Geography

By Neetu Singh

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2014

1. Geomorphology
2. climatology
3. Oceanography

OCEANOGRAPHY

⇒ Study Plan

(1) Submarine Topography (2nd Order Relief Only)

(2) Physical properties of Ocean Waters
- Salinity
- Temperature

(3) Ocean Water Movements
- Oceanic Currents
- Tides*

(4) Oceanic Deposits

(5) Marine Resources (UNCLOS)

(6) Coral Reef

"United Nations Convention on Laws of Seas." = UNCLOS

1. Submarine Topography

Oceanic crust that forms the example of first order relief includes diverse range of topographical features that are collectively referred as submarine topography. The submarine topography mainly includes second order relief features as per its location below the baselevel of erosion. The sub-stream of oceanography that analyses submarine topography is called Bathymetry. The study of bathymetry always takes into account Hypsometric Curve that is the graphical representation of on- and off-shore features in a single frame to avail the comparision of the height and the depth in a given location. Practically, however, hypsometric curve is utilised to analyse off-shore or submarine topography. In accordance, this curve depicts 3 major submarine features :

) Continental Shelf
) Continental Slope
) Deep Sea Plain or Abyssal Plain

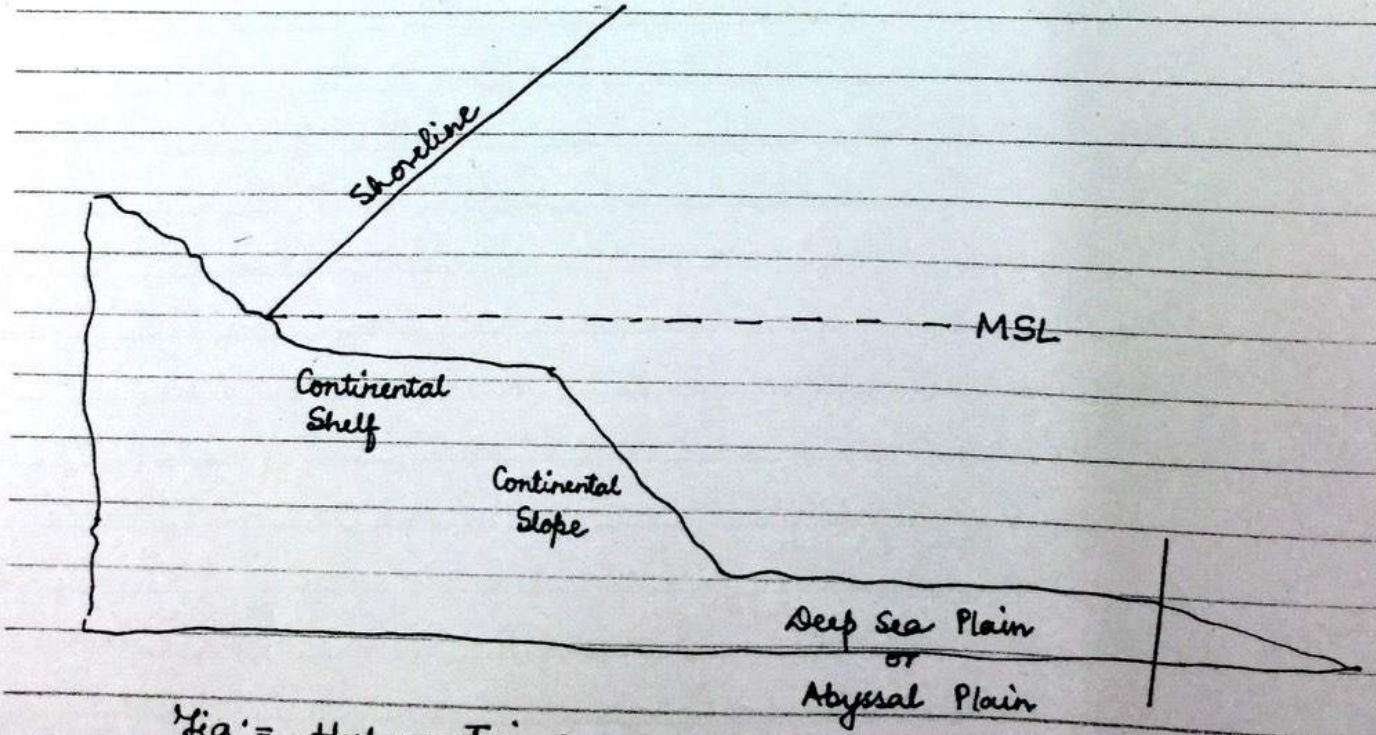


Fig:= Hypsometric Curve

Date 20/03/2014

Lecture # 30

Shoreline of Atlantic = Passive
Mid Atlantic Ridge : Dolphin
Challenger

1. Continental Shelf

It is the immediate offshore feature which represents to be submerged part of continent. Its development, thus, is synonym to positive rejuvenation involving tectonic as well as climatic factors. All the major continental shelves identified in global perspective represents rise of the MSL after the termination of Pleistocene ice age as this rise was upto 200 metres The continental shelves are identified with common depth of 200 m from the MSL. The occasional variation in the depth of continental shelves represent additional mechanism that includes substantive deposition along the passive tectonic boundary which makes continental shelves as shallow as 60 m. Similarly, in the presence of submarine canyons that the depth of continental shelves can be upto 600 m. Commonly, for continental shelves variations in the horizontal expanse is interpreted. This variation is largely the outcome of "height of the onshore features" that determines the nature of submergence. Shelves, therefore, are broader along coastal plains and narrower along tall mountains.

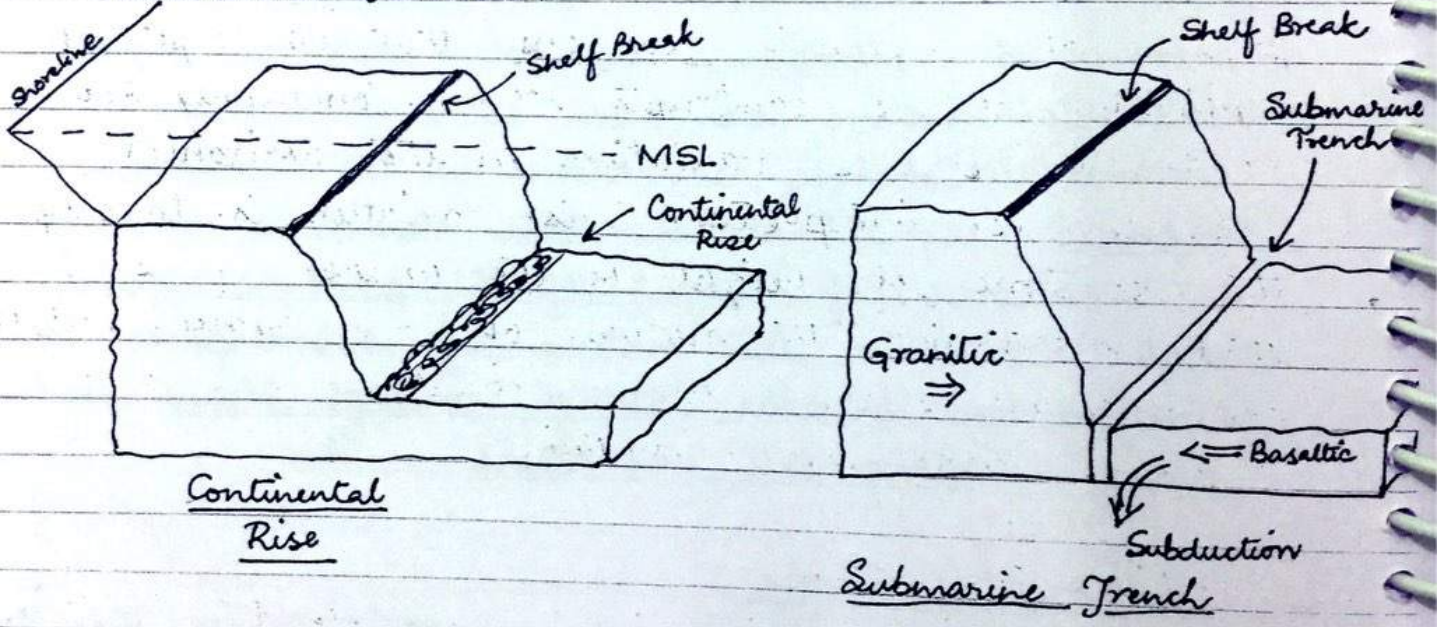
2. Continental Slope

This submarine feature is identified to be transitional feature between true granitic crust that is Continental Shelf and true basaltic crust i.e. deep sea plain. This submarine feature extends beyond shelf breaks i.e. from the depth of 200 m to upto 3500 metres. Along the passive tectonic boundary, it commonly

C. Rise = Depositional 3rd Order Relief

- Hudson River ⇒ Hudson Canyon
- Submarine Canyon ⇒ 3rd Order

incorporates foot deposits called continental rise. These deposits are sourced from the continents and fails to get deposited on the slope because of the available gradient. The continental rise, therefore, forms the example of depositional 3rd order relief of the Ocean bottom topography. Along the active tectonic boundary however, continental slope at its Piedmont location marks the development of submarine trench developed due to the subduction of heavier basaltic abyssal plain. In the presence of submarine trenches development of continental rise is ruled out. However, its location justifies presence of continent sourced material in the deepest parts of the ocean i.e. the foot of submarine trenches.



Submarine Canyons :

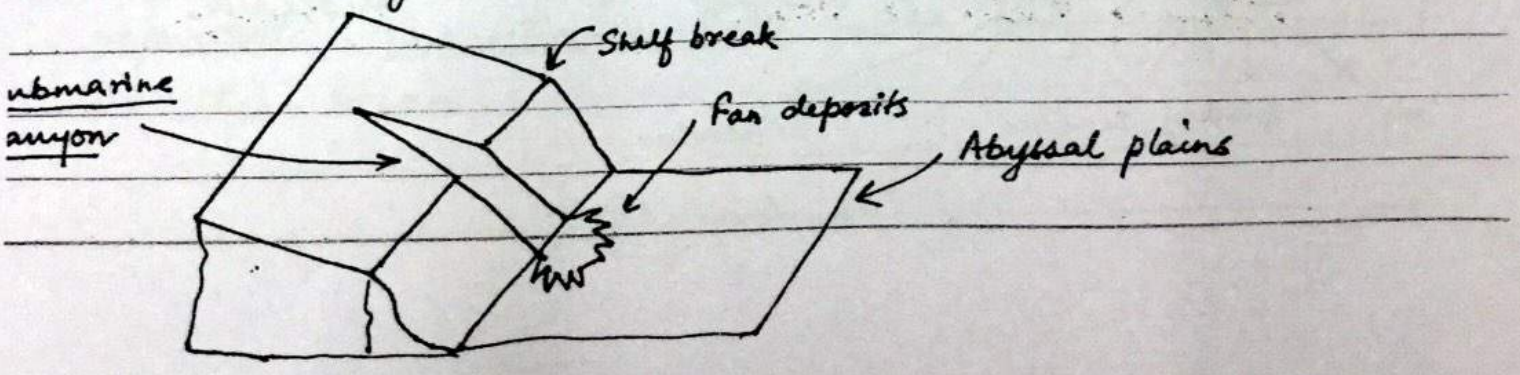
The submarine canyons are identified to be 3rd order relief features commonly recognised with continental shelves as well as continental slope. Lying below the base-level of erosion (Powell), this vertical abrasional

feature is explained by 2 different schools of thought:

① Development first and envindated later

② Effectivity of turbidity currents

The first school of thought recognises as classical approach absolutely maintains base level concept to explain the formation of submarine canyons. Referring positive rejuvenation, this school of thought identifies these canyons to have been developed by agents of gradation before the submergence of platform. Hudson Canyon (Atlantic Ocean), Indus Canyon (Arabian Sea), Padma Canyon (Bay of Bengal) forms the excellent examples supporting this school of thought. In the application of this school, canyons present in shelves were excellently explained. However with eventual realisation of presence of submarine canyons in continental slope facilitated the development of modern school of thought which recognises role of turbidity currents. These currents are defined to be subsurface water movement towards open ocean or sea. Such movements are triggered by submarine quakes, tsunamis and strong backwash. These currents facilitates movements of shelves' deposits making them agents of abrasion called turbides. In the effectivity of turbides submarine canyons marks their formation both on shelf as well as slope. Even this school of thought maintains that MSL is base level of erosion with turbidity currents as occasional development.



