

OCEANOGRAPHY

Teacher Guide
including
Lesson Plans, Student Readers, and More Information

Lesson 1 - Oceans

Lesson 2 - Oceanic Features (Lab)

Lesson 3 - Geologic Oceanography (Lab)

Lesson 4 - Chemical Oceanography

Lesson 5 - Physical Oceanography



*designed to be used as an Electronic Textbook
in class or at home*

materials can be obtained from the Math/Science Nucleus

EARTH SCIENCES - OCEANOGRAPHY

Lesson 1 - Oceans

MATERIALS:

reader

Objective: Students learn the physical, geologic, and chemical parameters of the oceans.

Teacher note

The oceanography section of this curriculum will focus on the geological, chemical, and physical parameters of the oceans. The oceans cover about 71% of the Earth's surface. The organisms found in the marine environment are discussed in the biological units.

Geological oceanography focuses on the sea floor features and sediments that are "rain" on the ocean's bottom. Students usually think that the ocean bottom is a flat bowl. The ocean bottom has canyons and mountains that rise higher and lower than any feature on land. Sediments that settle out on these features sometimes mask the topography. The ocean bottom is younger than the land. Mid-oceanic ridges produce new ocean floor, while trench areas caused by subduction, consume old ocean floor.

Chemical oceanography looks at the composition of ocean water. Over eons of time, erosion from the land added components through dissolution. Ocean water contains many naturally occurring elements. Marine water has a distinct "salty" taste. The chemistry of marine water also looks at the distribution of temperature and salinity and how different water masses are formed.

Physical oceanography focuses on the actual movement of water masses within the oceans. Students learn how and why currents exist and trace their movements.

There are many websites on oceanography that might be helpful in understanding the complexity of the oceans.

National Oceanographic and Atmospheric Agency

<http://www.noaa.gov/>

National Environment Satellite, Data, and Information Service

<http://www.nesdis.noaa.gov/>

Office of Satellite Data Processing and Distribution

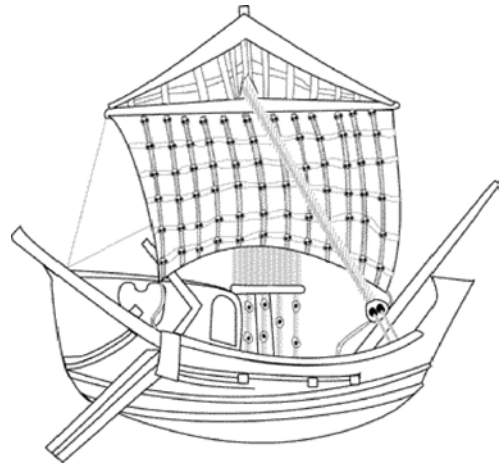
<http://www.osdpd.noaa.gov/>



Early Roman ship

The oceans have been a friend and foe of humans throughout history. It protected some civilizations from being invaded, while giving other civilizations the bounty of food and ease of transportation. Sailors have always been the adventurers, charting new courses to distant lands. They were half explorers and half crazy. While most land people felt ships could fall off the side of a flat world, most sailors knew that the oceans were endless. They could visually see there was a curve to our Earth as they were approaching land.

The early people who used the oceans had to become one with the oceans and the sky. Their very life depended on reading the sky in the day and night, to navigate to safety. They also needed to read the signals from the oceans that would warn them of upcoming storms or calm. The oceans were mysterious if you didn't interpret its signals correctly.



Tube worm living on the bottom of the oceans

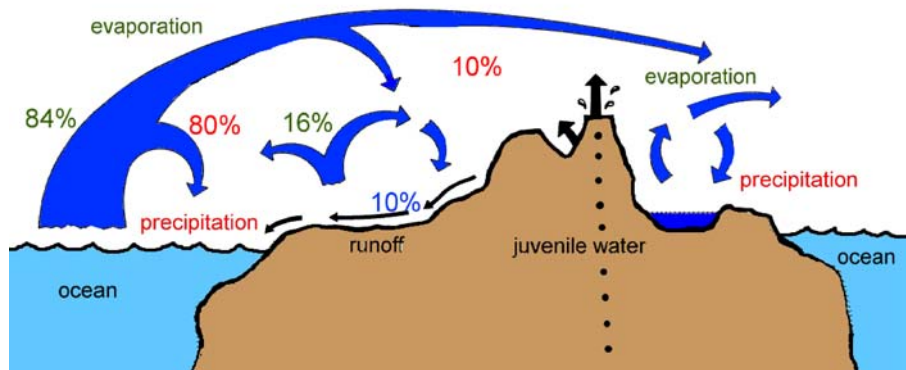
Oceanography is the scientific study of the ocean. Traditionally, the Earth has been viewed from land. However, if you look at the Earth from outer space, the oceans comprise 71% of the Earth's surfaces. The continents are really only the tops of high mountains from the ocean bottom. Oceanography is concerned with studying the biology, geology, chemistry, and physics of the oceans.

The oceans have evolved distinct features that are unique among the other planets in the Solar System.

The oceans harbor entire populations of organisms that use the marine environment to their benefit. The oceans also provide humans with valuable nutrition, transportation, and weather. Many organisms originated in the sea. The marine environments are more stable by continuously supplying the needs of organisms than the unforgiving land environments.



The oceans provide most of the water that is needed to fuel the water cycle on Earth. As the diagram shows, the majority of evaporation and precipitation occur over the oceans. Precipitation on land usually is dependant on how much moisture is left in the clouds as they move over land.

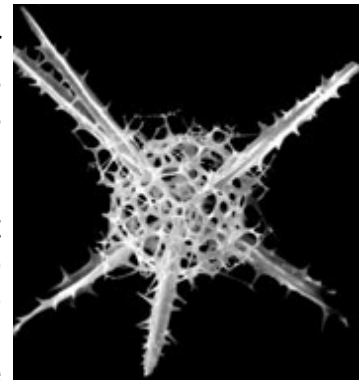


Distribution of water on the Earth's surface

The precipitation on land will create runoff. This will migrate down toward sea level bringing eroded sediment into the system. Most of the world's oceans are composed of 35 parts per million salts. This is called "**salinity**." The oceans have evolved through billions of years and represent the "end of the line" for rain water on land.

It is every drop of water's dream to live at sea level. Water precipitates on land and travels to sea through rivers. The rivers erode the land and chemically dissolves the components of rocks into ions. Over eons of time, most elements become dissolved in seawater. These ions help give the "flavor" to salt water.

Many of these ions can be combined into molecules that are used by living organisms. For example, little critters (protist) like foraminifers require CaCO_3 (calcium carbonate) to make skeletons. Radiolaria another protozoa require SiO_3 (silica dioxide) to make their skeleton.



Radiolaria



Sea ice

Other components can be dissolved in marine water while maintaining their own properties. Gases, like oxygen, are very important to help large organisms like fish survive. Small plants on the ocean's surface contribute the majority of oxygen in the water and the atmosphere.

The oceans become the largest holder of water. However, most land animals cannot use salt water directly. The only parts of the oceans that can be used as "fresh" water are icebergs. Only pure water can freeze, leaving behind the salt.

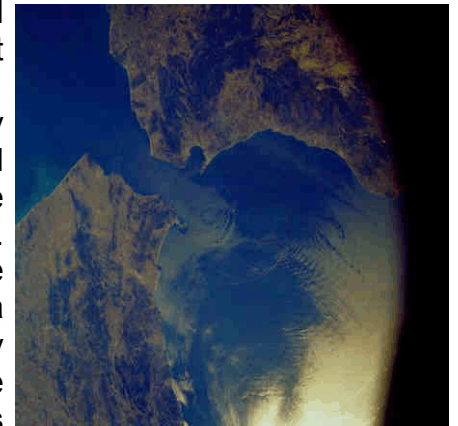


Defining the limits of the world oceans is difficult. There is no beginning and no end. The south Atlantic connects with the south Pacific in the southern part of South America. The Antarctica Ocean circulates through all the larger body of oceans. The oceans are in fact, connected and communicate with each other. Water can virtually travel around the world as it

moves from one area to another.

An **ocean** refers to the largest body of water. We generally think of three major oceans including the Pacific, Atlantic and Indian Ocean. The Arctic Ocean has communication with the Atlantic and Pacific, while the Antarctica Ocean touches all three.

Each of the oceans is subdivided into areas that have distinct geologic or chemical areas and these are referred to as “a **sea**.” The Mediterranean Sea for instance is physically confined by land, with only one outlet to the Atlantic Ocean. However, the **Sargasso Sea** in the western part of the Atlantic, is an area that is defined by its chemical make-up.

