UNIT 9 INTRODUCTION TO OCEANOGRAPHY

Structure

9.0 INTRODUCTION

The earth is divided into several plates. Each plate has two parts, i.e., continental and oceanic. The continental section comprises the land segment. It may be subdivided in (i) continental shelf (ii) slope and (iii) rise. On the shelf one finds remnant topographic features of land that have submerged because of sea level rise. The deep regions of ocean comprise oceanic plate. These regions have formed because of generation of new ocean at a convergent or a divergent boundary. During the antecedent cold climate phase over the earth, a sizeable amount of water got locked in the ice sheets and in the glaciers, and this has reduced the level and spatial extent of the oceans.

The plate tectonic determines the arrangement of continents and oceans and plays a vital role in destruction or expansion of the ocean. The new plate has a very young age at the mid-oceanic ridge, and it become older in the regions that have drifted away.

The sedimentation over the ocean is regulated by the supply of detritus from rivers, winds, and from biological productivity. Slumping supplies sediments over the rise. The oceanic plate receives negligible amount of sediments from land.

The chemical and physical processes regulate biogeochemical cycle of the ocean. The ocean has a layered structure. The density of seawater increases with depth. The salinity of the sea water declines in halohaline. Temperature decreases in thermocline. The physical, chemical and biological properties of the ocean are described to provide a glimpse of the influence of these on the processes of the earth that regulate the global climate.

9.1 OBJECTIVES

After studying this unit, you will be able to;

- Explain the physiographic subunits of the ocean;
- Describe the formation of oceans at a divergent plate boundary and destruction of plates at convergent plate boundary;
- Explain the sedimentary process at the shelf, slope, rise and in the deeper region;
- Discuss thermal and euphotic structures of the ocean and salinity variations in the ocean; and
- Describe the diverse life of the upper and deeper regions of the ocean.

9.2 PHYSIOGRAPHY OF OCEANS

The earth has formed as a molten mass of gasses billions of years back. The cooling of the earth has released gases and water vapour and that has formed atmosphere and water over the globe. It is believed that during the formation of the core, mental and crust of the earth, the water has migrated from the deeper region of the earth to the crust. About 96% of the water on the globe is stored in the ocean, and it has a horizontal extent of several hundred km. Ocean covers about 71% area of the globe. It has a variable vertical extent (average depth 3.7km). The physiography of the ocean is therefore very important because it determines the quantity of water that can be stored in the ocean. Exchange of water from the ocean to other reservoirs determines the extent of submergence of the continental margin under the ocean.

9.2.1 Physiographic Subdivision of Ocean

The physiography of the ocean is regulated by the ongoing geologic processes of the earth. The most of the oceans is very young compared to the age of the earth. It is because the ocean is created at the divergent centers and it is consumed at the convergence centers. The continued destruction of the ocean and reorganization of continents have reshaped the oceans. The present reorganization of continents started with the breakup of Pangaea, the supercontinent. The ocean crust, therefore, does not have age older than 200 million years. The physiographic features of the ocean therefore vary over the time. A brief glimpse of subdivision of the ocean is provided below:

9.2.2. Subdivision of Ocean

The submerged region of the continents is classified as continental margin while the oceanic crust that has formed due to tectonic processes at the divergent boundary is known as oceanic region. The tectonic and hydrological processes (that regulate the amount of water in the ocean) have shaped the physiographic features present on the floor. Based on the processes of their formation and extent of submergence, the margin of the ocean may be subdivided into two distinct categories, i.e., continental and ocean margins. The continental margin is the portion of the existing continent that is now submerged in the sea. It essentially is the land region that has a low density (average density 2.7 g/ cm^3). Being produced by the volcanogenic processes, the density of the oceanic plate is 2.9 g/cm^3. The continental section has a thickness of several km while the oceanic plate is very thin (Fig. 9.1).

9.2.3 The Continental Margin of the Ocean

This region comprises three main zones, i.e., (i) continental shelf, (ii) continental slope and (iii) the continental rise (Fig. 9.1). Adjacent to the land –ocean boundary, the submerged shallow flat region of the continent is termed a shelf region. The spatial extent of this region is highly variable. It varies from few to several hundred km depending upon the tectonic setting of the region. Generally for an active margin, the spatial extend of continental margin is very short. For example, the continental margin of the state of California, USA is only one km

The landward migration of sea is known as transgression of the sea.

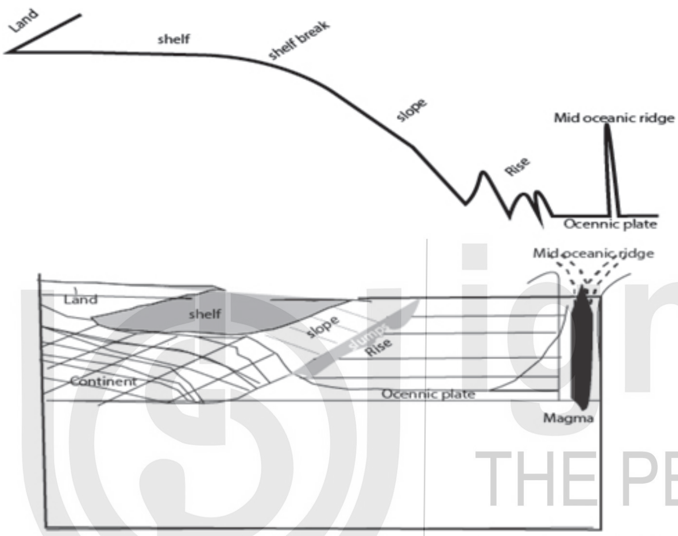

Fig. 9.1. The subdivision of the ocean

The landward migration of sea is known as transgression of the sea.

because it is an active margin. The width of shelf of the Siberia is, however, 1290 km. The depth of the shelf is also highly variable. It varies from 80 to 200 m. The shelf of an active margin has deeper depth.

