The Mid-Cayman Rise Expedition 2011

To Sink, To Rise, or To Float

Focus
Buoyancy applied to exploration for hydrothermal vents

Grade Level
5-6 (Physical Science)

Focus Question
How does the principle of buoyancy help ocean explorers find hydrothermal vents?

Learning Objectives
- Students will be able to define buoyancy and density.
- Students will be able to compare and contrast positive buoyancy, negative buoyancy and neutral buoyancy.
- Students will be able to explain how the concepts of buoyancy and density are relevant to exploration for hydrothermal vent systems.

Materials
For one student group:
- Piece of Styrofoam, about 2 cm x 2 cm x 4 cm, cut as a right rectangular prism
- Plastic tape (e.g., duct tape, electrical tape, package tape)
- Fishing weights or washers, at least 10 pieces with a total mass of about 60 g
- 100 ml graduated cylinder (be sure the Styrofoam pieces will fit inside the cylinder)
- Scissors
- Copies of Buoyancy and Vents Guided Design Portfolio Sheet

May be shared by several student groups:
- Triple-beam balance
- An aquarium filled with water

For demonstration:
- Clear cylindrical container, about 250 ml capacity (e.g., graduated cylinder, tall flower vase, tall glass)
- Hot (about 50°C) and cold (about 4°C) water, 500 ml or more each; if not available at school, may be brought from home in vacuum beverage bottles
Oral medication syringe, 10 ml capacity  
Plastic tubing, inside diameter to fit syringe tip; about 75 cm or long enough to reach to the bottom of the clear cylinder  
Food coloring  
Small clear container, about 100 ml capacity (e.g., beaker, plastic cup, storage dish)  
(Optional) Thermometer, 0 – 100° C  

Audio-Visual Materials  
Interactive white board or computer projection equipment; see Learning Procedure Step 1.

Teaching Time  
One or two 45-minute class periods

Seating Arrangement  
Classroom style

Maximum Number of Students  
30

Key Words  
Buoyancy  
Density  
Volume  
Mass  
Hydrothermal vent  
Plume

Background Information  
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.

One of the most exciting and significant scientific discoveries in the history of ocean science was made in 1977, deep on the ocean floor near the Galápagos Islands. Here, researchers found large numbers of animals that had never been seen before clustered around underwater hot springs flowing from cracks in the lava seafloor. Similar hot springs, known as hydrothermal vents, have since been found in many other locations where underwater volcanic processes are active. Hydrothermal vents are formed when seawater flows into deep cracks in the ocean floor, is heated by molten rock to temperatures that may be higher than 350° C, and then rises back to the surface to form hydrothermal vents where the superheated water erupts through the seafloor. The presence of thriving biological communities in the deep ocean was a complete surprise, because it was assumed that
food energy resources would be scarce in an environment without sunlight to support photosynthesis. Researchers soon discovered that the organisms responsible for this biological abundance do not need photosynthesis, but instead are able to obtain energy from chemical reactions through processes known as chemosynthesis. Photosynthesis and chemosynthesis both require a source of energy that is transferred through a series of chemical reactions into organic molecules that living organisms may use as food. In photosynthesis, light provides this energy. In chemosynthesis, the energy comes from other chemical reactions.

Deepwater biological communities associated with hydrothermal vents are fundamentally different from other biological systems, and there are many unanswered questions about the individual species and interactions between species found in these communities. These species include some of the most primitive living organisms (Archaea) that some scientists believe may have been the first life forms on Earth. Many species are new to science, and may prove to be important sources of unique drugs for the treatment of human diseases. Although much remains to be learned, new drugs and other useful products have already been discovered in hydrothermal vent organisms. At present, almost all drugs produced from natural sources come from terrestrial plants, but marine animals produce more drug-like substances than any group of organisms that live on land. Some chemicals from microorganisms found around hydrothermal vents (the exopolysaccharide HE 800 from *Vibrio diabolicus*) are promising for the treatment of bone injuries and diseases, while similar chemicals may be useful for treating cardiovascular disease. Other examples of useful products include *Thermus thermophylus*, a microorganism that is adapted to live under extremely high temperature conditions near hydrothermal vents. One of these adaptations is a protein (Tth DNA polymerase) that can be used to make billions of copies of DNA for scientific studies and crime scene investigations. Another microorganism (genus *Thermococcus*) produces a type of protein (an enzyme called pullulanase) that can be used to make sweeteners for food additives.