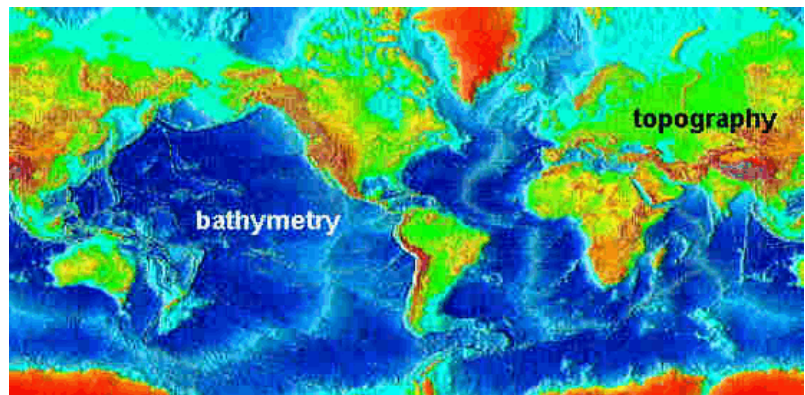


Strait of Gibraltar, Atlantic Ocean connection with Mediterranean Sea

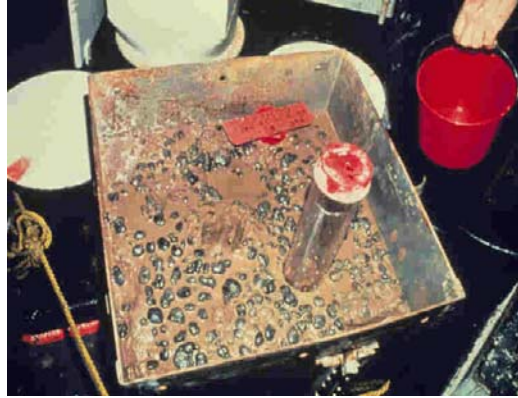
Topography refers to the elevation on land, and bathymetry is the depth of a depression. Sea level is an average level where topography and bathymetry both begin at zero for elevation and depth.

The **bathymetry** of the ocean floors varies, just like land. The eastern United States coast is shallower than the west coast of the United States. The deepest

trenches are found in the Marianas Trench in the south Pacific, which is the lowest point on the Earth’s surface. The Hawaiian Islands are just the tops of very high mountains. Seamounts are basically mountains that rise from the ocean floor but never surface. There are vast areas on the bottom of the oceans with no light and strange animals on an abyssal plain. There are also areas on the bottom where water of different densities can flow and erode just like rivers on the surface of the Earth.

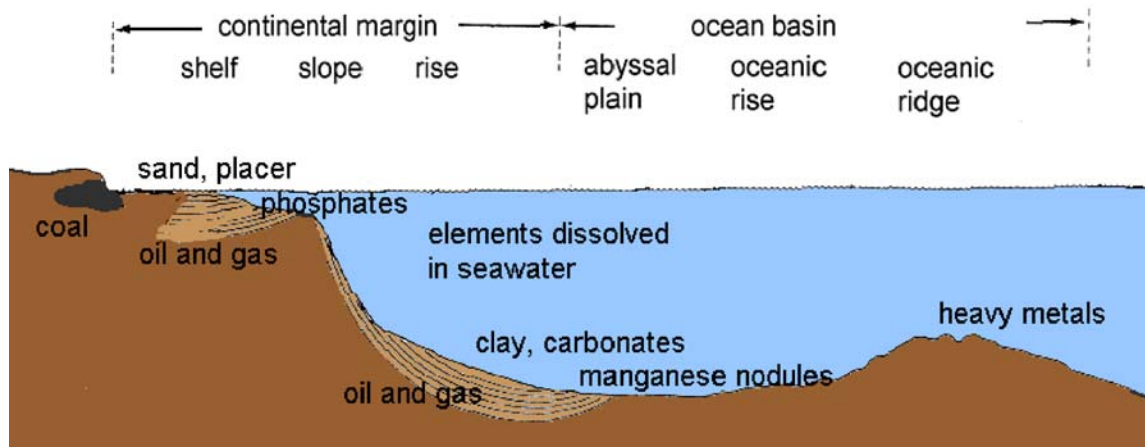


The oceans are important to humans not only because they fuel the amount of water that is available on land, but for their own natural resources. The oceans contain rich biological and mineralogical resources that help humans survive. The biological component includes marine life that humans and other organisms eat. In order for us to eat one fish, there would have been thousands of other organisms to provide food for that one fish through the food chain. Although the oceans do not have trees, they do have small plants that provide the necessary beginning of the food chain.



Manganese nodules from the Pacific Ocean

The bottom of the ocean contains resources like oil, gas, and heavy metals. But the sea also produces minerals like salt and gypsum that precipitate out of salt water. The bottom of the deep oceans is also a unique area where some mineral resources, like **manganese nodules** form in vast numbers. The oceans are a world unto themselves with many more habitats and features than land. You can only start learning all its secrets.



Divisions of the ocean bottoms

EARTH SCIENCES - OCEANOGRAPHY

Lesson 2 - Oceanic Features (Lab)

MATERIALS:

reader
topographic map of the ocean
physiographic relief map

Objective: Students will locate different ocean features using a world globe.

Teacher note

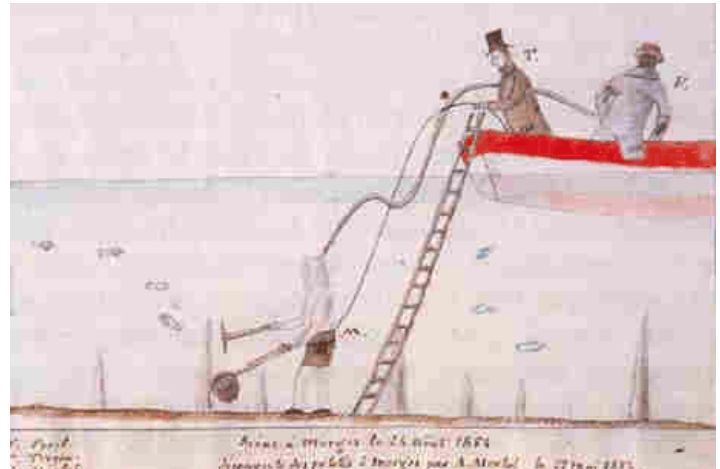
The major features of the ocean floor include the mid-oceanic ridge, the abyssal plain, fracture zones, seamounts, deep-sea trenches, and continental margins. These features may be explained in light of the theory of plate tectonics. The mid-oceanic ridge is a broad fractured arch of the sea floor. Sediment is thin or absent on the crest and thickest on the flanks. The abyssal floor consists of abyssal hills and abyssal plains (areas where abyssal hills are covered with sediment). Fracture zones cut the mid-oceanic ridge and show strong evidence of strike-slip movement and horizontal displacement of the sea floor. The size, shape, composition, and structure of seamounts indicate that they are similar to shield volcanoes. Deep-sea trenches are long, deep, linear depressions of the sea floor located adjacent to the subduction zones in the world. The continental slopes are typically covered with a thick sequence of sediments from the continents into which submarine canyons may have been eroded.

Sea floor surfaces were originally mapped using a process called echo sounding. Echo sounding uses the fact that ocean water is nearly transparent to sound waves. In other words, sound can travel through water. By accurately timing the interval between the transmission of a strong sound pulse by a ship and the detection of an echo from the bottom, it is possible to make accurate depth determinations and to draw profiles of the ocean bottom while the ship is underway. New advances in using sound waves (sonar) create clearer images. Seismic reflection can also be used to map the ocean floor. Pulses of energy are emitted from a ship and reflected back from the ocean floor. However, some of the energy penetrates the sediment and is reflected from the surface of the hard rock below. With the aid of electronics, a continuous profile of the sea floor and the configuration of the unconsolidated sediments are plotted automatically.

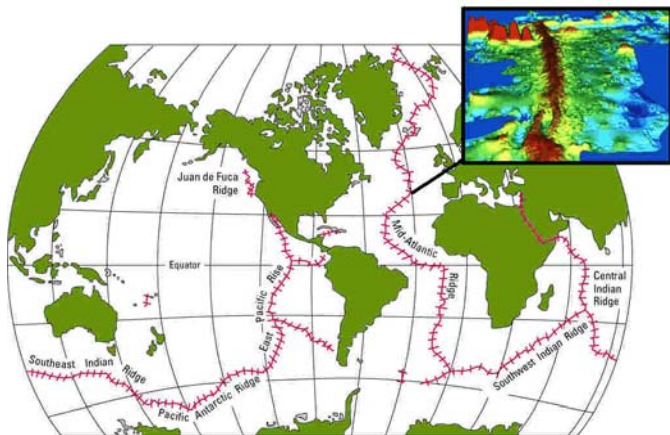
The type of map the students will be using is called a Physiographic map because it shows features and not just topography.

If you were a sailor, how would you find out if there were any dangers on the sea floor? How would you learn how deep the water is, or how water depth changes from place to place? Before the 20th century, the most common way to find the depth of the ocean was to use a sounding line. This was a rope with a lead weight attached to the end. The rope was tied in a knot every **fathom** (6 feet). A sailor would swing the line overhead and off the ship, and count the number of knots that went by before the weight hit the sea floor. This gave a good estimate of depth.

This depth information was very important. It allowed ships to navigate safely through unknown waters without being wrecked. By collecting many observations, early oceanographers learned that the sea floor gradually became deeper offshore. This region was called the **continental shelf**. However, the longest sounding lines were at most 1600 meters (1000 feet) long. Scientists and sailors quickly discovered that many parts of the ocean were deeper than this, but they could not tell what was there. Most people assumed the deep ocean floor was a broad, flat plain between the continents.