Abyssal Plains

It is the true basaltic crust that incorporates wide range of constructive and destructive submarine features. The constructive features correlates either spreading boundary or to transform faults. At the spreading boundary, development of main submarine ridge forms the most important constructive feature. It is this feature that corresponds to extensive vulcanism creating submarine mountains. In addition to such construction, along transform faults, magma ejection facilitates the development of ancillary ridges running perpendicular or near ⊥r to the main ridge along with formation of isolated sea-rises that includes conical seamounts or flat-top guyouts. All these construction features divides the abysal plains into variable sized BASINS. It is submarine basin that further incorporates destructive features along subdusive boundaries called submarine trenches. Moreover, it is with basins that fracture zones are also correlated which are transform faults without vulcanic activities.

Bathymetry : C. Shelf
C. Slope
Abyssal Plains
} + Marginal Water bodies + Names + Islands

↳ Include from all oceans.

Ridge → Basin → Trenches

Ridge → Ancillary, Sea Rises
Basin → S. Trenches
Basin → Fracture Zones

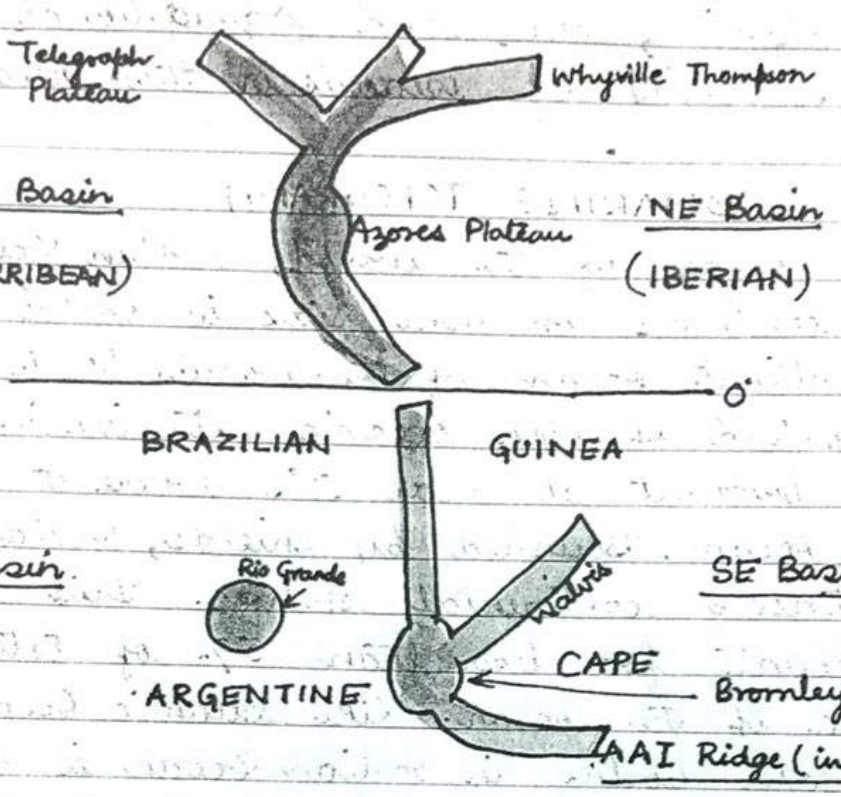
SUBMARINE TOPOGRAPHY OF ATLANTIC OCEAN

The second largest ocean of the world Atlantic Ocean excellently represents diverging oceanic boundaries. It marks its development to be associated with detachment of N. America & S. America from their respective Angaraland & Gondwanaland (Super continents constituents). Roughly 'S' in shape, the Atlantic Ocean largely denotes narrowest profile in equatorial belt and broadest at near 50°S where it opens up as the Southern Ocean. As the Atlantic Ocean shoreline denotes excellent examples of passive tectonic boundary, it involves extensive submarine shelves. This continent margin features accounts for more than 13% of total surface area of Atlantic Ocean making it designated as Shelf-Water body. Though entire shoreline of Atlantic includes extensive shelves, major examples are: North-eastern shelf (Dogger bank), North-western shelf (Grand and George) and south-western Atlantic (Patagonia shelf). It is nature of shoreline that makes northern basin of Atlantic Ocean include largest number of marginal water bodies. Combining both northern & southern basins, shallowest shelf water bodies (200 metres of depth) includes North Sea, Baltic Sea, Rio de la Plata and Grande Bay. Among the deep water bodies (4000-6000 m), Mediterranean Sea, Caribbean Sea and Gulf of Guinea forms major examples. It is Gulf of Mexico that excellently represents "Transitional Depth" water body (200-4000 m) in this ocean.

The submarine feature of Atlantic Ocean that dominates the Bathymetry of second largest Ocean is MID ATLANTIC RIDGE. Excellently representing diverging plate boundary, Mid-Atlantic Ridge is divided into 2 well defined parts called Dolphin Ridge in northern Basin and Challenger Ridge in southern basin. Representing the constructive margin, both the parts of mid-Atlantic ridge denotes the average depth of 2000 metres. The Dolphin Ridge extensive from Iceland to equator is significantly narrow ridge barring the exception of Azores Plateau i.e. broadest part at near mid-latitude. This ridge incorporates 2 ancillary extensions called Whyville Thompson Ridge and Telegraphic Plateau. Both these ridges are considered to be submarine boundary line between Atlantic and Arctic Oceans. It is therefore that Dolphin Ridge divides northern Atlantic Ocean into north-eastern basin including IBERIAN BASIN and north-western basin including CARRIBEAN BASIN. The Challenger Ridge is the mid-Atlantic Ridge in southern Atlantic Ocean running parallel to the shoreline of S. America. This narrow ridge includes well defined broad part at near mid latitude called BROMLEY PLATEAU. South of Bromley Plateau, the ridge marks its continuation as the part of Southern Ocean (AAI - Atlantic Antarctic Indian Ridge). Challenger Ridge includes one of the most prominent examples of ancilliary ridge called WALVIS RIDGE which divides south-eastern basin into 2 unequal parts called GUINEA BASIN (North) and CAPE BASIN (South). In the south-western basin, projected development of

Spain & Portugal - Iberian Peninsula

Rio Grande Rise demarcates northern Brazilian Basin from southern Argentine Basin.



The Atlantic Ocean Basins marks the presence of both fracture zones and trenches adding to the topographical features. Among the fracture zones, the Romanche Fracture Zone at equator demarcating Dolphin & Challenger Ridges forms the most important examples. Similarly, with active destructive boundary correlating to the minor plate, Peurto Rico Trench with Milwaukee Deep are recognised. Atlantic Ocean Diversity in the topographical features is also related to big range of Islands representing detached parts of the mainland that are continental islands as Carribean Islands, British Isles in northern basin and Terra del Fuego in Southern basin. The volcanic islands on the main ridge includes Azores and Tristan Da Cunha.

whereas the vulcanic islands along the small sea rises is best represented by Cannaries. Apart from these two categories, Coral and agradational islands adds to the diversity of islands in this Ocean.

INDIAN OCEAN SUBMARINE TOPOGRAPHY

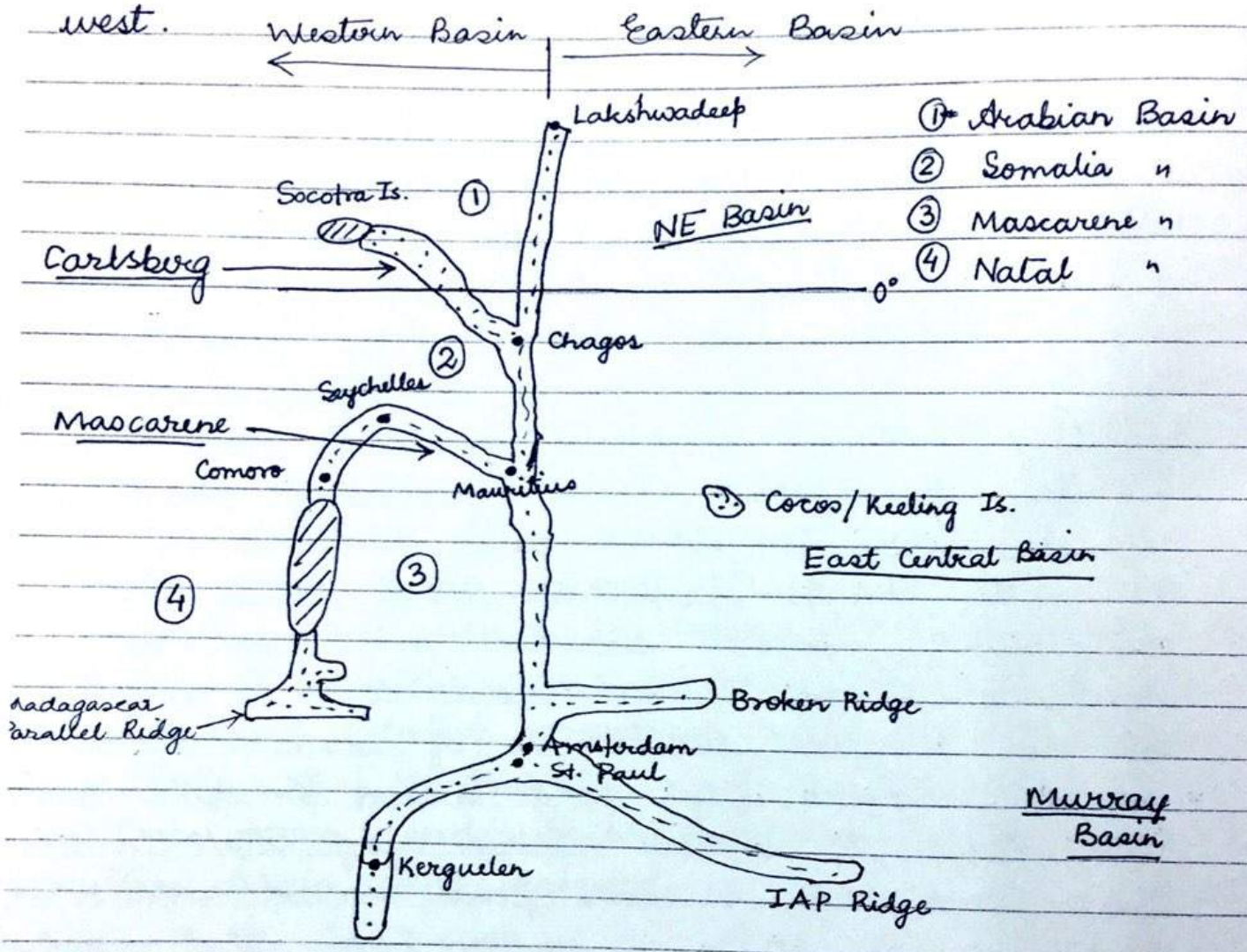
Third largest ocean of the world, Indian Ocean being bounded by continents on three sides is called half ocean or continent ocean of the world. It is near completely deprived of open oceanic extension in northern basin. It is broadest at near 50°S where it opens up at southern Ocean. Bounded by shields, Indian Ocean lacks in extensive continental shelves. This submarine feature accounts for less than 5% of total surface area of the ocean. Like Atlantic Ocean, marginal water bodies in Indian Ocean is more related to northern basin. Among the broad shelves and related marginal water bodies, Persian Gulf Shelf, Gulf of Khambat, Gulf of Martaban in northern basin and Joseph Bonaparde Gulf in southern basin are included.

