General Knowledge Today

Geography-4: Oceanography Basics

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Important Prelims MCQ Topics

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Ocean Relief

Mega relief Basics

There are various structures on the surface of the earth that give rise to various kinds of Landscapes. On a large scale, the landscapes of can be divided into three orders of relief called **Megarelief**. The Megareliefs include the largest landscapes by scale, from enormous ocean basins and continents down to local hills, spurs, cliffs, valleys, gorges and river terraces. Accordingly, there are three orders of relief as follows:

First Order of Relief

The broadest category of land forms includes huge **continental platforms** and **ocean basins**.

Continental platforms are the masses of crust that exist above or near sea level, including the undersea continental shelves along the coastline. The ocean basins are entirely below the sea level. Approximately 71 percent of the earth is covered by water, with only about 29 percent of its surface appearing as continents and islands. The distribution of land and water in evidence today demonstrates a distinct water hemisphere and continental hemisphere.

Second Order of Relief

In the ocean basins, the second order of relief includes continental rises, slopes, abyssal plains, mid-ocean ridges, submarine canyons, and subduction trenches.

Continental features that are classified in the second order of relief include continental masses, mountain masses, plateaus, plains and lowlands. A few examples are the Himalayas, Alps, Rocky Mountains, Andes, Tibetan plateau, plateau of Anatolia (Turkey), Indo-Gangetic plains, Siberian lowlands and the plains of Mississippi. The great rock cores (shields) that form the heart of each continental mass arc of this order.

Third Order of Relief

The third order of relief includes individual peaks, cliffs, valleys, hills, spurs, gorges, sand dunes, caves, moraines, cirques, ripples, beaches, etc. These features are identified as local landscapes.

Ocean Relief Features

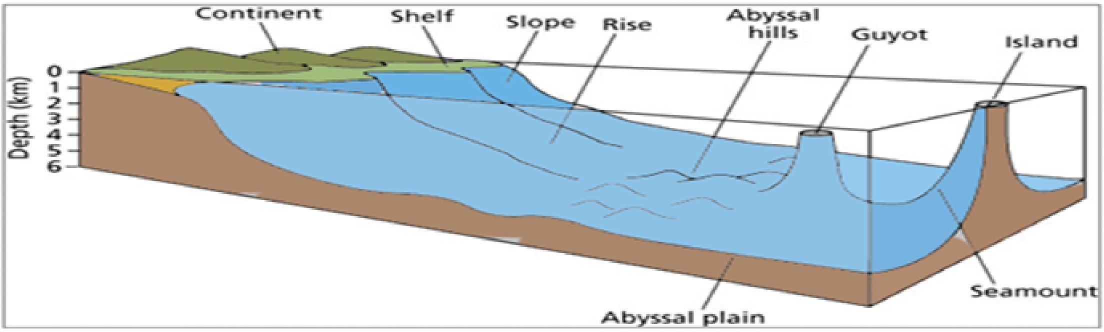
Surface area of earth is 510,072,000 km². It comprises of 148,940,000 km² land (29.2 %) & 361,132,000 km² water (70.8 %). Relief features of oceans are quite different from those of the continents. Please note that much of the oceanic crust is less than 60 million years old, while the great bulk of the continental crust is of Proterozoic age—mostly over 1 billion years old. Thus, the young age of the oceanic crust is quite remarkable.

Ocean is blue because water shows slightly blue color and that is because of the fact that it absorbs the Red photons of the light. Because the absorption which gives water its color is in the red end of the visible spectrum, one sees blue, the complementary color of red, when observing light that has passed through several meters of water.

Some Extreme Points in Oceans

- The deepest point in the ocean is the Mariana Trench, located in the Pacific Ocean near the Northern Mariana Islands.
- Its maximum depth has been estimated to be 10,971 meters (plus or minus 11 meters).
- British naval vessel, Challenger II surveyed the trench in 1951 and named the deepest part of the trench, the "Challenger Deep".
- In 1960, the Trieste successfully reached the bottom of the trench, manned by a crew of two men.

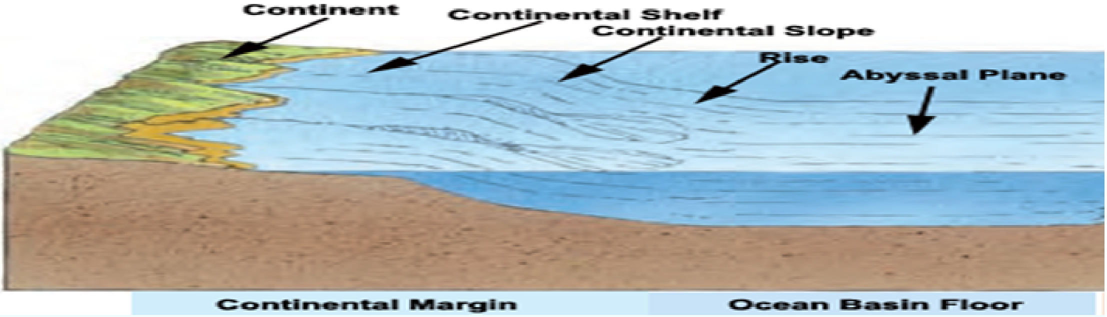
The ocean relief can be divided into various parts such as Continental Shelf, Continental Slope, Continental Rise or Foot, Deep Ocean basins, Abyssal plains & Abyssal Hills, Oceanic Trenches, Seamounts and Guyots.



Continental Shelf

Continental Shelf is the submerged edge of a continent. It is a gently sloping plain that extends into the Ocean. The typical gradient is less than 1°. Taken together, total area of the continental shelves is

18% of earth's dry land area. The width of the continental shelf varies considerably; *there are many places on earth where there is virtually no shelf at all*. The **largest continental shelf is the Siberian Shelf in the Arctic Ocean**, which stretches to 1,500 kilometers in width. The average width of continental shelves is about 80 km. The depth of the shelf also varies, but is generally limited to water shallower than 150 m. Continental shelf is made up of Granite rock overlain by the sediments. Because of the gentle slope, the continental shelf is influenced by the changes in the sea level.



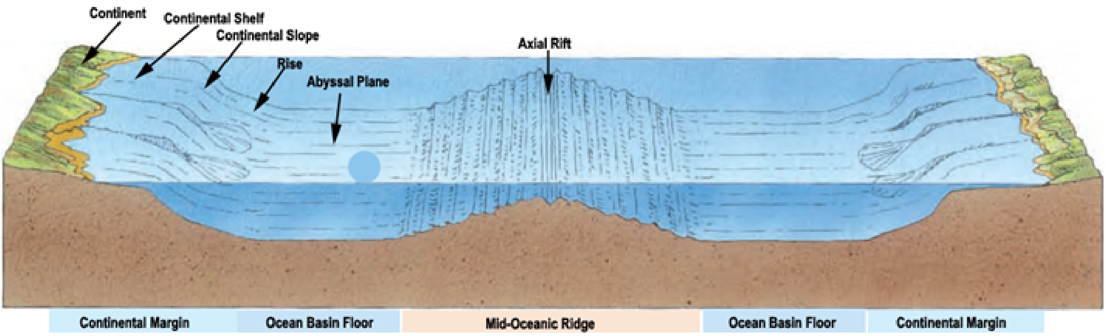
Continental Slope & Continental Rise

Continental slope is relatively steep descent from the shelf break to the deep sea floor. Inclination of the typical continental slope is around 4° and usually between 2° to 5°. Shelf break is almost constant all over the globe and is around 150 meters, except the Antarctica and Greenland continental slopes. The slope plunges down at least 1 kilometer and usually 2-3 kilometers.

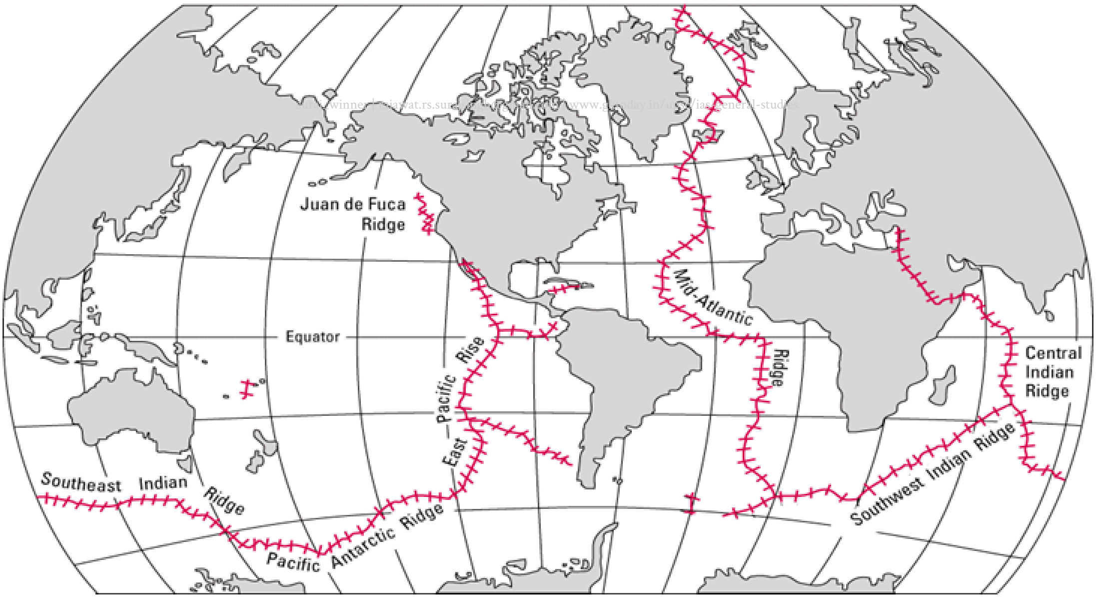
The Continental Rise connects the Continental slope to the deep sea or abyssal plain. Its width is around 100-1000 kilometers. Slope is gradual and around 1/8th of the continental slope. *The transition from continental to oceanic crust commonly occurs within the continental rise.*

Deep Ocean basin & Oceanic Ridges

Deep Ocean Basin is the lowest layer in the ocean. The sea floor is like a covering of sediments over a basalt rock which may be up to 5 kilometers thick. **Oceanic ridges** or **Mid-oceanic Ridges** refer to the boundary between the diverging plates. A mid-ocean ridge (MOR) refers to an underwater mountain system that consists of various mountain ranges (chains), typically having a valley known as a rift that runs along its spine, formed by plate tectonics. The midoceanic ridge of submarine hills divides the basin in about half. Precisely in the center of the ridge, at its highest point, is a narrow trenchlike feature called the **axial rift.** The location and form of this rift suggest that the crust is being pulled apart along the line of the rift.



