Seafloor Morphology

If we select a grid for the surface of the earth (*i.e.* 5 km^2) and assign it an average elevation in relation to sea level, we can construct a graph of elevation versus area of the Earth's surface. This hypsographic curve shows the surface morphology of the planet.

The shape of the seafloor is dominated by tectonic processes with igneous activity having a strong role. Initial structural and volcanic creations are modified by deposition of sediments. Erosional processes also modify the seafloor, but are not as effective as they are on shaping aerially exposed land surfaces.

A variety of tools are used to investigate the seafloor, ranging from diving and submersibles to seismic, magnetic, gravity and satellite observations.

The features are described and grouped into geomorphic categories. Most are an expression of structural and igneous activity.


Techniques of Investigation

In this section, we will examine the methods used to obtain data about the topography (bathymetry) of the sea floor and the sediment cover.

Bathymetry and Sediment Studies

Our earliest records of the ocean floor were soundings taken with a lead and line. To plumb the depths of the ocean, lengths of piano wire were used to lower a weight to the bottom. The Challenger expedition ran from 1872 to 1876 and took 492 deep sea soundings.

Modern oceanography in the United States began with the establishment of Scripps Institution of Oceanography as a biological research station in 1903, and Woods Hole Oceanographic Institution in 1930. The major cruise of this period was the voyage of the German ship, the Meteor, in 1925. This cruise carried two acoustic depth recorders which made soundings from a stationary position every two to three nautical miles, giving new detail on the configuration of the sea floor. With the military expansion of practical oceanography in World War II, studies of transmission of sound in the ocean resulted in extensive use of fathometers in continuous-line bathymetric surveys of the ocean.

Beam of sound waves travels to bottom and is reflected back to ship
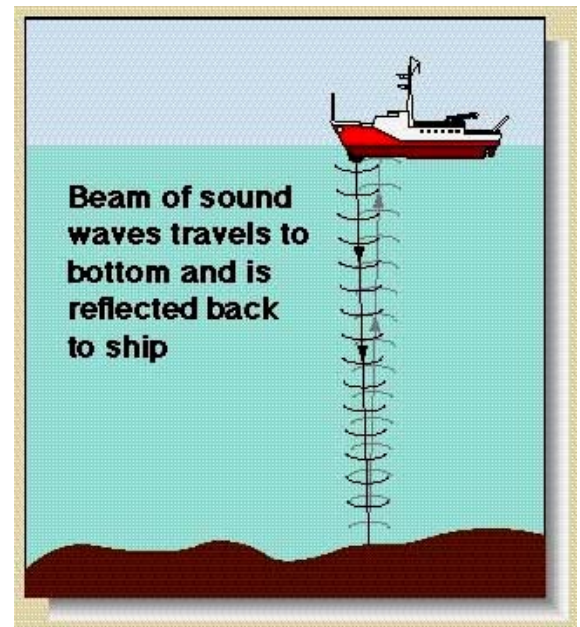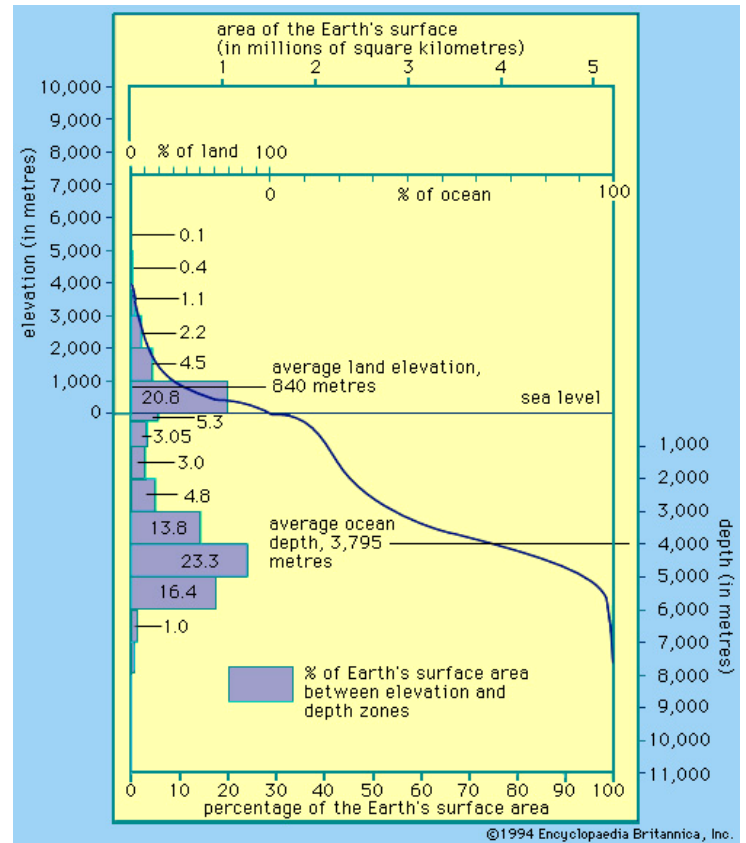
The fathometer is a fairly simple device consisting of a sender or sound source and a receiver for detection of the return signal. The difference in density between the water and the sea floor sends a reflected signal back to the unit. The travel time is directly proportional to the water depth (and density of the seawater column). As the ship moves, a continuous profile of the bottom is recorded.
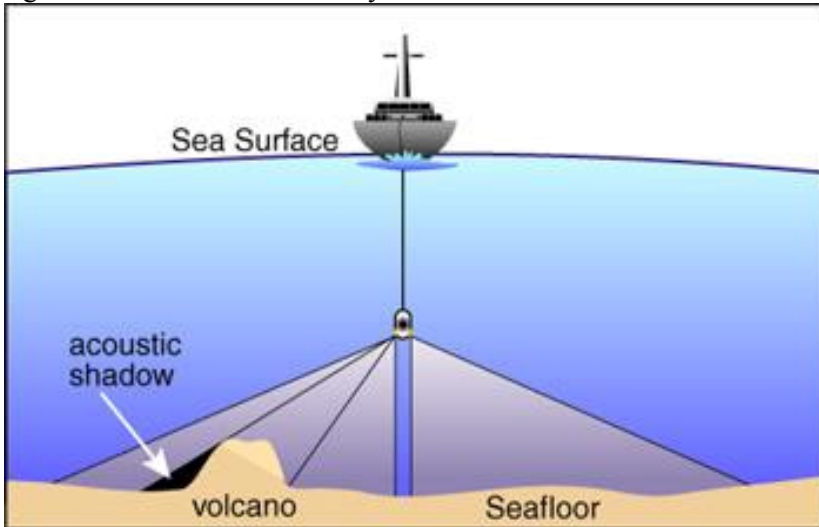
Side scan sonar towed behind a ship scans the sea floor with two divergent sonar beams that acoustically illuminate the sea floor in two swaths, from a few meters to as much as 30 km to each side depending on depth above the bottom of the tow. The sonographs show local topography as sonar shadows. This is used with a fathometer to expand the bottom bathymetric coverage. Actual depth is not measured. Reflectance as measured by side scan sonar can be related to sediment types so the nature of the bottom sediments can be described.