Lecture 31

Date
21/03/2014

In Indian Ocean deep marginal water bodies includes Arabian Sea & Red Sea as major examples in northern basin whereas transitional depth category includes Bay of Bengal in northern basin & Timor Sea in southern basin. Most defined submarine feature of Indian Ocean however is mid Indian Ocean ridge which dipids out to be 2nd most prominent example of central submarin ridge. Unlike Atlantic Ocean, this mid-ridge represents much broader profile and is known to be incorporating parallel ridges which makes unique characteristics of this Ocean. Representing one of the Cenozoic constructive boundaries, the Indian Ocean Ridge denotes the continuation of C. Shelf with northern basin incorporating Lakshwadeep Chagos ridge. The Central Ridge continues in southern basin as Chagos - Amsterdam ridge which near mid-latitude represents broadest profile forming Amsterdam St. Paul Plateau. Continuation of ridge south of this broadest plateau is of southern ocean called Kergueler Ridge and Indian Antarctic Pacific (IAP) Ridge. It is this central ridge that divides Indian Ocean into 2 equal parts called western & eastern basins. It is in western basin that numerous well-defined construct have generated distinctive sized basins. Among the important ancillary ridges Carlsberg extensive from Chagos to Scotra Island demarcating Arabian Basin and Mascarene Ridge extensive from Mauritius to Seychelles demarcating Somalia Basin are included. It is Mascarene Ridge that marks its continuation as Seychelles Comoro Ridge that extends upto northern part of

Madagascar Island. It is south of this continental island that Madagascar Parallel Ridge distinguishes Mascarene Basin to its east and Natal Basin to its west.



eastern basin:

The eastern basin of Indian Ocean incorporates fragmented extension of several rises which are collectively called as 90° East Ridge. The most recognisable part being Cocos/Keeling Rise. This rise combined with the ancillary ridge of Chagos Amsterdam mid-ridge called broker ridge divides eastern basin into less demarcated NE basin, East Central Basin

and Murray Basin. The Indian Ocean Basin is largely devoid of major examples of fracture zones commonly with all the major hotspots minor development of fracture zones is however outlined. In the reference of trenches Sunda or Java Trench makes one of the lengthiest example of submarine trenches and is the only trench of Indian Ocean. The oceanic basin incorporates prominent examples of islands of distinctive categories wherein in continental islands are best represented by Madagascar and Sri Lanka, and volcanic islands entire range of hotspots based on which the ridges of the ocean is named (barring the exception of Lakshwadeep which is a coral island).

SUBMARINE TOPOGRAPHY OF "PACIFIC OCEAN"

The largest ocean of the world Pacific Ocean, the contracted Panthalasa, represents oldest oceanic crust. With near triangular shape including Bering Strait (between Seaward Peninsula and Chuckhi Peninsula) as its narrowest point and at 50°S latitude as its broadest location, south of which it opens up as Southern ocean. This largest ocean with active converging & destructive boundary qualifies to be the deepest ocean of the world depicting the combination of taller shoreline and submarine trenches. It is in accordance that the ocean lacks in continental shelf which accounts for less than 5% of the total S. Area of the Ocean. Both C. shelf and marginal water bodies are confined along western shoreline of Pacific in between "mainland and island arcs".

Sunda Shelf (Broadest Shelf of PO) → Java Sea } Complete Shelf W.B.
→ G. of Thailand }
→ South China Sea } Transitional

The broadest submarine shelf of Pacific Ocean is Sunda Shelf comprised of Java Sea, Gulf of Thailand as complete shelf water bodies & South China Sea as transitional depth water body. Second prominent shelf confined in southern basin includes Arafura Sea and Gulf of Carpentaria as the absolute shelf water body. Among the transitional depth water, Bering Sea makes prominent example in northern basin & among the deep waters Sea of Japan (northern basin), Tasman Sea (Southern basin) forms the examples.

Arafura Sea, G. of Carpentaria } Southern Basin Absolute Shelf WB

Bering Sea – Trans. Sea of Japan (N), Tasman Sea (S) } Deep W.B.

Southern Basin

The submarine topography of P.O. incorporate multi dimensional combination of submarine ridges, rises, basins & trenches. These can be distinguished on the grounds of dividing P.O. into 2 parts: Southern Basin & Northern Basin.

The Southern Basin of PO incorporates range of submarine construction which includes well demarcated basins as well. Among the prominent ridges Albatross Plateau and Nazka Ridge in SE Pacific basin demarcates Peru Chile Basin, which is primarily known for lengthiest linear trench called Peru Chile Trench. Beyond Albatros Plateau central Pacific Basin incorporates several dotting rises paving way to additional destructive margin of Tonga-Kermedec Trenches along Macquarie Bellary Ridge. It is this ridge that demarcates central pacific basin from SW Pacific Basin that includes

Norfolk Ridge, Lord Howe Ridge with Caledonian and Tasman Basins paving way to mainland Australia.

Northern Basins:

The northern Pacific Basin is significantly deeper than southern counterpart including one of the largest uninterrupted abyssal plain called TUFTS PLAINS in NE part. This abyssal plain is demarcated by Central American Ridge in the equatorial belt that includes Gualemala Basin & Middle American Trench. towards West it is demarcated by Hawaiian Hotspot paving way to Central Pacific Basin. This basin towards NW part incorporates different basins with submarine trenches. Major examples includes Aleutian Basin with Aleutain Trench, Kwril Basin with Kwril Trench, Japanese Basin with Bonin Trench, Phillippine Basin with Phillipine Trench & Caroline Basin with deepest Submarine Trench, Mariana Trench. Uniqueness of Submarine topography of PO also correlates to more than 20000 globally recognisable islands which mainly includes big continental islands like Sunda Islands, Japanese-Phillippines Islands and incorporate varied combination of islands as Melanesia, Polynesia and Micronesia.

Fiji → Vulcanic Island
↳ Capital on Coral Island.

47 salts in ocean water

PHYSICAL PROPERTIES OF OCEAN WATER

Location and climatic characteristics of oceans and their marginal extensions forms the prominent determiners of both the physical properties of ocean water that are salinity & temperature.

Salinity of ocean water is defined to be amount of dissolved substances in the ocean water with sea water recognised to be universal solvents. There are more than 47 diff. sea salts present in ocean water from among which Nacl accounts for maximum share approx. 77% and the source of the main salinity. Salinity of ocean water is measured as parts per thousand or gms per kilograms. Average ocean water salinity is 34 - 35 parts per thousand which varies significantly from one location to the other. The factors that determines the distribution of salinity includes:

(i) Temperature
(ii) Precipitation
(iii) Oceanic Currents
(iv) Influx of fresh water
(v) Continentality

Lecture # 32

Date 22/03/2014

Facts for individual Oceans with names in Submarine topo.

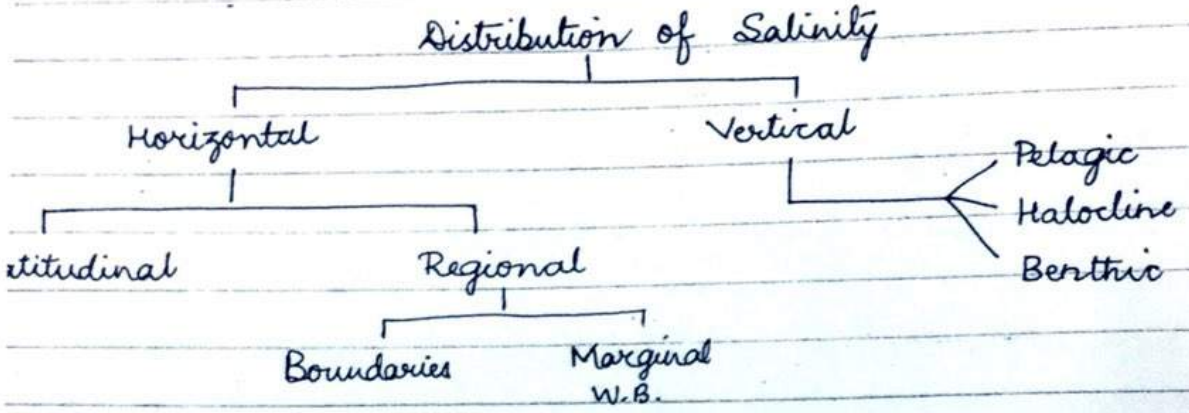
Marginal W.B. — Shelf WB
Transitional WB
Deep WB

- Latitudinal, Regional & Vertical dimension in aquatic environme
  - Regional: Open Vs Marginal
  - Vertical: → Depth

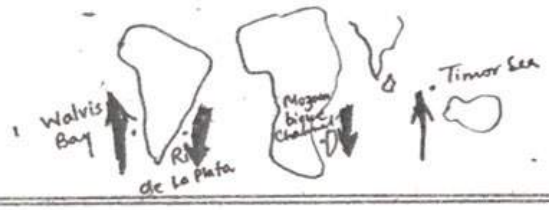
The sign of latitude or temperature as the factor influencing distribution of salinity correlate to evaporational loss. Higher temperature corresponding to higher rate of evaporation causes increase in salinity amount.

Precipitation as salinity determiner incorporates the role of diluting the water. It is therefore that in the wetter climate salinity levels are lesser than drier climate. Along the boundaries of the ocean, prevailing oceanic currents also regulates salinity distribution with west boundary warm current inducing atmospheric instability decreases salinity levels compared to east boundary cold currents which generates stable conditions and thus increases salinity. Along the mouths of the river and ablated water, salinity level decreases as both these sources of fresh water significantly dilutes the sea or ocean waters. The effect of continentality applied to 10°–60° N/S latitudes involves the influence of positive temperature anamoly in tropical marginal waters making them more saline than the open counterparts whereas the influence of negative T-anamoly in the temperate marginal waters makes them less saline than their open counterparts. Regulated by these factors, distribution

pattern of salinity is analysed in context of :



The latitudinal salinity distribution applied to the open oceans clearly reveals that, barring the equatorial water, salinity decreases with increase in the sign of latitude. In equatorial water, salinity levels of 32-33 parts per thousand depicts lower levels in the effect of perennial precipitation of upto 300 cms well distributed throughout the year. In tropical water, salinity level of 36-37 ppt depicts the highest level combining the effects of prevailing high temperature thus evaporational loss throughout the year with seasonal precipitation.
In the temperate water moderate temperature conditions combined with moderate precipitation forms the cause of average salinity levels of 34-35 ppt.
It is in sub-polar areas that least salinity levels 31-32 ppt depicting the influence of minimal evaporational loss with seasonal influx of ablated water.] This latitudinal distribution even in the open waters depicts variations along the boundaries of the ocean which are in the influence of boundary currents. This characteristic of distribution is recognised to be regional pattern



within the open oceans. This pattern reveals that west boundaries of open oceans always have lower salinity than the eastern counterpart within a given sign of latitude.