The oceanic ridges present a mountainous chain of **young rocks** which stretch around 65000 kilometers, i.e. 1.5 times of the earth's circumference. *Oceanic ridges are made up of basalt rocks,*, are geologically active as the new magma constantly emerging onto the ocean floor accumulates in the crust at and near rifts along the ridge axes. The adjacent graphic shows distribution of some Oceanic Ridges around the world.



Location of the important ridges are as follows:

- **Aden Ridge:** Gulf of Aden and Indian Ocean along the south-eastern coastline of the Arabian Peninsula.
- **Explorer Ridge:** Located 240 km west of Vancouver Island, British Columbia, Canada.
- **Gorda Ridge:** off the coast of Oregon and northern California north of Cape Mendocino

- **Juan de Fuca Ridge:** off the coasts of the state of Washington in the United States
- **Cocos Ridge:** Its is a Volcanic hotspot. Also known as **Galapagos hotspot** located in East Pacific Ocean *responsible for the creation of the Galapagos Islands as well as three major seismic ridge systems. Carnegie, Cocos and Malpelso.*
- **Gakkel Ridge:** located in the Arctic Ocean between Greenland and Siberia, and has a length of about 1,800 kilometers. It is **slowest known spreading ridge** on the earth.
- **Pacific-Antarctic Ridge:** located in South Pacific Ocean
- **Southeast Indian Ridge:** It is located in the Indian Ocean and separates the Indo Ocean plate from the Antarctic plate.
- **Carlsberg Ridge:** Located in the Indian Ocean.

Abyssal Plain

Abyssal plain is flat, cold and sediment covered ocean floor. Abyssal plains are more extensive in Atlantic and Indian Oceans and less extensive in Pacific Ocean. Abyssal plain is found at an average depth between 3000 and 6000 meters. They are among the flattest, smoothest and least explored regions on earth.

Oceanic Trench

An elongated through or deep in the ocean floor is called ocean trench. It is more or less a U shaped valley. Most of world's trenches are in Pacific Ocean. Trenches are ***most active geological features*** on earth where great earthquakes are Tsunamis are born. Here is a brief info about important trenches:

Mariana Trench

Mariana Trench is the deepest part of the world's oceans. It is located in the western Pacific Ocean, east of the Mariana Islands. The trench is about 2,550 kilometers long but has a mean width of only 69 kilometers. The maximum known depth is 11.03 kilometers at the Vityaz-l Deep and about 10 91 kilometers at the Challenger Deep.

Tonga Trench

Tonga Trench us located in South Pacific Ocean and is second deepest trench. Its deepest point is called Horizon Deep. It is Steepest Trench of the World.

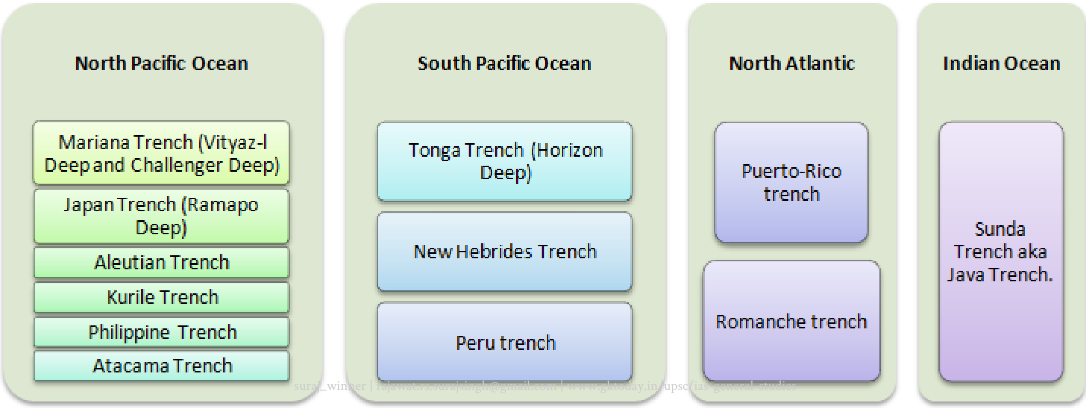
Factbox: Tonga Trench and Apollo 13

Apollo 13 was the third Apollo mission which was launched to land on the Moon. It was successfully launched toward the Moon, but the landing had to be aborted after an oxygen tank ruptured. It was launched on April 11, 1970 and subsequently failed. Its lunar module re-entered earth's surface on April 17. 1970 and was targeted over the pacific Ocean to reduce the contamination from the Radioisotope Thermoelectric Generator (RTG) on board, which would have provided energy to the mission. This

RTG was landed in the Tonga Trench. The RTG will remain active for next 2000 years. It has 3.9 kilogram of radioactive plutonium.

Puerto Rico Trench

Puerto Rico Trench is located on the boundary between the Caribbean Sea and the Atlantic Ocean. The trench is 800 kilometers long and has a maximum depth of 8,605 meters at Milwaukee Deep. which is the deepest point in the Atlantic Ocean.



Seamounts & Guyots

Seamounts are elliptical projections from the sea floor which look like mountains and have a steep slope of around 22° to 24°.Half of the world's total seamounts arc in Pacific Ocean. Guyots are basically inactive volcanoes which are flat topped. Some of them are tall enough to approach or even penetrate the sea surface. Guyots are confined to Central Pacific Ocean.

Rift valleys

A rift valley is linear-shaped lowland between highlands or mountain ranges created by the action of a geologic rift or fault in opposite or parallel. The result is the formation of a long steep sided, flat floored valley. **World's largest Fresh water lakes are typical rift valleys.** Examples are Lake Baikal in Siberia, Lake Tanganyika, Lake Superior, Lake Vostok, Lake Nipissing and Lake Timiskaming. **Jordan Rift Valley**, which is lowest land elevation on earth is located in the Dead Sea and is 760 meters below the surface of the Mediterranean Sea. **Gulf of Aqaba** in the Red Sea is also a rift valley.

Factbox: Important Lakes in Rift Valleys

Lake Baikal

Lake Baikal, also known as "Pearl of Siberia" is located in Siberia and is second most voluminous lake in the world after the Caspian Sea. It is also world's oldest and deepest lake. It's a Rift valley, created by the Baikal Rift Zone, and a World Heritage site declared in 1996. Lake Baikal is home to Buryats , the largest ethnic minority group and a tribe in Siberia. It was referred as North Sea by ancient Chinese writers.

Lake Tanganyika

After lake Baikal, Lake Tanganyika is second deepest lake in the world. It is world's longest Lake spanning in 4 countries of Africa viz. Burundi, Tanzania, Congo and Zambia. This lake is a Rift Valley and largest rift lake in Africa.

Lake Superior

Lake Superior is largest lake of North America, shared by Canada as well as USA. It is largest freshwater lake in the world by surface area if lake Michigan and lake Huron are NOT considered one.

Lake Vostok

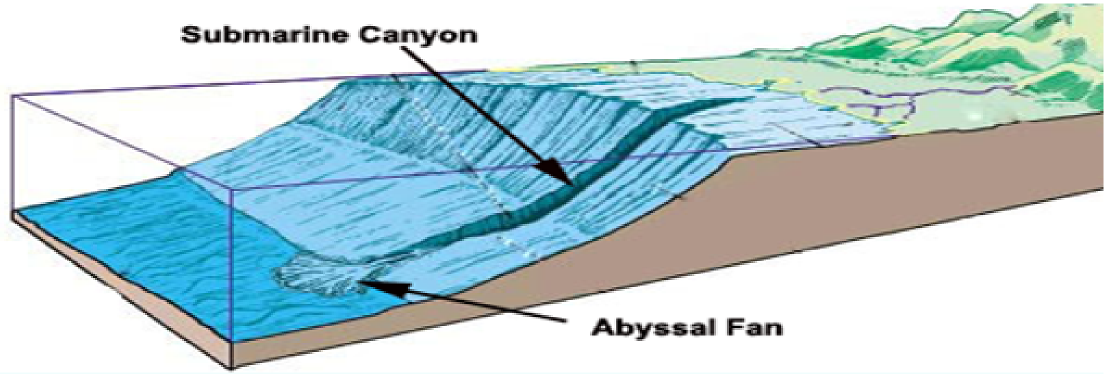
Lake Vostok is in Antarctica and is a Sub Glacial lake. It is located below the Vostok Station of Russia in Antarctica.

Lake Nipissing

Lake Nipissing is located in Canada. It's one of the shallowest lakes of Canada

Abyssal Fans

Abyssal fans are also known as **deep-sea fans**, **underwater deltas,** and **submarine fans**. They are delta like structures formed at the deep sea surfaces. Abyssal plain is found at the depths between 3000 and 6000 meters. Abyssal plains cover more than 50% of Earth's total surface. They are considered to be major reservoir of biodiversity.



Archipelago

Archipelago refers to a cluster of islands which are formed tectonically. This term was initially used for Aegean Islands located in the Aegean Sea between Greece and Turkey. Indonesia is often referred to as the world's largest archipelago; however, this means that it is largest by area and not by number of islands. Indonesia has 17,500 islands which span more than 5000 km². World's largest archipelago by number of Islands is Archipelago Sea which is located Baltic Sea between the Gulf of Bothnia and the Gulf of Finland. It has 50,000 Islands. Top 5 archipelagos in the world by number of Islands are as follows:

- Archipelago Sea (Finland) 50,000
- Canadian Arctic Archipelago 36.563
- Stockholm Archipelago 24,000
- Indonesian Archipelago 17.508
- Philippine Archipelago 7.107

Lagoon

Lagoon is a shallow body of sea water or brackish water **separated from the sea by some form of barrier**. The biggest lagoon in the world is located in New Caledonia, in southwest pacific. In India, **Chilika Lake** in Orissa and the **Vembanad Lake** in Kerala are both connected to the Bay of Bengal and the Arabian Sea respectively through a narrow channel and they are **typical lagoons**.

Coral Reefs

Coral reefs, which are also called as "rainforests of the sea", are underwater reefs made by calcium carbonate secreted by Corals. Coral is the hard exoskeleton of the polyps. Coral Reefs grow best in **warm, shallow, clear, sunny and agitated** waters.

Coral reefs are some of the most diverse ecosystems on earth which despite of covering less than 10% of world ocean surface (284,300 km²) provide home to 25% of marine species including fishes, molluscs etc. Coral Reefs are very fragile ecosystem and are **susceptible to "Surface Temperature"** of the oceans. They are threatened by the climate change, ocean acidification, **blast fishing**, **cyanide fishing** for aquarium fish, overuse of reef resources, and harmful land-use practices.