Remote sensing from satellites has become an important tool in Oceanography. Instruments on satellites are used to measure sea temperature, ice cover, bottom sediments in shallow water, and bathymetry. In shallow water, measurements are based on penetration, and in deep water, the sea surface elevation can be measured by satellite instrumentation reflecting larger features on the bottom. Satellite images can also be equated to bottom types by reflectance values in water depths less than 10 meters.

One of the earliest devices, and still important, are grab samplers for bottom sediment collection. These samplers are lowered from the ship until they reach bottom and collect a sediment sample. Where the bottom is hard, a dredge of heavy metal and chain mesh is used to dislodge and collect rocks.

Grab samplers collect a surface sample which depicts only recent sedimentation patterns. Geologists have used coring devices for many years to obtain a record of sedimentation over longer periods of time. These are essentially tubes that are pushed into the sediment layers to collect a complete layered sequence of sediments and they are effective in unconsolidated sediments to depths of more than 20 m.

For recovery of rock bottom of much greater lengths, cores are taken with a shipboard rotary drill similar to equipment used in drilling for oil.

Suspended sediments are taken from the surface with a bucket or from different depths in the water column with water samplers. The water can be filtered and the amount of suspended sediment determined by weighing the residue. Light transmission is also used to determine the amount of sediment in the water column. Longer term studies involve the use of sediment traps which are placed on or near the bottom to collect sediment settling out of suspension. These are collected periodically and the sediment is recovered to determine deposition rates.