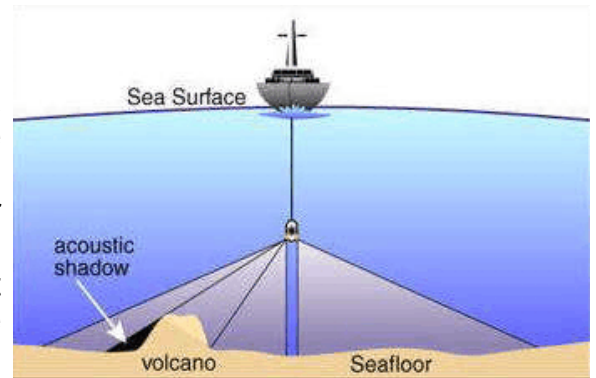
Early exploration of the ocean bottom



Insert of Mid-Atlantic Ridge

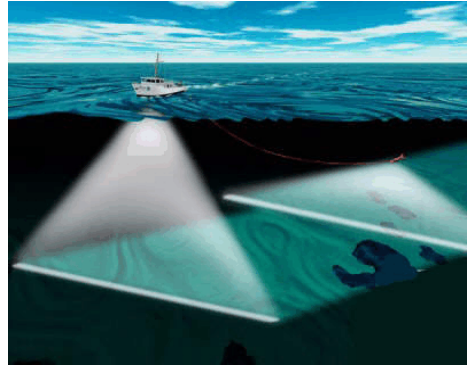
As more sonar work was done, underwater volcanoes, mountain ranges, and deep trenches were discovered. Sonar advances continued during and after the Second World War. Sonar work led to the development of the first global map of the sea floor, which was published in the 1960s. This information was very important in developing the geologic theory of plate tectonics.

In the First World War, **submarines** were used. To detect submarines, sonar was invented. Sonar machines broadcast sound pulses into the water, which reflect off submarines. **Sonar** could both locate and tell how far away submarines were. After the war, sonar was adapted to measure water depth. In the 1920's, this revolutionized scientists' understanding of the sea floor. As more

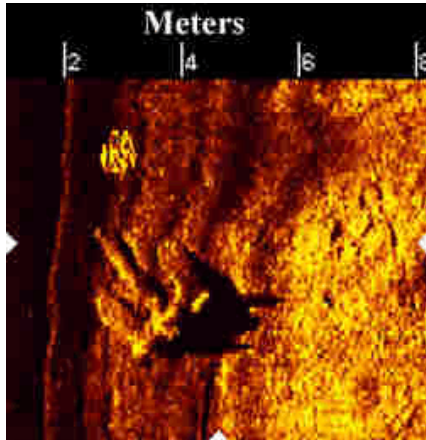


Principle of sonar

Sonar is still used today, but has gone through many technological improvements. One of the most important recent inventions is called side-scan sonar. Older sonar systems projected sound waves forward, in front of the ship. This was very useful for hunting submarines and navigation. In contrast, side-scan sonar projects sound waves sideways.



Sonar to the left and side scan sonar to the right.



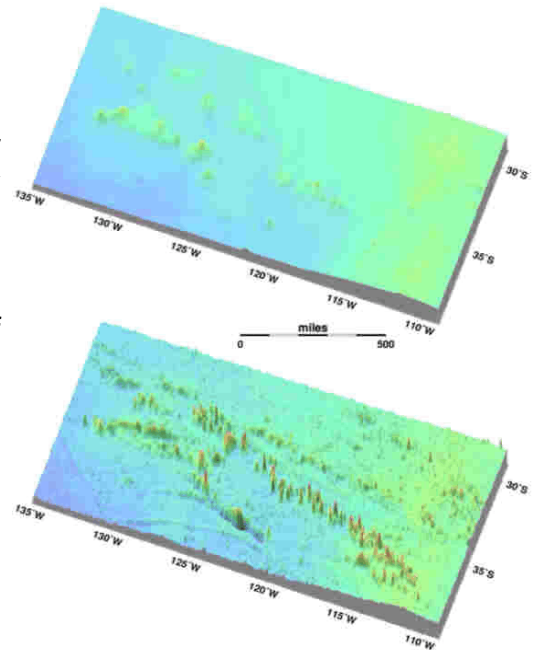
Ancient anchor

In addition, the sonar machinery is usually placed in an underwater sled which is towed behind the ship. Side-scan sonar gives very detailed pictures of the sea floor. It is used to make maps and find sea floor objects. It is a common tool used by treasure hunters when looking for shipwrecks.

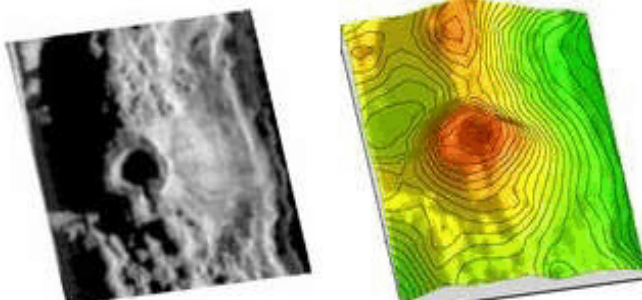


Side scan sonar

One of the latest developments in oceanography is to use **satellites** to study the ocean floor. Recently, a team of American scientists combined data from European and US military satellites to produce detailed sea floor maps. These maps are especially important because they cover all of the Earth's oceans, especially places where sonar scans are scarce. They are also easier to obtain than sonar maps. Many oil and mineral exploration companies, as well as governments, use satellite maps of the sea floor.



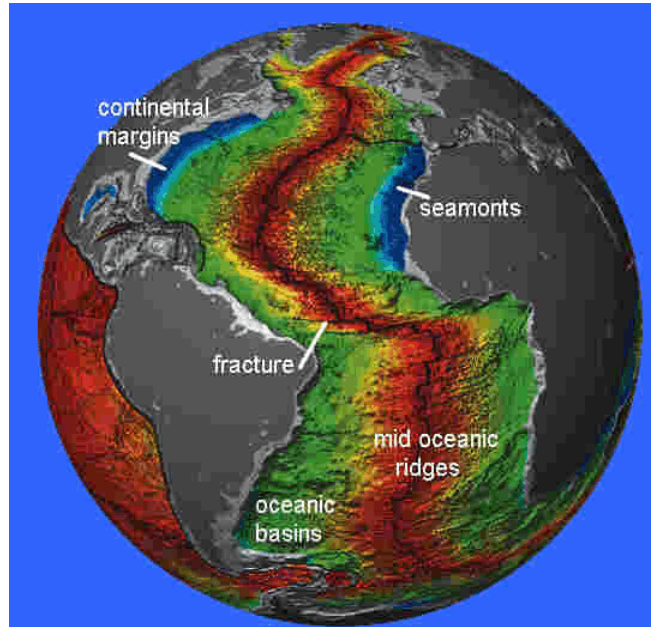
Interpretation from satellite data



Sonar on the left and interpretation of undersea volcano on the right

There are major features of the ocean floor that can be identified by undersea technology. The **mid-oceanic ridge** is a broad fractured arch of the sea floor, where plates are moving apart. Sediment cover is thin. The oceanic basin consists of **abyssal hills** and **abyssal plains**, areas where abyssal hills are covered with sediment. **Fracture zones** cut the mid-oceanic ridge and show strong evidence of transform movement. The size, shape, composition, and structure of seamounts indicate that they are similar to shield volcanoes.

The **continental margins** refers to the area near the meeting of the oceans and land. There are submerging and emerging coast lines dependant on the plate tectonic activity. **Submergent coastlines** are when there is no activity, so erosion creates wide margins like on the east coast of the United States. An **emergent coastline** is when the land is rising compared to sea level. You find these steep margins along the west coast of the United States.



EARTH SCIENCES - OCEANS

PROBLEM: Can you define the different features of the ocean bottom?

HYPOTHESIS:

MATERIALS: physiographic globe showing the ocean bottom, globe, worksheets

PROCEDURE: Use appropriate maps to answer the following questions either on the map or space provided.

1. Orient your map or globe to point north. What is the name of the northernmost ocean?

What types of features can you see on this ocean floor?

2. What is the name of the ocean between North America and Africa?

What is the major ocean floor feature in this ocean?

What caused this feature to form?

What other types of sea floor features can be found in this ocean?

3. Find the Indian Ocean. In what direction do the fault lines run?

What does the Y-shaped feature in the Indian Ocean represent?

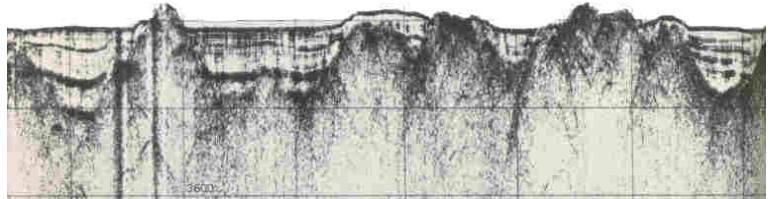
4. Find an ocean trench. Islands are usually associated with ocean trenches. Name some island chains that lie on ocean trenches (clue: South Pacific Islands).

5. What is the name of the major feature that is to the immediate left of the United States? What could have caused this feature to form?