Some Observations on Coral Reliefs

- The Indian Ocean and Pacific Ocean region including the **Red Sea, Indian Ocean, Southeast Asia and the Pacific** account for 91.9% or total Coral reefs in the world.
- Southeast Asia accounts for 32.3%, while the Pacific including Australia accounts for 40.8%. **Atlantic and Caribbean coral reefs only account for** 7.6%.
- **Largest Coral reef in the world is Great Barrier Reef.** It is located in the Coral Sea, off the coast of Queensland in north-east Australia. It is composed of over 2,900 individual reefs and 900 islands stretching for over 2,600 kilometers. This reef can be seen from outer space and is the world's biggest single structure made by living organisms. It is a World Heritage Site (1981). It is also a state icon of Queensland, made by Queensland National Trust. A large part is protected by the Great Barrier Reef Marine Park, established by Government of

Australia through Great Barrier Reef Marine Park Act 1975.

- **Belize Barrier Reef is world's second largest Coral Reef** which is a part of 900 kilometer Mesoamerican Barrier Reef System. It was described by Charles Darwin in 1842 as "the most remarkable reef in the West Indies".
- ***Pulley Ridge is*** *located off the coast of Florida, United States. It is deepest photosynthetic coral reef known so far.*
- Raja Ampat Islands, largest marine national park in Indonesia are located in Indonesia and New Guinea and comprise 1,500 small islands .***It is known for highest recorded marine biodiversity on Earth***. It makes the Coral Triangle which is a triangular shaped area of the tropical marine waters of Indonesia, Malaysia, Papua New Guinea, Philippines, Solomon Islands and Timor-Leste. These waters contain at least 500 species of reef-building corals in each ecoregion. Coral Triangle as well as Raja Ampat Islands is considered to be the global epicenters of marine biodiversity. INWF considers the region as a top priority for marine conservation and has launched the Coral Triangle Program in 2007

Beach

Beach is the shoreline of an ocean, sea or lake which consists of loose particles such as sand, gravel. pebbles etc. They are formed as a result of wave action by which waves or currents move sand or other loose sediments.

Cox's Bazaar

Cox's Bazaar sandy beach in Bangladesh's Chittagong is considered to be world's longest natural sandy beach. It has an unbroken length of 120 kilometers.

Marina Beach

Marina Beach is located in India's Chennai and is one of the largest beaches of India.

Ocean Sediment

Ocean sediments are particles and fragments of dirt, dust, and other debris that have settled out of the water and accumulated on the ocean floor. *The crucial importance of marine sediments is that they reveal much about Earth's history.* Marine sediments provide clues to past climates, movements of the ocean floor, ocean circulation patterns, and nutrient supplies for marine organisms.

Marine sediments can also be helpful in ascertaining the timing of major extinctions, global climate change, and the movement of plates.

More than half of the rocks exposed on the continents are sedimentary rocks deposited in ancient ocean environments and uplifted onto land by plate tectonic processes. Even the tallest mountains on the continents far from any ocean contain marine fossils, which indicate that these rocks originated on the ocean floor in the geologic past. Mount Everest consists of limestone, which is a type of rock that originated as sea floor deposits.

Over time, sediments can become lithified and turned to rock and form **sedimentary rock**. Particles of sediment come from worn pieces of rocks, as well as living organisms, minerals dissolved in water, and outer space.

There are several types of marine sediments such as:

- Lithogenous sediment
- Biogenous Sediment
- Hydrogenous sediment

Lithogenous Sediment

This type of sediment is derived from pre-existing rock material that originates on the continents or islands from erosion, volcanic eruptions, or blown dust. The another term used for lithogenous sediment is **terrigenous** sediment. Obviously, the origin of Lithogenous Sediment begins as rocks on continents or islands. Over time, weathering agents such as water, temperature extremes, and chemical effects break rocks into smaller pieces.

Neritic Deposits versus Pelagic Deposits

Marine sedimentary deposits can also be categorized as either neritic or pelagic. Neritic deposits are found on continental shelves and in shallow water near islands; these deposits are generally coarse grained. Alternatively, pelagic deposits are found in the deep ocean basins and are typically fine grained.

When rocks are in smaller pieces, they can be more easily eroded and transported. This eroded material is the basic component of which all lithogenous sediment is composed. Eroded material from the continents is carried to the oceans by streams, wind, glaciers, and gravity. The transported sediment can be deposited in many environments, including bays or lagoons near the ocean, as deltas at the mouths of rivers, along beaches at the shoreline, or further offshore across the continental margin. It can also be carried beyond the continental margin to the deep-ocean basin by turbidity currents. The greatest quantity of lithogenous material is found around the margins of the continents, where it is constantly moved by high-energy currents along the shoreline and in deeper turbidity currents

The majority of lithogenous deposits such as beach sands are composed primarily of quartz.

Biogenous Sediment / Ooze

Biogenous sediment is derived from the remains of hard parts of once living organisms. Origin of Biogenous Sediment Biogenous sediment begins as the hard parts (shells, bones, and teeth) of living organisms ranging from minute algae and protozoans to fish and whales. When organisms that produce hard parts die, their remains settle onto the ocean floor and can accumulate as biogenous sediment. Biogenous sediment can be classified as either macroscopic or microscopic. Macroscopic biogenous sediment is large enough to be seen without the aid of a microscope and includes shells, bones, and teeth of large organisms.

Ooze

The microscopic organisms produce tiny shells called **tests** that begin to sink after the organisms die and continually rain down in great numbers onto the ocean floor. These microscopic tests can accumulate on the deep ocean floor and form deposits called ooze. Ooze resembles very fine grained, mushy material like mud. The organisms that contribute to biogenous sediment are chiefly algae and protozoans. Algae are primarily aquatic, eukaryotic, photosynthetic organisms, ranging in size from microscopic single cells to large organisms like giant kelp. Protozoans are any of a large group of single-celled, eukaryotic, usually microscopic organisms that are generally not photosynthetic.

Opal

The two most common chemical compounds in biogenous sediment are calcium carbonate (which forms the mineral calcite) and silica. Silica is often chemically combined with water to produce the hydrated form of silica, which is called **opal**.

Diatoms and Diatomaceous Earth

Most of the silica in biogenous ooze comes from microscopic algae called diatoms and protozoans called radiolarians. Because diatoms photosynthesize, they need strong sunlight and are found only within the upper, sunlit surface waters of the ocean. Most diatoms are free floating, or planktonic. The living organism builds a glass greenhouse out of silica as a protective covering and lives inside. Where diatoms are abundant at the ocean surface, thick deposits of diatom rich ooze can accumulate below on the ocean floor. When this ooze lithified, it becomes **diatomaceous earth**, which is a lightweight white rock composed of diatom tests and clay.

Hydrogenous Sediment

Hydrogenous sediment is derived from the dissolved material in water. Chemical reactions within seawater cause certain minerals to precipitate. *Precipitation usually occurs when there is a change in conditions, such as a change in temperature or pressure or the addition of chemically active fluids.*

Manganese Nodules

Manganese nodules are rounded, hard lumps of manganese plus iron plus other metals typically 5 cms to 20 cms in diameter. When cut in half, they often reveal a layered structure formed by precipitation around a central nucleation object, which might be a piece of lithogenous sediment, coral, volcanic rock, a fish bone, or a shark s tooth.

Manganese nodules are found on the deep-ocean floor. The major components of these nodules are **manganese dioxide** (around 30% by weight) and **iron oxide** (around 20%). Other accessory metals present in manganese nodules include copper, nickel and cobalt. Although the concentration of these accessory metals is usually less than 1%, they can exceed 2% by weight, which may make them attractive exploration targets in the future.

Phosphates

Phosphates occur abundantly as coatings on rocks and as nodules on the continental shelf and on banks at shallow depths. Concentrations of phosphates in such deposits indicate abundant biological activity in surface water above where they accumulate. Because phosphates are valuable as fertilizers, ancient marine phosphate deposits that have been uplifted onto land are extensively mined to supply agricultural needs.

Carbonates

The two most important carbonate minerals in marine sediment are **aragonite and calcite**. Both

are composed of calcium carbonate but aragonite has a different crystalline structure that is less stable and changes into calcite over time. Most carbonate deposits are biogenous in origin. However, hydrogenous carbonate deposits can precipitate directly from seawater in tropical climates to form aragonite crystals

Metal Sulfides

Deposits of *metal Sulfides are associated with hydrothermal vents and black smokers along the mid-ocean ridge*. These deposits contain iron, nickel, copper, zinc, silver, and other metals in varying proportions. Transported away from the mid-ocean ridge by sea floor spreading, these deposits can be found **throughout the ocean floor** and can even be uplifted onto continents.

FactBox: Some important Facts on Diatoms

Diatoms are microscopic single-celled **photosynthetic** organisms. Each one lives inside a protective silica test, most of which contain two halves that fit together very much similar to a shoebox and its lid. The fossil record indicates that diatoms have been on Earth since the Jurassic Period (180 million years ago), and at least 70,000 species of diatoms have been identified.

The tests of diatoms are exquisitely ornamented with holes, ribs, and radiating spines **unique to individual species**.

Diatoms live for a few days to as much as a week, can reproduce sexually or asexually, and occur individually or linked together into long communities. They are found in great abundance floating in the ocean and in certain freshwater lakes but can also be found in many diverse environments, such as on the undersides of polar ice, on the skins of whales, in soil, in thermal springs, and even on brick walls.

When marine diatoms die, their tests rain down and accumulate on the sea floor as **siliceous ooze**. Hardened deposits of siliceous ooze, called diatomaceous earth, can be as much as 900 meters thick. Diatomaceous earth consists of billions of minute silica tests and *has many unusual properties* such as :

- It is lightweight and has an **inert chemical composition**.
- It is **resistant to high temperatures**, and
- It has excellent **filtering properties**.

Due these properties, diatomaceous earth is used to produce a variety of common products such as **filters**, **mild abrasives** (in toothpaste, facial scrubs, matches, and household cleaning and polishing compounds) **absorbents** (for chemical spills, in cat litter, and as a soil conditioner) **chemical carriers** (in pharmaceuticals, paint, and even dynamite) Other products from diatomaceous earth include **optical-quality glass** (because of the pure silica content of diatoms) and **space shuttle tiles** (because they are lightweight and provide good insulation). Diatomaceous earth is also used as an **additive in concrete**, a **filler in tires**, an **anticaking agent**, a **natural pesticide**, and as building stone in the construction of houses.

Apart from this, each living diatom contains a tiny droplet of oil. When diatoms die, their tests containing droplets of oil accumulate on the sea floor and thus they are the **beginnings of petroleum deposits**.

Resources from Ocean Sediments

Ocean beds are rich in potential mineral and organic resources. Much of these resources, however, are not easily accessible, so their recovery involves technological challenges and high cost.

Energy

The main energy resources associated with marine sediments are petroleum and gas hydrates. The ancient remains of microscopic organisms, buried within marine sediments before they could decompose, are the source of today s petroleum (oil and natural gas) deposits. Petroleum products account for 95% of the economic value of the ocean beds. This mainly includes the oil produced from offshore regions. Today major offshore reserves exist in the Persian Gulf, in the Gulf of Mexico, off

Southern California and in the North Sea.

