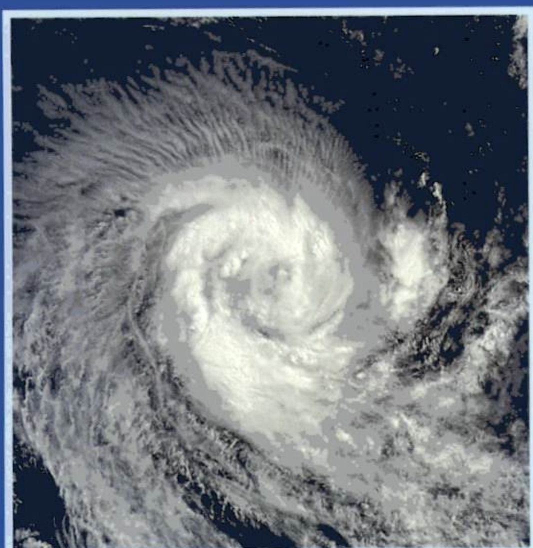
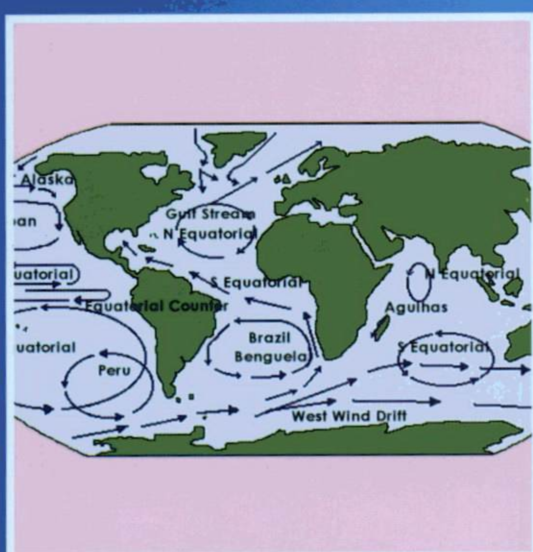
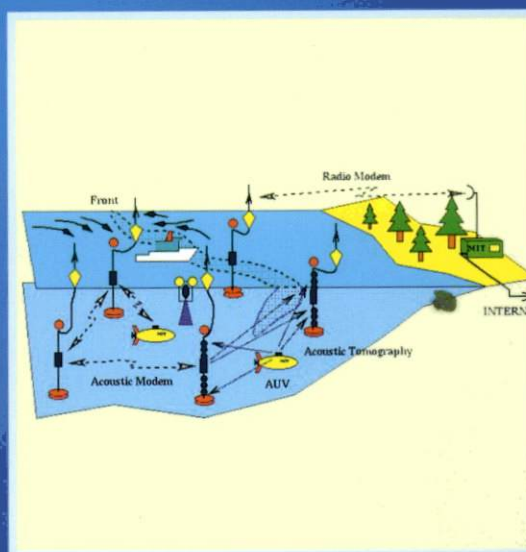
Karnataka State Open University

Department Of Studies In Geography
Manasagangotri, Mysore - 570 006

M.Sc. GEOGRAPHY
Second Semester







OCEANOGRAPHY

COURSE - 202 BLOCK - 1,2,3 and 4

ಕರಾಮುವಿ

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- ಕರ್ನಾಟಕ ರಾಜ್ಯ ಮುಕ್ತ ವಿಶ್ವವಿದ್ಯಾನಿಲಯವು ಜೂನ್ ೧, ೧೯೯೬ ರಂದು ಸರ್ಕಾರಿ ಅದೇಶ ಸಂಖ್ಯೆ : ED1/UOV/dated 12th February 1996 (Karnataka State Open University Act - 1992) ರ ಪ್ರಕಾರ ಕರ್ನಾಟಕ ರಾಜ್ಯಪಾಲರ ಅನುಮೋದನೆಯೊಂದಿಗೆ ಪೂರ್ಣಪ್ರಮಾಣದ ವಿಶ್ವವಿದ್ಯಾನಿಲಯವಾಗಿ ಸ್ಥಾಪನೆಗೊಂಡಿತು. ರಾಜ್ಯದ ಶೈಕ್ಷಣಿಕ ಪದ್ಧತಿಯಲ್ಲಿ 'ದೂರ ಶಿಕ್ಷಣ ಪದ್ಧತಿ'ಯನ್ನು ಆರಂಭಿಸುವ ಮತ್ತು ಉತ್ತೇಜಿಸುವ ದೃಷ್ಟಿಯಿಂದ ಈ ಮುಕ್ತ ವಿಶ್ವವಿದ್ಯಾನಿಲಯವನ್ನು ಅಧಿನಿಯಮದ ಮೂಲಕ ಸ್ಥಾಪಿಸಲಾಯಿತು.
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- ಕರ್ನಾಟಕ ರಾಜ್ಯ ಮುಕ್ತ ವಿಶ್ವವಿದ್ಯಾನಿಲಯವು ೧೯೯೯ ರಿಂದ 'ಏಷಿಯಾದ ಮುಕ್ತ ವಿಶ್ವವಿದ್ಯಾನಿಲಯಗಳ ಸಂಘ' (AAOU), ಬೀಜಿಂಗ್, ಚೀನಾ – ಇದರ ಶಾಶ್ವತ ಸದಸ್ಯ ಸಂಸ್ಥೆಯಾಗಿದೆ.
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Karnataka State Open University
Manasa Gangotri Mysore - 570 006

M.Sc
SECOND SEMESTER
GEOGRAPHY
COURSE - 202

OCEANOGRAPHY 202

PAGE NO

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BLOCK-2

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COURSE 202

OCEANOGRAPHY

COURSE INTRODUCTION

BLOCK 1,2,3 and 4

An extension of saline water on earths is called sea. Large sea areas are called oceans. The scientific study of the oceans is called "Oceanography". It deals with the nature of the water, its movements, temperature, salinity, depth and life in the oceans.

Land and sea are generally antiphonally arranged about two thirds of the land being in the northern hemisphere. It is calculated that about 71% of the earth's surface is occupied by seas and oceans. Only 1.5 percent of the earth's surface having land antipodal to land

First block introduces you to oceanography from Unit1, submarine topography Unit2, distribution of land and water, Unit 3, hypsometric curve and relief features of the Atlantic ocean Unit 4, relief features of pacific and Indian oceans.

Second block gives you knowledge about characteristics of ocean water especially temperature in unit-5. Unit -6 also helps to know the salinity of ocean water. Pressure – factors and distribution are discussed in unit 7, lastly unit-8 gives you knowledge about circulation of ocean water especially currents and its causes.

Third block divided into unit-9, currents of Atlantic ocean , Unit 10,currents of Pacific and Indian ocean, Unit11, Tides-causes, types and theories. And last unit of this block Unit 12 deals about ocean deposits and their types.

Fourth block ocean deposits divided into Unit13 distribution of ocean deposits, Unit14 coral reefs and Island, Unit 15, types of coral reefs and Unit 16 coral reefs and Island theories.

UNIT - 1: SUBMARINE TOPOGRAPHY

Structure:

1.0 OBJECTIVES

After studying this unit, you will be able to ;

- Understand the submarine topography of the oceans.
- Know the marine sediments.
- To study the Sediment samples are obtained with coring devices, which are driven into the ocean bottom by long drills suspended from surface ships.
- Identify the ocean floor is at a great depth, covered with water, ocean features at such locations can be accurately determined using the modern techniques of ocean topography.

1.1 INTRODUCTION

The term relief or" topography" implies the study of numerous landforms that exist on or below the earth The surface beneath the water is characterized by a great diversity relief features i.e. the towering mountain chains, deep canyons, flat plains, oceanic ridges, trenches, islands seamounts. Apart from the size and shape of oceans which are the most impressive characteristics, the depth of the ocean and seas is also very important. The topographical variety of the ocean floor which, to some extent, resembles the land features. Hence a comprehensive knowledge about the diversity of features of bottom topography is gathered which will helpful in knowing the character of the submarine geology.

1.2 MEASURING OF OCEAN DEPTH

Sounding

The measuring of ocean depth is known as sounding. By taking a number of soundings over a given region of ocean, oceanographers can identify ocean-bottom features. Today, sounding is usually done with an instrument called an echo sounder, a form of sonar. The echo sounder contains a transmitter that sends sound waves to the ocean bottom and a receiver that intercepts the sound waves reflected from the bottom.

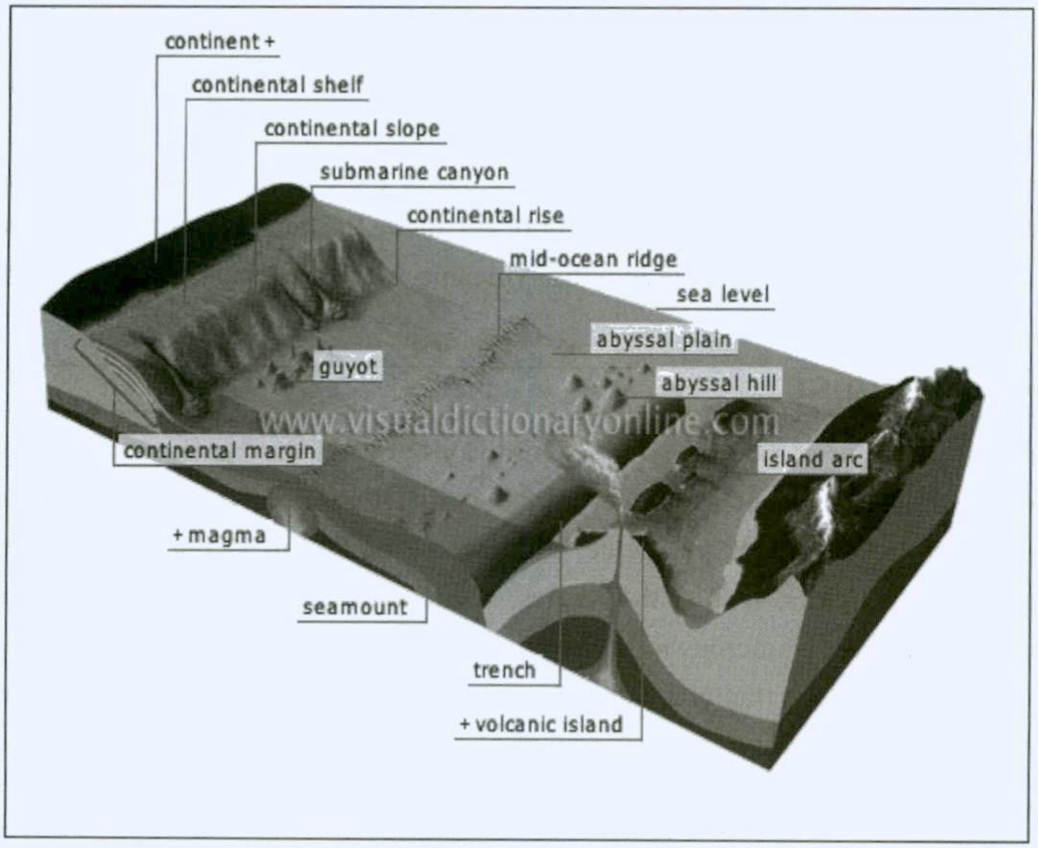
1.3 BOTTOM PHOTOGRAPHY

Photographs of the ocean bottom can be taken with cameras that are installed in submersible craft or suspended by cable from surface vessels. Waterproof television cameras can also be lowered into the ocean by cable, and the closed-circuit television pictures viewed on a screen aboard ship

1.4 SUBMARINE TOPOGRAPHY

The shape of the ocean floor is known to scientists as submarine topography. The floor contains mountains, plains, canyons, plateaus, basins, and other topographic features that are found on land. Usually, the ocean bottom is divided into three major zones: the continental margin, the ocean-basin floor, and the mid-ocean ridge.

Fig.1 Submarine Topography



1.5 CONTINENTAL MARGIN

Immediately offshore from the continents and some large islands is the continental shelf. It is a slightly inclined platform under shallow seas and is composed primarily of sediments. The shelf, which varies greatly in width, terminates on its seaward side with a sharp decline, called the continental slope. At the slope's base lies the continental rise, an area where the decline is much less pronounced. In some areas, such as the west coast of Central and South America, there is no continental rise; instead, there is a trench. Other topographic features are also found along the continental margin. There are submarine canyons, deep V-shaped depressions found mainly in the continental slope, and marginal plateaus, at the edge of the continental shelf. Also present, mainly on the shelf, are barely submerged features, such as banks, shoals, and reefs.

1.6 OCEAN-BASIN FLOOR

Beyond the continental margin, as far as the mid-ocean ridge, is the ocean-basin floor. It lies generally at great depths and is marked by various topographic features. Ridges, resembling low mountain ranges, and rises, elongated portions of the ocean floor with smooth, gentle slopes, are widespread. Abyssal plains are large, almost perfectly flat areas, usually near a continental rise. Adjoining many of the plains are expanses of abyssal hills, submerged volcanic peaks that rise less than 3,000 feet (914 m) above the ocean floor. Seamounts are submerged volcanic peaks that rise more than 3,000 feet above the ocean floor. Similar peaks with flat tops are called guyots, or table mounts. Volcanic islands are peaks that rise above the surface of the ocean.

1.7 MID-OCEAN RIDGE

Beneath the sea, in some places about midway between the continents, is a vast mountain chain that is almost continuous around the world. It is some 40,000 miles (64,000 km) long, up to 2,500 miles (4,000 km) wide, and generally 6,000 to 12,000 feet (1,829 to 3,658 m) high. In a few places, such as the Azores, volcanic peaks along the ridge protrude above the surface as islands. Numerous fracture zones cut across the ridge, creating unusually irregular topography. One deep fracture, called the rift valley or mid-ocean rift, runs virtually the entire length of the ridge along its crest.

1.8 ISLANDS & MARINE SEDIMENTS

The ocean contains thousands of islands. Continental islands, such as the British Isles, Vancouver Island, and Sri Lanka, once were joined by land to nearby continents. Oceanic islands, or islands that rise from the ocean-basin floor rather than from the continental margins, are usually of volcanic origin. Mauna Loa, an active volcano in Hawaii, is taller than Mount Everest if its height from submerged base to peak is considered. It rises 13,680 feet (4,170 m) above sea level, and its undersea height is about 18,000 feet (5,486 m).

The ocean bottom is covered with sediments. Sediments are derived from four kinds of materials: rock, decomposed sea creatures, minerals in sea-water, and debris from meteors. In some places the sediment layer is 6,000 feet (1,800 m) thick. Sediments composed mainly of the remains of microscopic sea organisms are called oozes.

1.9 ABYSSAL PLAIN

An **abyssal plain** is an underwater plain on the deep ocean floor, usually found at depths between 3,000 meters (9,800 ft) and 6,000 meters (20,000 ft). Lying generally between the foot of a continental rise and a mid-ocean ridge, abyssal plains are among the flattest, smoothest and least explored regions on Earth. Abyssal plains are key geologic elements of **oceanic basins** (the other elements being an elevated mid-ocean ridge and flanking abyssal hills). The abyssal plain is formed when the lower oceanic crust is melted and forced upwards by the asthenosphere layer of the upper mantle. As this basaltic material reaches the surface at mid-ocean ridges, it forms new oceanic crust.

1.10 OCEANIC TRENCHES

Oceanic trenches are long, narrow topographic depressions of the seabed. The deepest parts of the ocean floor, they define one of the most important natural boundaries on the Earth's solid surface: the one between two lithospheric plates. Trenches are a distinctive morphological feature of plate boundaries. There are three types of lithospheric plate boundaries: divergent (where lithosphere and oceanic crust is created at mid-ocean ridges), convergent (where one lithospheric plate sinks beneath another and returns to the mantle), and transform (where two lithospheric plates slide past each other). An oceanic trench is a type of convergent boundary at which two oceanic lithospheric slabs meet; the older (and therefore denser) of these slabs flexes and subducts beneath the other slab. Trenches are generally parallel to a volcanic island arc, and about 200 km from a volcanic arc. Oceanic trenches typically extend 3 to 4 km (1.9 to 2.5 mi) below the level of the surrounding oceanic floor. The greatest ocean depth to be sounded is in the Challenger Deep of the Mariana Trench, at a depth of 10,911 m (35,798 ft) below sea level.

1.11 OCEANIC PLATEAU

An **oceanic plateau** is a large, relatively flat submarine region that rises well above the level of the ambient seabed. While many oceanic plateaus are composed of continental crust, and often form a step interrupting the continental slope, some plateaus are undersea remnants of large igneous provinces. Continental crust has the highest amount of silicon (such rock is called felsic). Oceanic crust has a smaller amount of silicon (mafic rock). The anomalous volcanism associated with the formation of oceanic plateau at the time of the Cenomanian-Turonian boundary (90.4 million years) ago may have been responsible for the environmental disturbances that occurred at that time..

1.12 LET US SUM-UP

The surface beneath the water is characterized by a great diversity relief features i.e. the towering mountain chains, deep canyons, flat plains, oceanic ridges, trenches, islands seamounts. Despite advancements in science and technology, the ocean remains mystery to mankind. Beneath the sea, in some places about midway between the continents, is a vast mountain chain that is almost continuous around the world. The ocean contains thousands of islands. An **abyssal plain** is an underwater plain on the deep ocean floor. Submarine topography provides knowledge about the past and present and as scientific knowledge has advanced, the capability to envisage these remote sites has increased significantly. Science has established that the topography of the ocean floor is similar to the ground topography with features such as valleys, mountains, and plateaus.

1.13 KEY WORDS

Continental Margin, Ocean-Basin Floor, Mid-Ocean Ridge, Island, Marine sediments, Abyssal plain, Oceanic Trenches, Oceanic Plateau

1.14 QUESTIONS FOR SELF STUDY

1. What is Submarine topography? Explain its terminology.
2. Explain the method of measuring the Ocean depth?.
3. Discuss the characteristics of Continental Margin
4. What is mid oceanic ridge? Explain.
5. What is abyssal plain? Explain.
6. What are oceanic trenches? Explain with examples
7. Discuss the topography of the oceans with neat diagram

1.15 FURTHER READINGS

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UNIT - 2: DISTRIBUTION OF LAND AND WATER

Structure:

2.0 Objectives

2.1 Introduction

2.2 Distribution of Land

2.3 Distribution and Volume of Water

2.4 Areas And Depth of The Oceans

2.5 Important Features of Distribution of Land Water

2.6 Let Us Sum Up

2.7 Key Words

2.8 Questions For Self Study

2.9 Further Reading

2.0 OBJECTIVES

After studying this unit, you will be able to

- Know the pattern of land and sea distribution brings forth the overwhelming importance and extent of oceans of the earth surface.
- Identify the distribution of land and ocean(total land area of 148,892,000 sq.kms. and a total water area of 361,059,000 sq.kms ,i.e. 29% of land and 71% water ,or a ratio of 1:2.43.)
- Discuss the details about the various oceans and water bodies

2.1 INTRODUCTION

The detailed knowledge about the pattern of the land water distribution brought in to the fore front of the overwhelming importance and extent of reason on the earth's surface. The hydrosphere covers nearly ¾ of the earth's surface area as a vast expanse of water surroundings four great insular land masses known as continents. Thus there is a total land area of 148,892,000 sq.kms and a total water area of 361,089,000 sq.kms that is equal to 20 percent and 79 percent of the surface are of the globe.

2.2 DISTRIBUTION OF LAND

The shapes of the various continents and seas, their relative areas, and their dispositions with regard to each other, have always been attractive problems for geographers, and a number of characteristics have been formulated. The earth can be divided into two hemispheres in such a way that nearly all the land is concentrated in one hemisphere, and the other is nearly all covered with water. The land is everywhere opposite the water and the land is concentrated around the arctic regions, and the water around the Antarctic regions. The land sends three projections towards the south, and the oceans three projections towards the north. The continents are roughly triangular in shape, pointing southward and the oceans are roughly triangular in shape, pointing northwards. The continents are divided into a northern and a southern group by Mediterranean seas, and the southern group as offset towards the east.

The area of the Earth surface is equal to 510,100,000 km^2. Land covers 148,800,000 km^2 (29.2%) and the World Ocean covers 361,300,000 km^2 (70.8%). The World Ocean is a continuous water "blanket" over the Earth adjacent to all of the continents and islands and possesses a generally salty structure.

Distribution of Land

Continents	Area in sq.miles
Europe	3,700,000
Asia,	17,500,000
Africa	12,000,000
America, North	8,600,000
America, South	7,000,000
Australia	3,00,0000
Total	148,800,000

In the Northern Hemisphere, the World Ocean occupies 61% of the area and in the Southern Hemisphere, 81%. If we were able to arbitrarily divide the Globe into two equal parts so that in one hemisphere the land predominated, and in the other the water, water will appear to cover more than half of the area (53%). The oceanic hemisphere takes up about takes 91% of the area. The land and sea are also non-uniformly distributed on the planet. Land predominates only between latitudes of 45° N and 70° N, and to the south, from latitude 70° S to the South Pole. Water predominates over the remaining part of Globe. The shapes of the shorelines, bottom relief, and systems of oceanic currents, tides, atmospheric circulation and a number of other criteria subdivide the World Ocean into the Pacific, Atlantic, Indian and Arctic Oceans.

The distribution of the land is, however, very unequal. One half the earth is almost wholly covered with water; in the other, land largely predominates; so that we may, not inaccurately, speak of an aqueous in opposition to a terrestrial hemisphere. The quantity of land in the northern hemisphere is, in fact, three times greater than in the southern, as the most cursory glance at a map of the world will show the reader. In the latter it occupies only one-sixteenth of the area between the Antarctic Circle and the thirtieth parallel of south latitude; while between the Arctic Circle and the corresponding parallel of north latitude the extent of land and water is nearly equal.

2.3 DISTRIBUTION AND VOLUME OF WATER

Volume of the waters of the world ocean

The water cover of the Earth (called the "Hydrosphere") has volume of 1,389,500,000 million km^2, and 97.4% consists of salt water. Of this volume, 96.5% is in the World Ocean, and 0.9% is in salty underground and lake waters.

Fresh water comprises only 2.6% of the total volume of the Hydrosphere. This is the water contained in the atmosphere, rivers, lakes, glaciers, underground and ground water, and also the waters contained internally in animals and plants.

The waters of the World Ocean are distinguished from fresh water by their differing physical and chemical properties. By well-defined differences and a complex exchange of energy and matter peculiar to the animal and plant kingdoms, a subclass of the Hydrosphere exists, called the "Oceanosphere", can be separated from the rest of the hydrosphere. The Oceanosphere has a great influence on the formation and changes of the natural world.

2.4 AREAS AND DEPTHS OF THE OCEANS

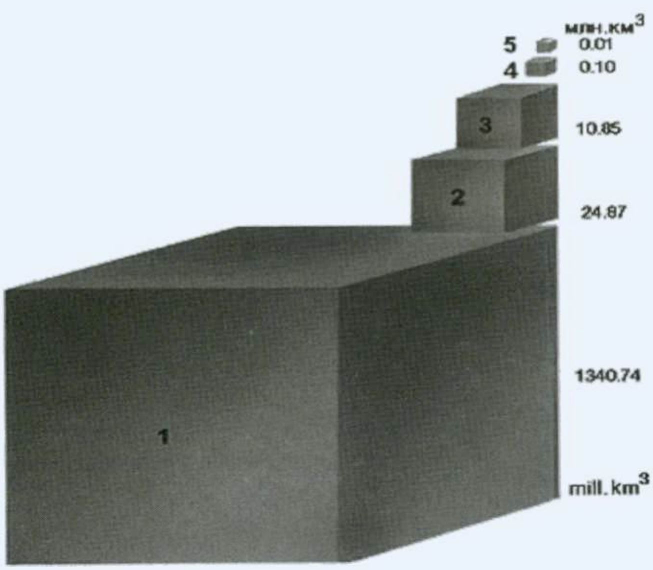
The following table 2 provides the details of world ocean and it depth and locations of the greatest depths of the oceans. The important oceans are Pacific which is the largest, followed by Atlantic, Indian and Arctic Oceans. The total area covered by these oceans are 361.3 million km^2 Apart from that there are continental seas(8.20%), Smaller enclosed seas (.64%) Fringing seas (2.22%) . Of the total expanse of the water bodies, the ocean constitute 90% of which the Pacific itself covers the largest (45%). Among the intercontinental seas, the Arctic Sea occupies half of the total area of their cetegory.

Table 2. Areas and Depths of the Oceans

Ocean and seas	Area in million km^2	% of the area of the World Ocean	Depth, m mean	Depth, m greatest	Locations of the greatest depths of the Ocean
Pacific	178.8	49.5	3 976	11 022	Marianas Trench
Atlantic	91.7	25.4	3 597	8 742	Puerto Rico Trench
Indian	76.2	21.0	3 711	7 729	Sunda Trench
Arctic	14.7	4.1	1 225	5 608	Greenland Sea (Molloy Deep)
World Ocean	361.3	100.0	3 711	11 022	Marianas Trench

On the surface of the Earth, altitudes less than 1,000 m and depths from 3,000 up to 6,000 m predominate. It is shown on a hypsographic profile constructed from the areas derived from various kinds of charts, showing the heights of the land and the depths of the Ocean over the entire planet.

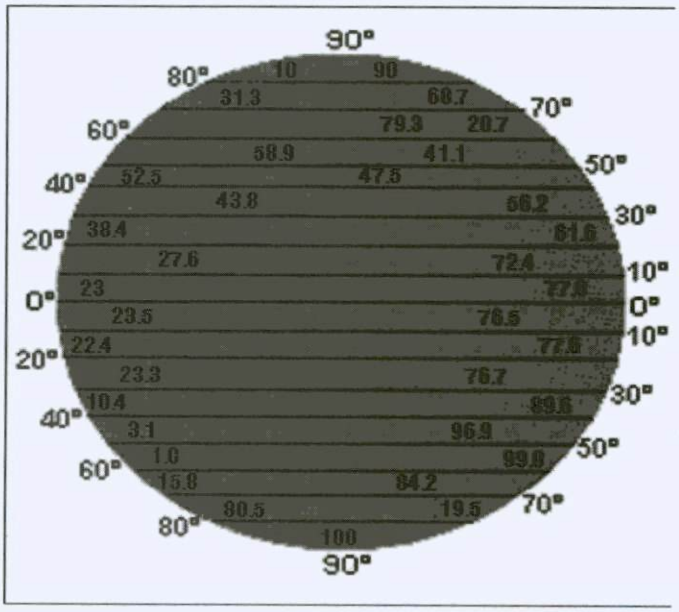
Fig.1 Source of water



1. The World Ocean
2. Glaciers and permanent snow cover
3. Ground water, permafrost
4. Lakes, rivers, bogs
5. Water in atmosphere

1.5 Important features of distribution of land and water

Fig.2 Distribution of land and water by latitude (%)



2.5 IMPORTANT FEATURES OF DISTRIBUTION OF LAND WATER

- According to Kossina's table the distribution of land and water according to 5 degree interval of latitudes in the northern and southern hemispheres is very irregular
- In the northern hemisphere water covers only 60.7% where as in the southern hemisphere it is 80.95 of the total area respectively
- Out of the total water area of the earth 43% lies in the Northern hemisphere and 57% in the southern hemisphere
- The centre of the land hemisphere is at the coast of France (mouth of River Roises 47degree 25' N and 2.5 degree W) and that of the water hemisphere in the Pacific Ocean, South-Coast of New Zealand (47 degree S and 177 degree E)
- According to the table we can also visualize the zones distribution of land and water. Between 80 degree South and 90 degree S latitude land predominates(Antarctic land mass) whereas along the same latitudes in the northern hemisphere, water is prominent (Artic Ocean) It continues up to 70 degree latitude where the pattern reports itself. Beyond this latitude the land –water ratios changes
- Between 35 degree and 65 degree latitudes land amounts to 24% of the earths surface area in the southern hemisphere and 55% in the Northern hemisphere

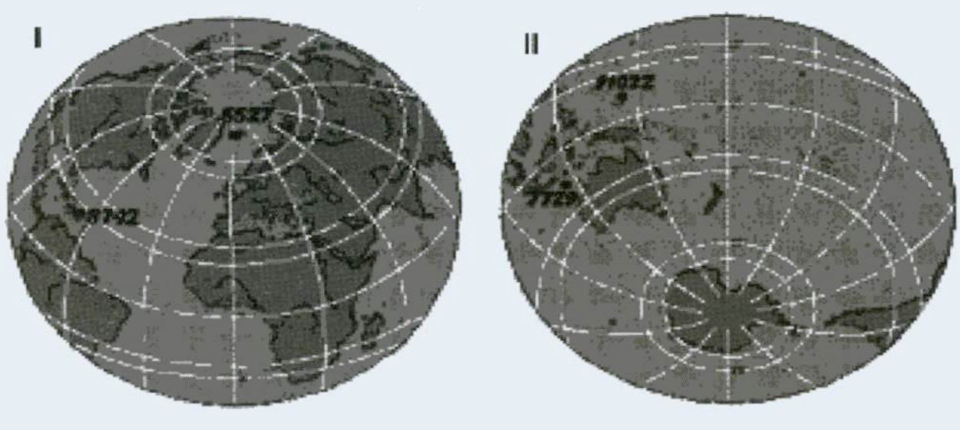
- Towards the equator in the northern hemisphere, land per centage diminishes due to the tapering of continents and so the sea occupies a major space. But in the southern hemisphere due to the broadening of South America and the location of Africa the land percentage increases. However there is still a predominance of water in these latitudes of southern hemisphere.
- The land and water ratio works out to 1:1.5 in the Northern hemisphere and 1: in the Southern hemisphere

The total superficies of the earth amounts, as we have already stated, to about 150,000,000 square miles, or 41,000 square degrees. The water occupies nearly three-fourths, or 30,000 degrees; the dry laud covers an area of upwards of one-fourth, or 11,000 degrees-nearly 38,000,000 of square miles.*

Africa is about three times larger than Europe, America four times, and Asia five times, The great continent-by which we mean Europe, Asia, and Africa-has an area of 24,000,000 square miles, while the extent of the New World is 11,000,000,and that of Australia, with its islands, scarcely 3,000,000. The superficies of the continents is twenty-three times greater than that of all the islands taken together.

The World Ocean (Oceanosphere) contains on the order of 1,340.7 million km^3 of water, making up 1/800th of the total volume of the Earth (1,083.3 billion km^3). Alternatively, the volume of fresh water is about 35.8 million km^3. If the Ocean sphere was shown in the form of a sphere, its radius would be equal to 690 km, or 0.11 mean radii of the Earth (6,371 km).