Because the shelf is an extension of the continental land mass, it has all the physiographic features of land. Even though not visible, the shelf has small hills, basins and remnant of channels of old rivers that were following over the shelf when it was subaerially exposed. We must remember that the shelf is the the region of the earth that has periodically submerged or has been aerially exposed depending upon regression or transgression of the sea in response to a change in the earth's climate. The earth has experienced several regression and transgression cycles. The most recent is 20 kilo (k) years old. It has been archived that about 20k years back the global sea level was about 120 meters less than the present level of the sea. At such time sea - land boundary was about 60-300 km oceanward. One may note here that at that time the present shelf was exposed land, and it was not part of sea. Size of oceans on the globe was, therefore, reduced during this period. As the sea level has gradually increased during past 14.5k years, the shore has migrated towards the land and has submerged considerable amount of land. This has shifted the shoreline and the mouth of the rivers inland. If one explores the shelf region by the underwater sensors, one will discover many buried channels of rivers on the shelf. The channels of old rivers are manifestation of antecedent sea level.

The east and the west coast of India has a passive margin. The width of the shelf along the east and the west coasts of India is highly variable. The west coast has a much wider shelf in the northern region that extends to some 300 km in the Bombay Offshore Region. The vast shelf width in this region has been attributed to the tectonic setting of the region. The shelf narrows down from north to south along the west coast. The width of the shelf along the eastern margin of India also varies from the north to south. It is narrow at the southern tip (about 60 km).

We have learned that the actual boundary of land and sea keeps shifting. Since we are in the transgression cycle, the shoreline has shifted towards land. It may be borne in the mind that sea may recede during transgression phase and shore at those times may shift again to the edge of the continental shelf.

The continental self has a gentle dipping (slope 1:1000), and it attains a depth of about 120-140 m at the shelf break in India. Some shelves are even and have a gentle slope, but some are steep. The sea bed of the shelf may vary from even to rugged. The sedimentation processes regulate the ruggedness. A large supply of terrigenous flux creates an even shelf. Relict features and mounds associated with reefs, small hills and depressions on shelf may build uneven shelf. The slope and evenness of the shelf is therefore related to the tectonic nature, physiographic setting and mechanism of detritus supply. The East Coast of India has a high concentration of rivers that discharge an enormous amount of sediments into the shelf. This supply has buried the antecedent hills and channels on the shallow regions of the shelf (< 50 m water depth). Formed by the biogenic or volcanogenic processes, isolated or a chain of bathymetric perturbations (known as seamounts) of low height (less than 50 m) occur on the shelf. It also has channels of the paleo rivers that are now submerged or buried under the modern sediments.

> Paleo-rivers are the extinct rivers that were following over the shelf prior to increase in the level of sea.

Check Your Progress 1

Note: a) Write your answer in about 50 words.

b) Check your progress with possible answers given at the end of the unit.

Why there are variations in the physiographic features of the shelf?

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The continental shelf terminates at shelf break, a region where the slope of the shelf increases several-fold. The shelf break may be abrupt or gradual depending upon the tectonic nature and sedimentation during the last or antecedent episodes of sea level. The continental slope is the region that dips steeply (6^0) and connects continental shelf with the base of the slope (Fig. 1).The depth of continental slope is highly variable and it extends down to 2000 - 2,500 m. It has several sea mounts and that may rise to several hundred meters above the slope. These mounts are a manifestation of either tectonic activities or are formed by the volcanic activities. The seamount with the flat top is termed as Guoyt. The base of the slope has deposition of a pile of the sediments (known as turbidities). Most of these are deposited by the down-slope movement of the sediments started at the shelf edge during the episodes of sea level changes or by the slope failure because of a change in the depositional environment. Along the Indian Coast, the east coast has shallower depth at the base of the slope due to a large supply of sediments by several perennial rivers such as the Ganga and the Brahmaputra. The slope has a much-reduced depth off the northern region of the west coast. The West Coast of India has a higher number of seamounts on the shelf.

Check Your Progress 2

Note: a) Write your answer in about 50 words.

b) Check your progress with possible answers given at the end of the unit.

What is the physiography of continental slope?

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At the base of the slope, a high bathymetric region is termed as continental rise. This region is the boundary between an ocean and a continental plate. For the legal demarcation of the Exclusive Economic Zone (EEZ) of a country, the thickness of sediments at the continental rise is very important. A 1% sediment thickness is the criteria to extend the EEZ of any country beyond a legal limit of 200 nautical miles (nm). India has claimed a larger region, i.e., over 200 nm based on a large supply of sediments by its rivers over the continental plate.