The oceanic currents in the southern Atlantic and southern Indian oceans regulates the salinity patterns even of the marginal water bodies as they as less demarcated. It, is, therefore, that Rio De La Plata and Mozambique Channel have lesser salinity than the eastern counterparts Walvis Bay and Timor Sea. Additionally, it is the effect of oceanic GYRE circulation that northern mid-Atlantic called Sargasso Sea have significantly high salinity levels involving the influence of prevailing anticyclonic conditions.

The regional distribution prominently, however, includes salinity distribution in marginal water bodies. In these water bodies clear distinction can be made between tropical marginal water bodies & temperate marginal water bodies. For the tropical marginal water, salinity levels are higher than open counterparts. However, elaborate range of variations is outlined on the basis of 3 factors:

(a) Magnitude of continentality
(b) Prevailing climatic conditions
(c) Presence/absence of river mouths

orth Sea, Norwegian Sea } M.W.B. in temperate ⇒ Higher Salinity than Open Ocean ⇒ NAD & Norwegian Current

Red Sea : Most Saline I.O.
Baltic Sea : Least saline Atlantic O.

for tropical marginal waters, therefore, salinity levels significantly varies with Mediterranean Sea, Arabian Sea and Gulf of California being more saline than G. of Mexico, B. of Bengal and South China Sea. Technically, G. of Aqaba (Indian Ocean) and G. of Sixte (Atlantic Ocean) forms highly saline water bodies revealing the combination of 3 defined factors.

In the temperate marginal waters, salinity levels are lesser than open counterparts with salinity decreasing with increasing continentality or influx of fresh water availing less variation than the tropical counterparts. It is, however, that salinity variations can be outlined with the reference of seasonal ablational water and perrennial influx of river water which makes Baltic Sea lesser in salinity than G. of Bothnia. The only exception represented by North Sea in Atlantic Ocean and Norwegian Sea in Arctic Ocean where salinity levels are higher than open water bodies in the effect of warm oceanic current NAD and Norwegian Currents respectively.

Vertical Distribution

Vertical salinity patterns is recognised to be regulated by surface salinity patterns. As all the factors that regulates salinity pattern are influencing only surface mixing zone called PELAGIC ZONE, Differences in the salinity levels remains applicable only upto 500 m of depth. In the absence of pattern determining factors, deep water called BENTHIC ZONE reveals uniform salinity throughout, irrespective of latitude

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Red Sea : Most Saline I.O.
Baltic Sea : least saline Atlantic.O.

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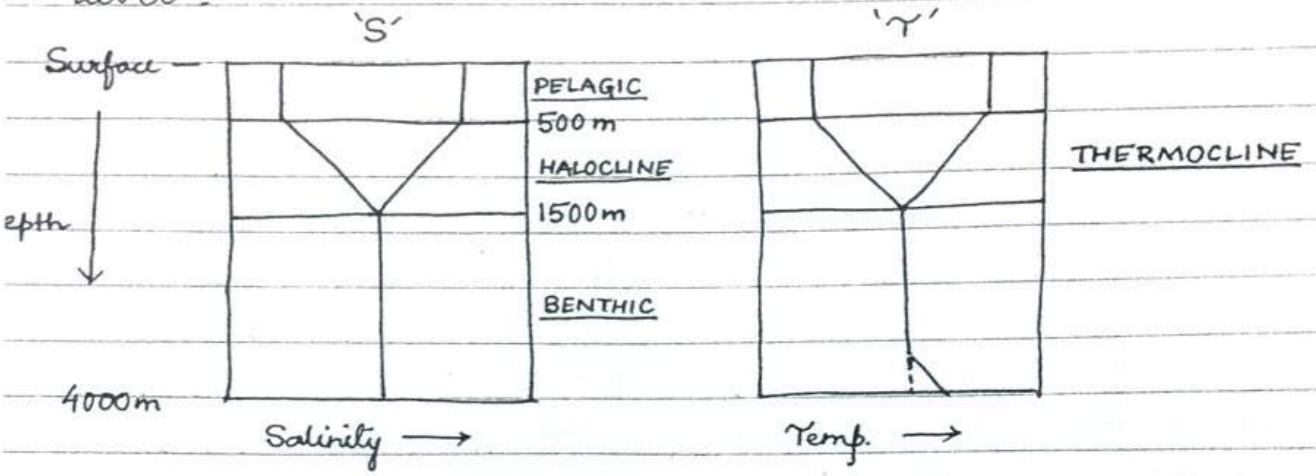
or regional location. It is, therefore, that vertical salinity patterns recognised as 'S'-Diagram denotes both decrease in salinity with increasing depth as well as increase in salinity with increasing depth in the compensating intermediate level called halocline level.



* HALOCLINE + THERMOCLINE = PYCNOCLINE

Ocean Water Temperature:

① It is important physical property of ocean water defined to be amount of heat present in sample sea water.
② The principle source being incoming solar radiation and secondary regional source submarine vulcanism.
③ Distribution is determined by sign of latitude, precipitation, boundary currents, continentality and influx of cold ablated water.
④ Latitudinally, ocean water temperature decreases with increase in sign of latitude barring the exception of equitorial water.
⑤ Regionally, western boundary water is warmer than eastern counterpart.

Tropical continental water is always warmer than the open counterpart.
Temperate continental water, however, is colder than open counterpart barring the exceptions of North Sea & Norwegian Sea.
Vertical distribution involves all the differences in surface mixing zone with homogeneity in Benthic zone.
The 'T'- Diagram, therefore, reveals both increase and decrease of temperature with increasing depth in the intermediate thermocline level.
In the locations of secondary source of heat, submarine vulcanism, T- Diagram involves additional thermocline in Benthic zone with only increasing temperature with increasing depth.

OCEAN WATER HEAT BUDGET

The energy stored in ocean water is considered to be one of the major regulator of the global circulation including almospheric circulation. The analysis of oceanic heat budget is therefore of prime concern for all the oceanographic studies. In the surface water, both regionally and locally, there is the development of imbalance between incoming and outgoing radiation called heat flux. The heat flux is maximum on the surface and goes on decreasing with increasing depth of ocean water. For the maintenance of heat budget of ocean water, the heat flux is required to be zero making the heat budget dependent on:

① Incoming solar radiation

② Outgoing IR radiation
③ Specific heat
④ Latent heat
⑤ Convection

The incoming solar radiation as the principle source of ocean water temperature is not just regulated by sign of latitude and season but also by the nature and the magnitude of ALBEDO, that is reflected energy which is determined by such minor factors as nature of water surface. Clearly regulated by such variable factors, insolation generates variable heating of the ocean water. Net IR radiation is the outgoing radiation which theoritically is the complete radiation of received heat by the surface water. Practically, apart from ~~being~~ being regulated by season (duration of night) it is also regulated by as variable factor as cloud cover generating heat flux. For the maintenance of heat budget, therefore, the additional 3 factors have significant roles to play.

The sensible heat represents flux out of sea due to the process of conduction. This process helps in maintaining heat budget by transferring the water heat to the air column with the rate determined by temperature contrast between the two. In comparision, the latent heat represents the flux out of sea due to the process of evaporation. This is regulated by not just the temperature of the air column but also its humidity levels. Maintenance of oceanic heat budget is also correlated to convection, that is movement

"NCERT"

Ocean Water Currents → Gyre
→ Thermohaline

of ocean water facilitating latitudinal mix (Gyre Circulation) and vertical mix (Thermohaline circulation)

Ocean Water Movement

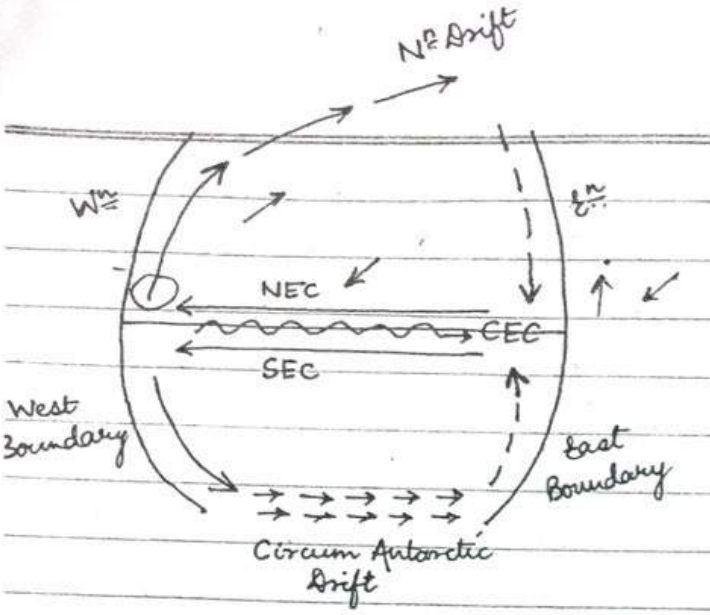
Mobility of ocean water in the global dimension includes oceanic current systems and tide generated movements. The oceanic current systems is further classified into surface and sub-surface currents system. The surface current system forms the closed current system with clockwise circulation in northern hemisphere and counterclockwise circulation in southern hemisphere, called Gyre Circulation. This circulation is defined to be large scale movement of surface water in the effect of prevailing winds.

Lecture # 33 Geography

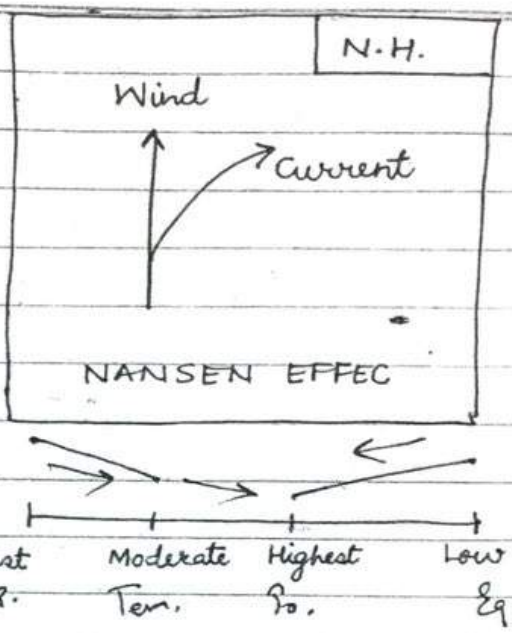
Date 23/03/2014

Ocean movements – Tide generated circulation
Oceanic circulation

The Gyre Circulation is comprised of two categories of surface water movements that includes open oceanic waters and boundary currents. The open oceanic water includes equatorial water and polar water. In all the open latitudinal oceanic basins, the equatorial water due to the effect of spin of the earth registers westward movement developing northern and southern equatorial currents. In the effect of shoreline barrier along the doldrums there is the possibility of counter equatorial current that moves towards east in contrast to the movement of the equatorial water. The polar water (subpolar as well) registers movement towards east in the combined effect of drag by westerlies and Coriolis deflection, called Nansen Effect. In Uninterrupted Southern Ocean avails absolute eastward movement generating circum-antarctic drift or west wind drift. In northern hemisphere, however, prevailing continental barriers generates the movement to be north-eastern. It is west flowing equatorial water combined with east flowing polar water that results in the development of closed current system combined with the boundary currents called Gyre Circulation. This circulation is always clockwise in northern hemisphere & counter clockwise in southern hemisphere.



