The Shelf and Sea Floor

By

M. G. Anantha Padmanabha Setty

Oceanography embraces all studies pertaining to the sea and submarine Geology deals with the topographic features of the sea bottom such as the shelf, slope and sea-floor, the agencies that have been active in the development of these features, the distribution of the different types of sediments and the various processes by which they are laid down in different areas of the ocean.

The physiographic map of the ocean is very similar to that of land. If, by any chance, one is able to remove all the water from the ocean what becomes visible to the naked eye is, a panoramic view of hills, valleys, mountain chains, deep gorges, canyons, etc. which in many respects is similar to land forms. However, broadly speaking, these features are described as continental shelf, slope, abyssal plains, submarine canyons, Rises, Ridges, Trenches, Sea mounts and a host of others.

I will now try to explain briefly these features and the impact they may have upon man by their influences and resources.

The continental shelf starts from the water's edge and runs out to the continental slope, approximately a depth of 100 fathoms or 600 feet from where the bottom drops off into the deep sea. The shelf varies greatly in width and slope. It is 190 miles wide off Cambay, about 45 miles off Goa and about 10-15 miles off Kanyakumari; however, in some cases, as off Somali coast it may be 2-3 miles wide or virtually absent off some mountaneous coasts. The average slope of the shelf is 10 feet per mile, average width being 42 miles and depth 72 fathoms. The shelf is not smooth and continuous at all but is interspersed by several irregularities. The shelf, in effect, is the extension of land into the sea. The shallow region adjacent to the continents is equal to 18% of the earth's total land area, or 7.6% of the ocean floor.

The rocks and sediments of the shelf are usually similar to those on the adjoining continents because it is from there they are derived. The common types are of 3 kinds—sand, silts and muds, and they are (1) terrigenous or land derived sands, (2) organic or calcareous sands of shells, coral fragments, foraminifera, etc. and (3) authigenic or chemical precipitates like oolites, glauconite, etc. In addition, there occurs gravel and occasionally mounds of solid rock sticking up from the sediments. The thickness of the sediment that envelopes the shelf is enormous and in some places it is over 10-15,000 ft. thick which is an accumulation in the past 15,000 years, constituting over 70% its volume.

As a result of advances and retreats of the sea during the Pleistocene period, shelves were periodically exposed and lowered. In some parts of the world other than coral reef areas, the shelves are dotted with anticlinal structures and salt domes, which, other than yielding salt and sulphur, are a source of petroleum and natural gas. A good example is Gulf of Mexico.
The present great interest in exploring the world’s shelves stems from their potential economic resources. About 90% of the world’s marine food resources now extracted comes from the shelves and adjacent bays. Second in importance is petroleum and natural gas; third in terms of present annual production and future potential in sand and gravel for construction purposes, however, in India it is the minerals such as Monazite, Rutile, Ilmenite and Zircon from the highly potential heavy mineral resources off Kerala coast and lastly Tin off Malaya, Gold and Dimonds off South Africa, Iron ore and some ccal off Japan, Phosphorite off Southern California, Peru and Florida. In addition, marine beaches like Kerala coast contain accumulations of Monazite, Ilmenite and Thorite, Gold on the beaches of Norton Sound, Alaska, Nova Scotia, Panama, Chile, Turkey and Russia. The beach in general represents a condition of equilibrium despite minor variations such as erosion and accretion. Building of piers breakwaters or jetties will change the character of the beach either by undesirable erosion in one place and unwanted accretion in another part.

As we reach the outer edge of the shelf, quite suddenly we find the ocean depth increasing and descending to the deep sea floor. This region of sudden plunge from 100 to 1000 or more fathoms into deep sea is known as Continental Slope. The inclination of the slope, however, varies with the character of the coast. Thus, actually it is this continental slope, and not the coastline, that marks the true boundary of each continent. Each continental slope is under constant attack from erosive and other destructive forces in the sea. Many slopes are incised with steep-walled canyons that serve as passageways through which the continental sediment flow out into the ocean basins. These were, at one time, considered to be the remanants of old river valleys, which were at high level than now, and the sea level was much lower. However, these submarine valleys or canyons are not restricted to areas off the river mouths but found elsewhere too. Recent studies have revealed that these giant canyons and their net work of tributotires extend up to hundreds of Kilometers and a depth of nearly 3000 m, formed as a result of scouring out by currents of sediment known as Turbidity current. This becomes denser and faster and moves at a speed nearly 50–60 miles an hour by the time it reaches the base of the slope. Such currents are set in motion either by earthquakes or tectonics. These turbidity currents moving at such enormous speed, cut gullies and channels on the way and sometimes cut the submarine telegraph cables and flow for hundreds of miles in the deep sea.

The swatch of no ground off Ganges and the Indus in the Indian sub-continent are the big submarine canyons however, smaller canyons near Pondicherry and Visakhapatnam were noticed recently.

The continental slope though has a vertical drop from nearly 100 to 1000 fathoms is by no means sudden. The world’s steepest slope is on the west coast of Ceylon. Several ridges and narrow plains are encountered normally in the region of the slope. The sediment found on the slope is chiefly composed of mud with sand, rock, gravel or fine ooze. It is reported that minerals like limestone, phosphorite, oil and natural gas also occur in this region.
Beyond 3000 m. the extensive oceanic abyss begins. This region which is an extremely flat area of the ocean floor is known as the abyssal plain. Features such as continental Rise, Ridge, Trench, Seamounts and Guyots are found here.