Fig.3.Continental and Ocean Hemisphere



I. Continental hemisphere   II. Oceanic hemisphere

The distribution of land and water is a factor with important implications for climate. Because water has a higher heat capacity than land and so exhibits a greater resistance to temperature change than does a land area (that is it has greater thermal inertia), land heats up more during the day and in summer, and cools down more at night and during winter than do adjacent bodies of water. This means that localities immediately adjacent to water exhibit smaller seasonal temperature variations than do localities that are situated well inland. For example, continental conditions cause the climate to be quite severe in the interior of northern Russia and Canada. The "Cold Pole," or coldest part of the Northern Hemisphere, is in northeast Siberia near Verkhoyansk.

The Arctic consists of an ocean surrounded by land, and the ocean has a warming influence on the land. However, because a large part of the Arctic Ocean is covered by an insulating layer of ice, the warming influence of the ocean in winter is decreased. Leads and polynyas (cracks and open areas in the ice) permit intense heat exchange from the water to the atmosphere during the cold part of the year because of the large differences between the air and water temperatures. But overall, the influence of the ocean in moderating local climate where sea ice is present is much less in winter than in summer. In Norway, where open water persists all year, the moderating effect of the ocean is largest in winter.

2.6 LET US SUM UP

The larger part of the ocean floor is nearly flat and is therefore very unlike the land. In spite of the general flatness of the sea bottom, its relief is not less than that of the land. The ocan floor like the land surface has many ridges and valleys, its area and depth may be represented diagrammatically by hypsographic curve. The structure and relief of the ocean floor, and of the marginal seas, afford contributory evidence towards the structure of the earth as a whole, concerned as we with the permanence or otherwise of the oceans and continents the oceans cover a greater area of the earth than does the land -71 percent or almost three quarters of the earth's surface. The depth of the oceans is very small compared with their area. The deepest part, the Mariana Trench in the western Pacific, is greater than the height of the highest mountain on land, Mount Everest at 8863 m.

2.7 KEY WORDS

Continental hemisphere , Oceanic hemispher Cold Pole, polynya , Oceanosphere.

2.8 QUESTIONS FOR SELF STUDY

1. Explain the distribution of water in the earth surface.
2. Discuss the distribution of land
3. Examine the important features of the distribution of land and water.
4. What is oceanic hemisphere? Explain.
5. What continental hemisphere? Explain with examples
6. Explain the volume of water in the world oceans

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UNIT - 3: HYPSOGRAPHIC CURVE

Structure:

3.0 OBJECTIVES

After studying this unit, you will able to

- know the different bottom relief features of the oceans
- Explain the structure and relief of the ocean floor afford contributory evidence towards the structure of the earth as a whole.
- Identify the characteristics of continental shelf, continental slope, deep sea plane and ocean deeps.

3.1 INTRODUCTION

The hypsographic curve is the representation of topography and relief in relative values with reference to the sea level. The magnitude of elevations or depressions thus represented brings out clearly relative importance found in the depths of the sea and on the land surface. It also shows the areas occupied by different depths and heights on the surface of the oceans. The sturcture, configuration and relief features of the different oceans vary from each other. The surface beneath the water is characterised by a great diversity of relief features i.e. the towering mountain chains, deep canyons, flat plains, oceanic ridges, trenches, island arcs etc,.

3.2 HYPSOGRAPHIC CURVE

Fig.1 Hypsometric curve and percent of earth's surface

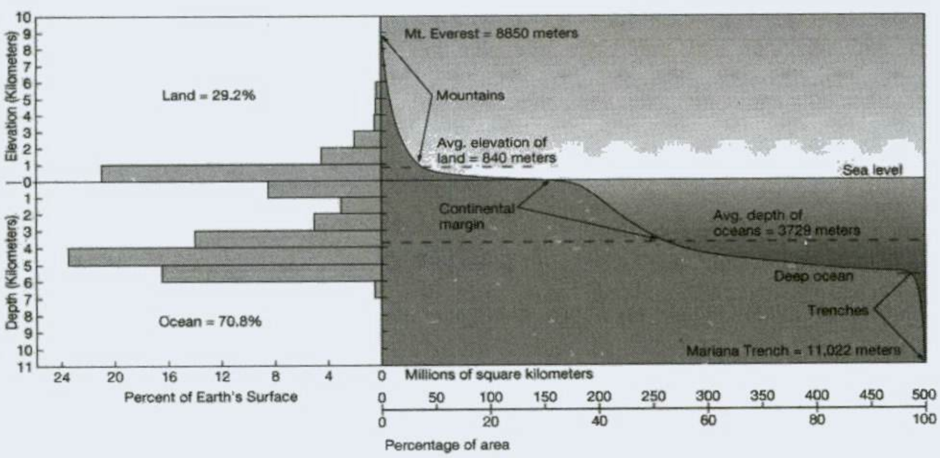
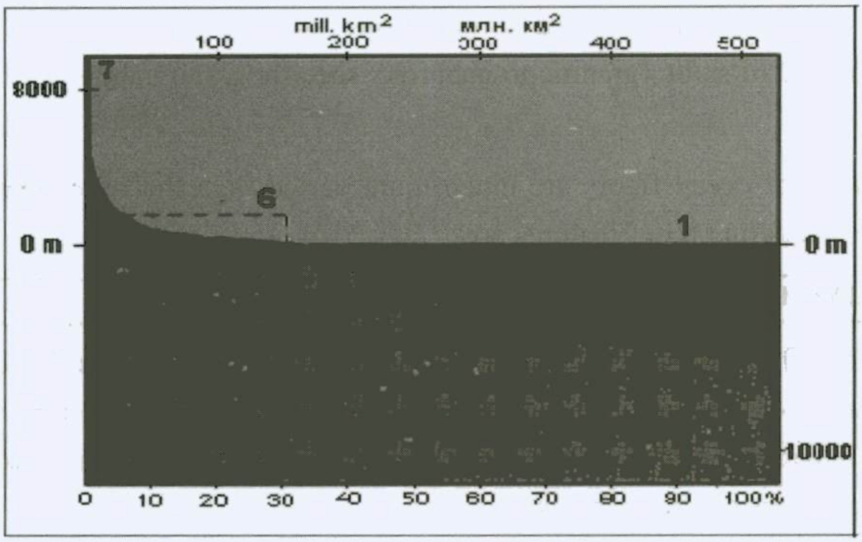


Fig.2 Hypsographic profile



Hypsographic profile

1. Sea level
2. Continental shelf
3. Continental slope
4. The Ocean floor
5. Mean depth of the World Ocean 3711m
6. Mean altitude of the land 840m
7. Jomolungma 8848m
8. Marianas Trench11022m

Hypsographic curve is the representation of the respective elevations and depths of points on the Earth's surface with reference to sea level. Hypsographic graph is a plot of the percentage of elevation and depth distribution of the continents and oceans.

Hypsometric curve, also called Hypsographic Curve, cumulative height frequency curve for the Earth's surface or some part thereof. A hypsometric curve is essentially a graph that shows the proportion of land area that exists at various elevations by plotting relative area against relative height. In the hypsometric curve of the total Earth surface there exist two maxima of frequencies—at the 100-metre (109-yard) and the 4,700-metre (5,140-yard) elevations, which correlate with the mean level of the lowland continental areas and the deep-sea floor. This aspect of the Earth's surface, revealed by hypsometric analysis, supports the theory of a crust consisting of simatic (peridotitic, specific gravity about 3.3) materials under the oceans and of sialic (granitic to gabbroic, specific gravity about 2.7) materials of the continents.

The relief features of ocean floors are much more varied than the relief features on the continents. The submarine relief features are:

3.3 SUBMARINE RELIEF OF THE OCEAN

The "ocean floor topography" term refers to the different forms in which the ocean floor bottom can exist. The percentage of relief features are shown in the table 2 and ocean deeps are more in pacific oceans and the percentage of deep sea plain area is also higher. The other relief percentages are given below.

Table 2. Submarine relief in (%) different oceans

Submarine relief	Pacific ocean (%)	Atlantic ocean (%)	Indian ocean (%)
Continental shelf	5.7	13.3	4.2
Continental Slope	7.0	12.4	6.5
Deep sea plain	80.3	54.9	80.1
Ocean deeps	32(Deeps)	19(deeps)	6(deeps)

3.4 CONTINENTAL SHELF

The continental shelf is a shallow platform which fringes the continents from a few kms. to more than 60 kms. Generally it is a smooth gently sloping floor and for the most part about 600' or (200Meters) deep. The extent of the continental shelf depends upon the physiography of the bordering land mass. If the coastal region is low-laying then the continental shelf is likely to be several kms. broad. On the contrary if the coastal region is mountainous, the continental shelf is very narrow and in some places even absent, for e.g. the west coast of North America and South America.

The continental shelf covers about 8 percent of the total ocean area of the earth. But this figure varies in different oceans. It is 13.3 percent in Atlantic Ocean 5.7 percent in Pacific Ocean and 4.2 percent in the Indian Ocean.

The average slope of the continental shelf is about 1 degree or 5.6. meters per kms. But it varies from place to place depending upon the nature of the continental masses. The shelves surrounding the glaciated lowlands of the world are of gentle slope in comparison to te shelves of the coasts where greater tectonic tensions prevail.

The valleys of many rivers are some times found to cross the continental shelf in the form of sub-marine canyons. These canyons may continue beyond the edge of the shelf into the deeper water.

The origin of the continental shelf is still uncertain. Some parts may be due to wave erosion and some parts may have originated due to changes in the sea level.

Characteristics in brief:

(i) It is the submerged part of the land adjoining the coast. It is shallow,

(ii) It is broad where the mountains are away from the coast, for example, eastern North America,

(iii) It is narrow where the mountains are nearer to the coast, for example, Western North America and South America,

(iv) The average width of the continental shelf is 70 km.

(v) Continental shelves provide rich fishing grounds, e.g., Grand Bank, off New Found land in North America and Dogger Bank in the North sea. One fourth of the world's petroleum is produced from oil wells in the continental shelves, e.g., Bombay High.

3.5 CONTINENTAL SLOPE

Along the sea ward margin, the continental shelf gives way to the continental slope from where a gentle deep sea plain takes its form. The continental slopes drops from depths of 100-200 meters (300'-600') down to depths of 1,500-3,500 meters (4,500'-10,500') where the slope lessens rapidly. It covers a smaller area (8.5%) of the total ocean surface, but it varies from one ocean to the other e.g 12.4 percent in the Atlantic, 7 percent in Pacific ocean and 6.5 percent in Indian ocean and the slope generally varies from 2 degree-5degree, and steeper gradients have also been found. A peculiar feature of the continental slopes is the presence of submarine canyons, mentioned earlier. In general the continental slope represents a transitional zone between the continental shelf and the deep sea plain.

Characteristics in brief:

(i) It is the edge of the continental block,

(ii) It is a link between the continental shelf and the deep sea floor,

(iii) It is narrower than the continental shelf,

(iv) It has a steep slope.

3.6 DEEP SEA PLAIN

The deep sea plain forms the most extensive portion of the ocean basins stretching from the continental slope to the oceanic abyssal. In all, this topographic features covers about 75.9 percent of the total ocean basin.. It is generally included in the depth range of 5,000-9, 000 meters. It is not actually a level surface and its depth accordingly is variable. The bottom of the ocean floor of the Pacific and Atlantic are found to be extremely rugged. In the pacific ocean the deep sea plain is dotted with volcanic cone while in the Atlantic ocean a mid-oceanic ridges rises from its floor. Occasionally volcanic peaks rise above the sea level and form isolated island. But these deep-sea plain is entirely free from deposition by agents of erosion. But it is largely covered by oozes derived from plant and animal remains.

The total area coverage of deep sea plain varies from one ocean to the other 80.3 percent in Pacific Ocean, 80.1 percent in the Indian Ocean and 54.9 percent in the Atlantic ocean.

Characteristics in brief:

(i) About 40% of the ocean floor is a relatively flat basin formed by the accumulation of sediments on the sea floor;

(ii) (ii) Its depth varies from 3000 to 6000 m.cover 75.9 percent of the total area of the basins

(iii) Deep sea plains are characterized by the pelagic deposits of plant, marine animal and siliceous remains but there is absence of erosional debris of terrigenous origin. Volcanic deposits have been found at few places.

(iv) Submarine ridges (narrow elongated ridges) rise steeply from the abyssal plain

(v) They resemble the ridges on the land, e.g., the Atlantic Ridge is about 14,400 km long. It is the longest ridge in the world,

(vi) The peaks of some of the ridges may rise above sea level to form islands, e.g., the Philippine islands.

3.7 OCEAN DEEPS OR TRENCHES

The Trenches are elongated depressions in the ocean floor deeper than the deep sea plain. Their sides are fairly steep and they cover a limited area of the ocean surface- only about 7 percent. They are most common near coast lines where volcanoes and earthquakes are frequent. The maximum depths of the deeps range between 8,000 and 10,000 meters (24,000-30,000'). Their aerial extent (7%) is more than the area covered by the high mountain peaks on the land surface. Only .1 percent of the total land surface rises to more than 6,000 meters where as 3 percent of the ocean bottom is deeper than 6,000 meters. There are about 57 deeps located in the different ocean bottoms. Out of this total number 32 are in Pacific Ocean, 19 are in Atlantic and only 6 in the Indian Ocean. The deepest deep is Mariana Trench in the Pacific Ocean laying off coast Mariana Islands near Philippines with a depth of 11,022 meters.

Characteristics in brief:

(i) Deep, narrow and steep sided depressions are found in the abyssal plain,

(ii) The trenches are the result of the tectonic forces and their depth may vary from 6000 to 11000 m, e.g., the Mariana trench (11,022m) and Nares deep (8385 m).

3.8 MID-OCEANIC RIDGES

Apart from the above said relief features the greatest features rising from the ocean floor are the mid-oceanic ridges. The first discovered was the mid Atlantic ridge extending for a total length of 14,400 kms through the centre f the Atlantic ocean in the northern and southern hemisphere. The higher points of this ridge lie at a depth of 2,000-3,000 meters (6,000-9,000') with reference to the deep sea plain it has a height of only 4,000 meters. These ridges are largely covered by lava and volcanic debris. They are also considered as fundamental structure of the earth's surface.

Submarine canyons

Long narrow and very deep valleys or trenches located on the continental shelves and slopes with vertical walls resembling the continental canyons are called submarine canyons because of their location under oceanic water,. On the basis of morphogenetic processes these are classified into

i) Glacially eroded canyons and

ii) Non-glacial canyons.

The non-glacial submarine canyons being more in number than the glacial canyons and widely spread in all the oceans.

3.9 LET US SUM UP

The larger part of the ocean floor is nearly flat and is therefore very unlike the land. In spite of the general flatness of the sea bottom, its relief is not less than that of the land. The ocan floor like the land surface has many ridges and valleys, its area and depth may be represented diagrammatically by hypsographic curve. The structure and relief of the ocean floor, and of the marginal seas, afford contributory evidence towards the structure of the earth as a whole, concerned as we with the permanence or otherwise of the oceans and continents the oceans cover a greater area of the earth than does the land -71 percent or almost three quarters of the earth's surface. The depth of the oceans is very small compared with their area. The deepest part, the Mariana Trench in the western Pacific, is greater than the3 height of the highest mountain on land, Mount Everest at 8863 m.

3.10 KEY WORDS

Continental shelf, Continental slope, Deep sea Plain, Ocean deeps, mid-oceanic ridges, submarine canyon, trenches

3.11 QUESTIONS FOR SELF STUDY

1. What is hypsographic curve? Explain.
2. Discuss the characteristics of continental shelf.
3. Explain continental slope and its distribution pattern in the oceans.
4. What is submarine canyon and mid oceanic ridges? Explain.
5. What are trenches? Explain with examples
6. Name the important ocean deeps and how they are formed?
7. Discuss the topography of the oceans with neat diagram.

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UNIT - 4: SUBMARINE TOPOGRAPHY OF THE ATLANTIC, PACIFIC AND INDIAN OCEANS

Structure:

4.0 OBJECTIVES

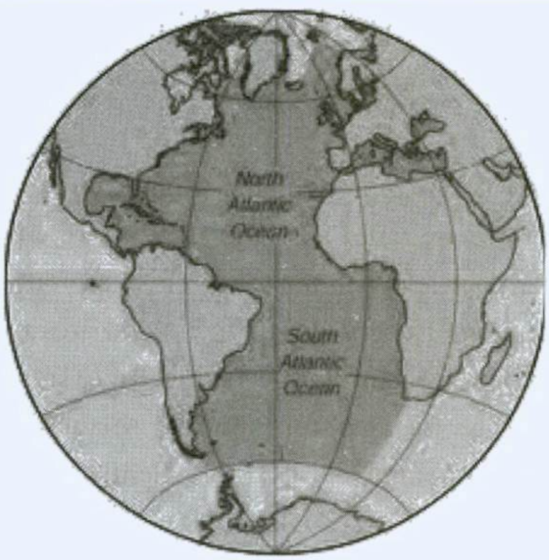
After studying this unit, you will be able to

- Identify the structure, configuration and relief features of the different oceans
- Differentiate the comparison to features on land, the ocean floors are monotonous,.
- Identify the major relief features of the Atlantic, Pacific and Indian

4.1 INTRODUCTION

The Atlantic ocean which is 'S' shaped, extends latitudinally from the Davis strait in the north to Antarctic in the south (60degree s latitude) through a distance of 16,000 kms. The east west extend of the ocean is greatest along the tropic of Cancer (23 ½ N) the coast of Africa and Mexico. The Atlantic Ocean occupies about 1/3 of the area of the earth's water cover and about 1/5 (20%) of the earth's total surface area. Although the ocean is not the largest ocean the Atlantic receives the inflow from a drainage area larger than that of the Pacific or Indian Ocean. It is estimated that the area of land which drains into the Atlantic Ocean is about four times as great as that of the Pacific or Indian Ocean. Out of the total area of the Atlantic 24 percent is less than 1,000 meters in depth due to the shallowness of many marginal seas, a wide continental shelf and the mid oceanic ridge.

4.2 SUBMARINE TOPOGRAPHY OF THE ATLANTIC OCEAN



The continental shelf

The continental shelf is a conspicuous feature all along the coast of America and Europe. But it varies in width. The shelf is narrower (80-100km wide) along the coast of Africa while of the coasts of N.America and Europe it is broader (between 240 and 400 kms)

Around new Foundland Island (N.East north America) and British Isels (N.W.Europe) the world's widest shelfs re located namely the"Grand Bank" and Doggar Banks respectively.

Mid-Atlantic Ridges

Another most striking feature of the bottom relief of the Atlantic Ocean is the medial ridge known as the "Mid-Atlantic Ridges". It extends through a distance of more than 11,200 kms from Iceland Island in the N.Atlantic to the Bouvet Island in the S.Atlantic. Many islands are located on the mid Atlantic Ridge. The northern part of the ridge is known as the Dolphin ridge and the part lying south of the equator is known as the Challenger Ridge. The depth of water over the ridge is generally less than 3,000 meters. It divides the ocean into two broad deep basins. There are Transverse Ridges which also a branch out from the main ridge. These break-up the deep ocean basins in to a series of basins. The important transverse ridges are the Walvis Ridge linking he main ridge with the African ridge at 20 degree south latitude and the "Rue Grand Ridge" linking the main ridge with south American coast at about 30-35 degree South latitude.

Ocean deeps

North of the equator there are several basins in which considerable depths are found. These basins unlike those of the south Atlantic are not well defined on the eastern side of the Dolphin Ridge and transverse ridges mark the boundaries of the west European basin, Siberian basin ,Canaries basins etc. On the western side transverse ridges form the boundaries of Labrador basin; New found land basin, North America basin, west Caribbean basin and the Guiana Basin.

Linear deeps or trenches are uncommon in the Atlantic due to the fact that the lines of recent folding near the coast lines are rare. Also the slopes on the both sides of the oceans aren't much and therefore deeps are lesser in number. There are only 19 deeps with a depth of less than 6,000 meters. The chief deeps lie off the island arcs of the West Indies. The greatest depth in the Atlantic ocean occurs in the Puerto Rico Trench (8,381m) . Another deep trench is the Romache trench laying across the mid Atlantic ridge its depth 7,369 m. The greatest depth which has so far being recorded in S.Atlantic is the south Sandurich trench (8,262 m).

The Atlantic Ocean has less number of islands than the Pacific. There are some continental islands in the North Atlantic which are merely the higher parts of the continental shelf. The important such groups are the W.Indies Island and the British Isles lying not far away from the main land. In the South Atlantic the island group forms the higher parts of the complicated ridges. In eastern Atlantic there are some volcanic Island built on cones.

Most of the marginal seas are situated on the continental shelf. In the North Atlantic the submergence of the continental land of Europe has resulted in the formation of a number of marginal seas namely Baltic sea, North sea, and the Mediterranean sea. The Baltic Sea and North Sea lying on the continental shelf of North West Europe are very shallow with a depth of less than 200 meters the Mediterranean Sea represents the foundering of a complicated structural area which was part of the great Alpine fold system during the tertiary period. The depth in the western part of this sea is only about 400 meters. But in the eastern parts depths of more than 12,000' are recorded. There are other marginal seas on the western side of the ocean –Baffin bay and Hudson Bay which are shallower and the Gulf of Mexico and Caribbean sea which are deeper. Marginal seas are absent along the coasts of S.America and Africa.

4.3 SUBMARINE TOPOGRAPHY OF THE PACIFIC OCEAN

The Pacific Ocean is the largest division of the hydrosphere, and its total area (165,246,200 sq.kms) accounts for merely half (45%) of the total water area of the earth.

The ocean has a broad triangular shape. It extends from the coast of Asia in the west to that of the America's in the east and from the Bering Strait in the north to Antarctica (Cape Arore) in the south. It is almost land locked in the north, being separated from the Artic Ocean by the shallow Bering Strait which is only 80kms wide. It broadens towards the south and attains it maximum east west extension of about 15,000 kms between Panama (Central America) and Philippines (East Asia).

PACIFIC OCEAN

Continental shelf

The average depth of the Pacific is about 5,000 meters. Only 7 percent of its area is less then 1,000 m deep where as a major portion lies below 5,000 M. The descent from the coast to the deep sea plain is very deep, in many parts ending in the deep sea trenches. The ocean floor is fairly uniform with broad gentle 'Swells' and depressions.

The average depth of the continental shelf ranges between 1,000 -2,000 meters and it is narrower and in many places absent along the west coast of the Americas.

East Pacific Rise

The Pacific Ocean has no central ridge. Only a few ridges are present on the eastern margin. The east pacific ridge located in the east pacific is quiet extensive. Another rise is the "Hawaiian Swell" on which are situated the island of Hawaii and Honolulu.

Ocean Basins

Many depressions and basins separated by the numerous 'Swells' can be found in the Pacific Ocean. Important among them are the Philippine basin, Fiji Basin, East Australian Basins and Peru Chile Basin.

Ocean Deeps/Trenches

A total of 32 deeps or trenches are located in the Pacific. Most of these trenches are elongated and lie close to the island Arcs with lofty mountains. The western Pacific Ocean is renowned for the largest number of these deeps or trenches. Important among the deep Sea trenches the western Pacific are the Aleutian Trench. , Japan trench, Kurale trench, Mariana trench, Philippine trench. The central part of the basin is devoid of trenches. The earth's deepest oceanic area is clearly that of western pacific with its great trenches extending from Japan to Philippians Island.

Islands

The Pacific Ocean contains a very large number of Island totaling about 20,000.

These islands can be divided into three groups:

1. The continental Island
2. The high volcanic Island
3. The low coral Island

The continental Island

These are the largest in the number and size. They are formed by the submergence of land in between and belong structurally to the mainland. The Aleutian island and Chillean Islands are important examples of this category.

The high volcanic island

These comprise the more extensive island areas with a high degree of volcanic in the eastern Asia. Most of these islands are the parts of Great fold ranges with numerous volcanic peaks.

The low coral island

These are smaller in size abd scattered in the warm water of S.pacific. A vast area to the north and east of Austrila is studied with coral island, many of them uninhabited.

Most of the island groups are found in western pacific. The North eastern and south eastern pacific contain few island and is marked by empty stretches of sea-water.

Marginal seas are almost entirely confined to the western part of the ocean(the coast ,line of Asia) On the other hand the eastern margin (the coast line of N.and S.America) is relatively smooth and unbroken and falls down to the deep-sea plain very steeply.

Marginal seas:

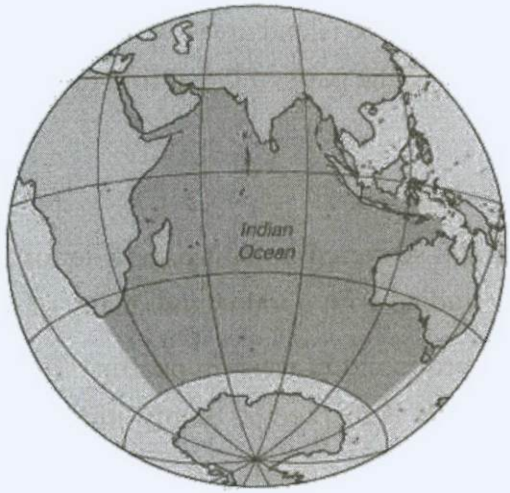
Many of the enclosed seas of the western Pacific are located between the main land of Asia and the Festoons of island areas. The important seas are the Bearing Sea, Sea of Okhotsk, Sea of Japan, Yellow Sea and South China Sea,

4.4 SUBMARINE TOPOGRAPHY OF THE INDIAN OCEAN

Introduction

With an area of 73,442,000 million sq.kms, the Indian ocean is smaller than the Atlantic Ocean. Unlike the Pacific and Atlantic oceans, it only slightly extends beyond the Tropic of Cancer (23 1/2 degree N) . It is a warm ocean blocked on three sides by the continents of Africa, Asia and Australia in the south it extends to the Antarctic Ocean where it merges with the Atlantic and Pacific Ocean. The shape of the ocean is compact with bold and regular unbroken outlines. The average depth is 4,000 meters. Out of its total area, 60 percent forms the deep sea plain, with many basins between 4,000 and 6,000 meters.

Indian Ocean



The continental shelf

The continental shelf is gently narrow and varies in width along the Asian and Australian coast lines. It is widest, attaining width of more than 100 kms in the Gulf of Cambay (India) and the head of the Bay of Bengal (Ganga, Brahamaputra delta). On the African side it is steeper and narrower.

Like the Atlantic Ocean, , The Indian ocean is also traversed by a central ridge running from north to south. It widens in the south to form a submarine plateau. This ridge carries numerous island groups like the Lakshsdiveep Maldeives, Chagos Island and new Amsterdom Island. The central and transverse ridges divided the ocean into many basins, having a depth of more than 4,000 meters. The important basins are Oman basin, the Arabian basins the Mauritius basin, the Natal basin. On the west and there is Andaman basin and Indian Arctic Basin.

Deep sea trenches or deeps

Deep sea trenches or deeps are fewer in number and almost absent in many parts of the ocean. The only sizable deep is the Sunda trench (south of Java Island) where a maximum depth of 7,450 m is found.

The Islands

The Island in the Indian Ocean is of great variety. The continental islands are the larger ones Madascar(Malagasy) Ceylon and the Andamn –Nicobar islands. The submarine ridge also carries several island groups mentioned earlier. A few volcanic cones forming the Mauritius and Reunion islands are found in the southern part of the ocean while a large number of smaller coral islands are found in the warmer waters of the northern part of the ocean.

The plateau coasts of the Indian Ocean are steep and regular resulting in few indentations (curves) large enough to form seas. The Arabian Sea and the Bay of Bengal are considered to be merely the north word extensions of the ocean separated by the Indian Peninsular. The only true marginal seas are the Red sea and the Persian Gulfs in the north western part. The former occupies a 'rift valley' between the African continent and the Arabian Peninsula and the later is only a shallow trough

4.5 LET US SUM UP

Atlantic Ocean has very few islands and ocean deeps are uncommon where as in Pacific Ocean with its bordering seas, gulfs and bays, occupies about the one-third of the total area of the world. It forms more or less a broad triangle in shape. The Indian Ocean is the third largest ocean and it has very few marginal seas. In brief, the ocean floor can be divided in to two regions: continental margins and deep-ocean basins. The continental margin, the relatively shallow ocean floor nearest to the shore, consists of the continental shelf and the continental slope. The continental margin shares the structure of the adjacent continents. Most of the ocean floor is covered with sediments.

4.6 KEY WORDS

Continental shelf, continental slope, Deep sea trenches, coral island, Marginal seas,

4.7 QUESTIONS FOR SELF STUDY

1. Explain the bottom topography of the Atlantic ocean
2. Discuss the prominent relief features of the Pacific Ocean.
3. What are the major relief features of the Indian Ocean?
4. Explain the Islands of the Pacific Ocean.
5. Narrate the prominent ocean deeps of the Atlantic ocean

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UNIT - 5 : OCEAN WATER: TEMPERATURE

Structure:

5.0 OBJECTIVES

After studying this unit, you will be able to;

- Identify the solar radiation that reaches the Earth
- Study of the temperature, distribution of temperature in different oceans.
- Analyse the heat budget of the oceans and water evaporation from the surface of the ocean

5.1 INTRODUCTION

The temperature of the oceanic water is important for marine organisms including plants ((phytoplanktons) and animals (zooplanktons). The temperature of sea water also affects the climate of costal lands and plants and animals therein. The study of both, surface and subsurface temperature of sea water is significant. Standard type of reversing thermometers and thermographs are used to measure the subsurface temperature. The major source of the temperature of the oceanic water is the sun. The radiant energy transmitted from the photosphere of the sun in the form of electromagnetic shortwaves and received at the ocean surface is called insolation. Most simply put, temperature is a measure of the hotness or coldness of an object. Some energy though insignificant, is also received from below the bottom and through the compression of sea water. The amount of insolation to be received at the sea surface depends on the angle of sun's rays, length of day, distance of the earth from the sun and effects of the atmosphere.

5.2 DISTRIBUTION OF TEMPERATURE

The distributional pattern of temperature of ocean water is studied in two ways viz.

i) Horizontal distribution

ii) Vertical distribution

Since the ocean has three dimensional shapes, the depth of oceans, besides latitudes, is also taken into account in the study of temperature distribution. The following factors affect the distribution of temperature of ocean water.

5.3 INFLUENCING FACTORS

1) Latitudes

The temperature of surface water decreases from eauator towards the poles because the sun's rays become more and more slanting and thus the amount of insolation decreases poleward accordingly. The temperature ofsurface water between 40 degree N and 40 degree south is lower than air temperature but it becomes higher than air temperature between 40^{th} latitude and the poles in the both the hemispheres.

2) Unequal distribution of land and water

The temperature of ocean water varies in the northern and the southern hemispheres because of dominance of land in the former and water in the latter. The oceans in the northern hemisphere receive more heat due to their contact with larger extent of land than their counterparts in the southern hemisphere and thus the temperature of surface water is comparatively higher in the former than the latter.