9.2.4 Oceanic Margin

The oceanic plate occurs at > 3000 m depth. This region is comparatively very young as it is formed rather recently at the divergent ocean spreading centre by the volcanic processes. We know the oceanic plate to be very flat, and it has a gradient of 1:10000. However, some region of the plate has a chain of hills of varying height (formed by the volcanogenic processes) and we know this region as mid-oceanic ridge. This is the place where two ocean plates are moving apart. Some hills are several km tall and give rise to a chain of islands in the ocean. Hawaii is one of the examples of oceanic islands. The Laccadive Islands of India is another example. These islands were formed during the northward migration of Indian Plate after its recent break up during Early Jurassic Period (201 million to 174 million years ago). The trench (a negative bathymetry formed because of subduction at a converging margin) is the deepest region of the ocean. The Mariana Trench is the deepest region of the world, and it has a depth of about 11km.

Check Your Progress 3

Note: a) Write your answer in about 50 words.

b) Check your progress with possible answers given at the end of the unit.

What is the gradient of the oceanic plate?

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9.3 ORIGIN AND EVOLUTION OF OCEAN BASINS

The age of the earth is about 4.54 billion years. The oldest continental crust on the earth is about 4.0 billion years. However, you will find in the Figure 9.2 (prepared by Encyclopaedia Britannica; https://www.britannica.com/science/ocean-basin/Evolution-of-the-ocean-basins-through-plate-movements) that the age of the ocean basin is ~ 200 million year, and these age becomes younger (recent - 2 million years) over the mid-oceanic ridges. From the forgoing example, it is evident that the land is younger than the earth, and oceanic crust is very young. A student may wonder why is there a variation in the age of different rocks on the land and in the ocean. The age of the continental crust is lesser than the earth because the land mass has formed by cooling of the magma at some later stage. The map of the Encyclopaedia Britannica (Fig. 9.2) confirms that at the mid-oceanic ridges a young oceanic plate is forming. This poses a question on the date of the origin of the ocean. Because of degassing of the magma, water molecules have formed over the earth. Dr. Graham Rider has found sedimentary rocks that have the age of 3.9 billion years, though the age of the igneous rock is found to be about 4.0 billion. We may infer, therefore, that water was existing on the earth in the initial stage. Considering the quantum of degassing and oldest ages of sedimentary rocks, it is also clear that the ocean may have come in existence some 3.9 billion years back. A student of earth science may find it unusual that even though oceans have formed on the earth in the early stage, no ocean is older than 200 million years. The answer to this riddle lies in the persistent destruction and regeneration of ocean. To understand the generation and destruction of the material of the crust, first, we shall briefly grasp some of the fundamentals of plate tectonics. The material of the land is made of sial (that is silica and aluminum, density 2.7) and is lighter compared to sima (material comprises of silica and magnesium; density > 2.85). The sial is mostly a continents crust, while the sima is found below sial on the oceanic crust. The continents by virtue of a low density have higher elevation due to isostasy.

It may be noted here that as per the plate tectonic, the lithosphere of the earth may be divided into seven major plates. These plates are African plate, Antarctic plate, Eurasian plate, Indo-Australian plate, North American plate, Pacific plate and South American plate. Each of these, except the Pacific Plate, has oceanic and continental crusts. It is believed that the arrangement and the geographical distribution of the landmass and the oceans of the globe are regulated by movements of these plates. We have learned that the crust of earth consists of oceanic and continental plates. We have also learned that oceanic plates are newly formed region and are much thinner though denser that the continental plates. The continental plates are old regions that have been the continents or the land masses of the globe. From the above description it is also learned that the ocean crust is very young at the mid-oceanic ridges in the Atlantic Ocean though it becomes older as it moves away towards continents. As per the theory of the plate tectonics, it is also known that mantle plumes are driving force to move plates of the lithosphere (as shown schematically in Figure 9.3).

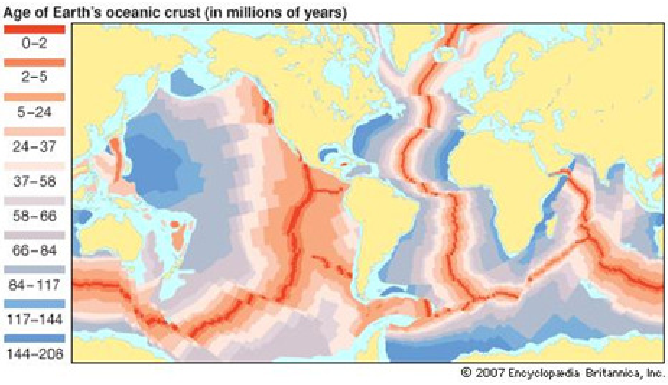

Fig. 9.2: Age of the oceanic plates (as provided in the Encyclopedia Britannica).

At the divergent boundaries, the plumes emanate from the mantle at the mid-oceanic ridges (Fig. 9.3). We have learned in the previous section that the volcanic activities at mid-oceanic ridges generate new plates and positive bathymetry by accumulating volcanic mater. The age of the oceanic plate at the mid-oceanic ridges and at the distal locations close to the continental rise, therefore, provides a clue that there is a constant generation of the new ocean at the divergent boundary, and the newly formed plates move away from the place of origin. The oldest age of an oceanic plate, therefore, gives a clue on the time of initiation of formation of a new ocean. However, we have yet to find the answer to the question "what has happened to the old ocean?"

