ocean ecosystems are defined by environmental factors and the community of organisms living there. Ocean life is not evenly distributed through time or space due to differences in abiotic factors such as oxygen, salinity, temperature, pH, light, nutrients, pressure, substrate, and circulation. A few regions of the ocean support the most abundant life on Earth, while most of the ocean does not support much life.

Fundamental Concept g. There There are deep ocean ecosystems that are independent of energy from sunlight and photosynthetic organisms. Hydrothermal vents, submarine hot springs, and methane cold seeps, rely only on chemical energy and chemosynthetic organisms to support life.

Essential Principle 6:
The ocean and humans are inextricably interconnected.

Fundamental Concept f. Coastal regions are susceptible to natural hazards (such as tsunamis, hurricanes, cyclones, sea level change, and storm surges).

Essential Principle 7.
The ocean is largely unexplored.

Fundamental Concept a. The ocean is the largest unexplored place on Earth—less than 5% of it has been explored. The next generation of explorers and researchers will find great opportunities for discovery, innovation, and investigation.

Fundamental Concept b. Understanding the ocean is more than a matter of curiosity. Exploration, experimentation, and discovery are required to better understand ocean systems and processes. Our very survival hinges upon it.

Fundamental Concept d. New technologies, sensors, and tools are expanding our ability to explore the ocean. Scientists are relying more and more on satellites, drifters, buoys, subsea observatories, and unmanned submersibles

Send Us Your Feedback

In addition to consultation with expedition scientists, the development of lesson plans and other education products is guided by comments and suggestions from educators and others who use these materials. Please send questions and comments about these materials to: oceanexeducation@noaa.gov.

For More Information

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Credit

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Appendix A
More About Methane Hydrates

Methane hydrates appear to be ordinary ice, but clearly are different since touching a match to one of these ices causes it to catch on fire.

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 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.

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 6o 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). The Cape Fear slide, the largest submarine slide on the U.S. East Coast, occurred approximately 20,000 years ago and may have been related to methane hydrates and sudden release of methane gas. The timing of the Cape Fear slide also roughly coincides with the end of the last major glaciation.

Methane Hydrate Model Construction Guide (Educator's Version)

Learning Objectives

- Students will demonstrate geometric properties through hands-on manipulation of geometric shapes.
- Students will be able to construct a pentagonal dodecahedron.
- Students will be able to construct a model of a methane hydrate.

Materials

For constructing a pentagon:

- Paper, unlined 8-1/2" X 11"
- Pencil
- Protractor or compass

For constructing the dodecahedron half, clathrate cage, methane molecule and methane hydrate model:

- Scissors
- Cardboard or card stock (enough to make 13 pentagons)
- Ruler, 12-inch
- 11 - Bamboo skewers, 12" long
- 20 - Styrofoam balls, 1/2" to 1" diameter
- 4 - Styrofoam balls, 1" diameter
- 1 - Styrofoam ball, 1-1/2" diameter
- Tape, wrapping or strapping
- Spray paint, water-based latex; dark blue, light blue, red, and black (colored markers can also be used for a simpler version)
- Fishing line, 8 lb test; or light colored thread
- (Optional) Glue gun

Teaching Time

Three or four 50-minute class periods or may be sent home as an enrichment activity

Definitions

- Polygon – a geometric shape made up of vertices that are connected with line segments
- Vertex – a point where the sides of an angle meet
- Pentagon – a geometric shape with five equal sides and five 108° angles
- Dodecahedron – a three-dimensional geometric shape that has 12 faces (regular pentagons), 20 vertices, and 30 edges

Prerequisite Skills

Students should have basic knowledge of geometric shapes and know how to draw a pentagon. If not, directions for drawing a pentagon using a compass or protractor may be found in middle school math textbooks or in the links below.

