INDEX/SATAL 2010

Earth's Ocean is 95% Unexplored: So What?

Image captions/credits on Page 2.

lesson plan

Focus

Deep ocean exploration

Grade Level

5-6 (Earth Science/Life Science)

Focus Question

Why is it important to explore the deep ocean in places such as Indonesia?

Learning Objectives

- Students will be able to describe at least three different deep ocean ecosystems.
- Students will be able to explain at least three reasons for exploring Earth's deep ocean.
- Students will be able to explain at least three ways that deep ocean ecosystems may benefit humans.

Materials

- Materials for creating Wall Magazines (see Learning Procedure, Step 4); may include poster board, colored markers, construction paper, glue, lightweight craft material for constructing three-dimensional objects that can be attached to posters (e.g., pipe cleaners, colored yarn, Styrofoam, floral sponge)
- Copies of Fact Sheets; one copy of each Fact Sheet for each student group

Audio-Visual Materials

- (Optional) Video or computer projection equipment; see Learning Procedure Step 1.

Teaching Time

Two 45-minute class periods, plus time for student research and creation of Wall Magazines

Seating Arrangement

Groups of 4-6 students

Maximum Number of Students

30

The NOAA Ship *Okeanos Explorer*
Formerly: USNS *Capable*
Launched: October 28, 1988
Transferred to NOAA: September 10, 2004
Commissioned: August 13, 2008
Class: T-AGOS
Length: 224 feet
Breadth: 43 feet
Draft: 15 feet
Displacement: 2,298.3 metric tons
Berthing: 46 (19 Mission/science)
Speed: 10 knots
Range: 9600 nm
Endurance: 40 days

Systems and Instumentation:
Kongsberg EM302 Multibeam rated to 7,000 m
SBE 911 Plus CTD
ROVs -
- Little Hercules - 4,000 m depth rating; USBL tracking; depth, altitude, attitude/heading sensors; Seabird SBE 49 FastCat CTD; HD camera and HMI lights
- Camera platform with depth/altitude/heading sensors, HD cameraand HMI lights.

Telepresence

Operations:
Ship crewed by NOAA Commissioned Officer Corps and civilians through NOAA's Office of Marine and Aviation; Mission equipment operated by NOAA's Office of Ocean Exploration and Research

For more information, visit http://oceanexplorer.noaa.gov/okeanos/welcome.html.

Images from Page 1 top to bottom:
The ROV Hercules being lowered into the water from the NOAA Ship *Okeanos Explorer*. Image credit: NOAA OER.

NOAA scientists examining live video feed from the ROV Hercules. Image credit: NOAA OER.

Mussels, shrimp, limpets, and crabs cover the slope of an underwater volcano near a hydrothermal vent. Image credit NOAA
http://www.photolib.noaa.gov/bigs/expl0071.jpg

Black smokers on the Kermadec Arc. Image courtesy of New Zealand American Submarine Ring of Fire 2007 Exploration, NOAA Vents Program, the Institute of Geological & Nuclear Sciences and NOAA-OE.
http://oceanexplorer.noaa.gov/explorations/07fire/logs/july31/media/brothers_blacksmoker_600.jpg

Key Words

Hydrothermal vent
Cold seep
Plate tectonics
Tsunami
Earthquake
Volcano
Seamount

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.

During the summer of 2010, scientists from Indonesia and the United States will work together on an expedition to explore the deep ocean surrounding Indonesia. This mission is called INDEX/SATAL 2010, since the expedition is focussed on INDonesia, EXploration, and the Sangihe Talaud (SATAL) region. Working from the Indonesian Research Vessel *Baruna Jaya IV* and the NOAA Ship *Okeanos Explorer*, these ocean explorers expect to find new deep-sea ecosystems, undiscovered geological features, and living organisms that have never been seen before. New discoveries are always exciting to scientists; but information from ocean exploration is important to everyone, because:

- Biodiversity in deep-sea ecosystems includes new species that can provide important drugs and other useful products;
- Some deep-sea ecosystems include organisms that can be used for human food;
- Information from deep ocean exploration can help predict earthquakes and tsunamis; and
- Human benefits from deep ocean systems are being affected by changes in Earth's climate and atmosphere.

Biodiversity –

Indonesia is well-known as one of Earth's major centers of biodiversity (which means the variety of all forms of life). Although Indonesia covers only 1.3 percent of Earth's land surface, it includes:

- 10 percent of the world's flowering plant species;
- 12 percent of the world's mammal species;
- 16 percent of all reptile and amphibian species;
- 17 percent of the world's bird species;
- 15 percent of the world's coral reefs;
- the highest number of coral species in the world (more than 600 identified species); and
- more than 2000 species of near shore fishes.

Indonesia's Research Vessel
Baruna Jaya IV

Port of Registry - Jakarta, Indonesia
Purpose - Oceanography, Fishery
Launched - 1995
Length - 60.4 m
Width - 12.10 m
Draft - 4.15 m
Draft mean - 4.15m
Cruising speed - 10 kts
BPPT Indonesia - owner
17 crew, 33 scientists, and engineers

Deck Gear:
6 ton A-Frame
3 ton Crane
2 - Gilson Winches
2 - Otter Trawl Winches
Hydrographic Winch

Oceanographic Equipment:
Seabeam ELAXC1050D Multibeam
Seabeam ELAC 1190 Multibeam
ELAC 4700
Acoustic Doppler Current Profiler RDI Broadband
Sea Bird SBE-911 CTD with Rosette
Aanderaa, MORS, RDI current meters
Gravity Core Sediment Sampler
Oretech 3000 Subbottom Profiler
Edge Tech 4200-MP Sidescan Sonar

Fishery Equipment:
Mid- and Deep-water Fisheries Trawl
Koden Fish Finder
Simrad EK 500
Plankton Net

Very little is known about Indonesia's deep ocean, but scientists expect to find high biodiversity there as well, along with new ecosystems and many species that have never been seen before.