The answer to this riddle is also provided in the plate tectonics. It has been learned that most of the plates are made of continental and oceanic plates, and these have divergent and convergent boundaries. At the convergent boundary or subduction zone, the plate is consumed as one plate subducts under the other plate (Fig. 9.3). The destruction of the oceanic plate at a subduction zone explains that the oceans are constantly

Divergent and convergent boundaries determine the points of the lithosphere where the mental plumes are emanating or sinking. At the divergent boundary, the mantle plumes bring the molten material that forms new oceanic crust. At divergent boundary, one plate subduct under the other and this process destroys a plate. The formation and destruction of plates are ongoing phenomena since the birth of earth.

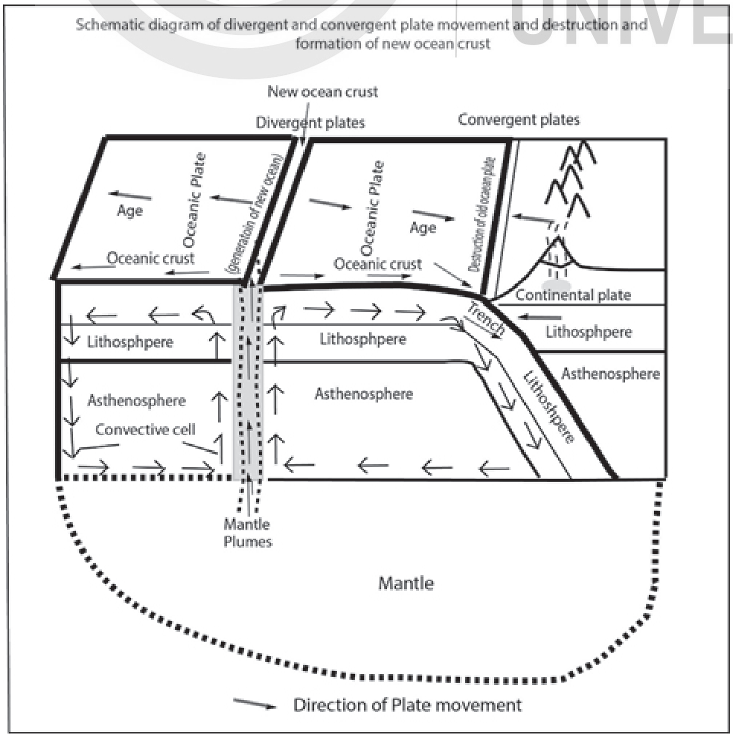

Fig. 9.3: Schematic diagram of formation and destruction of oceans at divergent and convergent boundaries. The Mantle plumes and their advection are also shown.

undergoing destruction. The rearrangement of plates is an ongoing phenomenon and it has changed the position of continents and ocean several times in the history of the earth. By the rearrangement of seven plates, individual ocean has expanded or shrank during the past. Some oceans are now a land mass. For example, the Indian Ocean has formed due to the breakup of a massive landmass known as the Gondwana Land. The fractionation of the Gondwana Land with multi-directional drifting of the India, the Australia, the Africa and the American plates has led to the opening of the Atlantic, the Pacific, and the Indian Ocean. Southward drifting and rearrangement of a section of the Gondwana Land has brought the Antarctica to its present position over the Southern Pole, and that has led to the formation of the Antarctic Sea. It may also to be noted here that at the present the Atlantic Ocean is widening while the Pacific Ocean is shrinking.

Check Your Progress 4

Note: a) Write your answer in about 50 words.

b) Check your progress with possible answers given at the end of the unit.

Why the ocean has a younger age than the continents?

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9.4 SHELF AND DEEP SEA SEDIMENTATION

As described in the previous section, the sedimentary processes are unique over the shelf as well as over the deep regions of the ocean. The shelf, being the extension of continents over the sea, has a variable environment of deposition and sedimentation. Being next to the land –ocean boundary, rivers discharge their load into the continental shelf. The erosion of the land by the forces of the sea also contributes detritus to ocean. The sediments that are supplied into sea from land are termed as allogenic. Most of the sediments over the inner shelf are allogenic. These sediments are also called terrigenous.

The redistribution of these detritus by the littoral and shelf currents is also very important. Two modes of advection is derived over the shelf. The movement of detritus parallel to the shore is termed as alongshore. This advection is carried out by the regional or local currents. For example, the eastern and the western boundary currents in the entire ocean carry detritus in alongshore direction. The alongshore transport is therefore regional in nature. The other mode of transfer is across-shelf movement. This advection carries the sediments from the inner shelf to the deeper region of the ocean. The alongshore winds have a cross-shelf component (if these are inclined to shore). These winds generate across shelf currents. Off the mouth of the rivers, the plumes of the rivers are carried for several hundred km. Such plumes carry a considerable amount of suspended matter into the outer shelf by the way of across-shelf transfer.

Bed load is advection of detritus along the sea bed.

The sediments are also carried along or across a shelf in the form of bed load. The direction of such sediment movement depends on the characteristics of bottom circulation. The re-suspension of sediments by high winds causes a large magnitude of bed load advection. These sediments are, however, coarser than the sediments that are carried in sea water as suspension. The movement of sediment at the sea-bed is by a layer that has a very high density (nepheloid layer).