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Seafloor Features

The three major ocean basins are the Atlantic, Indian, and Pacific oceans. These lie over oceanic crust and have an average depth of about 3800 meters. The Atlantic Ocean is the youngest of the three and is dominated by a central oceanic ridge and abyssal plains of fine sediment. The Atlantic Ocean has grown during the past 200 million years at the expense of the Pacific Ocean.
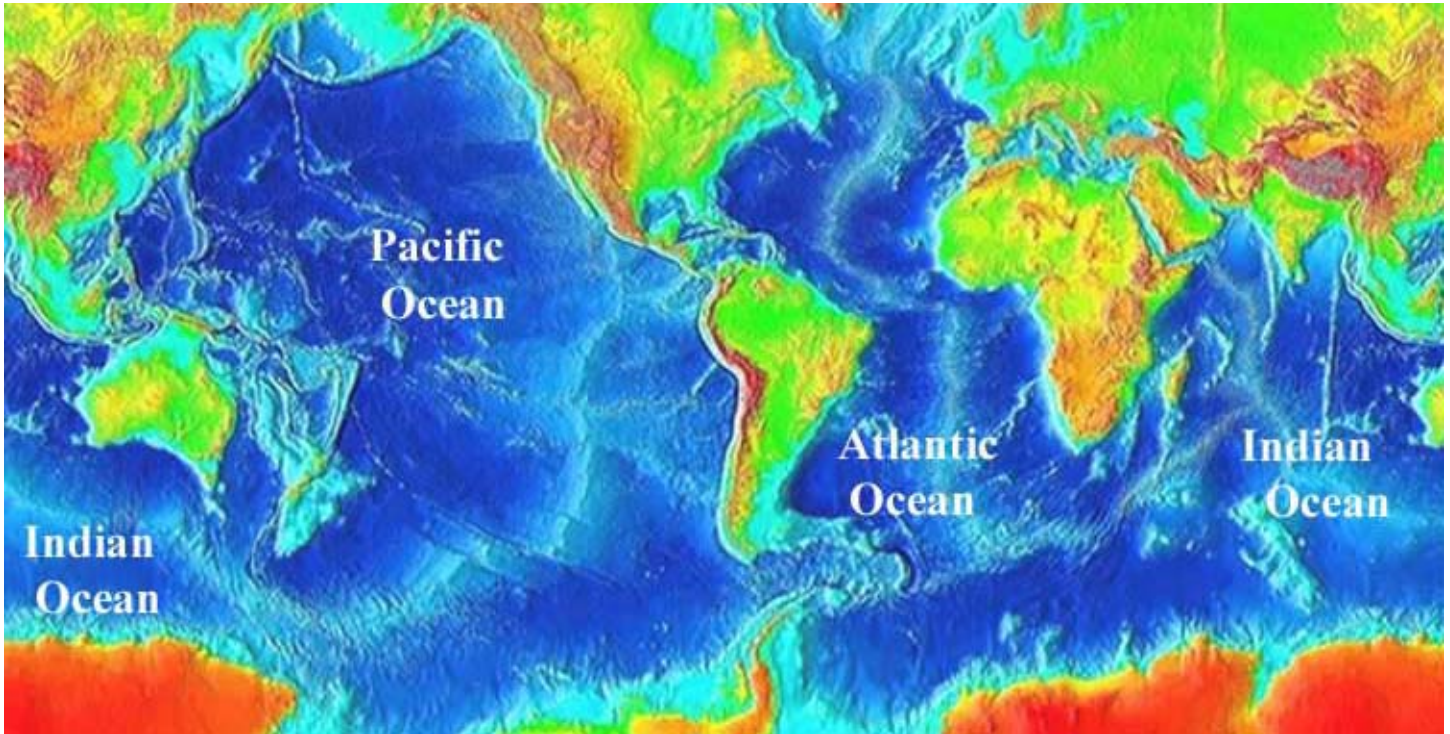

The oceanic provinces range from shallow coastal areas to the deepest ocean environments. Many of the ocean features have been named and the particular provinces described. These features are discussed in the following sections.
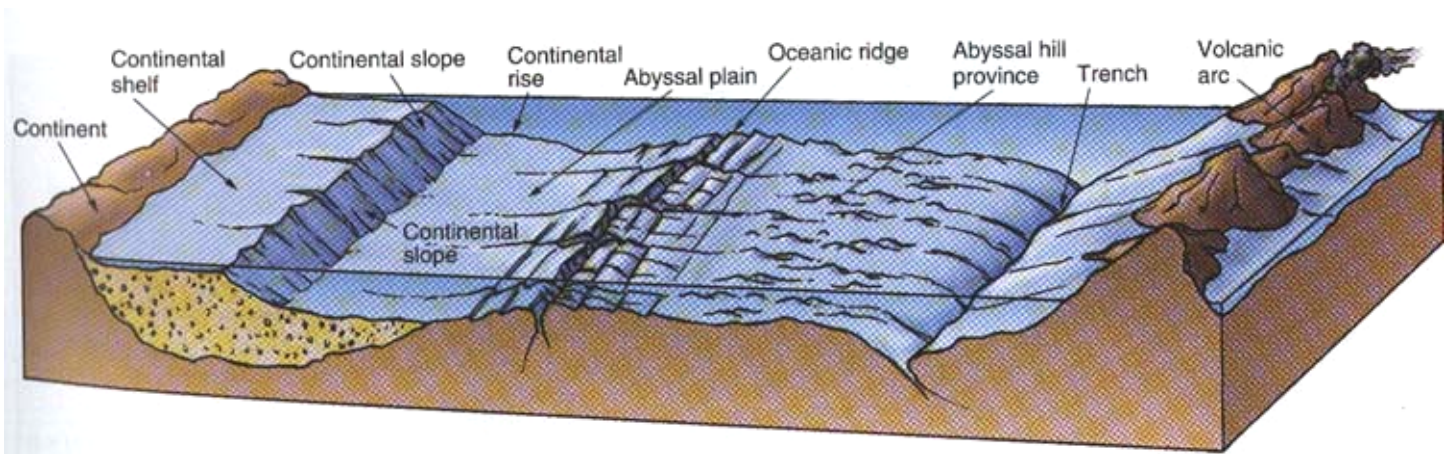