Conditions in the deep-sea environment include very high pressures, total darkness, extreme temperatures, and toxic chemicals. Hydrothermal vents, for example, are deep ocean habitats where hot fluids erupt from the seafloor. These habitats are found near mid-ocean ridges where Earth's tectonic plates are spreading apart. The ridges are formed by hot lava that erupts between spreading tectonic plates. Hydrothermal vents are produced when cold seawater seeps down into Earth's crust through cracks in the ocean floor near mid-ocean ridges. As the seawater moves deeper into the crust, it is heated by molten rock. As the temperature increases, sulfur and metals such as copper, zinc, and iron dissolve from the surrounding rock into the hot fluid. Eventually, the mineral-rich fluid rises again and erupts from openings in the seafloor. The temperature of the erupting fluid may be as high as 400°C, and contains hydrogen sulfide. When the hot hydrothermal fluid meets cold (nearly freezing) seawater, minerals in the fluid precipitate. The precipitated mineral particles give the fluid a smoke-like appearance, so these vents are often called black smokers or white smokers, depending upon the types of minerals in the fluid. Precipitated minerals may also form chimneys that can be several meters high.

The conditions around hydrothermal vents would be deadly to humans and many other species, but deep ocean explorers have found living organisms with special adaptations that allow them to thrive in the deep-sea environment. Some of these adaptations produce new drugs and other useful products. At present, almost all drugs produced from natural sources come from terrestrial plants, but marine organisms 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.

Seamounts are another little-explored deep-sea habitat. Seamounts are undersea mountains that are usually the remains of submarine volcanoes. They rise more than 1,000 m from the deep ocean floor and are entirely underwater. Seamount slopes are very steep, and produce current patterns that bring nutrients from deeper waters. These nutrients enhance the growth of marine plants that support complex food webs in the vicinity of seamounts.

Most deep-water fishes are not considered commercially-important because their flesh lacks protein and has a watery consistency that makes them unattractive as food for humans. In the 1980's, however, fishermen discovered large populations of deep water fishes living around seamounts. These fishes had firm, tasty flesh and high protein and lipid content. Moreover, these fishes were ten times more abundant than other deep-water fishes in neighboring areas. Unfortunately, many seamount species have been overfished. Seamount fish populations may be managed for smaller scale artisanal fisheries that are sustainable and still provide food and economic benefits for local communities. This type of management depends upon information on deep-sea ecosystems and populations that can come from deep ocean exploration.

Natural Disasters –

The geology of the seafloor around Indonesia is very complex and active. Active geology means that the land and seafloor of Indonesia frequently experience volcanoes, earthquakes, and tsunamis. Volcanoes in Indonesia have caused more human fatalities and generated more tsunamis than any other volcanic region on Earth. The reason for this geologic activity is that Indonesia is located at the junction of several tectonic plates that make up Earth's crust. Collisions between these plates cause volcanoes and earthquakes, and may also cause tsunamis.

On a global scale, Earth's crust seems to be divided into 14 large plates (Figure 1). At this scale, Indonesia is located at the junction of the Eurasian, Pacific, India, and Australian Plates. In many places, including Indonesia, there are also many smaller plates that make the geology much more complex. Figure 2 illustrates some of these smaller plates. The India and Australian Plates are pushing underneath the Burma and Sunda Plates, forming an arc of volcanoes in western Indonesia. To the east, several smaller plates collide in various ways that also produce earthquakes and volcanoes.

Motion between these plates is not constant, because friction between the plates tends to keep them from moving. But while they are not moving, tectonic forces cause stresses to accumulate in the upper plate which gradually become deformed. Stresses may accumulate over centuries, until the deformation suddenly releases causing the plate to rebound. This plate motion produces an earthquake, as well as a giant underwater "kick" that generates a tsunami. The Banda Aceh earthquake and tsunami on December 26th, 2004 was caused by a sudden slip when the India Plate slid beneath the Burma Plate.

Figure 1.
Global view of Earth's major tectonic plates.