Besides, detritus on the shelf are also supplied by the wind. Deserts and flood plains of rivers have unconsolidated sediments. Wind picks up the sediments from the deserts or the arid plains. Winds laden with the dust are known as dust storms. The dust storms carry a considerable amount of detritus in the tropics. In India, the Thar Desert is known for its dust storms and sediment contribution into sea. Similarly, other deserts also contribute a significant amount of sediments. Because the aerosols (dust particles) can be sustained in suspension for a longer time in the atmosphere, these are carried inter-ocean by winds. It may be borne in mind that the winds can supply sediments to a shelf or to deeper regions (oceanic plate) of ocean.

The other source of detritus to the ocean is through volcanic activities. The oceans receive sediments though volcanogenic processes at the sea bed. It may be borne in mind that the sediments contributed by the volcanogenic processes have very coarse grain size and these are termed as pyroclastic. The sediments that are discharged by the volcanoes in the atmosphere are also found to be deposited in the sea. These sediments become a distinct thin layer only in the deeper region of the sea. In the region of high sedimentation, the specific contribution of volcanogenic processes is noticeable only in the vicinity of the coast that has lava flows.

Volcanogenic detritus are clastic sediments that are discharged into atmosphere by way of a volcanic eruption. These sediments travel across the globe in the upper atmosphere.

The other major source of sediments over the ocean is authigenic supply. The unicellular organisms live in sea waters. Upon their death, the skeleton of these animals is deposited on the sea bed. In India, we find very high marine productivity along the SW continental margin of India. The shelf in that region has dominant deposition of remains of the skeleton of the organism.

Authigenic sediments form within ocean due to biological production.

If one looks at the pattern of sedimentation, the shelf has several specific features. The inner shelf has channels filled with sediments. These channels were active when the sea level was lowered. The deep incision off the mouth of the River Indus and the Ganga and Brahmaputra feed deeper fan in the Bay of Bengal and the Arabian Sea. The outer shelf receives fewer detritus compared to the inner shelf because the across-shelf movement is weaker than alongshore advection. The surface of the outer shelf, therefore, has more roughness. Because the deeper waters have more productivity because of upwelling or the presence of reefs, authigenic carbonate sediments are found over the outer shelf. In India, the outer shelf is covered with relict carbonate detritus.

Turbidites are thick, homogenous deposition of detritus. They are mostly found at the base of slope or in a fan.

The continental slope has a much reduced supply of the detritus. However, in India, the waters over the slope of the SW continental margin are productive. The slope of the most of the productive regions has a high amount of carbonate and organic carbon. Once buried, these deposits are an excellent source for production of petroleum product. The other source of sediments to the slope is through gravity transfer from the outer shelf. The slumping over the slope is episodic, and it is triggered by sea level fluctuations or by slope failure. The gigantic waves such as tsunamis and storm surges also cause slope failure and slumming in the sea. The continental rise is mostly covered with a thick pile of sediments. These sediments occur in the form of turbidites.

At the regions that have very high marine productivity, silica or calcite ooze on the shelf and in the deep ocean is found.

The deeper ocean receives very little supply from land. The sediments thickness over the oceanic plate is, therefore, tiny. These sediments are carried over the deeper water in suspension by across shelf advection. Windblown dust and volcanogenic sediments also occur over all the oceanic crust. In the vicinity of mid-oceanic ridges, the pyroclastic sediments are found in abundance.

The biological productivity is another source of the sediments in the deeper regions of the ocean. The deposition of the shells of the dead organism is termed as ooze. These oozes are of two types. The ooze that has carbonate shells is termed as calcareous ooze. The ooze with the skeleton of opal/silica is called radiolarian ooze.

It shall be bone in mind that the $CaCO_3$ dissolves below a certain depth known as carbonate compensation depth (CCD). CCD has varied in geological past. It is ~4- 5 km deep now. Therefore, there shall be no carbonate deposition below this depth. Because of this, most of the sediments in the deeper region (> 5 km water depth) are comprised of siliceous ooze.

Along the Indian Coast, the sediments from the rivers such as the Ganga and the Brahmaputra are found to have inter-basin advection (from the Bay of Bengal into the SW continental margin of India that is located along the Arabian Sea). The studies have documented deposition of detritus from the Bay of Bengal into the Arabian Sea.

As has been described earlier, the occurrence of intense biogenic activities has given rise to a sizeable amount of carbonate and silicate shells at the shelves of India. The shelves of India were aerially exposed during the last transgression (retreat) of the sea, and there were massive reefs and bioherms over the outer shelf. The age of these sediments is about 11-08k years. Such an environment has contributed a sizeable amount of authigenic carbonate sand over the mid-outer shelf. Submerged and exposed reefs over the islands of India have also been archived. It is very prominent at Lakshadweep and Andaman Islands. These regions have a high deposition of carbonate sands.

Check Your Progress 5

Note: a) Write your answer in about 50 words.

b) Check your progress with possible answers given at the end of the unit.

What kind of sediments is found over the deeper region of the ocean (oceanic plate)?

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9.5 PHYSICAL, CHEMICAL AND BIOLOGICAL ASPECTS OF SEA WATER

9.5.1 Physical Aspects

The water in the ocean/sea is heavier than the fresh water on the continents. Seawater has a density of 103 g/cm^3. The amount of salt (salinity) and temperature of seawater regulate its density. The density of sea water varies between 1.02 to 1.50 g per cm^3. The fresh water supply from the rivers and the melting of the continental and sea ice influence the density of local waters. For example, during the rainy season (during June - September) a large fluvial discharge of the rivers into the Bay of Bengal reduces the density of sea water at a regional scale. Evapotranspiration also influences density.