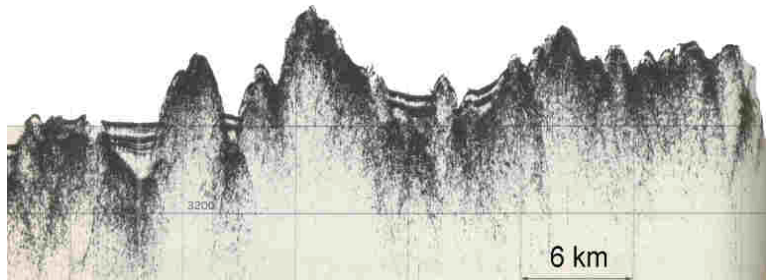
6. List all the basins named on the map. List them under the appropriate ocean (i.e., Atlantic).

7. MID-OCEANIC (Atlantic) RIDGE SEISMIC PROFILE:

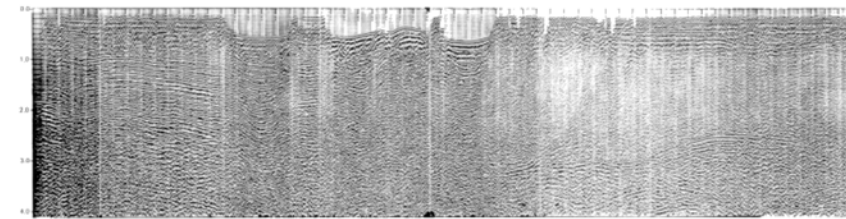
Describe where the sediments are located.



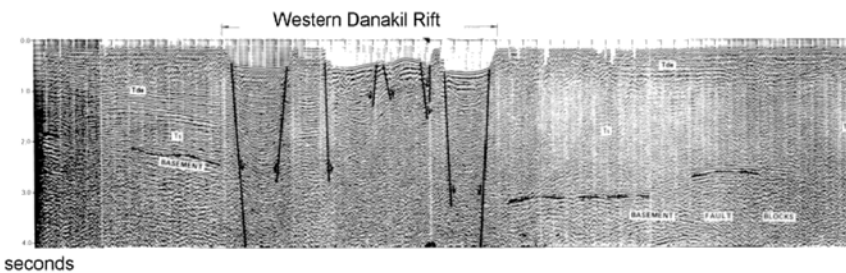
The Mid-Atlantic Ridge is commonly described as an arch that is broken by faults. What do the faults look like in this profile?



8. FRACTURE ZONES:

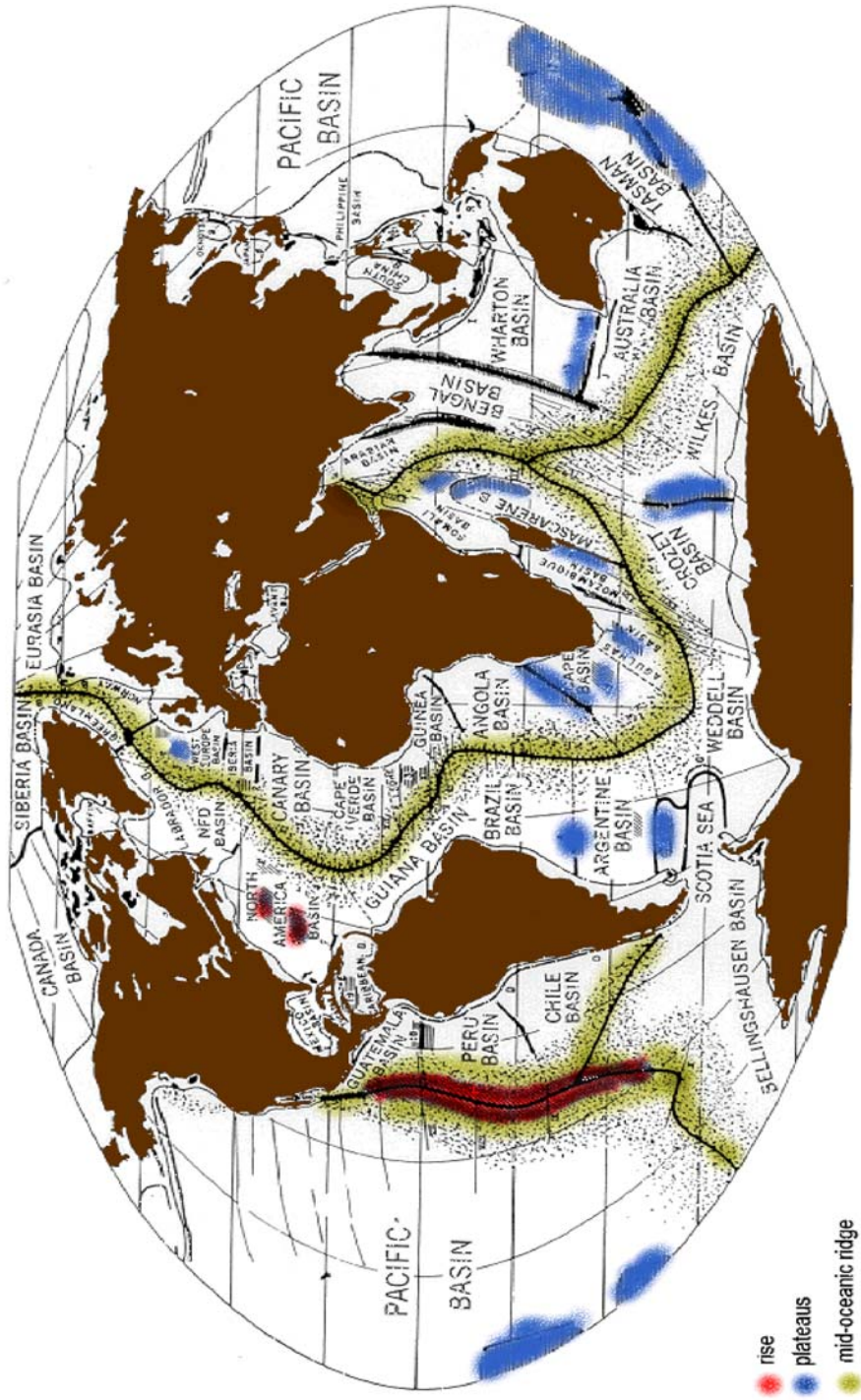


The top picture is a seismic profile in the Red Sea. The bottom is the interpretation. See if you can find the clues that allow for the bottom interpretation. See if you can mentally see these faults.



CONCLUSION: What features were the easiest and the most difficult to identify?

Basins of the World



EARTH SCIENCES - OCEANOGRAPHY

Lesson 3 - Geologic Oceanography

MATERIALS:

reader

Objective: Students learn about sediments and geologic features on the ocean floor.

Teacher note

Geologic oceanography involves looking at features such as ridges, seamounts, trenches, and fractures and interpreting their patterns. Marine geologists study the rocks and minerals from the sea floor and their overall part in plate tectonics. Marine sedimentologists, or geologists who study the formation of sediments in the ocean environment are important for the study of oil, gas, and mineral formation on the ocean's bottom.

An important component in geologic oceanography is equipment. Studying the bottom of the oceans is difficult and requires heavy equipment. Most studies of the ocean floor are joint projects with many nations.

Classification of sediments deposited in the ocean basins use the origin of components includes by authigenic, terrigenous, and biogenic ways.

1. Authigenic - Formed in situ by precipitation or submarine weathering, including evaporites (i.e., salt) and phosphorites (an important nutrient in marine ecosystems usually found in areas of upwelling).

2. Terrigenous - Detritus from continental erosion and explosive vulcanism. Most clastics are left along the margins of continents where large rivers empty into the ocean basin. The Ganges River in the Indian Ocean and Amazon Rivers in the Atlantic Ocean bring in sediments from their respective drainage system.

3. Biogenic - Shells, tests, or hard parts of dead marine organisms. Calcium carbonate found in warmer water used by mollusks, corals, foraminifers, and coccoliths, and some algae. Hydrated silica (opaline silica) include diatoms, radiolaria, and siliceous sponges

Imagine that you are at the beach. There is sand between your toes, and you can feel the Sun's warmth on your face. You look out at the ocean. You can see waves, gradually rising and breaking on the beach. Maybe there is a ship visible somewhere offshore.



Now think about what you cannot see at the beach, the sea floor. If you were to swim out into the ocean, where the water is clear, you might be able to see the bottom. Maybe you would see a coral reef or other sea life. However, if you were to swim further offshore, eventually you would not be able to see the bottom. As the ocean gets deeper, seawater absorbs more and more light until nothing is visible. The sea floor becomes a dark area, which you cannot see or observe.

For a long time, the best way to study geology and marine life was with dredges. A dredge is a large weighted metal or wooden box that is open at one end. Like the sounding line, a **dredge** is thrown off of a ship. It sinks to the sea floor. The motion of the ship pulls the dredge. It acts like a shovel, scooping up marine life and rocks. This allowed early scientists to learn what was down there. However, dredges are not very precise. Because they could not see the bottom, scientists could not tell exactly where their samples came from.



Dredge sample

Marine geologists have uncovered many secrets of the deep by looking at slices of the bottom or **sediment cores**.