The geologic processes that produce hydrothermal vents are linked to movements of tectonic plates, which are portions of the Earth’s outer crust (the lithosphere) about 5 km thick, as well as the upper 60 - 75 km of the underlying mantle. These plates move on a hot flowing mantle layer called the asthenosphere, which is several hundred kilometers thick. Heat within the asthenosphere creates convection currents (similar to the currents that can be seen if food coloring is added to a heated container of water). Movement of convection currents causes tectonic plates to move several centimeters per year relative to each other.
Where tectonic plates slide horizontally past each other, the boundary between the plates is known as a transform plate boundary; when tectonic plates collide more or less head-on, a convergent plate boundary is formed; where tectonic plates are moving apart, they form a divergent plate boundary. At divergent plate boundaries, magma (molten rock) rises from deep within the Earth and erupts to form new crust on the lithosphere. Most divergent plate boundaries are underwater (Iceland is an exception), and form submarine mountain ranges called oceanic spreading ridges. A rift valley is typically present along the top of the ridge. While the process is volcanic, volcanoes and earthquakes along oceanic spreading ridges are not as violent as they are at convergent plate boundaries. For additional discussion about convergent and transform plate boundaries, see the Galapagos Rift 2011 Expedition Purpose: [http://oceanexplorer.noaa.gov/okeanos/explorations/ex1103/background/edu/purpose.html](http://oceanexplorer.noaa.gov/okeanos/explorations/ex1103/background/edu/purpose.html).

On a global scale Earth’s oceanic spreading ridges are connected and form a single mid-ocean ridge system that is part of every ocean. This mid-ocean ridge system is about 50,000 km long, and is the longest mountain range in the world. Although they are connected, the ridges that make up the global mid-ocean ridge system are not all the same. This is because tectonic plates adjacent to different ridges may move apart at different rates. Plates that are part of fast-spreading ridge systems may move apart at rates of 20 cm/yr or more, while plates that...
are part of ultraslow-spreading ridge systems may move at rates of 2 cm/yr or less. In general, hydrothermal vents are most common along fast-spreading ridge systems; but about 50% of the global mid-ocean ridge system consists of slow- or ultraslow spreading ridges, and there is greater variety in the types of hydrothermal vents found along these ridges.

The Mid-Cayman Rise (MCR) is the world’s deepest and slowest-spreading mid-ocean ridge. Exploration of the MCR was underway in the 1970’s, but the discovery of the first hydrothermal vents on the Galápagos Spreading Center caused deep-sea researchers to change the focus of their investigations...until recently. In 2009, a systematic exploration along the MCR found evidence of three different types of hydrothermal vents within 100 km of each other. For more discussion about different vent types, see the Mid-Cayman Rise Expedition 2011 Exploration Purpose: http://oceanexplorer.noaa.gov/okeanos/explorations/ex1104/background/edu/purpose.html.

Hydrothermal vent communities on the MCR are interesting to biologists because they probably contain species that are new to science, some of which may provide useful bioproducts. In addition, the MCR is isolated from the rest of the global mid-ocean ridge system, though it was connected to the Galápagos Spreading Center until about 5 million years ago when the Isthmus of Panama closed the seaway connecting the Caribbean Sea and Pacific Ocean. This raises intriguing questions about MCR vent organisms: Do they resemble vent biota on other ocean ridges such as the Galápagos Spreading Center or the Mid-Atlantic Ridge? How similar are they to organisms in chemosynthetic communities of the Gulf of Mexico? Answers to these questions can provide new insights about how new hydrothermal vent systems are colonized, and whether vent organisms move between widely separated vent systems. It is also possible that some MCR hydrothermal vent systems produce organic molecules by processes that do not involve living organisms. These processes are potentially relevant to the origins of life on Earth, as well as exploration for similar systems that support living organisms in other parts of our solar system.

