OCEANS AND OCEANOGRAPHY

Oceanography is the scientific study of all aspects of the ocean, including the nature of water (salinity, chemical composition, etc.), temperature, movements (tides, currents, waves, etc), depth and biology (flora and fauna).Ocean is the vast expanse of salt water that covers over 70 percent of the earth's surface. The term world ocean refers to the combined ocean bodies and seas of the globe. Its average depth (when shallow seas are included with deep ocean basis) is 12.500 ft (3,800 m).

For major portions of Atlantic, pacific and Indian Oceans, the average depth is about 13,000 ft (4000 m). The total volume of World Ocean is about 1.4 billion cu km, comprising over 97 percent of world's free water. Of the remaining volume, about 2 percent is in the form of ice sheets of Antarctica and Greenland and about 1 percent in the form of fresh water of the land. Thus, the world ocean largely represents the hydrosphere.

THE OCEAN RELIEF

The ocean basins are in many ways similar to the land surface. There are submarine ridges, plateaux, canyons, plains and trenches. A section drawn across an ocean illustrates the typical submarine relief features.

1. The continental shelf.

This is, in fact, the seaward extension of the continent from the shoreline to the continental edge marked, approximately, by the 100 fathom (600 feet) isobath (isobaths are contours marking depths below sea level). The continental shelf is thus a shallow platform whose width varies greatly, from a few miles in the North

Pacific off the continent of North America, to over 100 miles off north-west Europe.

In some places where the coasts are extremely mountainous, such as the Rocky Mountain and Andean coasts, the continental shelf may be entirely absent. Off broad lowland coasts like those of Arctic Siberia, a maximum width of 750 miles has been recorded! A width of 20 to 100 miles is generally encountered. The angle of the slope is also variable, and is normally least where the continental shelf is widest. A gradient of 1 in 500 is common to most continental shelves.

Many regard the continental shelf as part of the continent submerged due to a rise in sea level, e.g. at the close of the Ice Age, when the ice in the temperate latitudes melted and raised the sea level by several hundred feet. Some smaller continental shelves could have been caused by wave erosion where the land is being eroded by the sea. Conversely such shelves might have been formed by the deposition of land-derived or river borne materials on the off-shore terrace.

The continental shelves are of great geographical significance for the following reasons.

Their shallowness enables sunlight to penetrate through the water, which encourages the growth of minute plants and other microscopic organisms. They are thus rich in plankton on which millions of surface and bottom-feeding fishes thrive. The continental shelves are therefore the richest fishing grounds in the world, e.g. the Grand Banks off Newfoundland, the North Sea and the Sunda Shelf.

Their limited depth and gentle slope keep out cold under-currents and increase the height of tides. This sometimes hinders shipping and other marine activities since ships can only enter and leave port on the tide. Most of the world's greatest seaports including Southampton, London, Hamburg, Rotterdam, Hong Kong and Singapore are located on continental shelves.

2. The continental slope.

At the edge of the continental shelf, there is an abrupt change of gradient to about 1 in 20, forming the continental slope.

3. The deep-sea plain.

This is the undulating plain lying tow to three miles below sea level, and covering two-thirds of the ocean floor, generally termed the abyssal plain. It was once thought to be featureless, but modern sounding devices reveal that the abyssal plain is far from being level. It has extensive submarine plateaux, ridges, trenches, basins, and oceanic islands that rise above sea level in the midst of oceans, e.g. the Azores, Ascension Island.

4. The Ocean deeps.

These are the long, narrow trenches that plunge as great ocean deeps to a depth of 5,000 fathoms or 30,000 feet! Contrary to our expectations, most of the deepest trenches are not located in the midst of oceans. They are more often found close to the continents, particularly in the Pacific Ocean, where several deep trenches have been sounded. The greatest known ocean deep is the Marianna Trench near Guam Island, which is more then 36,000 feet deep. We can see from this that ocean trenches are greater in magnitude than the highest mountains on land, for the highest peak Mt.Everest is only 29,028 feet. Other notable ocean deeps include the Mindanao Deep (35,000 feet). The Tonga Trench (31,000 feet) and the Japanese Trench (28,000 feet), all in the Pacific Ocean.