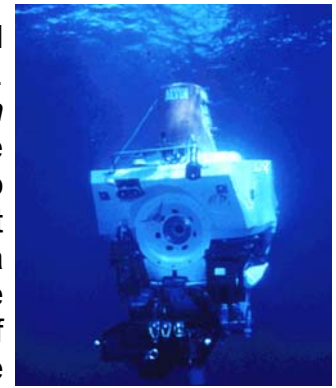
Looking at core samples

They have discovered that the ocean floors are relatively young. Rocks that are older than Cretaceous are very difficult to find throughout the world's oceans. Discovering the features and plotting all this information on maps, led to the confirmation of the patterns produced by plate tectonics. The ridges, seamounts, trenches, fractures, and continental margins all correspond to the idea of plates moving within the crust and upper mantle.

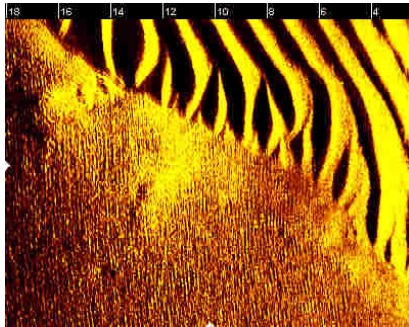


Resolution

Presently, scientists have additional methods to collect or observe the sea floor. Specially equipped ships like the *Resolution* can drill holes into the sea floor and retrieve cores of the ocean bottom. These ships also have sonar which can help them look at features in detail. Rocks and other data gathered by the ship have allowed marine scientists to develop a good understanding of the composition and history of the sea floor.



Alvin



Sand ripples on bottom of ocean floor (sonar)

Research submersibles like the Alvin, have been useful in studying the sea floor. These small submarines usually hold only a pilot and one scientist, but can record the ocean bottom through cameras.



Bottom of equatorial Pacific, camera

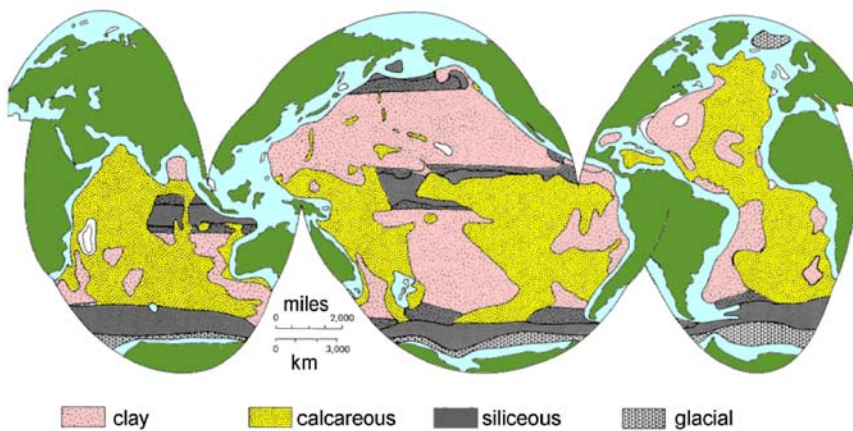
Marine geologists determine the distribution of sediments by coring the bottom of the oceans. They look at the sediments recovered and then analyze them for the different components, like clay and biological components.

When you plot all the different components in the surface layers, you can observe a pattern that reflects the overlying oceans. You can

group the sediments into clay, calcareous, siliceous, and glacial.



Core



Clay deposits refer to small particles that are associated with weathering. **Glacial deposits** are associated with erosion due to ice. These are also considered a **terrigenous deposits** or originating from land.

Calcareous sediments contain a high calcium carbonate content, usually biogenic in nature. They can be made of foraminifers (one celled protist) or



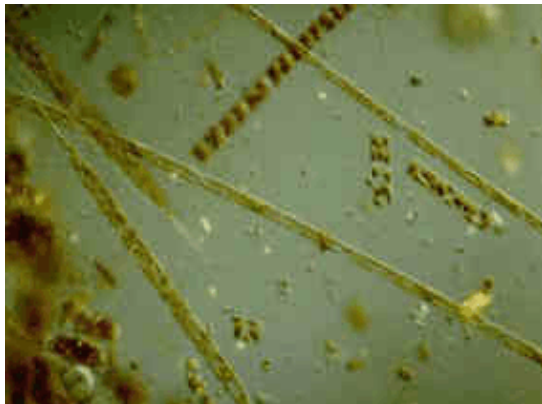
Foraminifers

deposits from coral reef organisms. Coral reefs are usually in shallower, warmer water like off of the southeast United States or the Great Barrier Reef in Australia. Many corals as well as calcareous algae make their skeleton from calcium carbonate.



Coral reefs

Generally, calcareous deposits are biogenic in nature and represent warm water.



Diatoms

Other **biogenic deposits** include those that are siliceous, which are rich in silica dioxide. Organisms that are siliceous include diatoms, radiolarians, and some sponges. **Siliceous sediments** are usually found in colder water.

These deposits reflect the biological life above the ocean basins. If you look at the productivity of the areas that contain the siliceous and calcareous component it is

much higher than the rest of the basins.

If you look at the currents and nutrients available these areas usually have an increase of **upwelling**. Upwelling is when water, rich in nutrients comes up toward the surface due to physical conditions of the water masses.

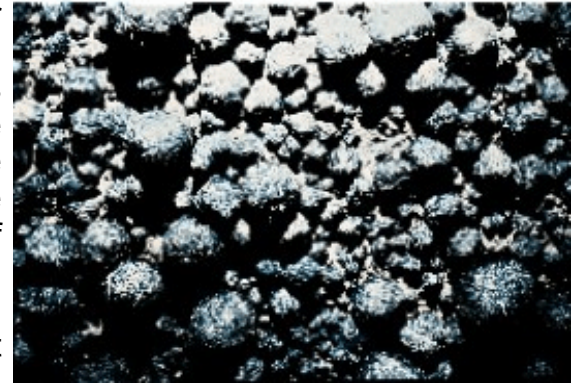


Siliceous sponge



Salt flats in Chile, South America

Many elements are dissolved in seawater. Some of these elements come out of solution in various forms which can be used for economic purposes. Manganese nodules which are potato-size masses found on the ocean floor are composed of manganese, cobalt, and nickel.



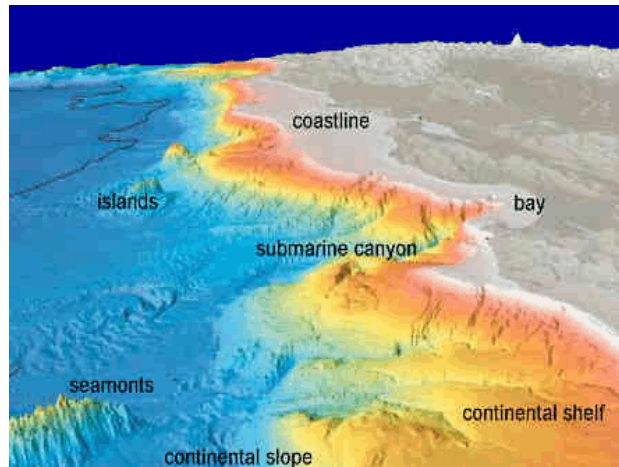
Manganese nodules

Salt is also produced by solar evaporation of salt ponds, that precipitate sodium chloride. These deposits are classified as **authigenic deposits**.

Marine geologists also study the coastal areas. These are important because humans interact most with this zone. The topography of the local coasts helps determine harbors for transportation, and to predict wave and tidal action.

Along the coast of California you have many geological features of interest. The bays of San Francisco and Monterey allow birds from the south to use this area as a fly path. The waters off this area are very deep close to the coast. This allows for large, thundering waves that are great for surfers. Along Monterey area, there is a spectacular **submarine canyon**, deeper than the Grand Canyon, that wiggles its way out toward deep water.

Geological oceanography has a vast area to look at and many features have probably not been observed yet.



San Francisco to Monterey, California coast

EARTH SCIENCES - OCEANOGRAPHY

Lesson 4 - Chemical Oceanography

MATERIALS:

reader
worksheet

Objective: Students will learn the different chemical properties of seawater.

Teacher note

The chemistry of seawater is very complex, because the properties of water allow many compounds to dissolve in water. However, the major properties of water are still maintained in the oceans. Oceans have a large capacity for absorbing heat, which influences the weather and climatic patterns. Water has a large capacity to dissolve substances that are held together by weaker ionic bond (i.e., salts). As flowing waters erode the surface of the Earth, ions are dissolved in water. Over the billions of years it has taken for the oceans to fill up the lower basins of the Earth, these ions have accumulated. Ocean water is older than fresh water.

Chemical oceanography is dependant on the other physical, geologic, and biological cycles that occur in the oceans. The chemistry of seawater changes laterally and with depth. The input of ions and how they are maintained through the water cycle is the essence of the geochemical cycles that occurs in water. The Biochemical Cycle includes organisms that take ions from the marine waters and then as they die input the very compounds they use.

This is an introductory lesson on the chemicals of the marine environment. Students should notice the major and minor components of seawater through the activity. The oceans are in constant change which reflects on changing chemical composition. As chemical oceanographers obtain data, they usually can interpret why these changes occur.