GYRE CIRCULATION

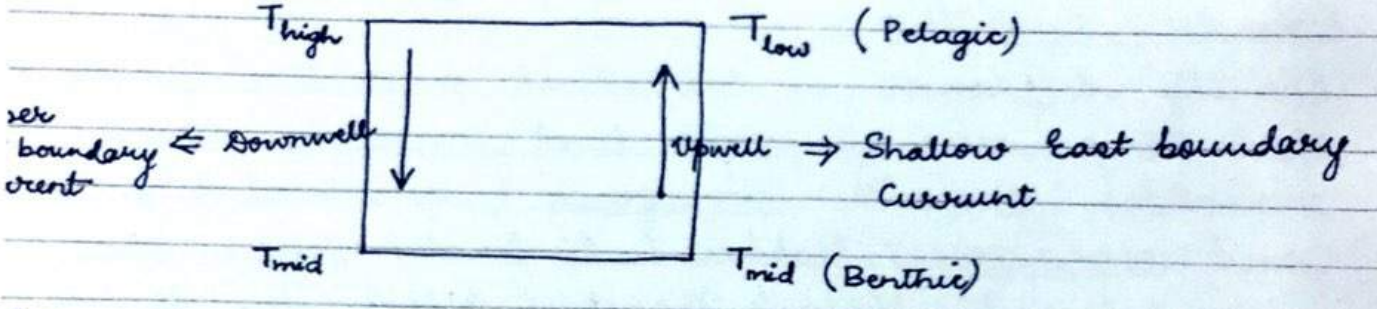


Boundary Currents :

Salinity differences in latitudinal perspective forms the elementary cause of water level variations. These variations generates divergence (equatorial & subpolar) and convergence (tropical & temperate) zones. These zones represent "Ekman's Transport Effect" due to which the convergence zones experiences piling up of the water called Ekman's Pumping Effect. This effect is primarily confined to boundaries of the oceans in the effect of prevailing winds. It is trade winds that causes convergence in the SW boundary of northern hemisphere & NW boundary of southern hemisphere whereas it is Westerlies that causes convergence in NE boundary of N-hemisphere and SE boundary in S-hemisphere. At all the convergence zones, piled up water facilitates Geostrophic Currents (gravity transfer + Coriolis force). All boundary currents, thus, are geostrophic currents though are distinguished in accordance to their location, water temperature and other related characteristics.

- "Peruvian Current = Humbolt Current" Advective fog = ??

The west boundary current transporting lower latitudinal water to higher latitudes are warm currents. They thus are narrow currents (10-100 kms), fast moving currents (100-1000 km/day) and are deep currents (upto 1500 m). In comparision the east boundary current transporting higher latitudinal water to lower latitude are cold currents. They thus are broad currents (100-1000 kms), slow moving (10-100 km/day) and are shallower currents (upto 500m).



{ Suez Canal → Atlantic - Indian Ocean
St. of Malacca → Indian - Pacific Ocean } Indian Ocean is transitional ocean b/w Atlantic & Pacific.

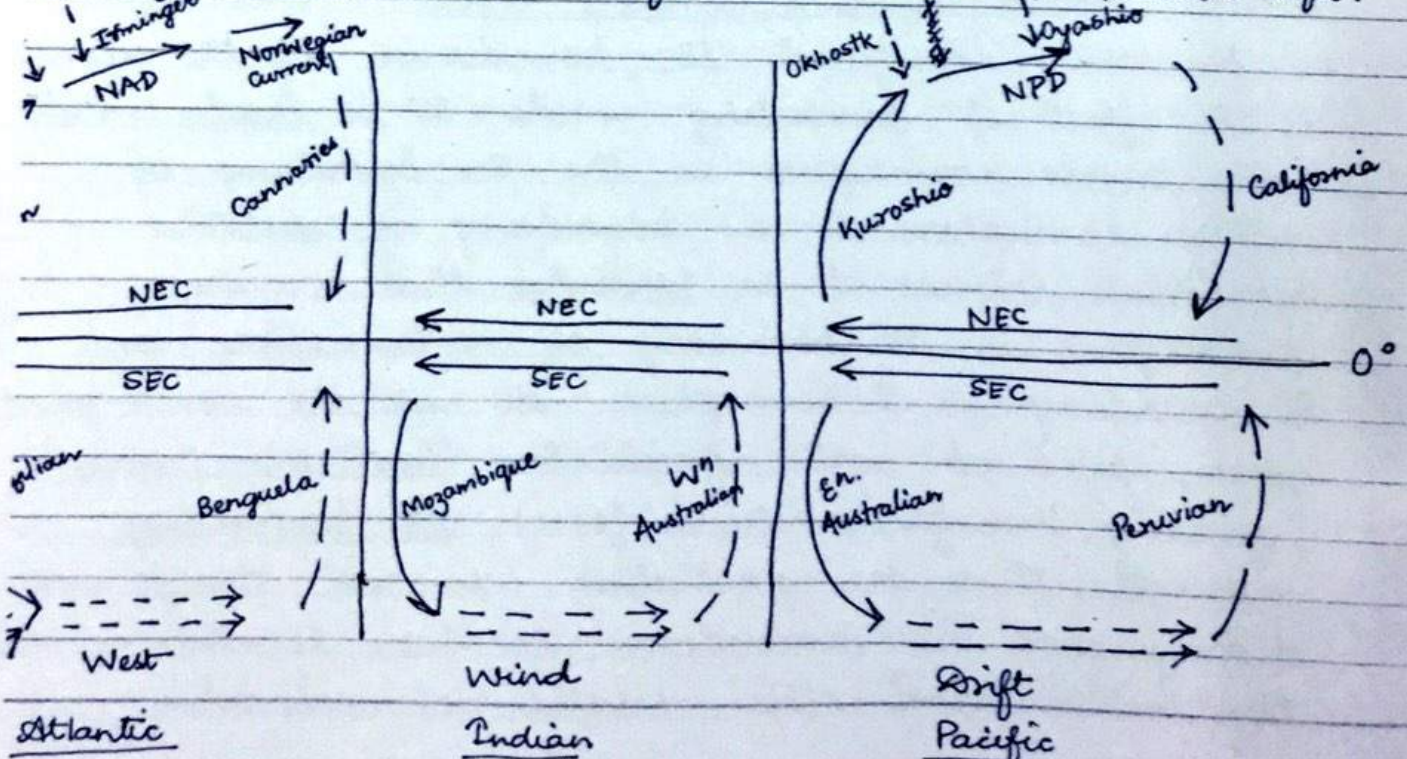


FIG. = "PRACTICAL GYRE CIRCULATION"

- - - → Cold currents due to ablated water (seasonal)
(Not geostrophic currents)

The practical Gyre circulation applied to all the 5 open latitudinal oceanic basins reveals that each ocean current system is comprised of all the recognised constituents of surface current systems. In the northern basins applicable to Atlantic & Pacific Oceans, Gulf Stream & Kuroshio Currents represents the west boundary currents with Canaries and California representing east-boundary currents. Apart from common North-eq. currents both the oceanic basins incorporate northern polar drift as north atlantic drift (NAD) and north Pacific Drift. It is due to the open connectivity of Atlantic Ocean and Arctic Ocean that NAD marks its further extension as the Norwegian Current. In the PO, however, Bering Strait restricts the development of counterpart. The southern basins applicable to all the 3 oceans includes Brazilian, Mozambique and E^n Australian as west boundary currents. Among the eastern counterparts, it is Benguela, W^n Australia and Peruvian Currents are included. Counterclockwise circulation in all the 3 basins includes common South Equatorial Current and West Wind Drift. For all the gyre circ^n perennial exis existence forms the common characteristics, barring the exception of Southern Pacific Ocean, where there is periodic development of El Nino restricting the gyre circulation. The genesis of

El Nino in the natural setup is correlated to the size, thus, the distance b/w the shorelines and is also related to the influence of oceanic currents on the prevailing weather conditions. As Peruvian current makes the farthest east boundary current from its western counterpart it form the COLDEST east boundary current not just involving thinnest characteristics but also generating driest weather conditions (Atacama Desert - driest tropical desert with 12cms of annual rain). It is this combination of extremely dry eastern shore and significantly wet western shore that there is the development of water gradient. It is in the effect of this gradient that weak warm water registers its movement from the western shoreline to the eastern shoreline taking minimal 9-10 months of time. This warm water when reaches the eastern shore, it combines with strongest upwell to terminate thinnest Peruvian current generating warm water in place of it, called El Nino. In the effect of this warm water, reversed pressure gradient generates abnormal wetter conditions along the eastern shoreline causing water gradient. It is the piled up water, both due to onshore winds and resultant precipitation that facilitates La Nina, which is reestablishment of Peruvian current, thus, gyre circulation & normal weather conditions. La Nina therefore, when compared to El Nino is more abrupt in its development.

Equatorial, Sub polar } Divergence Tropical, Temperate } Convergence } Surface Movements

Thermohaline Circulation :=

The Oceanic current systems incorporate sub-surface currents system called thermohaline circulation. This circulation incorporates all the 3 layers of ocean water called pelagic, pycnocline and benthic. This current system includes most evident movement called downwell i.e. sinking of cold dense water from the surface to the benthic zone. This evident movement is also recognised with vertical mixing of ocean water with transferring dissolved oxygen and dead remains of marine organisms into deeper waters sustaining acquatic habitat. The downwell water theoritically results in benthic currents which is horizontal movement of water at near abyssal plain. Practically near complete absence of salinity & temperature difference along with external factors like winds such movements are either missing or are extremely slow taking 100 to 1000 of years to register few degrees of latitudenal movement. These benthic currents at near submarine vulcanism or Hydro-thermal vents when gets sufficiently warmed up generates upwell. This part of thermohaline circulation also causes vertical mix and facilitates benthic water to become the part and parcel of surface gyre circulation.

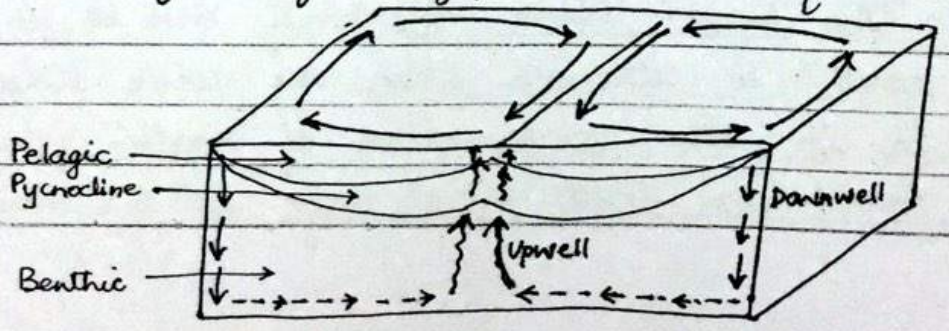


Figure: Thermohaline Circulation

TIDES :

Tides are defined to be the bulge or the pulse developed on the water surface due to the lunar and solar attractions. The study of tidal mechanism involves the analysis of bulge and ebb where bulge is always referred to be the tides and ebb the relative depressed water. Tidal mechanism is interpreted in the reference of :

(a) Equilibrium concept (Newton)
(b) Dynamic concept (Laplace)

The equilibrium concept is based on the assumption that surface of the earth is in equilibrium to tide generating forces, that is, the generated tidal bulge keeps pace with changing position of moon & sun in relation to earth. It is this approach that identifies tides to be planetary waves as on the spinning earth every attractive bulge generates equal and opposite centrifugal bulge. The planetary wave, therefore, has wavelength as half the circumference of earth & waveheight not more than 2 m. In reference to this approach, understanding of tidal mechanism is attained by classifying 3 different types of tides :

1) Lunar Tides
2) Solar Tides
3) Mixed Tides

The Lunar Tidal effectivity due to its nearness to earth is stronger than the solar tidal effectivity. It is in the combination of earth's rotation and lunar revolution that tidal day is 52 minutes

lengthier than spinning time of the earth making minimal tidal time gap to be 12 h 26 minutes. Moreover, it is declination of moon in b/w 28.5° N & 28.5° S of earth's latitude that it generates tropical & equatorial tides in the time frame of 27.5 days. i.e. revolution time of moon around earth. The tropical tides in this time frame registers successive sequence of high and low waters whereas the equatorial tides maintains the water levels. Additionally, with the axial inclination of the earth, attractive & centrifugal bulges will be experienced simultaneously in both the hemispheres.