Gas hydrates are unusually compact chemical structures made of water and natural gas. They form only when high pressures squeeze chilled water and gas molecules into an icelike solid. Although hydrates can contain a variety of gases including carbon dioxide, hydrogen sulfide, and larger hydrocarbons such as ethane and propane; methane hydrates are by far the most common hydrates in nature.

Gas hydrates occur beneath ***Arctic permafrost areas on land and under the ocean floor***, where they were discovered in 1976. In deep-ocean sediments, where pressures are high and temperatures are low, water and natural gas combine in such a way that the gas is trapped inside a lattice like cage of water molecules.

Sand and Gravel

The offshore sand and gravel industry is second in economic value only to the petroleum industry. These include the rock fragments that are washed out to sea and shells of marine organisms, is mined by offshore barges using a suction dredge. This material is primarily used as aggregate in concrete, as a fill material in grading projects, and on recreational beaches.

Evaporative Salts

When seawater evaporates, the salts increase in concentration until they can no longer remain dissolved, so they precipitate out of solution and form salt deposits. The most economically useful salts are gypsum and halite i.e, common salt.

Manganese Nodules and Crusts

Manganese nodules are rounded, hard, golf- to tennis-ball-sized lumps of metals that contain significant concentrations of manganese, iron, and smaller concentrations of copper, nickel, and cobalt, all of which have a variety of economic uses.

Ocean Temperature

Trends in Ocean Temperature

The temperature of the oceanic water is important for **phytoplanktons as well as zooplanktons**. The temperature of sea water also affects the *climate of coastal lands and plants and animals*. The study of both, surface and subsurface temperature of sea water is thus significant.

Measurement of Temperature

Standard type of thermometer is used to measure the surface temperature while reversing thermometers and **thermograph**s are used to measure the subsurface temperature. These thermometers record the temperature up to the accuracy of ±O.02° centigrade.

Layers of Temperature in tropics

Oceans absorb more than 80% of the solar radiation and water which has highest specific heat is the remarkable capacity of storing the heat. The *uppermost 10% of the oceans has more heat* than the entire atmosphere of earth!

With respect to temperature, there are three layers in the oceans from surface to the bottom in the tropics as follows:

- The first layer represents the top-layer of warm, oceanic water and is 500m thick with temperature ranging between 20° and 25°C. This layer is present within the tropics throughout the year but it develops in mid· latitudes only during summer.
- The **thermocline layer** represents vertical zone of oceanic water below the first layer and is characterized ***by rapid rate of decrease of temperature with increasing depth***,
- The third layer is very cold and extends upto the deep ocean floor. The *polar areas have only one layer of cold water from surface (sea level) to the deep ocean floor*.

The radiant energy transmitted from the photosphere of the sun in the form of electromagnetic short waves and received at the ocean surface is called **insolation**. Besides, 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. The mechanism of the heating and cooling of ocean water differs from the mechanism on land because besides *horizontal and vertical movements of water, the evaporation is most active over the oceans.*

Daily Range of Temperature

The difference of maximum and minimum temperature of a day (24 hours) is known as daily range of temperature. The daily range of temperature of surface water of the oceans is **almost insignificant** as it is around 1°C only. The daily range of temperature is usually 0.3°C in the low latitudes and 0.2° to 0.3°C in high latitudes.

The diurnal range depends on the

- Conditions of sky (cloudy or clear sky),
- Stability or instability of air and
- Stratification of seawater.

The heating and cooling of ocean water is rapid under clear sky (cloudless) and hence the diurnal range of temperature becomes a bit higher than under overcast sky and strong air circulation. The high density of water below surface water causes very little transfer of heat through conduction and hence the diurnal range of temperature becomes low.

Annual Range of Temperature

The maximum and minimum annual temperatures of ocean water are recorded in August and February respectively in the northern hemisphere. Usually, the average annual range of temperature of ocean water is -12°C but there is a lot of regional variation which is due to regional variation in insolation, nature of seas, prevailing winds, location of seas etc.

Annual range of temperature is higher in the enclosed seas than in the open sea (Baltic Sea records annual range of temperature of 4.4°C or 40°F). The size of the oceans and the seas also affects annual range of temperature e.g., *bigger the size, lower the annual range and vice versa*. The Atlantic Ocean records relatively higher annual range of temperature than the Pacific Ocean.

Distribution Pattern of Temperature

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

- Horizontal distribution (temperature of surface water) and
- Vertical distribution (from surface water to the bottom).

Since the ocean has three dimensional shape, 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.

Latitudes

The temperature of surface water decreases from **equator toward the poles** because the sun's rays become more and more slanting and thus the **amount of insolation decreases pole ward** accordingly. The temperature of surface water between 40°N and 40°S is lower than air temperature but it becomes higher than air temperature between 40°Latitude and the poles in both the hemispheres.

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 northern hemisphere and water in the southern hemisphere. As far as surface temperature is concerned, it has the following implications:

- *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 northern hemisphere than the southern hemisphere.
- The isotherms are not regular and do not follow latitudes in the northern hemisphere because of the existence of both warm and cold landmasses whereas they (isotherms) are regular and follow latitudes in the southern hemisphere because of the dominance of water.

The temperature in the enclosed seas in low latitudes becomes higher because of the influence of surrounding land areas than the open seas e.g., the average annual temperature of surface water at the equator is 26.7°C whereas it is 37.8°C in the Red Sea and 34.4°C (94°F) in the Persian Gulf.

Prevailing wind

Wind direction largely affects the distribution of temperature of ocean water. The winds blowing from the land towards the oceans and seas (i.e. 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.

Ocean currents

Surface temperatures of the oceans are controlled by warm and cold currents. Warm currents raise the temperature of the affected areas whereas cool currents lower down the temperature.

Other factors

Other factors include the following:

- Submarine ridges
- Local weather conditions such as storms, cyclones, hurricanes, fog, cloudiness, evaporation and condensation
- **Location and Shape of area:** The enclosed seas in the low latitudes record relatively higher temperature than the open seas whereas the enclosed seas have lower temperature than the open seas in the high latitudes.

Horizontal Distribution of Temperature

Average temperature of surface water of the oceans is 26.7°C and the temperature gradually decreases from equator towards the poles. The rate of decrease of temperature with increasing latitudes is generally 0.5°C per latitude. The average temperatures become 22°C at 20° N and S latitudes, 14°C at 40° N and S latitude, and 0°C near the poles. I have already mentioned above that the oceans in the northern hemisphere record relatively higher average temperature than in the southern hemisphere. Please note that the *highest temperature is not recorded at the equator rather it is a bit north of it.*

Also we should note that the average annual temperature of all the oceans is 17.2°C. The average annual temperatures for the northern and southern hemispheres are 19.4°C and 16.1°C respectively. The variation of temperatures in the northern and southern hemispheres is because of unequal distribution of land and water as Northern hemisphere is made up of more land, while the southern hemisphere is made up of more oceans.

In Northern Atlantic, there is a **very low decrease of temperature** with increasing latitudes towards north. This is because of the Gulf Stream currents which are warm currents. However, in southern Atlantic, the decrease of temperature with increasing latitude is more pronounced. The table shows the variations of three major oceans:

Latitudes	Pacific Ocean	Atlantic Ocean	Indian Ocean
00-10°	26	25.2	27
10-20°	25	23.2	26.9
20-30°	21.5	21.2	22.5
30-40°	17	17	17
40-50°	11.1	9	8.7
50-60°	5	1.8	1.6
60-70°	-1.3	-1.3	-1.5

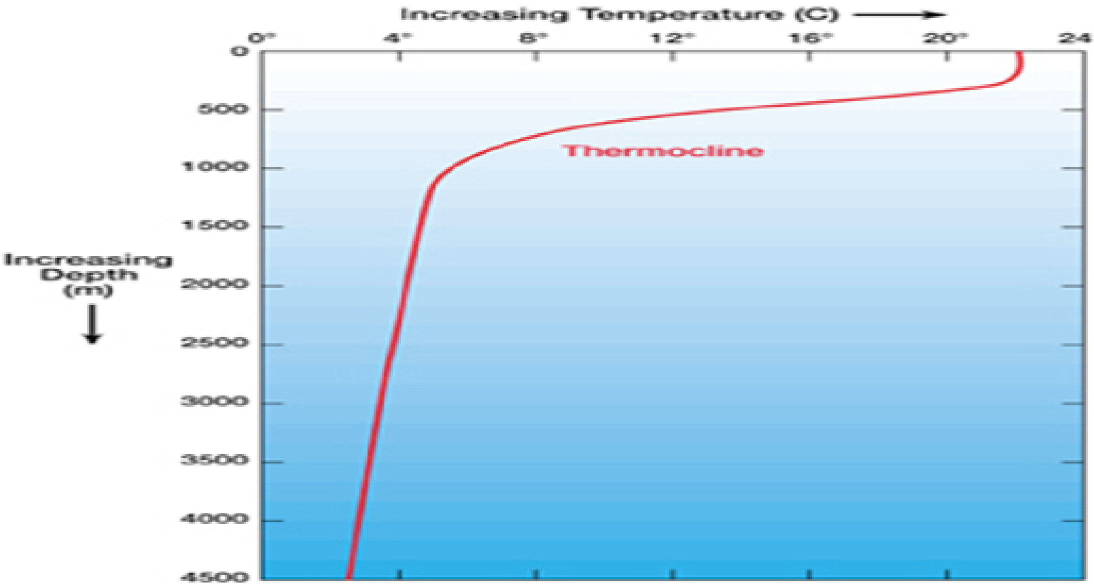
Vertical Distribution of Temperature

The maximum temperature of the oceans is always on the surface because it directly receives the

insolation. The heat is transmitted to the lower sections of the oceans through the mechanism of **conduction**.

Solar rays very effectively penetrate up to 20m depth and they seldom go beyond 200m depth. Consequently, the temperature decreases from the ocean surface with increasing depth but the ***rate of decrease of temperature with increasing depth is not uniform everywhere***. The temperature falls very rapidly up to the depth of 200m and thereafter the rate of decrease of temperature is slowed down.

On this basis, oceans are vertically divided into three zones as follows:



Photic Zone or Euphotic Zone

This is the upper layer of the ocean. The temperature is relatively constant and is 100 meters deep.

Thermocline

Thermocline lies between 100-1000 meters. There is a steep fall in the temperature. The following graph shows the thermocline.

Deep Zone

Below 1000 meters is the deep zone. Here, the temperature is near zero °C. Please note that near bottom, the temperature of water never goes to 0°C. It is always 2-3°C.

Important Observations

- Sea temperature decreases with increasing depth but the rate of decrease of temperature is not uniform.
- The change in sea temperature below the depth of 1000m is negligible. The maximum change in temperature is between 100-1000 meters which is called Thermocline or Pycnocline.
- Diurnal and annual ranges of temperature cease after a depth of 30 feet and 600 feet respectively.
- The rate of decrease of temperature with increasing depth from equator towards the poles is not uniform.