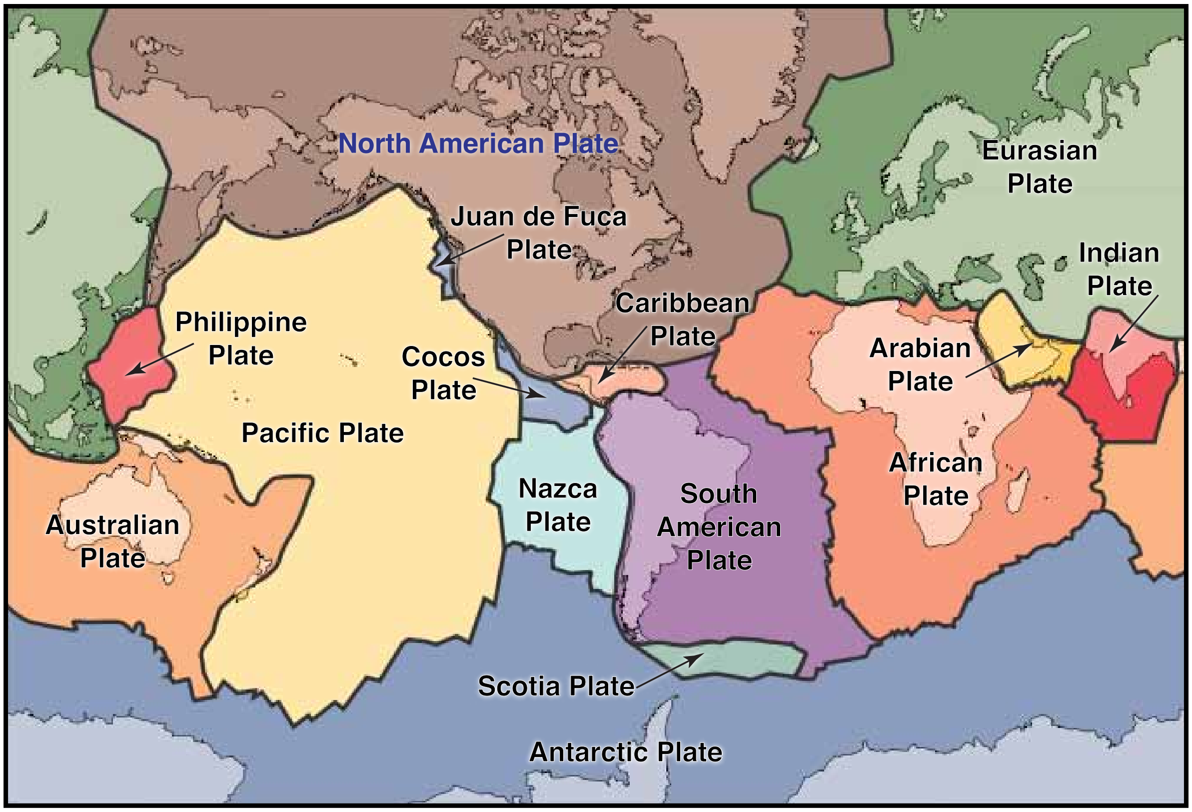
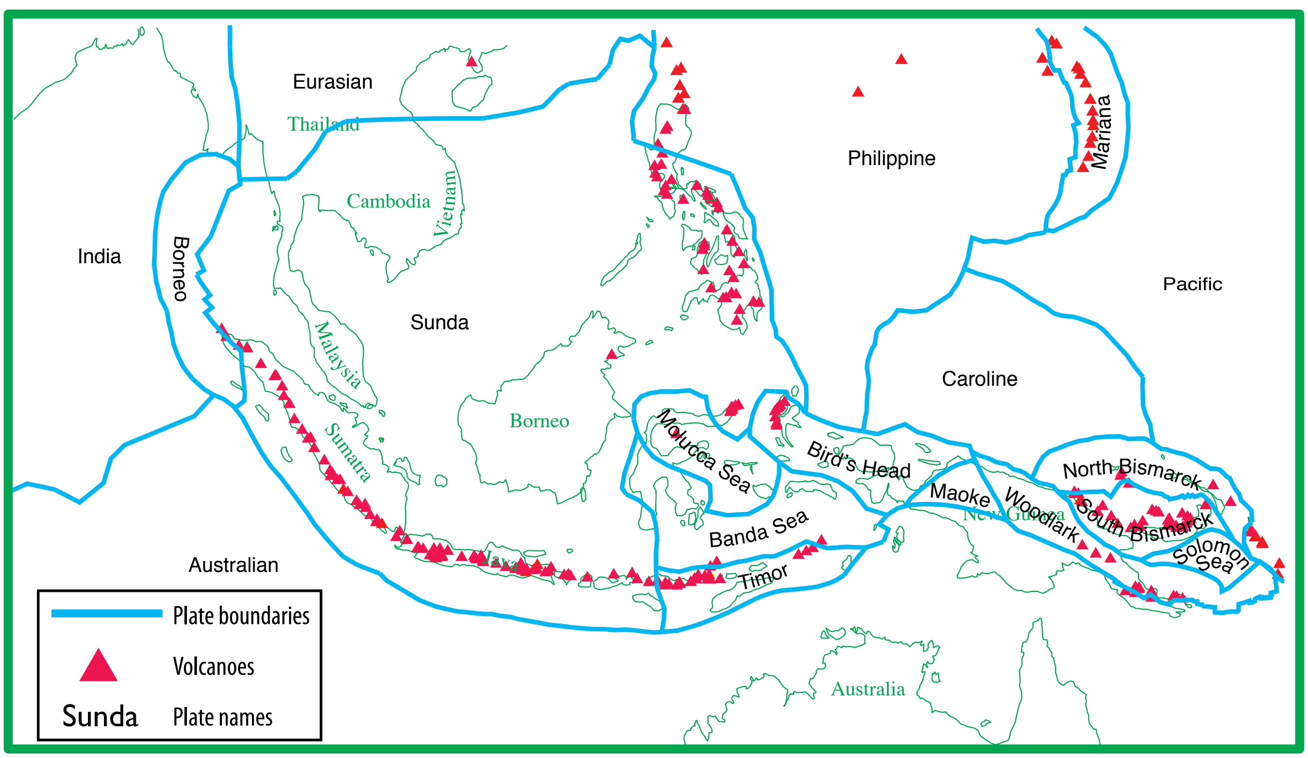


Figure 2.
Smaller tectonic plates in Indonesia.



Deep ocean explorations in other areas have mapped deformation patterns in tectonic plates, and used these patterns to predict earthquake and tsunami hazards. Similar information from Indonesia's deep ocean can be used to help prepare for these hazards.

Effects of Climate Change –

Earth's average temperature is now warmer than it has been at any time since at least 1400 AD. It is important to remember that averages include numbers that are higher and lower than the "average" value. So the warming in some areas can be much higher than the average while other areas may actually be cooler. Debate continues about the causes of climate change, but it is clear that

- Mountain glaciers are melting;
- Polar ice is decreasing;
- Springtime snow cover has diminished;
- Ground temperature has been increasing in many areas;
- Sea level has risen by several inches in the last 100 years.

Sea level rise makes coastal communities more vulnerable to storms and flooding. Another concern for Indonesia is the effect of higher temperatures on coral reefs. Many scientists believe that the health of many coral reefs is declining because of multiple stresses, one of which is increased water temperature.

While the deep ocean might seem to be far away from the atmosphere, deep sea currents transport heat throughout the world's ocean. This deep ocean circulation is sometimes called the "global conveyor belt," and has a significant influence on Earth's climate. Some scientists are concerned that warmer temperatures at the ocean surface and increased freshwater inflow from melting ice may weaken the global conveyor belt. Ocean exploration can provide some of the essential knowledge about ocean-atmosphere interactions that is needed to understand, predict, and respond to these impacts.

Interaction between Earth's ocean and atmosphere is producing another stress that affects many marine organisms. Carbon dioxide in Earth's atmosphere has been increasing for many years, and this has caused more carbon dioxide to be dissolved in the ocean. This increase in dissolved carbon dioxide is causing ocean waters to become more acidic. Increased acidity interferes with the formation of shells and other skeletal structures in corals, shellfish, echinoderms, plankton and many other ocean plants and animals.