3) Prevailing wind

Wind direction largely affects the distribution of temperature of ocean water. The winds blowing from the land towards the oceans and seas (e.g. offshore winds) drive warm surface water away from the coast resulting into upwelling of cold bottom water from below. Thus the replacement of warm water by cold water introduces longitudinal variation in temperature. Contrary to this, the onshore winds pile up warm water near the coast and thus raise the temperature.

4) Ocean currents

Surface temperatures of the oceans are controlled by warm and cold currents. Warm currents raise the temperature of the affected areas where as cool currents lower down the temperature. For example, the Gulf Stream raises the temperature near the eastern coast of N.America and the western coasts of Europe. Kuro Shivo drives warm water away from the eastern coast of Asis and raises the temperature near Alaska.

5) Minor factors

Minor factors include

i) Local weather conditions like storms, cyclones, hurricanes, fog, cloudiness, evaporation and condensation

ii) Submarine ridges

iii) Location and shape of the sea

5.4 HORIZONTAL DISTRIBUTION OF TEMPERATURE OF OCEAN WATER

The distribution of temperature in the surface layers of ocean water reflects the general distribution of heat supply from the sun. The value of heat is greatest towards the equator and falls off towards the poles. The temperature of the surface water in the open ocean varies between -2degree to 29 degree C. At the equator the average temperature of the surface water is about 26.6 degree C and there is general decrease towards the poles. The upper limit of 29 degree is related to the amount of solar energy absorbed by the sea and amount of heat relased from the water to the air resting upon it. In the enclosed seas close to tropics the surface temp are found to ruse cibsuderabke higher than 29 degree c. It reaches 32 degree C or even more in the Red Sea. In general the highest average temperature in the open ocean is found along 5 degree N latitude thermal equator which migrates latitudinal with the changing positions of the vertical rays of the sun.

Generally the range seasonal temperature of ocean water is only about 12 degree C. But in North West Atlantic off cost Newfoundland the range of temperature considerable. Likewise in North West Pacific close to the Asiatic Cost the difference between summer and winter temperature is considerable. The 0 degree isotherm roughly encircles the poles. But it shifts towards the equator during the winter. The temperature of the surface water in the Southern hemisphere is in general lower than those in the same latitudes in the northern hemisphere. The obvious reasons for this are that the ratio between land and sea masses for the southern hemisphere is much smaller than it is form the northern hemisphere. The effect of the cold southerly winds from the ice-covered Antarctic land mass is also believed to be a significant factor in this respect.

The average annual temperatures for the northern and southern hemispheres are 19,4 degree C and 16.1 degree C respectively. The variation of temperatures in the northern and southern hemispheres is because of unequal distribution of land and ocean water.

The decrease of temperature with increasing latitudes in the northern Atlantic Ocean is very low because of warm ocean currents. The average temperature between 50-70 degree N latitudes is recorded as 5 degree. The decrease of temperature with increasing latitudes is more pronounced in the southern Atlantic Ocean. According to Krunel the highest temperature of surface water of the oceans is at 5 degree N latitude whereas the lowest temperature is recorded between 80 degree N and the north pose and between 75.5 degree and the South Pole. The average annual temperature of the Pacific Ocean is slightly higher than the Atlantic Ocean (16.9degree C) and the Indian Ocean (17 degree C). The lowest and the highest temperatures of the oceans are recorded near New Scotland and in the western Pacific Ocean respectively. The highest temperature of the Indian Ocean is recorded in the Arabian Sea and Bay of Bengal but the enclosed seas of the Indian Ocean record still higher temperatures.

In the horizontal distribution of ocean temperature, the influence of ocean currents is also quite significant. It is all the more pronounced in the surface water ofNorth Atlantic .

5.5 VERTICAL DISTRIBUTION OF TEMPERATURE

The most important feature of the vertical temperature distribution in the oceans is the fact that the rate of change is different at different depths. Upto a depth of 1800 meters temperature decreases from 15°C to 2°C.

But between 1800 and 4000 meters depth the decrease in the temperature varies from 2° to 1.6°C. Another characteristic feature of the vertical temperature distribution is that in the equatorial and the Polar Regions the rate of decrease in temperature is not similar. The most important feature of the vertical distribution of temperature in the open oceans is that there is a decrease pf temperature with increasing depth. However, it may be stated that the above said decrease is not uniform everywhere. The most important source of heat for the ocean water is the solar radiation which reaches the sea surface as direct radiation and the diffuse sky radiation.

According to calculations made by oceanographers, in the topmost surface layer of clear ocean water about 27% of the incident short-wave radiation is absorbed in the first one centimeter, about 62% in the next one meter thick layer and only 0.45% of the solar energy is able to penetrate up to 100 meter depth.

However, most of the solar energy is absorbed in the dirty waters near the coast. But the mixing process going on in the ocean water which is always in constant motion, the energy lost in the process of evaporation, and the back radiation from the water surface reduces the heating effect of the absorbed solar radiation. Thus, it is clear that under normal conditions the temperature decreases from the sea surface downwards.

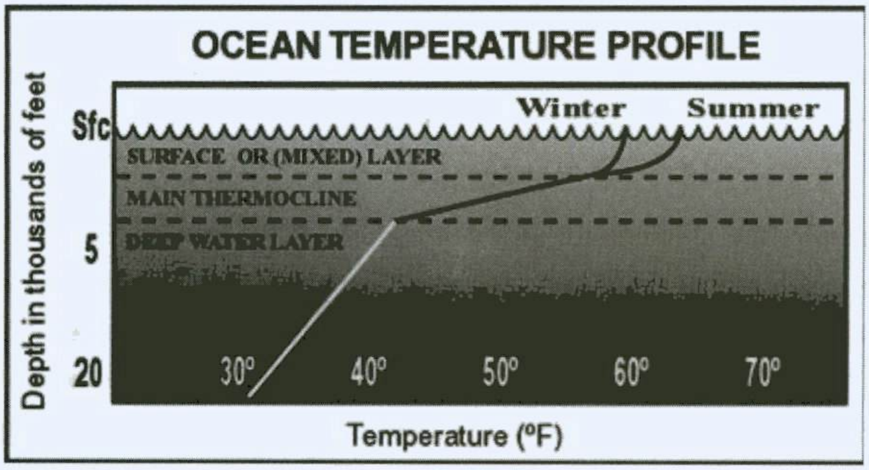
Like the atmosphere, the upper layers of the oceans are divided into the troposphere and the stratosphere, which differ in thickness and other characteristics. Of the two spheres, the upper layer called the oceanic troposphere extends from the surface down to about 600-1000 meters.

The uppermost part down to about 100 meters beneath the surface is under the direct influence of the atmosphere. In this layer there is strong mixing of water due to the effects of the wind and waves. Because of these characteristics it is called the layer of surface disturbances. It is the layer characterised by diurnal and annual convections originating at the surface. In the troposphere there is the strongest temperature decrease with depth. In the tropical and the temperate regions the troposphere forms an upper warm layer of water under which lie the cold water masses. The warm upper troposphere is separated from the underlying cold water masses by a sharply defined thermo-cline.

The oceanic stratosphere extends from the bottom of the troposphere (thermo-cline) down to the sea bottom. All the major water masses of the deep sea characterized by very small changes in temperature both in horizontal and vertical direction belong to the stratosphere. However, it should be borne in mind that the above said twofold subdivision (troposphere and stratosphere) is found in the tropical and subtropical oceans. Towards higher latitudes the troposphere is not so well developed as in the tropical and subtropical parts of the oceans.There is complete absence of the oceanic troposphere in the sub-arctic and sub-Antarctic regions. In these regions the stratosphere with its cold water masses extends to the surface.

In the tropical and subtropical regions the water masses of the troposphere lie on top of the stratosphere, but they become thinner and thinner and finally disappear in the arctic and sub-arctic regions in both the hemispheres.The oceanic troposphere is generally divided into three distinct parts. The top layer, that is about 100 meters thick, is more or less homogeneous. In this layer the vertical differences in temperature and salinity are very small.

It is also designated as the isothermal surface layer. It is present in the region lying between 35°S to 25°N in the Atlantic Ocean. Outside these limits this isothermal stratification is seldom found. In the vicinity of the equator and in the tropics this layer is shallower, while in the temperate regions its thickness is reduced to 50 meters. Underneath the top layer the decrease in temperature is very steep. However, decreasing slowly it continues down to the lower limit of the troposphere. The zones of rapid vertical changes in temperature show the maximum of vertical temperature gradient. This zone is called the thermo-cline. In the equatorial areas the intensity of the thermo-clines is greatest where the mean value exceeds 0.4°C per meter. Beneath the thermo-cline lie the water masses of the sub-troposphere. The vertical temperature gradient in these water masses registers a rapid decrease downwards. At this point it should be made clear that in the absence of the lateral influx of colder water by the oceanic circulation, the vertical temperature distribution in the troposphere would be disturbed.



The ocean can be divided into three vertical zones, depending on temperature. The top layer is the surface layer, or mixed layer. This layer is the most easily influenced with solar energy (the sun's heat), wind and rain. The next layer is the thermocline. Here the water temperature drops as the depth increases. The last layer is the **deep-water layer**. Water temperature in this zone decreases slowly as depth increases. Water temperature in the deepest parts of the ocean is averages about 36°F (2°C).

For the maintenance of the vertical temperature distribution in this sphere the heat from above through the dynamic convection and the horizontal advection must compensate each other perfectly. In the oceanic stratosphere, the vertical temperature differences in very deep layer are relatively smaller. With increasing depth the temperature gradient falls off rapidly. At depth below 1000 meters it is less than 0.4°C per 100 meters, but below 3000 m it is reduced to 0.05°C per 1000 m. In the polar and sub-polar regions the oceanic stratosphere comes up at the surface where it is in direct contact with the atmosphere. In this sphere the temperatures are very low.

It is in this sphere that the water masses sink and spread out in a quasi-horizontal direction towards the lower latitudes. They are subjected to a lot of lateral as well as vertical mixing.It may be stated that the factors that have an important influence on the subsurface temperature of the ocean water are the upwelling of water from beneath the surface, the sinking of more dense water masses from the surface, variations in the amount of incident solar radiation, and the submarine physical barriers etc. But the warm and cold ocean currents as well as the bottom relief of the oceans play a much more important role in this respect than the above mentioned factors. These two factors alone greatly influence the vertical distribution of temperature in the subsurface layers of the ocean water. There are certain special areas in the oceans where the temperatures are high even at great depths. The Sargasso Sea offers a typical example. In most of the partially enclosed seas, their bottom relief and the submarine ridges with shallow water do not allow the free mixing of open sea water. Because of these factors the temperatures of the subsurface layers of water are higher than those of the open oceans.

For example, the temperature at a depth of 1000 fathoms in the Red Sea is about 21°C, which is much higher than the temperature recorded at the same depth in the Indian Ocean. Similarly, in the Mediterranean Sea the temperature at a depth of 1200 meters varies from 12.2° to 13.3°C, whereas only 10°C is recorded at the same depth in the open Atlantic Ocean. Besides, the submarine ridges on the floor of the oceans present obstruction in the free mixing of water on their opposite sides so that different temperatures are recorded on the two sides.

The surface layer of the ocean water is normally warm while the deeper waters are generally cold. That is how temperature decreases according to the increasing depth of the ocean because the sun is the original source of energy. This is true even at the equator up to a depth of 200 meters. The temperature corresponds to the surface. Normally 90% of the heat that penetrates the surface layer is absorbed in the upper 60' of water. The sun's rays have no direct effect below 600'(100m) therefore a vast bulk of sea water is cold. Probably 80 percent of water in the oceans is permanently below 4.4 degree C. The fall in the temperature is very rapid between 400 and 800 meters. But below this depth the decrease becomes very slow till 200 meters where hardly any change is observed. Below this depth the temperature is everywhere about 1.6 degree C. The temperature of surface water may varies from place to place. The temperature of the bottom water is everywhere constant. There is generally a thin layer of warm water resting upon a mass or a great thickness of cold water. The greatest range and difference in temperature between the surface layer and that at any given depth is observed in the tropical area where the sea surface temperature is the highest in the world.

There are two exceptions to this general decrease in temperature of sea water with depth.

- In the polar seas there is a small inversion of temperature with depth. A thin layer of cold icy water over lays a layer of warmer water. But below 400 meters a general decrease of temperature is observed.

- The semi enclosed seas (Baltic Sea, red sea) particularly those with a mid oceanic ridge may different temperature chart then the open ocean. This results in a higher temperature even at greater depths. The existence of these barriers ridges holds back the free circulation of cold water from the open ocean to enter the enclosed sea -e.g. the Red sea is separated from the Indian Ocean by a submarine ridge near the Strait of

5.6 LET US SUM-UP

The surface beneath the water is characterized by a great diversity relief features i.e. the towering mountain chains, deep canyons, flat plains, oceanic ridges, trenches, islands seamounts. Despite advancements in science and technology, the ocean remains mystery to mankind. Beneath the sea, in some places about midway between the continents, is a vast mountain chain that is almost continuous around the world. The ocean contains thousands of islands. An **abyssal plain** is an underwater plain on the deep ocean floor. Oceanic trenches are long, narrow topographic depressions of the seabed. An **oceanic plateau** is a large, relatively flat submarine region that rises well above the level of the ambient seabed. Submarine topography provides knowledge about the past and present and prime link to the future.

5.7 KEY WORDS

Vertical oceanic plateau distribution, horizontal distribution, ocean currents, prevailing winds, abyssal plain.

5.8 QUESTIONS FOR SELF STUDY

1. What is ocean water temperature? Explain
2. Explain the factors influencing the distribution of temperature?.
3. Discuss the horizontal distribution of temperature.
4. Explain the vertical distribution of temperature.

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UNIT - 6: SALINITY OF THE OCEAN

Structure:

6.0 OBJECTIVES

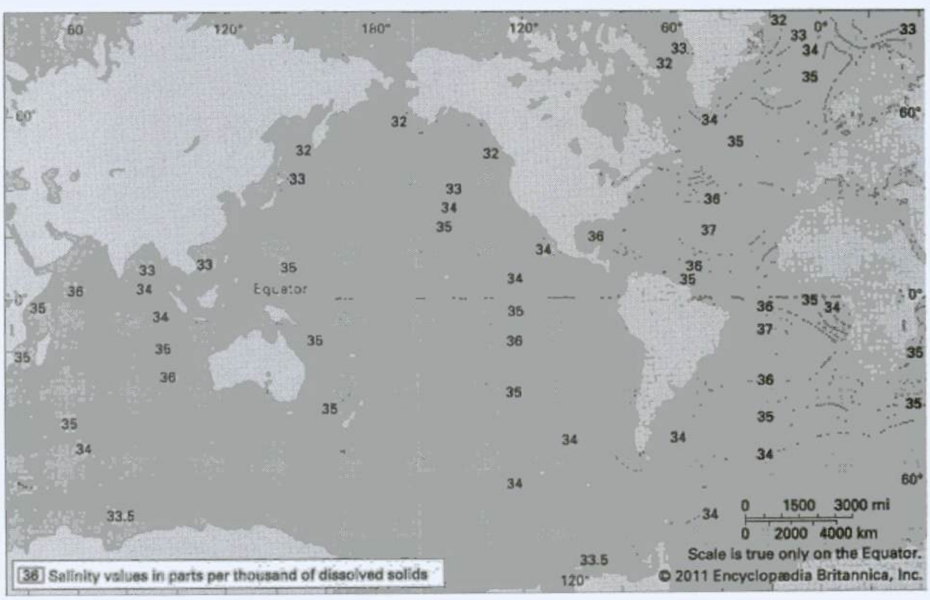
After studying This Unit, you will able to

* Identity the Sources of salive
* Know the horizontal and vertical distribution of Salvity
* Identity the compostion of Salivity.

6.1 INTRODUCTION

Different bodies of water have different amounts of salt mixed in, or different salinities. Salinity is expressed by the amount of salt found in 1,000 grams of water. The average ocean salinity is 35 ppt. This number varies between about 32 and 37 ppt. Rainfall, evaporation, river runoff, and ice formation causes the variations. For example, the Black Sea is so diluted by river runoff; its average salinity is only 16 ppt. Freshwater salinity is usually less than 0.5 ppt. Water between 0.5 ppt and 17 ppt is called brackish. Estuaries (where fresh river water meets salty ocean water) are examples of brackish waters. Most marine creatures keep the salinity inside their bodies at about the same concentration as the water outside their bodies because water likes a balance.

6.2 SALINITY DISTRIBUTION



Among the various physical properties of the ocean water salinity is one the most important ones. It is commonly defined as the ratio between the weight of dissolved salt and weight of a given sample of sea water. The amount or degree of salinity is expressed in terms of the mnumber of parts of salts per 1,000 parts of sea water. In simple wards 34 grams of salt per 1,000 grams of sea water is the same as the slanity of 34%0 .

Salinity determines the other physical properties of ocean water like density, temperature, thermal expansion, freezing point and colour. The freezing point of sea water is dependent on the amount of the salt present in it. It means that sea water begins to freeze only when the temperature falls below the freezing point of the dissolved substances. Consequently the freezing point of sea water varies according to the amount of dissolved salt in it. The gteater the amount of salt lower is the freezing point. Even the movement of the sea water the distribution of fish animals and plankton are determined by the degree of salinity.

6.3 COMPOSITION OF SEA WATER

Sea water contains a complex solution of several mineral substances in dilute form because it is active solvent. The total amount of salt in sea water is gradually increasing because it is brought from the land every year. The proportion of various elements remains constant in sweater everywhere though the total salinity may vary from place to place. There are numerous nutrients in the sea water which are used by living marine organisms. These elements are silicon, nitrogen, and phosphorous. Besides, arsenic, iron, manganese and copper are also found in the seawater. The average salanity varies from 33‰ to 37‰. The most important salts present in the sea water are given bellow:

Significant salts in the oceans

Table

Salts	**Amount (%)**
Sodium Chloride	77.8
Magnesium Chloride	10.9
Magnesium Sulphate	4.7
Calcium Sulphate	3.6
Potassium Sulphate	2.5
Calcium Carbonate	0.3
Magnesium Bromide	0.2

6.4 SOURCES OF OCEANIC SALINITY

The bulk of the salts must have been present since the ocean water first accumulated on the surface of the earth. Basically the source of oceanic salinity is land. Rivers bring salts in solution form from the continental areas. Though the amount of salts contributed by the rivers each year is negligible in proportion to the amount directly present they are the main source of salts for the oceans according to some scientist. However there is little similarity in the chemical composition of river water and that of sea water. River water contains only 2% of sodium chloride where as sodium chloride dominates in the salinity of oceans(77.8%). This shows that the rivers do not bring enough salts in to the sea or what they pour into the sea is continuously being lost. Yet it is concluded that the small amount of salts brought each year by rivers does increase the salinity of the sea in to some extent.

6.5 FACTORS CONTROLLING THE SALINITY

The amount of salts present in the oceans varies from place to place and from time to time due to various factors. The most important ones are the following.

1. Rapidity of Evaporation:

Evaporation is directly related to the amount of salinity in the sea as the salts left behind after continuous evaporation increase the salinity . Thus greater the evaporation leads to a higher degree of salinity. The salinity on the torpics is due to the rapidity of evaporation.

2. Amount of precipitation:

Precipitation is also an important factor which which affects the degree of salinity. In the equatorial latitudes inspite of high annual temperature, salinity is relatively low. This is because the high rainfall in these regions dilutes the surface water and the general cloudiness retards evaporation. In higher latitudes, the melting of ice barges and glaciers adds fresh waters to the ocean and accordingly the salinity is reduced. These ice bargs and glaciers are the result of excessive snowfall in the polar region.

3. Influx of River water

The amount of salinity in the ocean water also varies due to the influx of fresh water brought by rivers. Hence near the mouths of large rivers salinity may be low due to mixing with this fresh water. For e.g.river mouths of Amozon the salinity is 15‰ and near the mouth of Congo it is 20‰.

4. Movement of ocean water

The circulation of ocean water also results in a through mixing of the surface water and this affects the amount of salinity. The movement of currents and the upwelling of waters when long continued and permanent it causes the absolute uniformity of the composition of sea water at the surface. This mixing is easier in the open seas than in the partially enclosed water body. For e.g. Equatorial warm currents drive away salts from the western coastal areas of the continents and accumulate them along the eastern coastal areas. The high salinity of the Mexican Gulf is partly due to this factor.

5. Atmospheric pressure and wind direction

Anti-cyclonic conditions with stable air and high temperature increase salinity of the surface water of the oceans. Sub-tropical high pressure belts represent such conditions to cause high salinity. Winds also help in the redistribution of salt in the oceans and the seas as winds drive away saline water to les saline areas resulting into decrease of salinity in the former and increase in the latter. Trade winds drive away saline waters from the western coasts of the continents and pile them up near the eastern coasts causing low salinity in the former area and high salinity in the latter.

6.6 DISTRIBUTION OF SALINITY

The average salinity in the ocean and seas is 35‰ but it is spatially and temporally varies in different oceans, seas, and lakes. The variation in salinity is both horizontal and vertical. Salinity also varies from enclosed seas through partially closed seas to open seas. Thus, distribution of salinity is classified in to two ways

i) Horizontal distribution

ii) Vertical distribution

6.7 HORIZONTAL DISTRIBUTION

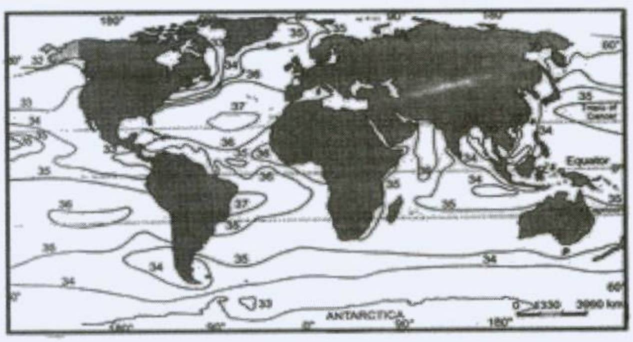
Horizontal distribution of salinity is studied in relation to latitudes but regional distribution is also considered. Latitudinally salinity decreases from equator towards the poles. It may be mentioned that the highest salinity is observed between 20-40 N(36‰) because this zone is characterized by temperature, high evaporation but significantly low rainfall.

Latitudinal distribution of salinity

Table

Latitudinal zones	Salinity (‰
70°-50°N	30-31
50°-40°N	33-34
40°-15°N	35-36
15°-10°N	34-35
10°-30°S	35-36
3°0°-50°S	34-35
50°-70°S	33-34

Horizontal distribution of salinity



Open Ocean

The salinity of ocean water on an average 35‰, it may differ from this average salinity. Since the salinity is influenced by heat (evaporation), precipitation, melting of ice and mixing of river water etc. The highest degree of salinity is found in two regions each of which lie close to the tropic of cancer (23 1/2°N) tropic of Capricorn(23 1/2°S) . Here the high salinity is due to the rapidity of evaporation and the clear sky and high temperature in these two belts. The salinity decreases towards the equator and the two poles. It is not so high at the equator because the excessive rainfall tends to dilute the ocean water. In the Polar Regions also the salinity is low because evaporation is less and the melting of ice , glacier and icebergs is considerable.

For the whole of the Northern hemisphere the average salinity is 36‰ and southern hemisphere it is 34‰. This difference is the result of the abandons of ocean waters and comparatively easy mixing due to the absence of large landmass in the southern hemisphere.

Partially enclosed seas

In the partly enclosed water bodies which communicate with the open oceans only by narrow gaps or stretches of water salinity may be quite high. High salinity is registered in the Mediterranean Sea, Gulf of Maxico, Red sea, and the Percian Gulf. At the eastern margin of the Mediterranean Sea the salinity rises to 39‰ and in the Red Sea it is more than 41‰ . Hence the rainfall amount is lower, evaporation is greater and there is restricted mixing with the open ocean. Moreover the Red Sea practically receives no river even the Mediterranean receives a comparatively smaller amount of river waters from the Rhone Po, etc.

In the Black Sea the surface salinity is lower about 28‰ . This is because evaporation I sless hen in the Mediterranean and may river like Denub, Deniper, Don etc., bring in large amount of fresh water in proportion to the size of the Sea.

Enclosed lakes and Inland water body

In a lake of water body which has no outlet there is no escape for the salts which are poured in it or get accumulated there. Hence the water must gradually grow more and more saline. The degree of salinity partly depends upon the length of time during which the lake or sea remained without an outlet.

The Dead Sea (west Asia) is the most saline of large lakes its salinity reaching 237‰. But even this figure is exceeded by some of the smaller lake in the hot desert regions of the world. In most of these inland seas and lakes the composition of th edissoloved salts isnot similar to that of the ocean.

6.8 VERTICAL DISTRIBUTION

Salinity increases with increasing depth in high latitudes i.e. there is positive relationship between the amount of salinity and depth because of denser water below.

The trend of increase of salinity with increasing depths is confined to 200 fathoms from the surface in middle latitudes beyond which it decreases with increasing depths. Maximum salinity is found in the upper layer of the oceanic water,. Salinity decreases with increasing depth.

6.9 LET US SUM UP

Salinity is defined as the total amount of solid material in grams contained in one kilogram of sea water. The oceanic salinity not only affects the marine organisms and plant community but it also affects the physical properties of the oceans such as temperature, density, pressure, waves and currents. Although the vast majority of seawater has a salinity of between 3.1% and 3.8%, seawater is not uniformly saline throughout the world. Where mixing occurs with fresh water runoff from river mouths or near melting glaciers, seawater can be substantially less saline. The most saline open sea is the Red Sea, where high rates of evaporation, low precipitation and river inflow, and confined circulation result in unusually salty water. The salinity in isolated bodies of water (for example, the Dead Sea) can be considerably greater still.

6.10 KEY WORDS

Vertical Distribution, Horizontal distribution, partially enclosed seas, Open Ocean, Enclosed lakes and Inland water body

6.11 QUESTIONS FOR SELF STUDY

1. What is salinity? How it is expressed?
2. Explain the composition of Sea?.
3. Discuss the factors controlling the salinity.
4. What is horizontal distribution of salinity? Explain
5. Explain the vertical distribution of salinity.
6. Discuss the distribution of salinity.

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UNIT - 7: OCEAN WATER: PRESSURE

Struction:

7.0 Objectives

7.1 Introduction

7.2 Meaning and Significance

7.3 Controlling Factors of Density

7.4 Relationships Between Pressure, Temperature And Salinity

7.5 Pressure Stratification of Oceans

7.6 Let Us Sum Up

7.7 Key Words

7.8 Questions For Self Study

7.9 Further Readings

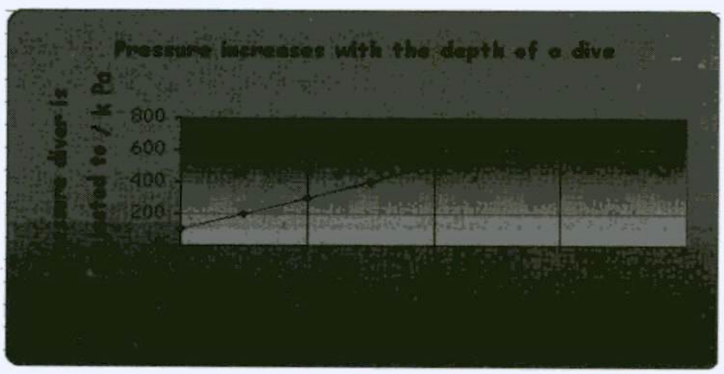
7.0 OBJECTIVES

At sea level, the air that surrounds us presses down on our bodies at 14.7 pounds per square inch (1 bar). You don't feel it because the fluids in your body are pushing outward with the same force. Dive down into the ocean even a few feet, though, and a noticeable change occurs. You can feel an increase of pressure on your eardrums. This is due to an increase in hydrostatic pressure, the force per unit area exerted by a liquid on an object. The deeper you go under the sea, the greater the pressure of the water pushing down on you. For every 33 feet (10 meters) you go down, the pressure increases by 14.7 psi (1 bar). In the deepest ocean, the pressure is equivalent to the weight of an elephant balanced on a postage stamp, or the equivalent of one person trying to support 50 jumbo jets

7.1 INTRODUCTION

Even though we do not feel it, 14.7 pounds per square inch (psi), or 1kg per square cm, of pressure are pushing down on our bodies as we rest at sea level. Our body compensates for this weight by pushing out with the same force. Since water is much heavier than air, this pressure increases as we venture into the water. For every 33 feet down we travel, one more atmosphere (14.7 psi) pushes down on us. For example, at 66 feet, the pressure equals 44.1 psi, and at 99 feet, the pressure equals 58.8 psi.

Fig.1.1 Pressure increases with ocean depth

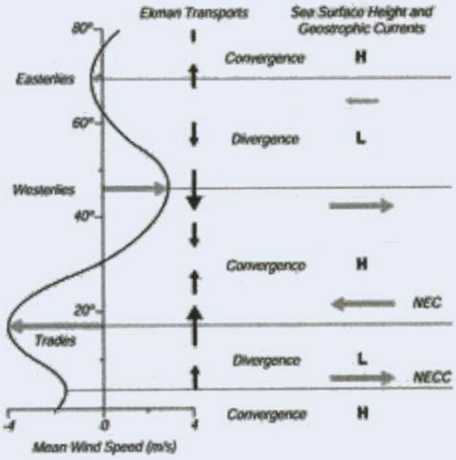


Even though we do not feel it, 14.7 pounds per square inch (psi), or 1kg per square cm, of pressure are pushing down on our bodies as we rest at sea level. Our body compensates for this weight by pushing out with the same force.

Since water is much heavier than air, this pressure increases as we venture into the water. For every 33 feet down we travel, one more atmosphere (14.7 psi) pushes down on us. For example, at 66 feet, the pressure equals 44.1 psi, and at 99 feet, the pressure equals 58.8 psi.

Animals that live in this watery environment undergo large pressure changes in short amounts of time. Sperm whales make hour-long dives 7,380 feet (2,250 meters) down. This is a pressure change of more than 223 atmospheres! By studying and understanding how these animals are able to withstand great pressure changes, scientists will be able to build better tools for humans to make such journeys.

Fig. 2 Pressure change



7.2 MEANING AND SIGNIFICANCE

Pressure refers to the amount of mass per unit volume of substance. It is usually measured in gram per cubic centimeter of volume and is expressed g/cm3. The pressure is very important physical property of seawater because it determines the dynamics of ocean water i.e. whether the sea water will sink or will float depends upon its density. The reason that a person floats over sea water having high salinity because pressure is low due to high temperature and salinity increases the density of sea water.