The solar tides like lunar tides generates attractive & centrifugal bulges. However, it is significantly weaker than lunar effectivity because of the distance involved b/w it and earth. In the reference of earth's revolution around the sun, with axial inclination, apparent shift in the sun's position b/w tropic of Cancer & Capricorn generates tropical & equatorial tides. However, as these tides involves 365 days of sequence, proves less significant than lunar counterpart. The solar effectivities, therefore, is more applied in mixed tides.

Lecture = 34

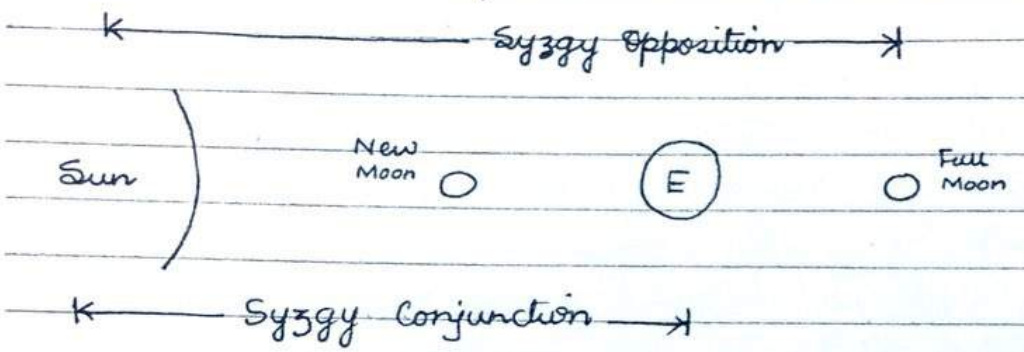
5/03.2014

MIXED TIDES :

The combined effectivities of lunar & solar attraction generates mixed tides. Characteristics of these tides is correlated to relative positions of the 3 celestial bodies in context of relative distance as well as relative alignment. It is in terms of relative alignment that 2 types of tide called spring tide and neap tide are generated. The spring tide correlates to the aligned position of sun, moon & earth called syzgy. This aligned position corresponds either to new moon or full moon positions. In the case of new moon position, both the celestial bodies i.e. sun & moon are on one side of the earth generating syzgy conjunction. In this position, lunar & solar attractions work along the same side with their centrifugal combined at the opposite side. This combined effect of attraction & centrifugal forces induced by sun & moon generates high tide called spring tide. Such high tides also correlates to syzgy opposition i.e. the alignment of the celestial bodies during full moon position. The recognised distance in syzgy opposition is that lunar attraction is combined with solar centrifugal & solar attraction with lunar centrifugal. Among the characteristics of spring tides — development of higher high waters (tides) and lower low water (i.e. ebb) is related. Duration b/w two spring tides is approximately 2 weeks.

The neap tides correlate to the quadrature positions that corresponds to

first and last quarters of lunar month. In both these positions sun & moon marks perpendicular alignment to each other generating diminishing tide called neap tides. These are low tides which corresponds to higher low water (in reference to moon) and lower high water (in reference to sun). The time gap between two neap tides is also 2 weeks.



In reference to distance between the three celestial bodies variation in tide generating forces is also registered. As earth revolves round sun in elliptical orbit, it generates nearest position to sun called perihelion as well as farthest position from sun called aphelion in revolution path of 365 days. Similarly, moon revolving round earth in the elliptical orbit also develops nearest perigee (3.5 lakh km) and farthest apogee (4 lakh km) positions in its revolution time of 27.5 days. The generated distance variation between these celestial bodies further adds to variations in the tidal bulges.

Perihelion (147 m.km) — Perigee (3.5 Lakh km)

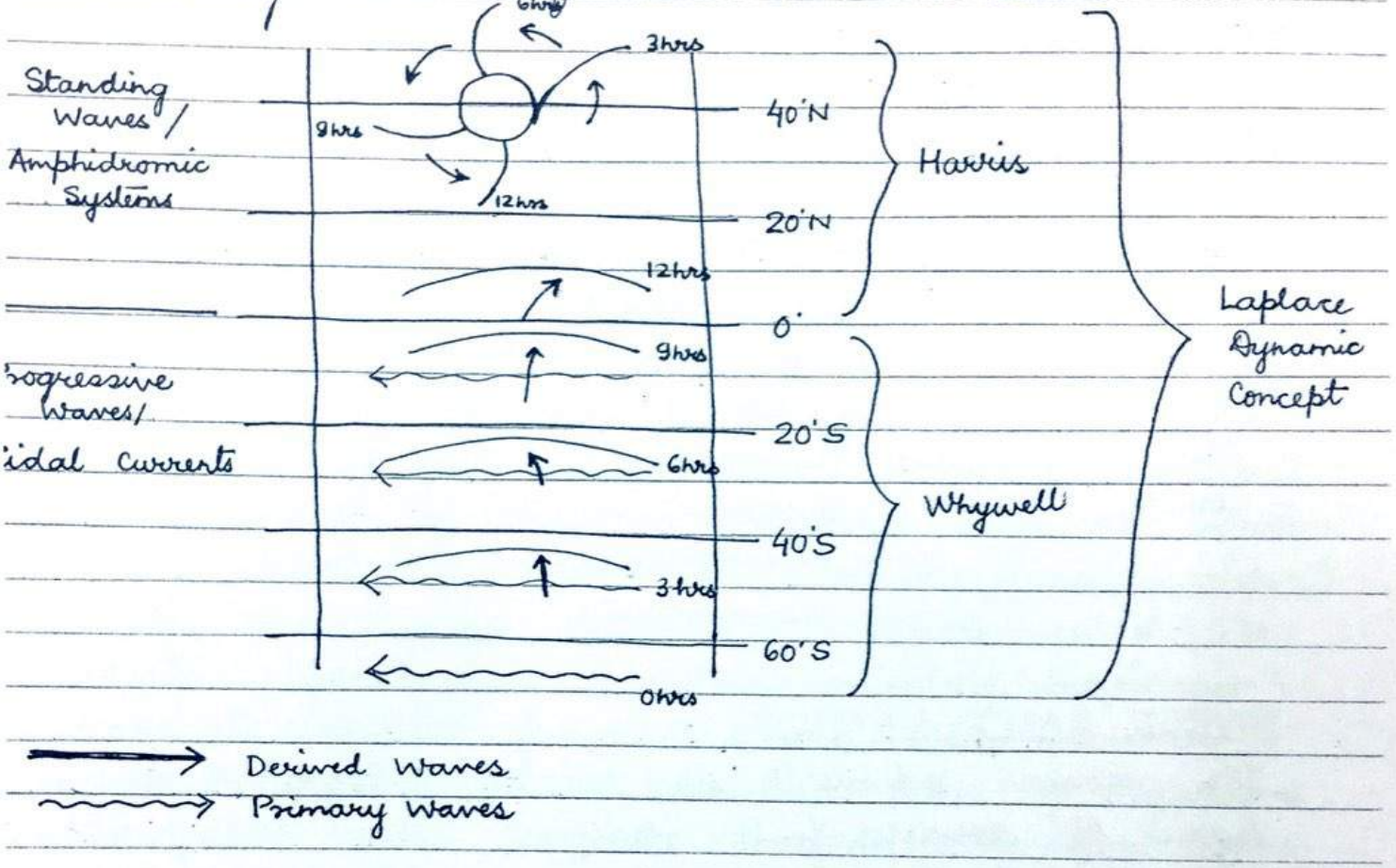
Aphelion (152 m.km) — Apogee (4 Lakh km)

YNAMIC CONCEPT OF TIDES

The equilibrium theory on tidal mechanism is based on the assumption that surface of the earth is in constant equilibrium to tide generating forces. Practically, the generated bulge fails to keep the alignment with the changing position of moon & in the combined effect of spin of the earth, shoreline barrier, coriolis force generates consisent water movements called tidal waves or tidal currents. As all the southern basins represent to be the examples of open counterparts, the created tidal bulge with the spin effect of earth, generates primary waves which moves from East to West as uninterrupted flow only in the southern ocean. In many of the southern basin, however, these primary waves are encountered with shoreline barrier making them piled up along the western shorelines generating sufficient gradient for high velocity movement. Such flow called derived waves. In the effect of coriolis force gets deflected to left generating western & north-western movement throughout the southern basin which maintains the water mobility approx. upto 12 hours after the moon has crossed the longitude.

In the northern basin, however, more enclosed characteristics of the water results in relatively 'higher' tidal bulge facilitating coriolis deflection being experienced by primary waves. As a result counterclockwise circulation of stationary or standing waves results in the formation of Amphidromic Systems maintaining water mobility.

for upto 12 hours after the moon has crossed the longitude. It is with amphidromic systems that higher tidal range is correlated making tidal energy harnessing more confined to northern basin.



synclinorium

Powell ⇒ Base Level

MARINE SEDIMENTS / OCEANIC DEPOSITS :-

'ying below the baselevel of erosion, submarine platforms incorporate large amount of unconsolidated debris deposits of variable texture, composition & origin. These deposits are correlated to potential commercial significance as well as proven commercial significance making their analysis important part of oceanographic study. These deposits are classified on the basis of :

Marine Deposits

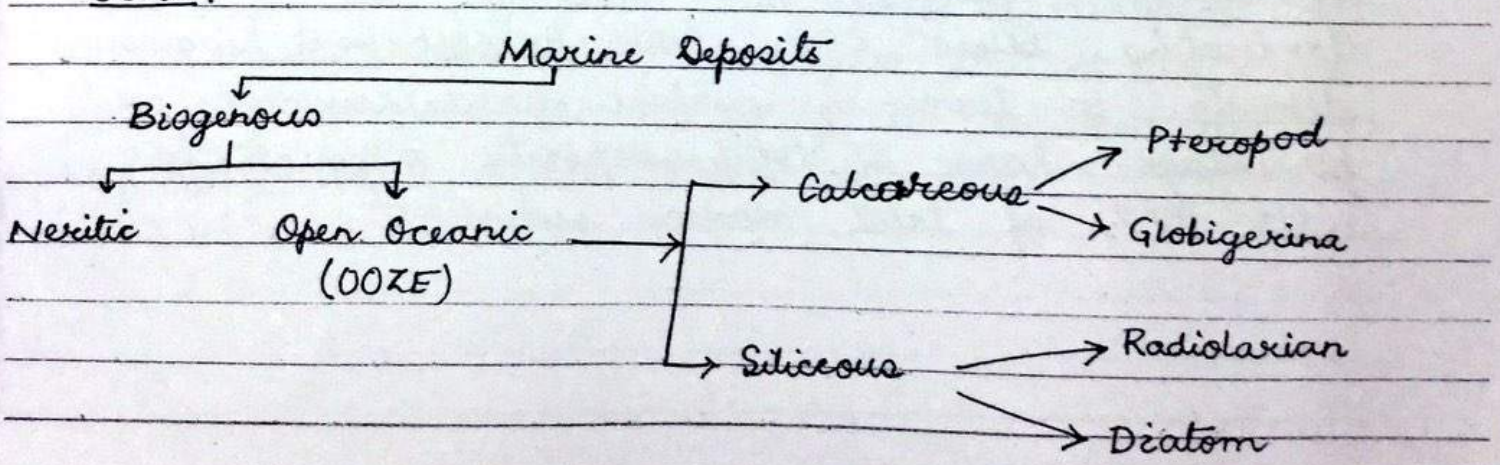
Texture	Source*	Location
- Fine	— Terragenous	— Neritic
- Coarse	— Biogenous	— Pelagic
	— Hydrogenous	— Benthic
	— Cosmogenous	