Ocean Ridges

The oceanic ridge system is a pronounced tectonic feature. The combined ridges are more than 60,000 km in length, with an area of 23% of the earth's surface, almost equal to the total area of the continents. These ridges extend as an

almost continuous feature around the globe in the form of spectacular mountain ranges of volcanic basalts. The ridges are arched up and broken by numerous fault blocks to form linear hills and valleys. A prominent rift valley marks the crest of the ridge throughout most of its length.
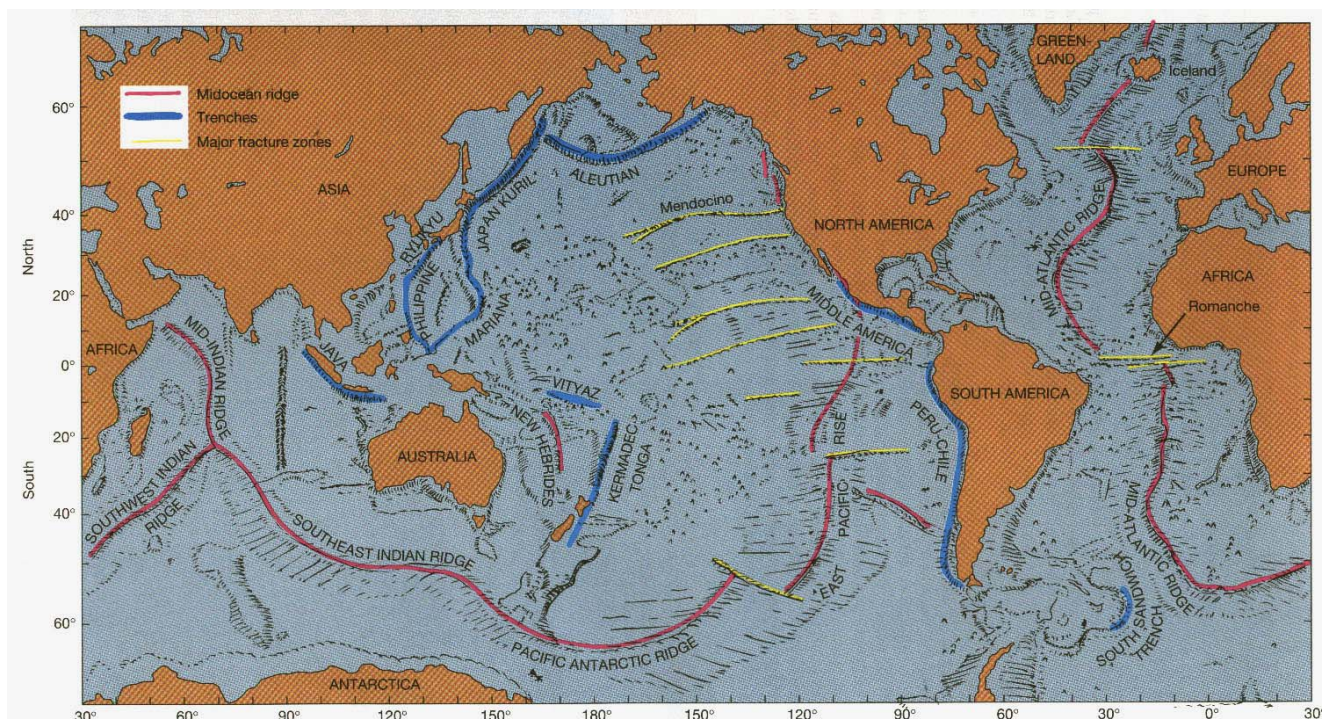
The general character of the ridge is a function of the rate of plate separation. A slow rate of spreading produces a higher and more rugged oceanic ridge than when the spreading rates are more rapid. Rift valleys are also more prominent on ridges between slow moving plates.

