

## Oceanography

### Short Notes PDF

This Short Notes appears a bit long because of the images

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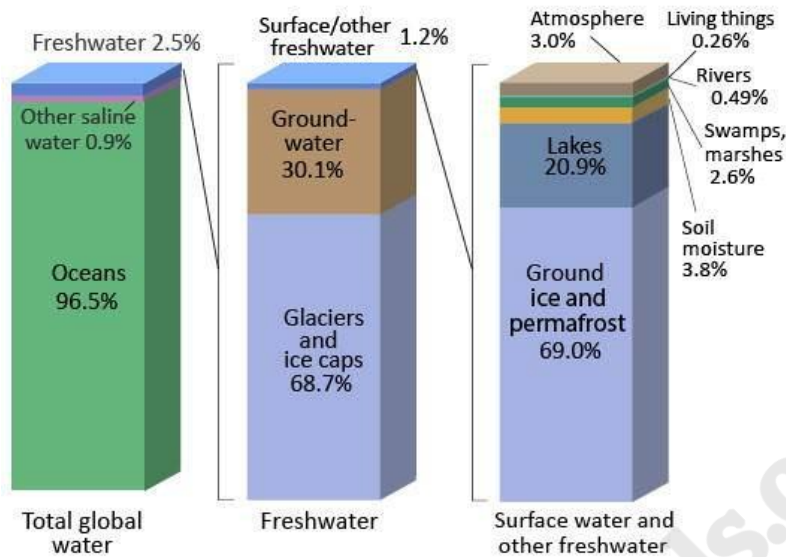
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**World Water Day – March 22**

**Water on the Earth’s surface**

<b>Reservoir</b>	<b>Volume (Million Cubic km)</b>	<b>% of the Total</b>
<b>Oceans</b>	<b>1,370</b>	<b>97.25</b>
<b>Icecaps and Glaciers</b>	<b>29</b>	<b>2.05</b>
<b>Groundwater</b>	<b>9.5</b>	<b>0.68</b>
<b>Lakes</b>	<b>0.125</b>	<b>0.01</b>
<b>Soil Moisture</b>	<b>0.065</b>	<b>0.005</b>
<b>Atmosphere</b>	<b>0.013</b>	<b>0.001</b>
<b>Streams and Rivers</b>	<b>0.0017</b>	<b>0.0001</b>
<b>Biosphere</b>	<b>0.0006</b>	<b>0.00004</b>

## Where is Earth's Water?



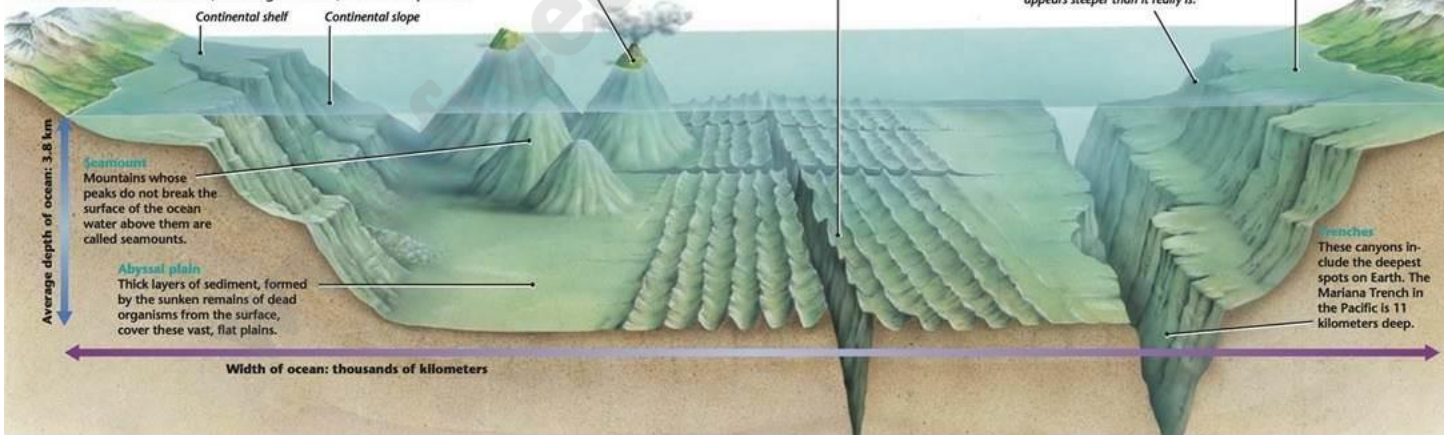
Source: Igor Shiklomanov's chapter "World fresh water resources" in Peter H. Gleick (editor), 1993, *Water in Crisis: A Guide to the World's Fresh Water Resources*.

NOTE: Numbers are rounded, so percent summations may not add to 100.

## 1. Ocean Relief

### EXPLORING the Ocean Floor

Earth's oceans are thousands of kilometers wide. To show the width of the ocean floor in this illustration, the vertical and horizontal scales are not the same. The vertical scale, showing depth, has been stretched. The horizontal scale, showing distances, has been squeezed.



Ocean Relief Features

### 1.1 Major Ocean Relief Features

Four major divisions in the ocean relief are:

1. the continental shelf,

2. the continental slope,
3. the continental rise,
4. the Deep Sea Plain or the abyssal plain.

## Continental Shelf

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- Gently sloping (**gradient of 1° or less**) seaward **extension of a continental plate**.
- It ends at a very steep slope, called the **shelf break**.
- Continental Shelves cover **7.5%** of the total area of the oceans.
- Example: Grand Banks around Newfoundland.

## Formation

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- The shelf is formed mainly due to
  1. **submergence of a part of a continent**
  2. **relative rise in sea level**
  3. **Sedimentary deposits brought down by rivers, glaciers**
- There are various types of shelves based on different sediments of terrestrial origin —
  1. **glaciated shelf (e.g. Shelf Surrounding Greenland),**
  2. **coral reef shelf (e.g. Queensland, Australia),**
  3. **shelf of a large river (e.g. Shelf around Nile Delta),**
  4. **shelf with dendritic valleys (e.g. shelf at the Mouth of Hudson River)**
  5. **shelf along young mountain ranges (e.g. Shelves between Hawaiian Islands).**



*Various types of shelves*

## Width and depth of continental shelves

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- Average width of **70-80 km**.
- Almost absent or very narrow along a convergent boundary. E.g. coasts of Chile.
- **Siberian shelf** in the Arctic Ocean is the largest in the world and stretches up to 1,500 km from the coast.



*Width of various continental shelves*

- Depth varies between 30 m to 600 m.

## Importance of continental shelves

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- 20% of the world production of **petroleum** and gas comes from shelves.
- Continental shelves form the richest fishing grounds. E.g. Grand Banks around Newfoundland.



*Grand Banks, the richest fishing grounds on earth*

- They are sites for **placer deposits** and **phosphorites** (explained in Ocean Resources).

## Continental Slope

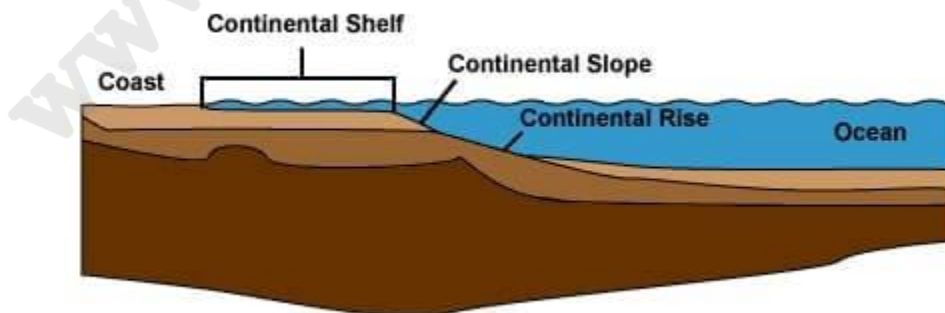
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- The gradient of the slope region varies between **2-5°**.
- Depth varies between 200 and 3,000 m.
- The **continental slope boundary indicates the end of the continents**.

## Continental Rise

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- When the slope reaches a level of between **0.5° and 1°**, it is referred to as the continental rise.



*Shelf, Slope and Rise ([Wikipedia](#))*

## Deep Sea Plain or Abyssal Plain

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- These are the **flattest** and smoothest regions of the world because of **terrigenous** (marine sediment eroded from the land) **and shallow water sediments**.
- It covers nearly **40%** of the ocean floor.
- The depths vary between 3,000 and 6,000 m.

## 1.2 Minor Ocean Relief Features

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- Ridges (along a divergent boundary),
- Abyssal Hills (submerged volcanic mountains): Seamounts and Guyots,
- Trenches (along a convergent boundary),
- Canyons (erosional landform),
- Island arcs (formed due to volcanism along a convergent boundary or hotspot volcanism),
- Atolls and Coral reefs.

### Oceanic Deeps or Trenches

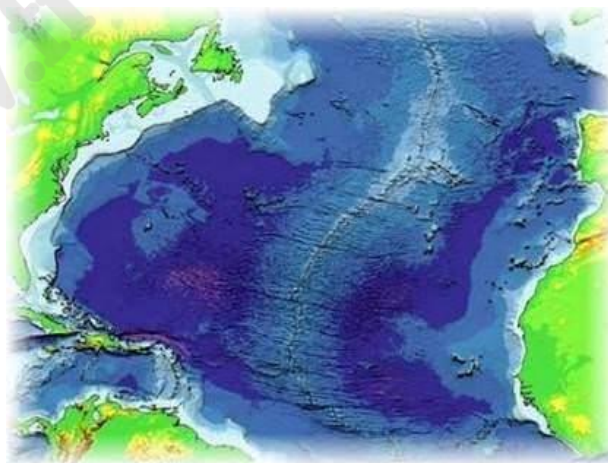
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- These areas are the deepest parts of the oceans.
- Formed due to ocean-ocean convergence and ocean-continent convergence.
- The **Mariana Trench off the Guam Islands** in the Pacific Ocean is the deepest trench (~11 km deep).

### Mid-Oceanic Ridges or Submarine Ridges

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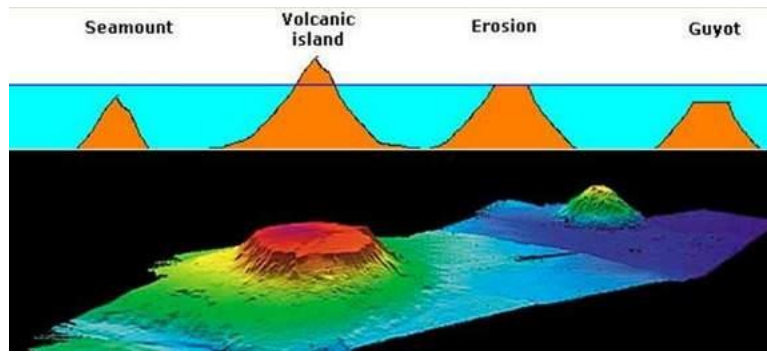
- Running for a total length of **75,000 km**, these ridges form the **largest mountain systems on earth**.



*Mid Ocean Ridge*

### Abyssal Hills

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*Abyssal Hills*

- **Seamount:** It is an underwater mountain of volcanic origin.
- The **Emperor seamount**, an extension of the **Hawaiian Islands** in the Pacific Ocean.
- **Guyots:** flat-topped mountains (seamounts).

## Submarine Canyons

**Canyon:** a deep gorge, especially one with a river flowing through it.

**Gorge:** a steep, narrow valley or ravine.

**Valley:** a low area between hills or mountains typically with a river or stream flowing through it.



*Canyon, George, Valley*

- Submarine canyons are deep valleys often extending from the mouths of the rivers to the abyssal plains.



*Submarine Canyon*



- The **Hudson Canyon** is the best-known canyon in the world.
- The largest canyons in the world occur in the **Bering Sea** off Alaska.

## Atoll

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- Coral reefs surrounding a central depression (**lagoon**).



*Atoll*

## Bank, Shoal and Reef

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- These marine features are formed as a result of **erosional, depositional and biological activity**.

### Bank

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- The depth of water here is shallow but enough for navigational purposes.
- E.g. The **Dogger Bank** in the **North Sea** and **Grand Bank** in the north-western Atlantic.
- **The banks are sites of some of the most productive fisheries of the world.**

### Shoal

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- A shoal is a detached elevation with shallow depths.
- They are **dangerous for navigation**.



*Shoal*

## Reef

- A reef is a predominantly organic deposit made by living or dead organisms.
- The largest reef in the world is found off the **Queensland coast of Australia**.
- They are generally **dangerous for navigation**.



Reef

## 2. Major Oceans and Seas

### 2.1 Oceans of the World by Size

Rank	Ocean	Area (million km <sup>2</sup> ) (%)	Average Depth (m)
1	Pacific Ocean	168 (46.6%)	3,970
2	Atlantic Ocean	85 (23.5%)	3,646
3	Indian Ocean	70 (19.5%)	3,741
4	Antarctic Ocean	21 (6.1%)	3,270
5	Arctic Ocean	15 (4.3%)	1,205

- **Total surface area of earth: 510 million km<sup>2</sup>**
- **Total water surface area: 70.8% (361 million km<sup>2</sup>)**
- **Total land surface area: 29.2% (149 million km<sup>2</sup>)**

### 2.2 The Pacific Ocean

- Largest and deepest ocean.
- Covers about **one-third** of the earth's surface.
- Its shape is roughly **triangular** with its apex in the north at the **Bering Strait**.

### **North and Central Pacific**

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- Characterized by **maximum depth** and a large number of **deeps, trenches and islands**.
- There are also a large number of **seamounts** and **guyots** (E.g. Hawaiian Hotspot).

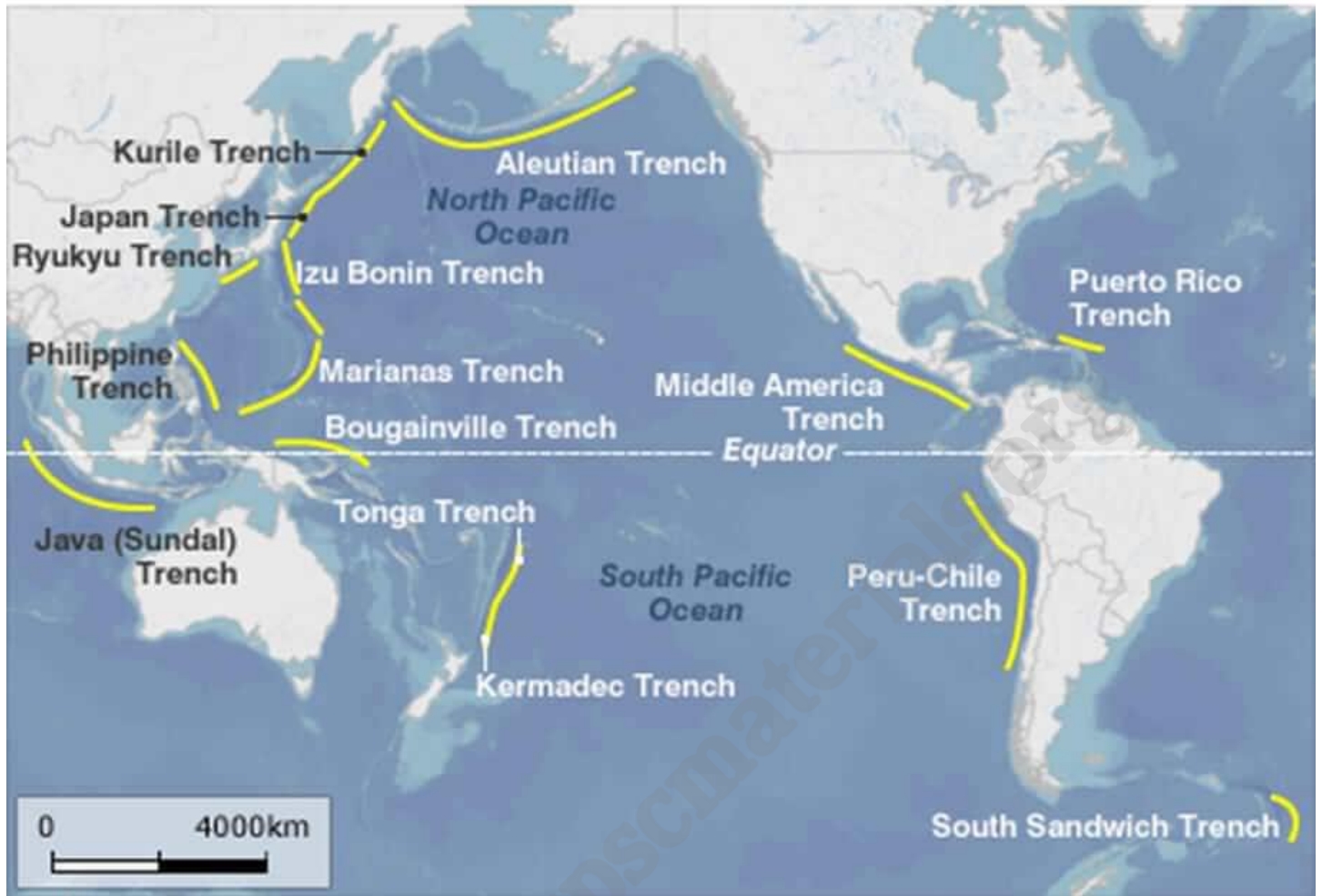
### **South-East Pacific**

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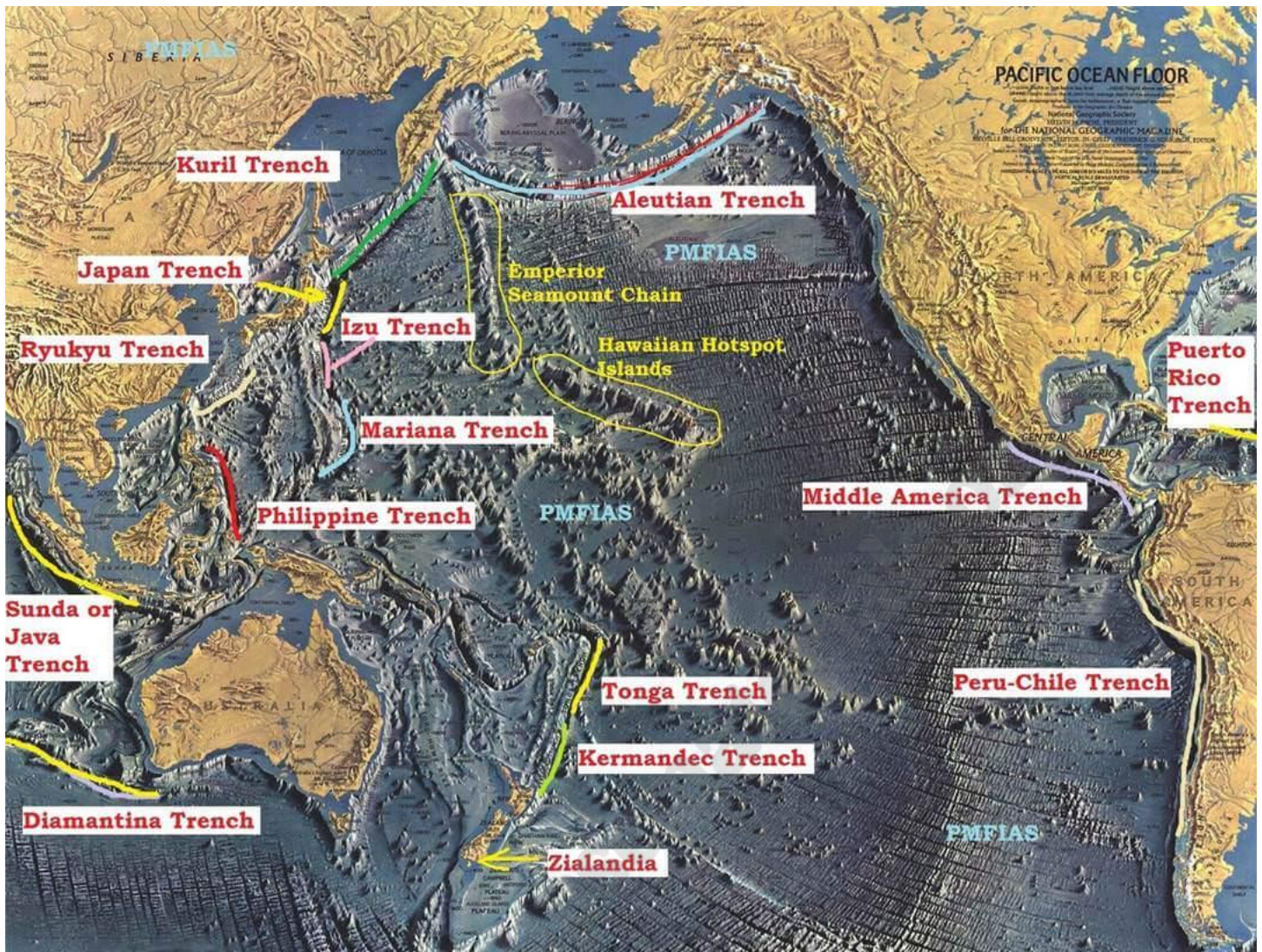
- This part is conspicuous for the **absence of marginal seas** and has submarine ridges and plateaus.