Answers:

1. Ions - which is the "dissolved" state of many compounds. Inert gases can also be found dissolved.
2. sodium, magnesium, potassium, calcium, sulfur, chlorine,
3. Bromine. Boron, Fluoride, silicon, strontium, carbon
4. Oxygen, Nitrogen, helium, neon, argon, krypton, xenon, Radon
5. Erosion
6. Marine has many more dissolved components in larger percentage than fresh water
7. Oxygen, hydrogen



It was recognized in early civilizations that most elements are dissolved in seawater. Many kings and queens in early dynasties would hire court “**alchemists**” to try and extract gold from seawater. Most alchemists were unsuccessful because it takes more money to extract the element than the element is worth.

The major chemical components include chlorine, sodium, magnesium, sulfate, calcium, and potassium. The bonding of chlorine and sodium produces a major resource from seawater, salt. The minor components include bromine, carbon, strontium, boron, silica, and fluorine.

Some of these elements and compounds go in and out of **dissolution** in seawater. Many of the elements are used in biological processes to produce skeletons and then deposited on the ocean bottom. If the sediments are buried, the elements are taken out of the chemical pot.



Sodium chloride, salt

The ocean’s chemical system is complicated and always changing. The minerals are dissolved in water and are in solution until either chemical or biological reactions in the oceans precipitate the different compounds.

Organisms that live in the marine environment tend to use two types of compounds, calcium carbonate (CaCO_3) and silica dioxide (SiO_2). Biological processes can actually transform the ions into microscopic minerals that grow with the organism. Calcium carbonate is a mineral called calcite. When incorporated into a biological system it is usually in a “disordered” form called aragonite. Most mollusks use calcium carbonate in their shells.



Calcium carbonate shells



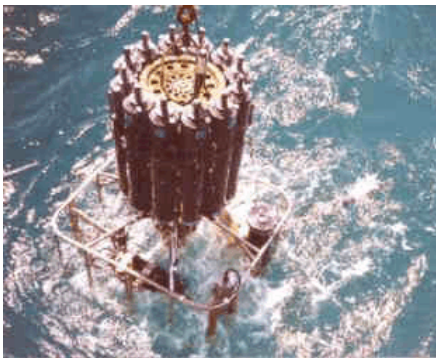
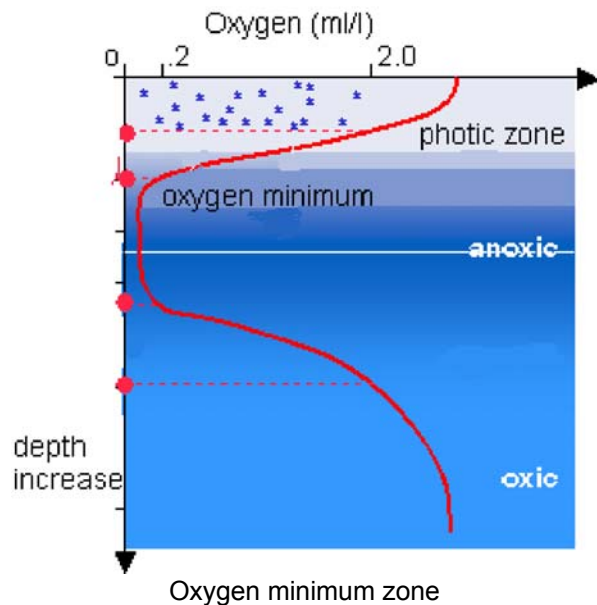
Venus flower basket, a sponge

Silica dioxide is also a common mineral, in the form of quartz. When used in the biological system it is also “disordered” and is called opaline silica. Siliceous sponges use **opaline silica** for its skeleton.

Gases are also dissolved in seawater which are mainly used in **biochemical** processes. The major gases dissolved in the marine environment include nitrogen, oxygen, and carbon dioxide. Helium, neon, argon, krypton and xenon also occur in lesser quantities.

The amount of gases in water is dependent on temperature, pressure, and salt content. The amount of oxygen availability with depth is a limiting factor for many organisms. There is an **oxygen minimum level** or oxygen poor zone a few hundred meters in depth.

Seawater has two sources of oxygen, the surface interface with gases in the atmosphere and plants. Through photosynthesis plants produce oxygen gas. With depth photosynthesis decreases because plants are dependant on light for these chemical processes to occur. Plants produce oxygen and other organisms consume it. The consumption of oxygen is high in the upper 200 meters, so it is easy to understand how oxygen can be removed from the system.



Sampling for chemical analysis

The ocean's chemical composition changes vertically and laterally because of geological and biological parameters. Scientists use sampling equipment that monitor portions of the oceans. The oceans are vast, so it is difficult to obtain continuous data, especially with respect to depth.

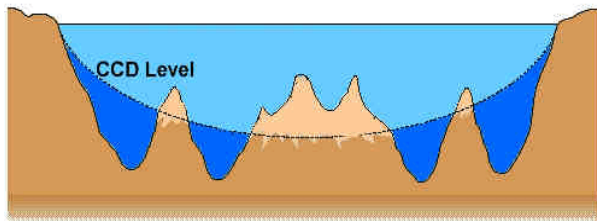
Chemical composition varies depending on many factors. The gas exchange with the atmosphere, the ability of compounds and elements to dissolve, anaerobic bacteria, interaction of the ocean bottom, inflow of fresh water, freezing and melting of sea ice, and biological process all play vital roles in determining the chemistry of seawater.



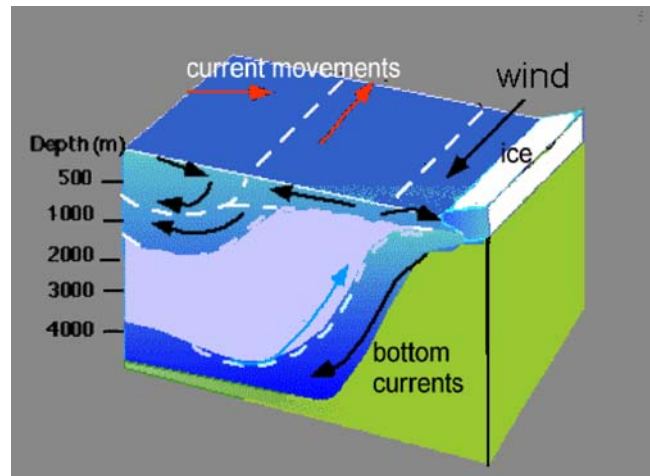
Chemical analysis on shipboard lab

All sciences are needed to understand the oceans. As an example, many oceanographers had noticed that there were no calcium carbonate deposits in certain deep portions of the oceans. They knew that there were organisms that lived on the surface under this water, but for some reason it did not reflect this in the bottom waters. After testing of the water vertically, chemists noticed that cold water holds more CO_2 which results in more carbonic acid with dissolve CaCO_3 faster. This leads to the **Carbonate Compensation Depth** or CCD.

Chemical oceanographers also work with water masses to determine their unique chemical composition. This is then used by physical oceanographers to chart their movements.



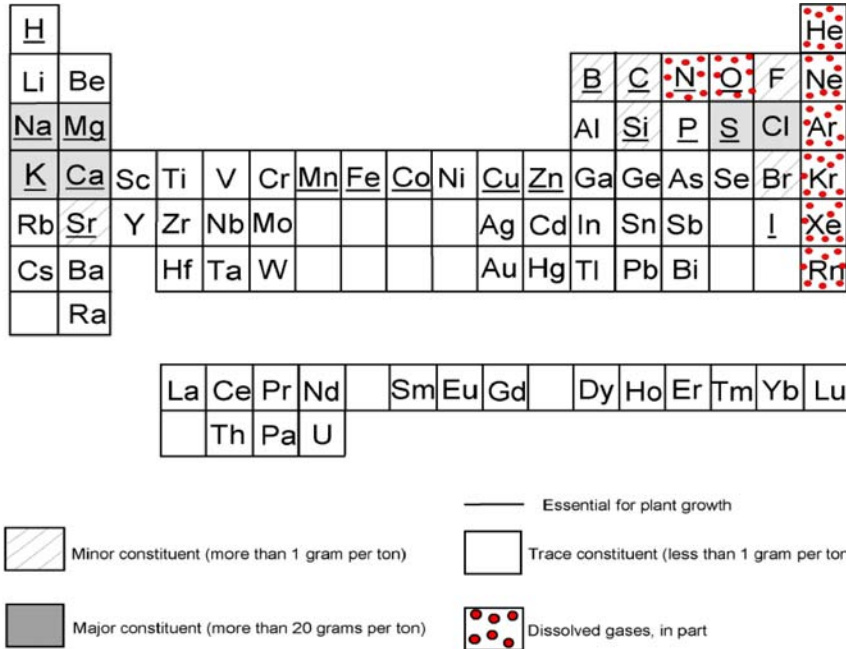
Carbonate compensation depth



Current movement laterally and vertically

ELEMENTS FOUND IN SEAWATER

1. Which form are elements found in marine water? (Clue: Molecule or ion.... what is the difference?)



2. List the elements that are major components of seawater?

3. List the minor components of seawater?

4. List the dissolved gases in seawater? (There is an error on the graph? Clue: one of the major gases dissolved is not shown, can you guess which one it may be if it is needed for living organisms?)