A higher rate of evaporation leads to loss of water in the form of vapour and that increases density of sea water.

The density of the seawater is crucial for vertical movement of sea water. The ocean has a layered structure. In the ocean, we find lighter density in the mixed layer. The density increases with the depth. The pycnocline is the second layer of the ocean, which has a higher density than the surface layer. The deeper regions of the ocean have higher density (Fig. 9.4).

The vertical variations in the temperature are presented in Figure 4. One finds a top warm layer with a uniform temperature. This layer is termed as a mixed layer. The water temperature below the mixed layer reduces rapidly with depth. This layer is known as the thermocline. The water of the deeper layer also show a reduction in the temperature, but the rate of decrease of temperature in the deeper layer is very low (Fig. 9.4). The temperature of the water is a very important parameter to regulate evaporation and vertical movement of water in the ocean. Associated with a low temperature, below the thermocline, the sea water has high density. This leads to floating of warm waters of upper surface over denser cold waters. Also, the water is cold near the poles because of prevailing climate. This water also has a higher density, and it sinks. It also aids the formation of cyclones. Because of a high sea surface temperature (SST), the Bay of Bengal has a frequent formation of cyclones.

Check Your Progress 6

Note: a) Write your answer in about 50 words.

b) Check your progress with possible answers given at the end of the unit.

What is the role of sea surface temperature (SST) on salinity and density of any parcel of sea water?

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9.5.2 Chemical Composition of the Sea Water

The seawater has a thermal conductivity of 0.6 W/mK at 25^0 C at a salinity of 35 g/kg (35‰ (parts per million)). The pH of the sea water ranges from 7.5 to 8.4. Sea water contains almost all the elements. The major constituents of the sea water are: Oxygen (85.84%), Hydrogen (10.82%) Chloride (1.94%), Sodium (1.08%), Magnesium (0.1292%), Calcium (0.04%), Potassium (0.04%), Sulphur (0.091), and Carbon (0.0028). Sodium, chloride, magnesium, sulphate and calcium are the most abundant dissolved ions. The salinity of sea water varies between 31-36‰. The salinity is not uniform. The highest saline region of the world is the Red Sea.

A large influx of fresh water from the rivers and from the melting of the ice into the sea reduces its salinity. Sir Edmond Halley was the first researcher to propose the reason for the salinity variations in the sea. He postulated that the proceeds of the continental weathering transported by the rivers contribute salt into the sea. The evapotranspiration of sea also increases the salt contents (similar to one found in enclosed lakes or inland water bodies such as the Caspian Sea). However, recent studies have shown that contribution of salts specifically that of sodium, through volcanogenic and hydrothermal activities are also important processes that contributes to salinity enhancement of sea water.

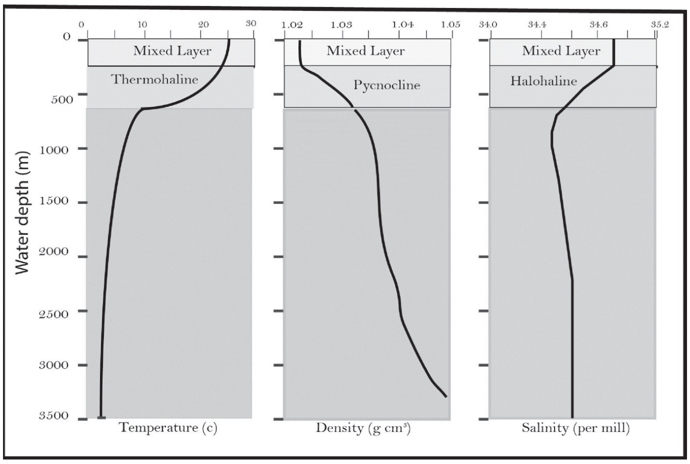

Fig. 9.4: Typical vertical profiles of temperature, salinity, and density in the ocean

The solubility of salts in the seawater also depends on the temperature and pressure. In the ocean, the atmospheric pressure increases with depth (the increases for every 10 m is 1013.25 hP). Because the temperature of the ocean at the deeper level is low, it also increases the dissolution of gases and salts and alters their physical and chemical properties. The residence time of various salts in the sea is highly variable. Sodium and chloride have a much longer residence time compared to calcium. Over the time, the average salinity of the sea has remained same. This has been attributed to three processes:

1. The input of the anion and cation estimated to be equal because there is continuous precipitation of salt by chemical as well as biogeochemical processes.

2. When sea water moves inland by the tidal forcing or during storm surges, sodium chlorite and calcium sulphate precipitate in warm or arid region of the marginal seas. The Rann of Kachchh is one such example where a large amount of sea salt is precipitated due to the cyclic influx of seawater and prevailing warm, arid climate.

3. The precipitation associated with super-saturation of salt in the sea. Gypsum and carbonates are the salts that precipitate in the shallow seas. Also, silica and carbon are extracted from sea water by biogenic processes, specifically by phytoplankton, the microorganism that fixes these in the presence of sunlight through photosynthesis. Corals, sponges, lobster and several other living animals including fish continuously extracts skeletons containing $CaCO_3$, phosphate and several other metals from seawater through primary and secondary productivity.

