For centuries, people have been challenged by the mysteries that lie beneath the blue depths of our ocean planet. Very little was known about the ocean until late in the nineteenth century, although nearly three-quarters of the planet is covered by ocean or seawater. Myths and misconceptions abounded. We used to think that the ocean depths were devoid of life. We thought that the seafloor was flat and that it was the same age as the continents. How different a picture we now have of the ocean as the sea has begun to yield its secrets. In the 1870s, the HMS *Challenger* left England and sailed the world's oceans, throwing out weighted lines and taking soundings to measure the depths of the Atlantic, Pacific, Indian, and Arctic Oceans. For the first time, scientists had an inkling of the contours of the ocean floor, took samples of the plants and animals, and measured differences in water temperature and salinity. But the cold, dark water and extreme pressure of the depths kept scientists from knowing the secrets of the deep abyss. Following in the footsteps of those pioneering oceanographers, today's scientists have overcome many of the challenges of the deep by using more sophisticated tools. They can send manned submersibles and sampling devices to plumb the ocean depths, taking photographs and samples of animal life and sediment to bring back to the surface for further study. Even space technology enters the picture. Satellite photos taken of the ocean provide a wide range of information, including water temperature and depth, seafloor topography, and the plankton populations. Using sonar and satellite data, scientists have been able to generate a new map of the ocean floor, thirty times more accurate than the best previous map. This map shows the ruggedness of the Mid-Ocean Ridge as it bisects the Atlantic Ocean. This contrasts to the relatively flat Pacific Ocean floor, its vast expanse broken up by more than a thousand newly discovered underwater volcanoes stretching from Hawaii to the Aleutians. And to what does this vast treasure trove of data lead?

Sea Secrets

For scientists, there is a broader understanding of how the ocean basin formed and continues to evolve. Molten magma from Earth's interior spews out at the mid-ocean ridges, spilling over to either side and hardening to rocky basalt. As the crust pushes away from the ridges, it cools and thins, forming new seafloor and thus "widening" the ocean here. As this portion of the ocean floor widens, a section of the seafloor elsewhere is slowly sliding beneath the crust, becoming part of Earth's magma once again. Plate tectonics, the theory of Earth's crustal plates, thus helps explain ocean formation. New observations also give scientists a greater understanding of the dynamic nature of Earth's water and oxygen cycles and how planetary winds affect ocean currents. Data allow scientists to hypothesize about global weather systems, earthquake and volcanic activity, and climatic trends of global consequence. Understanding the interactions of the ocean and marine life gives us an indication of the planet's health and the effects of human activity. The development of new technologies for underwater exploration has led to exciting and lucrative expeditions. Photographs of the doomed *Titanic* taken by remote cameras from a submersible craft as it probed deep in the North Atlantic captured the imagination of the world. Recently declassified information about the locations of sunken World War II vessels has attracted adventurers and investors who would like to bring up rich cargoes. The old romantic notion of diving for Spanish pieces of eight from pirate shipwrecks in the Caribbean has been replaced by the idea of using sonar and other sensors to locate sunken submarines carrying gold. But whether in pursuit of knowledge or profit, all of these activities contribute to our understanding of the ocean.

Sea Secrets
Lesson Plan

Objectives

Identify some of the features of the ocean, including a continental shelf, a deep ocean plain, a trench, and a mid-ocean ridge.

Draw a profile of the ocean using data points.

Infer the conditions of some undersea locations.

Materials

Student Pages

pencil, straightedge

Optional: world map, globe

Optional: small aquarium, sand, water, salt, metal objects

Subjects

social studies, oceanography, mathematics

Procedure

1. To introduce Sea Secrets, ask students to name the highest and lowest places on Earth's crust. They may name Mt. Everest and the Grand Canyon, respectively. Tell them that the tallest mountains and deepest canyons are found in the ocean. The Hawaiian Islands would dwarf Mt. Everest. These islands are merely the tops of huge mountains that have their base on the deep floor of the Pacific. Also in the Pacific is the deepest trench on the Earth, the Mariana Trench. It measures eleven kilometers below the sea's surface—seven times the depth of the Grand Canyon. The Pacific, named by Magellan because it looked peaceful, is the largest feature on Earth. It can look tranquil sometimes; but at other times huge waves roll, typhoons blow, and tsunamis strike the coast. Spin a globe and have students observe how great an area of Earth the Pacific occupies. Spin the globe again, and have students find and name the Atlantic, Indian, and Arctic Oceans.

