Geography Optional - 2024

BAHYMETRY : SUBMARINE TOPOGRAPHY

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Relief of the Sea Floor From the oceanographic point of view the chief interest in the topography of the sea floor is that it forms the lower and lateral boundaries of water. As 71 per cent of the earth's surface is water-covered, knowledge of the major features of the earth's relief will be fragmentary if based only upon those structures that can be seen on land. During the geological history of the earth which covers a span of some thousands of million years, areas now exposed above sea level have at one or more periods been covered by the sea, and parts of the now submerged surface have been above sea level. Many problems in historical geology are therefore dependent upon knowledge concerning the configuration of the sea floor surrounding the continents and the form of the deep-ocean bottom.

Although valuable work in the open ocean has been carried on by scientific organizations, by far the greater proportion of our knowledge of submarine topography is based on soundings taken by or for national agencies in the preparation or improvement of navigational charts. Because of their practical importance and the ease with which they could be obtained, the number of soundings in depths less than a few hundred meters accumulated rapidly during the nineteenth century, but in 1895 there existed only 7000 soundings from depths greater than about 2000 m, and of these only about 550 were from depths greater than 5500 m (Bencker, 1930). These data were used by Murray in preparing the bathymetric charts accompanying the reports of the Challenger Expedition.

During the next twenty-five years the number of deep-sea soundings increased slowly, but the introduction of sonic-sounding equipment after 1920 has completely changed the picture. Devices for measuring the depth by timing the interval for a sound impulse to travel to the sea bottom and back again are used in surveying work and are now standard equipment on many coastwise and oceanic vessels. The development of automatic echo-sounding devices not only made depth measurements simple but, by making accurate bathymetric charts available, introduced another aid in navigation, since passage over irregularities of the sea floor may be used to check positions. This development has necessitated extending accurate surveys into deeper water and, hence, farther from shore. With sonic methods, if the appropriate apparatus is available, it is no more trouble to sound in great depths than it is in shoal waters, and, since many naval vessels and transoceanic commercial vessels make systematic records of their observations, the soundings in the deep sea are now accumulating more rapidly than they can be plotted.

The accuracy with which submarine topography can be portrayed depends upon the number of soundings available and upon the accuracy with which the positions of the soundings were determined. Topographic maps of land surfaces are based on essentially similar data; namely, elevations of accurately located points, but the surveyor has one great advantage over the hydrographer. The surveyor is able to see the area under examination and thereby distribute his observation points in such a manner that the more essential features of the topography are accurately portrayed. The hydrographer, on the other hand, must construct the topography of the sea floor from a number of more or less random soundings. Sonic sounding methods and the introduction of more accurate means of locating positions at sea have made it feasible to obtain adequate data for constructing moderately accurate charts or models of parts of the sea floor.

Representations of submarine topography are usually referred to sea level, and particular interest has always been attached to those regions in which great depths are found. The greater detail with which the sea floor can now be mapped has emphasized the importance of relative relief;

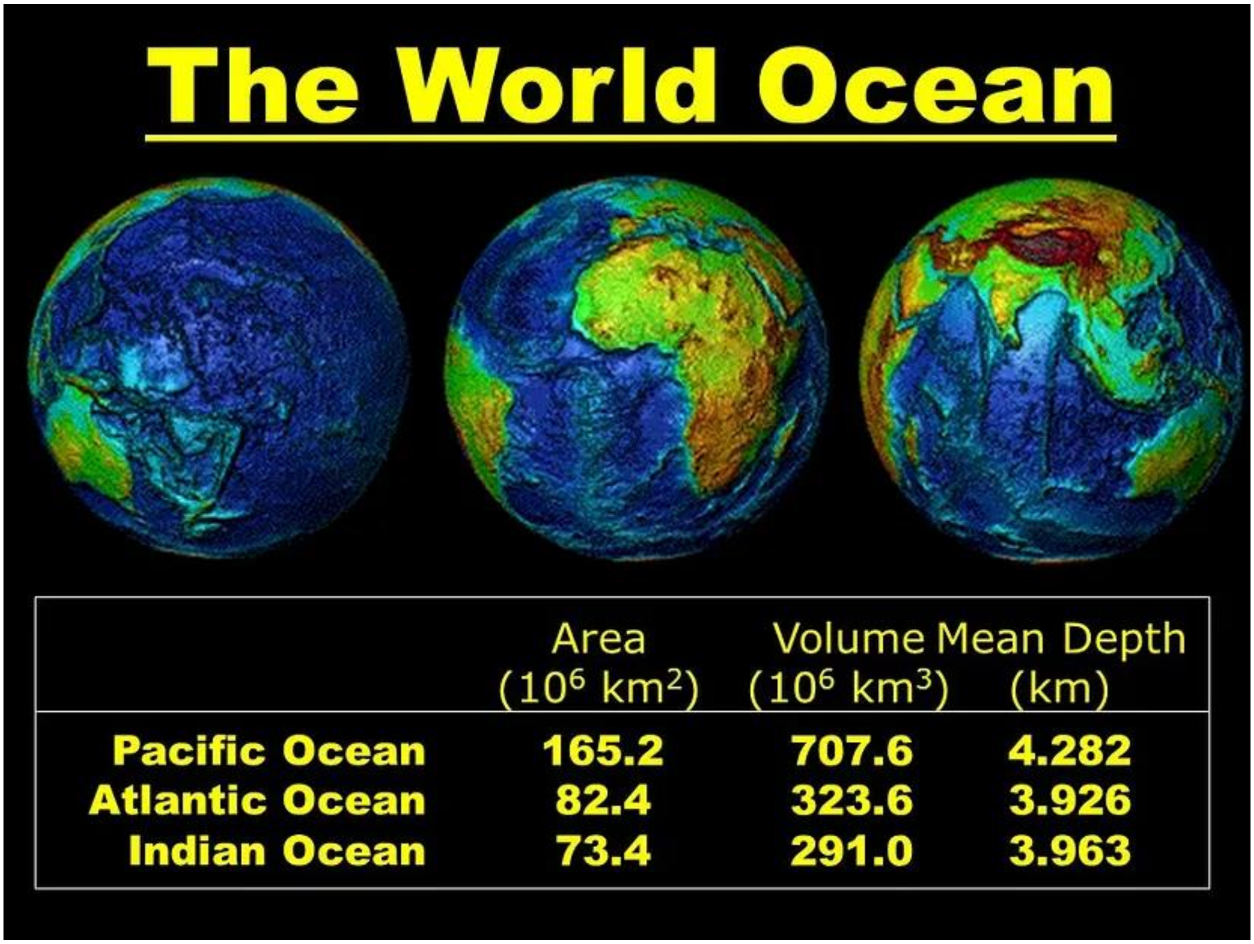
that is, the form and magnitude of elevations or depressions with respect to their general surroundings. In later pages it will be shown that there are two primary levels of reference on the earth's crust, one slightly above sea level, corresponding to the land masses, and a second at depths between 4000 and 5000 m, corresponding to the great oceanic basins. In comparing topographic features on land with those on the sea floor it is essential to consider them with reference to these levels.