Vertical variation in the salinity of the seawater is shown in Figure 4. As indicated earlier, average salinity of seawater is 35.5‰. The salinity of seawaters, however, varies locally depending upon the amount of evaporation, influx of freshwater from rivers or from the melting of sea ice. Formation of ice also enhances salinity of sea.

Alike temperature, the salinity of the surface waters of the ocean remains constant in the upper mixed layer. Below the mixed layer, the salinity reduces, and this layer has been termed as halohaline. Below halohaline there is very litter change in the salinity of sea waters.

Check Your Progress 7

Note: a) Write your answer in about 50 words.

b) Check your progress with possible answers given at the end of the unit.

Which gas has maximum concentration in seawater?

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9.5.3 Biological Characteristics of Ocean

The information about the biological characters in the ocean waters is rather scanty because an extensive section of the deeper region of the ocean remains virtually unexplored. On the land, primary productivity, to a large extent, is light limiting, and there is a well-defined food web. On the contrary, in the ocean, only top 100 m of the water column is prominently sunlit (zone of sunlight penetration is maximum 1000 m in rare cases). Yet the entire ocean including the deep, dark regions is found to have a life. The primary producers in the ocean are of two types, i.e., photosynthetic (fixing carbon using sunlight) and chemosynthetic (the organism that produces their food by chemical processes). The former are planktons, mostly algae and cyanobacteria (commonly called cyanophyta) that obtain their energy through photosynthesis. The chemosynthetic community lives in the deeper region of the ocean that does not receive any sunlight. The life here derives its food through chemical reaction around thermal plumes emanating from the hydrothermal vents.

The tropic levels in the ocean are given in Figure 9.5. The autotrophic communities (primary producers) are generally unicellular planktonic species that drift in the euphotic zone and produce their food through photosynthesis. It also comprises of some species of macroscopic algae termed as weeds. The depth of euphotic zone depends upon several factors, important among these is cloud cover and the turbidity of the sea waters. The waters with reduced or no turbidity are found to have a deeper euphotic zone. The water over the oceanic plates has very little sediments, and the depth of euphotic zone is more here. The depth of euphotic zone is also less off the mouth of the rivers. Despite a higher turbidity that attenuates deeper penetration of the sunlight, the primary productivity of these waters was found to be many-fold higher due to enhanced supply of the nutrients from the land. The mangroves and beach grasses are the only plants that are found in the submerged land of the coastal region.

Zooplanktons, the floating herbivorous consumers, are heterotrophic, and these occupy the next level in the tropic diagram (Fig. 5). These organisms vary in size from < 2 to 200 μm and mostly feed on eutrophic species. Over 1500 species of fungi are known from marine environments. These are parasitic on marine algae or animals, or are saprobes on algae, corals, protozoan cysts, sea grasses, wood and another substrate, and can also be found in sea foam. The carnivorous consumers of the higher order viz. fish, squid, and large mammals (e.g. whales and dolphin) occupy the top of the pyramid. Generally, at each level, only 10% of the energy from an organism is transferred to its consumer. The rest is lost as waste, movement energy, heat energy and so on. As a result, each higher tropic level supports a smaller number of organisms – in other words, it has less biomass. This means that a top-level consumer, such as a shark, is supported by millions of primary producers from the base of the tropic pyramid.

Unlike the land, there are diverse species that dwell in the bottom of the sea or float below the euphotic zone. The bottom dwellers are generally termed as benthic fauna, and most of these are heterotrophic, though a very small community may be the primary producer (chemosynthetic community). The life in the dark, deep ocean is sustained from the supply of organic matter from the primary production in euphotic surface via biological pump. The decomposers are active at each of the levels of the

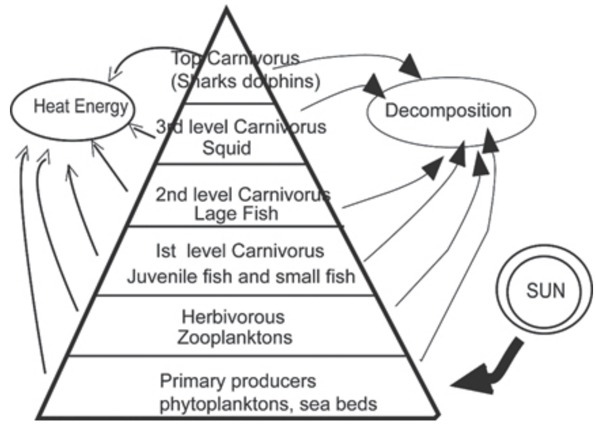

Fig. 9.5: Tropic levels in the oceans.

tropic and these play a vital role in dissolving organic matter and the nutrients from the remains of primary of secondary producers. Despite (i) a high pressure, (ii) no primary producer, and (iii) a low temperature, life in the deeper layers of the ocean is sustained from the rains of dead skeletons, organic remains, and dissolution of nutrients released from the decomposition of the biotic components. We find the marine biodiversity to be related to climate, the supply of nutrients and the availability of sunlight. A higher supply of nutrients from land or upwelling may lead to a high primary productivity, and it enhances the supply of organic matter into the deeper subsurfaces. Most of this organic matter is consumed by heterotrophs or bacteria. A high marine production leads to a large consumption of oxygen by sinking organic matter, which makes these waters sub-oxic or anoxic through the process of eutrophication. The oxygen-depleted waters are hazardous for marine life, specifically for the heterotrophs in the higher tropic order.