[www.freeupscmaterials.org](http://www.freeupscmaterials.org)

### Oceanic Trenches in the Pacific Ocean



www.freeupscmater



*Pacific Ocean Topography (Exaggerated) showing trenches and spreading sites*

## 2.3 The Atlantic Ocean

- Its shape resembles the letter 'S'.
- In terms of **trade**, it is the most significant of all oceans.



*Atlantic Ocean Topography (Exaggerated) showing trenches and spreading sites*

- **Grand banks continental shelf is the most productive continental shelf in the world.**
- The Atlantic Ocean has numerous marginal seas occurring on the shelves, like the Hudson Bay, the Baltic Sea, and the North Sea, and beyond the shelves like the Gulf of Florida (Mexican Gulf).

### **Mid-Atlantic Ridge**

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- The ridge has an average height of 4 km and is about **14,000 km long**.

### **Seamounts and guyots**

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- They are present in significant numbers but not as significant as in Pacific Ocean.
- Examples include **Pico Island of Azores, Cape Verde Islands, Canary Islands etc.**
- Also, there are coral islands like **Bermuda**.

## **2.4 The Indian Ocean**

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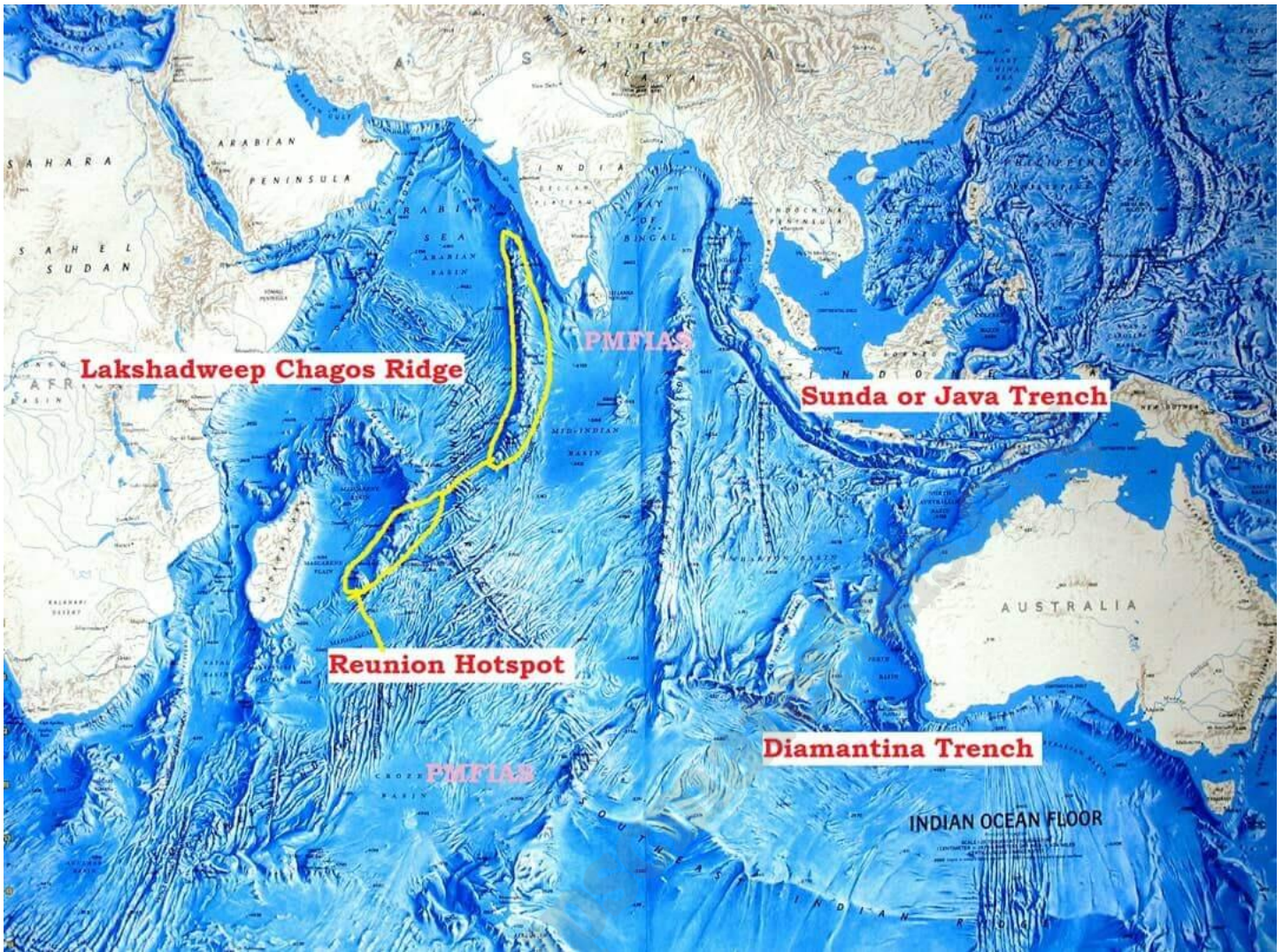
### **Submarine ridges**

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- Submarine ridges in this ocean include the **Lakshadweep-Chagos Ridge (Reunion Hotspot Volcanism)**, the **Socotra-Chagos Ridge**, the **Seychelles Ridge**, the **South Madagascar Ridge**, **Carlsberg Ridge etc.**







*Indian Ocean Topography (Exaggerated) showing trenches and spreading sites*

## Islands

- The **Lakshadweep** and **Maldives** are **coral islands** and **Mauritius** and the **Reunion Islands** are of volcanic origin.

## Continental Shelf

- The ocean's continental shelves are narrow, averaging 200 kilometres (120 mi) in width.
- An exception is found off Australia's northern coast, where the shelf width exceeds 1,000 kilometres (620 mi).

## Trenches

- Its deepest point is Diamantina Deep in Diamantina Trench, at 8,047 m.

## Straits

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- The major chokepoints include **Bab el Mandeb (between Yemen and Djibouti, Eritrea)**, **Strait of Hormuz (separates Persian Gulf from the Gulf of Oman)**, the **Lombok Strait (connects Java Sea to the Indian Ocean)**, the **Strait of Malacca (between Malay peninsula and Sumatra Island)** and the Palk Strait.