The rift valley along the center of the rise is a zone of shallow earthquakes. The rift and ridge system is not restricted to the oceans -- it emerges in continental areas in Africa, California, and in Iceland. Numerous open fissures have been observed and mapped in the rift valleys, which is evidence that the crust is being pulled apart along the ridge. The eruption of lava from these fractures parallels the rift valley and creates long narrow ridges.
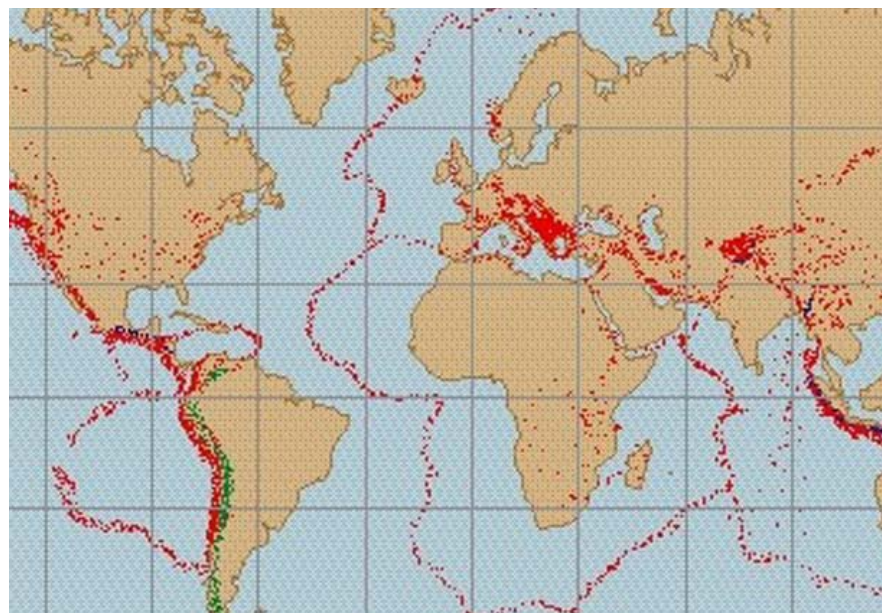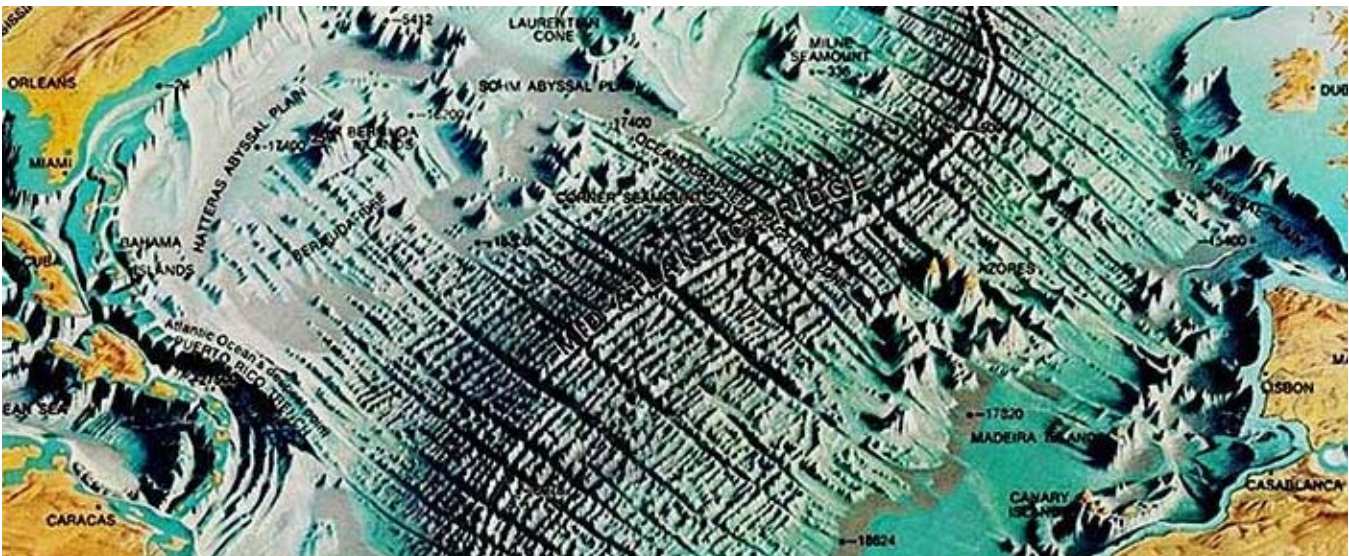
The oceanic ridge is cut by faults normal to the ridge. Although these are strike-slip faults, vertical displacement may form abrupt cliffs that can be traced for many kilometers . Horizontal movement on these transform faults is on the order of 1-2 cm/yr and the faults are marked by earthquake activity and vulcanism. The magnitude of the system and its nature indicates that it is related to major events and sources of energy in the Earth's interior.