THE OCEANIC DEPOSITS

Materials eroded from the earth which are not deposited by rivers or at the coast are eventually dropped on the ocean floor. The dominant process is slow sedimentation where the eroded particles very slowly filter through the ocean water and settle upon one another in layer. The thickness of the layer of sediments is still unknown. Its rate of accumulation is equally uncertain. Generally speaking, we may classify all the oceanic deposits as either muds, oozes or clays.

1. The muds.

These are terrigenous deposits because they are derived from land and are mainly deposited on the continental shelves. The muds are referred to as blue, green or red muds; their colouring depends upon their chemical content.

2. The oozes.

These are pelagic deposits because they are derived from the oceans. They are made of the shelly and skeletal remains of marine micro organisms with calcareous or siliceous parts. Oozes have a very fine; flour-like texture and either occur as accumulated deposits or float about in suspension.

3. The clays.

These occur mainly as red clays in the deeper parts of the ocean basins, and are particularly abundant in the Pacific Ocean. Red clay is believed to be an accumulation of volcanic dust out from volcanoes during volcanic eruptions.

THE OCEAN SALINITY

Almost every known chemical element can be found in varying proportions in the oceans whose most characteristic feature is their salinity, in contrast to the fresh water of lakes and steams. All sea water contains large amounts of dissolved mineral matter of which sodium chloride or common salt alone constitutes more than 77 percent. The other more important compounds include magnesium, calcium and potassium, while the rest are distinguishable only in traces of very minute quantities.

Due to the free movement of ocean water, the proportions of different salts, remain remarkably constant in all oceans and even to great depths. But the degree of concentration of the salt solution in oceans does vary appreciably in different areas. This is expressed as salinity, the degree of saltness of water, either as a percentage or more often in parts per thousand. Variations are shown in salinity distribution maps by isohalines, lines joining places having an equal degree of salinity.

Generally speaking, the average salinity of the oceans is 35.2%, about 35 parts of salt in 1,000 parts of water. In the Baltic Sea, where there is much dilution by fresh water and melting ice, the salinity is much lower, only about 7%. In the Red Sea where there is much surface evaporation and fewer rivers to bring in fresh water, the average salinity increases to 39%. In enclosed seas, which are areas of inland drainage, such as the Caspian Sea, the salinity is very high, 180%, and in the Dead Sea of Palestine, a salinity of 250% has been recorded. The highest salinity is perhaps, that of Lake Van, in Asia Minor, with 330 %. It is a salt lake, and salts are collected from its shores. The density of the water is so high that in Lake Van or the Dead Sea, it is almost impossible to sink. Beginner-swimmers will find it much easier to float here than anywhere else! The variation of salinity in the various seas and oceans is affected by the following factors.

1. The rate of evaporation.

The water fringing the High Pressure Belts of the Trade Wind Deserts, between 20 ^{o} and 30^{o} N and S., have high salinity because of the high rate of evaporation caused by high temperature and low humidity. The temperate oceans have lower salinity due to the lower temperature and a lower rate of evaporation.

2. The amount of fresh water added by precipitation, streams and icebergs.

Salinity is lower than the average 35% in equatorial waters because of the heavy daily rainfall and high relative humidity. Oceans into which huge rivers like the Amazon, Congo, Ganges, Irrawaddy and Mekong drain, have much of their saltness diluted and have a lower salinity. The Baltic, Arctic and Antarctic waters have a salinity of less than 32% because of the colder climate with little evaporation and because much fresh water is added from the melting of icebergs, as well as by several large poleward-bound river, e.g. Ob, Lena, Yenisey, and Mackenzie.