This lesson guides student inquiries into reasons for exploring Earth's deep ocean.

Learning Procedure

1. To prepare for this lesson:
   (a) Review introductory essays for the INDEX/SATAL 2010 Expedition at http://oceanexplorer.noaa.gov/okeanos/explorations/10index/welcome.html
   (b) Review background information about why it is important to explore Indonesia's deep ocean provided in the previous section and on the Deep Ocean Exploration Fact Sheets.
   (c) Make copies of Fact Sheets for student groups. You may want to provide each group with all four fact sheets, or have different groups focus on different reasons for deep ocean exploration.

2. Briefly introduce the INDEX/SATAL 2010 Expedition, highlighting that this expedition is a joint effort between scientists from Indonesia and the United States to explore Indonesia's deep ocean. Ask students for their ideas about why this kind of exploration might be important. You may want to mention some of the reasons discussed in the Background section, or allow students to discover this information on their own from Deep Ocean Exploration Fact Sheets or from other sources.

3. Tell students that very few people think about the deep ocean or understand why its exploration is important, but that they are about to learn a lot about why scientists are eager to explore the deep ocean around Indonesia. Explain that a very important part of science and exploration is communicating results to other people. For this reason, students have two assignments:
   - First, to find out about some of the reasons that it is important to explore Indonesia's deep ocean; and
   - Second, to communicate the results of their research to other people by creating a Wall Magazine. Explain that in many Asian countries, Wall Magazines are a popular communication tool for schools and other community groups.

4. Provide each student group with one of the Deep Ocean Fact Sheets, and some materials that they may use to create their Wall Magazine. Most students will be familiar with the idea of creating posters or bulletin boards, but emphasize that groups may also use a variety of materials and that they should be creative with layout (for example, the overall shape might look like a fish or shell), as well as content (for example, they may include their own articles, poems, short stories, illustrations, or other artwork). Note that Wall Magazines are a powerful and entertaining way to hone students' skills in writing and communication, information search and analysis, and presenting ideas in an aesthetic yet meaningful manner. Some of the best Wall Magazines consist of text and illustrations created entirely by students themselves.

5. Have each student group present and explain their Wall Magazine to the rest of the class. You may also want to invite other students, parents, or members of the community to these presentations.

The BRIDGE Connection

www.vims.edu/bridge/ – Click on "Ocean Science Topics" in the menu on the left side of the page, then select "Habitats" then "Deep Ocean," or select "Human Activities" then "Technology" for activities and links about deep ocean ecosystems or useful products from deep sea habitats respectively.

The "Me" Connection

Have students write a brief essay discussing how they expect to personally benefit from deep ocean exploration.

Connections to Other Subjects

English/Language Arts, Fine Arts, Social Studies

Assessment

Wall Magazines and class discussions provide opportunities for assessment.

Extensions

1. Visit http://oceanexplorer.noaa.gov/okeanos/explorations/10index/welcome.html for the latest activities and discoveries by the INDEX/SATAL 2010 Expedition.
2. Create models of some deep ocean organisms or features, such as tubeworms from hydrothermal vents (see http://oceanexplorer.noaa.gov/explorations/02mexico/background/edu/media/gom_tube_gr56.pdf), hydrothermal vent habitats (see http://oceanexplorer.noaa.gov/explorations/10chile/background/edu/media/aydrothermal.pdf), or underwater volcanoes (see http://celebrating200years.noaa.gov/edufun/book/MakeyourownVolcano.pdf).

Multimedia Discovery Missions

http://oceanexplorer.noaa.gov/edu/learning/welcome.html – Click on the links to Lessons 1, 3, 5, 6, and 12 for interactive multimedia presentations and Learning Activities on Plate Tectonics, Deep-Sea Corals, Chemosynthesis and Hydrothermal Vent Life, Deep-Sea Benthos, and Food, Water, and Medicine from the Sea.

Other Relevant Lesson Plans from NOAA's Ocean Exploration Program

And Now for Something Completely Different...

(PDF, 172 kb) (from the 2005 GalAPAGos: Where Ridge Meets Hotspot Expedition)

http://oceanexplorer.noaa.gov/explorations/05galapagos/background/edu/media/05galapagos_dfferent.pdf

Focus - Biological communities at hydrothermal vents (Life Science)

In this activity, students will identify and describe organisms typical of hydrothermal vent communities near the Galapagos Spreading Center, explain why hydrothermal vent communities tend to be short-lived, and identify and discuss lines of evidence which suggested the existence of hydrothermal vents before they were actually discovered.

InVENT a Deep-Sea Invertebrate

(PDF, 460 kb) (from the 2002 Galapagos Rift Expedition)

http://oceanexplorer.noaa.gov/explorations/02galapagos/background/education/media/gal_gr5_6_l3.pdf

Focus - Galapagos Rift Ecosystem: Structure and Function in Living Systems (Life Science)

In this activity, students will design an invertebrate capable of living near deep-sea hydrothermal vents, and in doing so, will learn about the unique adaptations that organisms must have in order to survive in the extreme environments of the deep sea.

Let's Make a Tubeworm!

(PDF, 464 kb) (from the 2002 Gulf of Mexico Expedition)

http://oceanexplorer.noaa.gov/explorations/02mexico/background/edu/media/gom_tube_gr56.pdf

Focus: Symbiotic relationships in cold-seep communities (Life Science)

In this activity, students will be able to describe the process of chemosynthesis in general terms, contrast chemosynthesis and photosynthesis, describe major features of cold seep communities, and list at least five organisms typical of these communities. Students will also be able to define symbiosis, describe two examples of symbiosis in cold seep communities, describe the anatomy of vestimentiferans, and explain how these organisms obtain their food.