2. Ask students to speculate on how people have learned about the ocean. They may know that many a sailor who went out to sea on a great clipper ship never actually went into the water—many of them could not swim. They measured depth using ropes and did their best to stay out of the briny deep. Tell students how the HMS *Challenger* went out to sea in 1872, and for three years the crew mapped and charted the many mountains and valleys of the ocean floor. Today we have a "window" into the gloom of the deep sea and can map the contours using sophisticated equipment. We use sonar—sound waves that bounce off the bottom of the ocean and back up to a research ship. The longer it takes for the sound to bounce back, the deeper the ocean floor. In some ways, robotic submersibles are like spacecraft charting the unknown regions of space. We have core samplers that drill holes into the ocean bottom and bring up layers of sediment.

3. Have students imagine they are taking the *Johnson Sea Link*, a submersible research vessel, into the gloomy darkness of the abyss. By five hundred feet below the surface, it is already dark on the sunniest day. Off the coast of Florida, it might take an hour to get down to the seafloor. The incredible water pressure of a million pounds per square inch actually squeezes the thick walls of the small capsule. Creatures of fantastic shapes are viewed for the first time by human eyes as they pass through the craft's lights. Robotic arms carefully funnel gauze-like invertebrate animals into sampling containers. The animals are brought up to the surface and studied.

4. Discuss with students how mapping, photographing, and taking core samples from the ocean floor have helped scientists to conclude how the oceans formed. Earth's crust is both younger and thinner beneath the ocean than it is under the continents. That is because new ocean floor is continually forming at the mid-ocean ridges. These ridges wrap around Earth like the seams on a baseball. Coming off the sides of the ridges are "rift valleys," from which molten rock from within Earth pours out like lava from a volcano. When it cools, it forms new ocean floor. As the rock cools, magnetic particles in the lava are frozen, pointing in the direction of the North Pole. Scientists have matched these particles with periods of pole shifts in the geologic record. They have also matched the particles on both sides of the ridge, showing that they have spread apart. The discovery of these matching "magnetic stripes" in the rocks surrounding the mid-ocean ridges propelled the theory of plate tectonics into the forefront of geology.

5. One interesting connection between biology and plate tectonics involves the life cycle of green sea turtles. The fact that South American green sea turtles swim to tiny Ascension Island in the middle of the Atlantic to lay eggs may help prove the theory of plate tectonics. Some scientists hypothesize that the ancestors of these animals made this journey before the continents were so far apart. The turtles have continued this behavior over many generations as the distance across the Atlantic has gradually increased by several centimeters each year.

6. Tell students that the deep, flat portions of the ocean floor are referred to as the abyss or the abyssal plain. Trenches occur where one of Earth's crustal plates is sliding under another. The continental slope is the area of ascent that leads to the continental shelf, the underwater edge of a continent.

7. Hand out the student pages. Have students examine the map of the Atlantic Ocean. Explain that it shows what the ocean would look like if all the water were removed. Compare the area of the map to a wall map of the world, then have students find the labeled continental shelves, abyssal plains, continental slopes, trenches, and ridges. Parts of the Atlantic trenches are more than eight kilometers deep. To make that distance more meaningful to students, use the distance between two familiar landmarks in your area (eight kilometers equal five miles). Or have them figure out how many school buses (each about ten meters long) would have to line up to cover a distance of eight thousand meters (eight hundred). Tell them that parts of the Atlantic Ocean are that deep from the surface down to the ocean floor.