3. The degree of water mixing by currents.

In wholly or partially enclosed seas such as the Caspian Sea, Mediterranean Sea, Red Sea and Persian Gulf, the waters do not mix freely with the ocean water and they are not penetrated by ocean currents. Salinity is high, often over 37%. In areas of inland drainage without links with the oceans, continuous evaporation under an almost cloudless sky causes the accumulation of salts around the shores. In the open oceans where currents freely flow, salinity tends to be near the average 35% or even a little lower. The range of salinity is negligible where there is free mixing of water by surface and sub-surface currents.

THE TEMPERATURE OF OCEAN WATER

Like land masses, ocean water varies in temperature from place to place both at the surface and at great depths. Since water warms up and cools down much more slowly than the land, the annual range of temperature in any part of the ocean is very much smaller. It is less than 10^{o}F, for most of the open seas. Generally, the mean annual temperature of the surface ocean water decreases from about 70^{o}F in equatorial areas to 55^{o}F at latitudes 45^{o} N. and S., and drops almost to freezing-point at the poles.

The reduction of temperature with latitude is however never constant, because of the interference by warm and cold currents, winds and air masses. Unlike the solid earth, ocean water is mobile and variations in the temperature between different parts of the oceans can be expected. Water flowing out from the

Arctic and Antarctic as cold currents, such as the Labrador Current off north-east Canada, tends to reduce the surface-water temperature. Ports of eastern Canada even at 45^o N. are thus icebound for almost half the year. In the same way, coasts warmed by warm currents, such as the North Atlantic Drift, have their surface temperature raised. The Norwegian coast, even at latitudes 60^o to 70^o N. is ice-free throughout the year!

The highest water temperatures are found in enclosed seas in the tropics, e.g. the Red Sea which records a temperature of 85^o to 100^o F. The Arctic and Antarctic waters are so cold that their surface is permanently frozen as pack-ice down to a depth of several feet. In the warmer summer, parts of the ice break off as icebergs that both dilute the water and lower the surface temperature of surrounding ice-free seas.

The temperature of the oceans also varies vertically with increasing depth. It decreases rapidly for the first 200 fathoms, at the rate of 1^o F. for every 10 fathoms, and then more slowly until a depth of 500 fathoms is reached. Beyond this, the drop is scarcely noticeable, less than 1^o F. for every 100 fathoms. In the ocean deeps below 2,000 fathoms (12,000 feet), the water is uniformly cold, just a little above freezing-point. It is interesting to note that even in the deepest ocean trenches, more than 6 miles below the surface, the water never freezes. It is estimated that over 80 percent of all ocean waters have a temperature between 35^o to 40^o F.

OCEAN CURRENTS MOVEMENTS

Ocean currents are large masses of surface water that circulate in regular patterns around the oceans. Those that flow from equatorial regions polewards have a higher surface temperature and are warm currents. Those that flow from polar regions equatorwards have a lower surface temperature and are cold currents.

Their direction of movement is indicated by the arrows. But why should they follow such a pattern? Some of the underlying factors are explained below.

1.The planetary winds.

Between the equator and the tropics blow the Trade Winds which move equatorial waters polewards and westwards and warm the eastern coasts of continents. For example the North-East Trade Winds move the North Equatorial Current and its derivatives, the Florida Current and the Gulf Stream Drift to warm the southern and eastern coasts of U.S.A. Similarly, the South-East Trade Winds drive the South Equatorial Current which warms the eastern coast of Brazil as the warm Brazilian Current.

In the temperate latitude blow the Westerlies. Though they are less reliable than the Trade Winds, they result in a north-easterly flow of water in the northern hemisphere, so that the warm Gulf Stream is driven to the western coast of Europe as the North Atlantic Drift. In a similar manner, the Westerlies, of the southern hemisphere, drive the West Wind Drift equatorwards as the Peruvian Current off South America and the Benguela Current off southern Africa. The planetary winds are probably the dominant influence on the flow of ocean currents. The strongest evidence of prevailing winds on current flows is seen in the North Indian Ocean. Here the direction of the currents changes completely with the direction of the monsoon winds which come from the north-east in winter and south-west in summer.