Though, the surface temperature of the oceans decreases from equator to the poles, the **temperature at the ocean bottom is uniform at all latitudes.** However, some studies have shown that the ***coldest bottom temperatures, just below — 0.25°C, occur at 60-70°S, near the Antarctic***

continent.

Salinity of Ocean Water

Salinity of the ocean water is between 3.3-3.7 percent. The maximum amount of salt is common salt i.e. Sodium Chloride, which is *followed by Magnesium Chloride*. The major salts are as follows:

Salt	‰ (parts per thousand)
Sodium Chloride	2.6
Magnesium Chloride	0.3
Magnesium Sulphate	0.2
Calcium Sulphate	0.1
Potassium Chloride	0.1
Potassium Bromide	0.001
Others	0.001

Most of the salinity of the sea comes from the dissolved material that originates from land and was carried by the rain, running water, ground water, wind, sea waves, glaciers etc. Some of the salts come from the deeper layers of earth. Volcanic lava, dead organic matters also contribute in the Ocean salinity. The salinity of the ocean water depends upon the following:

Evaporation

Higher the rate of evaporation, higher is salinity. The Highest evaporation has been recorded along the tropic of Cancer and that is one of the reasons that region of Red Sea and Persian Gulf has one of the highest salinity. Another reason is that enclosed seas tend to have more salinity in their water.

Temperature

There is a direct relationship between ocean temperature and salinity. So the warmer parts are more saline and frigid parts are less saline.

Precipitation

Precipitation is inversely related to salinity. Higher is the precipitation, lower is the proportion of salinity. The equatorial region records highest rainfall and that it is why it has low salinity in comparison to those which are near to tropics.

Influx of Freshwater

Low salinity will be found at the mouth of rivers. This salinity is minimum in the raining season.

Atmospheric Pressure

High pressure areas have high salinity and vice versa.

Circulation of Ocean water

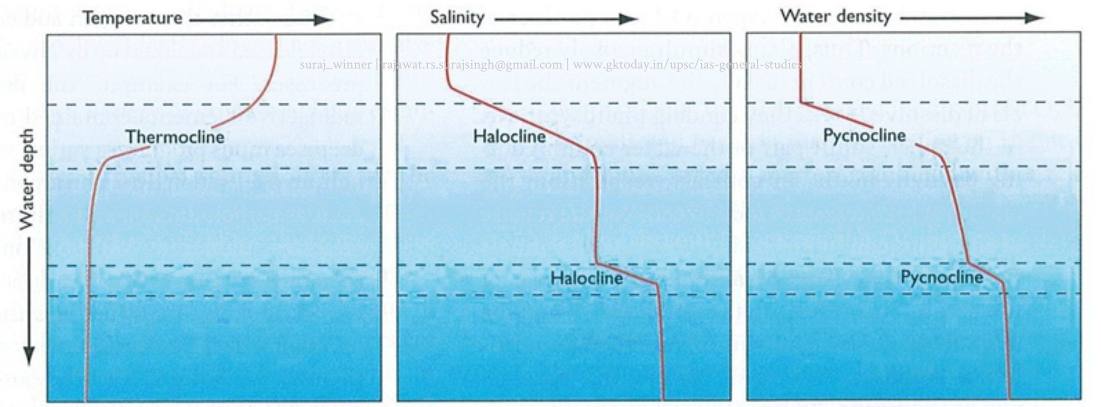
Ocean currents play a major role in distribution of salinity.

Horizontal Distribution of Salinity of Ocean Water

As a general rule, the salinity of the oceans decreases on both sides from the tropic of Cancer. This is attributed to the high occurrence of precipitation on equator. Highest salinity of the seawater has been recorded between 20°N to 40°N. The average salinity of the Northern and Southern hemisphere is 3.5 and 3.4 % respectively. This also because of the fact that the Northern Hemisphere is land dominated.

Vertical Distribution of Salinity of Ocean Water

There is no definite trend in the vertical distribution of salinity in the oceans, so there are no generalizations. However, it has been noted that **the salinity of the ocean increases with increasing depth in the higher latitudes and polar areas**. In the middle latitudes also, the same trends is seen but ONLY up to a depth of 370 meters after that it decreases with increasing depth.



Ocean Currents

Ocean current is the general movement of a mass of oceanic water in a definite direction, which is more or less similar to water streams flowing on the land surface of the earth. Ocean currents are most powerful of all the dynamics of oceanic waters because these drive oceanic waters for thousands of kilometers away.

Origin of Ocean Currents

The currents in the oceans are originated due to combined effects of several internal as well as external factors, which control the origin and other characteristics of ocean current. They are related to different characteristics of ocean waters, rotational mechanism of the earth, external factors or atmospheric factors, topographic characteristics of the coasts and ocean basins.

	Factors that cause Ocean Currents
1	Rotation of Earth
2	Coriolis Force
3	Pressure Gradient
4	Temperature Variations
5	Salinity Differences
6	Atmopsheric Pressure
7	Winds
8	Evaporation
9	Precipitation
10	Tides

Each of the above factors can also significantly affect / modify the ocean currents.

Difference between Drifts, Current and Streams

On the basis of velocity, dimension and direction, they can be divided into drifts, currents and streams. *The forward movement of surface water of the oceans under the influence of prevailing winds is called drift whereas the ocean current involves the movement of Oceanic water in a definite direction with greater velocity.* Ocean stream involves movement of larger mass of ocean water like big rivers of the continent in a definite direction with greater velocity than the drifts and currents such as in Gulf Stream.

Difference between Warm Currents and Cold Currents

Ocean currents are divided on the basis of temperature into *warm currents* and *cold currents*. Those currents that flow from the Equator towards the poles are warmer than the surrounding water and so *they are called warm currents*. The ocean currents that flow from the *polar areas towards the Equator are cooler compared to the surrounding water, so they are called cold currents*. The actual difference in temperature of warm and cold currents is only a few degrees.

- *The cold currents are usually found on the west coast of the continents in the low and middle latitudes in both the hemispheres and on the east coast in the middle latitudes in the Northern Hemisphere.*
- *The warm currents are usually observed on the east coast of the continents in the low and middle latitudes in both the hemispheres. In the Northern Hemisphere they are found on the west coasts of the continents in the high latitudes.*

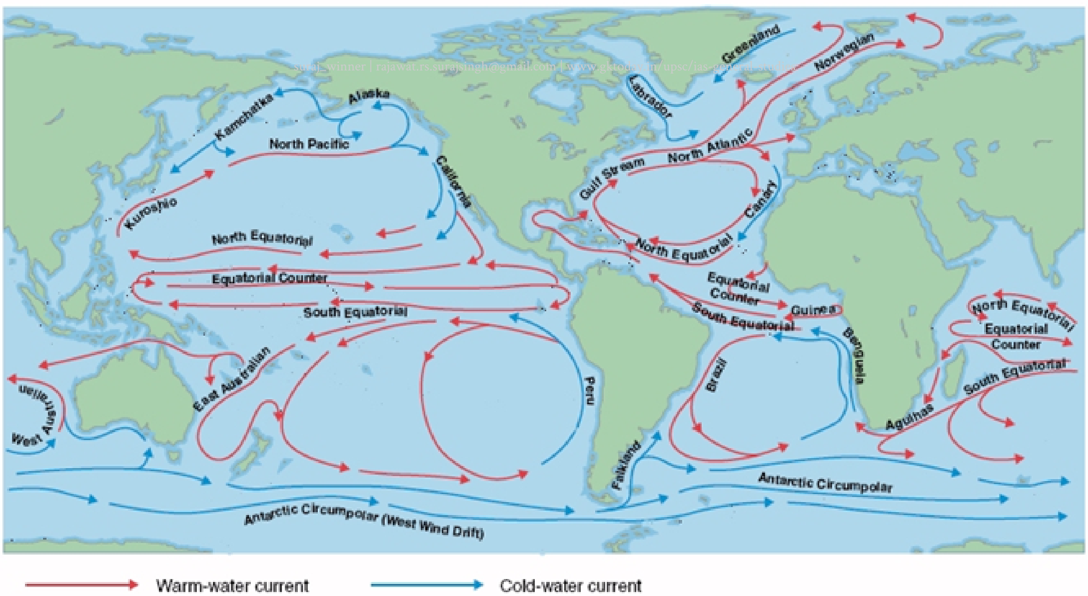
Difference between Surface Currents and Deep Currents

Ocean currents can also be divided into **Surface Currents** and **Deep Currents**. Surface currents affect surface water above the **pycnocline** (<10% of ocean water). These currents are primarily driven by major wind belts. The Deep currents affect deep water below pycnocline (90% of ocean water) and are primarily driven by **density differences**. The deep currents are larger and slower than surface currents.

Ekman Transport

The stress of wind blowing across the sea causes a surface layer of water to move. Due to the low viscosity of water, this stress is not directly communicated to the ocean interior, but is balanced by the Coriolis force within a relatively thin surface layer, 10-200m thick. **This layer is called the Ekman layer and the motion of this layer is called the Ekman transport**. Because of the deflection by the Coriolis force, the Ekman transport is not in the direction of the wind, but is 90° to the right in the Northern Hemisphere and 90° toward the left in the Southern Hemisphere. The amount of water flowing in this layer depends only upon the wind and the Coriolis force and is independent of the depth of the Ekman layer and the viscosity of the water.

The major surface currents are shown below:



Currents of Atlantic Ocean

Important Currents of the Atlantic Ocean are as follows:

North Equatorial Current (warm)

North equatorial current is a significant Pacific and Atlantic Ocean current that flows east-to-west between about 10° north and 20° north. This current is generated because of upwelling of cold-water near the west coast of Africa. This warm current is also pushed westward by the cold Canary current.

On an average, the north equatorial warm current flows from east to west but this saline current is deflected northward when it crosses the mid-Atlantic Ridge near 15°N latitude. It again turns southward after crossing over the ridge. This current, after being obstructed by the land barrier of the east coast of Brazil, is bifurcated into two branches viz. Antilles current and Caribbean current. The Antilles current is diverted northward and flows to the east of West Indies islands, and helps in the formation of Sargass Sea eddy while the second branch known as the Caribbean current enters the Gulf of Mexico and becomes Gulf Stream.

South Equatorial Current (warm)

The South Equatorial Current is a significant Pacific, Atlantic, and Indian Ocean current that flows east-to-west between the equator and about 20 degrees south. In the Pacific and Atlantic Oceans, it extends across the equator to about 5 degrees north. South equatorial current flows from the western coast of Africa to the eastern coast of South America between the equator and 20°S latitude. This current is more constant, stronger and of greater extent than the north equatorial current. In fact, this current is the continuation of the cold **Benguela current.** This warm current is bifurcated into two branches due to obstruction of land barrier in the form of the east coast of Brazil.