One method of presenting the character of the relief of the earth's crust is by means of a hypsographic curve showing the area of the earth's solid surface above any given contour of elevation or depth concerning bottom configuration may slightly modify this curve, the general features will not be changed. The high mountains form a relatively small part of the land surface, and hence the mean elevation of the subaerial crust is only 840 m. The large areas of low-lying land have their counterpart in the relatively large areas in shallow water between the surface and approximately 200 m.

These coastal areas of shallow depth correspond to the continental shelves. Below the continental shelf there is a relatively small area of depths between 200 m and 3000 m, corresponding to the continental slope, and then follows the extensive oceanic abyss, with depths between about 3500 and 6000 m. The deeps, which by definition exceed 6000 m, form a very small part of the sea floor. Shown in the figure is the mean sphere depth, which is the uniform depth to which the water would cover the earth if the solid surface were smoothed off and were parallel to the surface of the geoid. The mean depth of the sea, which is 3800 m, is also shown.

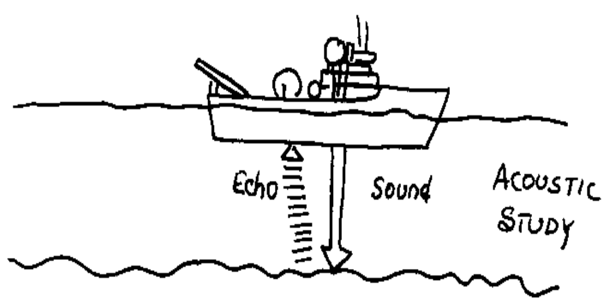
The hypsographic curve of the earth's crust should not be interpreted as an average profile of the land surface and sea bottom, because it represents merely the summation of areas between certain levels without respect to their location or to the relation of elevations and depressions. Actually, the highest mountains are commonly near the continental coasts, large areas of low-lying land are located in the central parts of the continents, and the greatest depths are found near the continental masses, and not in the middle of the oceanic depressions.

During the geological history of the earth, great changes have occurred in the relief of the land and sea bottom. The exact nature and extent of these vertical movements is beyond the scope of the present discussion, but it should be noted that changes in relative sea level of the order of 100 m, which are readily accounted for by the withdrawal and addition of water during glacial and interglacial periods, would expose and inundate relatively large areas.



Development in Bathymetry

- **Posidonius: fi**rst bathymetric studies in the Mediterranean (85 B.C.)
- During the HMS Challenger expedition in the 1870s the method to measure depth was still the same! (Although steam-powered). Confirmed the existence of the mid Atlantic ridge
- Slow, inaccurate, in incomplete Bathy = deep Meter = measure



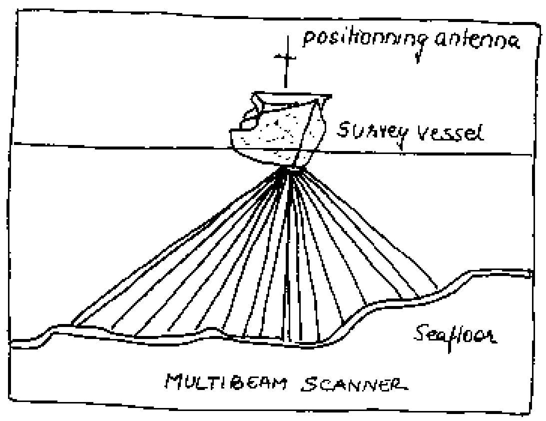
Echo Sounding

- In 1914 Reginald A. Fessenden developed an "Iceberg Detector and Echo Depth Sounder"
- The detector directs a sound pulse (ahead of the ship for iceberg detection or downward for depth measurements) and then listens for a returning echo
- Transit time of the return signal provides a measurement of depth
- The accuracy depends on water conditions and bottom contours
- First comprehensive charts of the ocean floor by 1959