7.3 CONTROLLING FACTORS OF DENSITY

The pressure of sea water is related to the following two factors in one way or the other:

- Temperature –Thermal expansion
- Salinity –addition of dissolved substances

Temperature

Temperature is the most significant controlling factor of pressure of sea water. Temperature and pressure of sea water are on an average inversely related i.e. higher the temperature, lower the pressure and the lower the temperature, higher the density. In fact, seawater is heated through insolation when more insolation is received on the sea surface and hence sea water expands. This phenomenon is called thermal expansion due to the insloational heating resulting into low density. On the other hand, low temperature causes cooling of seawater and hence thermal contraction resulting into decrease in volume and increase in density of seawater. The temperature of the ocean decreases and decreases as you go to the bottom of the ocean. So, the density of ocean water increases and increases as you go to the bottom of the ocean. The deep ocean is layered with the densest water on bottom and the lightest water on top. Circulation in the depths of the ocean is horizontal. That is, water moves along the layers with the same density.

Salinity

Higher the temperature more is evaporation and reflects higher salinity. This is because of the fact that dissolved salt in the seawater becomes denser than pure water. Increasing salinity also increases the density of sea water but pressure would becomes low due to high evaporation It is also important to note that salinity factor is sometimes offset by temperature factor. So a layer of water with higher salinity can actual float on top of water with lower salinity if the layer with higher salinity is quite a bit warmer than the lower salinity layer. The density of pure water is 1000 kg/m^3. Ocean water is denser because of the salt in it. Density of ocean water at the sea surface is about 1027 kg/m^3.

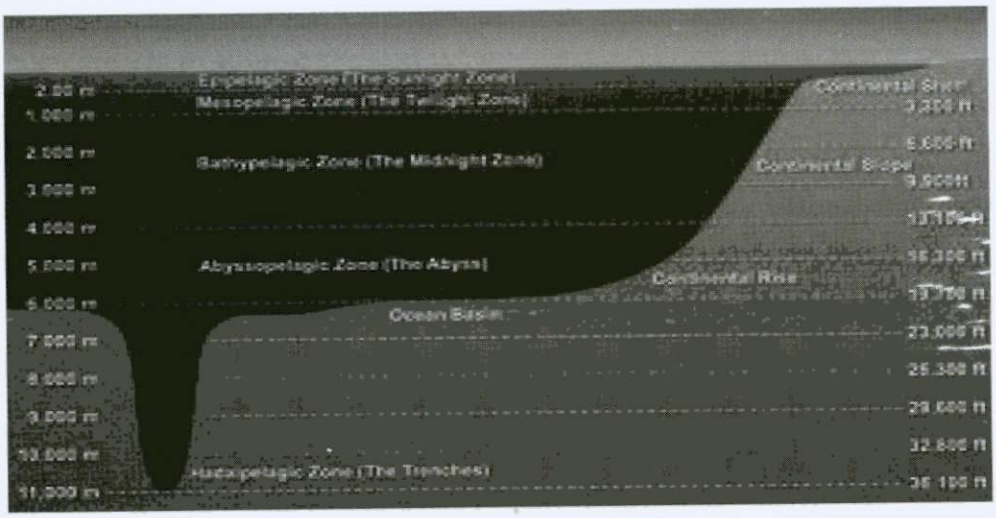
7.4 RELATIONSHIPS BETWEEN PRESSURE, TEMPERATURE AND SALINITY

Pressure of sea water and temperature are inversely proportional i.e. if temperature of seawater increases, its pressure decreases and vice versa. It is apparent from the fig. 2 that temperature of sea water sharply declines from 200 m depth to 1000 m depth in low latitudes areas and thereafter there is no variation in sea water temperature with increasing depth. On the other hand, there is no change in seawater temperature with increasing depth in high latitudes areas. The zone of sharp change of seawater temperature between 200m and 1000 m is called thermocline.

Pressure is the greatest environmental factor acting on deep-sea organisms. Pressure increases 1 atmosphere (atm) for each 10 m in depth. In the deep sea, although most of the deep sea is under pressures between 200 and 600 atm, the range of pressure is from 20 to 1,000 atm. Pressure exhibits a great role in the distribution of deep sea organisms. Until recently, people lacked detailed information on the direct effects of pressure on most deep-sea organisms, because virtually all organisms trawled from the deep sea arrived at the surface dead or dying. With the advent of traps that incorporate a special pressure-maintaining chamber, undamaged larger metazoan animals have been retrieved from the deep sea in good condition. Some of these have been maintained for experimental purposes, and researchers are obtaining more knowledge of the biological effects of pressure.

Since water is much heavier than air, this pressure increases as we venture into the water. For every 33 feet down we travel, one more atmosphere (14.7 psi) pushes down on us. For example, at 66 feet, the pressure equals 44.1 psi, and at 99 feet, the pressure equals 58.8 psi.

Fig.2 Pressure beneath the water



7.5 PRESSURE STRATIFICATION OF OCEANS

Surface layer represents the thin topmost layer of the oceans ranging in thickness of 100 to 200 m. This surface layer carries 2 percent of total volume of ocean water. Because of thermal expansion of seawater due to direct insolation heating pressure becomes low in this layer in the tropical oceans but due to more evaporation in the subtropical oceans, pressure becomes higher than the low latitude areas because of increased salinity. High pressure is found in 1000 m depth to the ocean floor, and carries 80 percent of total volume of the ocean water. Extremely low temperature in the polar areas in responsible of contraction of water, hence increase in seas water pressure.

Surface layer

Surface layer represents th thin topmost layer of the oceans ranging th ethickness of 100 to 200 m. This layer is also called as photic zone which is directly penetrated by solar radiation and hence it is illuminated layer. This surface layer carries 2 percent of total volume of ocean water. Because of thermal expansion of seawater due to direct insolational heating density becomes minimum in this layer in the tropical oceans but due to more evaporation in the subtropical oceans, pressure becomes a bit higher than the low latitude areasbecause of incresed salinity consequent pon more evaporation. Since this layer is subjected to temporal variations in the tempeature andsalinity of sea waterdue to its direct contact with the atmosphere and hence pressure in this zone is also liable to temporal variations.

Pycnocline layer

This layer represents a transition zone of rapidly changing seawater density between low pressure upper surface water layer and high pressure deep sea water. In fact, pycnocline consists of two words, namely pycno, which means density, and cline, which means slope or gradient. This layer found between 300 m to 1000 me depth of the ocean water. In this layer sharp incrase in sea water pressure, decrease in sea water temperature and sharp increase in salinity with increasing depth in the ttropical and subtropical oceans. It carries 18 percent of the total volume of the ocean water.

Deep layer

This layer represents high pressure water mass which extend from 1000m depth to the ocean floor, and carries 80 percent of total volume of the ocean waer. Extremely low temperature in the polr areas is responsible ofcontraction of waterand hence increase in seawater density. This leads to sinking of high density water mass of polar regions and causes still high density of deep water mass.

7.6 LET US SUM UP

Pressure is directly positively related to ocean water density through its compressive effects, sea water density increases with increasing pressure, and decreases with decreases in pressure of seawater. There are two main factors that make ocean water more or less dense than about 1027 kg/ m^3: the temperature of the water and the salinity of the water. Ocean water gets denser as temperature goes down. So, the colder the water, the more dense it is. Less dense water floats on top of more dense water. Given two layers of water with the same salinity, the warmer water will float on top of the colder water. Temperature has a greater effect on the density of water than salinity does. Pressure

7.7 KEY WORDS

Insolation, thermocline. Pressure, density, salinity, Pycnocline layer, Surface layer,Deep layer

7.8 QUESTIONS FOR SELF STUDY

1. Explain the meaning and significance of ocean pressure?
2. Discuss the factors controlling the pressure.
3. Explain the distribution of pressure.
4. Explain the pressure stratification of oceans.
5. Discuss the relationship between salinity temperature and pressure.

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UNIT - 8: OCEAN CURRENTS

Structure:

8.0 OBJECTIVES

After studying this unit, you will be able to;

- Define ocean currents and understand overall surface circulation.
- Show the relationship between global air circulation and oceanic currents.
- Explain how certain coastal and divergent wind patterns can cause upwelling.
- Demonstrate thermohaline and density currents and explain their importance to bottom-water currents

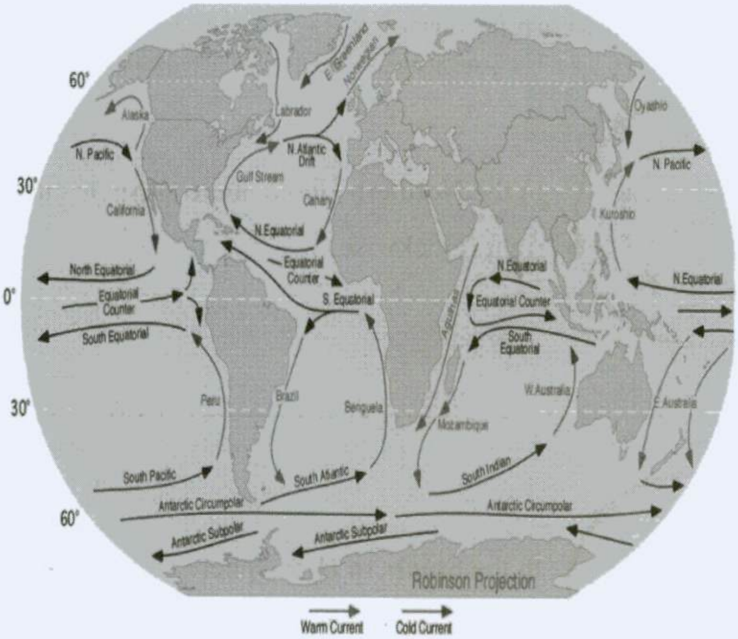
8.1 INTRODUCTION

An ocean current is a continuous, directed movement of ocean water generated by the forces acting upon this mean flow, such as breaking waves, wind, Coriolis effect, cabbeling, temperature and salinity differences and tides caused by the gravitational pull of the Moon and the Sun. Depth contours, shoreline configurations and interaction with other currents influence a current's direction and strength. Ocean currents can flow for great distances, and together they create the great flow of the global conveyor belt which plays a dominant part in determining the climate of many of the Earth's regions

Ocean currents are important in the study of marine debris, and vice versa. These currents also affect temperatures throughout the world. For example, the current that brings warm water up the north Atlantic to northwest Europe stops ice from forming by the shores, which would block ships from entering and exiting ports

8.2 OCEAN CIRCULATION

Energy from the Sun doesn't fall equally all over the Earth. Most of the Sun's energy enters the Earth at the equator. This leads to large temperature gradients between the equator and the Poles. Movement of both the air and the oceans is controlled by these temperature differences and the result is a transfer of heat from the equator to the poles. About half of the heat transport around the planet is by the oceans so the oceans are an extremely important part of the Earth's climate control system. Ocean circulation also transports oxygen from the air into the ocean making marine life possible. Large amounts of water in the ocean move in a definite path on the surface. There are many such streams flowing all over the world oceans. These are called ocean currents. In short, they constitute a large mass of water flowing along a fixed path on the surface of the ocean. A current may be swift with a speed of up to 10 km/hr, or it may be broad and slow moving at an average speed of 2 km/hr, in which case it is called ocean drift.



8.3 CAUSES OF OCEAN CURRENTS

The pattern of oceanic circulation is produced by the interaction of a number of factors. The main factors which produce the ocean currents are:

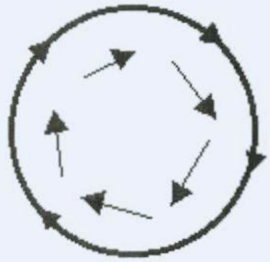
(a) **The prevailing winds** are the major cause of the ocean waters moving in a definite direction. The pushing action of these winds makes the waters flow as they do. Like the planetary winds, currents too are deflected from their original path due to the rotation of the Earth. All currents in the northern hemisphere move in a clockwise direction, while in the southern hemisphere they move in an anti-clockwise direction. Landmasses are also responsible for changing the course of a current.

(b) **Differences in temperature and salinity** are also responsible for the movement of ocean water. In the equatorial region, ocean water gets more heated than in the cold Polar Regions. This makes the water light. Water in the Polar Regions is cold and heavy, so it sinks and flows towards the equator. The light upper layers of water are forced to move towards the Poles where they get cooled.

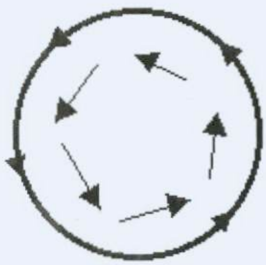
(c) **Rotation of the earth**

The earth rotates on its axis, from west to east. This rotation is the cause of deflective force known as Coriolis force which deflects the general direction of the winds and that of the ocean currents. For example, the currents flowing from equator towards the north and south poles are deflected to their right in the northern Hemisphere and towards their left in the Southern hemisphere respectively

Fig,1. Rotation of the earth and currents curve



In the Northern Hemisphere currents curve to the right (clockwise).



In the Southern Hemisphere currents curve to the left (counter-clockwise)

(d) Configuration of coastlines

The shape and configuration of the coastlines also have a close influence on the direction and movement of the ocean currents. For example, the equatorial current after bening obstructed by the Brazilian coasts is bifurcated into two branches. The Northern branch is known as the Caribbean current flowing along the northern coast of South America, while the southern branch moves along the eastern coast of Brazil which is known as the Brazilian current.

8.4 EFFECTS OF OCEAN CURRENTS

Currents influence the climate of the costal regions. This determines the agricultural and hence all other economic activities of the region. Ocean currents have the following effects:

Modification in the coastal climate

I. Ocean currents while flowing along the coasts modify their wheathr conditions in a number of ways. The most effective impacts of ocean currents are seen on the temperature of affected coastal lands. The effects are both positive and negative for flora and fauna. The warm currents, when they reach colder areas, donot allow their tempeatures to fall rather they keep them relatively warmer in winter months. Ocean currents help in maintaining the temperature balance of ocean water as the warm currents transport warm waters of the tropical zones to the colder areas of the temperate and polar zones and cold currents bring cold waters of high latitudes to the areas of low latitudes. Thus, ocean currents help in bringing homogeneity in the in the distribution of temperature of ocean water. Such winds bring down the temperature of the land like the kuroshio (warm) current, which flows along the east coast of Japan.

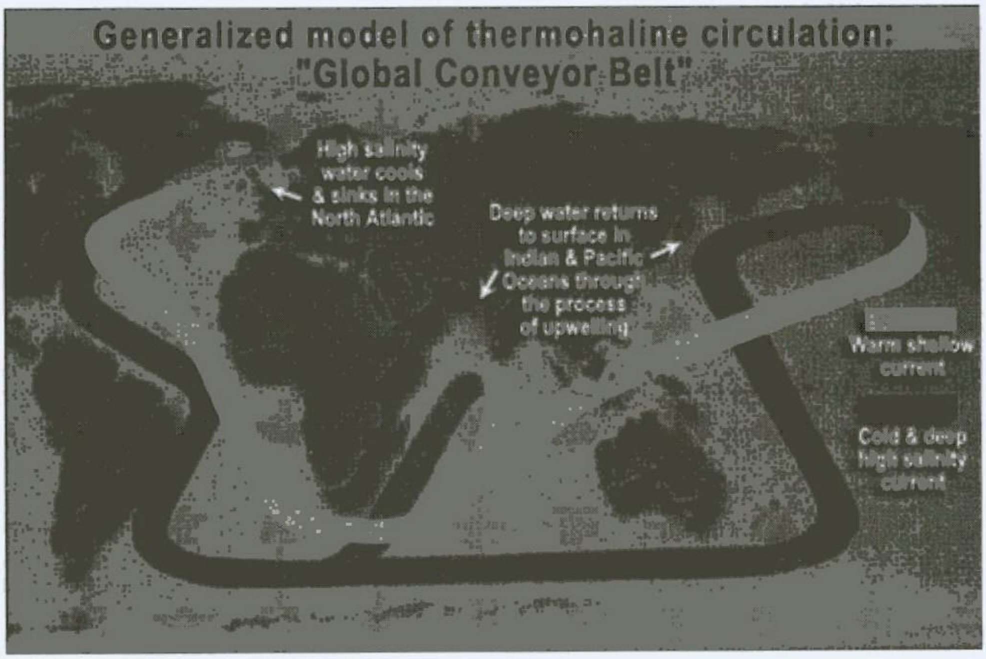
II. Winds blowing over a cold and dry. They help to bring down the temperatures in places, which would have been much hotter. The California (cold) current, which flows along the western coast of USA, makes the region much cooler than other places in the west coast on the same latitude.Such winds are bereft of any moisture and bring little or no rainfall over the coastal regions where they blow. As most cold currents flow along the western coast of continents, some of the major deserts are found in such regions. The Atacama desert in South America is influenced by the cold Peru current.

III. Places where cold and warm currents meet are ideal for the growth of Plankton. These are very small organisms, which are food for fish. These regions thus support a great number of fish. They have developed into major fishing grounds of the world. Newfoundland on the eastern coast of North America is the meeting point of the Gulf Stream and the Labrador Current. It is one of the major fishing centers of the world. However, these places may be dangerous for ships as the meeting of cold and warm currents gives rise to thick fog, which reduces visibility.

IV. Ships sailing with a current gain speed, which helps to save fuel and time. Ships moving against a current lose speed. Warm currents keep the Arctic regions free from icebergs, which can be dangerous for ships.

8.5 THERMOHALINE CIRCULATION

Deep water currents, also called thermohaline circulation, are found below 400 meters and make up about 90% of the ocean. Like surface currents, gravity plays a role in the creation of deep water currents but these are mainly caused by density differences in the water. Thermohaline circulation is known as the Global Conveyor Belt because its circulation of warm and cold water acts as a submarine river and moves water throughout the ocean.



This illustration shows cold deep high salinity currents circulating from the north Atlantic Ocean to the southern Atlantic Ocean and east to the Indian Ocean. Deep water returns to the surface in the Indian and Pacific Oceans through the process of upwelling. The warm shallow current then returns west past the Indian Ocean, round South Africa and up to the North Atlantic where the water becomes saltier and colder and sinks starting the process all over again.

In the Northern Hemisphere

Ocean circulation transports surface seawater to the polar region where it cools. This cooling releases heat which warms the air and makes the water cold and, therefore, dense enough to sink to the bottom of the ocean. This results in the formation of new deep water which displaces existing deep water pushing it towards the equator. The major regions for this deep water formation are the Labrador and Greenland Seas in the northern North Atlantic Ocean. This North Atlantic Deep Water then flows south along the ocean floor allowing more warm surface water to flow into the region to replace it. Strong cooling also occurs in the Bering Sea in the North Pacific, but the structure of the ocean floor here prevents the deep water that forms from entering the ocean circulation.

Antarctica

Deep water formation also occurs around Antarctica during the production of sea ice. This ice contains very little salt and so, as the ice forms, the surrounding water becomes saltier and more dense. This very dense water slides down the edge of the Antarctic continent to form Antarctic Bottom Water. This water then spreads out and moves around most of the ocean floor.

8.6 TYPES OF OCEAN CURRENTS

There are two types of Ocean Currents:

1. Surface Currents: Surface waters make up about 10% of all the water in the ocean.

2. Deep Water Currents: Deep waters make up the other 90% of the ocean. They move around the ocean basins by density driven forces and gravity. The density difference is a function of different temperatures and salinity. These deep waters sink into the deep ocean basins at high latitudes where the temperatures are cold enough to cause the density to increase.

Ocean currents are the vertical or horizontal movement of both surface and deep water throughout the world's oceans. Currents normally move in a specific direction and aid significantly in the circulation of the Earth's moisture, the resultant weather, and water pollution.

Vertical and ocean-bottom currents are mainly driven by density differences caused by changes in temperature and salinity. Originating in polar regions, cold, salty waters sink to the ocean bottom and move toward the opposite poles where they again surface. Vertical upwelling currents can also be caused by winds "blowing off" a coastline. The displaced waters are then replaced by underlying bottom waters. Currents are important to marine life as they help to move food and nutrients, making them available for photosynthesis, metabolic requirements and/or consumption.

Oceanic currents are found all over the globe and vary in size, importance, and strength. Some of the more prominent currents include the California and Humboldt Currents in the Pacific, the Gulf Stream and Labrador Current in the Atlantic, and the Indian Monsoon Current in the Indian Ocean. These are just a sampling of the seventeen major surface currents found in the world's oceans.

8.7 THE IMPORTANCE OF OCEAN CURRENTS

Because ocean currents circulate water worldwide, they have a significant impact on the movement of energy and moisture between the oceans and the atmosphere. As a result, they are important to the world's weather. The Gulf Stream for example is a warm current that originates in the Gulf of Mexico and moves north toward Europe. Since it is full of warm water, the sea surface temperatures are warm, which keeps places like Europe warmer than other areas at similar latitudes.

The Humboldt Current is another example of a current that affects weather. When this cold current is normally present off the coast of Chile and Peru, it creates extremely productive waters and keeps the coast cool and northern Chile arid. However, when it becomes disrupted, Chile's climate is altered and it is believed that El Niño plays a role in its disturbance.

Like the movement of energy and moisture, debris can also get trapped and moved around the world via currents. This can be man-made which is significant to the formation of trash islands or natural such as icebergs. The Labrador Current, which flows south out of the Arctic Ocean along the coasts of Newfoundland and Nova Scotia, is famous for moving icebergs into shipping lanes in the North Atlantic.

Currents plan an important role in navigation as well. In addition to being able to avoid trash and icebergs, knowledge of currents is essential to the reduction of shipping costs and fuel consumption. Today, shipping companies and even sailing races often use currents to reduce time spent at sea.

Finally, ocean currents are important to the distribution of the world's sea life. Many species rely on currents to move them from one location to another whether it is for breeding or just simple movement over large areas.

8.8 OCEAN CURRENTS AS AN ALTERNATIVE ENERGY

Today, ocean currents are also gaining significance as a possible form of alternative energy. Because water is dense, it carries an enormous amount of energy that could possibly be captured and converted into a usable form through the use of water turbines. Currently this is an experimental technology being tested by the United States, Japan, China, and some European Union countries.

Whether ocean currents are used as alternative energy, to reduce shipping costs, or in their natural to state to move species and weather worldwide, they are significant to geographers, meteorologists, and other scientists because they have a tremendous impact on the globe and earth-atmosphere relations.

8.9 LET US SUM UP

The general movement of a mass of oceanic water in a definite direction is called ocean current which is more or less similar to water streams flowing on the land surface of the earth. Ocean currents are most powerful of lall the dynamics of oceanic waters because these drive oceanic waters for thousands of kilomerers away. Ocean currents are divided in to warm currents and cold currents. The factors like direction, shape and configuration of coastlines, bottom reliefs, seasonal variations are modifying the ocean currents. Currents are use ful because it modifies the coastal climate.

8.10 KEY WORDS

Warm currents, cold currents, alternative energy, thermohaline, surface currents, deep water currents

8.11 QUESTIONS FOR SELF STUDY

1. What are ocean currents? Explain its types.
2. What is meant by oceanic circulations?
3. Briefly explain the causes of the ocean currents.
4. What are the effects of the ocean currents?
5. What are Thermohaline circulations?
6. Explain the types of the ocean currents.
7. Enumerate the importance of the ocean currents.

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UNIT – 9: CURRENTS OF ATLANTIC OCEAN

Structure:

9.0. OBJECTIVES

After studying this unit, you will be able to;

- Identify the location of Atlantic Ocean
- Distinguish between warm and cold currents
- List out the Warm and Cold currents of Atlantic Ocean
- Know about the counter current.

9.1 INTRODUCTION

The ocean water over the surface has been classified into four oceans like Pacific, Atlantic, Indian and Arctic. In this unit we are going to discuss the type of Ocean Currents of Atlantic Ocean.

9.2 LOCATION OF ATLANTIC OCEAN

Atlantic Ocean is the second largest ocean in the world. It covers an area of 82 million km^2, which is about $1/6^{th}$ (16.5%) of the total area of the world. It covers half of the Pacific Ocean. It looks like an elongated 'S' shape. It is wider (east to west) in south (5950 km) and narrow towards equator (2575 km, between Africa and South America). It is very narrow near Greenland. The most important submarine relief of this ocean is the presence of Mid-Atlantic Ridge, which divides this ocean into half. It rises near Iceland in the north to Bouvet Island in the south over a distance of about 15,000 km. The northern part of this ridge is known as **'Dolphin Rise'** and the southern part is known as **'Challenger Rise'.** Between Iceland and Scotland this ridge is known as **'Wyville Thomson Ridge'.** Puerto Rico deep, east of Puerto Rico Island is the deepest deep (9219 meters) in this ocean. Nearly 25.7% of area of this ocean is less than 2000 meters depth.

9.3 CURRENTS OF ATLANTIC OCEAN

The currents of Atlantic Ocean have a well-defined pattern of circulation. Both in North and South Atlantic currents are completing a cycle. Hence we can observe the **'Gyres'** in this part. The currents of this ocean are classified as;

1. Equatorial Currents
2. North Atlantic Ocean Currents
3. South Atlantic Ocean Currents.

9.3.1. Equatorial Currents

According to Defant the equatorial currents form the backbone of the system of currents in this ocean. The trade winds which are blowing on either side of the equator drives the ocean water from east to west. These are Warm Currents. The currents of Equatorial region are –

i. North Equatorial Currents

ii. South Equatorial Currents

iii. Equatorial Counter Currents.

i. North Equatorial Currents

This current is flowing from East to West. It is less constant in its boundary and strength. It is flowing between 5^0 to 20^0 North latitudes. North-East trade winds are the driving force of this current. This current was first described by **Findlay** (1853) states that 'it does not follow a straight course and covers different areas of the ocean in different time'. **Schumacher** (1940) points out that, North of 15^0 North latitude, the equatorial current bends to the right while approaching the Mid-Atlantic Ridge and again to the left after passing the ridge.

The North Atlantic Equatorial Current originates along the western coast of Africa (near **Capewarde**). It gets water from Canaries Cold Current. This equatorial current flows towards west, near Trinidad Island; it has been divided into two branches. One branch is known as **'Antilles Current'**, which flows along the eastern parts of West Indies, recurring continuously to the north and east of Sargasso Sea. Another branch of North Atlantic Equatorial Current which flows in Caribbean Sea known as **'Caribbean Current'**. It enters to Gulf of Mexico and flows along Florida coast as **'Florida Current'**.

ii. South Equatorial Current

It flows to the south of equator up to 12^0 south latitude between the coast of Africa and South America. This current is stronger, more constant and greater extent as compared to the North Atlantic Equatorial Current. It is strong between east of 30^0 West longitude and North of 15^0 South latitude. Near Cape San Roque, it is divided into two parts. The North-West branch moves along the North-East coast of South America and join the North Atlantic Equatorial Current near Trinidad and another branch turns southward and forms **Brazil Current**.

iii. Equatorial Counter Current

Between the North and South Equatorial Currents of the Atlantic, a typical calm zone exists in which the ocean water flows from West to East. The counter current is known as **'Guinea Stream'** in the eastern part. The width of these current changes according to the nature of winds. There are many causes have been identified to explain the origin of this current. There will be piling up of water in the west due to two equatorial currents and create slope from West to East. So water flows from West to East. It is known as **'Compensation Current'**.

There is another view regarding the origin of this current. It is supposed due to the presence of a discontinuity layer.

9.4 CURRENTS OF NORTH ATLANTIC OCEAN

It flows in clockwise direction leaving a central part known as **Sargasso Sea** with a Calm and variable wind. The currents complete a circle (Gyre). It consists of Gulf Stream, North Atlantic Drift and Canaries Current.

9.4.1. Gulf Stream

It is the most important Warm Current of North Atlantic Ocean. It is named by **Iselin**. The part of the Gulf Stream system is the meeting place of Florida and Antilles Current. Gulf Stream consist three important parts. They are-

a. Florida Current

b. Gulf Stream

c. North Atlantic Drift

a. Florida Current

It is northward continuation of North Equatorial Current flowing between Florida Strait and Cape Hatteras. It passes through Yucatan Channel into the Gulf of Mexico. Several scholars have noticed the various reasons for this. According to **Franklin** 'it originates due to stress of the trade winds'. Parr, Sverdrup and Montgomery have noticed that 'the difference in the sea level between Gulf of Mexico and Atlantic is responsible for the origin of this current'. Some other scholars have also believed that the differences of density of water between Gulf of Mexico and neighbouring ocean are the cause of origin of this current.

The direction and strength of this current changes. Pillsbury has noticed that the periodic variations in the current are due to the declination of the moon. The width of this current also varies from south to north according to influx of the water from sideways. It is broader in the east. The surface temperature of this current is about 23.8^0 C and salinity is $36\%_0$ grams.

b Gulf Stream

It flows from Cape Hatteras to Grand Bank as a **Warm Current.** It flows between Sargasso Sea in the east and cold water along the eastern coast of USA which was brought down by Labrador Current. Gulf Stream flows like a river in the ocean. After crossing 40^0 North latitude, it came under the influence of Westerlies. It changes its direction of flow towards east which is known as **North Atlantic Drift.**

c North Atlantic Drift

Near Grand Bank or at 45^0 West longitude, the Gulf Stream is divided into number of branches. One branch flows toward east with the influence of Westerlies and it is known as **North Atlantic Drift or North Atlantic Current**. It is a warm current, but lost several characters of Gulf Stream. This branch is divided into two parts. The northern branch flowing north-east is joined by the Labrador Current. The original nature of this current is slightly altered due to mixing of cold water. After some distance it is further divided into sub-branches. One of the branch flows in the Norwegian Sea along the coast of Norway crossing Wyville Thomson Ridge known as **'Norwegian Current'** and joins Arctic Ocean. To the north of Norway, this current branches into two. One branch flows as the **North Cape Current** into Barents Sea and the other flows North-westerly and turns to South-west. Ultimately it joins **East Greenland Current**.

Another branch flows along the southern coast of Iceland as **'Irminger Current'.** A small branch flows along the southern coast of Greenland and joins East Greenland Current. One of the branch of Gulf Stream flows toward Greenland. After mixing with cold waters of the East Greenland Current, it enters the Davis Strait and flows northward as **'West Greenland Current'.** The other branch of the drift, which is warmer due to less mixing of cold current, flows eastwards along 45^0 North latitude and moves along the coast of France, Spain and Azores Island. One of the branches of this current enters the Mediterranean Sea. A branch of the drift enters the Bay of Biscay, which is known as **'Renell Current'**, along the north coast of Spain and France.

Another branch of the drift flows southward along the western coast of Spain, Azores Island and Coast of North Africa. They are known as **'Azores Current'** and **'Canaries Cold Current'.** They change their nature due to upwelling of cold water.