The northward branch after taking north-westerly course merges with the north equatorial current near Trinidad while the second branch turns southward and continues as Brazil warm current parallel to the east coast of South America. This current is basically originated under the stress **of trade winds.**

Equatorial Counter Current

Equatorial Counter Current is a significant ocean current in the Pacific and Indian oceans that flows west-to-east at approximately five degrees north. The Counter Currents result from balancing the westward flow of water in each ocean by the North and South Equatorial currents.

In El Niño years, Equatorial Counter current intensifies in the Pacific Ocean.

The Equatorial Counter current flows from west to east in between the westward flowing strong north and south equatorial currents. This currents is less developed in the west due to stress of trade winds. In fact, the counter current mixes with the equatorial currents in the west but it is more developed in the east where it is known as the **Guinea Stream**. The Equatorial Counter current carries relatively higher temperature and lower density than the two equatorial currents. Several ideas have been put forth to explain the origin of the Equatorial Counter current. According to some scientists this current is originated because of the *influence of the westerlies which blow from west to east in the calm zone of the doldrums or in the convergence zone of the north east and south east trade winds.*

Gulf Stream

The Gulf Stream is a system of several currents moving in north-easterly direction. This current system originates in the Gulf of Mexico around 20°N latitude and moves in north easterly direction along the eastern coast of North America and reaches the western coasts of Europe near 70°N latitude. This system, named Gulf Stream because of its origin in the Mexican Gulf, consists of

- Florida current from the strait of Florida to Cape Hatteras,
- Gulf Stream from Cape Hatteras to the Grand Bank, and
- North Atlantic Drift (current) from Grand Bank to the Western European coast.

North Equatorial Current flows westward off the coast of northern Africa. When this current interacts with the northeastern coast of South America, the current forks into two branches. One passes into the Caribbean Sea, while a second, the Antilles Current, flows north and east of the West Indies. These two branches rejoin north of the Straits of Florida. Thus, Florida current is in fact, the northward extension of the north equatorial current. This current flows through Yucatan channel into the Gulf of Mexico, thereafter the current moves forward through Florida Strait and reaches 30°N latitude. Thus, the Florida warm current contains most of the characteristics of the equatorial water mass.

The trade winds blow westward in the tropics, and the westerlies blow eastward at mid-latitudes. This wind pattern applies a stress to the subtropical ocean surface with negative curl across the North Atlantic Ocean. The resulting Sverdrup transport is Equatorward. Because of conservation of potential vorticity caused by the northward-moving winds on the subtropical ridge's western periphery and the increased relative vorticity of northward moving water, transport is balanced by a narrow, accelerating poleward current, which flows along the western boundary of the ocean basin, outweighing the effects of friction with the western boundary current known as the Labrador Current. The conservation of potential vorticity also causes bends along the Gulf Stream, which occasionally break off due to a shift in the Gulf Stream's position, forming separate warm and cold eddies. This overall process, known as western intensification, causes currents on the western boundary of an ocean basin, such as the Gulf Stream, to be stronger than those on the eastern boundary.

As a consequence, the resulting Gulf Stream is a strong ocean current. It transports water at a rate of 30 million cubic meters per second through the Florida Straits. As it passes south of Newfoundland, this rate increases to 150 million cubic meters per second.

The average temperature of water at the surface is 24°C while the salinity is 3.6%. The temperature never falls below 6.5°C . The current becomes narrow while passing through the Florida strait but thereafter its width increases and current flows close to coast.

Canary Current (Cold)

The Canary current, a cold current, flows along the western coast of north Africa between Maderia and Cape Verde. In fact, this current is the continuation of North Atlantic Drift which turns sout.hward near the Spanish coast and flows to the south along the coast of Canaries Island. The average velocity of this current is 8 to 30 nautical miles per day. This current brings cold water of the high latitudes to the warm water of the low latitudes and finally merges with the north equatorial current. The Canary cold current ameliorates the otherwise hot weather conditions of the western coasts of North Africa.'

Labrador Current (Cold)

The Labrador Current, an example of cold current, originates in the Baffin Bay and Davis Strait and after flowing through the coastal waters of Newfoundland and Grand Bank merges with the Gulf Stream around 50°W longitude. The flow discharge rate of the current is 7.5 million ml of water per second. This current brings with it a large number of big icebergs as far south as Newfoundland and Grand Bank. These icebergs present effective hindrances in the oceanic navigation. Dense fogs are also produced due to the convergence of the Labrador cold current and the Gulf Stream near New-foundland.

Brazil Current (Warm)

The Brazil current is characterized by high temperature and high salinity. This current is generated because of the bifurcation of the south equatorial current because of obstruction of the Brazilian coast near Sun Rock. The northern branch flows northward and merges with the north equatorial current while the southern branch known as the Brazil current flows southward along the east coast of South America up to 40°S latitude. Thereafter it is deflected eastward due to the deflective force of the rotation of the earth and flows in easterly direction under the influence of westerlies. The Falkland cold current coming from south merges with Brazil current at 40° S.

Falkland Current (Cold)

The cold waters of the Antarctic Sea flows in the form of Falkland cold current from south to north along the eastern coast of South America up to Argentina. This current becomes most extensive and developed near 30°S latitude. This current also brings numerous icebergs from the Antarctic area to the South American coast.

South Atlantic Drift (Cold)

The eastward continuation of the Brazil current is called South Atlantic Drift. This current is originated because of the deflection of the Brazil warm current eastward at 40°8 latitude due to the deflective force of the rotation of the earth. The South Atlantic Drift, thus, flows eastward under the influence of the westerlies. This current is also known as the Westerlies Drift or the Antarctic Drift.

Benguela Current (Cold)

The Benguela current, a cold current, flows from south to north along the western coast of south Africa. In fact, the South Atlantic Drift turns northward due to obstruction caused by the southern tip of Africa. Further northward, this current merges with the South Equatorial Current.

Currents of Pacific Ocean

Important currents of the Pacific Ocean are as follows:

North Equatorial Current (Warm)

The north equatorial current originates off the western coast of Mexico and flows in westerly direction and reaches the Philippines coast after covering a distance of 7500 nautical miles. This current is originated because of the Californian current and north-east monsoon. The volume of water continuously increases westward because numerous minor branches join this current from the north. A few branches also come out of the main current and turn towards -north and south. One branch emerges from the north equatorial current near Taiwan and flows northward to join **Kuroshio current** while the southern branch turns eastward to form counter equatorial current. It is significant to note that north equatorial current flows as a continuous current i n the north Pacific Ocean but there are seasonal variations in its northern and southern marginal areas. The velocity of the current ranges between 12 and 18 nautical miles per day. With the northward (northern summer) and southward (south northward and southward but it always remains to the north of equator.

South Equatorial Current (Warm)

The south equatorial current is originated due to the influence of south-east trade winds and flows from east to west. This current is stronger than the north equatorial current. The average velocity is 20 nautical miles per day while the maximum velocity becomes 100 nautical miles a day. Numerous minor currents join this current. from the left and thus. the volume of water continuously increases west-ward, The current is bifurcated into northern and southern branches near New Guinea. The northern branch turns eastward and flows as counter equatorial current w rule the southern branch –moves towards the northern and north-eastern coasts of Australia.

Counter Equatorial Current (Warm)

The current flowing west to east between the north and south equatorial currents is termed counter equatorial current. Because of trade winds immense volume of water is piled up in the western marginal parts of the ocean, with the result there is general slope gradient of water surface from west to east. This higher water level in the west and descending slope gradient of water surface from west to east make the oceanic water flow in easterly direction in the name of counter equatorial current which is the most developed counter current in the Pacific Ocean. This counter equatorial current is extended up to the Panama Bay.

Kuroshio System (Warm)

The Kuroshio System consists of several currents and drifts is similar to the Gulf Stream system of the Atlantic Ocean. This system runs from Taiwan to the Bering Strait and consists of the Kuroshio current, the Kuroshio extension, the north Pacific drift, the Tsushima current and the counter Kuroshio current.

Oyashio Current (Cold)

The Oyashio cold current is also known as Kurile cold current. This cold current flows through the Bering Strait in southerly direction and thus transports cold water of the Arctic Sea into the Pacific Ocean. Near 50°N latitude this current is bifurcated into two branches. One branch turns east-ward and merges with the Aleutian and Kuroshio currents. The second branch moves upto the Japanese coasts. This current is comparable to the cold **Labrador Current** of the North Atlantic Ocean. The convergence of cold Oyashio (Kurile) and warm Kuroshio Current causes dense fogs which become potential hazards for navigation.

California Current (Cold)

The California current, an example of cold current, is similar to the Canary cold current of the Atlantic Ocean in most of its characteristics. In fact, this current is the eastward extended portion of the North Pacific drift. The cold California current is generated because of the movement of oceanic water along the Californian coast from north to south in order to compensate the loss of water which is caused due to large-scale transport of water off the coast of Mexico under the influence of trade winds in the form of the north equatorial current. This current after reaching the Mexican coast turns west-ward and merges with the north equatorial current.

Peru Current (Cold)

The cold current flowing along the western coast of South America from south to north is called Peru current or Humboldt current. This current is known as Peru coastal current near the coast w bile it is called Peru oceanic current off the coast. Mean annual temperature ranges between 14°C and 17°C and the average velocity of moving water is 15 nautical miles (27km) per day. The temperature of sea water increases from the coast towards the ocean.

East Australia Current (Warm)

South equatorial current is bifurcated near the Australian coast into northern and southern branches. The southern branch flows as east Australia current from north to south along the eastern coasts of Australia. New Zealand is surrounded by this current. It is deflected eastward near 40°S latitude due to deflective force of the earth and flows in easterly direction under the influence of the westerlies. This is a warm and more consistent current. It raises the temperature of east Australian coast for considerable distance southward.