The Mid-Cayman Rise Expedition 2011 is focused on locating new hydrothermal vent sites on the Mid-Cayman Rise, and exploring these sites with the Little Hercules remotely operated vehicle which will capture video images of biological and geological features of these sites. To find new vent sites, ocean explorers will take advantage of the fact that hydrothermal vents cause changes to the physical and chemical properties of seawater. These changes can be detected with a CTD, which stands for conductivity, temperature, and depth, and refers to a package of electronic instruments that measure these properties.
Conductivity is a measure of how well a solution conducts electricity and is directly related to salinity, which is the concentration of salt and other inorganic compounds in seawater. Salinity is one of the most basic measurements used by ocean scientists. When combined with temperature data, salinity measurements can be used to determine seawater density which is a primary driving force for major ocean currents. Often, CTDs are attached to a much larger metal frame called a rosette, which may hold water sampling bottles that are used to collect water at different depths, as well as other instruments that can measure additional physical or chemical properties.

Masses of changed seawater are called plumes, and are usually found within a few hundred meters of the ocean floor. Since underwater volcanoes and hydrothermal vents may be several thousand meters deep, ocean explorers usually raise and lower a CTD rosette through several hundred meters near the bottom as the ship slowly cruises over the area being surveyed. This repeated up-and-down motion of the towed CTD may resemble the movement of a yo-yo; a resemblance that has led to the nickname “tow-yo” for this type of CTD sampling.

In this activity, students will investigate properties of density and buoyancy, and will make inferences about how these properties are used to detect plumes from hydrothermal vents.

Learning Procedure

NOTES:

(a) Because the discovery of hydrothermal vents was so significant and exciting, there is a wealth of information available on the geology and ecology of vent ecosystems. Several sources and potential activities are highlighted below, and educators are encouraged to investigate these, and select combinations that are most appropriate to their own students and specific curriculum needs.

(b) This lesson is divided into two parts. Part A is a review of density and buoyancy concepts, and a Neutral Buoyancy Design Challenge. In Part B, students observe the behavior of fluid from a simulated hydrothermal vent, and make inferences about the buoyancy of plumes that might be detected by ocean explorers.

1. To prepare for this lesson:


(b) Review background information on hydrothermal vents from one or more of these Web sites:

- http://oceanexplorer.noaa.gov/explorations/02fire/logs/magicmountain/welcome.html – This site links to virtual fly-throughs and panoramas of the Magic Mountain hydrothermal
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vent site on Explorer Ridge in the NE Pacific Ocean, about 150 miles west of Vancouver Island, British Columbia, Canada. Explorer Ridge is a spreading center where two tectonic plates are spreading apart and there is active eruption of submarine volcanoes.

- http://www.pmel.noaa.gov/vents/nemo/index.html – Web site for NOAA’s New Millennium Observatory (NeMO), a seafloor observatory at an active underwater volcano near the spreading center between the Juan de Fuca and Pacific tectonic plates. The “Explore” section of the site offers images and essays that include mid-ocean ridges, hydrothermal vents, and seafloor animals. The “Education” section of the site provides Powerpoint® presentations and curriculum materials.
- http://www.nationalgeographic.com/xpeditions/lessons/07/g35/seasvents.html – National Geographic Xpeditions lesson plan, We’re in Hot Water Now: Hydrothermal Vents, includes links to National Geographic magazine articles and video with an emphasis on geography and geographic skills.

If an interactive white board or computer projection facilities are available, you may also want to bookmark selected Web pages or download some images from these sites to show your students.

(c) Review the Buoyancy and Vents Guided Design Portfolio Sheet.

2. Briefly introduce the Mid-Cayman Rise Expedition 2011, and NOAA Ship Okeanos Explorer, which is the only U.S. ship whose sole assignment is to systematically explore Earth’s largely unknown ocean for the purposes of discovery and the advancement of knowledge. Be sure students understand that discoveries of deep sea chemosynthetic communities during the last 30 years are major scientific events that have changed many assumptions about life in the ocean and have opened up many new fields of scientific investigation. Highlight the fact that hydrothermal vents cause changes in the surrounding seawater, and that these changes can be used to locate undiscovered vents.
The idea of buoyancy was summed up by a Greek mathematician named Archimedes: any object, wholly or partly immersed in a fluid, is buoyed up by a force equal to the weight of the fluid displaced by the object. Today, this definition is called the Archimedes Principle.

Archimedes is considered one of the three greatest mathematicians of all time (the other two are Newton and Gauss). Archimedes was born in 287 B.C., in Syracuse, Greece. He was a master at mathematics and spent most of his time thinking about new problems to solve.