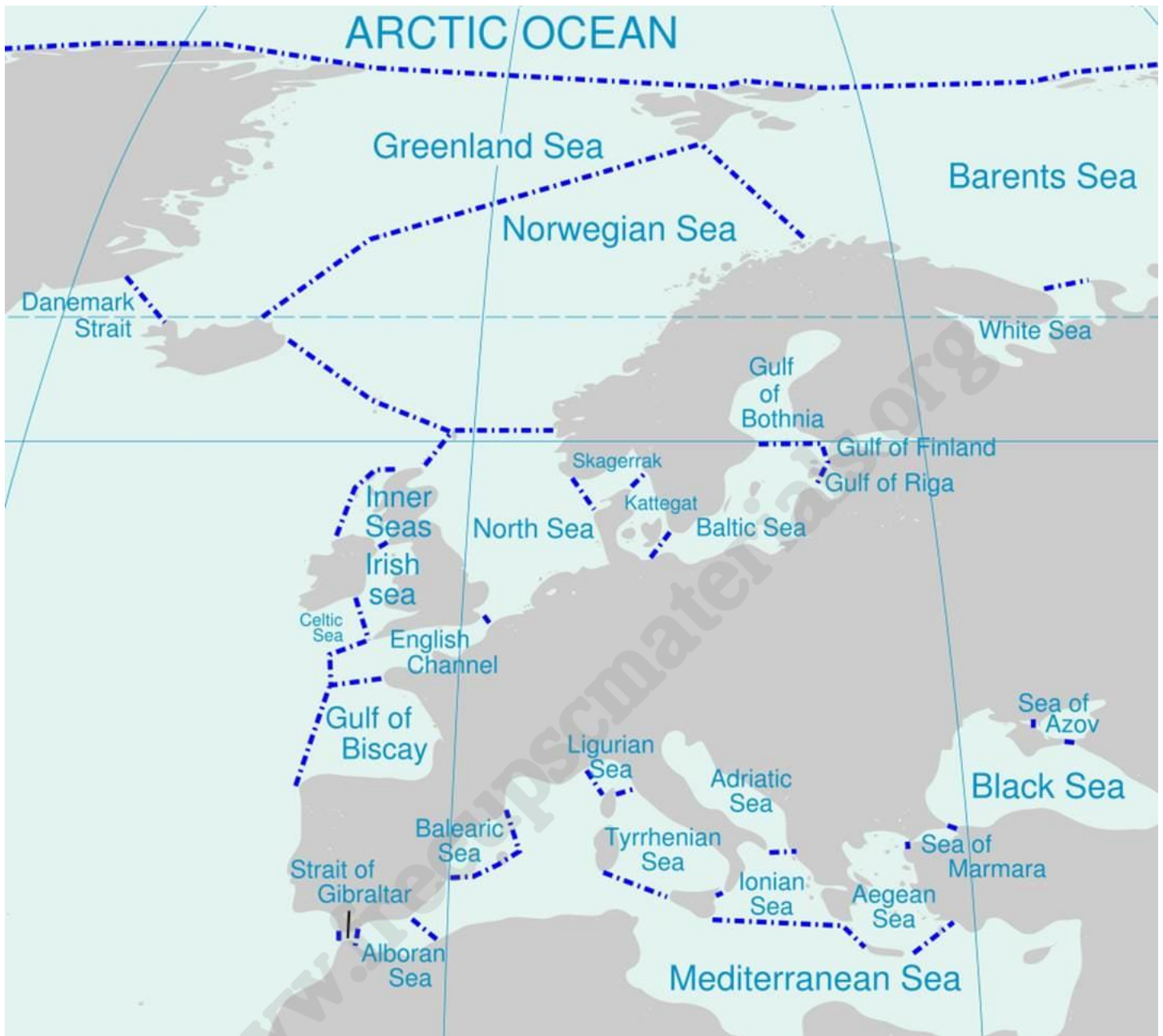
## 2.5 Marginal Seas

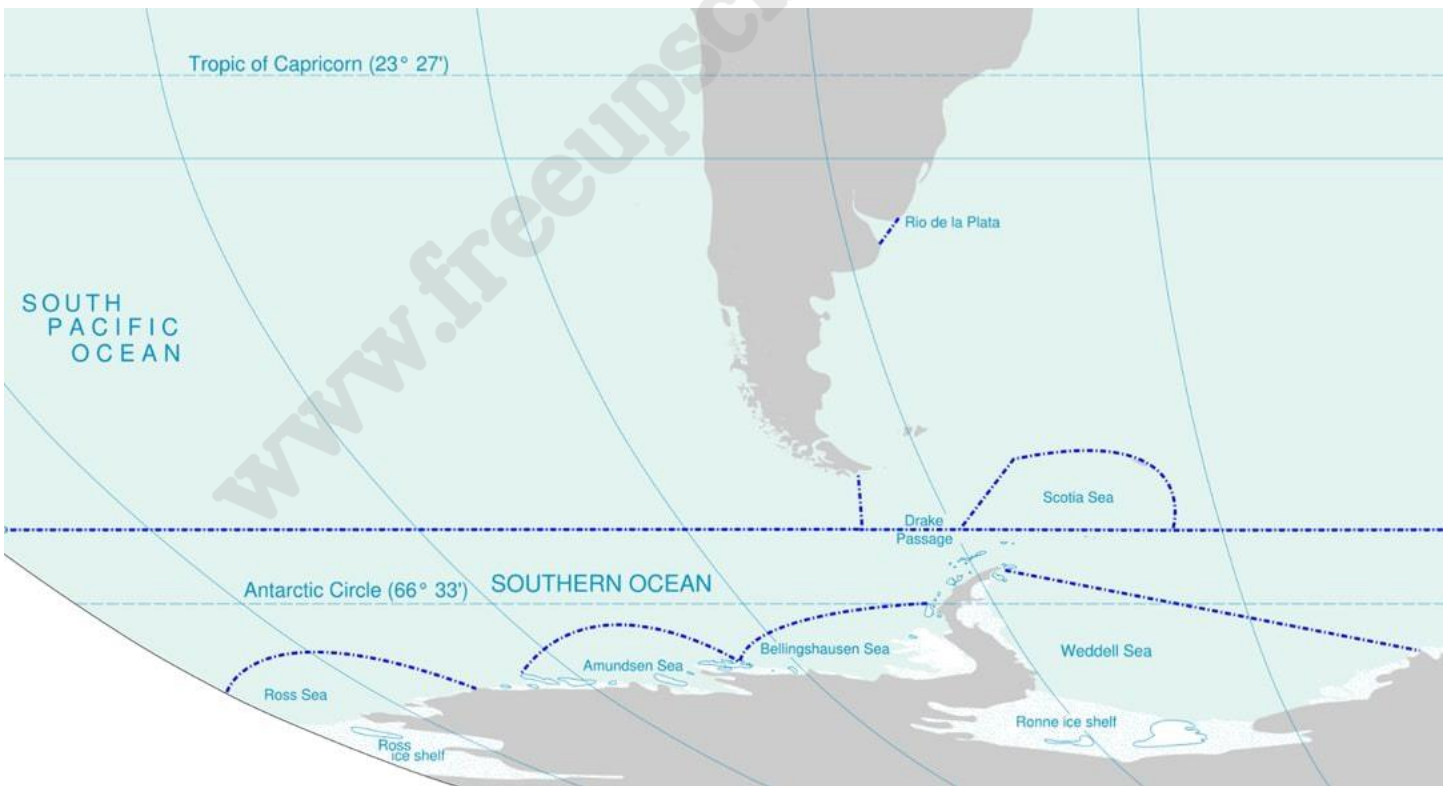
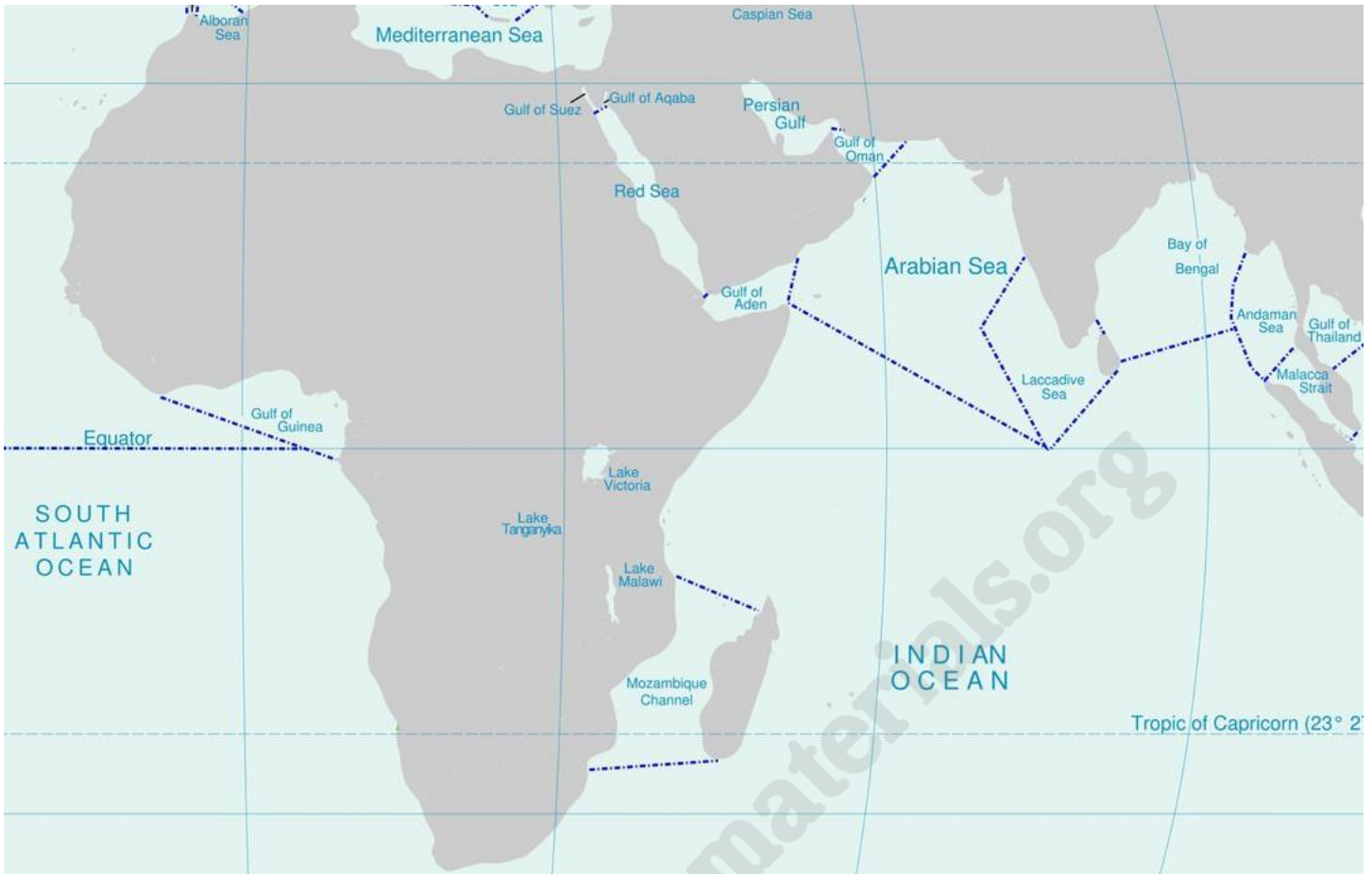
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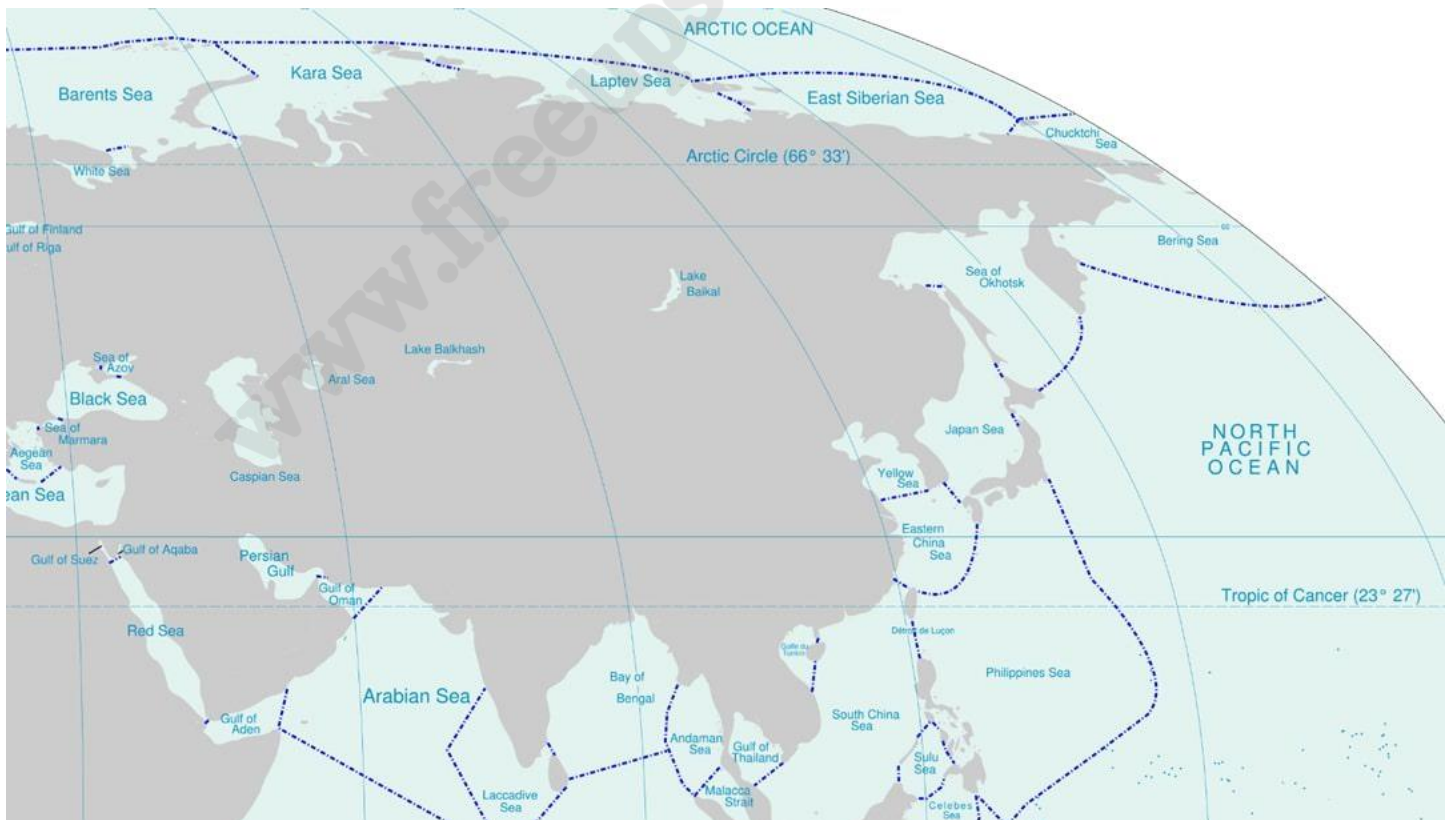
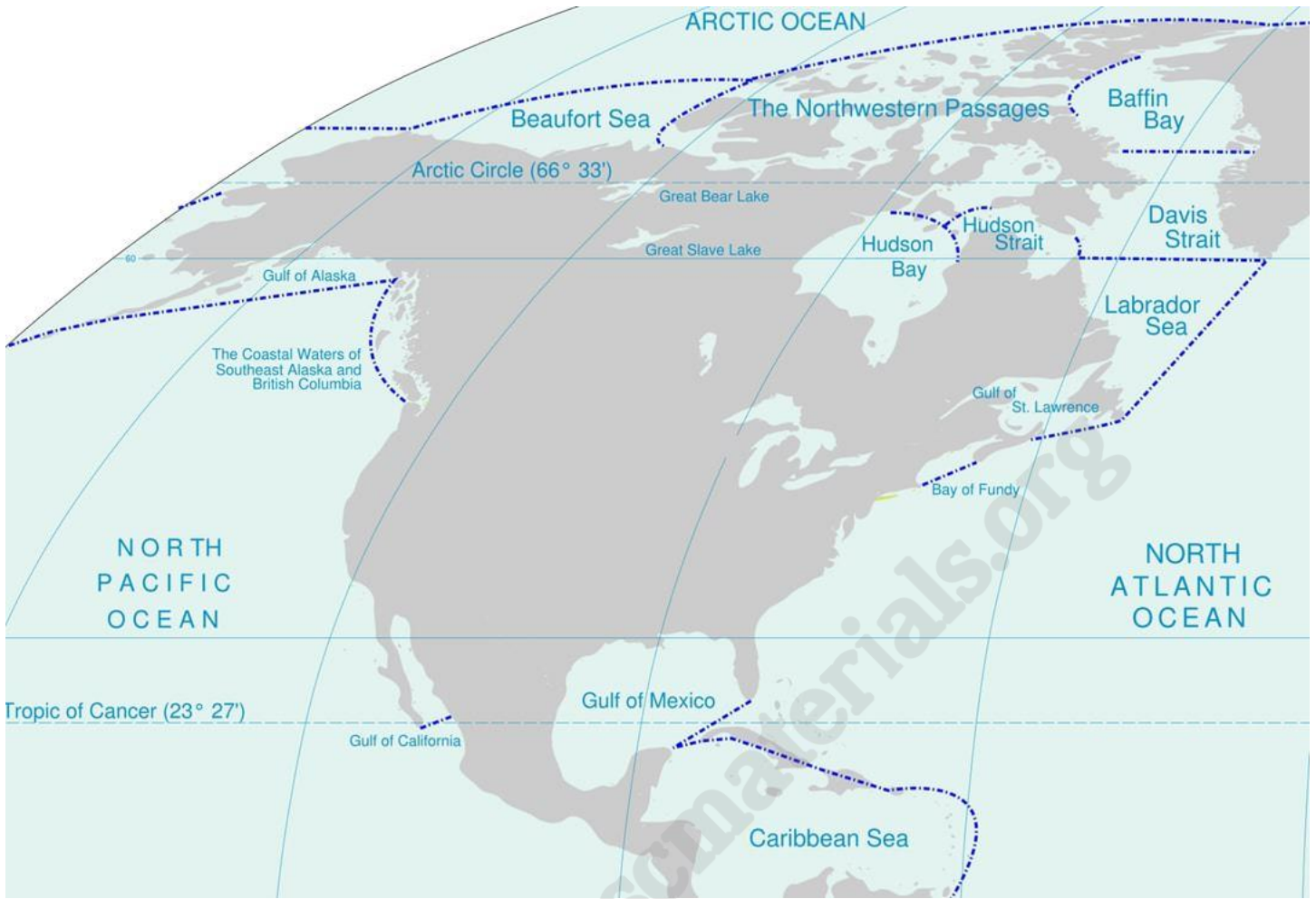
- Some of the major marginal seas include the **Arabian Sea, Baltic Sea, Bay of Bengal, Bering Sea, Black Sea, Gulf of California, Gulf of Mexico, Mediterranean Sea, Red Sea**, and all four of the **Siberian Seas (Barents, Kara, Laptev, and East Siberian)**.
- Marginal seas are generally shallower than open oceans, are more influenced by human activities.

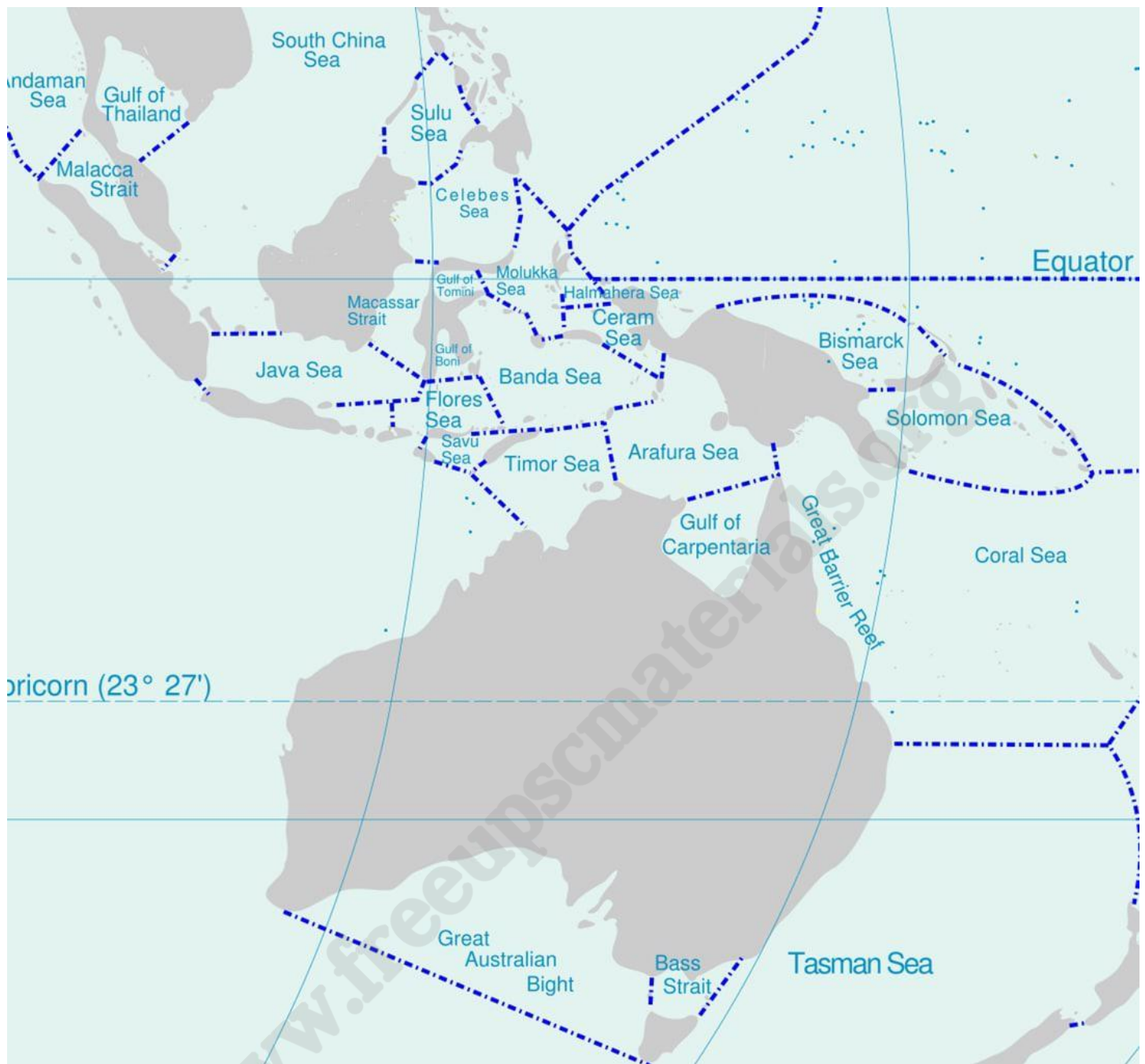
**Marginal Seas map:** <https://drive.google.com/file/d/0B1myJlOn-mMCNWJYSWtMZTtVGM/view?usp=sharing>

www.freeupscmaterials.org









*Major Marginal Seas*

### **Human Impact on marginal seas**

- Marginal seas are **more susceptible to pollution** than open ocean regions.

### **Phytoplankton Bloom (Algal Bloom) in Marginal Seas**

- The color difference between The Mediterranean Sea and the Black Sea is due to a **phytoplankton bloom** occurring in the Black Sea.



*Phytoplankton bloom in the Black Sea*

- Phytoplankton are good as fish feed on them. But when they proliferate indiscriminately, they **consume too much oxygen during nights**, thus **depriving other marine organisms of oxygen**.
- For example, the discharge of domestic sewage leads to elevated nutrient concentrations (particularly **phosphates**) which can result in harmful algal blooms.

### **Biomass Production and Primary Productivity**

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- Marginal seas generally exhibit intermediate levels of primary production, with the **highest rates found in coastal upwelling regions** and the **lowest primary production occurring in open ocean regions**.
- Although the addition of dissolved nutrients and trace elements, the addition of suspended particles increases water **turbidity**, which results in reduced sunlight penetration and **decreased** primary productivity.

### **Water Circulation in Marginal Seas**

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Circulation Patterns in Major Marginal Seas:

#### **Black Sea and Baltic Sea**

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- The Black Sea and Baltic Sea basins both possess **sills** that restrict subsurface water circulation.
- This type of subsurface-water restriction often leads to **stagnation**, which may eventually result in **local oxygen depletion**.

#### **Mediterranean Sea**

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- The Mediterranean Sea, which is divided by a 400-meter sill into two sub-basins, is connected to the Atlantic Ocean via the **Straits of Gibraltar**, to the Black Sea via the **Bosporus Strait**, and to the Red Sea via the **humanmade Suez Canal**.
- In Mediterranean Sea **evaporation exceeds precipitation** and hence salinity increases.
- Atlantic Ocean water replaces a fraction of the water that evaporates in the eastern Mediterranean Sea.

## Gulf of Mexico

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- A unique feature of the Gulf of Mexico's surface circulation pattern is the **Loop Current**, which results from the **Caribbean Current** entering the **Gulf of Mexico** through the **Yucatán Strait** and upon arrival, turning in a clockwise direction and "looping" around a warm "dome" of Gulf of Mexico surface water.

## 2.6 Bays, gulfs, and Straits

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### Bays

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- A bay is a small body of water that is set off from a larger body of water generally where the land curves inward.
- In simple words, bay is a water body surrounded on three sides by land with the fourth side (mouth) wide open towards oceans. (In Gulfs, the mouth is narrow).
- A bay is usually smaller and **less enclosed than a gulf**.
- Bay at a river's mouth is **New York Bay**, at the mouth of the **Hudson River (Hudson Estuary)**.

### Gulfs

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- A gulf is a large body of water, sometimes with a **narrow mouth**, that is almost completely surrounded by land. The world's largest gulf is the **Gulf of Mexico**.

### Straits

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- A strait is a narrow passageway of water.
- The **Strait of Gibraltar** is probably the world's most famous strait.
- Two other well-known straits are the **Strait of Bosporus** and the **Strait of Hormuz**.
- The Strait of Bosporus connects the **Black Sea (from the north) and the Sea of Marmara (from the south)** and splits north-western Turkey.
- The Strait of Hormuz is located at the **south-eastern end of the Persian Gulf**.



## Choke Point

- A body of water such as a strait is capable of being blocked or even closed.

## Isthmus

- Isthmus is the land-equivalent of a strait. i.e., a narrow strip of land connecting two larger land masses.
- Example: **Isthmus of Panama** and **Isthmus of Suez**.



*Isthmus of Panama and Isthmus of Suez*

## 3. Ocean Movements

- The movements that occur in oceans are categorized as **waves, tides and currents**.
- Tsunami, storm surge and tides are **tidal waves (meaning waves with large wavelengths)**.

### 3.1 Ocean Currents

#### Primary Forces Responsible for Ocean Currents

Explain the factors responsible for the origin of ocean currents. How do they influence regional climates, fishing and navigation? (Mains 2015)

#### Influence of insolation

- Near the equator, the ocean water is about 8 cm higher in level than in the middle latitudes.

#### Influence of wind (atmospheric circulation)

- Winds are responsible for both magnitude and direction (Coriolis force) of the ocean currents.
- Example: **Monsoon winds** are responsible for the seasonal reversal of ocean currents in the Indian ocean.

#### Influence of Coriolis force

- The Coriolis force causes the water to move to the **right** in the northern hemisphere.
- **Gyres**: large circular currents. **Sargasso Sea is a Gyre**.

## Secondary Forces Responsible for Ocean Currents

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- **Temperature difference** and **salinity difference** create **density differences**.
- Differences in water density affect **vertical mobility** of ocean currents (vertical currents).
- Water with high salinity is denser than water with low salinity.
- Similarly, cold water is denser than warm water.
- Denser water tends to sink, while relatively lighter water tends to rise.

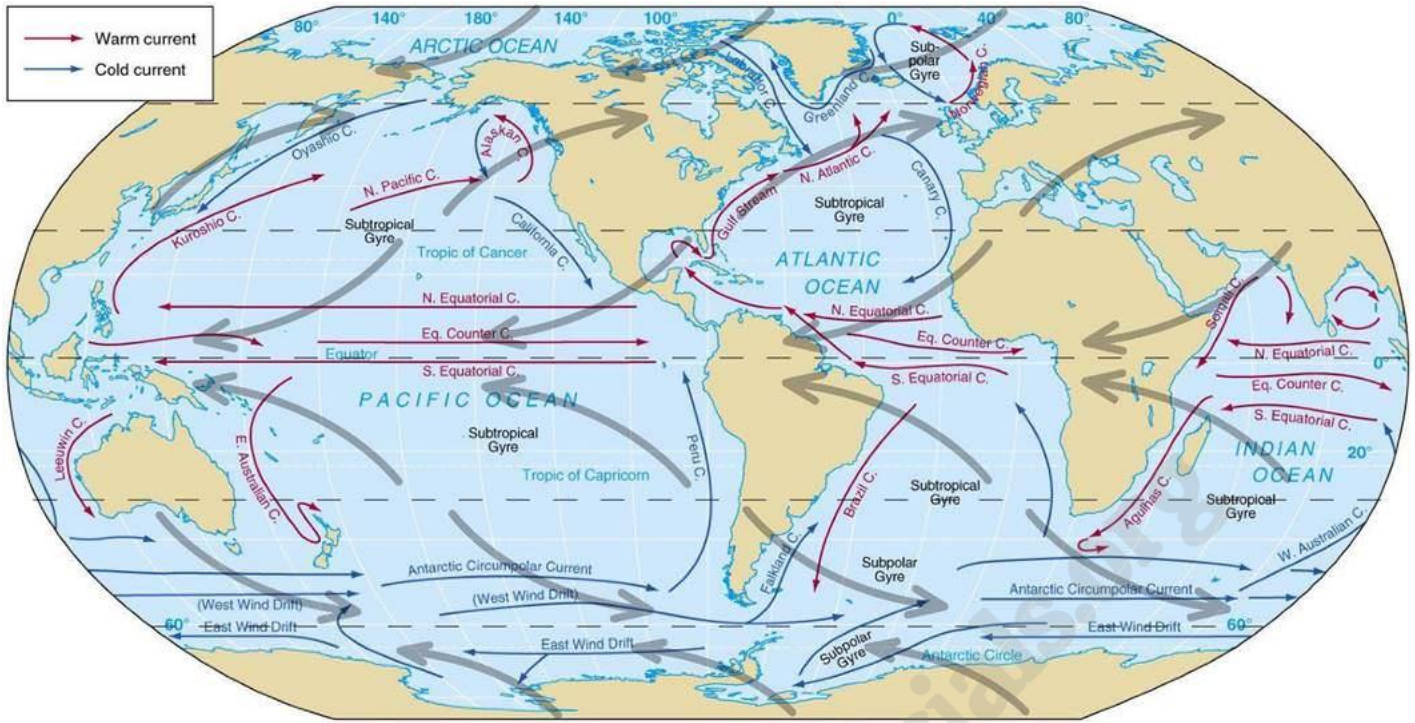
## Types of Ocean Currents

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- **Cold-water ocean currents** occur when the cold water at the poles sinks and slowly moves towards the equator as **subsurface flow**.
  - **Warm-water currents** travel out from the equator along the surface, flowing towards the poles to replace the sinking cold water.
1. Cold currents are usually found on the **west coast of the continents** (because of clockwise flow in northern hemisphere and anti-clockwise flow in southern hemisphere) in the low and middle latitudes (true in both hemispheres) and on the east coast in the higher latitudes in the Northern Hemisphere.
  2. Warm currents are usually observed on the east coast of continents in the low and middle latitudes (true in both hemispheres). In the northern hemisphere, they are found on the west coasts of continents in high latitudes.