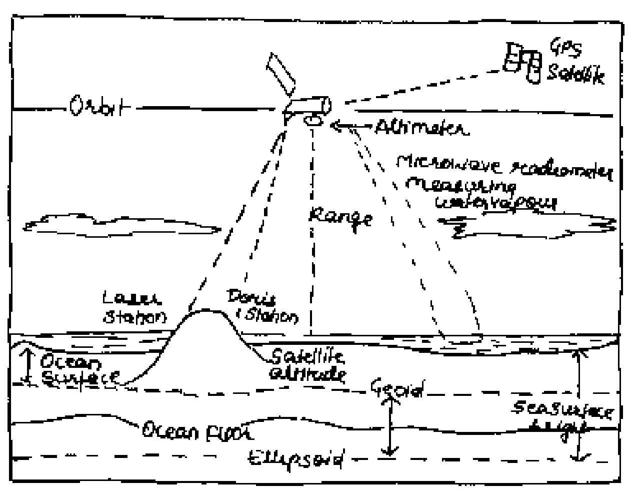
Multi beam Echo Sounding

- As many as 121 beams at once, covering a 120 arc, ~3.4 times wider than water depth
- Much less susceptible to contour error than single-beam detector
- With a mowing-the-lawn pattern you can build a complete map of an area
- Fewer than 200 ships are equipped with multibeam systems

Satellite Altimetry



- Satellites can measure small elevations in the surface of the ocean? very accurate measurements of the average height of the ocean surface (to within 0.03m!) Satellite Altimetry
- Extra gravitational attraction of ocean features cause differences in sea surface height
- Satellites have allowed rapid mapping of the world ocean floor from space.



An altimeter measures how high something is. Satellite radar altimeters measure the ocean surface height (sea level) by measuring the time it takes a radar pulse to make a round-trip from the satellite to the sea surface and back. Bathymetry is measurement of the depth of the ocean.

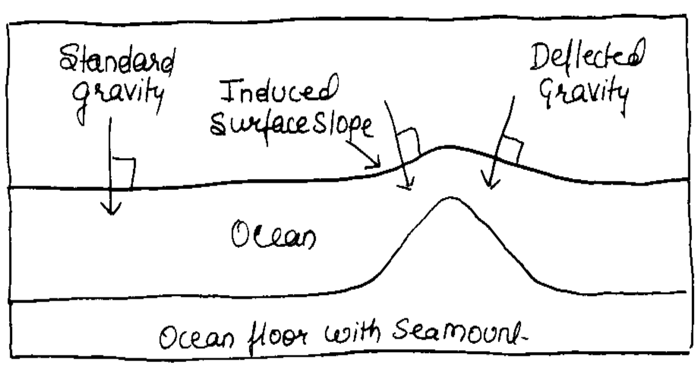
Our group does research to see how we can estimate bathymetry from space radar measurements of sea level.

Mars, Venus and Earth's Moon are better mapped than Earth. These other planetary bodies have dry surfaces, making their surface topography accessible to laser or radar measurements of their elevation. Seventy percent of Earth's surface topography is under the oceans, and cannot be directly sensed by lasers or radars. Direct measurement of ocean depths is done by echo sounders carried by ships, but only a few percent of the ocean has been mapped this way.

We use satellite radar altimeter measurements of the ocean surface height (sea level) to infer the presence of mountains below. Mountains on the sea floor add extra pull to Earth's gravity field, drawing more water around them and bulging the sea surface outward. This way of estimating depth we call "altimetric bathymetry".

An undersea mountain has to be about a mile high and several miles wide in order to generate enough of a bump in sea level to be recognizable in current radar altimeter data. Therefore altimetric bathymetry is not as accurate or detailed as echo sounding from ships. Even so, because altimeter satellites cover the whole Earth while ships have mapped only a few percent, the best global bathymetric models combine conventional echo soundings with altimetric bathymetry. Our research led to a bathymetric model that has been widely used in the scientific community for more than a decade, and was recently incorporated into GEBCO products and the popular web application Google Earth.

Improving this technique requires research in several areas, including more precise radar measurements (now coming from "delay-Doppler" or "SAR" altimeters) and improved understanding and calibration of the relationship between radar altimeter sea level and ocean bathymetry. These are research topics in our group.



The gravitational pull of a mountain adds to Earth's overall gravity, and this introduces small tilts in the direction that gravity pulls. By this mechanism, undersea mountains tilt sea level. We can use satellite radar measurements of sea level to detect these tilts and infer the presence of uncharted mountains below the sea surface.

This ***figure*** exaggerates the effect for clarity. In reality, though an undersea mountain can be a few kilometers high, the bump in sea level it produces is only a few meters high. A typical seamount tilts the sea surface by a very small angle, around 30 micro-radians. We are trying to measure these tilts to 1 micro-radian to discover the unknown topography of the sea floor. One microradian of sea surface slope means that sea level changes by 1 mm vertically for each 1 km you move horizontally. That is about 1/16th inch in one mile.