Abyssal Hills and Abyssal Plains

The abyssal hills have relatively low relief as they rise only 75 to 900 meters above the ocean floor. Abyssal hills were formed as an oceanic ridge. As the crust moved away from the spreading center, it cooled and sank to a lower depth. The mountainous terrain of the oceanic ridge is maintained, becoming low-lying abyssal hills at depths of more than 6,000 meters. The hills are usually covered with a blanket of unconsolidated pelagic sediments deposited with reasonable uniformity which gradually modifies and smoothes the features but does not change the original volcanic ocean floor topography that formed at the ridge.

A flat featureless surface known as an abyssal plain occurs when the hilly sea floor has been covered by a thick fill of sediments, which were deposited by turbidity currents. These river-like flows of a sediment-water mix are carried along the sea floor from continental margins via submarine canyons which act as conduits for turbidity current transport. Unlike pelagic sediment snowfall which provides a uniform cover, the turbidites flowing on the bottom surface fill from the seafloor upward to eventually cover the abyssal hills. The original irregular surface of a volcanic province remains under the turbidite fill. These plains, which may slope less than 1:8000, are found adjacent to land masses – extending from the continental rise to the abyssal hills. On prominences that rise above the plain, only sediments settling in the water column (pelagic deep-sea sediments) occur. On the surface of the plain, the pelagic sediments are interbedded with a dominating sequence of sands, silts, and clays of terrigenous origin that can be identified as turbidites by displaced benthic fauna and sediment patterns characteristic of turbidites.
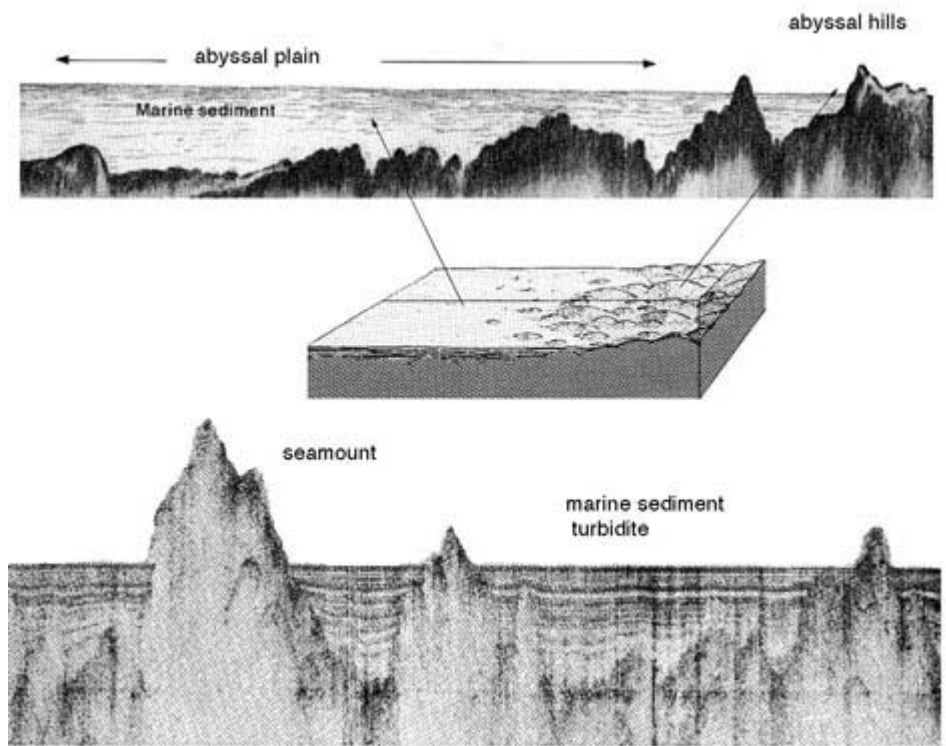
Deep Sea Trenches and Continental Rises