9.4.2 Cannaries Current

It is one of the important **cold current** of North Atlantic Ocean. It flows along the western coast of North Africa between Maderia and Cape Verde. The average speed of this current is about 12 miles per day. It completes clockwise circulation in North Atlantic. Trade winds and upwelling of Cold water are responsible for the origin of this current. One of the branches of this current enters into the Gulf of Guinea on the west coast of Africa, which is known as **'Guinea Current'.**

9.4.3 Labrador Current

It originates in Baffin Bay and Davis Strait and flows toward south along the east coast of North America as **Cold Current.** It strikes the coast of New Found land, then flows over the easterly part of the Grand Bank and merges with the Gulf Stream at east of 50^0 west. In the south of New Found land, this current has been divided into two branches. One of the branch flows along east coast of USA, known as **'Cabot Current'.** Another branch called **'Strait Current'** flows south-west and joins the main current.

Labrador Current brings down ice bergs along with it from the Baffin Bay. Near New Found land and Grand Bank, Ice bergs are found due to this current. It causes problem for navigation.

Labrador is a **'Cold Current'.** It originates in Arctic region, where the temperature is extremely less and the presence of Ice bergs makes this current cold.

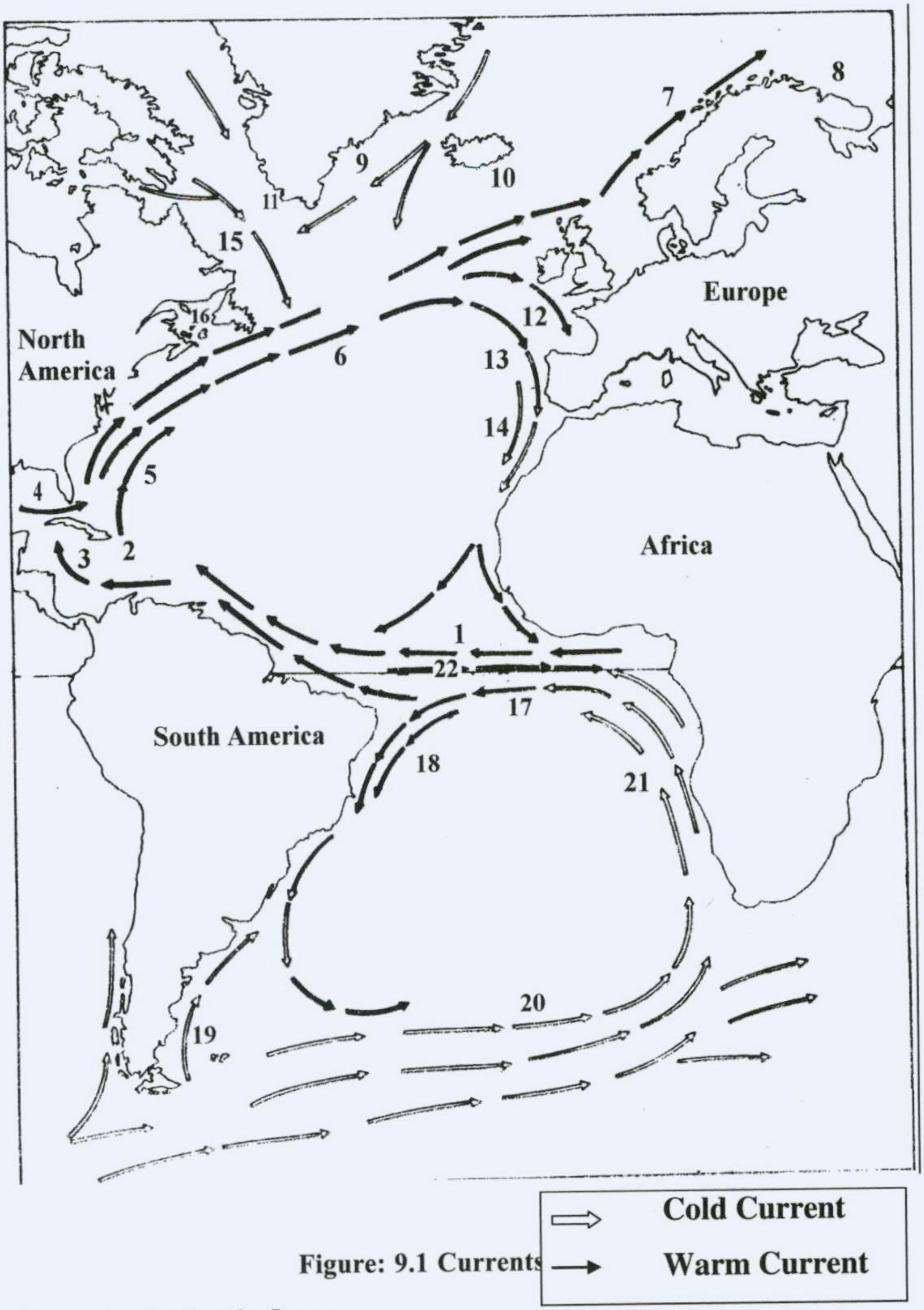

Figure: 9.1 Currents

Currents of Atlantic Ocean

1. North Equatorial Current

2. Antilles Current

3. Carribean Current

4. Florida Current

5. Gulf Stream

6. North Atlantic Drift

7. Norweigian Current

8. North Cape Current

9. East Greenland Current

10. Irminger Current

11. West Greenland Current

12. Rennel Current

13. Azore and Canaries Current

14. Guinea Current

15. Labrador Current

16. Cabot Current

17. South Atlantic Current

18. Brazil Current

19. Falkland Current

20. South Atlantic Drift

21. Benguela Current

22. Counter Current

9.5. CURRENTS OF SOUTH ATLANTIC OCEAN

In South Atlantic Ocean, the ocean currents flow in anti-clockwise manner. Here it completes a Gyre (circle). But there is no central region of similar nature as the Sargasso Sea as in the North Atlantic Ocean. The South Equatorial Current, Brazil Current, South Atlantic or West Wind Drift and Benguela Current form the boundary of the Gyre.

We have already studied about South Atlantic Equatorial Current (9.3.1.ii) in the previous page. In this part you are able to understand the nature of the rest of South Atlantic Currents.

9.5.1 Brazil Current

Near the coast of South America, the westward South Atlantic Equatorial Current is diverted to south. It flows southward up to 40⁰ South latitude. It is a **Warm Current.** It flows along the coast of Brazil, known as **'Brazil Current'.** It meets Falkland Current at 30⁰ – 35⁰ South latitude. Near Laplata estuary, this current splits and most of it turns toward east due to the influence of westerlies.

9.5.2: Falkland Current

This current was first noticed by Wikes in 1839. It is a **Cold Current**, which is similar to Labrador in the North. The cold water of Antarctica moves along the Argentina Coast up to 30⁰ South latitude, under the influence of South-Easterly winds. It brings Ice-bergs from Antarctica.

9.5.3: South Atlantic Drift:

Between 40⁰ to 60⁰ South latitudes, due to the influence of strong westerlies, the water (Brazil Current) in this region flows toward east. **Rennel** has stated that it is common in all the southern oceans and runs in the direction of earth's rotation from west to east. It is flowing at a velocity of 6 to 33 miles per day. A branch of this current flow along the west coast of Africa.

9.5.4: Benguela Current

The **Cold Current** flowing along the western coast of Africa toward north is known as **'Benguela Current'.** The deflection of South Atlantic Drift at Cape of Good Hope and upwelling of cold water are responsible for the origin of this Current. At north of 20⁰ south, the current moves towards west and joins to South Atlantic Equatorial Current completing a cycle (Gyre).

9.6 SARGASSO SEA

In the centre of North Atlantic Ocean an anti-cyclonic circulation is formed by the Gulf Stream, Canaries Current and Equatorial Current. In between this Gyre, there is a calm and motionless sea called **'Sargasso'.** Circulatory currents in all the sides of this sea make this completely motionless. This region is situated at a transition zone of westerlies and trade winds. The term Sargasso is derived from the **Portuguese word 'Sargassum'** which means **Sea Weed.** This sea is covered by Sea Weeds extending miles together, creating problems for navigation. According to Marmer, this sea is situated between 20^0 to 40^0 North and 35^0 to 75^0 west longitudes in a oval shape. This sea consist high salinity of about 37 grams / thousand grams of sea water (Average salinity of Atlantic Ocean is 35.5 grams / thousand grams of sea water). It is due to high temperature and greater evaporation. There is a lack of mixing of fresh water also responsible for high salinity in this sea. Temperature of water is also more in this sea.

9.7 LET US SUM UP

The ocean currents in this Ocean are clearly noticed. Winds, rotation of the earth, temperature, submarine topography and other factors are responsible for the movement of water. You can notice that complete of circles (Gyre) in both North and South Atlantic Ocean. You can see all these currents in the diagram.

9.8 KEY WORDS

Gyre, Warm Current, Cold Current, West wind drift, Gulf Stream, Labrador, Canaries, Brazil, Falkland, Benguela, Counter Current, Sargasso Sea.

9.9 QUESTIONS FOR SELF STUDY

1. Explain the Currents of North Atlantic Ocean.
2. Describe the currents of South Atlantic Ocean.
3. List out Warm and Cold currents of Atlantic Ocean.
4. Write a note on Sargasso Sea.

9.10 FURTHER READING

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UNIT – 10: CURRENTS OF PACIFIC AND INDIAN OCEAN

Structure:

10.0 OBJECTIVES

After studying this unit, you are able to list out –

- Location of Pacific and Indian Ocean
- Warm and Cold currents of Pacific Ocean
- Warm and Cold currents of Indian Ocean

10.1 INTRODUCTION

In this unit you are going to learn about the location, extent of Pacific and Indian Ocean. You can notice the similarities of currents in Atlantic and Pacific Ocean. You will also come to know that how and why currents will change their directions in North Indian Ocean.

10.2 LOCATION OF PACIFIC OCEAN

It is the largest and deepest ocean in the world. It covers 2/3rd of area of the earth. It extends from the coast of Asia in the west and America in the east for about 16000 km (10000 miles). It extends from Bering Strait in the north to Cape Adare (Antarctica Continent) in the south for about 14900 km (9300 miles). The average depth of this ocean is about 5000 meters. Only 3.9% of its area is less than 1000 meter depth. 37.7% of its area lies between 4000 to 5000 meters depth. This ocean is triangular in shape. Nearly 11000 miles of folded mountains are found in the coastal area of this ocean, which are parallel to this ocean. It consist more than 20000 islands. It has 5.7% area of Continental Shelf, 7% of Continental Slope and 88.3% is covered by Deep Sea Plain. It consist 32 deeps which are mostly parallel to island arc or the mountain chain. Most of these deeps are located in the western side. **Challenger Trench** or **Mariana Trench** near Philippine island is the deepest point (11,033 meter) in the world.

10.3 CURRENTS OF PACIFIC OCEAN

There is a marked similarity between the currents of Pacific Ocean with Atlantic Ocean. In the North Pacific Ocean, the current flows in Clockwise completing a circle (Gyre), whereas in Southern Hemisphere, it flows in Anti-clockwise direction. The currents of this ocean are classified as –

1. Equatorial Currents – North Pacific Currents
2. South Pacific Currents
3. Counter Current.

10.3.1. Equatorial Current

The Pacific trade winds give rise to the North and South Equatorial Currents. The North Equatorial Current originates at **Revilla Gigedo Island of Mexico** and flows towards west for about 7500 nautical miles to Philippine Island. It is a **Warm Current.** In the equatorial region, the width of Pacific Ocean is maximum than any other ocean. Hence the North Pacific Equatorial Current carries more water compared to Atlantic and Indian Ocean. As it flows towards west, it gets more water. Towards west, it is divided into two branches. One branch flows through Balintang Channel into the China Sea. A part of this flows around Taiwan (Formosa) and joins Kuroshio Current. Another branch turns abruptly and forms the Pacific Counter Current. This equatorial current flows between 5^0 to 10^0 North latitudes. The average speed of this current is about 12 to 18 nautical miles per day.

10.3.2 South Pacific Equatorial Current

It originates due to trade winds. It covers a distance of 13,600 km. It flows between 3^0 to 10^0 south latitudes. It is stronger than the north equatorial currents. The average velocity is 20 miles per day. The cold Peru Current which flows along the coast of Peru joins this current. In the west, it is divided into many branches due to uneven nature of the bottom and surface topography. In the western part, it is divided into several branches. One branch flows along the coast of New Guinea and joins the Pacific Equatorial Counter Current. The other two branches move towards the northern and eastern coasts of Australia.

10.3.3 Equatorial Counter Current

Between North and South Equatorial currents, a zone of calm belt is found where no stress is exerted on the oceanic surface except for the weak equatorial westerly winds. This current originates due to piling up of water in the west. To maintain the balance the water flows from west to east between two equatorial currents. It is known as Counter Current. It originates from **Mindanao** in the west and flows towards east up to the coast of Panama. In the equatorial region, there is a sub-surface current moving east below the south equatorial current at the equator. It is known as **'Cromwell Current'**. It becomes weak towards east. According to Knauss, 'this current originates due to mixing which takes place at equator'.

10.4 CURRENTS OF NORTH PACIFIC OCEAN

In the North Pacific Ocean, we can observe three major currents. They are-;

1. Currents of Kuroshio System
2. Oyashio Current
3. California Current.

10.4.1 Currents of Kuroshio System

Wust (1936) has given the name 'Kuroshio System' to all branches of the Kuroshio which flow north-easterly up to 30^0 North latitude. It carries warm water from the Taiwan Coast. Near Japan, it turns toward east and flows as **'Japanese Current'.** Then it moves toward North America. This system consists of five important branches. They are –

a. Kuroshio Current

b. Kuroshio Extension

c. North Pacific Current

d. Tshushima Current

e. Kuroshio Counter Current.

a Kuroshio Current

The North Pacific Equatorial Current turns toward north-east near Taiwan to Ryukyu and flows close to coast of Japan up to 35^0 North is known as **'Kuroshio Current'.** It is diverted and deflected to the right due to the rotation of the earth. Near Ryukyu Islands this current has great similarity to Florida current of North Atlantic Ocean. Trade winds which are blowing continuously towards the west drags the water and pile up along the western boundary of this ocean. According to **Koenuma,** the Japanese Oceanographer, 'Kuroshio current between Taiwan to South Ryukyu, the current reaches to a depth of about 700 meter and its maximum speed is 89 cm per second. The average temperature of this current is 8^0 C and salinity is 35 grams per one thousand grams of ocean water.

b Kuroshio Extension

It is a warm current. When Kuroshio Current leaves the coast of Japan it is divided into two branches. One branch flows towards east up to 160^0 east longitude. Another branch flows in north-east up to 42^0 north and bends towards east. Just like Gulf Stream of North Atlantic Ocean, the Kuroshio Extension joins with the Oyashio cold current.

c. North Pacific Current

Further movement of Kuroshio Current from 160^0 west towards coast of North America is known as **'North Pacific Drift'.** It was influenced by Westerlies. Near the coast of North America, it is divided into two branches. One branch flows in the coast of British Colombia as **' British Coloumbia Current'.** The northward branch of Kuroshio Current, which flows along Aleutian Islands, is known as **'Aleutian Current'.** The temperature and salinity are reduced due to excessive precipitation and inflow of Cold Arctic Water. This branch is further divided into two. One branch enters the Bering Sea, flowing along the northern parts of Aleutian Islands. It encircles the whole of the Bering Sea in Anti-clockwise direction. Another branch of the Aleutian Current is bifurcated near the coast of America which flows south into the Gulf of Alaska in anticlockwise and joins the current again. It influences on the climate of that region.

A branch of North Pacific Drift turns southward along the coast of California and known as **'California Cold Current.'**

d Tsushima Current

Near 30^0 North, a branch of warm Kurushio passes to the west of Japan into the Sea of Japan is known as **'Tsushima Current'.** It flows northward along the eastern side of the Sea of Japan. It influences the climate of the coast especially in winter. A south flowing stream on the western side of the Sea of Japan is known as **'Tsushima Counter Current'.**

e Kuroshio Counter Current

There is a big gyre in the centre of the Pacific Ocean, east of Hawaiin Island. Here the water flows in opposite direction to Kuroshio. It is known as **'Kuroshio Counter Current'.** The location of this gyre changes according to seasons. Sometimes it covers Hawaiian island and in other times it lies in north-east.

10.4.2 Oyashio Current

The cold water from Arctic Ocean enters to Pacific Ocean through Bering Sea along the eastern coast of Kamchatka. It is known as **'Kamchatka Current'.** The southward extension of Kamchatka Current is known as **'Oyashio Current'.** It is a **cold current** and it can be compared with Labrador Current of North Atlantic Ocean. In 50^0 North latitude some of the water of Oyoshio Current moves eastward and mixes up with Aleutian and Kuroshio currents. It joins the northern branch of Kuroshio current near the east coast of Hokkaido. A branch of this flow along the Kurile Islands and it is known as **'Kurile Current'.** A current flow along the west coast of Kamchatka Peninsula from Okhotsk Sea towards south is known as **'Okhotsk Current'.** It is also a cold current. It joins Oyoshio current near Hokkaido Island.

10.4.3 California Current

It is similar to Canaries Cold Current of North Atlantic Ocean. It flows along the coast of North America between 48^0 North to 23^0 North latitude. It is a **Cold Current.** It is a part of the North Pacific Drift. It moves from North to South. It also exhibits a great amount of upwelled water between 35^0 to 41^0 North latitudes. When this current flows toward south, it is influenced by trade winds and again it turns toward west joining North Pacific Equatorial Current completing a Gyre.

During winter, the upwelling of cold water has ceased. A counter current starts to flow towards north is known as **'Davidson Current'.** In winter season it extends as far as north of Vancouver Island and joins Alaska Current.

10.5 CURRENTS OF SOUTH PACIFIC OCEAN

In South Pacific Ocean also, the currents complete a Gyre like North Pacific Ocean. The major currents of South Pacific Ocean are –

1. East Australian Current
2. West Wind Drift
3. Peru Current
4. El Nino or Counter Current.

10.5.1. East Australian Current

The South Pacific Equatorial Current is divided into many branches near New Guinea. It flows along the northern coast of New Guinea, turn southwards and flow along the east coast of Australia and surrounds the Newzeland. At 40^0 South latitude, it diverted toward east under the influence of westerlies and rotation of the earth.

10.5.2 West Wind Drift or South Pacific Drift

Like in Atlantic Ocean, westerlies in South Pacific Ocean drag water and a flow toward east from Tasmania to the South American Coast is known as **'West Wind Drift'.** Due to absence of land bodies, westerlies are strong in this region. The wind pulls the cold water from Antarctic region and flow towards east. At 45^0 South latitude, the west wind drift splits into two branches. One branch flows to the south of the Cape Horn and enters into the South Atlantic Ocean. Another branch flows northward along the coast of South America and it joins with Peru or Humboldt Cold Current.

10.5.3. Peru Current

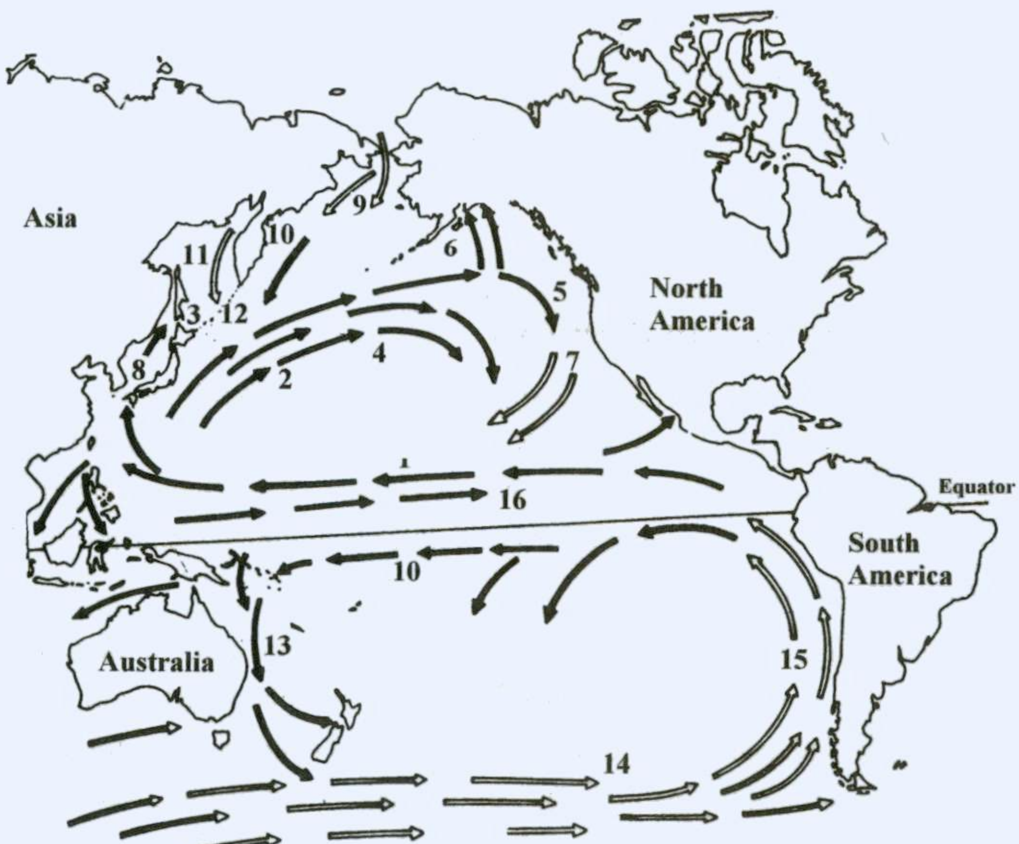
According to Gunther, the current which flow along the coast of South America (Chile and Peru) is known as **'Peru Cold Current'.** It flows from south to north and joins South Equatorial Current. The current also gets water from northerly deflection of Sub-Antarctica water moving in 40^0 South latitudes. The part of this current which is close to the coast of Peru is known as **'Peru Coastal Current'. Humboldt (1802)** has studied in detail about Peru Current. Hence this current is also known as **'Humboldt Current'.** Between 5^0

to 15⁰ South latitudes maximum upwelling of cold water has been observed by scholars. Peru Current flows at an average speed of 24 km / day. The characteristic of this current change nearer to the northern limit of this due to changing of seasons. Finally the Peru Current joins the Equatorial current completing a circle.

10.5.4. El Nino or Counter Current

Close to Peruvian Coast, a sub-surface warm Pacific Equatorial Counter Current flows southward up to a distance of 180 km at a depth of 400 meter between 3^0 to 36^0 South latitudes. Coker has observed that the water along the coast of Peru shows two different water masses. One is warm and other is cold. The existence of this current is due to seasonal disturbance and change of equatorial pressure.

This El Nino current is uncertain in nature and occurs in certain years. When it occurs, desert region of Peru gets unusual rainfall. The temperature of water along coastal region increases. It caused the disappearance of Plankton and fisheries and the appearance of diseases of Guano and Pests.



Currents of Pacific Ocean

1. North Pacific Equatorial Current
2. Kuroshio Current
3. Kuroshio Extension
4. North Pacific Drift
5. Coloumbia Current
6. Aleutian Current
7. California Current
8. Tsushima Current
9. Kamchatka Current
10. Oyashio Current
11. Okhotsk Current
12. Kurile Current
13. East Australian Current
14. South Pacific Drift (West wind drift)
15. Peru Current
16. Counter Current

10.6. LOCATION OF INDIAN OCEAN

It is the third largest ocean, covering 20% of area of all the oceans. It is bounded by three continents of Africa (West), Asia (North) and Australia (East). In the south it extends up to Antarctica and joining Atlantic and Pacific Oceans. The average depth of this ocean is about 4000 meters. The major part of this ocean lies in Southern Hemisphere. The Ocean is broader in southern hemisphere.

The currents of Indian Ocean differ from the Atlantic and Pacific Oceans due to its geographical location. The northern part of this ocean is bounded by continents and it is different from all the oceans. The North Indian Ocean is under the **influence of Monsoon Winds** which is seasonal in nature. Due to this the current changes according to seasons. But the currents in South Indian Ocean are similar to South Atlantic and Pacific Oceans. Because it is influenced by prevailing winds.

10.7. CURRENTS OF NORTH INDIAN OCEAN

As mentioned above, the currents of North Indian Ocean are completely influenced by the changing nature of Monsoon Wind. Hence no particular current is found throughout the year and changes are frequent in summer and winter seasons. The major currents of North Indian Ocean are–

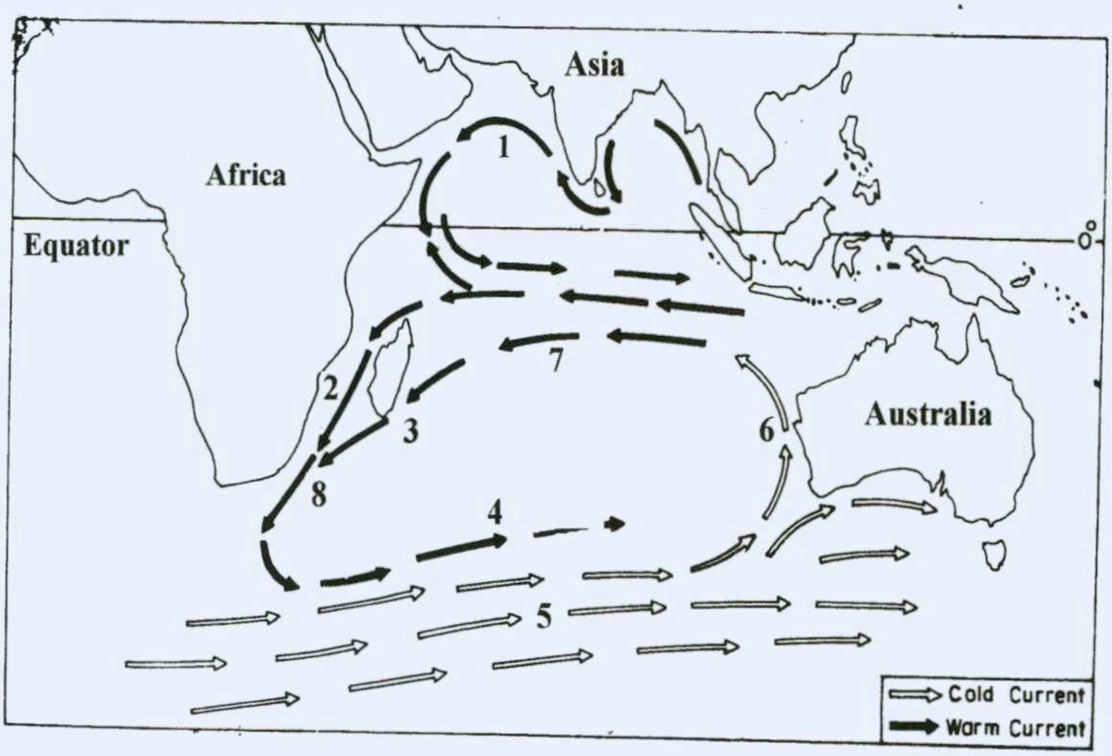
1. North –East Monsoon Current
2. South-West Monsoon Current.

10.7.1. North-East Monsoon Current (Winter Season)

During the North-East Monsoon season, North-East wind is predominant. Hence the current flows from east to west. The water flows from Malacca Strait and moves in Bay of Bengal and Arabian Sea according to this wind and reaches the east coast of Africa. This current is also known as **'North-East Monsoon Drift'.**

South of this current, a counter current is also developed. It originates at 7^0 South latitude. This current starts from **Zanzibar** on the east coast of Africa and continues up to Sumatra. The North – East Monsoon drift supplies water to this current. The North-East Monsoon Drift bends southward near the coast of Africa and joins with the equatorial counter current. During this season, the currents are in anticlockwise.

Figure 10.2 North-East Monsoon Current (Winter season)

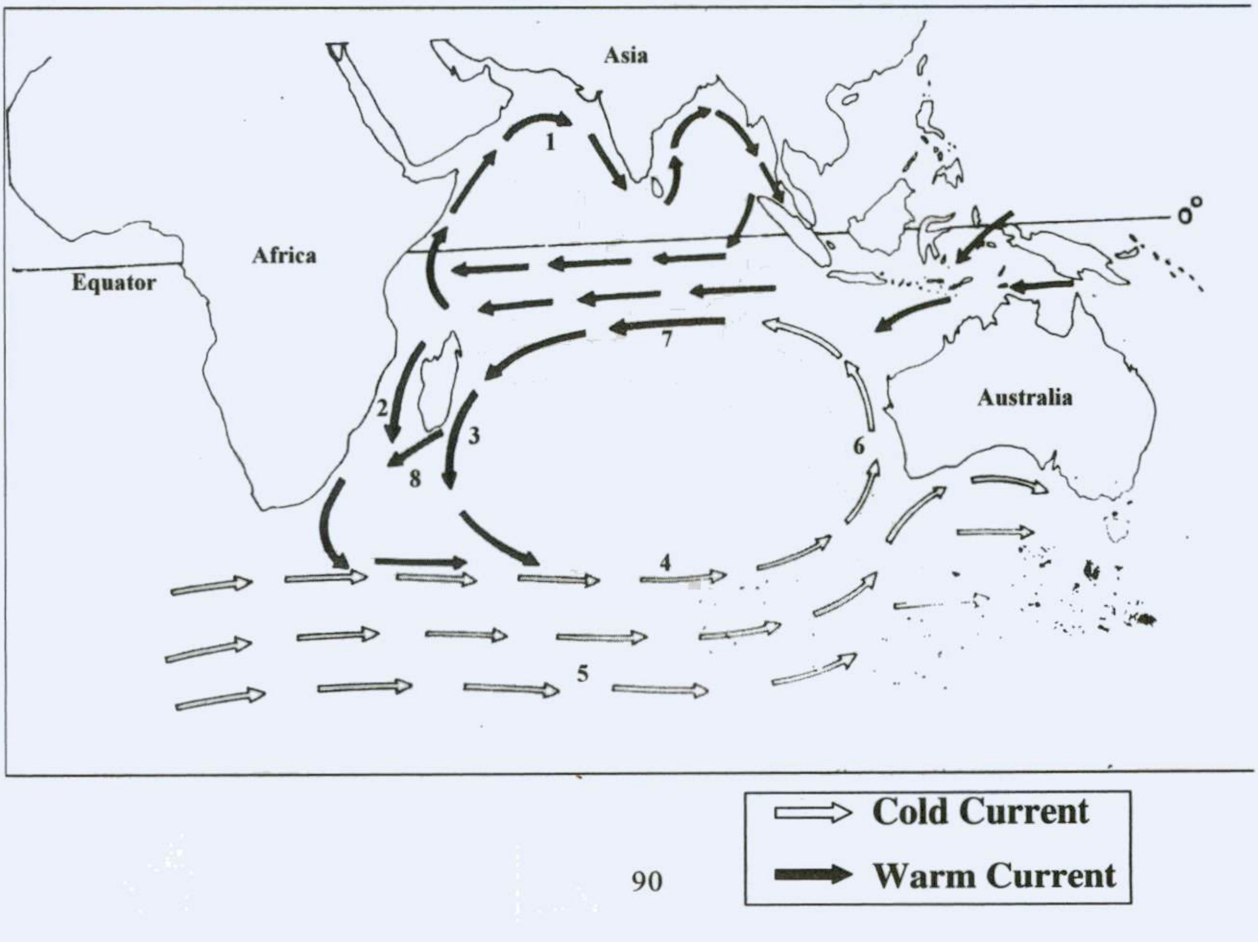


1. North-East Monsoon Current.
2. Mozambique Current
3. Madagascar Current
4. West Wind Drift
5. Antarctica Cold Current
6. West Australia Current
7. South Equatorial Current
8. Agulhas Current

10.7.2. South-West Monsoon Current

In the beginning of Summer Season, there is a complete reversal of Monsoon wind. In this season South-West Monsoon wind is predominate. Due to this there is disappearance of North Equatorial Current, which is replaced by South-West Monsoon Current flowing from west to east. The branches of these current flows in Bay of Bengal and Arabian Sea. Near Somalia of Africa, upwelling of water takes place. As a result, the water flows from south to north along the coast of Somalia, joins South-West Monsoon current. During this season currents are in Clockwise direction.