SOURCE BASED CATEGORY :

The marine sediments are mainly classified on the basis of source of the sediment. This classification is credited to Murray & Renard (1891) involving four different categories of marine sediments. The terragenous sediments are sourced from the continents primarily including gradational materials along with biotic constituents as dead remains of terrestrial organisms. It is gradational load that, however, accounts for maximum share of terragenous deposits. These are sub-classified primarily on the basis of texture wherein coarser textured material are more confined

on the shallower platform and are poorly sorted whereas finer textured materials are more confined to deeper locations and are well sorted. It is with well sorted terragenous deposits that continental rise as the depositional feature is correlated and it is with poorly sorted shelf deposits that apart from turbides and submarine erosion, marine mineral resources are also correlated as uranium deposits in Walvis Bay, phosphorite deposits in the shallower Peru-Chile basin as important examples. The terragenous sediments also includes biotic sediments which are combined with biogenous sediments.

ỷ **Biogenous Sediments**: The biogenous category represents entire range of marine sediments that are sourced from organism. Within this category, neritic deposits and open oceanic deposits are distinguished. The neritic deposits apart from including biogenous sediments sourced from the land also includes deposits of excreta or dead remains of organisms living in richest aquatic ecosystem i.e. continental shelf or neritic zone. More broader category, however, includes open oceanic biotic sediments, called OOZE.



Ooze Deposits :

The ooze deposits are the biogenous deposits identified with open oceans. These are compositionally sub-categorised into calcareous and siliceous ooze. The calcareous ooze is sourced by the organism like pteropod and globigerina which have more than 70% of their skeleton made up of $CaCO_3$. Though these organism very well thrive in oper oceanic habitat, their dead remains sourcing calcareous ooze is absolutely confined in the photic zone i.e. sun-lit zone. Combining both season cycles and sign of latitude, maximum depth of photic zone is 2000 metres, which is also "Calcium-Carbonate Compensation Depth (CCD)". It is defined to be the depth below which calcareous ooze is completely missing. The justified reason is acidic water in the complete absence of phytoplanktons, thus photosynthesis. Siliceous ooze in comparision is well distributed in both photic & aphotic zones as it is sourced by organisms like Radiolarian and Diatom, which have more than 70% of their skeleton made up of silica. These deposits clearly are more dominating below CCD. Both terragenous & biogenous deposits in terms of surface area coverage and percentage share of total deposits accounts for upto 99% of total marine sediments.

Persian Gulf Red Sea G. of Kutchh	} NaCl

ii) Hydrogenous (Authegenic)

- Evaporites → OOLITES ($CaCO_3$), NaCl
- Precipitates → Mn Nodules, Phosphorites, Iron rich Red Clay

These deposits are sourced by ocean water itself. These are therefore called authegenic deposits i.e. deposited at the absolute sourced area. In accordance to the location as well as involved processes, these are classified into evaporites and precipitates.

Evaporites : The evaporites confined mainly to neritic platforms in the drier climate includes the deposits that are commercially mobilised called oolites (calcium carbonate nodules) and sodium chloride

Precipitates : The precipitates in comparision are mainly confined to deeper platforms precipitated by ocean water. Manganese nodules, phosphorites deposits and iron-rich red clay make important examples

v) Cosmogenous: The sourced based categories of marine sediments theoritically also includes cosmogenous deposits. It includes extra-terrestrial material as inter-planetary dust adding to the characteristic of marine deposits. Practically, not just that this source of material is trace in its availability but also that it is such fine textured that it is likely to remain as suspended load rather than deposits.

Maxm. questions from PELAGIC

OCATION BASED CATEGORY :

Neritic (Shelf)	Pelagic	Benthic (On the bottom)
rarse	Neritic	Precipitate
rorly sorted	+	Siliceous Ooze
Terragenous	Ooze	Terragenous
Biogenous	Precipitate	
Evaporites		

13.2014

Lecture: 35

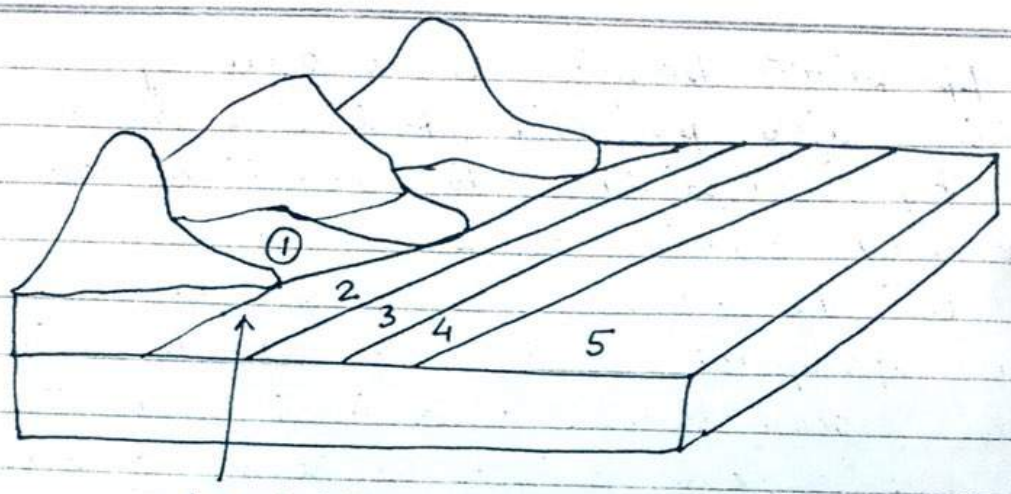
Azoic era – Metalliferous
Karjas – Brazil
Hamersley – Australia } Iron-ore

MARITIME ZONASIONS / LAWS OF SEAS

The maritime boundaries have been demarcated in context of UNCLOS (UN Convention on the Laws of Sea). In accordance to this convention, political & economic jurisdiction of the maritime states are being demarcated. It also includes "appropriated" jurisdiction of the landlocked countries belonging to the rim region. The maritime zonations was attempted with the tusples objective of minimising the politico-economic ~~tussles~~ between the neighbouring maritime States to not just facilitate peaceful co-existence but also favourable economic utilisation of extractable & non-extractable marine resources. Among the demarcated maritime zones based on appropriate baseline includes :

Inland water
Territorial water
Contiguous zone
Exclusive Economic Zone (EEZ)
Open water / High Sea.

The appropriate baseline is drawn by connecting all the major projecting peninsulas of maritime States by appropriating the interest of all the neighbouring maritime States. It is with this baseline that all the distances are measured. Demarcated within appropriate baseline is inland water which includes lagoon lakes, creek inlets where the maritime states has complete political authority as will be in the case of inland lakes or reservoirs. The territorial water forms the first absolute maritime zone beyond the appropriate baseline. It extends upto 12 nautical miles from the appropriate baseline. where the maritime state has absolute administrative and economic authority. Deployment of naval forces, custom excise obligations are thus applied to the territorial waters. In the larger water bodies with lesser number of maritime states extension of territorial water to maximum distance of 24 nautical miles from appropriate baseline is called contiguous zone. Beyond territorial waters exclusive economic zone (EEZ) forms the largest maritime zone that extends upto 200 nautical miles from the appropriate baseline. In this zone, maritime states have exclusive economic rights of exploration, exploitation though there is complete absence of military or custom obligations. It is in this zone that "prior consent" norm of third party intervention is also permissible. Beyond this zone is open water or high sea that is open to global community.



① Inland Water
② Territorial "
③ Contiguous Zone
④ Exclusive Economic Zone (EEZ)
⑤ Open Water / High Sea.

esotho, Swaziland } Maritime thro' S. Africa

Nepal, Bhutan } Maritime thro' India

MARINE RESOURCES :

Categorised into biotic & abiotic categories as extractable resources.

The biotic category includes Nectonic, Planktonic, Pearl & Seal as important subcategories.

The nectonic biotic resources includes fishes that represents most prominent life-styles of aquatic habitat. This marine resource is commercially mobilised in temperate water with general absence

↑ Sign of latitude ⇒ Biodiversity decreases. Nectonic – Swimmers
B/W shoreline & coastline ⇒ Inter tidal Zone

of commercial potentiality in tropical water. This is due to the fact that in tropical waters fishes are in impure shoals and have high oil content which not just increases the cost of harvesting but also restricts the utility of fishes as direct food resource for human consumption. In the commercially developed temperate fishing ground there is the combined harvesting of fishes from all the three habitats – pelagic, anadromous and benthic (or demersal)

Pelagic, the shallow habitat, involves larger shoals of the fishes with prominent most harvest being Halibut and Haddock. The applied technique for harvesting includes drifters. The anadromous habitat represents dual habitat where the fishes like Salmon (critically endangered) though lives in open water but for the specific purposes like breeding moves to inter-tidal zones. These are harvested by utilising wall nets. The demersal habitats are deep habitats largely correlating to smaller size of shoals. Most prominent harvest Cod is harvested by the technique utilising trawlers.

The major fishing grounds of the world primarily confined in temperate latitude:

(I) NE Atlantic (Dogger Bank)
(II) NW Atlantic (Grand & George Banks)
(III) NE Pacific (California Current)
(IV) NW Pacific (Japan)
(V) Southern Ocean, the ~~of~~
(VI) → The opened ocean of the world

Kuroshio — Circum Pacific Belt

G. of Mannar
G. of Thailand
G. of Tongking
} Less transparent due to river mouth loads.

have evolved as sound commercial fishing ground providing i. whale (storehouse of resource), krill (ecologically & economic most conducive nectonic variety) and White King fish (that is highest priced fish of the world also called White Gold fish). Japan, Norway, USA and Russia are important fishing nations.

In the biotic resource planktons have always been indirect food resource for human population as it is the phototrophs that support aquatic ecosystem. Similarly sea weeds have been utilised traditionally as one of the inputs in the food processing industry. In the present perspective, however, both planktons & sea weeds are now utilised as direct food resource for human consumption. For planktons apart from the major fishing grounds, all upwelling zones are included as commercial harvesting zone. Sea weeds, however, are more common in the inter-tidal zones largely of tropical land. The non-food resource in biotic category includes pearl and seal. Pearl fishing is mainly confined to tropical high saline body or less transparent water where the natural injection of nuclei in the oysters facilitates favourable conditions for pearl development. G. of Mannar, G. of Tongking, G. of Thailand and Red Sea makes important water bodies of natural pearl fishing. Seal fishing is primarily confined to colder water bodies as White Sea.

and Gulf of Alaska. Seal is primarily harvested for its skin utilised for fur cloth making. Montreal in Canada and St. Petersberg in Russia are the most prominent fur cloth making centres.