The Continental Rise is that part of the elevation, which fringes the bottom of the continental slope, and it often merges smoothly into abyssal plain. This Continental Rise includes the fan-like structures, found at the entrance to the submarine canyons. Much of the sediment found here is driven from the shelf and the slope. These rises are present where continental slope does not merge with the Trench.

The volcanic conical seamounts, flat-topped guyots and such other isolated hills ranging in height to a few hundred feet appear in the abyssal plain and are located between the base of the Rise and Mid-oceanic ridge. The seamounts may give rise to atolls, and some others to islands.

We might expect the sediments lowering the abyssal plain to be perfectly smooth like a new-fallen snow. This carpet of the sea floor is nearly half a mile thick, the result of millions of years of slow accumulation, at the rate of nearly an inch or so every 3000 years. This sediment is chiefly composed of pelagic ooze, which is nothing but the hard parts of minute shells of calcareous and siliceous organisms covering nearly 60% or 65 million square miles, followed by red, green and brown muds and also in some places by the turbidites. In addition wide areas of the floor appears to be dotted by Manganese nodules which seem more frequent in the Pacific than in the Atlantic and Indian Oceans. These nodules are rich in manganese, copper, cobalt, nickel and iron with traces of molybdenum. Titanium and vanadium. Though the percentage of manganese is less than the manganese ore mined on land, it seems economical to mine for the content of the included metals. The size of these nodules varies from a small pea to a big boulder weighing over 100 kilograms.

The long narrow but very deep depressions upto about 11,000 m. depth bordering island arcs or continental slopes are known as Trenches. These occupy only about 1% of the total area of the ocean. They are never found in the center of the ocean except on margins. The world’s deepest trench is the Mindanao Deep at 37,782 ft. or a depth of over 7 miles, near Phillipines. Most of these trenches are found on the outer margins of Japan, Java arc and South America.

The flat bottomed, narrow walled trenches are floored by unconsolidated recently supplied turbidites. They are seismic but show negative anamolies. Though they are deep depressions they are well aerated and allow life to exist.

The biggest single feature of the whole earth is the greatest undersea ridge of mountains known as the Mid-oceanic Ridge. It is the longest and the broadest mountain system in the world. It covers approximately \( \frac{1}{2} \) of the oceans and recognised over 60,000 Kms. across all the oceans. It runs over 10,000 miles as Mid-Atlantic Ridge from Greenland to Antarctic, then branches out into all the other oceans and the seas almost girdling the globe. This Mid Oceanic ridge continues eastward and extends as Carlsberg Ridge in the Arabian Sea and from there it branches
out to the Mediterranean and the Himalayas. Again, it is connected through an inverted 'Y' in the Indian Ocean going round south Australia into the Pacific. A valley like break runs along the crest of the mid-oceanic ridge for most of its length and it is here that new ocean floor is being formed today.

From a study of the numerous earthquakes along this break, it is noticed that the two sides are moving apart and that the region of break would continuously widen if it were not filled with material from below; however, the molten rock extrudes into this region and deposits itself on either side. As the cracking and spreading goes on a strip on magnetised rock is produced and in course of time reversal of polarity may take place which may be once in several million years.

Thus, according to the concept of Sea floor spreading, the spreading on each side of mid-ocean ridge varies from less than a centimeter to as much as 8 cms. per year. The fastest is from the East Pacific Rise and the slowest is from the Mid-Atlantic Ridge, and the Carlsberg Ridge in the Indian Ocean.

Another concept in this connection is the one known as Plate tectonics. According to this theory the earth crust is divided into huge segments which are afloat on the mantle. When two plates move apart, a fissure develops through which hot, molten lava rises and solidifies and continues to spread and thus collide against another plate. As a result, the leading edge deflects downward and sinks into the asthenosphere and gives rise to a Trench e.g. Tonga Trench in the Pacific. On the contrary, if the leading edges of two plates come together at less than 6 cms. speed per year a young mountain range is formed due to buckling.

Thus the concepts of sea floor spreading and plate tectonics allow a quantitative evaluation of the interaction of many variables in marine geology. Also they further support the theory of continental drift.

If all that is talked about so far is correct, then drilling at any point should show sediments of all described kinds at different areas referable to different ages have to be subjected to verification. In recent years, highly sophisticated research vessels like METEOR, OCEANOGRAPHER and GLOMAR CHALLENGER are in a position to core deposit anywhere in the ocean and take up to a hundred feet long core samples. A detailed study of such cores stratigraphically, and palaeontologically has revealed the correctness of these observations. However, such a study and deeper understanding of the oceans, is continuing. Earlier, the Mohole project was attempted on this type of study but now the Joint Oceanographic Institutions deep sea drilling project known as JOIDES is continuing.

In order to make oceans a man's business and exploit its resources such as catch more fish and shrimp, mine more metals, minerals and diamonds and tap more oil and gas, desalinate more salt water into fresh water, extract more nonmetals from the sea than at present we need progress in ocean technology to provide new improved equipment in the form of superships, deep diving submarines, more submersibles like TRIESTE and bathyscaphes, long deep penetrating corers and the like, unanchored
deep ocean drilling systems and floating platforms for mining and oil production, ability to navigate precisely with the help of satellites, radio, television, sonar and other electronic equipment and also more deep diving, aquanauts but not astronauts, underwater labora-
tories and above all bands of devoted researchers and international cooperation programs in ocean research. In addition, non scientific problems like political, legal, social and organisational matters must be looked into, so that they may not hinder further research.