Figure 10.3 South-West Monsoon Current.



1. South-West Monsoon Current.
2. Mozambique Current
3. Madagascar Current
4. West Wind Drift
5. Antarctica Cold Current
6. West Australia Current
7. South Equatorial Current
8. Agulhas Current

10.8 CURRENTS OF SOUTH INDIAN OCEAN

The effect of Monsoon wind is not well found in South Indian Ocean. Hence there is a complete circulation of Currents (Gyre). It is similar to the currents of South Pacific and South Atlantic Oceans. The major currents of the South Indian oceans are –

1. South Equatorial Current
2. Agulhas Current
3. West Wind Drift
4. West Australia Current.

These currents are flowing in anti-clockwise manner completing a circle.

10.8.1 South Equatorial Current

This current flows between 10^0 to 15^0 South latitudes. West Australian Currents joins this current at 100^0 East. It flows between North Australia and East coast of Africa. In 10^0 South latitudes near Madagascar of Africa, it splits into several branches. One of the branch flows toward south to form **'Agulhas Current'.**

10.8.2: Agulhas and Mozambique Current

A branch of South Equatorial Current deflects toward the south and flows along the east coast of Africa. Near Madagascar, it splits into two branches. One branch which moves along the east coast of Madagascar Island is known as **'Madagascar Current'.** Another branch flows through Mozambique Channel is known as **'Mozambique current'.** To the south of Madagascar island (30^0 South) these two branches join together and form **'Agulhas**

Current'. It is a narrow warm current and extends 80 km from the coast. To south of South Africa, a major portion of Agulhas stream deflects to the south and then towards east. Some quantity of water of this current also rounds up the Cape of Good Hope into the Benguela Current (South Atlantic Ocean) along the west coast of Africa. Between the African coast and Agulhas current, upwelling of cold water is found. The cold water also moves towards north. It reduces the temperature of the coast.

10.8.3 West Wind Drift

Due to the influence of westerlies **(Roaring Forties in South)**, the cold water in 40^0 South latitude flows towards east. It is known as **'West Wind Drift'.** At 110^0 East longitude, this current splits into two. One branch flows toward north along the west coast of Australia to form **'West Australia Cold Current'.** The other branch flows along the southern coast of Australia and joins the Pacific Ocean. The west wind drift of Indian Ocean is also subject to seasonal changes. In winter, a greater part of it passes through the south coast of Australia, where as in summer, major portion of water turns toward north before reaching the coast of Australia.

10.8.4 West Australian Current

At 110^0 East longitude, a part of west wind drift turns and flow along the west coast of Australia is known as **'West Australian Current'.** It is a cold current. It joins south equatorial current completing a circle (Gyre).

10.9 LET US SUM UP

In this unit, we have discussed about the currents of Pacific and Indian Ocean. You come across the similarities of currents of Atlantic and Pacific Ocean. You have also noticed that the influence of Monsoon wind over the currents of North Indian Ocean and how it changes according to seasonal variation of this wind.

10.10 KEY WORDS

Kuroshio System, Oyashio, Tsushima, Okhotsk, Kamchatka, Davidson, West Wind Drift, Peru or Humboldt currents, El Nino Current, North-East Monsoon, South-West Monsoon Current, Madagascar Current, Mozambique, Agulhas Currents, West Australia Current.

10.11 QUESTIONS FOR SELF STUDY

1. Explain the currents of Pacific Ocean with a neat diagram.
2. Describe the ocean currents of North Indian Ocean with a neat diagram.

3. Explain the Currents of South Indian Ocean.

4. List out the Warm and Cold currents of Pacific Ocean.

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UNIT – 11: TIDES – CAUSES, TYPES AND THEORIES

Structure:

11.0 OBJECTIVES

After studying this unit, you will able to understand

- Causes of tides
- List out the various terms used in understanding tidal phenomena
- Types of Tides
- Various theories regarding the origin of Tides
- Effects of Tides

11.1 INTRODUCTION

In the previous unit, we have studied about ocean water circulation. Ocean Tides are also among various types of motions in the ocean. Ocean tides are also effecting on man. There are several theories regarding the origin of tides.

11.2 MEANING AND CAUSES OF OCEAN TIDES

Tides are one of the most fascinating aspects of the ocean. Tides occur in every day and in every place of ocean. **'It is the periodic rise and fall of the sea level'.** From the last three centuries, several great mathematicians have studied about Tides. It is generally accepted that the tide is caused primarily by the Universal Gravitation of matter. But other factors are responsible for the occurrence of tides.

Tides have been studied from ancient period. The earliest reference has been found in the writings of Greek Historian Herodotus. In 325 B.C., Pytheas of Massila has noticed the relationship between tides and moon. In 77 A.D., Pliny has observed that tides occur due to the combined action of the Sun and the Moon. A leading role is played by Moon in the occurrence of tides has been established. In Medieval period also several scholars have noticed the influence of Moon and Sun over the ocean. In 1687, Sir Isaac Newton first formulated the Laws of Motion and Gravity. The law of gravitation states that 'every particle of matter attracts every other particle of matter, the force of attraction varying directly as the product of their masses and inversely as the square of their distance between them'. It means that the bigger mass will exert more gravitational pull as compared to the smaller mass, the farthest located mass will exert lesser force than those located nearer. It is expressed as –

$$G = \frac{m_1 m_2}{r^2}$$

G = Universal Gravitational Constant.

m_1, m_2 = masses

r = distance between masses

To understand the cause of tide, it is essential to understand the relative movements of the Earth, Moon and the Sun. The mathematical explanation of these movements is related to the law of gravitation. This law was first explained by Newton in relation with the movements of planets in their orbits around the Sun.

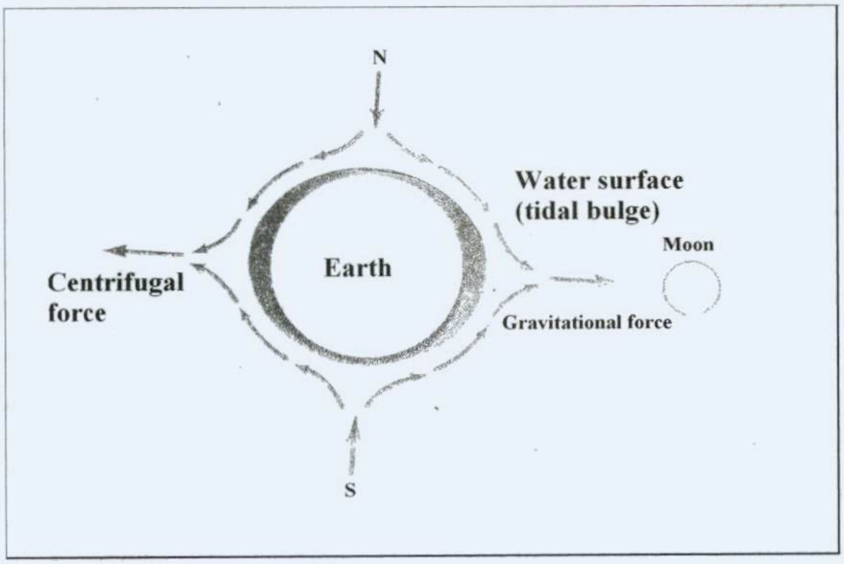

Figure 11.1Tides due to Gravitational force & Centrifugal force.

Even though the Moon is small heavenly body, but its gravitational attraction over the Earth is more powerful than the planets and Stars due to its nearness. Moon's attraction is greater at the surface (near to Moon) than at the centre of the Earth. Rotation of the Earth causes Centrifugal force, which is directed away from the centre. It is found in all the places of the Earth, varying from the centre to the surface and from north to south.

Moon is the major tide causing agent. The mass of Moon is about $1/80^{th}$ of the mass of the earth and it has a distance about 60 times the earth's radius. There is a balance between Moon's Gravitational force and Centrifugal force of the Earth. But the ratio between the above two forces is not similar on all parts of the Earth. It creates tides over the earth. The figure 11.2 shows that the attraction of Moon is maximum at the point 'Z' which is nearer to the Moon and minimum in the opposite side(N).

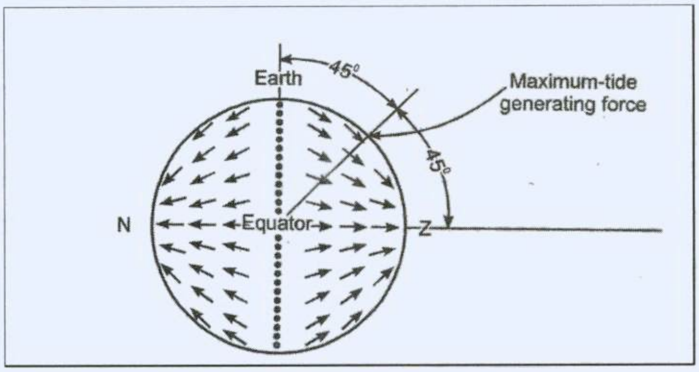

Figure 11.2 Tide generating force

The attraction (Gravitational) force of Moon is higher than the Centrifugal force of the Earth in the region which is facing the Moon. But in opposite side Centrifugal force is greater than the attraction force. These two forces are equal in the centre of the Earth. In all other places, small residual forces are acting as the result of these two forces, which are acting as tide generating force.

Sun is another important tide generating force. The average distance between Sun and the Earth is about 150 million km. It has great tide generating force, but to its great distance from the Earth, the effect of Sun over the Earth is less than the Moon.

The tide producing forces do not have much effect on the solid surface of the Earth. But it has great influence over the water bodies.

11.2.1. Terms used to explain Tides

Due to the influence of Sun and Moon, the sea level increases. It is called **'High Tide'.** When the sea level falls, it is known as **'Low Tide'.** The height between high tide and low tide is known as **'Tidal Range'.** The time interval between two high tides is called **'Tidal Interval'.** When horizontal currents are generated in a Bay or Inlet due to tides, are known as **'Tidal Currents'.** When tidal currents are moving towards coast is known as **'Flood Tide'.** The returning tides from the coast towards sea are known as **'Ebb Tides'.**

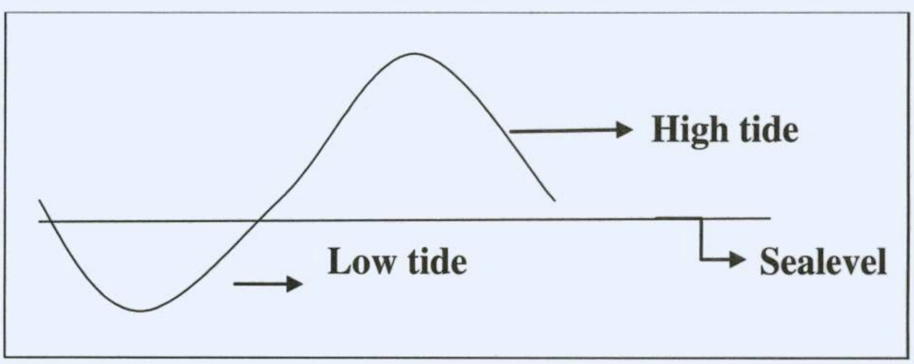

Figure 11.3 High & Low tides

The gravitational attraction between two objects decreases with increase in distance between them. So the gravitation attraction of Moon over the Earth is high, where the portion of the Earth is facing Moon directly. Due to this, the water bulge towards the Moon. This is called **'Direct High Tide'.** The opposite of this, bulging of water occurs due to Centrifugal force. It is known as **'Indirect High Tide'.** So there are two high tides in a day. **Two high tides and two low tides occur in every day.**

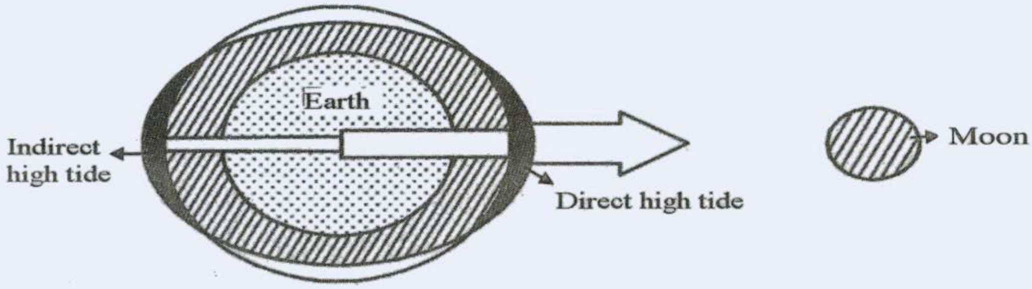

Figure 11.4 Direct and Indirect high tides

The tide producing forces vary according to the changing positions of the heavenly bodies in relation to each other. So the time of tide and tidal height at any place on the earth's surface will change.

11.2.2. Tides and positions of Sun, Moon and Earth

Each place of the ocean is affected by the combined forces of Sun and Moon. It results in the formation of Tidal bulge. These forces can act as a combined force or opposite also. In these two cases tidal bulge are produced. The various positions of Sun, Moon and Earth causes different tides as –

1. When Sun, Moon and Earth are in a straight line (Moon in Syzygy), the combined force of Sun and Moon exerts over the Earth and produce High or Spring tide. It occurs in every full moon and new moon days. In these days the bulging of water is high.

2. When Sun, Moon and Earth are in right angle (Moon in Quadrature), the forces of Sun and Moon over the earth are in opposite direction. It produces Neap Tides, which are not so high compared to Spring Tides.

3. During Equinoxes (Equal day and night – March 21 and September – 23), the Sun is directly on Equator. On this time there is a zero declination. Within 15 days, the

Moon is also over the equator with a zero declination. At this time, the combined force of Sun and Moon pulls the water to their side. So there is an occurrence of **Equinoctical Spring Tide.** During Solstice (June-21, December-22), the angle of declination of Sun and Moon are maximum. So their force is also less. Due to this ordinary Spring Tides are produced.

4. Moon is revolving around the Earth in an elliptical orbit. When it is nearer to the Earth (Perigee), higher tides are produced. When it is far away from the Earth (Apogee), the tides are below normal. Perigee and Apogee occurs twice in a lunar month. The same conditions are also found on the earth's orbit around the Sun, when the Earth is near to the Sun (Perihelion). Tides are higher than the normal and when it is farthest to the Sun (Aphelion), the tides are lower than Perihelion.

5. Long periodic variations of the Moon and Sun will also affect on the size and occurrence of tides.

11.3. TYPES OF TIDES

The characteristics of tides are not uniform due to various reasons as stated earlier. There are different types of tides. They are

1. Diurnal Tides
2. Spring and Neap Tides
3. Apogean and Perigean Tides

11.3.1. Diurnal Tides

The occurrence of these tides in ocean is diurnal in nature. But they are in different order. These are classified as –

a. **Diurnal :**In certain places there is an occurrence of one high tide and one low tide. It is known as Diurnal Tide. Ex: Philippine Islands.

b. **Semi-Diurnal tides** : It is most common in different places of the world. For every 12 hours and 26 minutes two high tides will occur. Between this, low tides will occur. Between one high tide and low tide, there will be a time gap of 6 hours and 13 minutes. So in 24 hours and 52 minutes two high tides and two low tides will occur.

c. **Mixed Tides:** These are having the characteristics of Semi and Diurnal tides. After two high tides, very low tides will occur in this stage. It is common in Arabian Sea, Bay of Bengal, East coast of Japan, China, Korea and others.

11.3.2. Spring and Neap Tides

Tides do not rise to the same height in every day. The relative position of the Moon and the Sun with respect to the Earth is responsible for this variation in the height of the tides. On every full moon and new moon days, Moon and Sun are almost in a straight line with the Earth. Hence they exert their combined force over the earth. Due to this, the tides are above the normal high tides. These are known as Spring Tides. They occur on every full moon and new moon days.

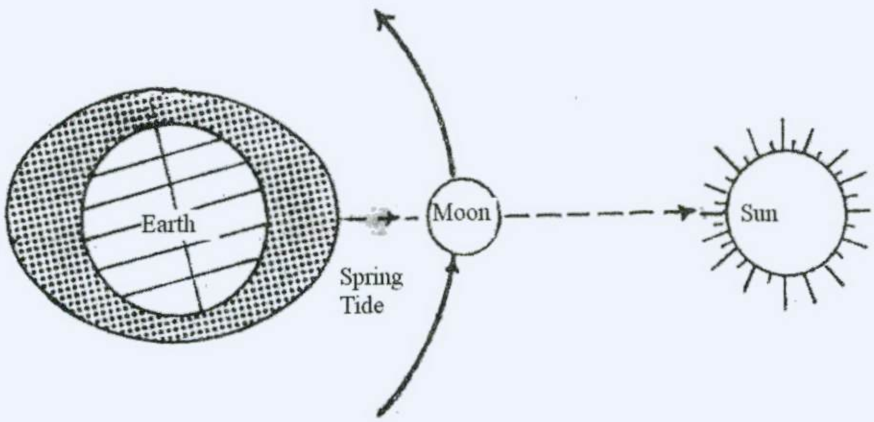

Figure 11.5 Spring Tide

When the Moon is at first and last quarter, Sun and Moon makes a right angle with the Earth. The attraction force of Moon and Sun are in opposite. Their attraction tends to balance each other. Due to this low tides occur below normal tides. These are known as Neap Tides.

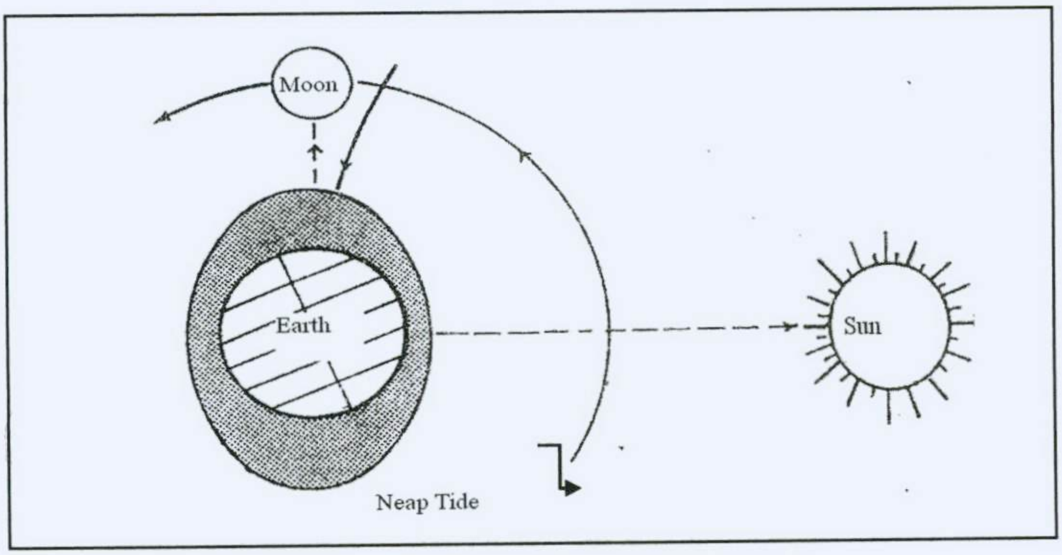

Figure 11.6 Neap Tide

11.3.3 Apogean and Perigean Tides

Moon is revolving around the Earth in an elliptical orbit. When it is nearer to the Earth (Perigee), higher tides are produced. When it is far away from the Earth (Apogee), the tides are below normal. Perigee and Apogee occurs twice in a lunar month. The same conditions are also found on the earth's orbit around the Sun, when the Earth is near to the Sun (Perihelion). Tides are higher than the normal and when it is farthest to the Sun (Aphelion), the tides are lower than Perihelion.

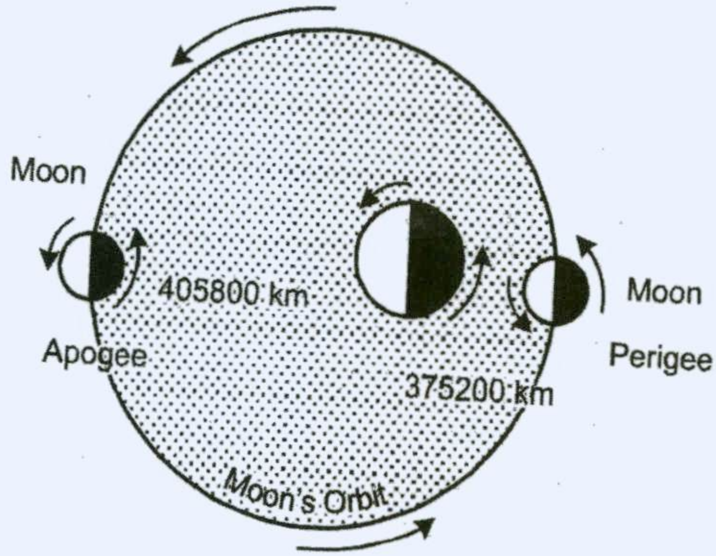

Figure 11.7 Apogee and Perigee of Moon

11.4 TIDAL BORE AND TIDAL CURRENTS

When ocean tide enters the mouth of the river and there is a forced entry of wave against river water. The nature and magnitude of the tides in the rivers and estuaries are affected by a number of factors like – Slope of the river, Volume of Water, Range of tides and factor of friction. In the shallow and narrow channel of the river, the tidal wave gains more height. This is due to steep front of the tidal wave. The front often has a breaking crest which advances up river as a **'Tidal Bore'** or **'Aeger'.** It is common in rivers which have funnel shape mouth and when estuaries are having extensive shoals and floats and tidal ranges are large. Due to these, the direction and flow of the river is reversed to a certain distance. The deepening and improving of tidal channels often reduces the tidal bores. We can observe a well developed tidal bore is on the river Tsientang-kiang River in northern China, where the front of the wave is about three meters high. In India, tidal bores are common in the Hooghly River. The bores of Amazon, Seine and Severn rivers are famous in the world.

Tides also occur in the Gulfs and Bays. Gulf with wide fronts and narrow rears experience higher tides. The height of these tides may be ten meters or more. When a Gulf is connected with the open sea by a narrow channel, water flows into the Gulf at the time of high tide and comes out of the gulf during low tides. This inward and outward movement of water is known as **'Tidal Current'** or **'Tidal Stream'.**

The tidal currents flowing towards the deep and open water of the sea are termed as the off-shore tidal currents.

11.5 THEORIES ABOUT THE ORIGIN OF TIDES

In this section, you will able to understand the theories regarding the origin of tides. Oceanographers and other Scientists are making efforts to find the answer for the differences in height of tides, types, variations and their movements in the open oceans. The first mathematical theory was postulated by **Newton** in 1687. His approach became the foundation for the development of other theories. The important theories regarding origin of tides are

1. Equilibrium Theory of Newton.
2. Dynamical Theory of Laplace.
3. Progressive Wave theory of Whewell . W and Airy.
4. Stationary Wave theory of Harris R.A.

11.6 EQUILIBRIUM THEORY OF NEWTON

Sir Isaac Newton has developed this theory of equilibrium in 1687. He assumed a mass of equilibrium under the combined forces of gravitation of the Celestial bodies. Earth, Moon and the Sun are all in equilibrium due to their attraction to each other. The gravitational force of the Moon over the Earth is greater than the Sun due to its nearness. So the water in ocean is piled up towards Moon, where as the bulging of water is less towards Sun. At one time there are two tides occur over the water bodies. Earth and Moon are revolving their common centre of gravity (Sun), which produces two forces – Centrifugal force (away from the centre) and attraction force directed towards the Moon.

The part of the earth surface which faces the Moon, the Centrifugal Force is less than the Gravitational force. So there will be a bulge of water towards the Moon. The opposite side of this place, which is far away from the Moon will also experience rising of water (bulging) due to Centrifugal force of the earth which is more than the attractive force of the Moon. Perpendicular to these places, these two forces are balancing each other, creates and lowering of the Sea level. So high tide is found in nearest to Moon and opposite side of the earth lowest tide is at place perpendicular.

These four phenomena occur simultaneously in the oceans, due to rotation of the earth from west to east. The crest of the side under Moon's meridian moves like a wave towards west with its crest directly under the Moon. The height of the tide is also affected by waxing and Waning of Moon, in the monthly cycles. Changing position of the Sun, Moon and the earth, gravitational positions of the Earth, the force is regarded as the sum of 'Harmonic Consists which varies harmonically with time.

Based on the above concept, the time intervals between various types of tides have been calculated on the basis of declination of Moon and the earth's rotation of the earth's rotation.

Merits:

1. Newton's law of Gravitation laid foundation stone for the later theories.
2. His work made possible to understand tide generating forces.
3. It helps to understand the periodicity of the tides.

Limitations:

1. The bulging of sea water as stated in this theory, cannot takes place unless water mass actually change their positions. Horizontal movement of tide is essential for this.
2. High tides occur when the moon is exactly on its meridian and all the places on the same longitude should have high tides. But in reality it is not the case. Ex: High tides which occurs at Liverpool and Leith which are situated at 8^0 West longitudes, have difference of time of three hours.
3. The equilibrium position over the earth is not possible.
4. It completely neglects the effect of the continents and the land masses which checks the movement of water.
5. In certain areas near by locations experience high tides at different points of time, the difference being several hours.
6. It also ignored Coriolis force, bottom relief of the ocean, depth of ocean etc., Which effect the movement of tidal waves.

11.7 DYNAMIC THEORY OF LAPLACE

A famous mathematical astronomer Laplace advocated this theory in 1755. He adopted the dynamics as the water in motion to study the tides. According to him, horizontal tide producing forces are important than the vertical forces. Because in the latter the periodical variation of acceleration of gravity is absent. Under the influence of oscillation there is a horizontal movement of water towards the moon's meridian, where bulge is created. Due to rotation of the earth, every place of the earth comes under the moon and there will be a change of water movement. Hence the water flows in one direction at one time and another direction at other time.

11.8 PROGRESSIVE WAVE THEORY OF WHEWELL W AND AIRY

In 1833 William Whewell has presented a paper called 'Essay towards a first approximation to a map of Co-tidal lines'. In this he presented the concept of Progressive Waves explaining the varying intensity and amplitude of tides at different places. He also drew co-tidal lines over the world map. These lines are joining points at which high water occurs at the same time. His theory is known as **'Progressive Wave Theory'.** In 1842, **G.B.Airy** presented **'Waves and Tides'** and explained different intensity and amplitude of tides at several places. His approach is known as **'Canal Theory'.**

This theory considered the earth as a heterogeneous body and not a perfect fluid. In the same meridian tide occurs at different times has been observed. On a globe surrounded by water, a tide appears to take the form of a tidal wave travelling from east to west.

This theory observes that under the Moon's influence the tide moves from place to place. The tides have Crest and Trough. The length of the tidal wave is measured from Crest to Crest. The rate of progressing wave is dependent on the depth of the water bodies. Due to rotation of the earth, the progress of the wave is from east to west. These waves are affected by the location of continents. The continents located from north to south hampers the movement of this wave. Due to this great intensity of tidal waves are not possible in different oceans and also free movement from east to west is not also possible due to obstructions. The only unobstructed and open course of ocean for the tidal wave is found around the Antarctic Continent.

The progressive wave originates under the influence of tidal generating force and as known as **'Primary Wave'.** This tidal wave has the same period like lunar tides (24 ¾ hrs). During the Spring tide, this primary wave is in its maximum speed. When the water is at its average height, the speed is almost zero. When it is in depression, the water will runback at maximum speed.

Due to the influence of Moon, when the tide originates in the southern ocean, it moves toward the west in a form of a **'Forced Wave'.** Location of landmasses, check the westward flow of this wave, a deviation will takes place from southern ocean towards north. In the north, when they strike landmasses, fresh tidal waves will originate. These northward moving tidal waves are known as **'Secondary Waves'** or **'Derived Waves'.** They affect along the coast of continents. For this tidal phenomenal, Atlantic, Pacific and Indian Oceans may be considered as the Gulf openings in the southern ocean.

This theory believes that all waves will originate in the Antarctica Ocean and they travel progressively towards north higher latitudes of Pacific, Atlantic and Indian Oceans. With the movement of this wave, a series of fronts are formed, where crest front represent the co-tidal lines (These are the lines joining the places having high tides at one time). So, it shows that how the wave progresses as it moves from south to north. The crest of wave form high water along the coast and trough results in low water.

With the help of co-tidal lines, the tides in Atlantic Ocean have been studied. Tides travel more rapidly in the mid of ocean than along the coast. As the tide moves towards north, in coast of Africa and South America, the time of high water and low water slightly changes (the age of tide). The range of tide becomes more as we move from Cape Horn to the Amazon due to narrow of ocean. The direction of tidal waves appears in the coast of Europe is from the west, where as in the coast of USA, it is from the east. So the time and nature of tide changes in the north, due to the differences in the depth of ocean and the nature of coastal lines.

This theory has also explained various anomalies and complications found in the tides of British Islands.

Limitations:

Even though there is a great popularity of this theory, it has the following limitations. They are,

1. According to this theory, the age of the tide increases from south to north due to progressive wave originates in the south. The collected data shows that, the time of Spring tides is almost the same from Cape Horn (south) to Greenland (north). It is contrary to this theory.
2. There is a difference of characteristics of the same type of tides in different areas. In the Atlantic, semi-diurnal tides have less daily irregularity, while California coast

have greater irregularity. Here the effect of Sun is more than the Moon. It shows that, in the other oceans also independent tides are produced.