2. Temperatures.

There is much difference in the temperature of ocean waters at the equator and at the poles. As warm water is lighter and rises, and cold water is denser and sinks, warm equatorial waters move slowly along the surface polewards, while the heavier cold waters of the Polar Regions creep slowly along the bottom of the sea equatorwards.

3. Salinity.

The salinity of ocean water varies from place to place. Water of high salinity are denser than waters of low salinity. Hence waters of low salinity flow on the surface of waters of high salinity while waters of high salinity flow at the bottom towards waters of low salinity. For example in the Mediterranean region, there is great difference in salinity between the waters of the open Atlantic and those of the partially enclosed Mediterranean, Sea. The less saline water of the Atlantic flows on the surface into the Mediterranean, and this is compensated for by an outflow of denser bottom water from the Mediterranean.

4. The earth's rotation.

The earth's rotation deflects freely moving objects, including ocean currents, to the right. In the northern hemisphere this is a clockwise direction (e.g. the circulation of the Gulf Stream Drift and the Canaries Current). In the southern hemisphere it is an anti-clockwise direction (e.g. the Brazilian Current and the West Wind Drift).

5. Land.

A land mass always obstructs and diverts a current. For instance, the tip of southern Chile diverts part of the West Wind Drift northwards as the Peruvian Current. Similarly the 'shoulder' of Brazil at Cape Sao Roque, divides the west-flowing equatorial currents into the Cayenne Current which flows north-westwards and the Brazilian Current which flows south-westwards.

THE CIRCULATION (THE ATLANTIC OCEAN)

Let us now study more closely the circulation of ocean currents in the Atlantic Ocean .We shall begin with the North and South Equatorial Current at the equator. The steady Trade Winds constantly drift two streams of water from east to west. At the 'shoulder' of north-east Brazil, the protruding lands mass splits the South Equatorial Current into the Cayenne Current Which flows along the Guiana coast, and the Brazilian Current which flows southwards along the east coast of Brazil.

In the North Atlantic Ocean, the Cayenne Current is joined and reinforced by the North Equatorial Current and heads north-westwards as a large mass of equatorial water into the Caribbean Sea. Part of the current enters the Gulf of Mexico and emerges from the Florida Strait between Florida and Cuba as the Florida Current. The rest of the equatorial water flows northwards east of the Antilles to join the Gulf Stream off the south-eastern U.S.A. The Gulf Stream Drift is one of the strongest ocean currents, 35 to 100 miles wide 2,000 feet deep and with a velocity of three miles an hour. The current hugs the coast of America as far as Cape Hatteras (latitude 35^oN), Where it is deflected eastwards under the combined influence of the Westerlies and the rotation of the earth. It reaches Europe as the North Atlantic Drift. This current, flowing at 10 miles per day, carries the warm equatorial water for over a thousand miles to the coasts of Europe.

From the North Atlantic, it fans out in three directions, eastwards to Britain, northwards to the Arctic and southwards along the Iberian coast, as the cool Canaries Current. Oceanographic researches show that almost tow-thirds of the water brought by the Gulf Stream to the Arctic regions is returned annually to the tropical latitudes by dense, cold polar water that creeps southwards in the ocean depths. The Canaries Current flowing southwards eventually merges with the North Equatorial Current, completing the clockwise circuit in the North Atlantic Ocean.

Within this ring of currents, an area in the middle of the Atlantic has no perceptible current. A large amount of floating sea-weed gathers and the area is called the Sargasso Sea.

Apart from the clockwise circulation of the currents, there are also currents that enter the North Atlantic from the Arctic regions. These cold waters are blown south by the out-flowing polar winds. The Irminger Current or East Greenland Current flows between Iceland and Greenland and cools the North Atlantic Drift at the point of convergence. The cold Labrador Current drift south-eastwards between West Greenland and Baffin Island to meet the warm Gulf Stream off Newfoundland, as far south as 50^{o} N. where the icebergs carries south by the Labrador Current melt.