5. How does the marine water get so many elements dissolved in it?

6. What is the difference between fresh water and marine water?

7. Which two elements make up the majority of marine water?

EARTH SCIENCES - OCEANOGRAPHY

Lesson 5 - Physical Oceanography

MATERIALS:

reader
globe with currents

Objective: Students will explore the reasons of motion in the oceans.

Teacher note

Physical oceanography is the movement of the oceans called currents. The movements of the oceans are caused by many different things. The oceans are governed by the principles of fluid motion. Wind drags and pushes surface water. The influences of wind changes intensity and direction as you increase depth. This is referred to the Ekman spiral.

Density is also a cause for motion. Temperature and salinity are the basic causes of different densities in seawater. Since temperature can change as solar radiation warms the surface or as icebergs melt, density of water changes causes movement as more dense water mass replaces a less dense water mass.

Physical constrains of a rotating sphere imprints the general direction of water. Owing to Earth's rotation a particle at rest at the equator is moving at a velocity of about 1600 km (1000 miles) per hour eastward, as you go north it decreases in velocity. (The circumference of the Earth is 38,400 km (24,000 miles) and you divide this by 24 hours, you get the speed of the Earth along the equator.) Theoretically it goes to zero at the north and south poles.

It is difficult to measure the physical parameters of the ocean by ships. New technology uses satellites to collect data. Satellites can orbit the Earth several times in a day. By placing instruments on a satellite, an oceanographer can obtain data from all over the world in a short amount of time. These instruments are able to measure the temperature of the ocean's surface, the height of the water, the speed of the wind above the water and many other things.

Students in this reader learn about the different causes of this movement. The activity centers on students looking at a globe and finding the different surface currents.

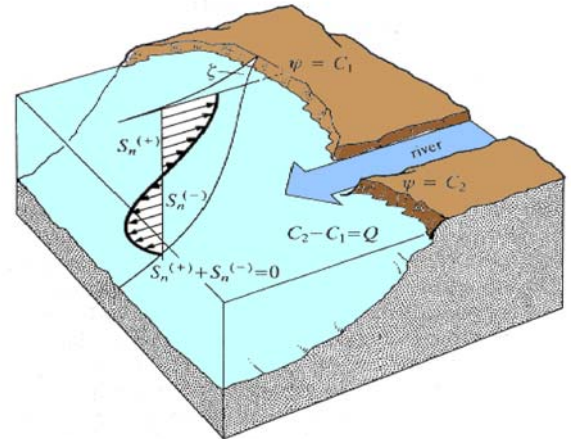
We also suggest that if you live near the ocean you teach your students how to find out the tides along the beach. This will help them with boating or looking at tide pools. Consult your internet search engine or <http://www.harbertides.com>.



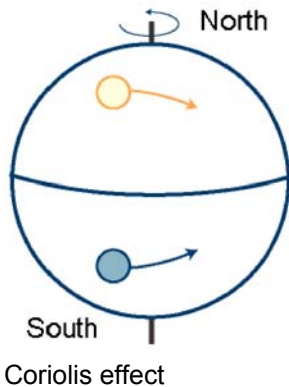
I sit down by the seashore and listen to the rumbling ocean. The waves approach the sand appearing to gobble all that might be found along the coast. But it never does. It makes a loud roar and then tumbles into calm ripples before my feet. I need to find out more about the oceans and why it moves so mysteriously as I watch it.

The oceans are always moving. The movement is graceful and subject to the principles of fluid motion. Fluid motion refers to the response of liquid to forces of wind, density, and rotation of the Earth in space. Locally you must include factors such as topography and tidal forces.

The waters of the oceans are not **homogeneous**. There are ocean masses that move as units, called currents. The ocean's movement is predictable based on mathematical modeling. The model takes into account many factors that control currents not only on the surface but with depth.



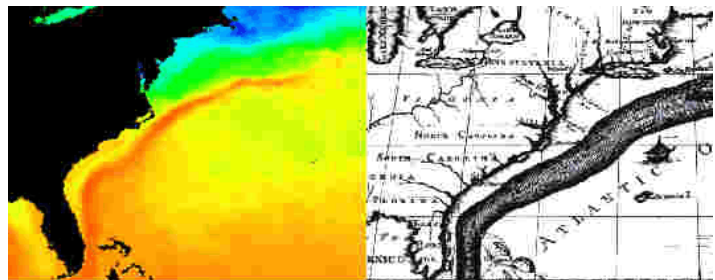
You can mathematically model the movement of water



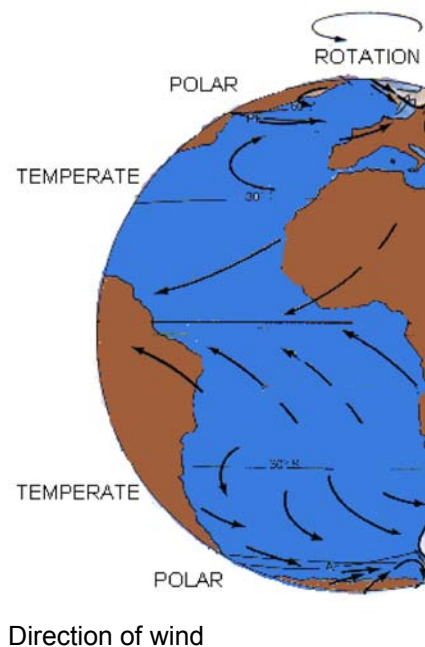
Currents were known to most ancient **mariners**. Benjamin Franklin in the late 1700's first charted the Gulf Stream Current in the North Atlantic using temperature. His maps helped many ships to get to England faster. The Earth's rotation explains the general surface circulation. As the Earth spins on its axis, the equator moves faster than the poles. As you go from the equator you are traveling 1600 km (1000 miles) per hour, while at the poles you are standing still. In the northern hemisphere the currents are deflected to the right, or clockwise. In the southern hemisphere the surface currents are deflected to the left or counterclockwise. This especially holds true in the Atlantic and Pacific because the north

and southern portions are open. The Indian Ocean, on the other hand does not have a northern hemisphere equivalent. There is only a large land mass (Asia). This will become an important point when we look at weather patterns.

This deflection is referred to as the **Coriolis Effect**, and is the overprint of other factors that will make motion in the oceans.



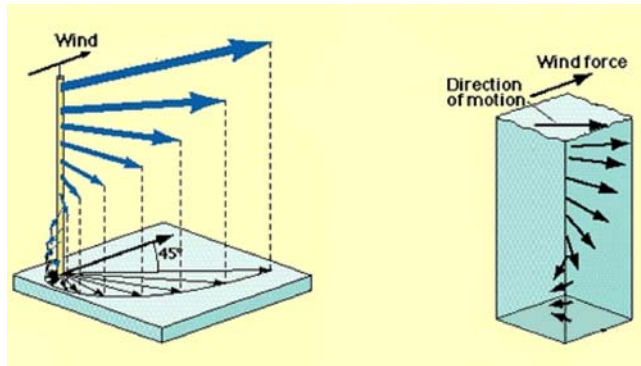
Benjamin Franklin's Gulf Stream map (right); satellite temperature map on (left)



Wind also moves water around, especially the upper portions of the water column. However, wind is generally moving in the same direction caused by the rotation of the Earth, so they “add” forces. In areas where land and water meet, the direction of the wind is controlled by temperature differences of the land and water. Strong winds can influence the movement of coastal waters.

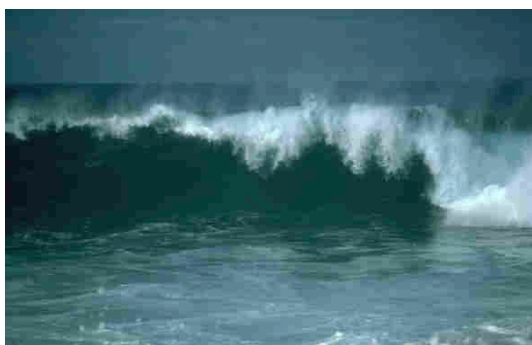
Wind is actually a bizarre phenomenon. It can change quickly depending on the balance of heat. A mountain can stop wind and add to the chaos of wind motion. Wind produces energy throughout the water column in a predictable pattern called the **Ekman spiral**.

The transfer of wind energy from the atmosphere to the waters can cause motion far from where the energy first entered the system.