Many of these problems came from Hiero, the king of Syracuse. Archimedes came up with his famous principle while trying to solve this problem: The king ordered a gold crown and gave the goldsmith the exact amount of metal to make it. When Hiero received it, the crown had the correct weight but the king suspected that some silver had been substituted for the gold. He did not know how to prove it, so he asked Archimedes for help.

One day while thinking this over, Archimedes went for a bath and water overflowed the tub. He recognized that there was a relationship between the amount of water that overflowed the tub and the amount of his body that was submerged. This observation gave him the means to solve the problem. He was so excited that he ran naked through the streets of Syracuse shouting “I have found it!” The goldsmith was brought to justice and Archimedes never took another bath... (just kidding!).


Portrait of Archimedes, by Domenico Fetti, about 1620

Part A. Buoyancy, Density and the Neutral Buoyancy Design Challenge

A-1. If necessary, review Archimedes’ Principle and the concepts of density and buoyancy. Be sure students understand the meaning of positive buoyancy, negative buoyancy and neutral buoyancy. If students are not already familiar with the Engineering Design Process, review information in the Engineering Design Process sidebar on Page 9.

A-2. Neutral Buoyancy Design Challenge – Provide each student group with:

- a piece Styrofoam
- plastic tape
- fishing weights or washers
- 100 ml graduated cylinder
- access to water and a balance.

Tell students that their assignment is to design a neutrally buoyant object using materials provided. This design should be based upon appropriate measurements and calculations, and they should prepare a written description of their design in Part A of the Buoyancy and Vents Guided Design Portfolio Sheet before actually constructing their object. If desired, you can have a competition between students groups based on which group’s object is closest to neutral buoyancy.

A-3. When each group has completed their model, test the buoyancy of two or three objects at a time using an aquarium filled with water. Students should hold their objects about halfway to the bottom of the aquarium (you can use rulers to ensure that all objects are the
same distance from the bottom). When the “Go” signal is given, students release their objects and a timekeeper should begin timing with a stopwatch or watch with a sweep second hand. The time required for each model to sink to the bottom or rise to the surface should be recorded, and the competition repeated until the winner is determined. If desired, students may be given an opportunity to fine-tune their objects for a return engagement.

A-4. Lead a discussion of the design calculations that produced the most successful neutrally buoyant object. Students should realize that key parameters are:

- the total volume of the object, which will determine the volume of water displaced;
- the mass of the volume of water displaced, which will determine the buoyant force acting on the object (since this is fresh water, a volume of 1 cm³ can be assumed to have a mass of 1 gram); and
- the mass of the weights attached to the model.

The volume of the model can be determined by immersing the piece of Styrofoam in a partially-filled graduated cylinder (by placing the Styrofoam inside the cylinder, then pushing it down with the tip of a pencil or a straightened paper clip until all of the Styrofoam is just submerged) and noting the change in volume within the cylinder. Once the volume (and hence the buoyant force) is determined, an appropriate combination of weights can be selected. These calculations should be recorded before the object is constructed or tested. If necessary, could be broken into smaller pieces to bring the buoyant force closer to the mass of the weights. Once the appropriate combination of peanuts and weights has been determined, the components can be secured together with the plastic tape.

Ask students how they would modify their object for a competition in saltwater. Students should recognize that the density of saltwater is greater than the density of freshwater, so the volume of water displaced will have a greater mass, and hence the buoyant force on the model will be greater; so they would need to add additional weight to cause the model to sink.

Part B. Inferences About Buoyancy of Hydrothermal Vent Plumes

B-1. Arrange the following on a demonstration table so that they are within easy reach and visible to students:

- clear cylindrical container
- hot (about 50°C) and cold (about 4°C) water; about 500 ml each
- oral medication syringe with plastic tubing attached to tip
- food coloring
- small clear container
- (optional) thermometer, 0 – 100˚C
B-2. Pour about 100 ml cold water into the small container, and add 10 drops of food coloring. Pour about 200 ml hot water into the cylindrical container. Optional: Have one or two students measure the temperature of the two fluids.

B-3. Draw the cold, dyed water through the plastic tubing by pulling out the syringe plunger until the syringe is full. Carefully position the open end of the plastic tubing at the bottom of the cylindrical container of hot water, then slowly expel the cold, dyed water by pushing in the syringe plunger.

B-4. Tell students to record their observations on the Buoyancy and Vents Guided Design Portfolio Sheet. Students should continue to observe the fluids in the cylindrical container for two minutes, and record any additional observations at the end of this time.