Living With the Heat
(PDF, 88 kb) (from the Submarine Ring of Fire 2002 Expedition)
http://oceanexplorer.noaa.gov/explorations/02fire/background/education/media/ring_living_heat_5_6.pdf

Focus: Hydrothermal vent ecology and transfer of energy among organisms that live near vents. (Life Science/Physical Science)

In this activity, students will be able to describe how hydrothermal vents are formed and characterize the physical conditions at these sites, explain what chemosynthesis is and contrast this process with photosynthesis, identify autotrophic bacteria as the basis for food webs in hydrothermal vent communities, and describe common food pathways between organisms typically found in hydrothermal vent communities.

When Plates Collide
(PDF, 1.1 Mb) (from the INSPIRE: Chile Margin 2010 Expedition)
http://oceanexplorer.noaa.gov/explorations/10chile/background/edu/media/whenplates.pdf

Focus:Plate Tectonics – Movement of plates, results of plate movement, and the Chile Triple Junction

Students will describe the motion of tectonic plates, compare and contrast three typical boundary types that occur between tectonic plates, describe the plate boundaries that occur and the Chile Triple Junction, and explain why a variety of chemosynthetic communities are expected to occur in this area.

A Hydrothermal AdVENTure
(PDF, 948 Kb) (from the INSPIRE: Chile Margin 2010 Expedition)
http://oceanexplorer.noaa.gov/explorations/10chile/background/edu/media/aydrothermal.pdf

Focus:Hydrothermal Vents

Students will 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.

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/okeanos/explorations/10index/welcome.html – Web site for the INDEX/SATAL 2010 Expedition, with links to lesson plans, career connections, and other resources

http://oceanexplorer.noaa.gov/okeanos/edu/welcome.html – Web page for the NOAA Ship *Okeanos Explorer* Education Materials Collection

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.

http://www.divediscover.whoi.edu/vents/index.html – Woods Hole Oceanographic Institution's Dive and Discover Web site about hydrothermal vents includes details about vent formation, education resources, and the story of the discovery of the first hydrothermal vent in 1977.

Bird, P. (2003). "An updated digital model of plate boundaries". Geochemistry, Geophysics, Geosystems 4 (3): 1027. http://peterbird.name/publications/2003_PB2002/2003_PB2002.htm

http://explore.noaa.gov/special-projects/indonesia-u-s-scientific-and-technical-cooperation-in-ocean-exploration/files/Corals_for_WOC_-_FINAL.pdf – NOAA Fact Sheet about coral reefs

http://explore.noaa.gov/special-projects/indonesia-u-s-scientific-and-technical-cooperation-in-ocean-exploration/files/Okeanos_Explorer_for_WOC_-_FINAL.pdf – NOAA Fact Sheet about the NOAA Ship *Okeanos Explorer*

National Science Education Standards

Content Standard A: Science As Inquiry

- Abilities necessary to do scientific inquiry
- Understandings about scientific inquiry

Content Standard C: Life Science
- Structure and function in living systems
- Populations and ecosystems
- Diversity and adaptations of organisms

Content Standard D: Earth and Space Science
- Structure of the Earth system

Content Standard E: Science and Technology
- Understandings about science and technology

Content Standard F: Science in Personal and Social Perspectives
- Personal health
- Populations, resources, and environments
- Natural hazards
- Risks and benefits
- Science and technology in society

Content Standard G: History and Nature of Science
- Science as a human endeavor

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

Essential Principle 4. The ocean makes Earth habitable.
Fundamental Concept b. The first life is thought to have started in the ocean. The earliest evidence of life is found in the ocean.

Essential Principle 5.
The ocean supports a great diversity of life and ecosystems.
Fundamental Concept b. Most life in the ocean exists as microbes. Microbes are the most important primary producers in the ocean. Not only are they the most abundant life form in the ocean, they have extremely fast growth rates and life cycles.
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 6.
The ocean and humans are inextricably interconnected.
Fundamental Concept b. From the ocean we get foods, medicines, and mineral and energy resources. In addition, it provides jobs, supports our nation's economy, serves as a highway for transportation of goods

and people, and plays a role in national security.
Fundamental Concept f. Coastal regions are susceptible to natural hazards (such as tsunamis, hurricanes, cyclones, sea level change, and storm surges).
Fundamental Concept g. Everyone is responsible for caring for the ocean. The ocean sustains life on Earth and humans must live in ways that sustain the ocean. Individual and collective actions are needed to effectively manage ocean resources for all.

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 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.

Send Us Your Feedback

We value your feedback on this lesson.
Please send your comments to:
oceanexeducation@noaa.gov

For More Information

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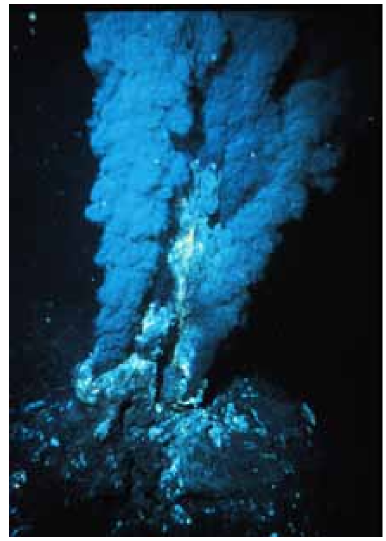
Acknowledgements

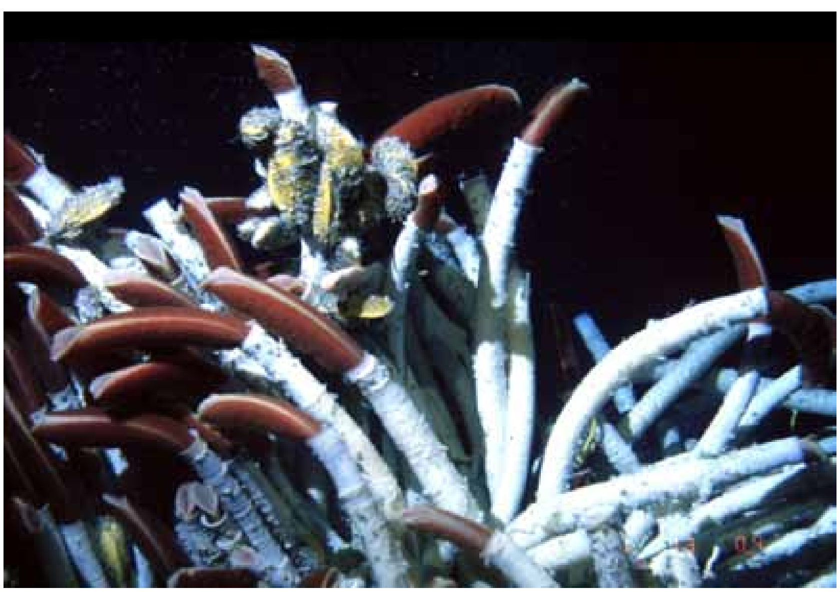
This lesson was developed by Mel Goodwin, PhD, Marine Biologist and Science Writer for NOAA's Office of Ocean Exploration and Research. Layout and design by Coastal Images Graphic Design, Charleston, SC. If reproducing this lesson, please cite NOAA as the source, and provide the following URL: http://oceanexplorer.noaa.gov/