8. When students seem ready to work on their own, have them plot the data points to draw an ocean profile between Florida and Dakar, Senegal. (These data are approximate and have been simplified somewhat.) Make sure students understand that a profile is a side view of the ocean floor if you made the journey along a straight line between two locations.

9. Tell students that this treasure hunt for the location of gold is based on real salvage efforts to bring up the cargo of a World War II Japanese submarine torpedoed en route to Europe with supplies of precious metals. It takes the work of people of many nations to accomplish such a task. This activity raises the issue of respect for the dead who were lost with the vessel as well as more temporal and legal disputes about who owns bounty that lies in international waters. Tell students that a nation has legal rights to waters two hundred miles off its coast. At one time countries claimed a mere three miles because that was as far as a cannonball could reach. Later, the limit was extended to twelve miles, then two hundred.

10. When students finish their profiles, have them answer the questions on the student page. They will find that the Nares Deep and Cape Verde Basins are the deepest areas in this section of the ocean and that they are separated by the Mid-Atlantic Ridge. The sunken sub is located at data point 11 at a depth of five and a half kilometers. To work on such a project, they would likely operate from the Cape Verde Islands, the closest landmass. They would probably choose to use a remotely operated vehicle because of the great depth and risk. Perhaps they would choose to erect a memorial to those who died in the sub. Gold survives well under adverse conditions because it does not react easily with other compounds and thus does not corrode like other metals or deteriorate like organic materials.

11. Challenge students to make a model ocean profile using a small aquarium, sand, and water. They can make their own seawater by dissolving thirty-five grams of salt for every liter of water. They might bury a metallic object at a specific location and challenge other students to find it without disturbing other parts of the ocean floor.