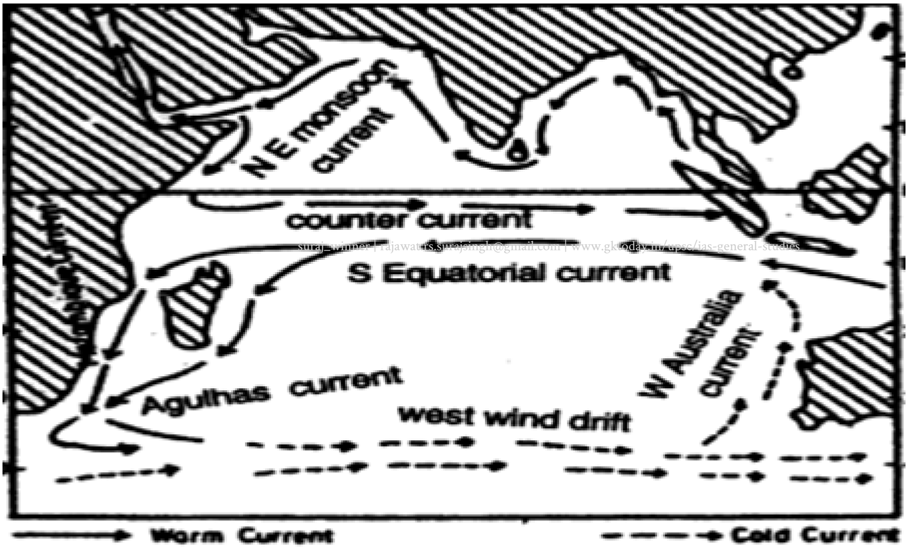
Currents of the Indian Ocean

The current systems of the Indian Ocean are largely controlled and **modified by landmasses**

and monsoon winds. Indian Ocean being surrounded by the Indian subcontinent, Africa and Australia does not present most favourable conditions for the development of consistent system of ocean currents. *The currents in the northern Indian Ocean change their flow direction twice a year due to north-east and south-west monsoon winds.*

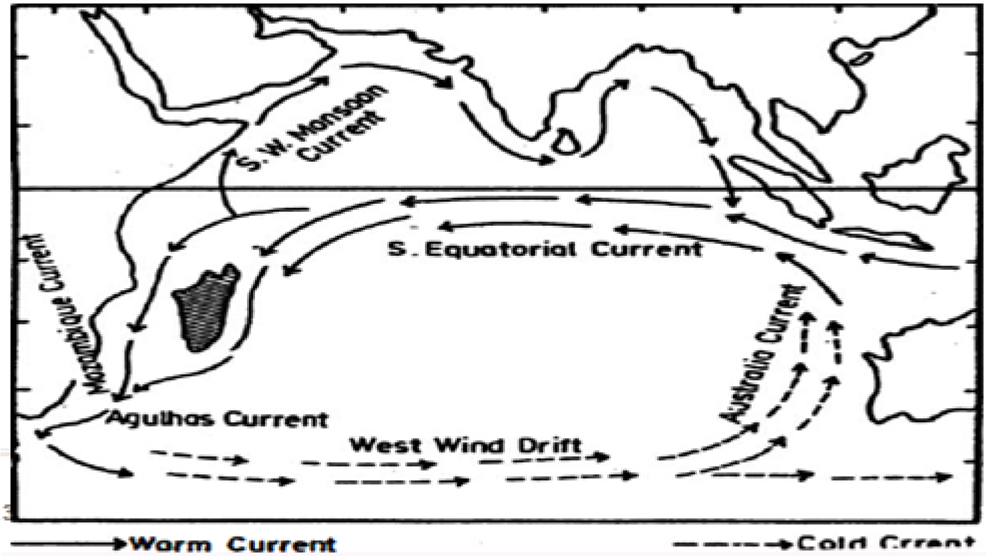
North-East Monsoon Current (Warm)

North-east monsoon winds blow from land to the ocean during winter season in the northern hemisphere and thus westward blowing north-east monsoon currents are produced in Indian Ocean. This current flows to the south of 5°N latitude. Besides, some independent currents originate in the Bay of Bengal and Arabian sea and flow in south-westerly direction.



S.W. Monsoon Current (Warm)

There is complete reversal in the direction of monsoon winds during summer season. The north-easterly direction of winter monsoon winds becomes south-westerly during summer season in the northern hemisphere. This reversal of direction of monsoon winds also reverses the direction of ocean currents of Indian Ocean during summer season. North-east monsoon ocean currents disappear and south-west monsoon ocean currents are developed. The general direction of monsoon currents is from south-west to north-east but several minor branches emerge from the main branch and move in the Bay of Bengal and Arabian Sea. The Indian counter current developed during winter season disappears due to this current.



Origin and Factors Affecting Ocean Currents

The main effect of temperature differences on the earth occurs in a north-south direction i.e. from equator to poles. Warm equatorial waters therefore move slowly along the surface towards the poles while heavier cold waters of the polar areas creep slowly towards the Equator along the bottom of the sea. Thus, the difference in the temperature of the ocean waters causes ocean currents. They are convectional currents giving rise to a transfer of heat energy in the ocean waters from the areas of excess to the areas of deficit heat energy.

- The factors relating to the earth's nature and its rotation include the gravitational force and deflective force by earth's rotation also known as Coriolis force.
- Oceanic factors include the pressure gradient, temperature variations and salinity differences. Ex-oceanic factors are atmospheric pressure and winds, evaporation and precipitation.
- Tides caused by the gravitational pull of the Moon and the Sun also play role in the forming of oceanic currents.
- The factors that can modify the currents are direction and shape of coastlines, bottom reliefs of the ocean basins, seasonal variations and *rotation of the earth.*
- Ocean circulation is driven by winds and by differences in water density. Along with the winds, ocean currents distribute the tropical heat worldwide, thus they play a very important role in maintaining Earth's heat balance.
- Please note that water at the poles travels in slow creeps below the surface water towards

equator, which is called Ocean Creep. Ocean Creep is not a surface movement of water. It is an undercurrent flow occasioned by the sinking of cold and heavy water. The water, on becoming cold, contracts and its density increases.

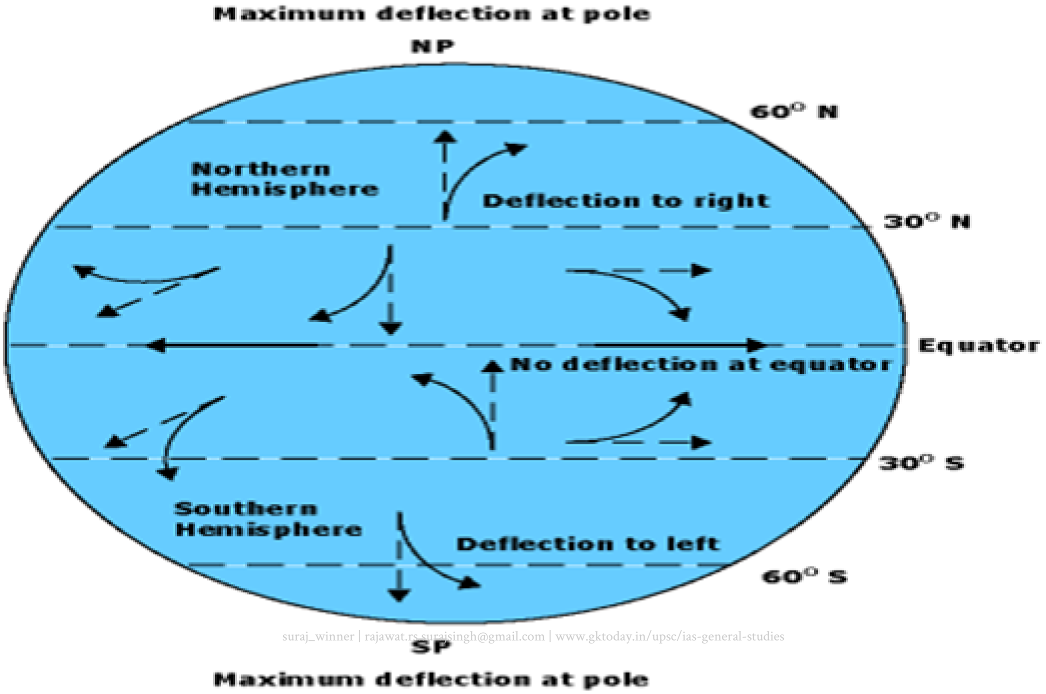
- The density of the ocean water varies from place to place, a movement in the ocean waters occurs due to this.
- A gyre is any large system of rotating surface ocean currents, particularly those involved with large wind movements. Gyres are caused by the Coriolis Effect; planetary vorticity along with horizontal and vertical friction, which determine the circulation patterns from the wind curl (torque).

Impacts of Coriolis Force

Coriolis Effect is a deflection of moving objects when they are viewed in a rotating reference frame. In a reference frame with clockwise rotation, the *deflection is to the left of the motion of the object*; in one with counter-clockwise rotation, the *deflection is to the right*. Coriolis Effect is causes ONLY in a rotating reference frame. The deflective force causes by the Coriolis Effect is caused Coriolis force. It has its own say in many geographical phenomena, most important being the deflection of the general direction of ocean currents.

Important Observations about Coriolis Force:

The currents flowing from equator towards the North Pole and from North Pole towards the equator are deflected to their right while the currents flowing north-south and south-north in the southern hemisphere are deflected towards their left.



The rotational force of the earth causes movement of ocean water near the equator in opposite direction to '**the west to east rotation of the earth** and thus equatorial currents are generated. These currents flow from **east to west**. Some ocean water moves in the direction of the rotation of the earth i.e. from west to east and thus counter equatorial currents are also formed.

Please note that the magnitude of the deflection, or "Coriolis effect," varies significantly with latitude. The **Coriolis Effect is zero at the equator** and **increases to a maximum at the poles**. The deflection is *proportional to wind speed; that is, deflection increases as wind strengthens*. The resultant balance between the pressure force and the Coriolis force is such that, in the absence of surface friction, air moves parallel *to isobars (lines of equal pressure)*. This is called the geotropic wind.

The Coriolis force explains why winds circulate around high and low pressure systems as opposed to blowing in the direction of the pressure gradient.

Impact of Physical Properties of Ocean on Ocean Currents

Local variations in the physical properties of the ocean such as pressure gradient, temperature differences, salinity differences, density variations etc. generate ocean currents.

Temperature

The amount of insolation received at the earth's surface and consequent temperature decreases from equator towards the poles. Due to high temperature in the equatorial region the water density decreases because of greater expansion of water molecules whereas the density of sea water becomes comparatively greater in the polar areas. Consequently water moves due to expansion of volume from equatorial region (of higher temperature) to polar areas (colder areas) of relatively very low temperature.

There is movement of ocean water below the water surface in the form of subsurface current from colder polar areas to warmer equatorial areas in order to balance the loss of water in the equatorial areas. Thus, the poleward surface current and Equatorward subsurface currents form a complete circulatory system of ocean water. The Gulf Stream and Kuroshio warm currents moving from equator towards north are examples of such currents.

Salinity

Oceanic salinity affects the density of ocean water and density variation causes ocean currents. Salinity increases the density of ocean water. If two areas having equal temperature are characterized by varying salinity, the area of high salinity will have greater density than the area of low salinity. The denser water sinks and moves as subsurface current whereas less saline water moves towards greater saline water as surface current. In other words, *ocean currents on the water surface are generated from the areas of less salinity to the areas of greater salinity. Such system of surface and subsurface currents caused by salinity variation is originated in open and enclosed seas.* For example, the current flowing from the Atlantic Ocean to the Mediterranean Sea via Gibraltar Strait is caused because of the difference in salinity.