Earth's Ocean is 95% Unexplored: So What?
Deep Ocean Exploration Fact Sheet No. 1

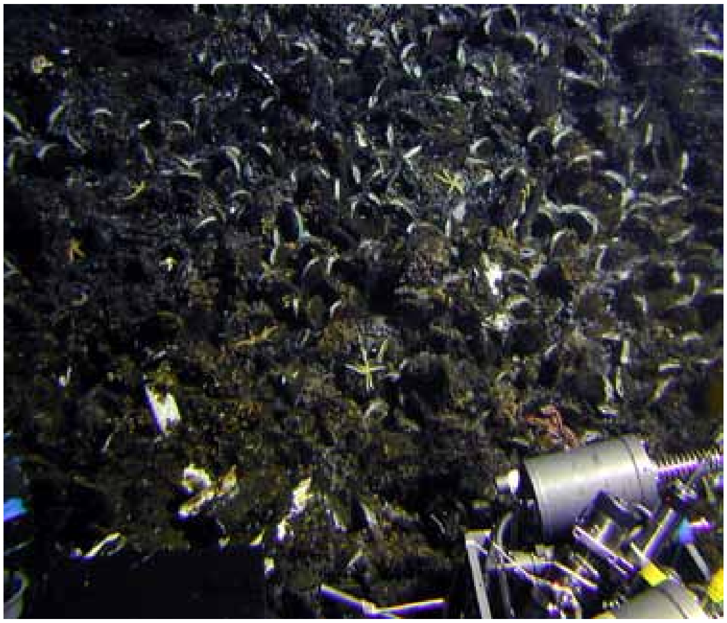
Deep-sea ecosystems include new species that can provide important drugs and other useful products.


Hydrothermal vent. *Image courtesy NOAA.*

Conditions in the deep-sea environment include very high pressures, total darkness, extreme temperatures,and toxic chemicals. Hydrothermal vents, for example, are deep ocean habitats where where hot fluids erupt from the seafloor. These habitats are found near mid-ocean ridges where Earth's tectonic plates are spreading apart (see Fact Sheet #3). The ridges are formed by hot lava that erupts between spreading tectonic plates. Hydrothermal vents are produced when cold seawater seeps down into Earth's crust through cracks in the ocean floor near mid-ocean ridges. As the seawater moves deeper into the crust, it is heated by molten rock. As the temperature increases, sulfur and metals such as copper, zinc, and iron dissolve from the surrounding rock into the hot fluid. Eventually, the mineral-rich fluid rises again and erupts from openings in the seafloor. The temperature of the erupting fluid may be as high as 400°C, and contains hydrogen sulfide. When the hot hydrothermal fluid meets cold (nearly freezing) seawater, minerals in the fluid precipitate. The precipitated mineral particles give the fluid a smoke-like appearance, so these vents are often called black smokers or white smokers, depending upon the types of minerals in the fluid. Precipitated minerals may also form chimneys that can be several meters high.


The giant tubeworm, *Riftia pachyptila*, from the hydrothermal vents at the East Pacific Rise at 2,500 m depth. Each individual in the photo exceeds one meter in length. *Image courtesy of Monika Bright, University of Vienna, Austria.*

Earth's Ocean is 95% Unexplored: So What?
Deep Ocean Exploration Fact Sheet No. 1 - pg 2



Mussels dominate the hydrothermal biological community at Rumble V volcano, just as at all the other volcanoes we have explored during this expedition. However, the Rumble V mussels are much larger (over a foot long) than found at the other sites. Image courtesy of New Zealand-American Submarine Ring of Fire 2005 Exploration, NOAA Vents Program.
http://oceanexplorer.noaa.gov/explorations/05fire/logs/hires/mussels_hires.jpg

The conditions around hydrothermal vents would be deadly to humans and many other species, but deep ocean explorers have found living organisms with special adaptations that allow them to thrive in the deep-sea environment. Hydrothermal vent tubeworms are a famous example. Some adaptations in deep sea organisms produce new drugs and other useful products.

Chemicals from microorganisms found around hydrothermal vents are promising for treating bone injuries and cardiovascular diseases. Other deep-sea species produce powerful chemicals that act as antibiotic, anti-cancer, and anti-inflammatory drugs in humans. At present, almost all drugs produced from natural sources come from terrestrial plants, but marine organisms produce more drug-like substances than any group of organisms that live on land. Other examples of useful products include microscopic organisms from hydrothermal vent ecosystems that produce proteins used by crime scene investigators to make billions of copies of DNA. Proteins from other organisms are used to make sweeteners for food additives.