B-5. Empty both of the containers. Pour about 100 ml hot water into the small container, and add 10 drops of food coloring. Pour about 200 ml cold water into the cylindrical container. Optional: Have one or two students measure the temperature of the two fluids.

B-6. Draw the hot, dyed water through the plastic tubing by pulling out the syringe plunger until the syringe is full. Carefully position the open end of the plastic tubing at the bottom of the cylindrical container of cold water, then slowly expel the hot, dyed water by pushing in the syringe plunger. Tell students that this models some features of hydrothermal vent fluid when it enters the cold water of the deep ocean. Have students record their observations on the Buoyancy and Vents Guided Design Portfolio Sheet. Students should continue to observe the fluids in the cylindrical container for two minutes, and record any additional observations at the end of this time.

B-7. Instruct students to answer questions in Part B of the Buoyancy and Vents Guided Design Portfolio Sheet. When all groups have completed their answers, lead a discussion of the results.

- Students should have observed that when dyed cold water enters hot water, it forms a more or less motionless mass at the bottom of the cylindrical container. The mass slowly mixes with the surrounding hot water. In this part of the demonstration, the cold water had the higher density, so the warm water remained above the cold water.

- When dyed hot water enters cold water, students should have observed that the hot water rises toward the top of the cylindrical container, and that swirls (eddies) form on the edges of the rising plume of hot water. The hot water mixes much more quickly with the cold water, and cannot be seen after a few
In this part of the demonstration, the cold water had the higher density, so the warm water rose through the cold water toward the surface.

- When hydrothermal vent fluid rises through cold ocean water, it forms eddies similar to those observed in the second part of the demonstration. These eddies bring cold seawater into the plume, and this process gradually increases the density of the plume. At some point, usually within a few hundred meters of the bottom, the density of the plume becomes equal to the density of the surrounding seawater. At this point the plume is neutrally buoyant, and stops rising. This is why hydrothermal vent plumes are typically found within a few hundred meters of the bottom, instead of rising all the way to the ocean surface. Over time, the plume will gradually mix with the surrounding seawater.

Students’ inferences may vary from this description if they do not consider that the ocean is much deeper than the cylindrical container used in the demonstration, and that eddies will bring seawater into the plume and change its density.

The BRIDGE Connection
www.vims.edu/bridge/ – Click on “Ocean Science Topics” in the menu on the left side of the page, then select “Geology” or “Habitats” for activities and links about hydrothermal vent formation and ecology.

The “Me” Connection
Have students write a brief essay discussing how the properties of density and buoyancy could be personally important.

Connections to Other Subjects
English/Language Arts; Life Science; Social Studies (Geography)

Assessment
Written reports and class discussions provide opportunities for assessment.

Extensions
2. Visit the education sections of Web sites provided in Step 1 for additional activities about hydrothermal vents.
Multimedia Discovery Missions

http://oceanexplorer.noaa.gov/edu/learning/welcome.html – Click on the links to Lessons 1 and 5 for interactive multimedia presentations and Learning Activities on Plate Tectonics and Chemosynthesis and Hydrothermal Vent Life.

Other Relevant Lesson Plans from NOAA’s Ocean Exploration Program

The Okeanos Explorer Atlas
(from the Galapagos Rift 2011 Expedition)
http://oceanexplorer.noaa.gov/okeanos/explorations/ex1103/background/edu/media/ex1103_exatlas.pdf

Focus: Time, speed, distance, and velocity (Physical Science)

Students define velocity, and explain why this is a vector quantity; use the Okeanos Explorer Atlas to obtain information about position and movement of the NOAA Ship Okeanos Explorer, and calculate velocity from information about geographic position at two different times.

A Hydrothermal AdVENTure
(from the Galápagos Rift 2011 Expedition)
http://oceanexplorer.noaa.gov/okeanos/explorations/ex1103/background/edu/media/ex1103_hladvent.pdf

Focus: Hydrothermal vents (Earth Science)

Students explain the overall structure of hydrothermal vents and how they are related to the motion of tectonic plates, and will create a model of a hydrothermal vent.

Earth’s Ocean is 95% Unexplored: So What?
(from the INDEX-SATAL 2010 Expedition)
http://oceanexplorer.noaa.gov/okeanos/explorations/10index/background/edu/media/so_what.pdf

Focus: Importance of deep ocean exploration (Life Science/Earth Science)

Students describe at least three different deep ocean ecosystems; explain at least three reasons for exploring Earth’s deep ocean; and explain at least three ways that deep ocean ecosystems may benefit humans.