The South Atlantic Ocean follows the same pattern of circulation as the North Atlantic Ocean. The major differences are that the circuit is anti-clockwise and the collection of sea-weed in the still waters of the mid-South Atlantic is not so distinctive.

Where the South Equatorial Current is split at Cape Sao Roque, one branch turns south as the warm Brazilian Current. Its deep blue waters are easily distinguishable from the yellow, muddy waters carried hundreds of miles out to sea by the Amazon further north. At about 40 ^{o} S. the influence of the prevailing Westerlies and the rotation of the earth propel the current eastwards to merge with the cold West Wind Drift as the South Atlantic Current.

On reaching the west coast of Africa the current is diverted northwards as the cold Benguela Current (the counterpart of the Canaries Current). It brings the cold polar water of the West Wind Drift into tropical latitudes. Driven by the regular South-East Trade Winds, the Benguela Current surges equatorwards in a north-westerly direction to join the South Equatorial Current. This completes the circulation of the currents in the South Atlantic. Between the North and South Equatorial Currents is the east flowing Equatorial Counter Current.

THE CIRUCLATION (PACIFIC OCEAN)

The pattern of circulation in the Pacific is similar to that of the Atlantic except in modifications which can be expected from the greater size and the more open nature of the Pacific.

The North Equatorial Current flows westwards with a compensating Equatorial Counter Current running in the opposite direction. Due to the greater expense of Pacific and the absence of an obstructing land mass the volume of water is very much greater than that of the Atlantic equatorial current. The North-East Trade Winds blow the North Equatorial Current off the coasts of the Philippines and Formosa into the East China Sea as the Kuroshio or Kuro Siwo or Japan current. Its warm waters are carried polewards as the North Pacific Drift, keeping the ports of Alaskan coast ice-free in winter.

The cold Bering Current or Alaskan Current creeps southwards from the narrow Bering Strait and is joined by Okhotsk Current to meet the warm Japan Current as the Oyashio, off Hokkaido. The cold water eventually sinks beneath the warmer waters of the North Pacific Drift. Part of it drifts eastwards as the western U.S.A. and coalesces with the North Equatorial Current to complete the clock-wise circulation.

The current system of the South Pacific is the same as that of the South Atlantic. The South Equatorial Current, driven by the South-East Trade winds, flows southwards along the coast of Queensland as the East Australian Current, bringing warm equatorial waters into temperate waters. The current turns eastwards towards New Zealand under the full force of the Westerlies in the Tasman Sea and merges with part of the cold West Wind Drift as the South Pacific Current. Obstructed by the tip of southern Chile, the current turns northwards along the western coast of South America as the cold Humboldt or Peruvian Current.

The cold water chills any wind that blows on-shore so that the Chilean and Peruvian costs are practically rainless. The region is rich is microscopic marine plants and animals that attract huge shoals of fish. Consequently, millions of seabirds gather here to feed on the fish. Their droppings completely whiten the coastal cliffs and islands, forming thick deposits of guano, a valuable source of fertilizer. The Peruvian Current eventually links up with the South Equatorial Current and completes the cycle of currents in the South Pacific.

THE INDIAN OCEAN CIRCULATION

The currents of South Indian Ocean form a circuit. The Equatorial Current, turning southwards past Madagascar as the Agulhas or Mozambique Current merges with the West Wind Drift, flowing eastwards and turns equatorwards as the West Australian Current.

In the North Indian Ocean, there is a complete reversal of the direction of currents between summer and winter, due to the changes of monsoon winds. In summer from June to October, when the dominant wind is the South-West Monsoon, the currents are blown from a south-westerly direction as the South-West Monsoon Drift. This is reversed in winter; Monsoon blows the currents from the north-east as the North-East Monsoon Drift. The currents of the North Indian Ocean, demonstrate most convincingly the dominant effects of winds on the circulation of ocean currents.