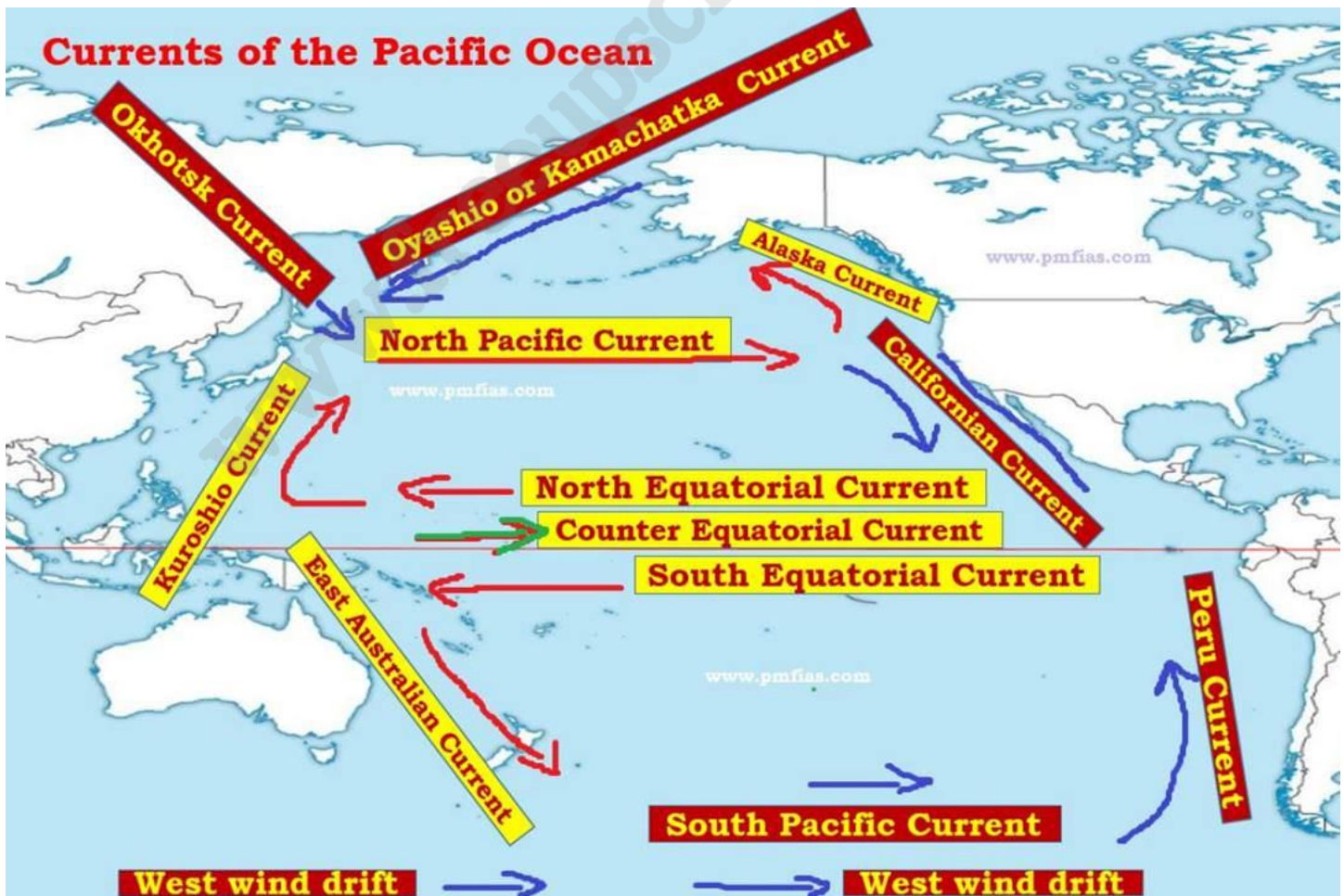
**Convergence:** warm and cold currents meet.

**Divergence:** a single current splits into multiple currents flowing in different directions.



Cold and Warm Ocean Currents

**Pacific Ocean Currents**



*Pacific Ocean Currents***Equatorial currents – warm**

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- Under the influence of **prevailing trade winds [tropical easterlies]**, the **north equatorial current** and the **south equatorial current** flow from **east to west**.
- This raises the level of western Pacific (near Indonesia and Australia) ocean by few centimetres.
- And this creates a **counter-equatorial current** which flows between the north equatorial current and the south equatorial current in **west-east** direction.

**Factors that aid the formation of Counter-Equatorial current**

1. Piling up of water in the western Pacific due to trade winds.
2. The presence of doldrums (calm region in equatorial low-pressure belt) in between the north equatorial current and the south equatorial current.

**Question Prelims 2015: What explains the eastward flow of the equatorial counter-current?**

- a) The Earth's rotation on its axis
- b) Convergence of the two equatorial currents
- c) Difference in salinity of water
- d) Occurrence of the belt of calm near the equator

Point 1: Earth's rotation creates Coriolis force, but Coriolis force is not responsible for counter-current.

Point 2: Convergence is a prerequisite, but not all convergences lead to counter-currents.

Point 3: Salinity greatly influences vertical currents and its influence on horizontal movement is less significant.

So, ruled out.

Point 4: This is the main reason behind counter equatorial current (the backward movement of equatorial waters). Doldrums are calm regions facilitating the backward movement of water.

Answer: D

- Okhotsk current flows past **Sakhalin Islands** to merge with the Oyashio current off Hokkaido (Northern Japanese Island).
- The **convergence of cold and warm currents makes the zone one of the richest fishing grounds**.

**Peru current or Humboldt Current – cold**

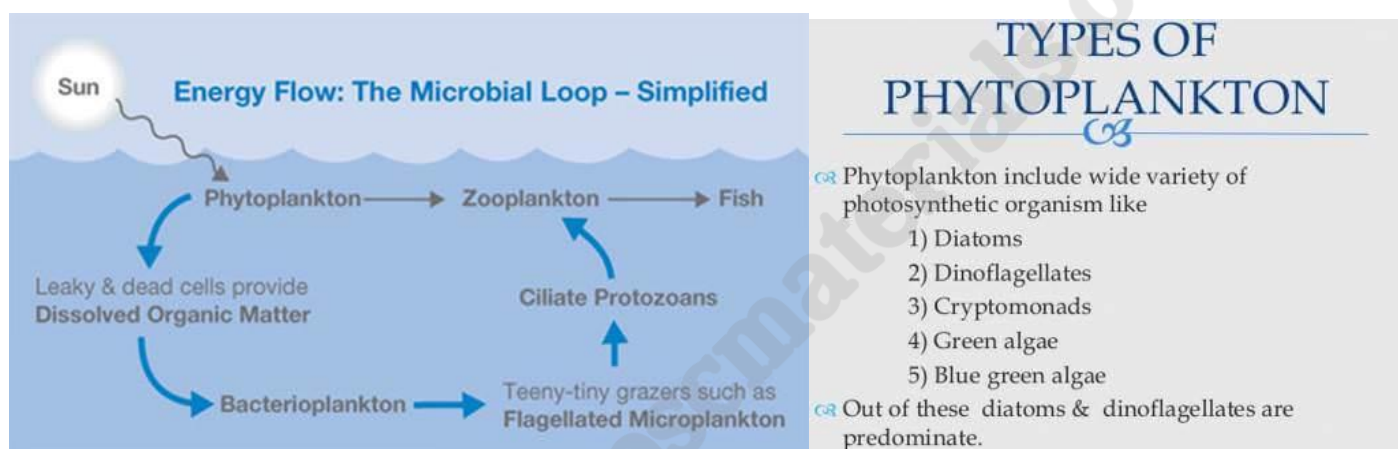
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- The zone where Peru Cold current meets the warm equatorial ocean waters is an important fishing zone.

## Phytoplankton and Fishing

Mixing zones of Cold and Warm Ocean Currents (Grand Banks) and cold water upwelling zones (Peru coast) are the most productive fishing grounds on earth. Why?

- Phytoplankton are the **primary producers** in the marine food chain and hence they are called the **grass of the sea**.
- Phytoplankton are predominantly **microscopic, single-celled** organisms.



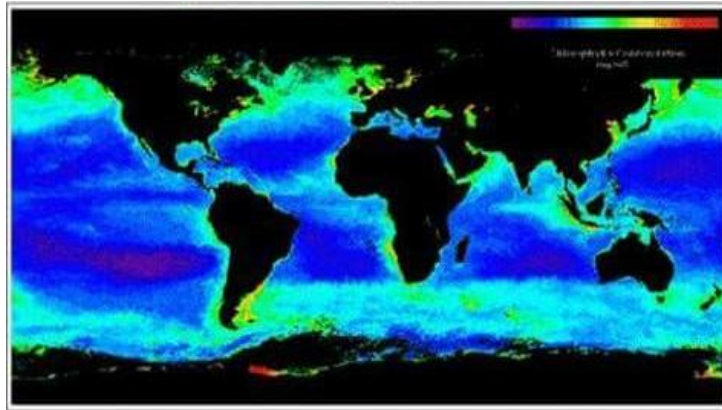
*Aquatic Food Web (Left); Types of Phytoplankton (Right)*

**Why are cold and warm current mixing zones the good fishing grounds? Why are tropical waters highly unproductive?**

- Algae and other plants are able to **photosynthesise** to produce **organic material** from inorganic nutrients.
- Almost all biomass in the ocean is derived from the **phytoplankton** and to a lesser extent the **benthic algae** (*found on the bottom of a sea or lake*).
- However, there is a fundamental problem phytoplankton in the open ocean have to face. They **need both sunlight and nutrients** (such as **nitrate** and **phosphate**) to be able to photosynthesise.
- Sunlight is only available in the uppermost layers.
- During photosynthesis, the nutrients are quickly used up by phytoplankton, so they are not available for long periods in the upper layers under normal circumstances.

**This is indeed the case in tropical waters, and as a result, they are very unproductive.**

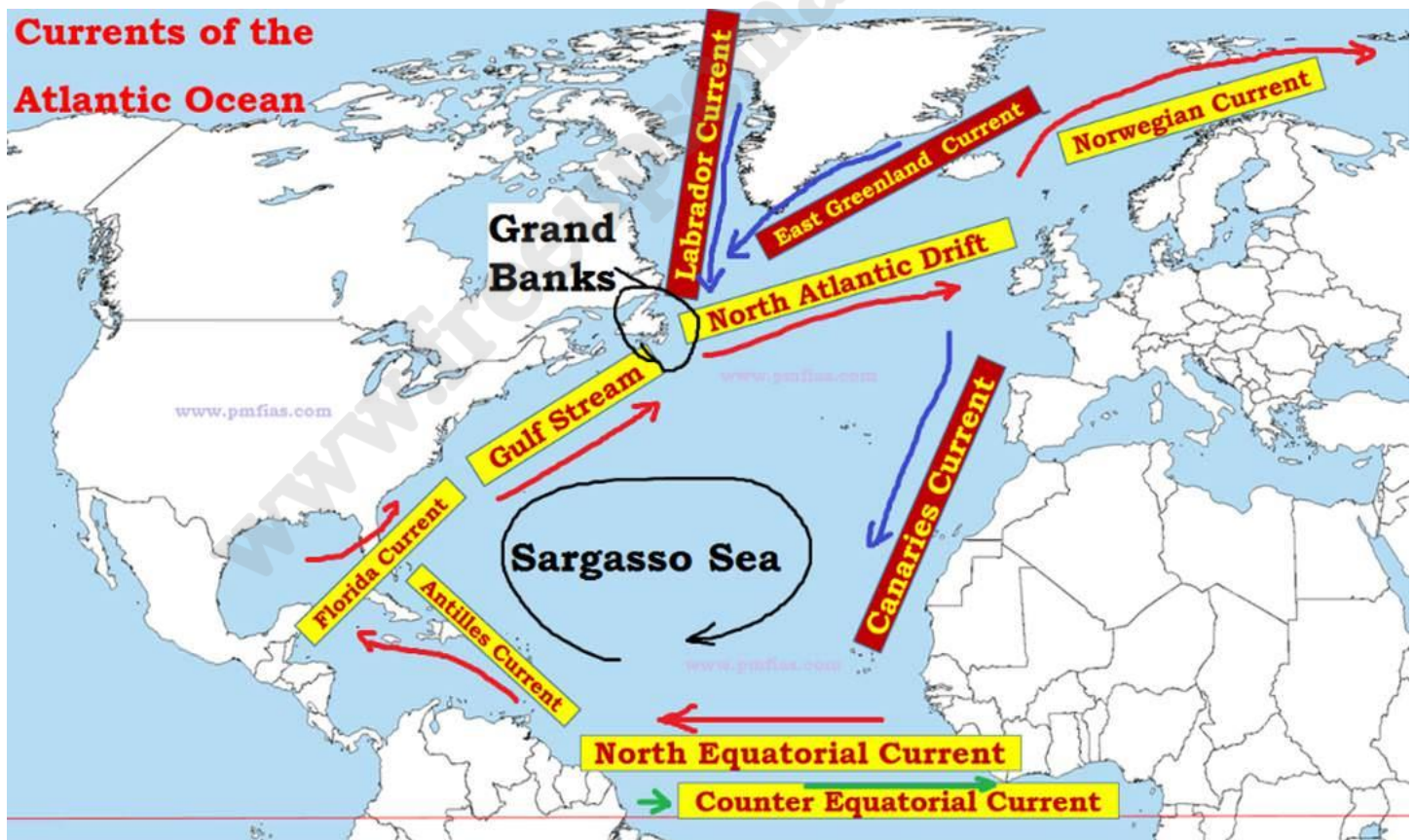
- To escape this problem the seawater needs to be **mixed regularly** to bring the **nutrient-rich deep waters** up to the sunlight zone where the phytoplankton can grow.



*Phytoplankton production is highest at high latitudes*

This is one of the reasons why cold and warm currents **convergence zones** (mixing happens; e.g. **Grand Banks**) and **upwelling zones** (e.g. upwelling near Peruvian coast) are very productive.

## Atlantic Ocean Currents



*North Atlantic Ocean Currents*

## Gulf Stream and North Atlantic Drift – warm

- **Antilles current** creates a current that flows out through the Strait of Florida as **Florida current**, which mixes with Antilles current from the south.
- This combined current moves along the east coast of USA and is known as the Florida current up to the **Cape Hatteras** and as the **Gulf Stream** beyond that.
- Near the **Grand Banks**, the **Gulf Stream mixes with cold Labrador and East Greenland currents and flows eastward across the Atlantic as the North Atlantic Drift**.
- Here, westerly movement of North Atlantic Drift is due to the influence of **westerlies**.

### **Norwegian current – warm**

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- The North Atlantic Current breaks up into two branches on reaching the eastern part of the ocean.
- The main current, continuing as the North Atlantic Drift, reaches the British Isles from where it flows along the coast of Norway as the **Norwegian current** and enters the Arctic Ocean.
- Norwegian current is **very important** as it **keeps ocean to the north of Norway partly free from ice** and also moderates the extremes of climate.
- It is because of this current, Russia is able to move cargo in summers through **Arctic ocean (Barents Sea)**.
- The **Sargasso Sea**, lying within this circuit, is full of large quantities of **seaweed** and is an important geographical feature.

### **Sargasso Sea – a sea without a land boundary**

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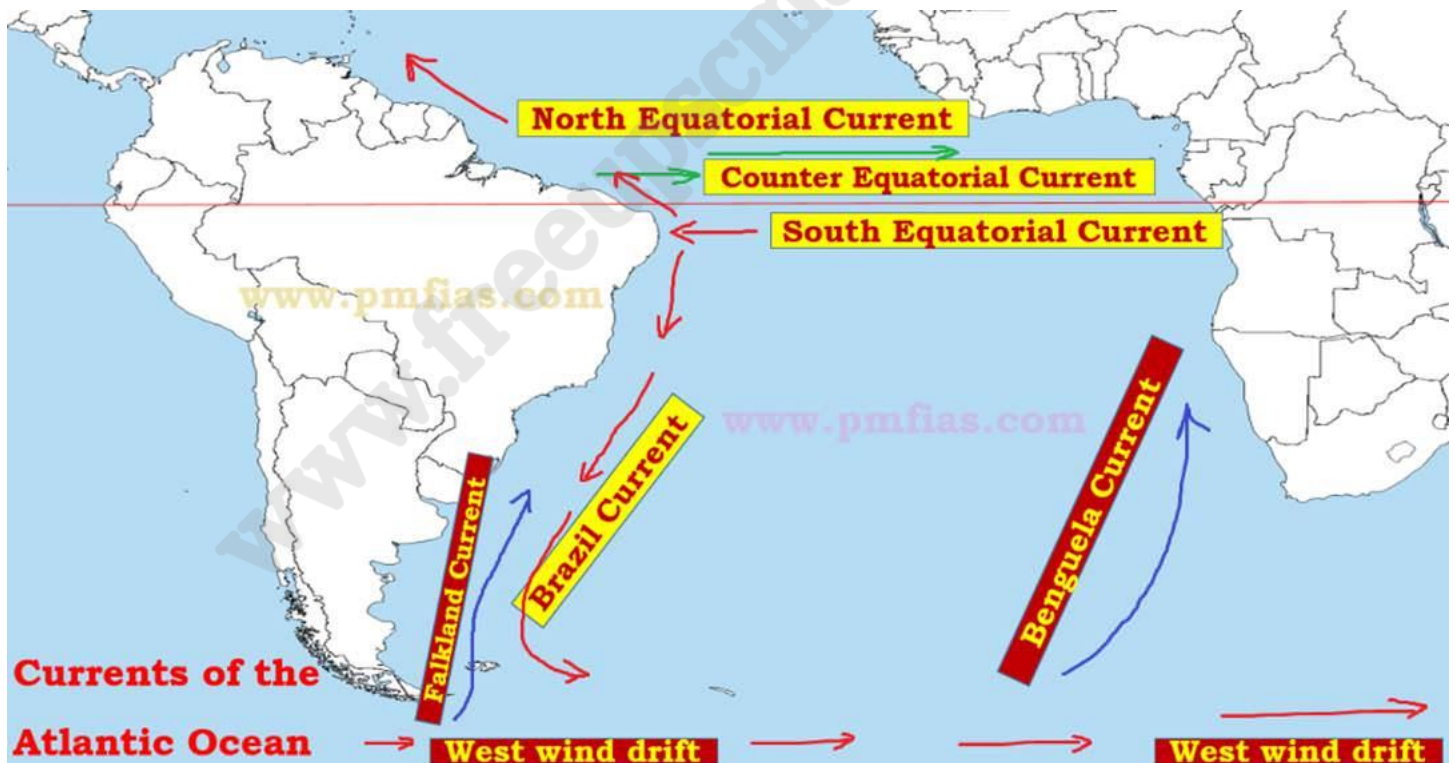
- The Sargasso Sea is a region in the **gyre** in the middle of the North Atlantic Ocean.
- It is the only sea on Earth which has **no coastline**.
- It is bounded on the
  1. west by the **Gulf Stream**;
  2. north, by the **North Atlantic Current**;
  3. east, by the **Canary Current**; and
  4. south, by the **North Atlantic Equatorial Current**.
- This system of ocean currents forms the **North Atlantic Gyre**.
- All the currents deposit the marine plants they carry into this sea.