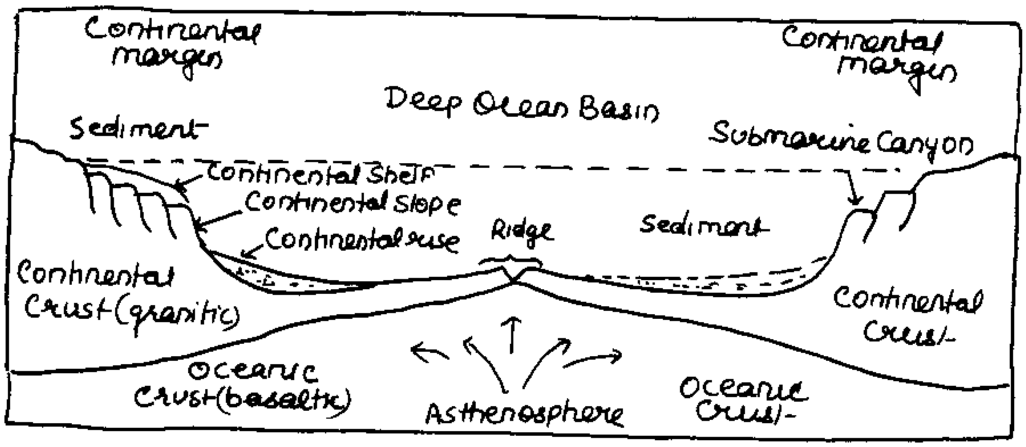
Features of the Continental Margins

Continental Shelf

The continental shelf consists of the rims of the continents flooded by ocean water. This part of the sea floor slopes gently from sea level to depths of about 200 meters (656 ft) below sea level. The continental shelf varies a great deal in width. In some places it is almost nonexistent; in others it is as wide as 1300 kilometers (800 mi). Generally, where broad continental plains slope to meet the ocean (passive margins), the continental shelf is quite wide. Where mountains are found along the edge of the continent (active margins), the shelf is narrow. These two extremes are found on the two coasts of the United States. Beyond the “passive” plains of the Atlantic and Gulf coasts, the continental shelf extends out ward as much as 480 kilometers (300 mi). On the Pacific Coast, with its “active” mountainous margins, the continental shelf is narrow. It is, of course, not surprising that the character of the continental shelf is related to the character of the nearby land, especially when we remember that the shelf is an extension of that land and geologically is not a part of the ocean basins.

The continental shelf area is the “treasure chest of the sea.” The amount of sunlight and the supply of nutrients washed into these waters from the continents allow marine plants and animals to grow and thrive. Thus it is in the shallow waters above the continental shelf that 90 percent of the fish we eat are caught. Virtually all the lobster, crab, shellfish, and shrimp live in these rich waters. Vast untapped quantities of gas and oil are stored in the shelf sediments, as are other minerals, including diamonds, tin, and gold.

The topography of the continental shelf is not as smooth as we might expect from the effects of constant wave motion, settling of sediments (sand, silt, and clay) brought from the adjacent land, and sea-level changes. Actually, though it is a relatively smooth, sloping plain, the shelf has ridges, depressions, hills, valleys, and canyons. Some of the higher features break the surface of the water and appear as islands, such as New York's Long Island and Massachusetts' Martha's Vineyard. During periods of lower sea level during the Pleistocene Epoch, when much water ordinarily stored in the seas was held on the land as glacial ice, the continental shelves formed land-bridges connecting Alaska to Siberia and Great Britain to continental Europe. The teeth and bones of grazing Pleistocene land mammals are occasionally dredged up by fishermen from shelves previously exposed as land areas.

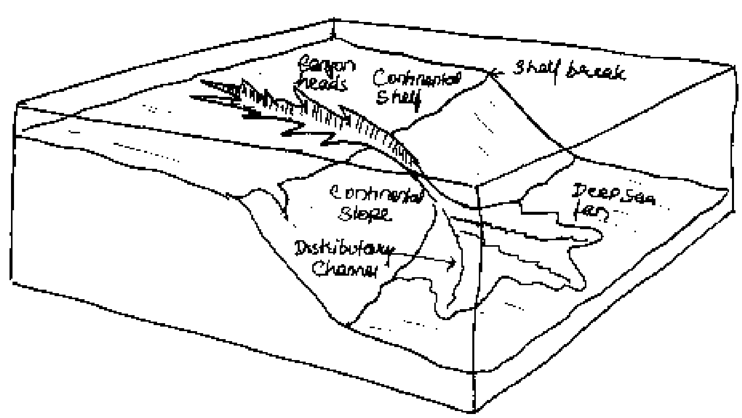


Submarine canyons are probably the most striking features of the continental margin. These canyons are usually steep-sided erosional valleys cut into the sediment and rock of the shelf and slope. They resemble the canyons cut by rivers on land and some are larger than the Grand Canyon. V-shaped in cross section, these submarine canyons are often found opposite the mouths of major rivers, such as the Congo or Hudson. This distribution has led to the hypothesis that rivers have helped form the canyons. Yet there are canyons that are not located opposite either present-day or ancient river mouths. Many theories have been advanced as to how the submarine canyons were formed. The most widely accepted explanation is that they were produced by **turbidity currents** - periodic massive submarine flows of sediment and water (a slurry) that move from the continental shelves down to the deep-ocean floor. Apparently such flows have a high capacity for eroding the ocean floor. The upper portions of the canyons may have developed by normal erosional processes during the Pleistocene Epoch, when low sea levels exposed much of the shelf areas. The lower portions of the canyons may be cut thousands of meters below sea level and have fans of sediment, such as beach sand, at their mouths on the deep-ocean floor.