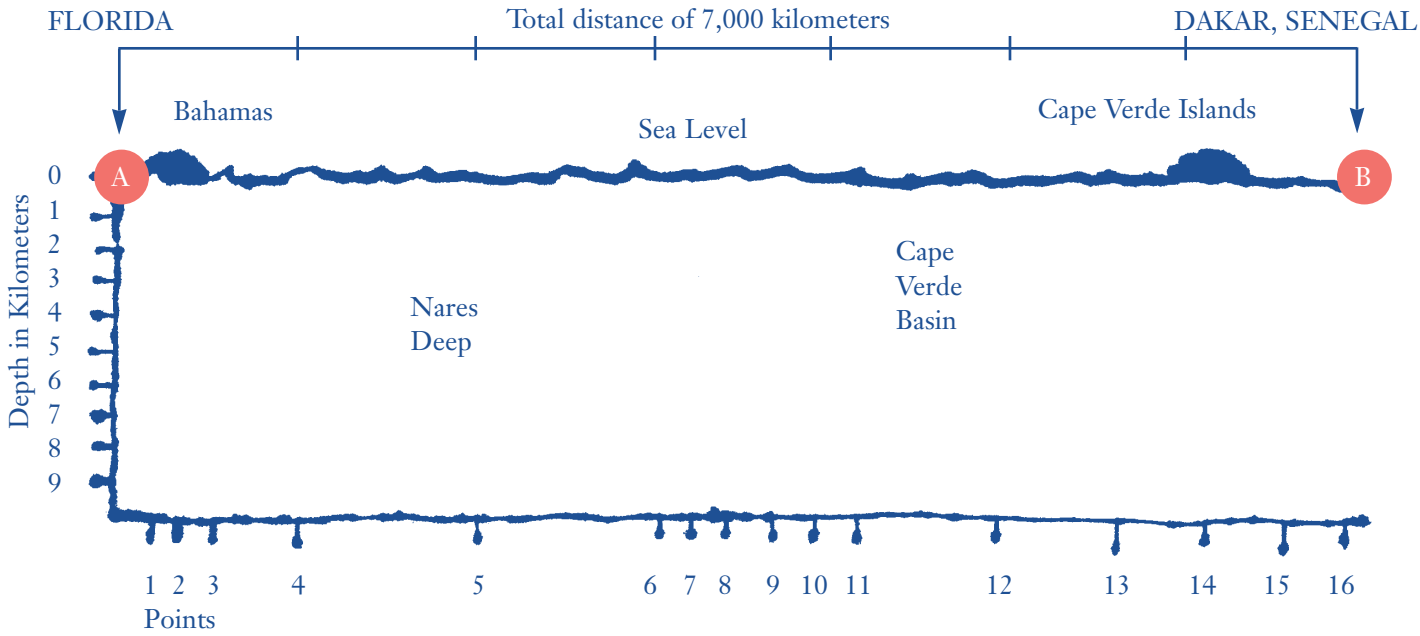
Sea Secrets Student Page

How does the sea reveal its secrets? What does the ocean floor look like? Scientists have a rough idea based on depth soundings and satellite pictures from space. The picture of the Atlantic Ocean that you see here is what the seafloor would look like if somebody could "pull the plug" and drain the water. The Atlantic Ocean floor is very rugged, with as many ups and downs as there are on land.

Find the Sunken Sub

Student Page

Find points A and B on the map—one in Florida and one in Dakar, Senegal, in West Africa. Connect the two with a straight line. Somewhere along this route there is a sunken submarine from World War II, filled with two tons of gold. To find the treasure sub you will have to draw an ocean profile on the chart provided.



1. Use the data to plot the depth of each point onto the chart, then connect the dots.
2. Label the two continental slopes—the parts of the ocean profile that show the steep drop from the continental shelf to the deep ocean plains.
3. Name two parts of the Atlantic that have depths of six kilometers.
4. Label the area of the Mid-Atlantic Ridge.
5. Now you're ready to locate the sunken treasure sub. It is located at the data point approximately two thousand kilometers west of the Cape Verde Islands and east of the Mid-Atlantic Ridge. How deep is it? Mark the spot on your profile.
6. Answer these questions on another sheet of paper.

a. Do you think you'll send down a team to look at the sub, or will you use a remotely operated vehicle?

b. Do you think that you'll make your base of operations the Cape Verde Islands or the Bahamas? Why?

c. What will you do about preserving the memory of sailors who went down with the sub?

d. Why does gold stay preserved in the deep? What happens to other materials that have been there for fifty years?

Point Location	Approx. Ocean Floor Depth in km.
1	1.2
2	above sea level
3	5.0
4	5.9
5	6.3
6	5.8
7	2.0
8	3.0
9	2.0
10	3.5
11	5.5
12	6.0
13	5.0
14	above sea level
15	1.8
16	above sea level

Resources

Online resources

The September/October 1995 issue of the Office of Elementary and Secondary Education's quarterly curriculum guide, *Art to Zoo* (**http://educate.si.edu/art-to-zoo/azindex.htm**), explores the relation between the world's oceans and the weather. A background essay, four lesson plans, and activity sheets help teach students about currents and navigation, coastal and inland climates, and changes in weather due to El Niño.

Visit Ocean Planet online at **http://seawifs.gsfc.nasa.gov/ocean_planet.html**.

Using the Exhibition Topic Outline, look under Ocean Science to become fully immersed in ocean exploration. Under the Resource Room, go to the Image Catalog for photographs and illustrations of submersibles and other equipment used to plumb the depths of the sea. To view the latest images of the ocean compiled from satellite and sonar data, look at the National Oceanic and Atmospheric Administration's global gravity map at **http://www.ngdc.noaa.gov/mgg/announcements/announce_predict.html**.

Resources for students

Conley, Andrea. *Window on the Deep: The Adventures of an Underwater Explorer*, Sylvia Earle. New York: Franklin Watts, 1991.

Simon, Seymour. *Oceans.* New York: Morrow Junior Books, 1990

Waters, John F. *Deep-Sea Vents: Living Worlds without Sun.* New York: Cobblehill Books, 1994.

Resources for teachers

Duxbury, Alyn C., and Alison B. Duxbury. *An Introduction to the World's Oceans.* 4th ed. Dubuque, Iowa: William C. Brown, 1994.

Whipple, A.B.C. *Planet Earth: Restless Oceans.* New York: Time-Life Books, 1983.