*Sargasso Sea*

### Grand Banks-Richest Fishing Grounds on Earth

- The Labrador current flows along part of the east coast of Canada and meets the warm Gulf Stream.
- The confluence of these two currents, one hot and the other cold, produce the famous **fogs around Newfoundland**.
- As a result of mixing of cold and warm waters, **one of the world's most important fishing grounds is created**.



*South Atlantic Ocean Currents*

### Brazil current – warm



- In the South Atlantic Ocean, the south equatorial current, flowing from east to west, splits into two branches near **Cape de Sao Roque (Brazil)**.

### **Benguela current – cold current**

---

- A branch of the South Atlantic splits at the southern tip of Africa and flows along the west coast of South Africa as the cold Benguela current, which joins the south equatorial current to complete the circuit.

**Prelims 1999: In the given map, which one of the following pairs of ocean currents are shown?**

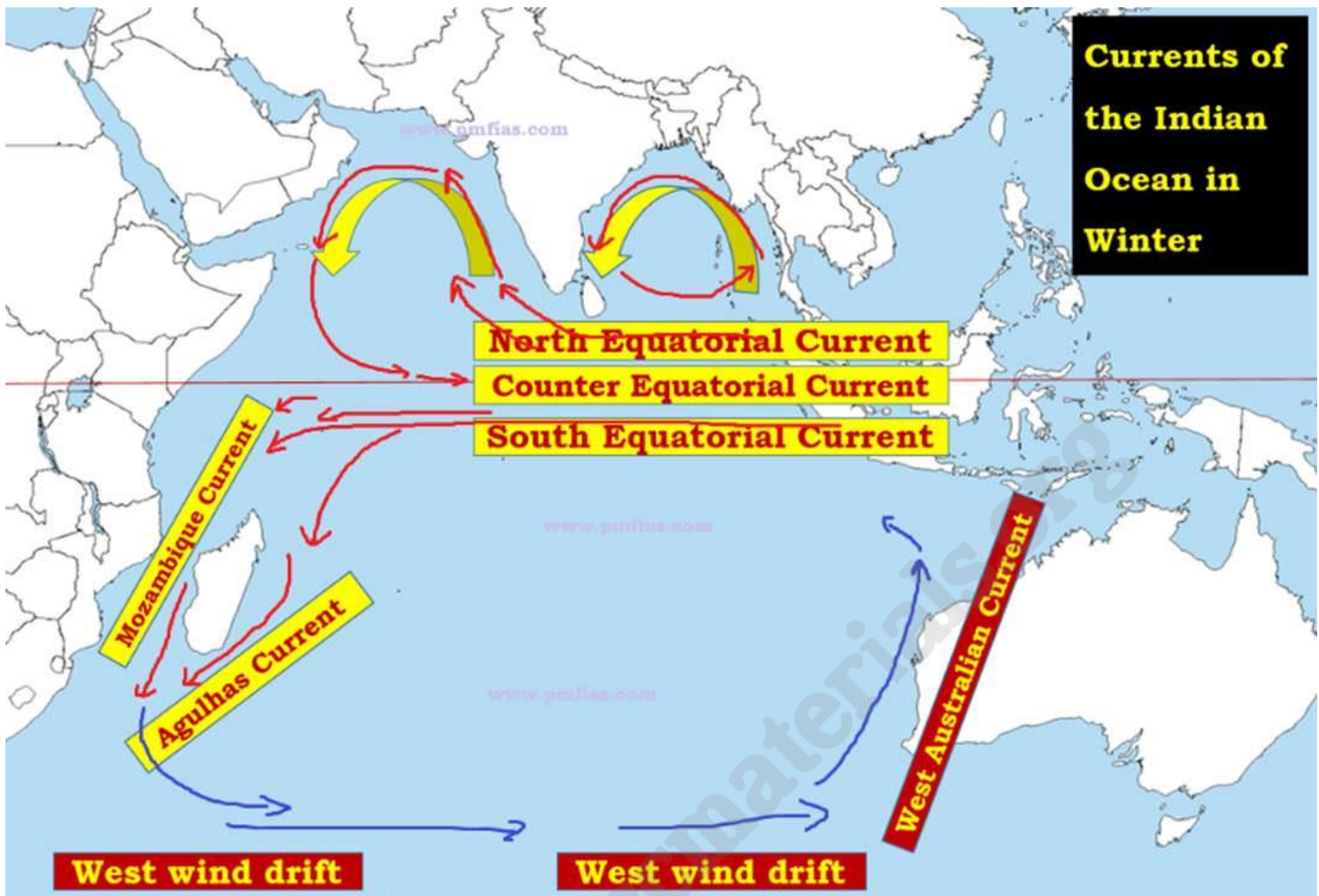


- a) Bengula and Falkland
- b) Canary and Humboldt
- c) Agulhas and Guinea
- d) Benguela and Guinea

### **Indian Ocean Currents**

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- Indian ocean is **half an ocean**; hence the behaviour of the North Indian Ocean Currents is different from that of Atlantic Ocean Currents or the Pacific Ocean Currents.
- Also, **monsoon winds** in Northern Indian ocean are peculiar to the region, which directly influence the ocean surface water movement (North Indian Ocean Currents)



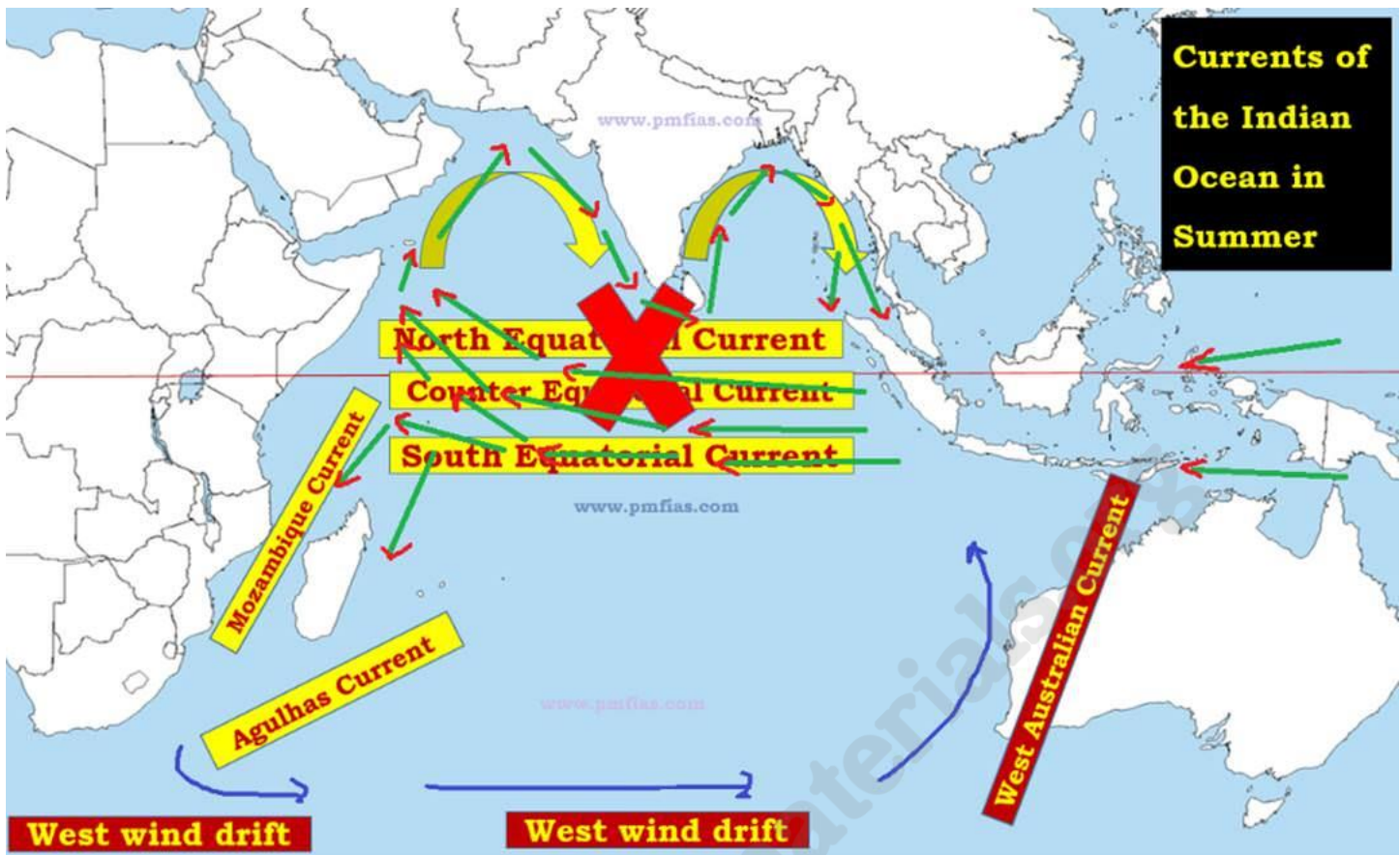
North Indian Ocean Currents

### Winter Circulation

- The **north-east monsoons** drive the water along the coast of **Bay of Bengal** to circulate in an **anti-clockwise direction**.
- Similarly, the water along the coast of **Arabian Sea** also circulate in an **anti-clockwise circulation**.

### Summer Circulation – North Equatorial Current & Counter-Equatorial Current are Absent

- In summer, due to the effects of the strong south-west monsoon and the absence of the north-east trades, a strong current flow from west to east, which completely **obliterates the north equatorial current**.
- Hence, there is **no counter-equatorial current as well**.
- Thus, the circulation of water in the northern part of the ocean is **clockwise** during this season.



South Indian Ocean Currents

## Effects of Ocean Currents

- Ocean currents have a number of direct and indirect influences on human activities.

### Desert formation

- Cold ocean currents have a direct effect on **desert formation** in west coast regions of the **tropical and sub-tropical continents**.
- There is **fog**, and most of the areas are **arid due to desiccating effect (loss of moisture — fog or temperature inversion inhibits convection)**.

### Rains

- Warm ocean currents bring rain to coastal areas and even interiors. Example: Summer Rainfall in **British Type climate (North Atlantic Drift)**.
- Warm currents flow parallel to the east coasts of the continents in tropical and subtropical latitudes. This results in warm and rainy climates. These areas lie in the western margins of the subtropical anti-cyclones.

### Moderating effect

- They are responsible for moderate temperatures at coasts. (**North Atlantic Drift brings warmth to England. Canary cold current brings cooling effect to Spain, Portugal** etc.)

### Fishing

- Mixing of cold and warm ocean currents bear richest fishing grounds in the world.
- Example: **Grand Banks around Newfoundland, Canada and North-Eastern Coast of Japan.**
- The mixing of warm and cold currents helps to replenish the oxygen and favour the growth of **planktons**, the primary food for fish population.
- The best fishing grounds of the world exist mainly in these mixing zones.

### Drizzle

- Mixing of cold and warm ocean currents create foggy weather where precipitation occurs in the form of drizzle (**Newfoundland**).

### Climate

- **Warm and rainy climates in tropical and subtropical latitudes (Florida, Natal etc.),**
- **Cold and dry climates on the western margins in the sub-tropics due to desiccating effect,**
- **Foggy weather and drizzle in the mixing zones,**
- **Moderate climate along the western coasts in the sub-tropics.**

### Tropical cyclones

- They pile up warm waters in tropics, and this warm water is the major force behind tropical cyclones.

### Navigation

- Currents are referred to by their "drift". Usually, the currents are strongest near the surface and may attain speeds over five **knots (1 knot = ~1.8 kmph)**.

**Explain the factors responsible for the origin of ocean currents. How do they influence regional climates, fishing and navigation? (Mains 2015)**

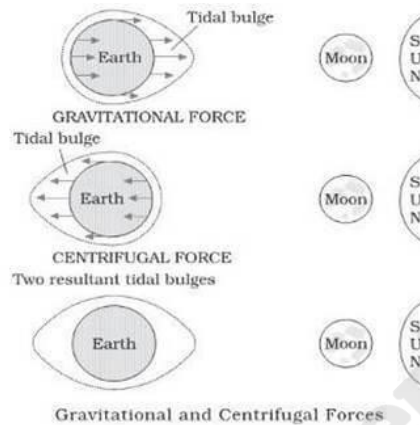
## 3.2 Tides

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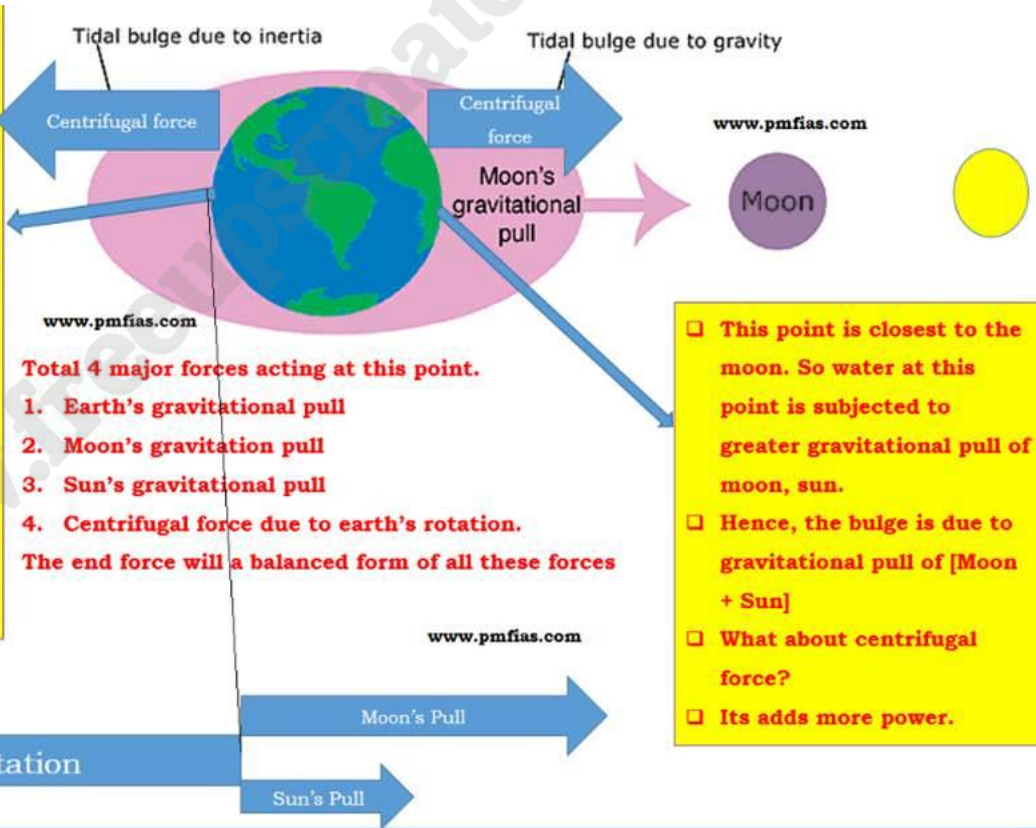
- The periodical rise and fall of the sea level, once or twice a day, mainly due to the attraction of the sun and the moon, is called a tide.

- The **moon's gravitational pull** to a great extent and to a lesser extent the **sun's gravitational pull**, are the major causes for the occurrence of tides.
- Another factor is **centrifugal force** which acts **opposite** to **gravitational pull** of earth.
- Tides occur due to a balance between all these forces.

### Tidal Bulge: Why there are two tidal bulges?



- ❑ This point is farthest from the moon.
- ❑ So, the gravitational pull of moon and sun are least at this point due to greater distance.
- ❑ Hence, the resultant gravitational pull at this point is the least. [www.pmfias.com](http://www.pmfias.com)
- ❑ Gravitational force counter balances centrifugal force.
- ❑ So, decreased resultant gravitational force strengthens centrifugal force.
- ❑ Hence, the bulge here is created due to increased centrifugal force



- ❑ This point is closest to the moon. So water at this point is subjected to greater gravitational pull of moon, sun.
- ❑ Hence, the bulge is due to gravitational pull of [Moon + Sun]
- ❑ What about centrifugal force?
- ❑ Its adds more power.

Formation of Tidal Bulges

- Together, the gravitational pull and the centrifugal force are responsible for creating the two major **tidal bulges** on the earth.

- The 'tide-generating' force is the difference between these two forces; i.e. **the gravitational attraction of the moon and the centrifugal force**.
- On the surface of the earth nearest to the moon, pull or the attractive force of the moon is greater than the centrifugal force, and so there is a net force causing a bulge towards the moon.

### Why is there a tidal bulge on the other side?

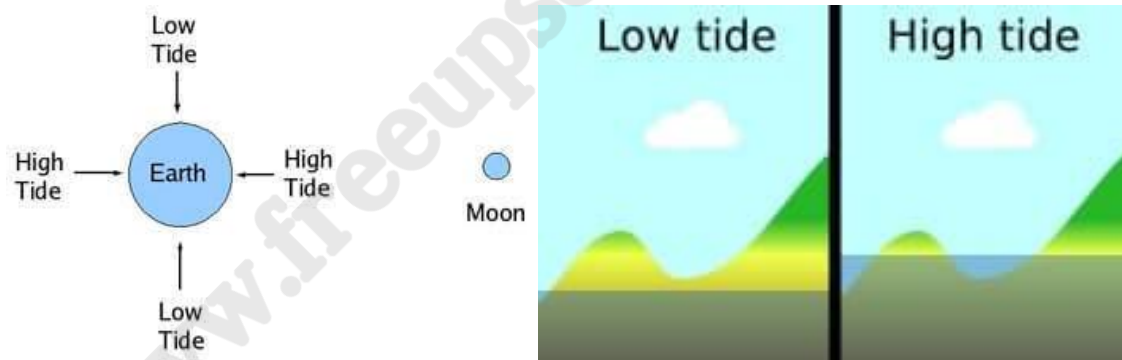
- On the opposite side of the earth, the **attractive force is less**, as it is farther away from the moon, the **centrifugal force is dominant**. Hence, there is a **net force away from the moon**.
- This creates the **second bulge** away from the moon.

## Types of Tides

### Tides based on Frequency

#### Semi-diurnal tide

- It is the most common tidal pattern, featuring **two high tides and two low tides each day (it varies between 3 tides to 4 tides — 3 tides in rare cases but 4 is normal)**.
- The successive high or low tides are approximately of the same height.