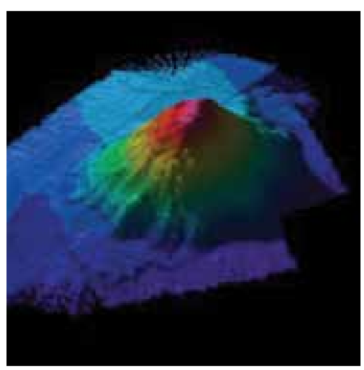
Hydrothermal vent fluids provide iron for the growth of a thick mat of orange bacteria near the Eifuku volcano. Image credit NOAA.
http://www.photolib.noaa.gov/bigs/expl0064.jpg

Earth's Ocean is 95% Unexplored: So What?
Deep Ocean Exploration Fact Sheet No. 2

Food from Deep-sea Ecosystems

Seamounts are another little-explored deep-sea habitat. Seamounts are undersea mountains that are usually the remains of submarine volcanoes. They rise more than 1,000 m from the deep ocean floor and are entirely underwater. Seamount slopes are very steep, and produce current patterns that bring nutrients from deeper waters. These nutrients enhance the growth of marine plants that support complex food webs in the vicinity of seamounts.

Most deep-water fishes are not considered commercially-important because their flesh lacks protein and has a watery consistency that makes them unattractive as food for humans. In the 1980's, however, fishermen discovered large populations of deep water fishes living around seamounts. These fishes had firm, tasty flesh with a high protein and lipid content. Moreover, these fishes were ten times more abundant than other deep-water fishes in neighboring areas. Unfortunately, many seamount species have been overfished. Seamount fish populations may be managed for smaller scale artisanal fisheries that are sustainable and still provide food and economic benefits for local communities. This type of management depends upon information on deep-sea ecosystems and populations that can come from deep ocean exploration.



Grenadiers, oreos, and armorheads are tasty food fish found on many seamounts, but are in danger of overexploitation from large-scale industrial fishing operations. *All photos courtesy NOAA.*

Earth's Ocean is 95% Unexplored: So What?
Deep Ocean Exploration Fact Sheet No. 3

Deep ocean exploration can help predict earthquakes and tsunamis.

The geology of the seafloor around Indonesia is very complex and active. Active geology means that the land and seafloor of Indonesia frequently experience volcanoes, earthquakes, and tsunamis. Volcanoes in Indonesia have caused more human fatalities and generated more tsunamis than any other volcanic region on Earth. The reason for this geologic activity is that Indonesia is located at the junction of several tectonic plates that make up Earth's crust. Collisions between these plates cause volcanoes and earthquakes, and may also cause tsunamis.

On a global scale, Earth's crust seems to be divided into 14 large plates (Figure 1). At this scale, Indonesia is located at the junction of the Eurasian, Pacific, India, and Australian Plates. In many places, including Indonesia, there are also many smaller plates that make the geology much more complex. Figure 2 illustrates some of these smaller plates. The India and Australian Plates are pushing underneath the Burma and Sunda Plates, forming an arc of volcanoes in western Indonesia. To the east, several smaller plates collide in various ways that also produce earthquakes and volcanoes.

Motion between these plates is not constant, because friction between the plates tends to keep them from moving. But while they are not moving, tectonic forces cause stresses to accumulate in the upper plate which gradually becomes deformed. Stresses may accumulate over centuries, until the deformation suddenly releases causing the plate to rebound. This plate motion produces an earthquake, as well as a giant underwater "kick" that generates a tsunami. The Banda Aceh earthquake and tsunami on December 26th, 2004 was caused by a sudden slip when the India Plate slid beneath the Burma Plate.

Deep ocean explorations in other areas have mapped deformation patterns in tectonic plates, and used these patterns to predict earthquake and tsunami hazards. Similar information from Indonesia's deep ocean can be used to help prepare for these hazards.

Figure 1.
Global view of Earth's major tectonic plates.