Let’s Make a Tubeworm!
(from the INDEX-SATAL 2010 Expedition)
http://oceanexplorer.noaa.gov/okeanos/explorations/10index/background/edu/media/tubeworm.pdf
Focus: Hydrothermal vent ecosystems (Life Science)

Students explain the overall structure of hydrothermal vents and how they are related to the motion of tectonic plates; describe the process of chemosynthesis in general terms; contrast chemosynthesis and photosynthesis; describe the anatomy of vestimentiferans; and explain how these organisms obtain their food.

A Day in the Life of an Ocean Explorer
(from the Okeanos Explorer Education Materials Collection, Volume 2: How Do We Explore?)
http://oceanexplorer.noaa.gov/oceanos/edu/lessonplans/media/hdwe_56_dayinlife.pdf

Focus: Telepresence and communications for ocean exploration (Physical Science)

Students identify the basic requirements for human communication; describe at least three ways in which humans communicate; discuss the importance of scientific communication; and explain the concept of telepresence, how it is implemented aboard the NOAA Ship Okeanos Explorer, and how it is used to increase the pace, efficiency, and scope of ocean exploration.

Wet Maps
(from the Okeanos Explorer Education Materials Collection, Volume 2: How Do We Explore?)
http://oceanexplorer.noaa.gov/oceanos/edu/lessonplans/media/hdwe_56_wetmaps.pdf

Focus: Bathymetric mapping (Physical Science/Earth Science)

Students describe three types of bathymetric map, and discuss how each type may be used by ocean explorers; compare and contrast bathymetric mapping technologies; explain why multibeam mapping is used aboard the Okeanos Explorer; and simulate a multibeam sonar system to create a three-dimensional map of a model seafloor.

What’s a CTD?
(from the Okeanos Explorer Education Materials Collection, Volume 2: How Do We Explore?)

Focus: Measuring physical properties of seawater for ocean exploration (Physical Science)
Students define “CTD” and explain how this instrument is used aboard the Okeanos Explorer; define salinity and density; explain how relationships between temperature, salinity, and density in seawater are useful to ocean explorers; and use data from the Okeanos Explorer to create and interpret graphs of temperature, salinity, and depth.

Invent a Robot!
(from the Okeanos Explorer Education Materials Collection, Volume 2: How Do We Explore?)
http://oceanexplorer.noaa.gov/oceanos/edu/lessonplans/media/hdwe_56_inventrobot.pdf

Focus: Engineering Design (Physical Science/Technology)

Students discuss advantages and disadvantages of using underwater robots in scientific explorations, and how underwater robots are used aboard the Okeanos Explorer; use the process of engineering design to develop potential solutions for an ocean exploration problem; and explain the principle of hydraulic power transfer systems, and construct a robotic arm that demonstrates this principle.

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://www.ncddc.noaa.gov/website/google_maps/OkeanosExplorer/mapsOkeanos.htm – Web site for the Okeanos Explorer Atlas, which provides a map-based link to information about current and previous ocean exploration expeditions conducted aboard the NOAA Ship Okeanos Explorer

http://celebrating200years.noaa.gov/edufun/book/welcome.html#book - A free printable book for home and school use introduced in 2004 to celebrate the 200th anniversary of NOAA; nearly 200 pages of lessons focusing on the exploration, understanding, and protection of Earth as a whole system

http://www.nationalgeographic.com/xpeditions/lessons/07/g35/seasvents.html – National Geographic Xpeditions lesson plan, We’re
in Hot Water Now: Hydrothermal Vents, includes links to National Geographic magazine articles and video with an emphasis on geography and geographic skills


Correlations
Framework for K-12 Science Education
A. Scientific and Engineering Practices
   1. Asking questions and defining problems
   2. Developing and using models
   3. Planning and carrying out investigations
   4. Analyzing and interpreting data
   5. Using mathematics and computational thinking
   6. Constructing explanations and designing solutions
   7. Engaging in argument from evidence
   8. Obtaining, evaluating, and communicating information

B. Crosscutting Concepts
   2. Cause and effect: Mechanism and explanation
   4. Systems and system models
   7. Stability and change