A subduction zone is where two lithosphere plates converge and one slab plunges into the mantle. Because of the drag, a trench is formed. Deep-sea trenches are long, narrow depressions in the ocean floor with depths greater than 6000 meters and they can reach 11,000 meters in depth. Trenches are found adjacent to land areas and associated with island arcs worldwide. They are more numerous in the Pacific Ocean. The trench is usually asymmetric, with the steep side toward the adjacent land mass. Where a trench occurs off continental margins, the turbidites from the slope are trapped, forming a hadal plain on the floor of the trench.
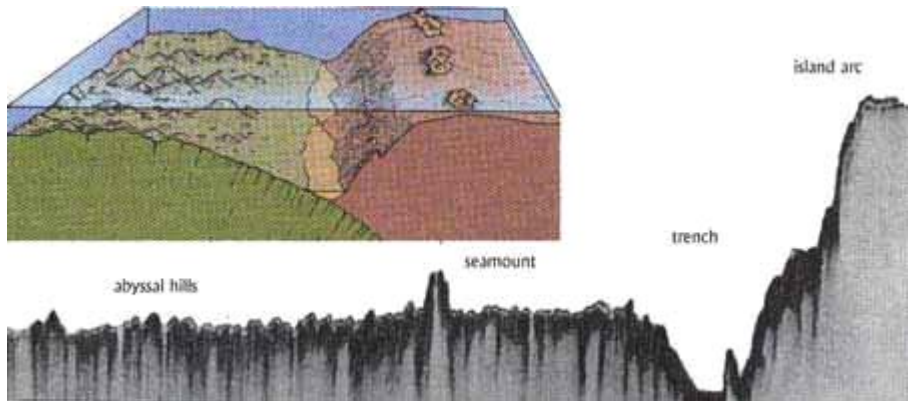
At the junction of continental and oceanic crust where there is no trench, sediments from the continental slope accumulate at the base of the slope to form a continental rise. The rises generally are adjacent to abyssal plains.

Volcanic Islands, Seamounts, Guyots, Atolls

Volcanos reaching the ocean surface form volcanic islands. Subsidence of a volcanic island with growth of coral keeping pace as it subsides will result in the formation of an atoll. Drowning of ancient volcanic islands by isostatic adjustment is shown by the coral atoll deposits drilled in the Pacific. More than 1400 meters of shallow water carbonates -- deposited in less than 100 meters water depth -- have been recovered from Bikini Atoll.
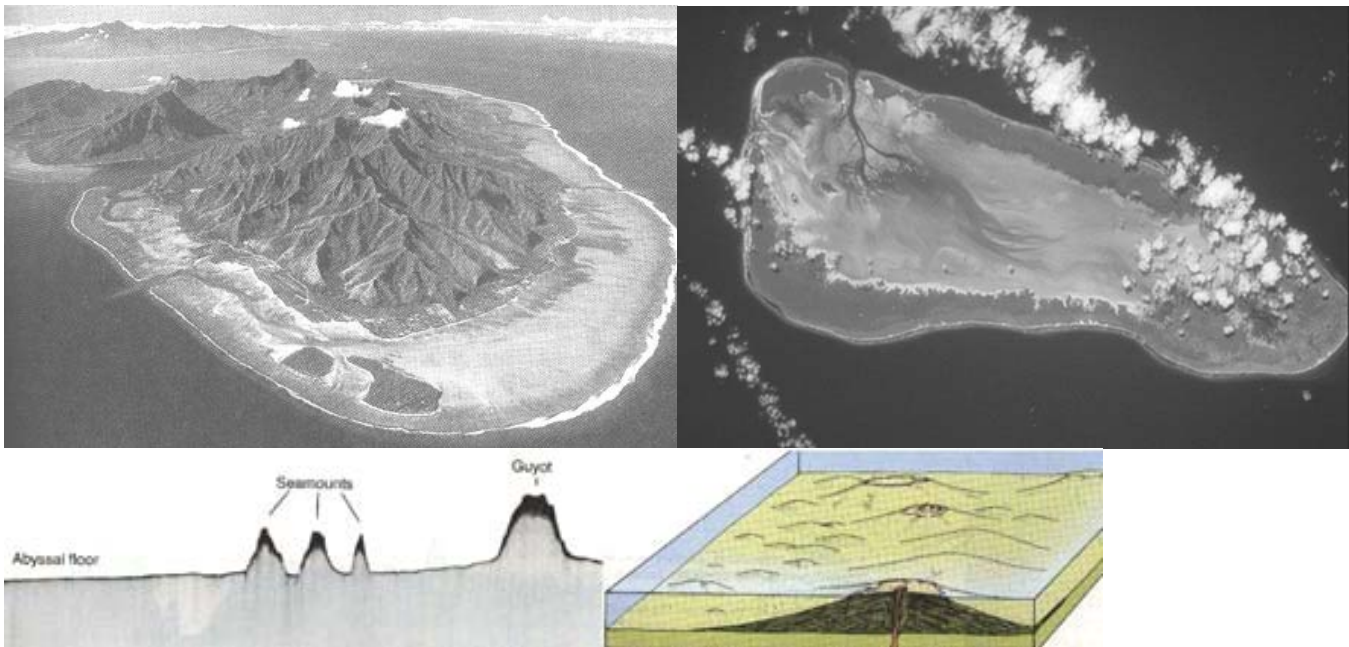