High tide and low tide ([Wikipedia](#)). High tides and low tides are formed due to earth's rotation relative to moon

#### Ebb and Flood

- The time between the high tide and low tide, when the water level is **falling**, is called the **ebb**.
- The time between the low tide and high tide, when the tide is **rising**, is called the **flow or flood**.



*Flood (between low tide and high tide)*



*Ebb (between high tide and low tide)*

**Although tides occur twice a day, their interval is not exactly 12 hours. Instead, they occur at regular intervals of 12 hours and 25 minutes. (This is because of the changing relative positions of the moon and the sun)**

- This is because the moon revolves around the earth from west to east, and each day it moves a bit to the east if observed from the same place on earth at the same time on two consecutive days.
- This time lag explains the tide interval of 12 hours and 25 minutes, as tides occur twice a day.
- **Southampton** experiences **tides 6-8 times a day (2 high tides from North Sea + 2 high tides from English Channel + 2 low tides from North Sea + 2 low tides from English Channel).**
- This happens because the **North Sea** and the **English Channel** push the water at different intervals.



### Diurnal tide

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- There is only one high tide and one low tide during each day.
- The successive high and low tides are approximately of the same height.

### Mixed tide

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- Tides having variations in height are known as mixed tides. These tides generally occur along the **west coast of North America** and on many islands of the Pacific Ocean.

### Tides based on the Sun, Moon and the Earth Positions

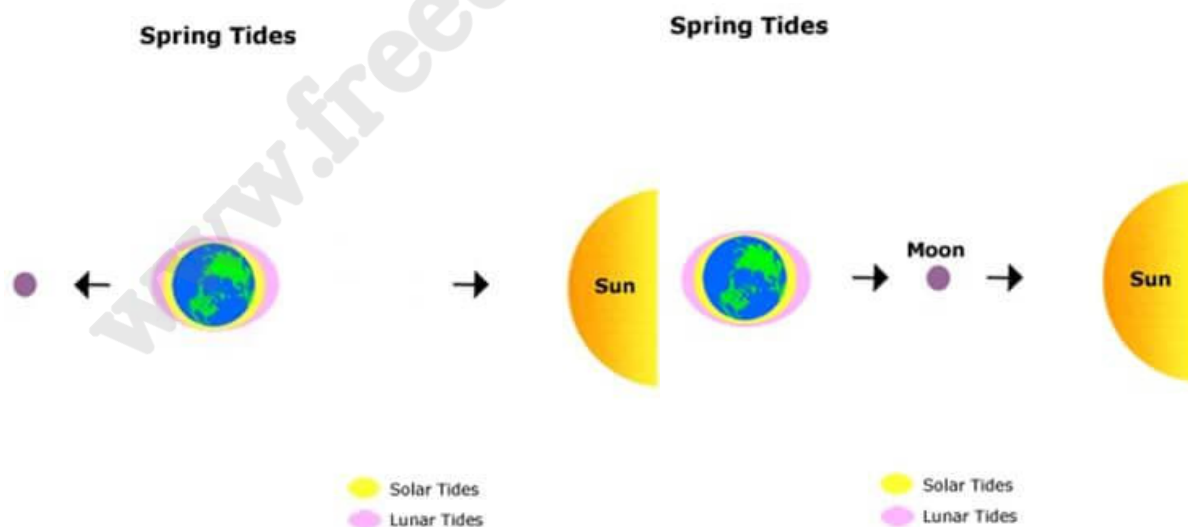
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- The height of rising water (high tide) varies appreciably depending upon the position of sun and moon with respect to the earth. **Spring tides** and **neap tides** come under this category.

### Spring tides

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- The position of both the sun and the moon in relation to the earth has direct bearing on tide height.
- When **the sun, the moon and the earth are in a straight line**, the height of the tide will be higher.
- These are called **spring tides** and they occur **twice a month**, one on **full moon period** and another during **new moon period**.



*Spring Tides (New Moon and Full Moon)*

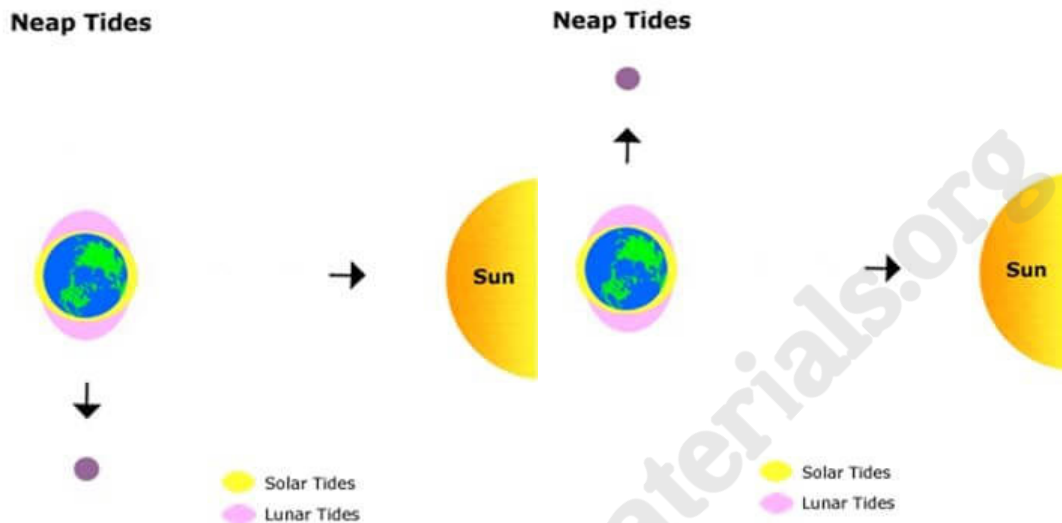
### Neap tides

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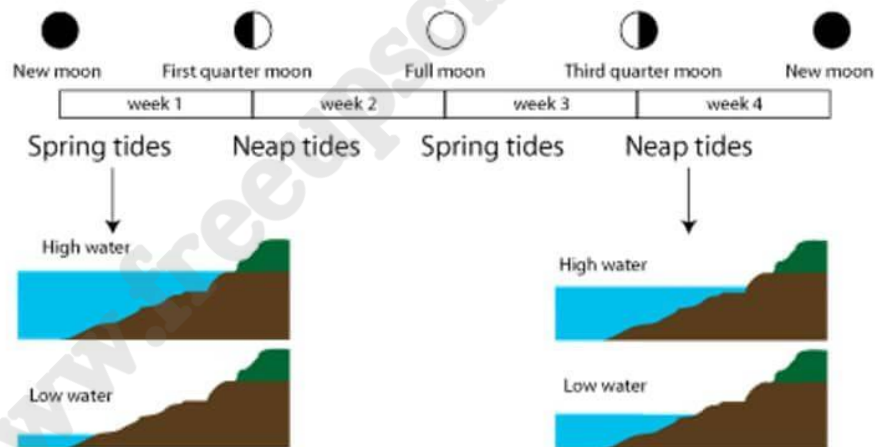
- Normally, there is a **seven-day interval** between the spring tides and neap tides.



- At this time the sun and moon are at **right angles** to each other, and the forces of the sun and moon tend to counteract one another.
- The Moon's attraction, though more than twice as strong as the sun's, is diminished by the counteracting force of the sun's gravitational pull.
- Like spring tides, these tides also occur **twice a month**.



*Neap tide (Half Moon – First Quarter and Last Quarter)*

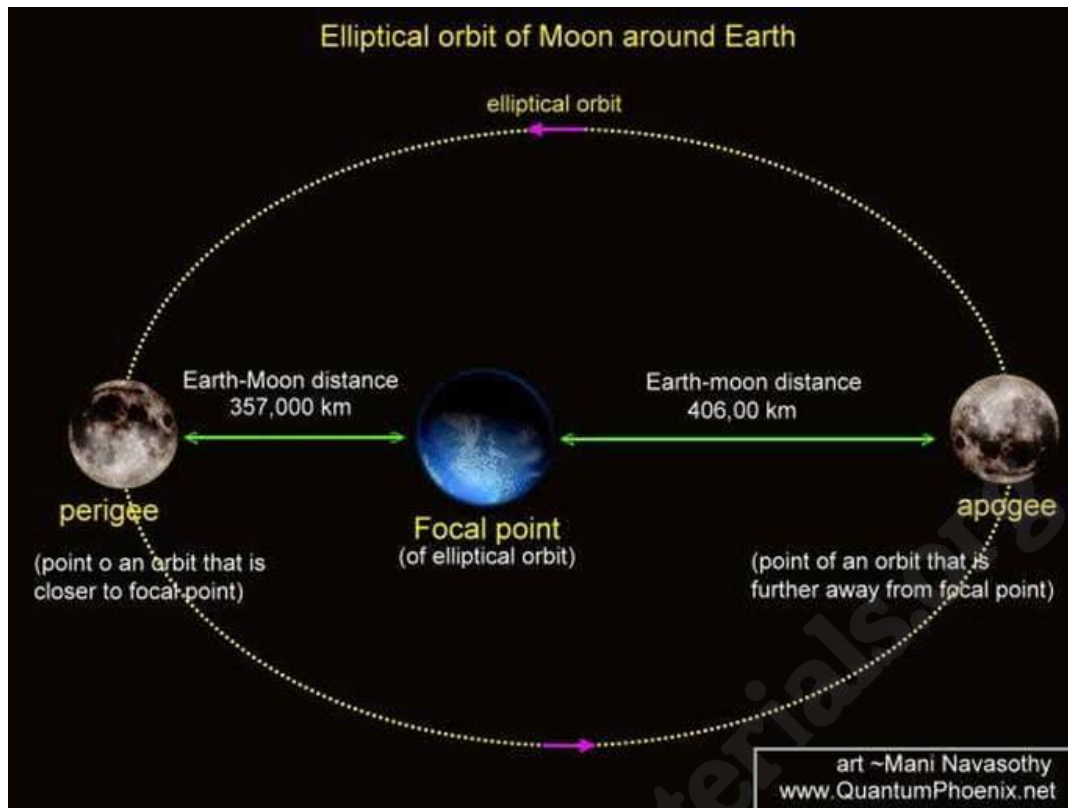


**Spring tide: high tide is higher than normal; low tide is lower than normal**

**Neap tide: high tide is lower than normal; low tide is higher than normal**

### **Magnitude of tides based on Perigee and Apogee**

- Once in a month, when the moon's orbit is closest to the earth (**perigee**), unusually high and low tides occur. During this time the tidal range is greater than normal.
- Two weeks later, when the moon is farthest from earth (**apogee**), the moon's gravitational force is limited, and the tidal ranges are less than their average heights.



*Perigee and Apogee*

### Magnitude of tides based on Perihelion and Aphelion

- When the earth is closest to the sun (**perihelion**), around **3rd January** each year, tidal ranges are also much greater, with unusually high and unusually low tides.
- When the earth is farthest from the sun (**aphelion**), around **4th July** each year, tidal ranges are much less than average.

### Importance of Tides

- Since tides are caused by the earth-moon-sun positions which are known accurately, the tides **can be predicted well in advance**. This helps the navigators and fishermen plan their activities.

### Navigation

- Tides generally help in making some of the rivers navigable for ocean-going vessels. **Port of London and Haldia Port, Kolkata (tidal ports)** have become important ports owing to the tidal nature of the mouths of the Thames and Hooghly respectively.

### Characteristics of Tides

- The **tidal bulges on wide continental shelves have greater height. When tidal bulges hit the mid-oceanic islands, they become low.**
- The shape **of bays and estuaries along a coastline can also magnify the intensity of tides.**



*Landform affected by tides*

- When the tide is channelled between islands or into bays and estuaries, they are called **tidal currents (tidal bore is one such tidal current)**.
- **Funnel-shaped bays** greatly change tidal magnitudes. Example: **Bay of Fundy — Highest tidal range.**
- The highest tides occur in the **Bay of Fundy in Nova Scotia, Canada.** The tidal bulge is **15-16 m.**



*Bay of Fundy in Nova Scotia, Canada*

## **Tidal bore**

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- Tides also occur in gulfs. The gulfs with wide fronts and narrow rears experience higher tides.
- The in and out movement of water into a gulf through a channel is called a tidal current.



*Tidal bore*

- The steep-nosed tide crest looks like a vertical wall of water rushing upstream and is known as a **tidal bore**.
- The favourable conditions for tidal bore include strength of the incoming tidal wave, slim and depth of the channel and the river flow.
- There are exceptions. The **Amazon River** is the largest river in the world. It empties into the Atlantic Ocean. The mouth of the Amazon is not narrow, but the river still has a **strong tidal bore**.
- In India, tidal bores are common in the **Hooghly river**.
- Most powerful tidal bores occur in **Qiantang River** in China.



*Enormous Tidal bore*

- A **tidal bore takes place during the flood tide** and **never during the ebb tide** (Tidal bores almost never occur during neap tides).

## **Impact of Tidal Bore**

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- Tides are stable and can be predicted. Tidal bores are **less predictable** and hence can be **dangerous**.

## **Multiple Choice Questions**

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**1. Upward and downward movement of ocean water is known as the:**

- (a) tide
- (b) wave

- (c) current
- (d) none of the above

**2. Neap tides are caused:**

- (a) As result of the moon and the sun pulling the earth gravitationally in the same direction.
- (b) As result of the moon and the sun pulling the earth gravitationally in the opposite direction.
- (c) Indention in the coastline.
- (d) None of the above.

**3. The distance between the earth and the moon is minimum when the moon is in:**

- (a) Aphelion
- (b) Perihelion
- (c) Perigee
- (d) Apogee

**4. The earth reaches its perihelion in:**

- (a) October
- (b) July
- (c) September
- (d) January

Answers: 1. A) Tide 2. D) None 3. C) Perigee 4. B) July

## 4. Temperature Distribution of Oceans

### 4.1 Factors Affecting Temperature Distribution of Oceans

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- **The physical characteristics of the sea surface:** Boiling point of the sea water is increased in the case of higher salinity and vice versa (**if Salinity is increased → Boiling point will increase → Evaporation will decrease**).
- **The presence of submarine ridges and sills:** Temperature is affected due to lesser mixing of waters on the opposite sides of the ridges or sills (e.g. subsurface layers in Mediterranean Sea).
- **The shape of the ocean (enclosed seas):** enclosed seas in the low latitudes record relatively higher temperature than the open seas (due to less mixing and higher overall insolation); whereas the enclosed seas in the high latitudes have lower temperature than the open seas.
- E.g. Mediterranean Sea records higher temperature than the longitudinally extensive Gulf of California.
- **Prevalent winds** generate horizontal and sometimes vertical ocean currents: The winds blowing from the land towards the oceans (**off-shore winds**: moving away from the shore) drive warm surface water away

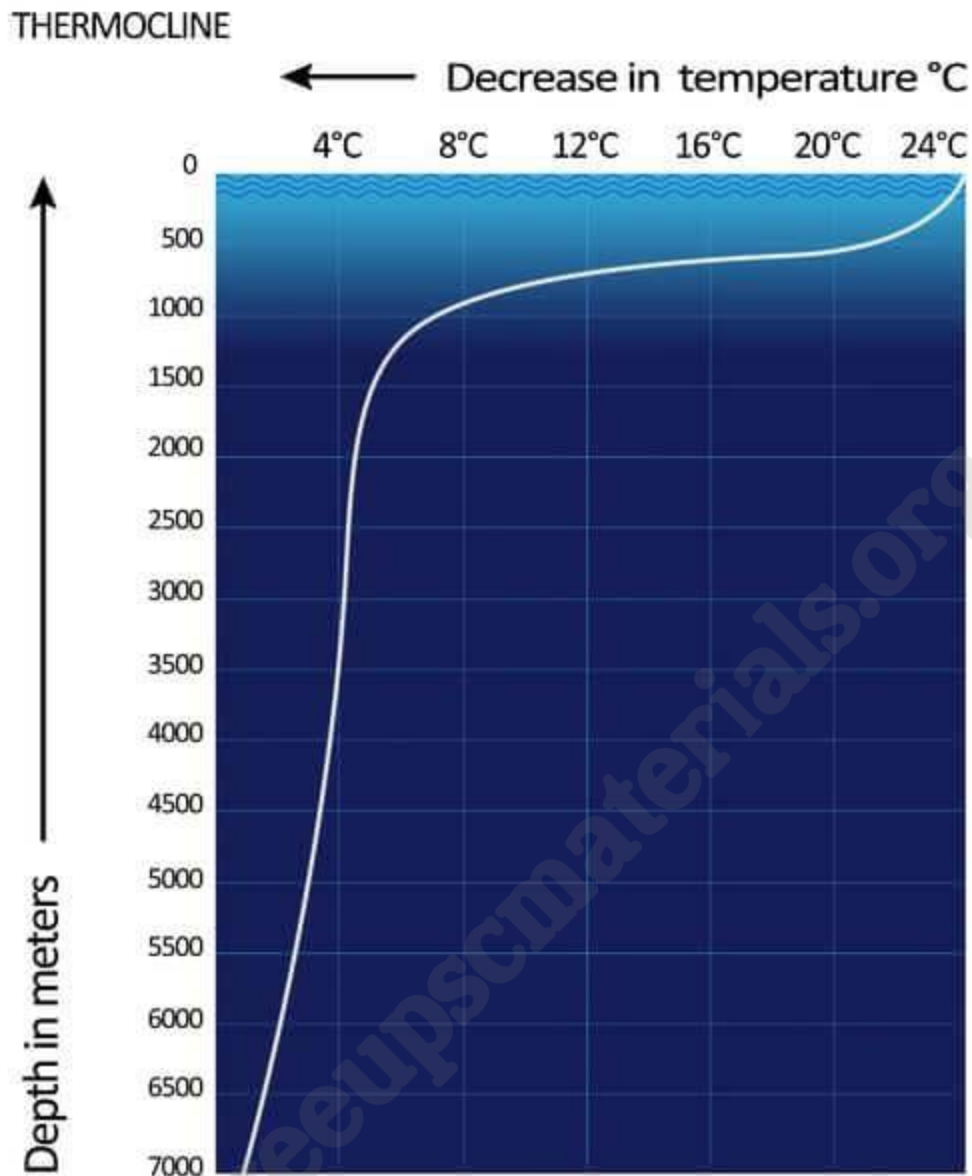
from the coast resulting in the **upwelling of cold water** from below (this happens near **Peruvian Coast during normal years**).

- Contrary to this, the **onshore winds** (winds flowing from oceans into continents) pile up warm water near the coast, and this raises the temperature (this happens near the **Peruvian coast during El Nino event**).
- **Ocean currents:** Warm ocean currents raise the temperature in cold areas while the cold currents decrease the temperature in warm ocean areas.
- **Gulf stream (warm current)** raises the temperature near the eastern coast of North America and the West Coast of Europe while the **Labrador current (cold current)** lowers the temperature near the north-east coast of North America (Near Newfoundland).

## 4.2 Vertical Temperature Distribution of Oceans

---

- **Photic or euphotic zone** extends from the upper surface to ~200 m. The photic zone receives adequate solar insolation.
- **Aphotic zone** extends from 200 m to the ocean bottom; this zone does not receive adequate sunrays.