C. Disciplinary Core Ideas
   Physical Sciences
   Core Idea PS1: Matter and Its Interactions
   Core Idea PS2: Motion and Stability: Forces and Interactions
      PS2.A: Forces and Motion
      PS2.C: Stability and Instability in Physical Systems
   Earth and Space Sciences
   Core Idea ESS2: Earth’s Systems
      ESS2.B: Plate Tectonics and Large-Scale System Interactions
   Engineering, Technology, and the Applications of Science
   Core Idea ETS1: Engineering Design
      ETS1.A: Defining and Delimiting an Engineering Problem
      ETS1.B: Developing Possible Solutions
      ETS1.C: Optimizing the Design Solution
Ocean Literacy Essential Principles and Fundamental Concepts

Essential Principle 2.
The ocean and life in the ocean shape the features of the Earth.

Fundamental Concept a. Many earth materials and geochemical cycles originate in the ocean. Many of the sedimentary rocks now exposed on land were formed in the ocean. Ocean life laid down the vast volume of siliceous and carbonate rocks.

Fundamental Concept e. Tectonic activity, sea level changes, and force of waves influence the physical structure and landforms of the coast.

Essential Principle 5.
The ocean supports a great diversity of life and ecosystems.

Fundamental Concept g. 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 7.
The ocean is largely unexplored.

Fundamental Concept a. The ocean is the last and largest unexplored place on Earth—less than 5% of it has been explored. This is the great frontier for the next generation’s explorers and researchers, where they will find great opportunities for inquiry and investigation.

Fundamental Concept b. Understanding the ocean is more than a matter of curiosity. Exploration, inquiry and study are required to better understand ocean systems and processes.

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

Fundamental Concept f. Ocean exploration is truly interdisciplinary. It requires close collaboration among biologists, chemists, climatologists, computer programmers, engineers, geologists, meteorologists, and physicists, and new ways of thinking.

Common Core State Standards for Mathematics

Grade 5
Geometric measurement: understand concepts of volume and relate volume to multiplication and to addition.

Grade 6
Solve real-world and mathematical problems involving area, surface area, and volume.
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.

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Credit
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To Sink, To Rise, or To Float
Buoyancy and Vents Guided Design Portfolio Sheet

Part A. Neutral Buoyancy Design Challenge –
1. Define the problem.
   State the problem in your own words:

   _______________________________________________________________
   _______________________________________________________________
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   _______________________________________________________________
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2. Gather relevant information.
   List information that you think is needed to find solutions for the problem:

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3. **Brainstorm possible solutions.**
   Use words or sketches to describe some possible solutions:

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   ______________________________________________________
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4. **Analyze possible solutions and select the most promising.**
   State which of the possible solutions is most promising and why:

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   ______________________________________________________
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5. **Test the solution by building a prototype.**
   The test will be a contest described by your teacher.
6. **Revise and improve the solution.**
   Based on the results of the contest, describe improvements that you might make to the selected solution:

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7. **Report the design process and results.**
   Summarize your conclusions:

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To Sink, To Rise, or To Float
Buoyancy and Vents Guided Design Portfolio Sheet

Part B. Buoyancy of Hydrothermal Vent Plumes
1. Your teacher will show you a demonstration that models some features of hydrothermal vent fluid when it enters the cold water of the deep ocean. Record your observations below.
   (a) Dyed, Cold Water Entering Hot Water:
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   (b) Dyed, Hot Water Entering Cold Water:
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2. In Part (a) of the demonstration (Dyed, Cold Water Entering Hot Water), which fluid had the higher density?

How does this explain your observations during Part (a) of the demonstration?

3. In Part (b) of the demonstration (Dyed, Hot Water Entering Cold Water), which fluid had the higher density?

How does this explain your observations during Part (b) of the demonstration?
4. Use your answers to Question 3 to predict what happens to hydrothermal vent fluid when it enters the cold water of the deep ocean:

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5. Does the density of hydrothermal vent fluid change when it enters the cold water of the deep ocean? Why or why not?

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6. When ocean explorers look for new hydrothermal vent sites, they look for masses of seawater that have been changed by hydrothermal vent fluids. Masses of changed seawater are called plumes, and are usually found within a few hundred meters of the ocean floor. How does your answer to Question 5 explain the presence of hydrothermal vent plumes a few hundred meters above the ocean floor?

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