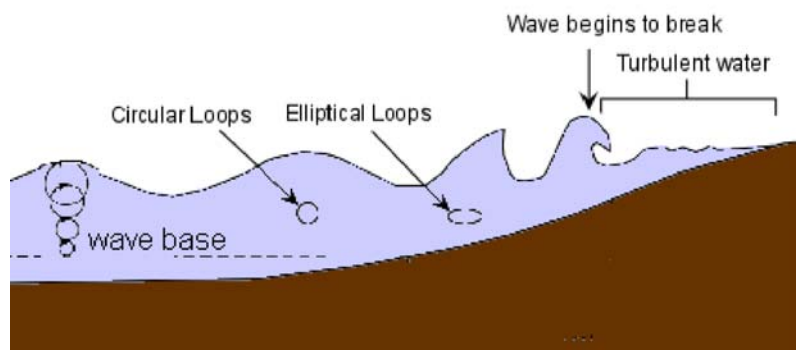


Ekman spiral

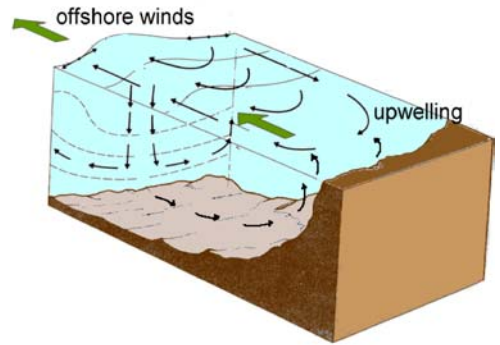
Large, thundering waves along the coast can have their origin in the transfer of energy far out to sea. In the open ocean, the wind energy can slowly dissipate from the surface to depth. But the wind is also pushing energy laterally. If it travels a long distance, it can pick up more energy because of the motion of the Earth due to Coriolis.



When this energy hits the coastline or a high topographic feature, the water has to get rid of this energy somehow. The energy becomes unstable, and is released as large waves along some coastlines that change quickly. Surfers know these areas, because they are the ones that produce the large surfer waves.

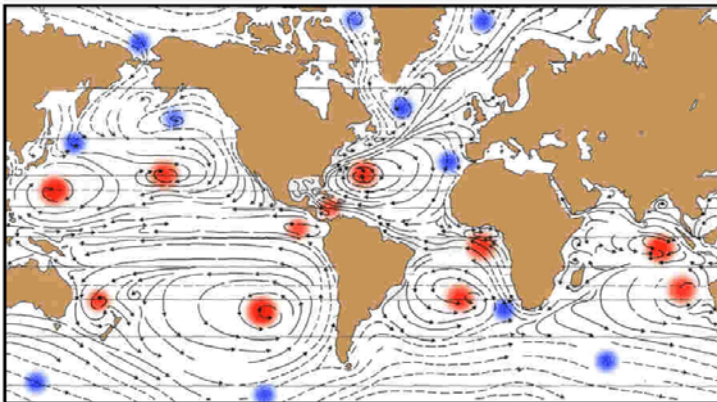


Temperature and density can define a **water mass**. Warmer water can hold more salt, and colder water holds less salt. Salt water is more dense than fresh water of the same temperature. The salt water will layer itself below the fresh water. Warm water is less dense than cold water. So cold water will layer under warm water. Add the combination of different amounts of salt and different temperature and you have a layering effect in the water column. The world's oceans are a three-dimensional nightmare of layers of different water masses that can



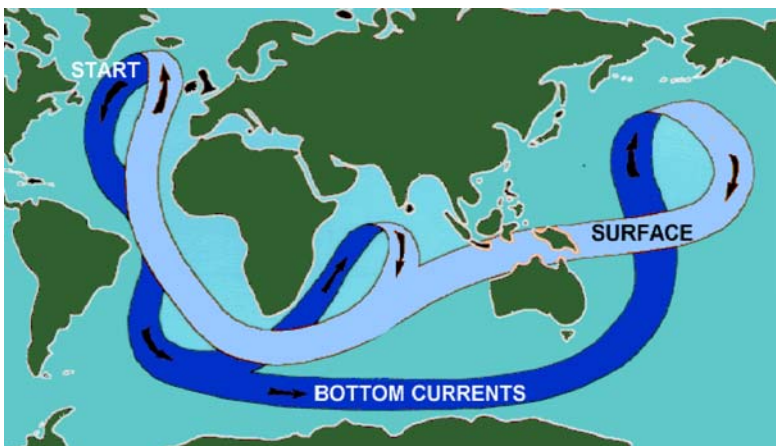
Water masses move in different directions

move in different directions.



Surface currents , red refers to cold water and blue refers to warm water

Bottom topography can act as a barrier to water masses already in motion. If a cold saline water mass is moving along the bottom and “hits” a mountain it would be forced upwards. This is one form of upwelling. This would displace the water masses above it, causing lots of movement.



New water formation and its travels

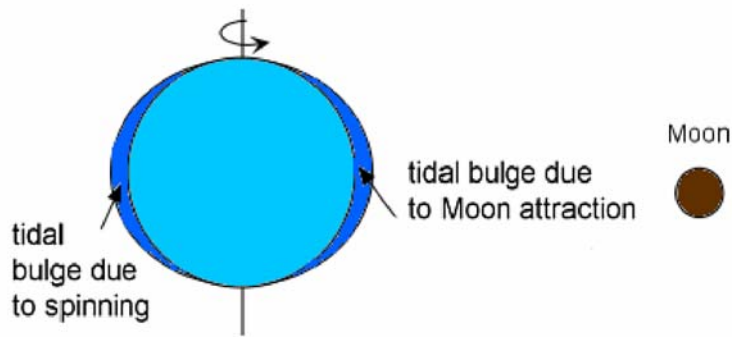
Cold, high saline water is very dense. When icebergs form, that means fresh water is taken out of the system, concentrating the salt in the water. This water is so dense it drops to the bottom and remains there for tens of years, as it travels on the bottom. The diagram shows “new” water starts in the North Atlantic and moves along the bottom. The cold water warms up slowly and emerges in the

Pacific Ocean only to start circulating through different routes.

All these reasons cause the movement of the oceans to spin into smaller eddies. Please keep in mind that although this motion looks chaotic, it really is responding to natural forces, which we can mathematically model.



Santa Catalina Island, notice eddy formation



Tides can create a rhythmic high and low twice every day. But in some locations like San Francisco Bay, the entire bay moves in an out twice a day because of tidal action in an irregular timetable. Tidal forces are caused mainly by gravitational attraction of the Moon and Sun. The entire envelope of water responds to this attraction.

However, tides are not generally “felt” in deep waters, only coastal.

In the Bay of Fundy, in Nova Scotia, Canada, the tides travel along a narrow inlet, all at once. The energy that this “**bore**” brings is enough to create electricity through tidal energy. That is a lot of moving water.

Alexander the Great, in 325 BC was exploring the Indian Ocean for Greece. They took shelter in a small cover due to impending storms and found their boats were caught by the **ebb tide** and were left high and dry. When high tides returned, many boats could leave, but others were badly damaged. They had never seen this strange event before.



Bay of Fundy, incoming bore

WATER SCIENCE - OCEANOGRAPHY

PROBLEM: How many ocean currents are there in the world?

HYPOTHESIS:

MATERIALS: inflatable globes

PROCEDURE:

Locate the following currents on your inflatable globe. Record the general direction, location, and possible countries that it may affect.

Gulf Stream	
Aleutian Current	
Kuroshiro Current	
West Wind Drift	
Agulhas Current	
Benguela Current	
Equatorial Countercurrent	
Peru Current	

CONCLUSION: What did you discover about ocean currents around the world?

Earth Science - Ocean - Unit Test

Part 1. Definitions Match the number of the term or concept in Column 1 with the letter of the correct definition in Column 2.

Column 1	Column 2
1. Salinity	a. depth of a depression
2. Surface of oceans	b. land is rising compared to sea level
3. Seamount	c. study of the oceans
4. Siliceous sediments	d. foraminifers and mollusk
5. Ekman spiral	e. caused by density, wind, and motion of the Earth
6. Currents	f. diatoms and radiolarians
7. Emergent coastline	g. about 35 parts per million of salts
8. Calcareous sediments	h. majority of evaporation
9. Oceanography	i. caused by wind
10. Bathymetry	j. underwater mountain that reaches the surface

Part 2. Multiple Choice Choose the best answer to complete each statement.

- Oceans comprise about what percentage of the Earth's surface?
 - 60%
 - 50%
 - 70%
 - 40%
- Salinity of oceans have evolved over
 - 10 years
 - thousands of years
 - 1 month
 - billions of years
- Icebergs are composed of
 - fresh water
 - salt water
 - old water
 - warm water

4. Which is not a major ocean?
 - a. Pacific Ocean
 - b. Indian Ocean
 - c. Arctic Ocean
 - d. Atlantic Ocean

5. Manganese nodules are mainly composed of
 - a. sulfur
 - b. magnesium
 - c. oxygen
 - d. manganese

6. Which is not a major feature of the ocean floor?
 - a. ridge
 - b. valley
 - c. continental margin
 - d. fracture

7. Which of the following is not classified as some major way sediments are created?
 - a. outer space
 - b. authigenic
 - c. biogenic
 - d. terrigenous

8. Currents are not caused by
 - a. density
 - b. wind
 - c. topography
 - d. ships

9. The Coriolis effect
 - a. is only found in the northern hemisphere
 - b. is only found in the southern hemisphere
 - c. caused by the rotation of the Earth
 - d. caused by the attraction of the Moon

10. Tides are
 - a. largest in bays
 - b. only found in the Atlantic Ocean
 - c. caused by rotation of the Earth
 - d. caused by the attraction of the Moon

ANSWERS:

Part 1.

1. G
2. H
3. J
4. F
5. I
6. E
7. B
8. D
9. C
10. A

Part 2.

1. C
2. D
3. A
4. C
5. D
6. B
7. A
8. D
9. C
10. D