Procedure

1. General Notes:
   - For grade 6-8 students, the educator may want to demonstrate each step of drawing the pentagon as students follow along.
   - Use a good quality latex spray paint; oil-based paints containing organic solvents tend to melt the Styrofoam.
   - When constructing the clathrate cage, the educator should demonstrate each step as students follow along.
   - Be sure the skewers are inserted into the middle of the Styrofoam balls.
2. (Advance Preparation) Spray paint skewers and Styrofoam balls or mark with colored markers:
   a. Paint ten skewers light blue to represent hydrogen bonds between water molecules
   b. Paint one skewer red to represent the covalent bonds in the methane molecule
   c. Paint twenty 1/2" Styrofoam balls dark blue to represent water molecules
   d. Paint one 1-1/2" Styrofoam ball black to represent the carbon atom
   e. Note: the four 1" Styrofoam balls remain white to represent hydrogen atoms
   f. Cutting skewers at an angle, cut light blue skewer sticks into thirty 3-3/4" lengths. Cut the red skewer stick into four 2" lengths.

Be sure students understand that each of the dark blue Styrofoam balls represents a water molecule consisting of two hydrogen atoms and one oxygen atom. To keep the model simple, we don't show all of these atoms separately.

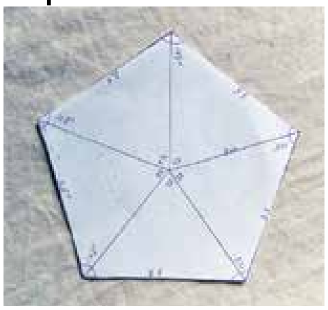
Resources

http://wiki.answers.com/Q/How_would_you_draw_a_regular_pentagon
http://www.barryscientific.com/lessons/polygon.html

Methane Hydrate Model Construction Guide

Part 1 – Build half of a pentagonal dodecahedron

Step 1



Step 2

Step 3

1. Draw a pentagon on paper and cut it out. Each side of the pentagon should be four inches long (72° angles). Option: Use Adobe Illustrator or Corel Draw.

2. Trace the paper pentagon onto cardboard or card stock and cut it out. Your group will need 7 pentagons.

3. Lay one pentagon on a flat surface and surround it with five more pentagons matched side to side. Tape the five outside pentagons to the center pentagon.

4. Carefully pull up one pair of pentagons and tape their common sides together. Repeat until the five pentagons have been taped together, forming a five-sided bowl. This is half of a pentagonal dodecahedron.

Part 2 – Build the Model

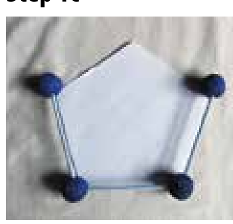
Build the clathrate cage:

1. Place the 7th pentagon on a flat surface. Place a blue stick on one side and two blue balls at each end. Carefully insert the end of the blue stick into the middle of each ball. Repeat with three more balls and four more sticks to form a ball-and-stick pentagon.

Step 1a

Step 1b

Step 1c



Step 1d

Step 1e

Step 2

2. Place the ball-and-stick pentagon in the dodecahedron half – be careful, it will lie approximately an inch up from the bottom. The dodecahedron half (bowl) is used as a template to build the ball and stick dodecahedron with the correct stick angle.

3. Place five light blue sticks inside the center of each of the dark blue balls using the dodecahedron half as a guide for the correct stick angle. *It's very important to insert the sticks into the center of the ball at the same angle as the side of the dodecahedron half.*

4. Insert a dark blue ball on top of each light blue stick. Carefully remove the incomplete cage from the dodecahedron half and place it on a flat surface.

5. Use the 7th pentagon to complete the bottom half of the cage. Turn the ball-and-stick model onto one side and, using the pentagon to determine the correct angle, insert a light blue stick into the center of the two dark blue balls. Then, attach another dark blue ball to connect the two light blue sticks you've just attached. This makes the second face and second pentagon of the cage. The first face was the bottom.