Thermocline (Praveenron, [Wikipedia](#))

## Thermocline

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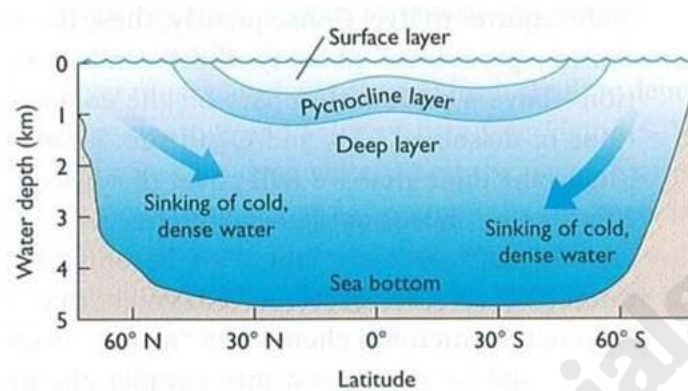
- About 90 per cent of the total volume of water is found below the thermocline in the deep ocean. In this zone, temperatures approach 0° C.
- The boundary usually begins around 100-400 m below the sea surface and extends several hundred of meters downward.
- This boundary region, from where there is a rapid decrease of temperature, is called the **thermocline**.

## Pycnocline

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- Pycnocline is a boundary separating two liquid layers of different densities.

- Pycnocline exists in oceans at a depth of 100-1000 m because of large density difference between surface waters and deep ocean water.
- Pycnocline effectively prevents vertical currents except in polar regions.
- Because the pycnocline zone is **extremely stable**, it acts as a barrier for surface processes.
- Thus, changes in salinity or temperature are very small below pycnocline but are seasonal in surface waters.



*Pycnocline*

Similar Terms: **Thermocline, Halocline.**

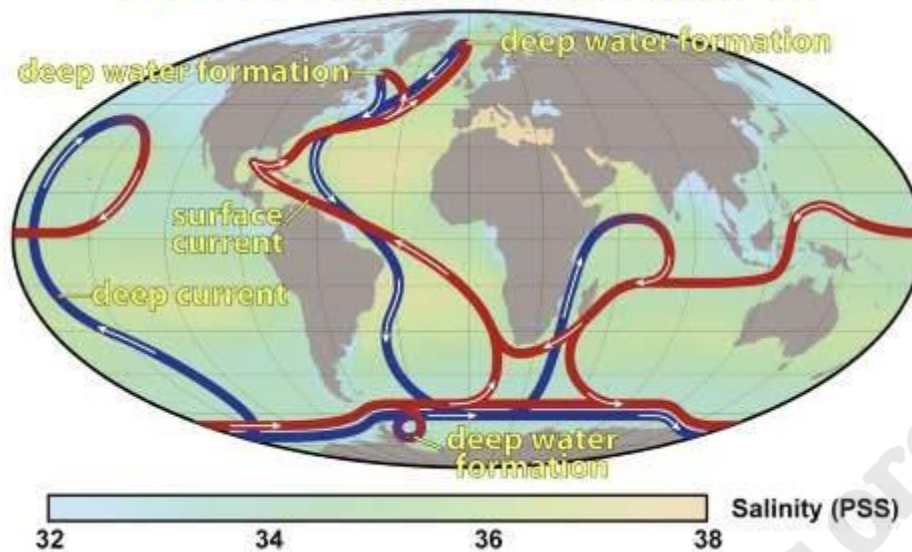
### **Thermohaline Circulation**

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- These deep-ocean currents are driven by differences in the water's density, which is controlled by temperature (thermo) and salinity (haline).
- This process is known as thermohaline circulation.
- The thermohaline circulation is sometimes called the **ocean conveyor belt**, the great ocean conveyor, or the global conveyor belt.
- Ocean bottom relief greatly influences thermohaline circulation.



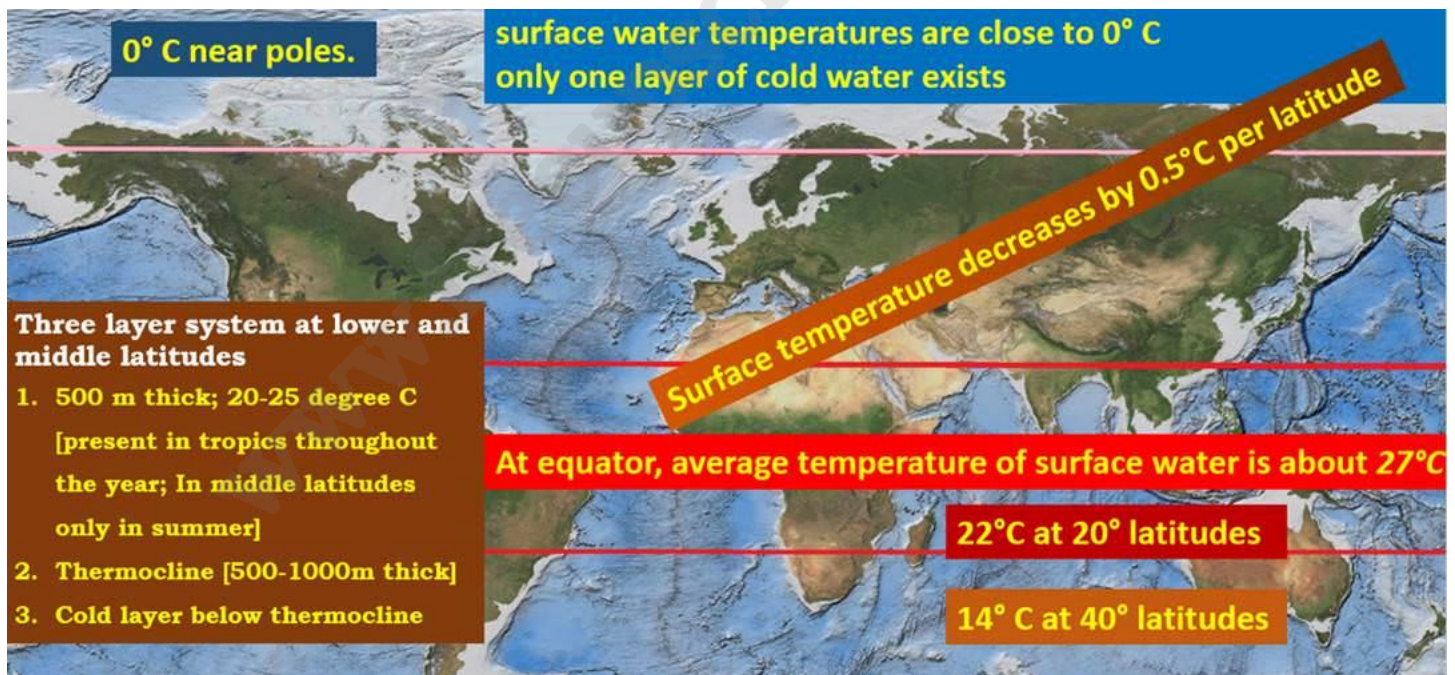
## Thermohaline Circulation



Thermohaline Circulation ([Wikipedia](#))

### 4.3 Horizontal Temperature Distribution

- The average temperature of surface water of the oceans is about 27°C.
- The rate of decrease of temperature with increasing latitude is generally **0.5°C per latitude**.



Ocean Temperature Distribution

### 4.4 General behaviour

- In the Arctic and Antarctic circles, the surface water temperatures are close to 0° C and so the temperature change with the depth is **very slight (ice is a very bad conductor of heat)**.
- Here, **only one layer of cold water exists**, which extends from surface to deep ocean floor.

***The rate of decrease of temperature with depths is greater at the equator than at the poles.***

- The enclosed seas in both the lower and higher latitudes record **higher temperatures at the bottom**.
- The enclosed seas of low latitudes like the **Sargasso Sea**, the **Red Sea** and the **Mediterranean Sea** have high bottom temperatures due to high insolation throughout the year and lesser mixing.
- In the case of the **high latitude enclosed seas, the bottom layers of water are warmer as water of slightly higher salinity and temperature moves from outer ocean as a sub-surface current**.

## 4.5 Range of Ocean Temperature

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- Ocean surface temperature is **highest at 2 p.m.** and the **lowest, at 5 a.m.**
- The maximum and the minimum temperatures in oceans are slightly delayed than those of land areas (the **maximum being in August** and the minimum in February (tropical cyclones occur mostly between August and October. It is **slightly different in Indian Ocean due to its shape**).

## 5. Ocean Salinity

- It is calculated as the amount of salt (in gm) dissolved in 1,000 gm (1 kg) of seawater.
- Salinity of **24.7 ppt** (the symbol for ppt is ‰) → '**brackish water**'.

**Share of different salts is as shown below**

- **sodium chloride — 77.7%**
- **magnesium chloride—10.9%**
- **magnesium sulphate — 4.7%**
- **calcium sulphate — 3.6%**
- **potassium sulphate — 2.5%**

**Dissolved Salts in Sea Water (gm of Salt per kg of Water)**

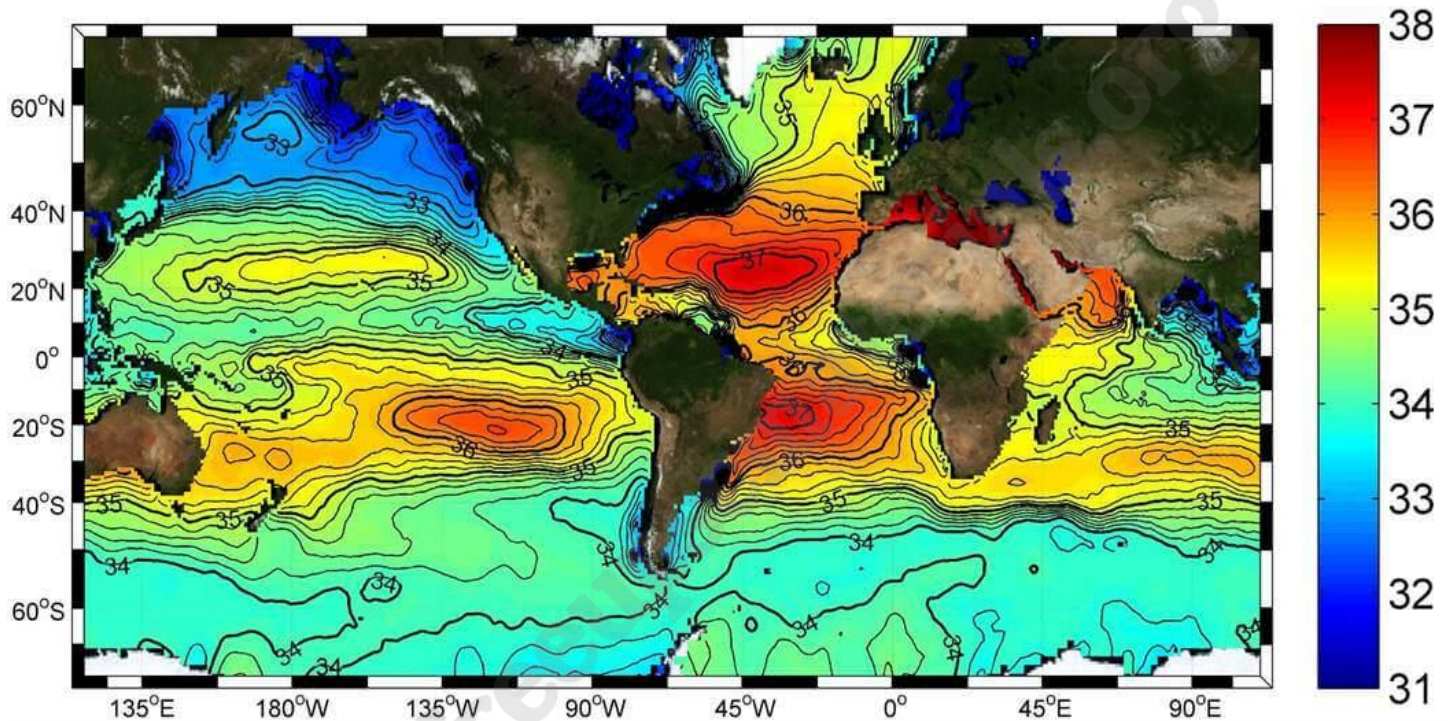
<b>1. Chlorine</b>	<b>18.97</b>
<b>2. Sodium</b>	<b>10.47</b>
<b>3. Sulphate</b>	<b>2.65</b>

4. Magnesium	1.28
5. Calcium	0.41
6. Potassium	0.38

## 5.2 Horizontal distribution of salinity

All values are in ppt (parts per thousand or ‰)

- The salinity for normal open ocean ranges between **33 and 37**.



Ocean surface salinity ([Source](#))

- The regions of high salinity in vast oceans coincide with high-pressure cells.
- Here, there is hardly any rain and subsiding dry winds cause lots of evaporation.

### High salinity regions

- In the landlocked Red Sea, it is as high as 41.
- In the Mediterranean Sea in Europe the salinity is very high – 38 or more.
- In hot and dry regions, where evaporation is high, the salinity sometimes reaches to 70.

### Low salinity regions

- In the estuaries (enclosed mouth of a river where fresh and saline water get mixed) and the Arctic and Antarctic, the salinity fluctuates from 0 to 35, seasonally (fresh water coming from ice caps).

## Atlantic

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- The average salinity of the Atlantic Ocean is around 36-37.
- **Maximum salinity (37) is observed between 20° N and 30° N and 20° W - 60° W (high-pressure cells).**

## Indian Ocean

---

- The average salinity of the Indian Ocean is 35.
- The low salinity trend is observed in the Bay of Bengal due to influx of river water by the river Ganga.
- On the contrary, the Arabian Sea shows **higher salinity** due to high evaporation and less fresh water.

## Marginal seas

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- **The North Sea**, in spite of its location in higher latitudes, records higher salinity due to more saline water brought by the North Atlantic Drift.
- **Baltic Sea** records low salinity due to influx of river waters in large quantity.
- The **Mediterranean Sea** records higher salinity due to high evaporation.
- Salinity is, however, very low in **Black Sea** due to enormous freshwater influx by rivers.

## Inland seas and lakes

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### Highest salinity in water bodies

- **Lake Van in Turkey (330 ppt)**
- **Dead Sea (238 ppt)**
- **Great Salt Lake, Utah (220 ppt)**

## 5.3 Vertical Distribution of Salinity

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- In high latitudes, salinity increases with depth. In the middle latitudes, it increases up to 35 metres and then it decreases. At the equator, **sub-surface salinity is lower.**
- Salinity, generally, increases with depth and there is a distinct zone called the **halocline** (compare this with thermocline), where salinity increases sharply.

### Questions

1. Salinity is expressed as the amount of salt in grams dissolved in seawater per (a) 10 gm (b) 1,000 gm (c) 100 gm (d) 10,000 gm

2. Which one of the following is the smallest ocean? (a) Indian Ocean (b) Arctic Ocean (c) Atlantic Ocean (d) Pacific Ocean

Answers: 1. B) 1000 gm 2. B) Arctic

## 6. Coral Reefs

- Coral reefs are made up of calcareous skeletons of thousands of tiny marine organisms called **coral polyps**
- Polyps are related to **anemones and jellyfish**.
- They are **shallow warm water organisms** which have a soft body covered by a **calcareous skeleton**.
- The polyps extract calcium salts from seawater to form these hard skeletons.
- Shallow rock layers created by the depositions of corals is called a **coral reef**.
- Coral reefs over a period of time transform or evolve into **coral islands (e.g. Lakshadweep)**.

### 6.1 Coral Reef Relief Features

- **Fringing reef, barrier reef and atoll (coral islands are formed on atolls)** are the most important relief features.



*Coral Reef Relief Features*

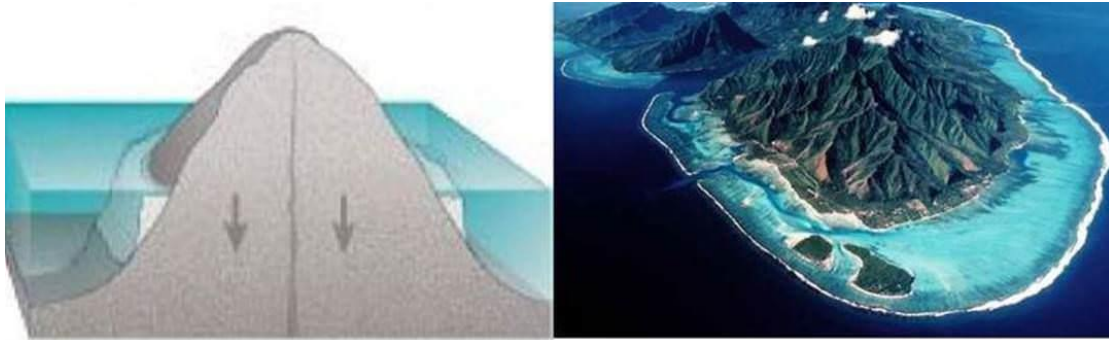
#### Fringing Reefs (Shore Reefs)

- Fringing reefs are reefs that **grow directly from a shore**.
- They are very narrow (1-2 km wide) and are located very **close** to the land.
- A **shallow lagoon** exists between the beach and the main body of the reef.

*A lagoon refers to a comparatively wide band of water that lies between the shore and the main area of reef development and contains at least some deep portions.*

- Fringing reef grows from the deep sea bottom with the seaward side sloping steeply into the deep sea.
- Coral polyps do not extend outwards because of **sudden and large increase in depth**.

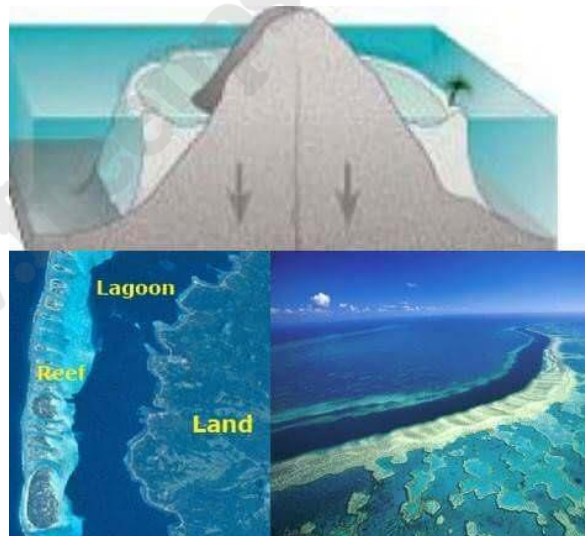
- The fringing reef is by far the most common of the three major types of coral reefs.



*Fringing Reef*

## Barrier Reefs

- Barrier reefs are **extensive linear reefs** that run parallel to the shore and are separated from it by a **lagoon**.
- This is the **largest (in size, not distribution)** of the three reefs.
- It extends as a broken, irregular ring around the coast or an island, running almost parallel to it.
- Barrier reefs are **far less common** than fringing reefs or atolls.
- The **1200-mile long Great Barrier Reef** off the NE coast of Australia is the world's largest barrier reef.
- The GBR is not a single reef, but rather a very large complex consisting of **many reefs**.