Submarine Canyon, deep, steep-sided valleys on the sea floor. Submarine canyons begin as shallow valleys on the continental shelf, a submerged shallow plain that borders most continental coasts (see Oceans and Oceanography). They deepen farther from land as they cross the steeper continental slope—a region where the ocean floor descends steeply—then generally open onto the continental rise, a segment of the ocean floor present along most continental shelves, which gently descends to the flat abyssal plains of the deep-ocean floor. Many submarine canyons are located off the mouths of major rivers such as the Amazon, Mississippi, St. Lawrence, Congo, Indus, Ganges, Hudson, and Columbia.

Similar to canyons on land, submarine canyons are very deep (up to 2 km/1 mi in depth) and have nearly vertical walls. Tributaries often funnel into a main canyon channel, just as they do in river valleys on land. The slope of the channel floor may be as gradual as 1 percent, or as steep as 30 percent. These similarities led early geologists to believe that submarine canyons must have originally formed as river valleys and that these valleys were later submerged. This theory, however, would have required the sea level to drop or land to rise by as much as 4000 m (2.5 mi) worldwide, far in excess of the 120 m (390 ft) that the sea level fell during Ice Ages when sea water was transferred to glaciers on land. Only the shallowest reaches of canyons on the shelf could have been carved directly by rivers.

It was not until the 1950s that oceanographers determined that turbidity currents, flows of dense mixtures of water and sediment, could carve submarine canyons. The first evidence came in 1929, following an earthquake on the Grand Banks off Newfoundland, when submarine telegraph cables were broken in sequence,



from shallow to deep, by a turbidity current racing down the continental slope at speeds of 40-80 km/h (25-50 mph). Similar observations have been made since then on other cable breaks.

The presence of shallow-water artifacts, such as wood fragments and tree leaves, in deep-water sediments is further evidence that turbidity currents form submarine canyons. Following a cable break in a canyon off the Magdalena River (South America) in 1935, for example, a repair crew found the cable at a depth of 1500 m (1 mi) with large masses of shallow-water marsh grass twisted around it.

Turbidity currents are created by large masses of river sediments that are carried across the continental shelf by currents and waves. The material may follow ancient riverbeds carved during glacial times. When enough sediment accumulates near the shelf break, its own weight, or a vibration such as an earthquake, can trigger it to slide down the slope and carve out the canyon channel.

The carving of canyons can also proceed more gradually. Divers have observed a slow, steady current of sand flowing 0.3 km/h (0.2 mph) down the San Lucas canyon off Baja California. The slow or rapid erosion of the central channel of the canyon can create a steep-sided canyon by undercutting the canyon walls.

Where the coast is steep and the continental shelf is narrow, submarine canyons are often geologic extensions of canyons on land. The Monterey and Scripps canyons along the California coast are some of the most spectacular canyons in the world. The Congo Canyon (800 km/500 mi long) extends right up to the mouth of the Congo River, and river sediment bypasses the shelf to travel directly down the canyon to the continental rise.

Submarine canyons are the main pathways by which sediments reach the deep sea. Turbidity currents leave characteristic sediment patterns when they come to rest on the continental rise. They spread out horizontally and create depositional features called deep-sea fans. They also leave layers called graded beds or turbidites, in which fast sinking, coarse particles are on the bottom and finer particles gradually settle on top of them. This pattern of upward grading from coarse sediment to fine sediment is repeated as successive turbidity currents occur. The sedimentary rocks created from these deposits are found in numerous mountain ranges, including the Alps in Europe. They signal the presence of material that once resided on the continental rise at the mouth of a submarine canyon.

Continental Slope

Marking the outer edge of the continental shelf is a relatively steep drop, usually 3000 to 3600 meters (10,000-12,000 ft), to the ocean floor. This drop, called the continental slope, forms the boundary between the adjacent continent and the ocean basin. The landward boundary of the continental slope, where the land drops off abruptly, usually occurs where the waters are somewhere between 120 and 180 meters (400-600 ft) deep.

The continental slope is actually not a steep incline, since it descends at an angle of 15 degrees at the most, though it definitely slopes more sharply than does the shelf. What is most characteristic of the continental slope is its great descent, usually some 3600 meters (12,000 ft) but sometimes as much as 9000 meters (30,000 ft), to the deep-ocean floor or to the trenches.

Far less sediment is deposited on the continental slope than on the shelf because of the slope's greater incline and increased distance from the continents. Sediment is transported across the slope by turbidity currents in submarine canyons.

Sometimes a gently sloping surface, known as the continental rise, forms at the base of the continental slope. It has an average descent of less than one degree. Although the continental rises are well developed along the passive margins due to the presence of trenches at the edges of the continental margins. The continental rise is a depositional feature consisting of muddy sediments from turbidity currents and slumped materials from the shelf and slope.

Features of the Deep-Ocean Floor

The deep-ocean floor lies at an average depth of 3600 to 3900 meters (12,000-13,000 ft) below sea level. Until recently it was believed to be a relatively smooth plain. Now, with sophisticated hydrographic profiling devices, we have discovered that the topography of the deep-ocean floor is almost as irregular as that of the land. The ridges and depressions of the ocean floor rival and surpass those found on continents, both in size and complexity of pattern. On the other hand, large areas blanketed by marine sediments are virtually featureless plains.