6. Repeat Step 5 four more times to form the remaining faces for the bottom half of the cage.

7. Repeat Steps 1, 2, and 3 to construct the top half of the cage.

8. Carefully place the bottom half of the cage into the bottom of the cardboard bowl.

9. Carefully, attach the two halves of the cage together: Working together with your partners, hold the top half of the cage over the bottom half. The two halves will only fit together one way. Rotate the top half until all of the unattached sticks line-up with a ball. Insert each light blue stick into the center of the corresponding dark blue ball.

10. (Optional) Use a glue gun to adhere the styrofoam to the sticks for added strength and durability of the model.

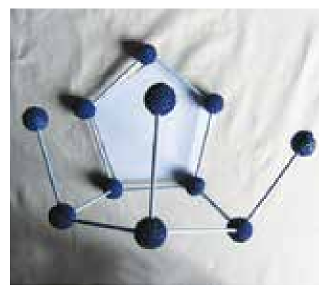
Build the Methane Molecule:

11. Insert four red sticks into the black Styrofoam ball so that they are evenly spaced (when the model is placed on a flat surface, three of the sticks and the black ball should look like a tripod with the fourth stick pointing straight up). Attach a white Styrofoam ball to the other end of each of the red sticks.

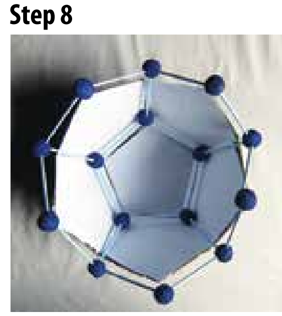
Step 3

Step 4

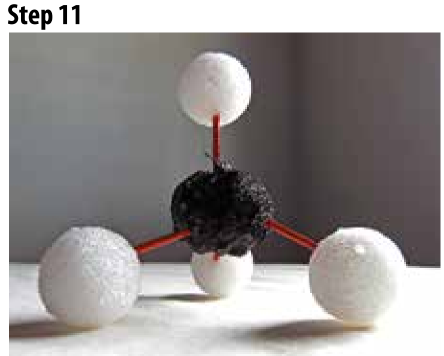
Step 5



Step 8



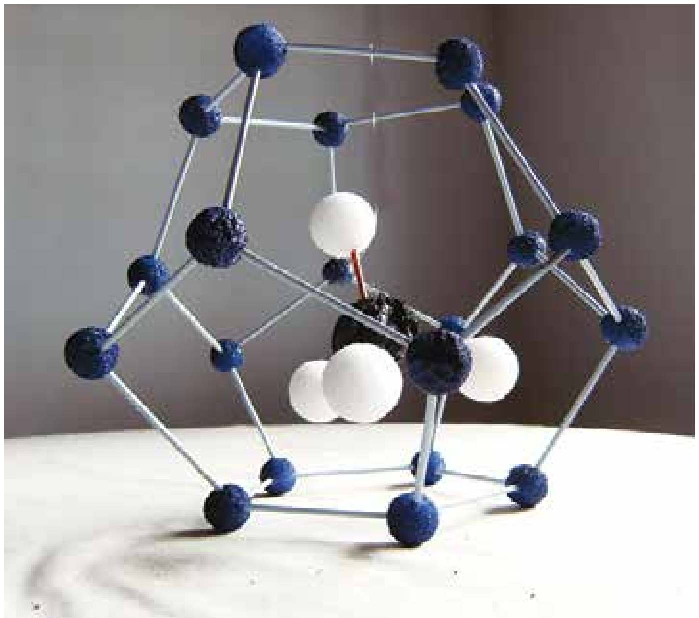
Step 11



Assemble the Methane Hydrate Model:

12. Suspend the methane molecule model in the middle of the clathrate cage by attaching fishing line from one of its covalent bonds (red sticks) to two opposing hydrogen bonds (light blue sticks) at the top of the cage. Your Methane Hydrate Model is finished!

Step 12



All photographs by Mellie Lewis, Teacher Facilitator, The College of Exploration.