White Sea – M.W.B. of Arctic Ocean → Seal fishing.
St. Petersberg – G. of Finland →
G. of Alaska – Seal fishing
Monreal – Port City of Canada – Fur Cloth
↳ Eastern Canada.

Abiotic resource

This category prominently includes energy resources and mineral resources. The energy resources includes both conventional and non-conventional categories. In the conventional category crude oil and natural gas are extracted from submarine platforms. For crude oil, all the habital continents except Oceania incorporate big commercially mobilised extraction locations. In Asia, Persian Gulf & Sunda Shelf makes most important global examples of offshore crude oil reserves. In Anglo-America – Gulf of Mexico in Latin America – Gulf of Venezuela and Lake Maracaibo, in Africa – Bight of Benin & Bight of Bonny and in Europe – North Sea, represent major examples. For natural gas, Black Sea, Caspian Sea, Sea of Okhostk along with Bay of Bengal and G. of Khambat collectively accounts for all the major production with all the proven

commercially viable reserves.

Non - Conventional Energy Resource

In the marine environment, this category includes geothermal energy & tidal energy The geothermal energy sources correlating to active tectonic boundaries which represents steeper geothermal gradients at commercially utilisable depth. Eastern Russia, Japan, Western Canada & USA forms the examples of commercial mobilisation of this energy. It is Iceland, however, representing the projection of mid-Atlantic Ridge that makes the most prominent examples with upto 85% of commercial energy requirements of the country fulfilled by geothermal energy. For tidal energy, required tidal range makes it commercially viable in northern oceanic basins which are beneficiaries of amphidromic systems. Canadian Bay of Fundi & French Bay of Biscay and English Channel that makes ~~coo~~ commercially mobilised examples.

The Mineral Resources as both dissolved & deposited includes biggest range as Ocean water qualifies to be universal solvent and is the mouth of agents of gradation. It is however that apart from big size & depth commercial viability of mineral resources is highly restricted due to lack of concentrated amount. From among 47 different sea salts, commercially viable mineral resource includes NaCl, and oolites — both representing

Russian E. boundary
USA/Canadian W. boundary } Not Active Boundary

evaporite deposits. Similarly deposited minerals which are commercially mobilised includes phosphorites deposits in Peru-Chile basin and manganese nodules in Indian Ocean region - both representing precipitate deposits.

CORAL REEFS

The organic submarine construct which adds to the diversity of oceanic relief is called coral reef. These are developed due to deposition, compaction and cementation of dead remains of marine colonial organisms, called coral polyps. These organisms requires well defined conditions as their habitat restricting coral reefs in limited geographical parts of the world. Among the required conditions : shallow (200m), saline (34-35ppt), transparent, complete absence of suspended load and warm water (temperature b/w 20-25°C) are included. Even in such habitat structure of coral reef includes well demarcated constituents called Reef-flat representing delicate coral growth, reef crest representing thick coral growth are distinguished.

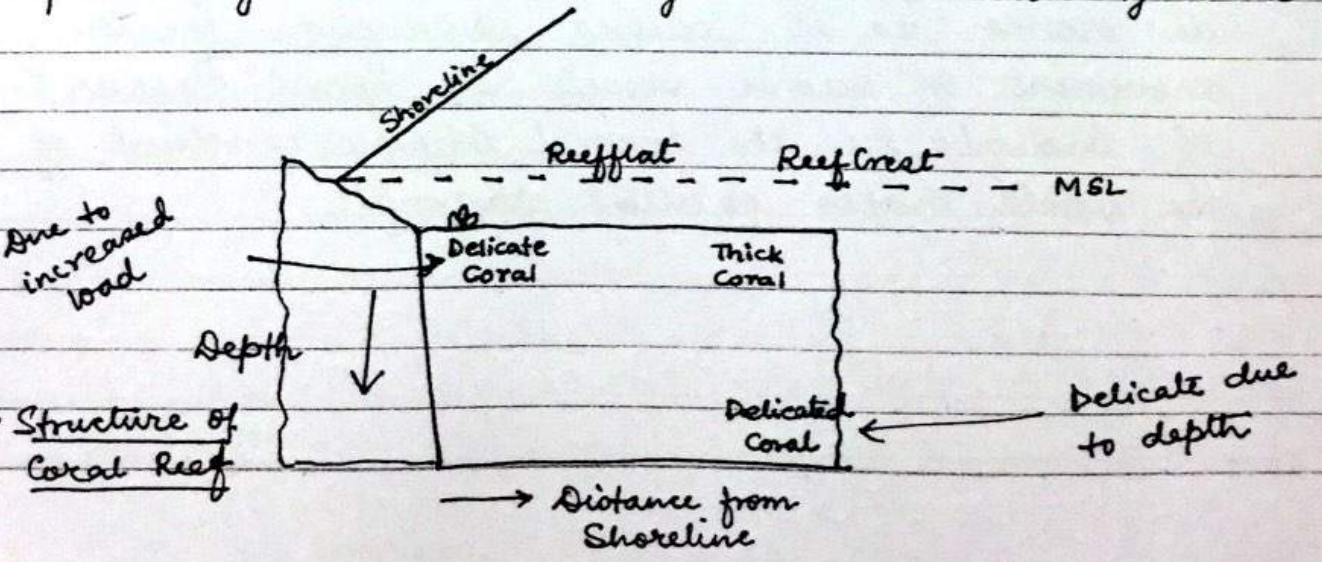


Fig. → Structure of Coral Reef

TYPES OF CORAL REEFS :

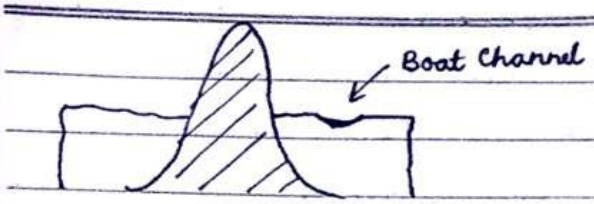
It is the structural components that forms the base of classifying coral reefs into 3 different categories :

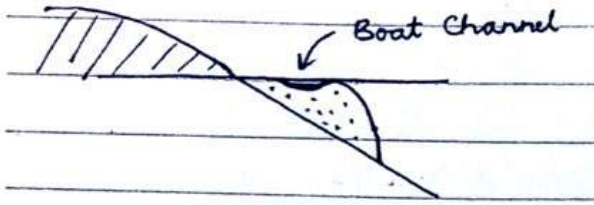
i) Fringing Reef
ii) Barrier - Reef
iii) Atoll

The fringing reef represents the smallest coral reef that fringes to the shoreline of an island or mainland. It is in accordance that it structurally incorporates reefflat, Completely attached to the shoreline, it is always devoid of demarcated lagoon lake. However, in the effectivity of chemical weathering, solution of reefflat do marks the development of small water body called boat channel. Fringing reef is recognised to be representing the beginning phase of development of coral reefs.

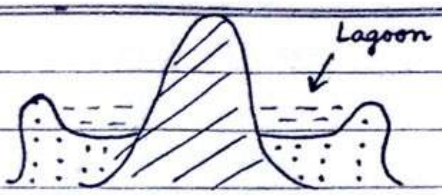
The barrier reef in comparison is more offshore reef and thus is always correlated to well demarcated lagoon lake. Structurally it always includes reef crest. This bigger sized reef is given its name as it causes obstruction for the movement of oceanic vessels. The Great Barrier Reef of Australia i.e. the largest organic construct of the world makes excellent example.

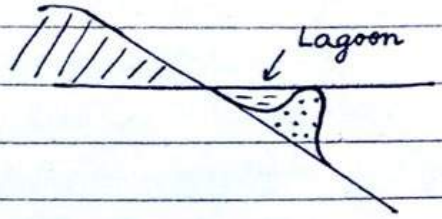
Fringing



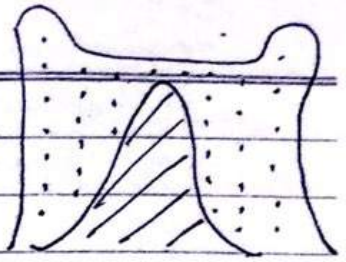


Barrier





Atoll



The Atolls are coral islands making more consolidated coral constructs though with these islands are largely circular or oval in shape with the effect of chemical weathering making them broken arc surrounding variable sized lagoon lakes. Maldives & Lakshwadeep in Indian Ocean & Fiji Islands in Pacific Ocean makes excellent habitat examples of atoll.

Lecture 36

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6.03.2014

Pleistocene ice-age → 10,000 yrs ⇒ Lower Neozoic
Sunderbans - named after Sundari trees
- mangroves
Kyoto Protocol

STUDY / THEORIES ON CORAL REEFS

The development process of coral reefs are completely explained and excellently deciphered oceanographic study. It correlates to the specified challenges of ~~ext~~ existence of reef at the depth of more than 200 m as well as its projection on the water surface as coral islands. These 2 problems of coral reef development is explained in the reference with:

1) Subsidence theory of Darwin & Dana
2) Glacial controlled theory of Daly.

The subsidence theory represents tectonic modifications leading to the formation of the coral reefs in geological course of time. In accordance to this theory, development of coral reefs are an absolute sequence developing fringing, barrier & atoll islands. St explains that in the first stage of reef development small fringing reef attached to the shoreline marks its development with the beginning of subsidence Development of reef is extended towards rising water levels as well as to the open water setting in second stage i.e. development of barrier reef In case of these developments taking place all around an island further subsidence will

result into 3rd and the final stage i.e. formation of atolls. This approach of Darwin excellently explains presence of coral reefs at the depth of more than 200 m. However, it do not explain formation process of coral islands. Similarly as it binds the coral reef development process in well-defined sequence, it fails to explain co-existence of the 3 different types. Moreover, tectonic subsidence can be practically applied to one specific island and is not applicable to entire tropical belt. It is therefore that the subsidence approach is utilised for explaining specific location of coral reef development. For the general purpose applied to all tropical water, it is climatologically correct glacial controlled theory of Daly that is taken into account.

During pleistocene ice age tropical water included coral polyps at the depth of more than 200 metres. With the termination of iceage, rise in the water level resulted in the development of any of the 3 types in accordance to the available conditions. Moreover, this concept avails the explanation of coral island formation in the effect of consolidation by island building trees of littoral vegetation.

CORAL BLEACHING

The coral reefs in the tropical photic zones sustains one of the richest aquatic ecosystems which is recognised to be matching in its density & diversity to that of equatorial rainforests on land. Coral bleaching or de-colourisation of coral reefs is fundamentally decay of coral reefs. This is primarily caused by increasing water temperature (global warming) and increasing water pollution.

The combination of these 2 processes have resulted in increase of chemical weathering surpassing the natural pace of reef construction. Moreover, under these 2 causative components — habitat destruction of coral polyps have decreased. the rate of construction decreasing coral reefs in significantly high rate. The decrease of coral reef simultaneously marking decrease of phytoplanktons & other green plants that are aquatic carbon sinks, which in turn is increasing acidic characteristics of ocean water further multiplying the rate of chemical weathering of coral reefs. It is this cascading sequence of effectivity that makes artificial implantation of coral reefs as immediate measure primarily taken up by Australia & India.