Smoothing and leveling agents are important in shaping land above sea level. Running water, glaciers, wind, weathering, and gravity all work to smooth and level the land. They do this by wearing down landforms that are higher than their surroundings and by filling in depressions that are lower than their surroundings. Under the sea, these leveling agents are either missing entirely or much less active than they are on land. Consequently, many of the submarine landforms created by volcanic action and by breakage and bending of Earth's crust remains basically in their original form. The two most impressive submarine features of the deep-ocean floor are the oceanic ridges and the trenches. Other major features of deep-ocean submarine topography are abyssal plains, seamounts, and guyots.

Oceanic Ridges

The **oceanic ridges** (or **mid-ocean ridges)** are interconnected chains of mountains found in all three major oceans. The best known on these is the Mid-Atlantic Ridge, which extends from Iceland almost to Antarctica before it swings eastward from Africa toward the Indian Ocean. The Mid-Indian Ridge forms an inverted Y shape that extends into the Red Sea. Its southerly arms link the Mid-Atlantic Ridge to the Pacific Ridge and on to the East Pacific Rise. This continuous chain of mountains 64,000 kilometers (40,000 mi) long averages about 1600 kilometers (1000 mi) wide and raises an average of 1500 to 3000 meters (5000-10,000 ft) above the ocean floor. In some places its highest peaks rise above the surface of the water as islands. The Azores, Ascension Island, and Iceland are high peaks of the Mid-Atlantic Ridge. For example, the Azores rise 8100 meters (27,000 ft) above the ocean floor.

From the results of recent oceanogeographic research, especially ocean-floor drilling and direct conservation of the oceanic ridges from the manned U.S. submersible Alvin, Earth scientists now know that new material is being added to Earth's oceanic ridges.

The topography of the oceanic ridges is very rugged, and the whole range consists of volcanic rocks, chiefly basalts forming "pillow lavas". Pillow lavas are globular formations formed by lava cooling rapidly under seawater. Numerous fractures and faults add to the complexity of the oceanic ridges. Running parallel through the middle of the oceanic ridges is a central rift valley which may reach several kilometers in width. It is volcanically active and the center of earthquake activity. Most dramatic are the undersea volcanoes called **"black smokers"** that spew out hydrothermal fluids (hot water mixed with fine grains of iron and zinc sulfides). The central rift valleys and oceanic ridges axis are offset by fracture zones that cut perpendicularly across the oceanic ridges. These **fracture zones** are actually transforming faults, where sections of oceanic plates slide past each other. They usually form long fault scraps that may extend several thousand kilometers beyond the oceanic ridges. Where they cross the rift valleys, the greatest concentration of seismic activity occurs.

The Deep Sea Drilling Project (DSDP) operated the drill ship Glomar Challenger between 1968 and 1983. Glomar Challenger drilled over 1000 cores in all the major oceans. The most remarkable discovery was the confirmation of sea floor spreading. The addition of new crustal rock material along the mid-ocean ridges is pushing the older parts of the crust apart. Those drilling in the ocean floor now seek more detailed data on the hidden three-quarters of Earth's geology. The Ocean Drilling Program (ODP) continues to explore the ocean bottom with the newer drill ship JOIDES Resolution.

Trenches

Trenches represent the deepest parts of the ocean. Usually long, narrow, arc-shaped, and steep-sided, these depressions are aptly named. Most trenches are found not in the middle of the ocean basins, but near their active margins. Trenches are usually found adjacent to zones that have a concentration of volcanic and earthquake activity and are most common on the seaward (convex) side of curving chains of volcanic islands (called **Island arcs**), such as the Aleutians. Most trenches, including all of the deepest ones, are found around the Pacific "Ring of Fire". Challenger Deep, in the North Pacific's Mariana Trench, is the deepest known part of the ocean, reaching 10,915 meters (35,810 ft) below sea level. In 1960 Jacques Piccard and Donald Walsh descended in the bathyscaphe Trieste to the bottom of that trench. Placed in that trench, Mount Everest, the highest mountain on Earth, would still have a mile of seawater above its summit. Other major trenches in the Pacific are the Kuril, Japan, Philippine, Tonga, and Peru-Chile Trenches. The deepest part of the Atlantic is the Puerto Rico Trench, at 8648 meters (28,374 ft), while the Java Trench, at 7125 meters (23,377 ft), is the Indian Ocean's deepest point.

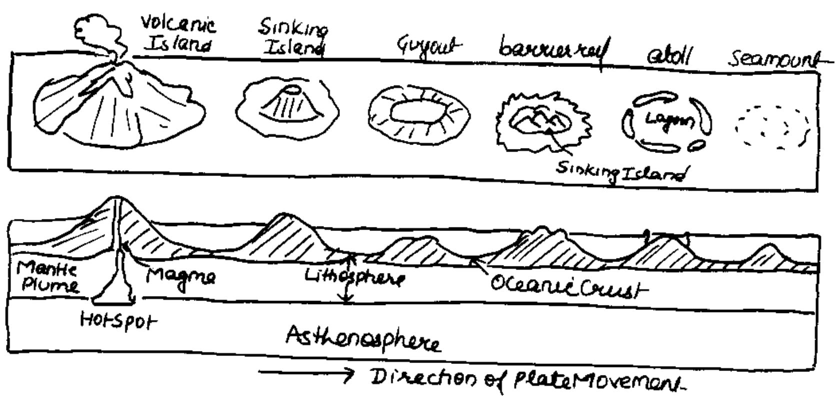
As with the oceanic ridges, the trenches play a major role in Earth's geologic evolution. Earth scientists believe that oceanic plates are descending below continental plates and are being recycled to Earth's interior by way of the trenches. This, process, known as subduction, is a key concept in the theory of plate tectonics. Ocean-floor drilling has shown that no ocean-floor rock is older than 200 million years. The youngest oceanic crustal rock is being created at the oceanic ridges, while the oldest oceanic crustal rock is being destroyed in the tenches by subduction. Thus, the oceanic crust is completely recycled over a period of a few hundred million years.