The salinity of the Mediterranean Sea is much higher than the adjoining Atlantic Ocean. Consequently, water sinks in the Mediterranean Sea. In order to compensate the loss of water Atlantic water flows as surface current into the Mediterranean Sea. The sinking water in the Mediterranean Sea moves as subsurface current towards the Atlantic Ocean. Similarly, such system of surface and subsurface currents is generated between the Red Sea and the Arabian Sea via Bab-el-Mandeb Strait.

The salinity of the Baltic Sea is lowered due to the flow of fresh water by the rivers but the level of water is raised. With the result water moves northward as a surface current into the North Sea and subsurface current moves from the North Sea to the Baltic Sea.

Impact of Air Pressure and Winds on Ocean Currents

Air pressure on the oceanic water causes ocean currents through density variations. The areas of high atmospheric pressure are characterized by low volume of water and thus lowering of water level. Contrary to this the areas of low atmospheric pressure record higher volume of water and higher water level. Thus, water moves as surface current from the areas of higher water level (Low pressure areas) to low water level areas (high pressure areas).

Prevailing or planetary winds (e.g., trade winds, westerlies and polar winds) play major roles in the origin of ocean currents. The wind blowing on the water surface also moves water in its direction due to its friction with the water. Most of the ocean currents of the world follow the direction of prevailing winds. For example, equatorial currents flow westward under the influence of N.E. and S.B. trade winds. The Gulf Stream in the Atlantic and the Kuroshio in the Pacific move in northeastern direction under the influence of the westerlies. There is seasonal change in the direction of currents in the Indian Ocean twice a year (after every 6 months) due to seasonal change in the direction of monsoon winds. Friction caused by the wind sets the sea water in motion.

Prelims Model Questions

1. With reference to the Ocean Currents, which among the following observations is / are correct?

1. They are slow surface movements of water
2. They generally comprise warm water
3. Configuration of Oceans affects them

Choose the correct option from the codes given below:

[A] Only 1 & 2

[B] Only 3

[C] Only 1 & 3

[D] 1, 2 & 3

Answer: [B] Only 3

First statement is not correct. Ocean currents are not always slow; in fact most of them are swift, deep and narrow. The slow and shallow currents are called Drifts. Then, this statement is also incorrect in the sense that when we talk only about the surface currents, we miss the more important Global Thermohaline circulation. Surface Currents are generally wind driven movements of water at or near the ocean's surface. Thermohaline currents (which are caused by variation of temperature and salinity and density) are slow deep currents that affect bulk of the seawater beneath the Pycnocline.

2. With reference to the general features of Ocean bottom relief, which among the following statements is / are correct?

1.Continental Slope connects the continental shelf and the ocean basins

2.Deep sea plains are the flattest and smoothest regions of the world

3.Guyot is a volcanic mountain on seabed with its flat tip over the surface of sea

Choose the correct option from the codes given below:

[A] Only 1 & 2

[B] Only 2 & 3

[C] Only 1 & 3

[D] 1, 2 & 3

Answer: [A] Only 1 & 2

The ocean floors can be divided into four major divisions:

1. The Continental Shelf;
2. The Continental Slope;
3. The Deep Sea Plain;
4. The Oceanic Deeps.

Besides, these divisions there are also major and minor relief features in the ocean floors like ridges, hills, sea mounts, guyots, trenches, canyons, etc. Continental Shelf is the extended margin of each continent occupied by relatively shallow seas and gulfs. Continental Slope connects the continental shelf and the ocean basins. It begins where the continental shelf sharply drops off into a steep slope. Deep sea plains are gently sloping areas of the ocean basins. These are the flattest and smoothest regions of the world. Oceanic Deeps or Trenches are the deepest parts of the oceans. They are relatively steep sided, narrow basins.

A guyot also known as a table mount is an isolated underwater volcanic mountain (seamount), with a flat top over 200 meters (660 feet) below the surface of the sea. The diameters of these flat summits can exceed 10 km.

3. Which among the following play role on formation of Ocean currents?

1.Rotation of Earth

2.Revolution of Earth

3.Gravitational Pull by Sun and Moon

4.Prevailing Winds

Choose the correct option from the codes given below:

[A] 1 & 4

[B] 1, 3 & 4

[C] 1, 2, 3 & 4

[D] 1, 2 & 3

Answer: [C] 1, 2, 3 & 4

The currents in the oceans are originated due to combined effects of several internal as well as external factors, which control the origin and other characteristics of ocean current. Regarding Revolution, we know that Earth is tilted and due to revolution of earth, various regions are tipped away or toward the sun during round the year journey around Sun. This creates opposite seasons in northern and southern hemispheres. This affects global air circulation and global air circulation would affect the ocean currents.

4. Consider the following comparisons of the Surface Oceanic Currents and Deep Oceanic Currents?

1. While surface currents are primarily driven by winds, deep currents are primarily driven by density differences
2. While surface currents are swift, deep currents are relatively slower

Which among the above observations is / are correct?

[A] Only 1

[B] Only 2

[C] Both 1 & 2

[D] Neither 1 nor 2

Answer: [C] Both 1 & 2

Ocean currents are of two type's viz. Surface Currents and Deep Currents. Surface currents affect surface water above the pycnocline (<10% of ocean water). These currents are primarily driven by major wind belts. The Deep currents affect deep water below pycnocline (90% of ocean water) and are primarily driven by density differences. The deep currents are larger and slower than surface currents.

5. With reference to the Ocean Currents in Indian Ocean, consider the following statements:

1. Indian Ocean is known for one of the most consistent system of Ocean Currents
2. The currents in the northern Indian Ocean change their flow direction twice a year

Which among the above statements is / are correct?

[A] Only 1

[B] Only 2

[C] Both 1 & 2

[D] Neither 1 nor 2

Answer: [B] Only 2

The current systems of the Indian Ocean are largely controlled and modified by landmasses and monsoon winds. Indian Ocean being surrounded by the Indian subcontinent, Africa and Australia does not present most favourable conditions for the development of consistent system of ocean currents. The currents in the northern Indian Ocean change their flow direction twice a year due to north-east and south-west monsoon winds.

6. Consider the following observations:

1. Abyssal plains are more extensive in Atlantic / Indian Oceans in comparison to pacific ocean
2. Oceanic trenches are more extensive in Pacific Ocean in comparison to Atlantic / Indian Oceans
3. Seamounts are more common in Pacific Ocean in comparison to Atlantic / Indian Oceans

Which among the above statements is / are correct?

[A] Only 1 & 2

[B] Only 1 & 3

[C] Only 2 & 3

[D] 1, 2 & 3

Answer: [D] 1, 2 & 3

Abyssal Plain

Abyssal plain is flat, cold and sediment covered ocean floor. Abyssal plains are more extensive in Atlantic and Indian Oceans and less extensive in Pacific Ocean. Abyssal plain is found at an average depth between 3000 and 6000 meters. They are among the flattest, smoothest and least explored regions on earth.

Oceanic Trench

An elongated through or deep in the ocean floor is called ocean trench. It is more or less a U shaped valley. Most of world's trenches are in Pacific Ocean. Trenches are most active geological features on earth where great earthquakes are Tsunamis are born.

Seamounts

Seamounts are elliptical projections from the sea floor which look like mountains and have a steep slope of around 22° to 24°. Half of the world's total seamounts arc in Pacific Ocean.

Guyots

Guyots are basically inactive volcanoes which are flat topped. Some of them are tall enough to approach or even penetrate the sea surface. Guyots are confined to Central Pacific Ocean.

7. With reference to the temperature of the surface of Ocean, consider the following statements:

1. Temperature of the surface of the Oceans is higher in Northern Hemisphere in comparison to Southern Hemisphere
2. Isotherms drawn in the Northern Hemisphere are more regular in comparison to southern

hemisphere

Which among the above statements is / are correct?

[A] Only 1

[B] Only 2

[C] Both 1 & 2

[D] Neither 1 nor 2

Answer: [A] Only 1

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 northern hemisphere than the southern hemisphere warm and cold landmasses whereas they (isotherms) are regular and follow latitudes in the southern hemisphere because of the dominance of water.

8. Which two hot and cold ocean currents meet at the Grand Banks of Newfoundland in the North American continental shelf, making it one of the richest fishing grounds in the world?

[A] Agulhas Current and Labrador Current

[B] Gulf Stream and Labrador Current

[C] Falkland current and Norwegian current

[D] Labrador Current and Norwegian current

Answer: [B] Gulf Stream and Labrador Current

The Grand Banks of Newfoundland are a group of underwater plateaus southeast of Newfoundland on the North American continental shelf. These areas are relatively shallow, ranging from 80 to 330 feet (24–101 m) in depth. The cold Labrador Current mixes with the warm waters of the Gulf Stream here. The mixing of these waters and the shape of the ocean bottom lifts nutrients to the surface. These conditions helped to create one of the richest fishing grounds in the world.

9. With reference to the relief features of Indian Ocean, consider the following statements:

1. The average depth of the Indian Ocean is more in eastern side in comparison to western side
2. The deeps and trenches are almost absent in Indian Ocean

Which among the above is / are correct statements?

[A] Only 1

[B] Only 2

[C] Both 1 & 2

[D] Neither 1 nor 2

Answer: [A] Only 1

The Indian ocean is smaller than Pacific and Atlantic ocean. It is bounded by Asia in North, Africa in West, Asia in East, Australia in South East and Antarctica in the South. It has got connected with Pacitic and Atlantic oc.ean near Antarctica. The average depth of the ocean is 4000 m. Majority of this ocean is formed by the block mountains of Gondwanaland. Here some prominent marginal seas are Mozambique channal, Red sea, Persian gulf, Andaman sea, Arabian sea, Bay of Bengal etc. The Indian subcontinent in the North divides the Indian ocean into Arabian sea and Bay of Bengal.

Johnson has divided the Indian ocean into three zones.

1. The Western zone : It is between the African coast and the mid Indian oceanic ridge, and average depth is around 400 m. or 2000 fathoms in this zone.
2. The Eastern zone : It is deepest with a depth of around 550 m or 3000 fathoms.
3. The Central zone : It represents the mid oceanic ridge where many tiny island are located

Deeps and Trenches : Important deep-Sea trenches are Sunda trench (7450 m deep), o b trench (687.5 m deep). Mauritius trench, Amirante trench etc. The deeps are almost absent.

10. Consider the following ocean currents:

1. Kamchatka Current
2. Humboldt Current
3. Leeuwin Current
4. Agulhas Current

Which of the above is/are cold water currents?

[A] Only 1 & 2

[B] Only 1, 2 & 3

[C] Only 2, 3 & 4

[D] 1, 2, 3 & 4

Answer: [A] Only 1 & 2

Agulhas Current is warm water current along the east coast of South Africa. Leeuwin Current is a warm ocean current.