Guyots and seamounts are geomorphic forms developed from submarine volcanoes. They are isolated, but do lie in chains or provinces of volcanic activity. They are found in all oceans, but more have been recorded in the Pacific Ocean. The distribution that has been mapped may represent a small percent of the total number since they are only noted where crossed during bathymetric profiling. The seamount is a relatively isolated elevation of the seafloor of more than 1000 meters height, with a small rounded top – a volcano that did not reach the sea surface. Guyots are drowned volcanic islands that did not become coral atolls. They were planed flat by wave action when at shallow depths, after which

subsidence occurred so that they are like seamounts but with flattened tops that lie more than 200 meters below the surface. Although some coral rubble may be found on guyots, they are abrasional platforms that have subsided as a result of isostatic adjustment, with some contributing effect from sea level change.

Continental Shelf and Slope

The continental shelf (extending from the shoreline to the shelf break) is part of the continental crust and water depths over the shelf are a function of sea level and isostatic change. The continental slope lies over and is caused by the transition from continental crust to oceanic crust.
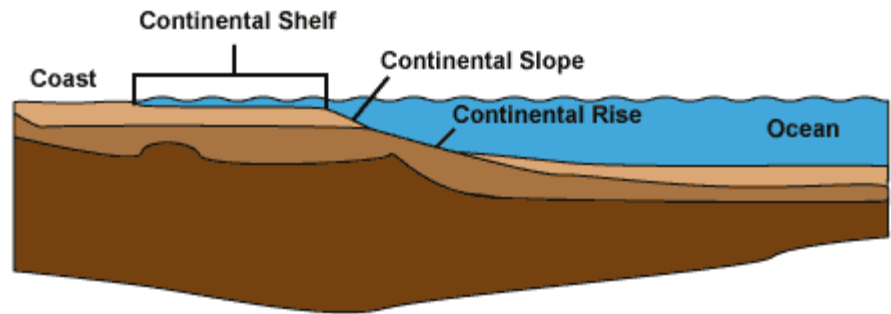
Summary

The most striking division of the earth's surface is into continental and oceanic areas underlain by oceanic and continental crust of different density and thickness.
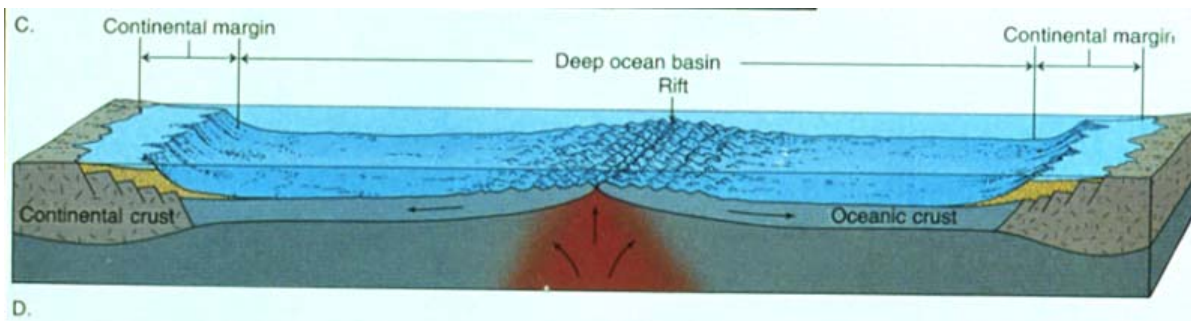
The major features of the sea floor are formed by tectonic processes of plate divergence, convergence, and transform faulting. Volcanic activity is the dominant process on the surface of the sea floor and the final shaping is the emplacement of volcanic features over the tectonic patterns.

The continental margins covered by present sea level are on continental crust. The morphology of these surfaces results from tectonics, sediment deposition and a history of sea level changes.