3. A study proves that tidal phenomenon to be local or a regional rather than a feature originating in southern ocean.

11.9 STATIONARY WAVE THEORY OF HARRIS R.A.

Dr. R.A. Harris of the U. S. Coast and Geodetic Survey has first propounded this theory. It offers the best explanation for local differences in tides. It is opposed the ideas of Progressive wave theory. It insists upon the regional occurrence of tidal phenomenon in the water bodies like Atlantic, Pacific and Indian Ocean. Due to this water is made oscillate under the lunar force. The waves formed by this force are known as Stationary waves. For ex: we can take a rectangular tank containing water. If it is disturbed at one side or just tilted, the level of water vibrates as a whole resulting in rising or lowering, but the level will remain stationary at the centre. The water level moves rhythmically from one end to another along a line which is called the nodal line and rise and fall is greatest at the two points near the boundary of the basin.

When the lines of movements are two that is the high water is in the middle and low water occurs in the boundary, it will be known as Binodal Oscillation system. Stationary wave movement may be produced in basins of various shapes with single or more nodal lines. The oscillation of the wave is determined by the formula –

$$T = \frac{2L}{gh}$$

Where , L = length of the tank

h = depth of the tank

g = acceleration of gravity.

It shows that each wave has definite period of oscillation. The oscillation and the character of waves are different which are present in separate basins. The direction of these waves depends on the character of the rocking. It changes with the rocking of the basin, though the central part remains stationary at level. An impulse is needed to start the series of stationary waves, which rapidly disappear after the dissipation of the energy. If the force is regular, waves will also be regular in the oceans. Over the earth, oscillation of water in ocean occurs due to changing positions of Sun and the Moon. Some times solar forces alone create such waves. Among the main forces are the semi-diurnal forces of the moon (12 hours 26 minutes) and the Sun (12 hours). Diurnal forces with a period of 24 hours, 52 minutes (Moon) and 24 hours (Sun), helps in oscillation in all different oceans. But it is modified by configuration of sea bottom, depth of the sea, rotation of the earth, shape of the ocean, projection of lands and bays, islands.

The amplitude of the wave is directly controlled by the depth of the ocean. The friction reduces the range of the tide. So the height of the stationary wave is greater in the open ocean than in the shallow bay. Rotation of the earth also causes this type of waves. The crest and trough of the waves bring about high and low tides.

Dr. R.A. Harris has developed natural basins of oscillation of the stationary wave with the help of mathematical and physical principles.

The views of Harris about stationary wave movement were modified by the factor of earth rotation. Due to this water swings around a point called Amphidromic Point. There is several numbers of these points according to configuration of the basin. Hence rotation of the earth and amphidromic point will modify the oscillating system. The theory cleary explains the phenomenon of tides.

Limitations:

- The effect of the deflective force produced by the rotation of the earth has been ignored in this theory.
- His assumption that two neighbouring oscillating areas do not react with one another has been proved wrong.
- It will not answer the question like why the type of tide varies in different places.
- But this theory provides a foundation for the development of other theories.

11.10 IMPORTANCE OF TIDES

They generally help some rivers navigable for ships and vessels. Ex: London and Kolkatta have become important ports due to the tidal nature of the mouths of the Thames and Hooghly. It clears the sediments brought down by the rivers in coastal areas. It also avoids the process of delta formation. Tidal force may also be used as a source for generating electricity. Ex: France and Japan have power stations which convert tidal energy into electricity.

11.11 LET US SUM UP

Tides are caused by gravitational force of Sun and Moon and Centrifugal force of the Earth. Different scholars have postulated their views regarding the origin of the tides. Among these Equilibrium theory of Newton, Dynamical theory of Laplace, Progressive Wave theory of Whewell W and Airy, Stationary Wave theory of Harris R.A. are prominent.

11.12 KEY WORDS

Gravitational force, Centrifugal force, High tide, Low tide, Tidal range, Tidal interval, Tidal currents, Flood tides, Ebb tides, Direct high tide, Indirect tide, Equinoctial Spring tide, Apogee, Perigee, Semi-diurnal tides, Spring tide, Neap tide, Tidal bore.

11.13 QUESTIONS FOR SELF STUDY

1. What are Ocean tides? State the causes of tides. Explain the tides with the positions of Sun, Moon and Earth.
2. Explain types of tides with neat diagrams.
3. Explain Equilibrium theory about the origin of tides.
4. Explain Dynamical theory of Laplace.
5. Discuss Progressive Wave theory and Stationary Wave theory about the origin of tides.

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UNIT - 12: OCEAN DEPOSITS AND TYPES

12.0. OBJECTIVES

After studying this unit, you will be able to

- Know Meaning of Ocean Deposits
- Identity Constituents of Ocean Deposits
- Explain the types of Ocean Deposits

12.1 INTRODUCTION

The term ocean or maritime deposits refers to all the materials that are being deposited on the bottom of the sea or ocean. These unconsolidated materials were deposited on the ocean floor by rivers, wind, glaciers, ocean waves etc., It also consist of plants, animals remains etc., In 1773, Captain Phipps for the first time has attempted to study the materials of the ocean depth. The actual development of the study of marine deposit was started by Sir John Murray in his Challenger Expenditure (1872-76). He and Prof.Alphonse Renard published the results of the expedition in 1891. They constructed the world map of various ocean deposits for the first time and also they classified the ocean deposits.

12.2. TYPES OF OCEAN DEPOSITS

Ocean deposits are classified into different types based on source and nature of deposits, location of deposits and others.

12.2.1. Based on Source and Nature of Ocean Deposits

Marine sediments are derived from various sources and are distinguished by the nature of their source regions. Marine deposits are classified as –

A. Terrigenous Materials

B. Volcanic materials

C. Organic materials

D. Inorganic materials

E. Red Clay

F. Extra Terrestrial materials

A. Terrigenous Materials :

Rocks are disintegrated due to work of weathering and agents of denudations. But the disintegration depends upon the nature of rocks. The small pieces of rock fragments are carried down by agents of gradation. Larger particles are deposited along the coast and smaller sediments are deposited in the sea. On the basis of texture of the source, mode of formation, nature of transporting agency and chemical compositions, the sediments are broadly classified as Gravel, Sand and Mud.

Silt clay and Mud deposits are finer particles, which are smaller than sand. Clay is finer than the Mud and act as a binding material of sediments. Generally silt clay is formed by the disintegration of the continental rocks.

Murray has identified three types of mud based on the colour of the sediments ranging from black to white with addition of blue, yellow, red or mixture of all these.

The deposition of terrigenous material varies from one coast to another. It is more in Atlantic than in other oceans. It is due to large rivers depositing materials to this ocean. Generally fine sediments are found along the coast and pebbles are far away from the coast.

B. Volcanic Materials:

There are two types of volcanoes like sub aerial and submarine, which ejects the same materials. The sub aerial volcanoes which erupt the materials are deposited over the surface. These are eroded by mechanical and chemical weathering. These materials are transported by agents of gradation to the sea. Pumice, rock fragments, volcanic dusts, mineral grains and others are the important volcanic materials deposited in the sea.

In Pacific Ocean, submarine volcanoes are very common. The volcanic materials are found in other oceans also. Volcanic deposits are found on the floor of the ocean.

C. Organic Materials:

In the ocean floor, we can found several kinds of vegetation and animals. It has remains of these. It consists of more amount of sand and silt which are very rich in Calcium Carbonate.

The organic deposits consist more than 30% of organic material. These are known as **'Oozes'**. Based on chemical composition and organisms which are predominate in them, these are classified as –

i. Calcareous Ooze.

ii. Siliceous Ooze.

i. Calcareous Ooze: It consist more than 30% of Calcium Carbonate. These are found in between 1000 to 2000 fathoms depth. These are formed in shallow water, when remains of organisms are converted into Calcareous Oozes. These are further classified into two types. They are –

a) **Pteropod Ooze :** It consists of the remains of the shells of pelagic molluses. Pteropod is a molluse which is a floating marine animal. It consist more than 30% of Calcium Carbonate. It is found between 1600 to 2000 meter depth. Generally these are found in tropical seas.

b) **Globigerina Ooze :** It is formed by the accumulation of the Calcareous skeletons of foraminifera. It consist Calcium Carbonate of 75 to 89%. It is found in 2000 to 4000 fathoms depth, especially in large areas of Atlantic, Pacific and Indian Oceans. The deposits are often white in colour. It covers an area of 29.2% of ocean floor.

ii. **Siliceous Oozes :** It consist more amount of Silica. Silica is produced by Planktomic plants and animals. It is classified into two types. They are –

a) **Diatom Ooze**: The term was first used by Murray to the plant shells which are very microscopic in size in his challenger report. Silica is mostly found in this ooze. It is yellow or cream in colour. Near land it is blue in colour. It consist clay between 3 to 30%. It is found in high latitudes of both the hemispheres. South of 40^0 south latitude it covers an area of 10 million square miles.

b) **Radiolarian Ooze :** It is formed by the shells of Planktomic animals. The shells of these animals are rich in siliceous matter. It consist less than 20% of Calcium Carbonate. But it consist more amount of inorganic materials. Its colour resembles to the inorganic red clay. This ooze is mainly found in deep sea, because with the increasing depth Calcium Carbonate decreases. It is mostly found in tropical regions of the Pacific Ocean. In Indian Ocean it is limited between 2000 to 5000 fathoms of depth.

D) Inorganic Materials:

Due to change of temperature in the atmosphere and ocean, there is a variation in Carbon dioxide and precipitation. Due to this, inorganic precipitates fall in various parts of the earth. But these are very limited. It consist of Dolomite, Amorphous Silica, Iron, Manganese Oxide, Phosphate etc., these are affected by chemical transformation. It forms Phosphorus, Feldspar, Philipsite and Clay minerals. Due to chemical decomposition it is difficult to differentiate between inorganic and organic sediments.

E) Red Clay :

It is the most important inorganic deposit of the deep sea basins. It belongs to pelagic deposit. It consists mainly of hydrated silicate of aluminum and oxide of iron. According to Wyville Thomson, 'it to be organic deposit, which is a residue of the insoluble calcareous organisms or formed from chalk'. According to Murray it is formed due to chemical decomposition of aluminous silicates and other sub-oceanic rocks. This clay is soft, greasy and plastic in nature. It also consists of decomposed volcanic material. Hence it is largely found near the volcanoes. Clay consist of 6.7% of Calcium, 2.39% of Siliceous organisms, 5.56% of minerals etc., Radio active substances are also found in this clay. In the deepest parts of the oceans red clay is found. It is brick red colour in Atlantic, Dark Chocolate colour in Pacific and Indian Ocean.

e) Extra-Terrestrial Materials :

It is very rare in the oceans. It comes from meteoric dust, which is microscopic in size, black or brown in colour and it has more iron oxide. Murray and Renard are the pioneers, who discovered these sediments.

12.4. LOCATION OF OCEAN DEPOSITS

Murray has classified the ocean deposits on the basis of its location into two types. They are –

A. Terrigenous

B. Pelagic deposits.

In previous pages we have already discussed about this deposits. There is a clear difference between Terrigenous and Pelagic deposits. Terrigenous deposits are formed by the erosion of continental rocks and deposited along the continental shelf and slopes. These deposits contain inorganic elements in large scale like quartz, sand etc., due to the nearness to the land. Where as Pelagic deposits are mainly formed from skeletons, shells and some inorganic sediments, which are found in pelagic deposits. These are red or brown in colour and fine particles. The amount calcium carbonate decreases with increase in depth. Due to this Globigerina and Pteropod contain higher calcium than red clay and diatom ooze. At greater depth, siliceous materials predominate.

12.5. CLASSIFICATION OF OCEAN DEPOSITS

Again ocean deposits are classified into three types

1. Continental or Terrigenous deposits
2. Neritic deposits
3. Pelagic deposits.

12.5.1 Continental or Terrigenous deposits

Nearly 66% of the continental deposits consit of quartz. It is further classified as –

a. Littoral deposits

b. Shallow water deposits

c. Terrigenous muds.

a. Littoral Deposits: These are formed in between high and low tidal line. According to Murray and Renard, this material is deposited on the foreshore. Boulders, gravels, sand and mud are common in this type. Large number of plants and organisms are found in coral reefs and mangrove forests. During the time of high tide, fine materials are carried away to the low tidal area. In this region sand is deposited according to its size. It covers an area of 62500 km^2 in the ocean.

b. Shallow water deposits

It extends up to 100 fathoms from the shore. Near the land, it provides stone, boulder, gravel, sand and mud in a large scale, strong waves and currents transport these materials. According to Shephard, currents are the main causes of removing sediments from the beach.

c. Terrigenous muds

It is found beyond 100 fathom line. It is finer than the sand particles.

12.5.2. Neritic Deposits

It consists of the organic shells and skeletons of various animals and plants. Shells, gravels and sand found at 50 fathoms depth. Tidal streams and currents are greatly responsible for this deposit. It varies according to the temperature, salinity of ocean water, direction of currents etc., It occurs around the oceanic islands. Volcanic sand and mud are the important neritic deposits.

12.5.3 Pelagic Deposits

Johnson has identified three types of pelagic deposits. They are – Benthos which consist of sedimentary or semi-sedimentary organisms which include corals, sponges etc., It is found in the sea bottom sand or mud. Nekton – calcareous skeletons of mammals, Plankton consisting unicellular plants, and marine worms. Pelagic deposit covers about $3/4^{th}$ of area of the ocean.

12.6. CONSTITUENTS OF OCEAN DEPOSITS

Ocean deposits have been classified into three types. They are -

A. Littoral deposits which are derived from the land. Ex: Shore and Shelf deposits.

B. Hemipelagic – It is partly land and marine. Ex: Green, volcanic and coral mud.

C. Eupelagic – Marine and Cosmic origin. Ex: Red clay, Radiolarian, Diatom, Globigerina and Pteropod ooze.

The colours of the sediments are depending on the amount of moisture, grain colour, size, oxidation and matter. Coarse grain consist of quartz and lime stone have white colour, iron consist deposits are in black colour, river born sediments are yellow, red or brown, organic material sediments are black or brown in colour.

12.7. LET US SUM UP

In this unit you have studied about the origin and types of ocean deposits. Various scholars have classified the ocean deposits into different types like Terrigenous or Lithological deposits, Hydrogenic deposits and others with their sub-types.

12.8. KEY WORDS

Terrigenous, Volcanic, Organic, Inorganic, Red Clay, Extra-Terrestrial materials, Calcareous Oozes, Pteropod Ooze, Globigerina Ooze, Siliceous Ooze, Diatom Ooze, Radiolarian Ooze, Pelagic deposits, Neritic deposits, Littoral deposits, Shallow water deposits.

12.9. QUESTIONS FOR SELF STUDY

1. Classify the ocean deposits into different types with examples.
2. Explain the type of ocean deposits based on source and nature of deposits.
3. What is Ooze? Explain the different types of Oozes.

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UNIT -13: DISTRIBUTION OF OCEAN DEPOSITS

Structure:

13.0. OBJECTIVES

After studying this unit, you will be able to

- Agents of gradation erode the land forms and bring the sediments and deposits in the ocean.
- Volcanoes, marine organisms, vegetation are also responsible for the formation of ocean deposits.
- The nature and the character of the sea water have an important effect on deposition.

13.1 INTRODUCTION

Various agents of gradation erode the land forms and bring the sediments and deposits in the ocean. The other activities like volcanoes, marine organisms, vegetation are also responsible for the formation of ocean deposits. The nature and the character of the sea water have an important effect on deposition. Ex: Temperature of the water, marine organisms, the depth of the sea, etc., at certain extent salinity also influences and precipitation of Calcium Carbonate.

Kuenen (1937) has estimated the sedimentation of all the deposits is extremely small in the open ocean which is about 1 cm per 1000 years. The rate of deposition is calculated by two methods. They are –

1. **Stratigraphic method:** In this, the total thickness of sediment is calculated in the given or total time. It is suitable for an individual area. Calculation of deposition is based on the material derived by rivers only. Schuchert (1931), Schott (1931) and others have also calculated the rate of deposition.

2. **Supply method:** It gives estimation on the amount of material available in the given time. This method is favourable for general area. But there are some difficulties in the study of data due to changes in the level of area, variation if the rate of accumulation and difficulties in the estimation of material produced by volcanoes. Clarke (1924) has identified chemical sedimentation by the river. Kuenen and Cambrian have estimated terrestrial deposition. But all the scholars have found that large variations occur all over the oceans.

13.2 DISTRIBUTION OF MARINE SEDIMENTS

Marine distribution can be studied through vertical and horizontal distribution.

13.3.1. Vertical distribution

Philippi has observed stratification of sediment in the bottom. He found the difference of colour in the same layer which varied from blue in the lower portion to reddish brown in the upper part due to change of ferric oxide to sulphide oxide. In the shallow part, we can observe the presence of Globigerina. After this, Radiolarian, Diatom ooze and at the deepest part red clay is found. Nearly 51.9 km^2 of pacific, 41.6 million km^2 of Atlantic and 34.4 million km^2 area of Indian Ocean are occupied by Calcareous oozes. Siliceous and diatom oozes are mostly found in Pacific (21.0 million km^2 and 4.4 million km^2 area) ocean.

13.3.2 Horizontal Distribution

When we observe the distribution of these, Terrigenous deposits are mostly found near East Indies, North part of Pacific and Labrador Coast. Globigerina Ooze is mostly found in Western part of Indian Ocean. Diatom and Red Clay are found in southern and eastern part of Indian Ocean. Red clay is also found in parts of Atlantic Ocean. Between 50^0 to 60^0 South latitude of Pacific, Diatom Ooze is found. In between 5^0 to 15^0 North latitude and 90^0 to 160^0 West longitudes Radiolarian Ooze is mostly found. Red clay is predominant in North Pacific, while Globigerina is found in South Pacific. Pelagic sediments are found in all the oceans.

13.3 LET US SUM UP

We can observe that various factors are influencing on the distribution of these deposits. Colour and type of deposit varies from one depth to another. Different kinds of deposit are found in certain areas of the ocean.

13.4 KEY WORDS

Stratigraphic method, Marine sediments, Terrigenous deposits, Globigerina Ooze, Diatom, Red clay, Radiolarian Ooze.

13.5 QUESTIONS FOR SELF STUDY

1. State the factors influencing on the distribution of Ocean deposits.
2. Explain the vertical and horizontal distribution of ocean deposits.

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UNIT -14: CORAL REEFS AND ISLANDS

14.0 OBJECTIVES

After studying this unit, you will be able to

- Coral Reefs is very big mass of limestone and dolomite, which is formed by lime secreting organisms like Coral Polyps.
- The skeletons of this marine organism are accumulated to form Coral Reefs.
- These organisms are in different colors like red, yellow, green, pink, purple and white.

14.1 INTRODUCTION

Coral Reefs is very big mass of limestone and dolomite, which is formed by lime secreting organisms like Coral Polyps. The skeletons of this marine organism are accumulated to form Coral Reefs. These organisms are in different colours like red, yellow, green, pink, purple and white. They are in different shapes. When each Coral dies, the skeleton accumulates to form white coral to lime stone. Calcium Carbonate binds the dead Corals. According to Colman J.S. 'some of corals live apart in their cup-shaped depressions; but their habit of forming colonies, among true reef builders, results in growth with such luxuriance and abundance that neighbouring colonies fill up all the available space and become welded together in a solid mass of coral rock.

14.2 CONDITIONS OF GROWTH

There are certain conditions are required for the growth of the Corals. Due to this, corals are not uniformly deposited in the tropical warm ocean waters. The most important conditions required for the development of Corals are –

1. **Temperature of the sea water:** It is one of the most important factor for the growth of Corals. The temperature of sea water should be between 68^0 to 70^0 F (20^0 C). Below this temperature it cannot live.

2. **Depth of the Sea:** Generally Corals live between 200 to 250 feet below the sea level. Ladd M.S. and Hoffmeister J.E. (1936) have estimated the depth between 200 to 300 feet, where maximum number of Corals can grow. Because with increase in depth the amount of Calcium and temperature of water decreases. The creatures which are depending on Calcium Carbonate will not exist in deep water.

3. **Salinity of Water:** Normal salinity is favourable for this living being. Less saline along the coastal margins, where river water joins, Corals will not develop. High saline water is also not favourable. So the average salinity should be between $27\%_0$ to 40 grams $\%_0$.

4. **Clear Water:** Corals need sediment free clean water. Due to this Coral Reefs cannot develop where river joins the sea and where wave erosion is high. But in certain areas Coral Reefs are growing nearer to river mouths as in Hawaiin islands, Indonesia and Madagascar. Even though the water is muddy, there is a growth in Great Barrier reef of Australia. According to P.Lake 'a slow but more or less continuous supply of sediment is far less destructive than a sudden influx'.

5. **Ocean Currents:** It provides food to Coral Polyps. Ex: Extensive Coral Reefs are found on the east coasts of Australia, Central America and Africa, where warm currents flowing along them.

6. **Submarine Platforms:** These platforms which lie near the sea shore or attached to some islands are favourable for the growth of these. But the depth of these platforms should not be more than 50 fathoms.

7. Corals cannot live for long out of water. So they rarely found above the low tidal level.

8. It needs oxygenated water with sufficient supplies of microscopic life as food. Food supply is mostly available on the sea side. Hence it tends to grow at faster rates at outwards.

14.3. CORAL ISLANDS

These islands are one to two feet height from the sea level. These are formed by living Coral Polyps. These are common in tropical, sub-tropical regions. Ex: Marshal Islands, Gilbert Islands of Pacific Ocean, Bermuda, Bahamas' islands of Atlantic, Lakshadweep islands of Indian Ocean etc. The western part of South Pacific Ocean consists of a large scale of Coral Reefs. Due to this, it is also known as Coral Sea (North-East of Australia). As the reef grows in size, waves break the Corals in the form of boulders and sand over the crest, building up a reef flat. Many plants are grown over this. According to Arthur Holmes, 'the reefs and atolls are easily drowned if their upward growth cannot keep place with any submergence that may be in progresses. The average growth rate of reef is about 14mm per year.

14.4 STRUCTURE OF CORAL REEFS

There are certain common features in reef structure, even though they have some peculiarities. The most important are –

14.4.1 Lagoon

It is developed along the margins of the shore. On one side it is formed by island rock and another is made up of dead corals. Due to outward growth of the coral reef, the sea water is enclosed between the reef and the land. In Barrier reef, the lagoon have gentle slope. Dead Corals form the bottom of the lagoon, which is almost flat. The depth varies from 30 to 50 fathoms. The width of the lagoon varies from one type of reef to another. In Fringing reef the lagoon is rare or very narrow, while in Barrier reef it is wide and in Atolls it is quite wide and shallow. The shore of the lagoon is sandy. Calcareous sediments are common in the lagoon. Some lagoons have innumerable masses of Coral which rise abruptly from deep floor in the form of Coral Pinnacles. The sediments are also deposited by the river.

14.4.2 Reef

Outside the lagoon, reef develops up to the low water tidal line. Surface of the reef is formed by dead Corals and it is often rugged, uneven and with fissures. They are more in number near the margins of the reefs. The hollows of the reef are filled with Calcareous sand. Only a small portion of the reef is exposed above the sea level. Several oceanographers have identified deposition and erosion zones over the Coral Reef. They are-

a. **Sand Belt :** In the border areas of the lagoon, sand deposits are found over the reef. It consist of parts of corals, calcareous algae, sand and others. Wider reefs have extensive sand mounds. Some times vegetation is also found in this region.

b. **Boulder Zone:** Behind the sand belt, we can found boulder zone. The debris are big and loose. Pieces of coral boulders are deposited. The height of this zone is between 10 to 30 feet above the sea level and it is known as Beach Conglomerate. The width and nature of this zone depends on the character of the reef. If the reef is narrow, the boulder zone extends up to the lagoon. Wherever the powerful waves are absent, this zone is also absent. Ex: Red Sea and Indonesian Reefs.

c. **Reef :** It is deeply fissured, flat and only a few inches above the low water level. The edge of the reef is known as Algae Ridge. It is formed due to Calcareous Algae rather than of Corals. It is absent in Red Sea and Indonesian Reefs.

14.5 LET US SUM UP

Coral Reefs are formed by Coral Polyps. The skeleton of these marine organisms form these reefs. The colour of reefs varies. The development of these reefs is determined by several factors. Coral Islands are common in tropical, sub-tropical regions. The structure of the reef depends on the nature of the reefs.

14.6 KEY WORDS

Coral Polyps, Coral Islands, Lagoon, Reef, Sand belt, Boulder Zone

14.7 QUESTIONS FOR SELF STUDY

1. Explain the conditions required for the growth of Coral Reefs.
2. Explain the structure of Coral Reefs with neat diagrams.

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UNIT – 15: TYPES OF CORAL REEFS

Structure:

15.1. OBJECTIVES

After studying this unit, you are able to know -

- various types of Coral Reefs
- characteristics of reefs
- their distribution

15.2 INTRODUCTION

Coral Reefs are formed by the skeletons of Coral Polyps and other Calcium secreting organisms. These are found in the oceans and does not resemble to each other. They are classified into different categories.

15.3 TYPES OF CORAL REEFS

Coral Reefs are broadly classified into two categories. They are –

1. Based on the nature and mode of occurrence
2. According to location of Coral Reefs

15.4.1 Based on the nature and mode of occurrence

Based on these factors, Darwin has divided the Coral Reefs into three types. They are -

a. Fringing Reef
b. Barrier Reef
c. Atolls

a Fringing Reefs : These are formed on the submarine platforms attached to the shore of the land. They grow towards sea from the land rather than upwards. The surface of this is uneven and rough. Between this reef and the coast, shallow lagoon is generally formed. Lagoon is filled with water. The outer part of this reef generally grows up to a depth of 30 fathoms. The growth of this reef is continuous and uniform, unless they are broken by rivers and strong waves.

This reef will grow quickly in the areas where there is a continuous supply of food for Coral Polyps. In these areas the width of the reef increases toward sea. In the river mouths, these are small in size. In the regions where warm currents are flowing, these reefs are large in size. In lime stone regions and the regions facing strong waves, there is no development of these reefs.

Occasionally, this reef is separated from the shore by a narrow and a shallow lagoon with a depth of 0.3 meter to 1.5 meter known as **'Boat Channel'.** These are found in Madagascar and Red Sea.

There are two types of Fringing Reefs. One is facing the open ocean and another is protected by a Barrier. Fringing reefs are found in Sakau island of Maskelyne islands in New Hebrides, Southern Florida etc.,

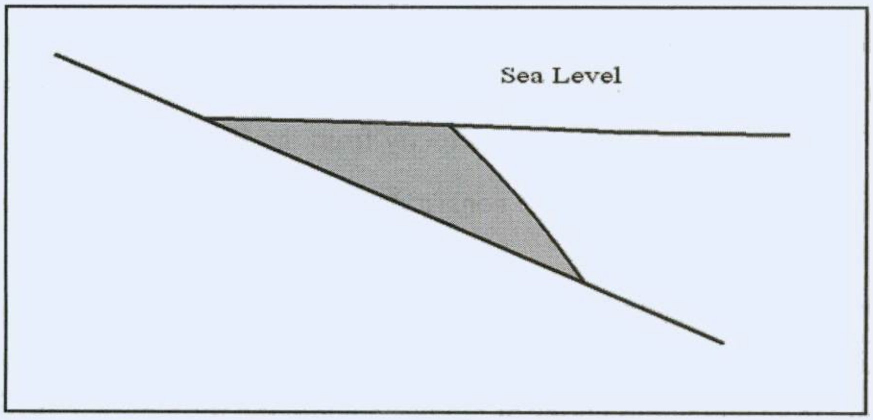

Figure 15.1 Fringing Reef

b Barrier Reef : It is developed at some distance from the shore. It is separated from the shore by a lagoon. These reefs rise from deep water. The lagoons are associated with these reefs are usually wide and deep. The surface of these reefs consist boulders, coral debris and deposits. The out ward slope of this reef is 45^0, but in some cases it is between 15^0 to 25^0. The base of this reef extends below 30 fathoms depth. The exposed part of this reef is several km wide and is cut by several channels, providing an easy passage to lagoon. Some reefs are continuous for hundreds of miles cut by big rivers. Some islands are also found in lagoons. The reef is in a circular in shape.

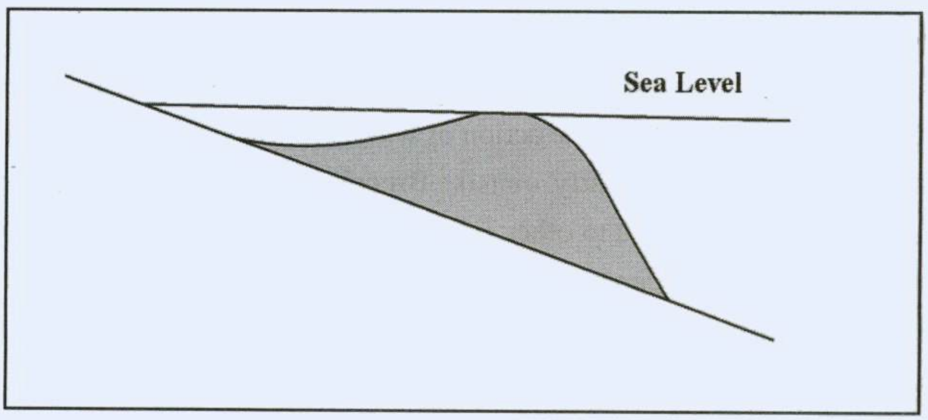

Figure 15.2 Barrier Reef

Great Barrier Reef of Australia is the largest in the world. It is located on the eastern side of Australia. It extends from Torres Strait to Swain Reefs (9^0 to 22^0 South) for about 1200 miles. It covers 2/3rd of length of the Queensland Coast. It is separated from the main land by a flat bottom shallow lagoon. The average distance from the coast to this reef varies from 20 to 30 miles. The shallow lagoon of this reef is nearly 40 fathoms deep and 7 to 8 miles in width. According to the nature of this reef, the width and shape of the lagoon varies. A series of individual reefs are found over the platform. Usually it has crescent in shape with the ends of the reef is toward landwards. The outer part of northern reefs are long and narrow parallel to the coast. Ex: Ribbon reef. Whereas, the southern reefs are isolated and cut by narrow channels. The inner reefs are growing directly from the floor of the lagoon.