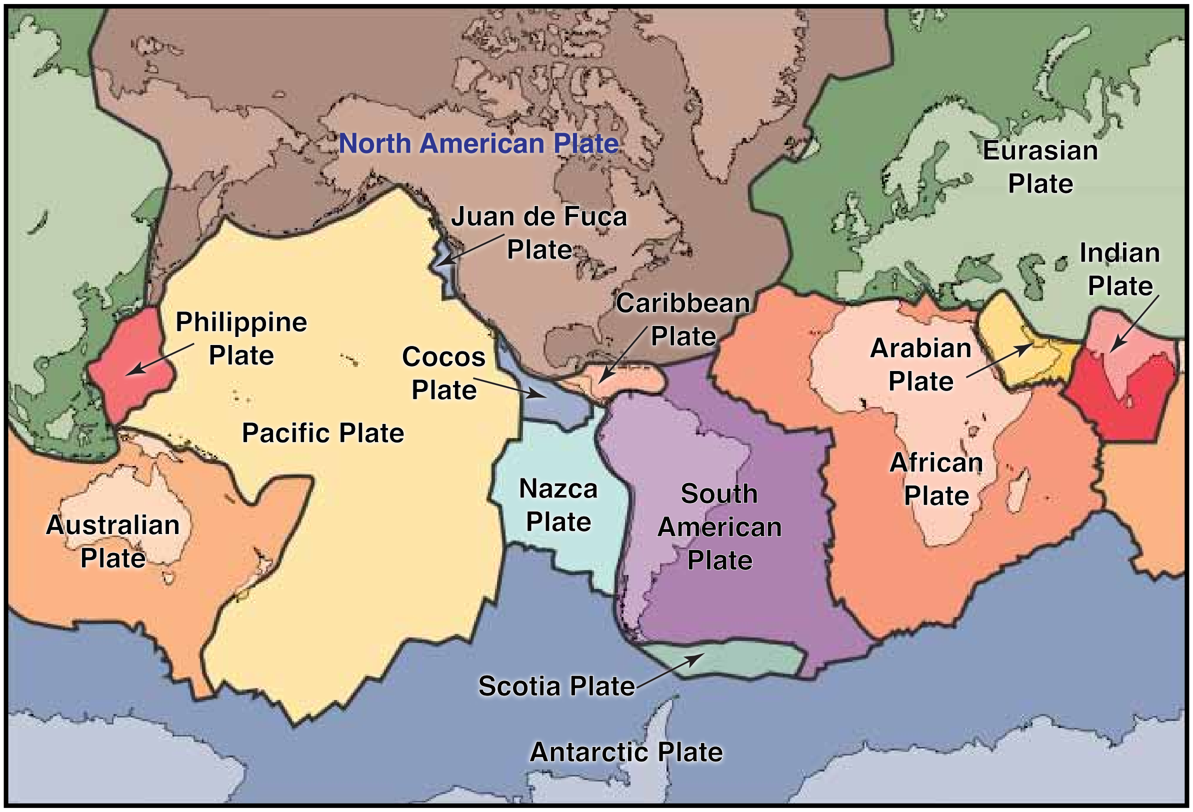
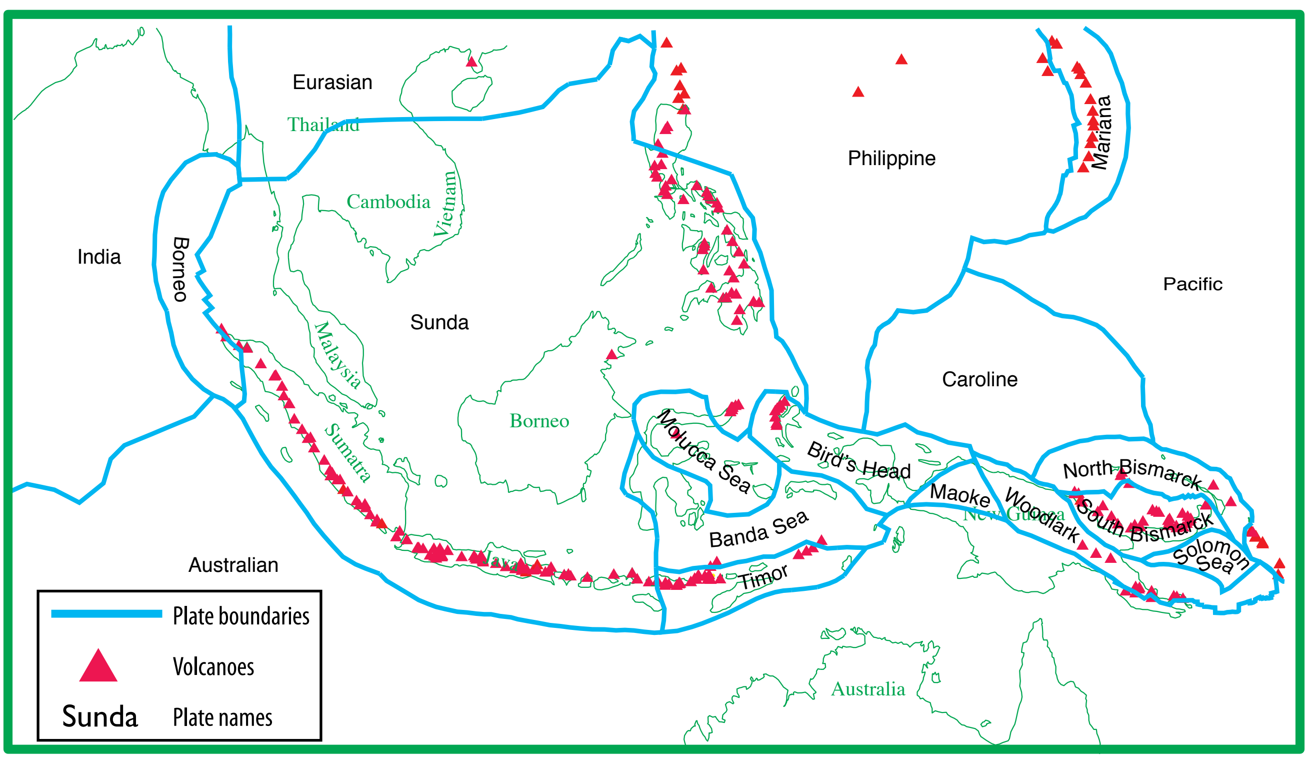


Figure 2.
Smaller tectonic plates in Indonesia.



Earth's Ocean is 95% Unexplored: So What?
Deep Ocean Exploration Fact Sheet No. 4

Changes in Earth's climate and atmosphere are affecting deep ocean systems.

Earth's average temperature is now warmer than it has been at any time since at least 1400 AD. It is important to remember that averages include numbers that are higher and lower than the "average" value. So the warming in some areas can be much higher than the average while other areas may actually be cooler. Debate continues about the causes of climate change, but it is clear that

- Mountain glaciers are melting;
- Polar ice is decreasing;
- Springtime snow cover has diminished;
- Ground temperature has been increasing in many areas;
- Sea level has risen by several inches in the last 100 years.

Sea level rise makes coastal communities more vulnerable to storms and flooding. Another concern for Indonesia is the effect of higher temperatures on coral reefs. Many scientists believe that the health of many coral reefs is declining because of multiple stresses, one of which is increased water temperature.

Limacina helicina, a free-swimming planktonic snail. These snails, known as pteropods, form a calcium carbonate shell and are an important food source in many marine food webs. As levels of dissolved CO_2 in sea water rise, skeletal growth rates of pteropods and other calcium-secreting organisms will be reduced due to the effects of dissolved CO_2 on ocean acidity. Image credit: Russ Hopcroft, UAF/NOAA.
http://www.noaanews.noaa.gov/stories2006/images/pteropod-limacina-helicina.jpg

While the deep ocean might seem to be far away from the atmosphere, deep sea currents transport heat throughout the world's ocean. This deep ocean circulation is sometimes called the "global conveyor belt," and has a significant influence on Earth's climate. Some scientists are concerned that warmer temperatures at the ocean surface and increased freshwater inflow from melting ice may weaken the global conveyor belt. Ocean exploration can provide some of the essential knowledge about ocean-atmosphere interactions that is needed to understand, predict, and respond to these impacts.

Interaction between Earth's ocean and atmosphere is producing another stress that affects many marine organisms. Carbon dioxide in Earth's atmosphere has been increasing for many years, and this has caused more carbon dioxide to be dissolved in the ocean. This increase in dissolved carbon dioxide is causing ocean waters to become more acidic. Increased acidity interferes with the formation of shells and other skeletal structures in corals, shellfish, echinoderms, plankton and many other ocean plants and animals.