Abyssal Plains

Abyssal plains, or basins of low relief, lie at depths between 3000 and 6000 meters (10,000-20,000 ft) and cover about 40 percent of the ocean floor. Most are covered by thick masses of marine sediments that bury the ocean-floor relief. Much of this sedimentary blanket consists of fine brown and red clays, contributed by turbidity flows from the continental slopes, wind deposition, and volcanic eruption. A significant portion also consists of the remains of microscopic marine organisms. Such organic deposits are known as **ooze**. Britain's famous white chalk cliffs of Dover are uplifted ancient ocean-floor ooze deposits. In regions of slow deposition, manganese nodules form on the abyssal plains. These potato-sized concentrations of manganese, iron, copper, and nickel may someday be an important source of minerals.

Seamounts and Guyots

One of the most common features of ocean topography is the seamount, a **submarine** volcanic mountain. Unlike the continuous chains of mountains that form the oceanic ridges, seamounts are relatively isolated mountains or groups of mountains, usually with an elevation above the ocean floor of 900 meters (3000 ft) or more. Often steep-sided with small summits, seamounts are volcanic peaks that grow from the deep-ocean floor. Though most seamounts are not nearly as impressive in size as the mid-ocean ridges, some are high enough to break the ocean surface and appear as oceanic islands, such as the Canary Islands, Tahiti, and Hawaii.



Guyots, discovered during World War II, are seamounts with flat instead of peaked tops, found at depths of a few thousand meters below sea level. The origin of their flat tops at such depths is not certain. Where they have been studied, research indicates that they are volcanoes whose summits have been planed off by wave erosion. Later they subsided to their present depths, possibly during lateral movement of the sea floor away from the oceanic ridges and "hot spots," where new volcanic material rises to the oceanic crust surface, anchored in the mantle.

Islands and Coral Reefs

There are three basic types of islands - continental, oceanic, and coral. **Continental islands** are usually found on the continental shelves. They are geologically part of the continent but are separated from it because of sea-level changes or tectonic activity. The world's largest islands, such as Greenland, New Guinea, Borneo, and Great Britain, are continental. Smaller continental islands include Washington's San Juan Islands, New York's Long Island, and California's Channel Islands. The hundreds of barrier islands along gulf and Atlantic coasts of the United States are also continental. A few large continental islands, such as New Zealand and Madagascar, are "continental fragments" that separated from continents millions of years ago.

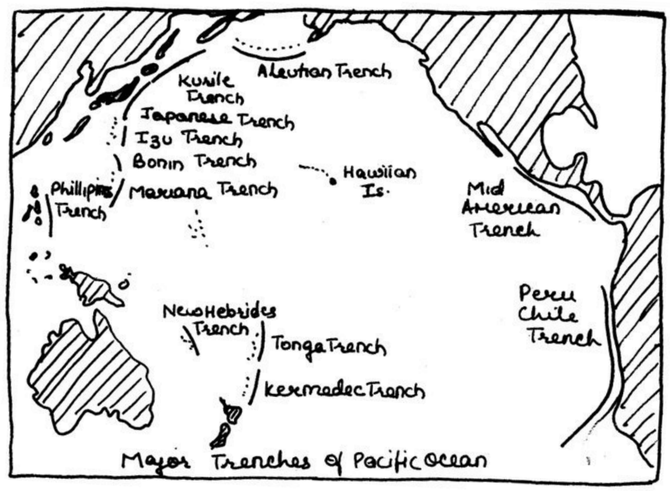
Oceanic islands are volcanoes that rise from the deep-ocean floor. They are not geologically related to the continents. Most of the oceanic islands, such as the Aleutians, Tonga, and the Marianas, occur in island arcs along the edges of the trenches. Others, like the Azores, are peaks of the oceanic ridges rising above sea level. Many oceanic islands occur in chains or lines, such as the Hawaiian Islands. These **island chains** are caused by the oceanic crust sliding over a stationary "hot spot" in the mantle. The exact cause of these hot spots is not known. Yet we can predict, for instance, that the Hawaiian Islands will move with the Pacific plate toward the northwest, and that the islands will slowly sink deeper into the thin oceanic crust. Hence, the islands to the northwest will submerge to become seamounts. A new volcanic island, named Loihi, will form to the southeast. Evidence of this motion is indicated by the fact that the youngest islands of the Hawaiian chain, Hawaii and Maui, are to the southeast, while the older islands, such as Kauai and Midway, are located to the northwest.

Coral reefs are shallow, wave-resistant structures formed by an accumulation of skeletal remains of tiny sea animal called polyps that secrete a limy skeleton of calcium carbonate. Many other organisms, including algae, sponges, and mollusks, add material to the reef structure. Reef corals need special conditions to grow - clear and well - aerated water, water temperatures above 20° C (68° F), plenty of sunlight, and normal salinity. These conditions can be found in the shallow water of tropical regions such as Hawaii, the West Indies, Indonesia, and the Queensland coast of Australia. Today, increasing pollution, dredging, souvenir coral collecting, and other man-made stresses threaten the survival of many coral reefs.