The size of this reef varies in size. It consist deposits like sand and clay towards the leeward side.

c **Atolls :** When a Coral Reef looks like a ring or a horseshoe and surrounds a lagoon is called an Atoll. It has an oval shape, where its axis is determined by the wind direction. In Indonesia, according to changing directions of monsoon wind, the form of reef also changes. This type of reefs are common in Indonesian Sea, South China Sea, Red Sea, around Great Barrier Reef of Australia etc.,

According to the nature of Atolls, it can be classified into three types. They are –

i. **True Atoll:** It is circular around a shallow lagoon and does not consist any island in the middle.

ii. **Island Atoll:** An atoll which consist a central island in the lagoon, around which the reef is found.

iii. **Coral Island or Atoll Island:** An atoll reef by the process of erosion and deposition of waves, island is formed on them. The formation of these islands is due to the wave action which breaks down the living corals or the coral boulders. The fine sediments are deposited on the wind ward side, along the boulders and it is cemented by the sand and lime. Due to the same action of wind and waves, they form a discontinuous crescent shape, which mostly consist Breccias material. This fine sediment is transported and distributed to other side of the ridge and the platform is formed. The development of island depends on supply of sand. It is carried to the leeward side, where sand is low and low wooded islands are formed. Trees are grown due to the seeds brought down with the sand. When mangrove swamps grow along the boulder zone, it is called as Low Wooded Island.

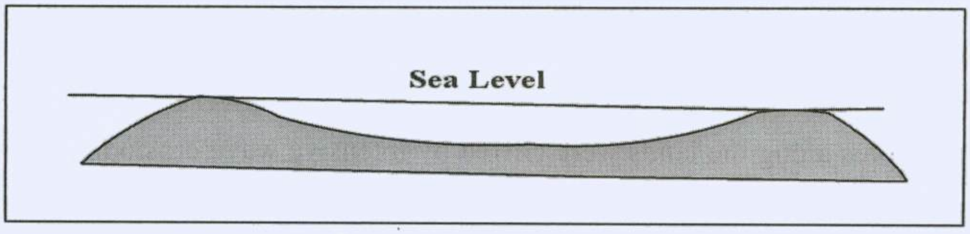

Figure 15.3 Atoll

Funafuti Island is one of the important Atolls of Elice Island. The shape of this island looks like Caricature of the human head. The enclosed lagoon is 8 miles broad and 12 miles long. Its depth varies from 20 to 25 fathoms.

Faros are chains of small Atolls with lagoons which are not so depth. Ex: Maldives, South-East New Guinea etc.,

The isolated shapeless reefs are known as **Coral Banks**. Sometimes it is a part of Fringing Reef isolated from main reef.

There are certain old reefs which are once formed in the past are no longer built up. These are submerged reefs. Ex: West Central Carolinas. But certain reefs were raised and are known as **Raised reefs**. Ex: Solomon Islands.

Coral Pinnacles of small size rising within the lagoons and coming close to the lagoon surface.

15.3.2 Based on Location of Reefs: *They are classified as –*

i. Tropical Coral Reefs

ii. Marginal Belt Coral Reefs

i. Tropical Coral Reefs: These are found in tropical areas. They are mostly situated between 25^0 North to 25^0 South latitude. They are circular in form with 100 to 400 feet above the sea level. Their shores are irregular. These are common in eastern shores of the continents. There is absence of coral reefs along the western part of the tropical seas due to It is the zone of trade winds and along western side (leeward) upwelling of cold water takes place. But in the equator, water is warm and it is favourable for the development of Corals.

Examples of tropical coral reefs are Wake Island of Pacific, Great Barrier Reef of Australia, Coral reefs of Indonesia etc., All types of Coral Reefs are found in tropical region.

ii **Marginal Belt Corals:** These are found in between 25^0 to 30^0 North and 25^0 South to 30^0 South latitudes. It is believed that Coral Polyps to be suspended during glacial period, where the temperature of the sea is less. The reef was exposed over the sea and polyps were killed. The shores along the lands were cliffed by intensive wave erosion. It gives evident for extensive marine platforms and banks.

15.4 GEOGRAPHICAL DISTRIBUTION OF CORAL REEFS

Coral reefs are limited in tropical seas and are found between 30^0 North and 25^0 South latitudes. In this zone, coral reefs are not found towards the western coast of the continents. It is due to trade winds which carry ocean water away from the coast. It causes the upwelling of cold water and development of cold currents is the reasons for not development of coral polyps. Ex: Peru Current, western coast of South America. But in equator high temperature is favourable for the growth of corals. Wherever water is muddy, the sediments block the mouth of the corals. Due to this corals are not found in the river mouth, which bring large quantity of sediments. Ex: West of Java and Sumatra. But corals are mostly grown along the eastern coast of North America, Africa and Australia.

Coral reefs are numerous in Pacific and Indian Oceans. In tropical islands of these oceans, they are relatively shallow, warm and clear water, which are favourable for the growth of Corals. Along the western part of middle Pacific Ocean, corals are extensively developed. In the east coast of Australia and in the Philippines, Indonesian islands and several islands lying further east are the regions known for coral reef growth. Around Indonesia, Indian Peninsula, Madagascar and off the eastern coast of Africa and in Red sea several Coral islands were developed.

Only a few coral reefs are found in outside the Indo-Pacific tropical area. Near West Indies, Gulf of Mexico and in Caribbean Sea have some Coral reefs. But in Mid-Atlantic ocean there are no significant reefs.

Special type of corals is found in temperate latitudes and in deep waters. But they donot live in colonies and are unable to built reefs. They grow like bushes and build **'Banks'.** They are found in the deep, cold and dark waters of the continental slope and the outer edge of the shelf. They live in waters which are 33 to 110 fathoms depth. Where the minimum water temperature ranges between 4^0 to 15^0 C. These deep water Coral Banks (thickets) are found along the eastern Atlantic coast from Norway to Cape Verde islands. Similar coral banks are also found near the Niger delta, Orinoco delta, Gulf of Mexico and Japan.

15.5 LET US SUM UP

Coral reefs are classified into different types. Fringing, Barrier reef and Atolls are most important. Great Barrier Reef is one of the most astonishing reef in the world.

15.5 KEY WORDS

Fringing reef, Barrier reef, Atolls, Boat Channels, True Atoll, Island Atoll, Atoll Island, Faros, Coral Banks, Raised reefs, Coral pinnacles, Coral Banks.

15.7 QUESTIONS FOR SELF STUDY

1. Explain different types of Coral Reefs with neat diagrams.
2. Write a note on Great Barrier Reef.
3. Explain the geographical distribution of Coral Reefs in the world.

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UNIT – 16: CORAL REEFS AND ISLAND – THEORIES

Structure:

16.1. OBJECTIVE

After studying this unit, you will be able to know –

- Views of different scholars regarding origin of Coral Reefs.
- Charles Darwin's view about Subsidence theory.
- Non-Subsidence or Stand Still theories.
- Views of Murray, Agassiz, Daly and W.M. Davis.

16.2 INTRODUCTION

Several scholars have explained the origin of Coral Reefs and Islands considering the fluctuation of the Pleistocene Sea Level and stability of land. There are two important theories which explain the origin of Coral Reefs. They are –

1. Subsidence Theory of Darwin and Dana
2. Non-Subsidence or Stand Still or Antecedent Platform Theories

16.3 SUBSIDENCE THEORY OF DARWIN AND DANA

Charles Darwin has propounded this theory in 1837 and modified in 1842. It was supported by Dana (1885). He understood that Coral Polyps grown only in shallow water during his Beagle Voyage. A scholar called Chamisso had also attempted to explain the origin of Coral Reef due to subsidence, but this idea was not fully developed by him.

Darwin assumes that group of Coral Polyps grew upward along a favourable platform towards a low water level. It will be a Fringing Reef. When the sea floor and projecting land in Coral Seas start submerging, Coral Polyps live in deeper water. Coral Polyps to grow upward and outward which would be balanced by the subsidence of the land. Near the outer edge, they will grow quickly and near the shore, its growth would be reduced. In between the land and reef a lagoon would be formed.

According to Darwin, sinking of land is slower than the upward growth of Corals. So he postulated that Fringing Reef, Barrier Reefs and Atolls are the three stages in the evolutionary growth of a reef. Fringing Reef would grow upwards and outwards forming shallow lagoon when the land subsides. When subsiding of land continues, Fringing reef is converted into Barrier reef forming a deep and wide lagoon. In the final stage, when the land completely submerged, around the lagoon coral reef is found like a ring (Coral Ring)

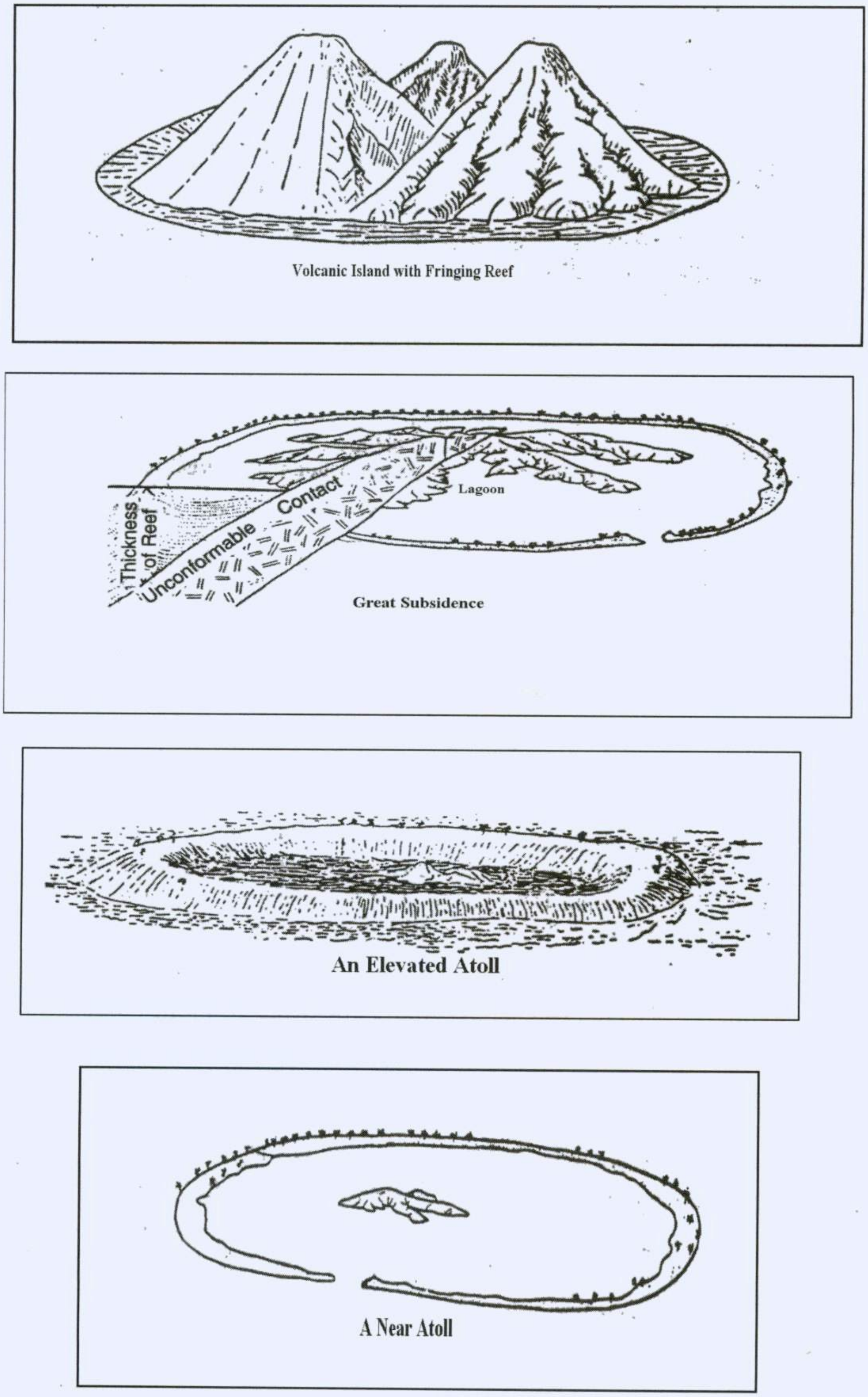

Figure 16.1 Stages in reef development on a Subsiding Island

He states that the shallowness of the lagoon is due to continuous deposition of sediments from the nearby subsiding land. The fine materials are found in the bottom of the lagoon and coral debris were brought down by the action of waves. According to him, Barrier Reef and Atoll can occur only in the areas of submergence. In these places, the vertical growth of Coral material is due to upward growth of Coral Polyps and subsidence of land.

16.3.1 Evidences

There are several evidences in favour of this theory. The most important are –

a. J.H. Dana in his Wilke's expedition observed that valleys of Pacific Islands which were formed by sub-aerial erosion were quite different from the coastal line landscapes, which were the characteristic of submerging coast line.

b. The coasts of Queensland in Great Barrier Reef and Indonesian Sea also support the views of Darwin.

c. In Pacific Ocean there is a sign of elevation in the form of raised beaches are without Coral Reefs. In certain areas only Fringing Reefs are found even after the emergence of land.

d. Along the shores of island, the absence of cliffs proves that the land is submerging as cliffs are visible only in stable area.

e. Actual observations of submergence have also supported the views of Darwin. Ex: North of Fiji Islands.

f. According to W.H.Davis, Society group of islands stretching for 200 miles east to west shows a complete sequence in the formation of Coral Reefs.

g. 'Pathfinder' (1938) a survey ship of U.S.Coast and Geodetic Survey found that Palawan Bank in Philippine islands, submerged Atolls are rising from 40 fathoms of deep water.

h. Dr.Kuenen found that the islands of Dutch East Indies are related to the submergence.

i. The reefs are built along the steep slopes of the rock a side which resembles a mountain summit is due to the submergence of land rather sub-aerial erosion.

j. Unconformable contacts between the reef and the land mass also prove this theory. There is a sub- aerially eroded land hidden under the reef deposition, which is possible only after subsidence.

k. The width of the coral reef and their huge thickness far below the required depth is against the idea of reefs growing on a stable foundation. Only on subsiding land, corals could grow vertically and simultaneous sinking of total width. It has been verified by boring tests through the Coral Reefs conducted in different places and period.

16.3.2 Demerits of this theory

There are several critics regarding this theory. Most important are –

a. Continuous subsidence of land in the Pacific, leads to the disappearance of vast land mass, geologically it is not possible.

b. Anomaly is found due to the presence of both fringing and barrier reefs along the same island. Ex: Narai island of Fiji.

c. Murray has criticized the borings of Funafuti Island. The pieces of coral rocks which are found are broken from the edge of the reef and rolled down into deeper water.

d. Semper's work in Pelew reef has shown that a recent elevation which took place is only 60 miles far from the Atolls. Davis had noticed that the raised reefs of the island have suffered sub aerial erosion before the growth of corals. After some time the land has subsided to form reef. Again after some time the island was uplifted. It is found that an Atoll could also be found in areas. It disproves this theory.

16.4 NON-SUBSIDENCE OR STAND STILL OR ANTECEDENT PLATFORM THEORIES

Several scholars have opposed the Darwin's theory of subsidence and propagated non-subsidence theories. These theories are grouped into two. According to one group, Coral Reefs have developed over favourable stable platform with an unchanging sea level. Another group has suggested that reefs were developed along the wave cut platform due to the lowering of the sea level.

Various scholars have postulated their own views regarding the origin of Coral Reefs. Ex: Murray propagated Solution Lagoon, Rein has advocated Up growth on Still Standing aggraded Submarine Banks, Guppy's outgrowth on rising foundation, Agassiz postulated growth on sub-aerially sub-marine eroded platform, Wharton's growth on cut off foundation and Tyreman's 'development on incompletely truncated platform'.

16.5 SOLUTION LAGOON OF MURRAY

Murray was first advocated this theory in 1880 based on stable landform and biological observations, when he observed during his Challenger Expedition (1872-76). In his expedition, he found that several submerged volcanic peaks with Calcareous deposits are located in Pacific Ocean. Semper had also the similar views. According to them, unchanging sea level and a stable landform were responsible for the origin of Coral Reefs. Murray has observed that a large number of submarine platforms and hills are found under the sea forming the base for reefs. But the depth of this volcaninc summit may be 30 fathom, where Coral Polyps can grow on them. The summits which are higher than these are eroded by sea waves. Some peaks which are far below the depth for coral growth have sufficient pelagic deposits.

At 30 fathoms depth, which is ideal for the growth of Coral Polyps, they start to grow upward in the form of fringing reef. After some time they would grow outward on their own coral debris. So without any subsidence of land, reef would be extended to deep sea. This continuous outgrowth of fringing reef forms barrier reef. In the centre of the lagoon, due to stagnation of water there will be lack of food for Coral Polyps, which would die due to starvation. In this region the dead Coral Polyps are easily dissolved. Due to this the outer edge grows outward and the lagoon goes on dissolving the dead corals. All these leads to the formation of Barrier Reef from the Fringing Reef even on a stable land.

The Atolls are formed on the top of the submarine platforms growing outward in all the directions. Inside the reef, corals are mostly dead, but living corals tend to grow toward sea. He observed that with the passage of time, the ring of reef automatically grows outward and lagoon widens and becomes shallower. His idea is supported by Guppy by stating the example of Solomon Islands.

16.5.1 Critics

Even though, the theory was supported by different scholars, it is not free from critics. They are -

a. It requires a large number of submarine peaks which is not a feasible factor.

b. It is difficult to explain erosion and deposition at the same time over different peaks.

c. 30 fathom depth is not sufficient for the work of erosion and deposition by waves.

d. According to Murray, the lagoon will become lower than the area surrounding it. It was questioned by W.M.Davis and states that sea water has a small dissolving action.

e. This theory over looked the deposition of sediment into the lagoon.

f. It is difficult for Coral Polyps to grow over steep slope toward sea with a greater depth.

g. Murray has observed that Coral Reefs were developed in 30 fathom depth. But observations show that Coral Reefs are developed even in the areas of more than 30 fathom depth.

h. Geologists are not fully accepted that marine erosion can erode the platform at that depth.

16.6 VIEWS OF AGASSIZ

Louis Agassiz made an important observation at Florida reef in 1851. He found that a succession of concentric reefs separated by deep channels was found. His son Alexander Agassiz made Blake expedition along the coast of Florida and propagated similar views to Murray. He observed that due to action of waves around landmasses and islands, submarine platforms were formed at a depth of 30 to 50 fathom, on which Coral Polyps can grow. Due to outward growth of the reef, the lagoon between barriers and the adjacent shorelines or enclosed by Atolls are formed and believed to be cleaned and deepened by wave action. In his expedition in several tropical areas, he never found the formation of Coral Reef due to subsidence. So he rejected the theory of subsidence.

16.6.1 Critics

The thickness of Corals as stated by Agassiz has been criticized. The action of cliffing and formation of submarine rocks as stated by him, remove all the islands found between the reef and the shore. But the absence of cliffs and presence of islands in the lagoon are found in New Caledonian Reef in Australia. Another objection regarding his theory is about cliffing along the shorelines, even after its enclosure by a lagoon. Stagnant water of the lagoon is not active as ocean waves; there will be a long period of erosion in cliffing. Hence Coral Reefs would be absent.

16.6 GLACIAL CONTROL THEORY OF DALY

This theory has been advocated by Daly. He conducted a voyage to the Hawaii Island and based on this, he postulated the origin of Coral Reefs in 1915. During his voyage, he observed the marks of glaciations on the Mauna Kea and narrowness of the Coral Reefs. He identified that there is a relationship between the growth of coral and temperature of the ocean water. During Pleistocene Ice age, there was a fall of temperature and sea level. Due to this Coral Reefs were destroyed and Corals were dead. In this time all the Coral Reefs and islands associated with them were eroded by sea waves and formed wave-cut platforms and benches along the continental coast and islands.

Rise of temperature has made ice age to an end. Ice covered area began to melt and sea level was raised. Due to this wave cut platforms and others were submerged under the water. New Coral Polyps and other reef building creatures started to grow on newly formed shelves vertically. Their base was submerged about 30 to 50 fathom depth. The seaward growth of these formed Fringing Reef on narrow eroded platforms. On broad eroded platforms Barrier Reefs were formed. Atolls were formed on isolated submarine plateau eroded at the time of low sea level. He doubts that the present day Atolls and barrier reefs existed before the glacial period. The thickness of the Corals would also be equal to the lowering of the sea level.

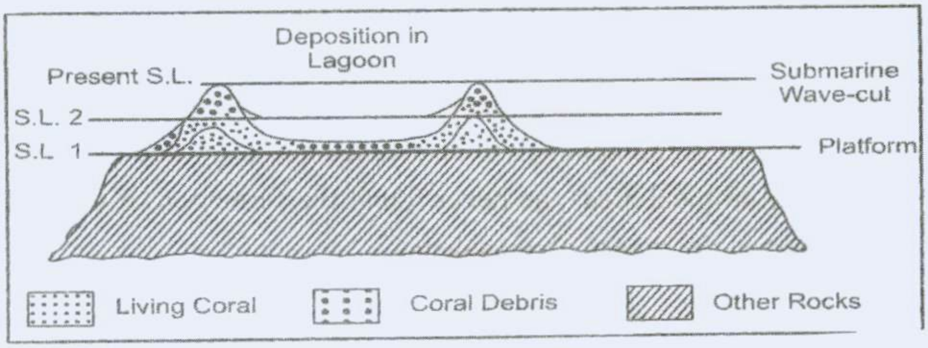

Figure 16.2 Glacial Control Theory of Daly.

16.7.1 Critics

- **a.** There is no uniformity in the depth of the lagoon as stated by Daly.
- **b.** Davis pointed out that there is no difference in the depth of lagoon in stable and unstable areas. It seems to be there may be other cause than the lowered sea level erosion for the varied depth of the lagoons.
- **c.** No proofs are found that corals were killed due to coldness in Ice age.
- **d.** The formation of submarine platforms and benches by low-level marine erosion was doubtful.
- **e.** Few miles wide shallow bank explained in this theory remains a problem.

f. Cliffing found along the shores remains a doubt. In marginal seas, cliffs are clearly visible due to lack of coral growth along the shore. But cliffs are mostly absent in coral seas gives strong critique.

16.8. VIEWS OF W. M. DAVIS

Davis wrote several essays on the problem of Coral Reef formation. He published a book **'The Coral Reef problem'** in 1928. He does not postulate any new theory, but critically evaluated the existing theories and gave a new approach to understand the formation of Coral Reefs. He supported the Subsidence theory of Darwin. According to Davis, the presence of embayment and the absence of cliffs are indicative of submergence of land and it confirms the subsidence theory. The original depth of the embayment's and the inclination of the rock walls also indicate subsidence.

According to Davis, large amount of sediments from the land is deposited in the lagoon located between the reef and the land. Excessive sediment is harmful for coral growth. If we assumed that if the land was stable, excessive sediments were deposited in the lagoons, the development of coral may be retarded. In the case of subsidence, the sediments would be deposited in the subsiding lagoon with no adverse effect on the coral growth.

The Subsidence theory is able to explain the formation of reefs in different situations. Where as Glacial Control theory is based on the movements of sea level. The subsidence theory is not against the changes in the sea level. Both tectonic movements and sea level changes are included in the subsidence theory. A period of subsidence may be followed by a period of Stand-still. These unequal movements may form a Barrier Reef on one side of an island, while a long period of Stand-still may subsequently lead to the formation of a new Fringing Reef on the other side of the island.

Davis had tried to explain that Darwin's subsidence hypotheses could be applicable in a variety of situations and the form of the coast is definitely favour to this theory. But this hypotheses has not been successful in providing a satisfactory reason for uniformity in the depth of the lagoons. He tried to explain the characteristics of the marginal belt Coral Reefs with the help of subsidence theory. He divided the islands of the world in this context in to three groups. They are –

a. Islands located in the Coral Seas.

b. Islands located in Cold or Temperate sea where corals are not found. They were absent in Pleistocene ice age.

c. Transitional zone between Coral Sea and Cold Sea where coral growth was not found in Pleistocene ice age. But today Corals are found. These zones are located between 25^0 to 30^0 north to 30^0 south latitudes.

The islands which are located in the two transitional zones contain well marked cliffs and encircling the islands are shallow banks and submarine platforms on which the Coral Reefs have developed. Ex: North-west part of Hawaiian Islands. The geomorphic nature of the coasts in this transitional zone supports the Subsidence hypotheses and erosion during lower sea level supported the Glacial Control hypotheses of Daly.

16.9 LET US SUM UP

The analysis of the above theories highlights the complexity of the problem. The evidence which is available not only supports one theory and it is difficult to arrive for conclusion. In present conditions, the Subsidence theory is most acceptable and receives wide support from the new evidences and arguments advocated by Davis. Glacial Control theory of Daly is based on rise and fall of sea level is in a way implied in the subsidence theory. The drillings (borings) made in the reefs at different parts of the world do not fully support the subsidence theory, but provide strong evidences to support this theory.

16.10 KEY WORDS

Subsidence, Cliffing, Ice Age, Pleistocene, Embayment

16.121 QUESTIONS FOR SELF STUDY

1. Give a critical account of the Subsidence theory regarding the formation of Coral Reefs.
2. Examine critically Glacial Control theory about the origin of Coral Reefs.
3. Discuss the geographical distribution of Coral reefs with reference to ecological conditions for their growth.
4. Evaluate the views of Darwin about the origin of Coral reefs.
5. 'Subsidence is better able to explain Atolls and Barrier reefs than any other theories'. Discuss this statement.

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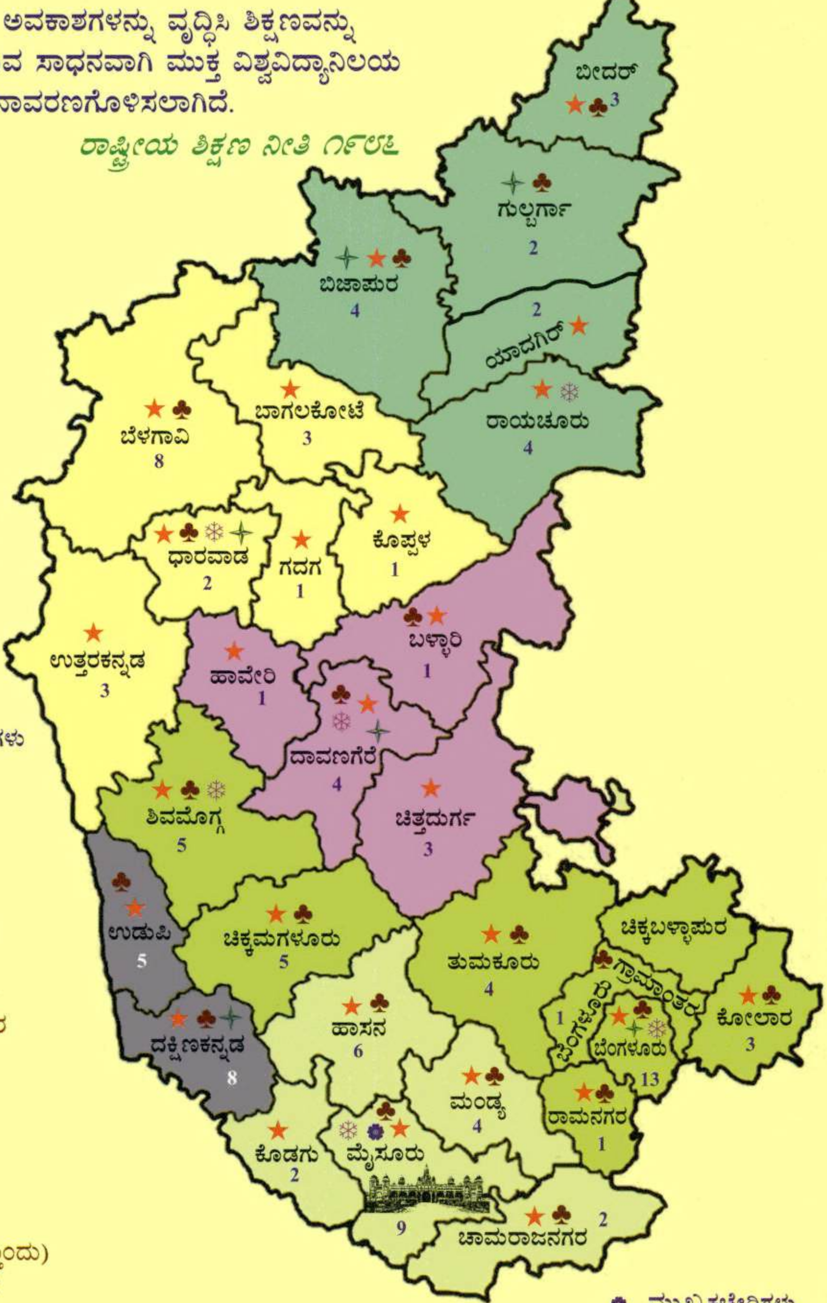
ಕರ್ನಾಟಕ ರಾಜ್ಯ ಮುಕ್ತ ವಿಶ್ವವಿದ್ಯಾನಿಲಯ

ಮಾನಸ ಗಂಗೋತ್ರಿ ಮೈಸೂರು – 570 006

ಉನ್ನತ ಶಿಕ್ಷಣದ ಅವಕಾಶಗಳನ್ನು ವೃದ್ಧಿಸಿ ಶಿಕ್ಷಣವನ್ನು ಪ್ರಜಾತಾಂತ್ರಿಕರಿಸುವ ಸಾಧನವಾಗಿ ಮುಕ್ತ ವಿಶ್ವವಿದ್ಯಾನಿಲಯ ವ್ಯವಸ್ಥೆಯನ್ನು ಅನಾವರಣಗೊಳಿಸಲಾಗಿದೆ.

ರಾಷ್ಟ್ರೀಯ ಶಿಕ್ಷಣ ನೀತಿ ೧೯೮೬



♣ ಪ್ರಾದೇಶಿಕ ಕೇಂದ್ರಗಳು

ಬೆಂಗಳೂರು
ದಾವಣಗೆರೆ
ಗುಲ್ಬರ್ಗಾ
ಧಾರವಾಡ
ಶಿವಮೊಗ್ಗ
ಮಂಗಳೂರು
ತುಮಕೂರು
ಹಾಸನ
ಚಾಮರಾಜನಗರ
ಬಳ್ಳಾರಿ
ಮಂಡ್ಯ
ಕೋಲಾರ
ಬಿಜಾಪುರ
ಬೆಳಗಾಂ
ರಾಮನಗರ
ಬೆಂಗಳೂರು (ಮತ್ತೊಂದು)
ಚಿಕ್ಕಮಗಳೂರು
ಉಡುಪಿ
ಕಾರವಾರ
ಬೀದರ್
ಮೈಸೂರು

- ❁ ಮುಖ್ಯಕಚೇರಿಗಳು
- ★ ಒಟ್ಟು ಅಧ್ಯಯನ ಕೇಂದ್ರಗಳು: ೧೨೩
- ♣ ಪ್ರಾದೇಶಿಕ ಕೇಂದ್ರಗಳು: ೨೧
- ❄ ಬಿ ಎಡ್ ಅಧ್ಯಯನ ಕೇಂದ್ರಗಳು: ೧೦
- ✦ ಎಂ ಎಡ್ ಅಧ್ಯಯನ ಕೇಂದ್ರಗಳು: ೦೬

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