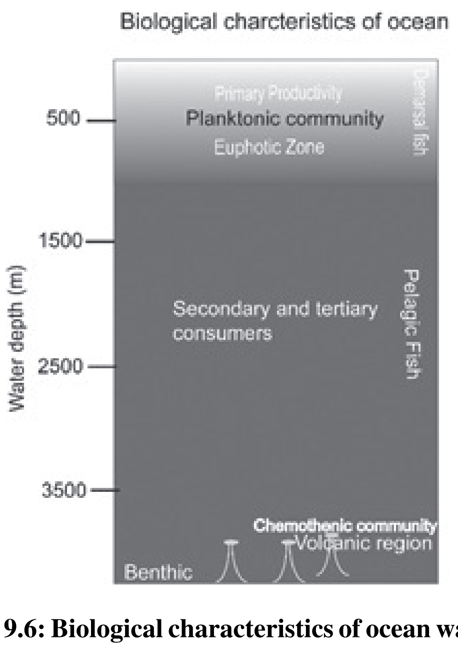

Fig. 9.6: Biological characteristics of ocean water.

Marine habitats are broadly divided into two sections, i.e., coastal and open Ocean. Coastal habitat extends from the coast to the edge of the continental shelf. The region beyond the shelf edge is termed as Open Ocean Habitat. The deep ocean fish is termed as pelagic whereas shallow water species are known as demersal.

Check Your Progress 8

Note: a) Write your answer in about 50 words.

b) Check your progress with possible answers given at the end of the unit.

What is the tropic level of the ocean water?

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9.6 LET US SUM UP

Oceans have been storing water for 3.9 billion years, but their age is only 200 million years. This is because the ocean is constantly being formed and destroyed. At a divergent plate boundary, ocean forms. At the convergent plate boundary, the ocean gets consumed.

The ocean has two physiographic units. Continental margins are submerged portion of the continental plate. This region is further divided into shelf, slope, and rise. The oceanic plate is newly formed ocean, and it occurs in the deeper regions. It has a chain of bathymetric highs and low at the mid-ocean ridge and at subduction zones.

The sedimentation in the ocean is regulated by the supply of sediments from the continents. The physiographic features present on the shelf get buried under the sediments. If the supply of sediments is very high, shelf or slope region has an even physiography.

The oceanic plate receives very low amount of sediments. These sediments are mostly contributed by water column deposition. The other source of sediments is by biological production. The shells of the primary producers rain over the ocean floor.

Ocean has layered structure. The upper most layer has a uniform, salinity, density, and temperature, and it is known as mix layer. The temperature and salinity decline in the ocean below mix layer. The salinity and temperature of deeper water of the ocean are having least variability. The density of seawater increased with depth.

The primary producers in the euphotic zone are the only source of food for the secondary produces. Secondary producers live on the supply of organic matter from the euphotic zone.

Terminal Questions

1. What is a continental shelf?

2. What is the maximum age of oceanic crust?

3. What causes slumping in the ocean?

4. What is the role of the wind in supplying sediments into ocean?
5. In which layer the density of water reduces in the ocean?
6. What is the depth of euphotic zone in the ocean? What controls this depth?

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9.8 ANSWERS TO CHECK YOUR PROGRESS

Your answers should include the following points:

1. Continental margin is an extension of land that is now submerged in the sea due to a change in the sea level.

2. The maximum age of the ocean crust is 200 million years.

3 Sea level variability is the major factor that causes slumping from the shelf into the rise. The storm surges and tsunami also cause slumming.

4. Winds supply sediments of deserts into the ocean. The volcanogenic sediments are also transproted into the ocean by the wind. The wind is, therefore, the one of the major agents that supplies sediments to the deeper region of the ocean.

5. Pycnocline is the layer in which the density of the ocean water increases

6. The depth of euphotic zone is generally 100 m. Sunlight is known to have penetrated as deep as 1000 m in the seawaters over the oceanic regions.

   It depends on the sun light and turbidity of sea waters.

Answers of Terminal Questions

1. The submergence of the shelf and associated sedimentation causes exposure or burial of physiographic features. Tectonic setting and sedimentary environment is different over each shelf. The physiographic features are also variable due to change in these parameters.

2. The continental slope has a high slope (6^0). It has hills of varying size formed due to antecedent volcanic activities. Some of these hills may also be formed due to biological activities such as reefs during the time when the sea level was low.

3. The oceanic plates have a very high gradient (1:10000).

4 The ocean plate is consistently destroyed due to plate tectonics. The continental plate does not undergo such destruction. Because of this, the ocean is younger than continents.

5. A thin layer of clastic or biogenic sediments is found over the oceanic plates. The region deeper than 4.5 km does not have any carbonate sediments because of CCD.

6. The SST is linked with the salinity and density of sea water. A high SST leads to evaporation, and this increases salt contents in sea water (enhanced salinity), and its density

7. Oxygen has maximum concentration in seawaters

8. The tropic level is the arrangement of primary and secondary consumers with respect to supply of food. It also depicts the source of food.