THE PACIFIC OCEAN

This Ocean with its bordering seas occupies about 1/3 of the area of the world and exceeds the total land area by about 1/8. It forms a rough triangle with its apex in north in Bering Sea (Strait) enclosed on the west by the long broken lines of Asia – Australiasia on the east by the Americas and on the south by the edge of Antarctic Continent.

This largest ocean has great distances involved, from Bering Strait to Cape Adare on the Antarctic continent is 15000 km while the width along Equator exceeds 16000 km. The Pacific basin begun its development some 250-300 million years ago, when as a result of continental drift. Gondwanaland in the south and Laurasia in the north broke up and the sialic continental rafts moved apart.



Major Trenches of Pacific Ocean

These movements are still in progress into the linear deeps and into the enormous tear faults which define the margins of the Pacific plate along the coasts of the Americas, North-eastern Asia, New Guinea and the line of New Zealand and Tonga-Samoa.

The greater part of the floor of the pacific comprises the deep sea plain, whose average depth is considerably greater than that of the plains of other oceans. Its surface is fairly uniform with broad gentle swells and depressions and much lines at an average depth of about 7300 m. To the west of Americas lies the South East Pacific Plateau that broadens itself towards equator as Albatross Plateau, Central American ridge and narrows down to north as Markus Necker ridge. In the northern Pacific, the Hawaiian swell is nearly 1000 km wide and 3000 km long.

The most characteristics features of the margins of this ocean are the elongated deeps lying close and parallel to the island arcs with their lofty mountain ranges. The deepest of them, Mariana trench lies off Guam, Philippines trench, Japanese trench (Ramapo deep) Tonga – Kermedec trench are the other examples.

The Peru Chile trench parallel to Andean Cordilleras is the most extensive submarine trench. The Pacific basin contains vast number 20,000 – islands but their aggregate area is relatively small. The continental islands are much larger as Japanese, Indonesian, Philippines, New Zealand etc. Most of the scattered group of islands Melanesia, Micronesia and Polynesia are the examples. The marginal seas are precisely absent in eastern basin, barring the exception of Gulf of California. The western basin includes more of marginal water bodies – Sea of Okhostk, Japan Sea, East China, South China, Yellow Seas, Gulf of Carpentaria, Arafura Sea etc.

THE ATLANTIC OCEAN

This ocean without its marginal seas occupies less than 1/6 of the total area of the world, that is near ½ of the extent of Pacific Ocean. Its general outline is that of letter 'S', for as the coast of Saharan Africa bulges westward so does the north coast of South America recede into the Caribbean embayment. Similarly while Cape Sao Roque projects eastward, so does Gulf of Guinea. This complementary nature of coasts helps in the interpretation of united landmass. The most striking feature of Atlantic floor is its central ridge – Dolphin ridge of northern basin and challenger ridge in southern basin.

It is covered by an average depth of about 3000 m. In the North Atlantic, the ridge widens to form telegraphic plateau.

There are several other transverse ridges in the Atlantic – the Walvis ridge, Whywhille Thompson etc. Linear deeps and trenches are uncommon in Atlantic. Along West Indies – Cayman, Nares, Puerto Rico deeps are the examples. South Sandwich trench are the examples. The continental islands as British Isles and Newfoundland West Indies are larger islands. Whereas the volcanic islands as Azores, Tristan da Cunha, St. Helena, Cape Verde, Cannaries, Madeira etc. are smaller in size.

ATLANTIC RIDGES

The southern Atlantic ocean is truely deprived of marginal water bodies.

However, north basin includes – Baltic, Mediterranean, Caribbean seas, Gulf of Mexico as major marginal water bodies. The Mediterranean with its several basins, interrupted by peninsulas and islands represents complicated structural area. The depth of Strait of Gibraltar is only 360 m forming a submarine sill which slopes quite steeply on either side. The Mediterranean basin has some areas exceeding 3600 m with deepest near Crete and Greece. The Black Sea with 2200 m of depth is separated from Mediterranean by Sea of Marmara and straits of Dardaneilles and Bosporous.

THE INDIAN OCEAN

The Indian Ocean is the enclosed continental ocean. Its shores consists mainly of ancient plateau – the remnants of Gondwanaland . It is only north east where it is bounded by Indonesian islands. The depth of the ocean is less diverse than the other two oceans. About 60% of total area forms deep sea plain with depth between 3600-5500 m.

Linear deeps are absent except the Sunda trench. A large number of submarine ridges separates several individual ridge. Amsterdam, St. Paul Plateau, the transverse Calsberg and Mascarene ridges and the Madagascar ridge are the prominent examples.

The islands of the ocean are mostly continental Madagascar, Sri Lanka. Scotra are the examples. The volcanic islands includes – Chagos, Pr. Edward, Crozet, Heard, McDonald, Seychelles, Mauritius etc. The marginal seas are comparatively few in number. Mozambique Channel, Arabian Sea, Bay of Bengal, Timor Sea, Red Sea, Persian Gulf are the major examples. In the southern basin less demarcarted Geography Bay. Joseph Bonaparde Gulf are the examples.