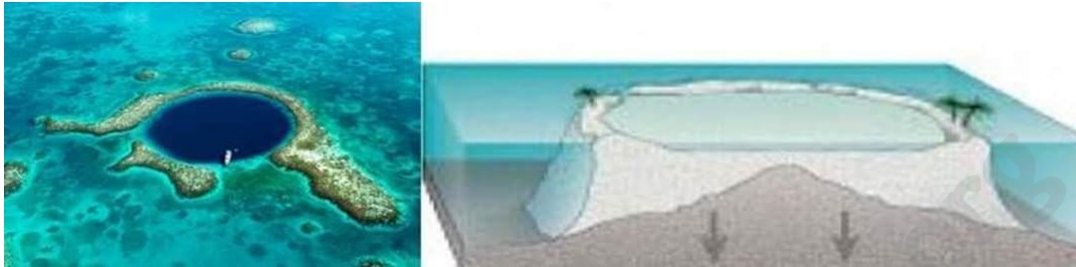


*Barrier Reef*

## Atolls

- An atoll is a roughly circular oceanic reef system surrounding a large **central lagoon**.
- Atolls are located at **great distances** from deep sea platforms.

- They form on submarine features such as a **submerged island or a volcanic cone** which reaches a level suitable for coral growth.
- The **Fiji atoll** is a well-known example of atolls.
- A large number of atolls occur in the **Lakshadweep Islands**.
- Others are found in the **Maldives** and **Chagos island groups**, the **Seychelles**, and in the **Cocoss**.



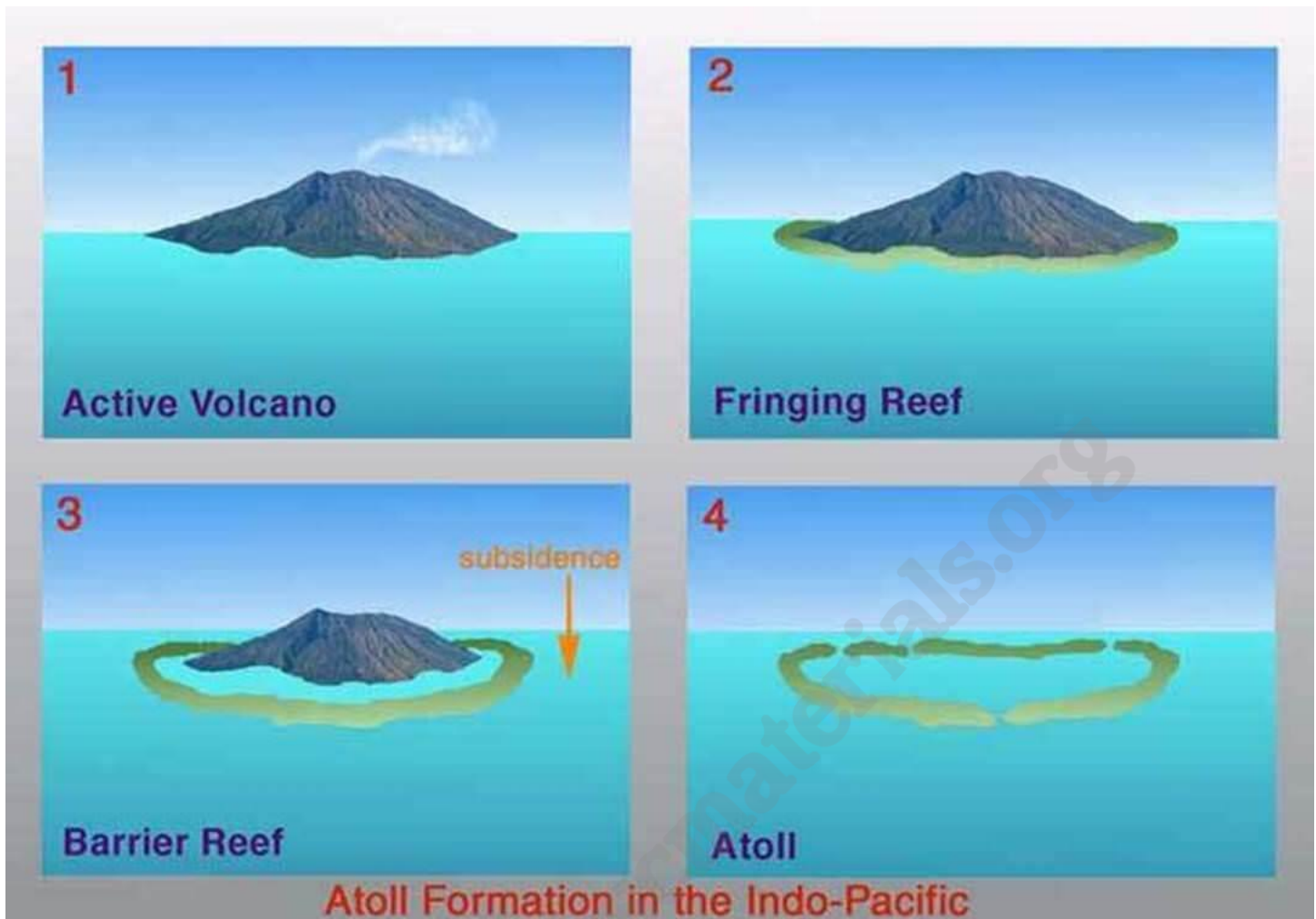
Atoll

## 6.2 Development of Major Coral Reef Types

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### Formation of Lakshadweep Islands (You must include the concept of Reunion Hotspot)

- The basic coral reef classification scheme described earlier was first proposed by **Charles Darwin** and is still widely used today.
1. Step 1: A **fringing reef forms first** and starts growing in the shallow waters close to a tropical island.
  2. Step 2: Over time, the **island subsides, and the reef grows outwards**, and the distance between the land and the reef increases. The fringing reef develops into a barrier reef.
  3. Step 3: If the island completely subsides, all that is left is the reef. The reef retains the approximate shape of the island it grew around, forming a ring enclosing a lagoon (**atoll**).



Development of Major Coral Reef Types

### 6.3 Ideal Conditions for Coral Growth

- **Stable climatic conditions:** Corals are highly susceptible to quick changes. They grow in regions where climate is significantly stable for a long period (Equatorial oceans with warm ocean currents).
- **Perpetually warm waters:** Corals thrive in **tropical waters** (30°N and 30°S latitudes, the temperature of water is around 20°C) where diurnal and annual temperature ranges are very narrow.

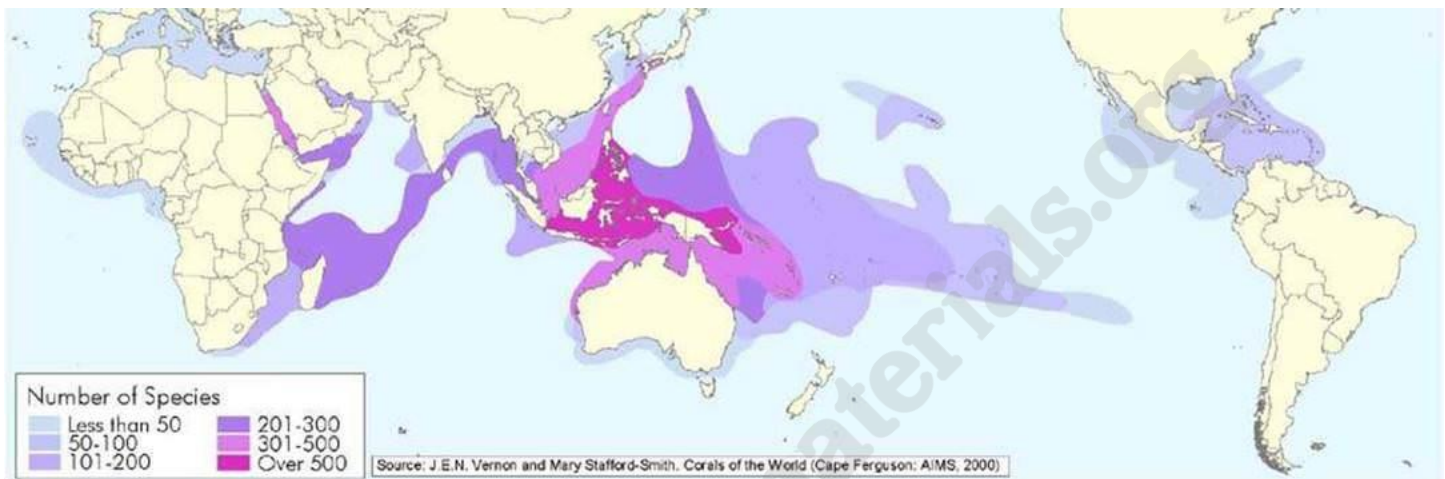
**Why are coral reefs absent on west coast of tropical continents? Because of Cold Ocean Currents.**

- **Shallow water:** Corals require fairly good amount of **sunlight** to survive. The ideal depths for coral growth are 45 m to 55 m below sea surface, where there is enough sunlight available.
- **Clear salt water:** Clear salt water is suitable for coral growth, while both freshwater and highly saline water are harmful.



- **Abundant Plankton:** Adequate supply of oxygen and microscopic marine food, called **plankton (phyto-plankton)**, is essential for growth. As the plankton is more abundant on the **seaward side**, corals grow rapidly on the seaward side.
- **Little or no pollution:** Corals are highly fragile and are vulnerable to climate change and pollution and even a minute increase in marine pollution can be catastrophic.

## Distribution of Coral Reefs



*Distribution of Coral Reefs*

## 6.4 Corals and Zooxanthellae

- Many invertebrates, vertebrates, and plants live in close association with corals, with **tight resource coupling and recycling**, allowing coral reefs to have **extremely high productivity and biodiversity**, such that they are referred to as **the Tropical Rainforests of the Oceans**.
- Scleractinian corals build skeletons of calcium carbonate **sequestered** from the water.
- Scleractinian corals come under **Phylum Cnidaria**, and they receive their nutrient and energy resources in two ways.
  1. They use the traditional cnidarian strategy of capturing tiny planktonic organisms with their tentacles.
  2. Having a symbiotic relationship with a **single cell alga** known as **zooxanthellae**.
- Zooxanthellae are **autotrophic (prepare their own food) microalgae** belonging to various taxa in the **Phylum Dinoflagellata**.

**Coral** → **Phylum Cnidaria**

**Zooxanthellae** → **Phylum Dinoflagellata**

## Symbiotic Relationship Between Corals and Zooxanthellae

- Zooxanthellae live symbiotically within the coral polyp tissues and **assist the coral in nutrient production through its photosynthetic activities.**
- These activities provide the coral with **fixed carbon compounds for energy, enhance calcification, and mediate elemental nutrient flux.**
- The host coral polyp in return provides zooxanthellae with a **protected environment** to live within, and a **steady supply of carbon dioxide** for its **photosynthetic processes.**
- The symbiotic relationship allows the slow-growing corals to compete with the faster growing multicellular algae.
- The corals feed by day through **photosynthesis** and by night through **predation.**

*The tissues of corals themselves are actually not the beautiful colours of the coral reef but are instead clear. The corals receive their colouration from the zooxanthellae living within their tissues.*


## 6.5 Coral Bleaching or Coral Reef Bleaching

# CORAL BLEACHING

Have you ever wondered how a coral becomes bleached?

**HEALTHY CORAL**


**1** Coral and algae depend on each other to survive.



Corals have a symbiotic relationship with microscopic algae called zooxanthellae that live in their tissues. These algae are the coral's primary food source and give them their color.

**STRESSED CORAL**


**2** If stressed, algae leaves the coral.



When the symbiotic relationship becomes stressed due to increased ocean temperature or pollution, the algae leave the coral's tissue.


**BLEACHED CORAL**


**3** Coral is left bleached and vulnerable.





Without the algae, the coral loses its major source of food, turns white or very pale, and is more susceptible to disease.

**WHAT CAUSES CORAL BLEACHING?**


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**Change in ocean temperature**  
Increased ocean temperature caused by climate change is the leading cause of coral bleaching.
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**Runoff and pollution**  
Storm generated precipitation can rapidly dilute ocean water and runoff can carry pollutants — these can bleach near-shore corals.
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**Overexposure to sunlight**  
When temperatures are high, high solar irradiance contributes to bleaching in shallow-water corals.
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**Extreme low tides**  
Exposure to the air during extreme low tides can cause bleaching in shallow corals.



NOAA's Coral Reef Conservation Program  
<http://coralreef.noaa.gov/>

- Natural disturbances which cause damage to coral reefs include **violent storms, flooding, high and low-temperature extremes, El Nino Southern Oscillation (ENSO) events, subaerial exposures, predatory outbreaks and epizootics.**
- Coral reef bleaching is a common **stress response** of corals to many of the various disturbances mentioned above.
- Bleaching occurs when
  1. **the densities of zooxanthellae decline and/or**
  2. **the concentration of photosynthetic pigments within the zooxanthellae fall. (it is no more useful for the coral and the coral will bleach it)**



*Coral Bleaching*

- When corals bleach, they commonly **lose 60-90% of their zooxanthellae** and each zooxanthellae may **lose 50-80% of its photosynthetic pigments.**

## **Ecological Causes of Coral Bleaching**

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### **Temperature**

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- While the rising temperatures have increased the frequency and intensity of bleaching, **acidification** has **reduced corals calcifying ability.**
- Small temperature increases over many weeks or large increase (3-4 °C) over a few days will result in **coral dysfunction.**

### **Subaerial exposure**

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- The consequent exposure to high or low temperatures, increased solar radiation, desiccation, and seawater dilution by heavy rains could all play a role in **zooxanthellae loss.**

### **Inorganic Nutrients**

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- Rather than causing coral reef bleaching, an increase in ambient elemental nutrient concentrations (e.g. **ammonia and nitrate**) actually increases zooxanthellae densities 2-3 times.
- Although **eutrophication (excessive nutrients that results in harmful algal blooms)** is not directly involved in zooxanthellae loss, it could cause secondary adverse effects such as **lowering of coral resistance and greater susceptibility to diseases**.

### Xenobiotics

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- When corals are exposed to high concentrations of chemical contaminants like copper, herbicides and oil, coral bleaching happens.

### Epizootics

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- **Pathogen** induced bleaching is different from other sorts of bleaching.
- **Acanthaster planci outbreaks (crown-of-thorns seastar, a large starfish that preys upon coral polyps)**.

## 7. Resources from the Ocean

### 7.1 Ocean Deposits

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1. the **terrigenous deposits** (deposits derived from land; found mainly on the continental shelves and slopes), and
2. the **pelagic deposits** (found over deep sea plains and the deeps).

#### Terrigenous Deposits

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- They are **mainly inorganic deposits** (compounds not containing carbon) derived from disintegrated rock material (due to weathering and water erosion).
- The terrigenous deposits are found mainly on the **continental shelves and slopes**.

#### Pelagic Deposits

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- Pelagic deposits cover nearly 75% of the total sea floor.
- The pelagic deposits consist of both organic (remains of plants and animals) and inorganic material.

### 7.2 Mineral Resources

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#### Mineral deposits found on continental shelves and slopes

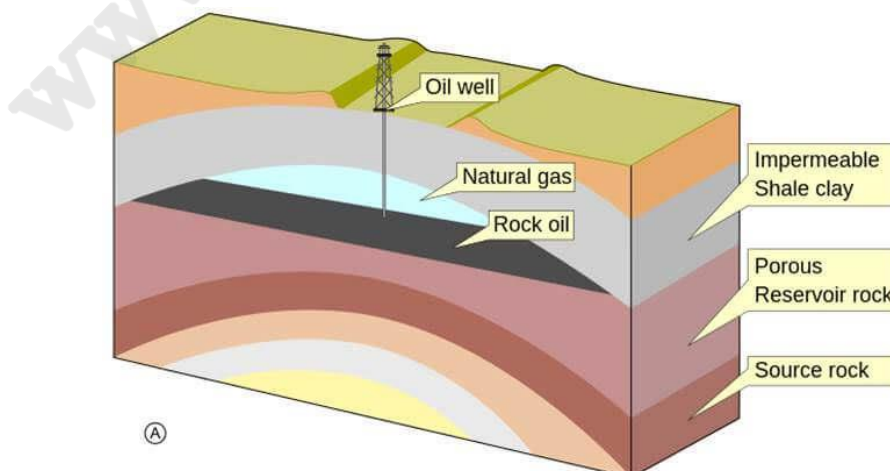
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## Marine Placer deposits

- A placer deposit is an accumulation of valuable **heavy minerals** that have been weathered and eroded from their source rocks.
- As a result of their high density, placer minerals **accumulate just a few tens of kilometres away** from their source rocks.
- Marine placers deposits accumulate on the continental shelves very close to the shoreline.
- The most economically important of placer minerals are **cassiterite (ore of tin), ilmenite (titanium), rutile (titanium), zircon (zirconium), chromite (chromium), monazite (thorium), magnetite (iron), gold and diamonds**.
- The beach sands of western India, coastal Brazil, Australia have zircon, monazite (**thorium is extracted from monazite sands found across the Kerala coast**) and rutile.
- **Kerala's placer deposits** contain **90 per cent of the world's monazite reserves**.
- The eastern and western coasts of **Australia** account for about 30 per cent of **rutile**.
- Placer diamonds are mainly mined in shelf sediments along the west coast of South Africa and Namibia.
- Gold placers occur along the coast of Alaska on the East Pacific shelf.
- The **tin ore, cassiterite**, a residue of granite weathering, occurs in the shelf of South East Asia.

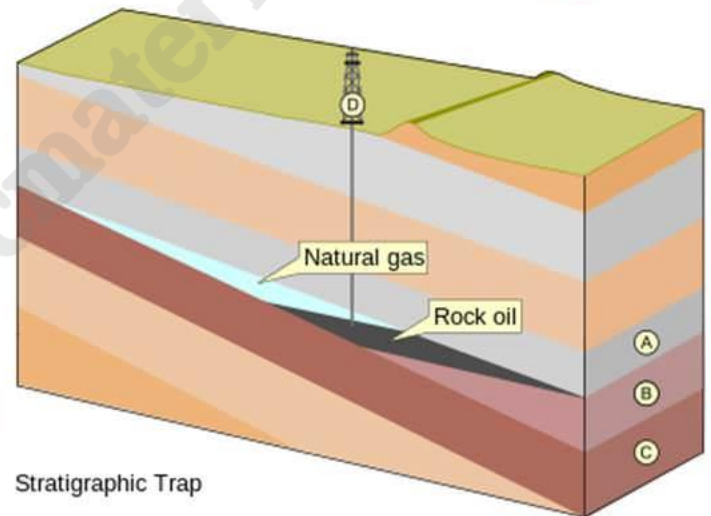
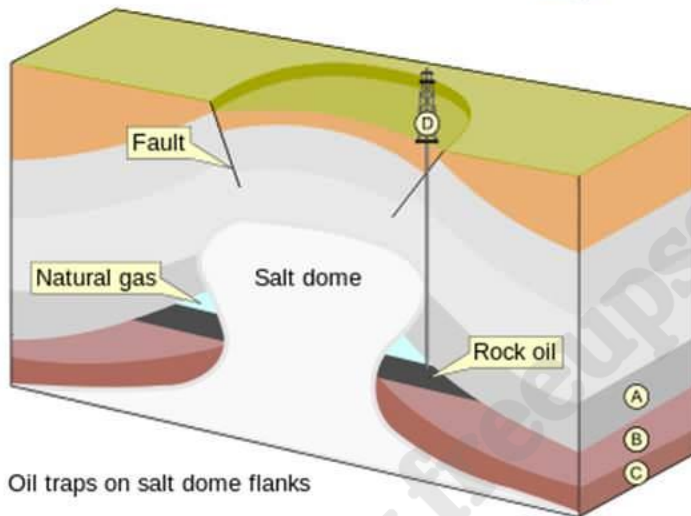
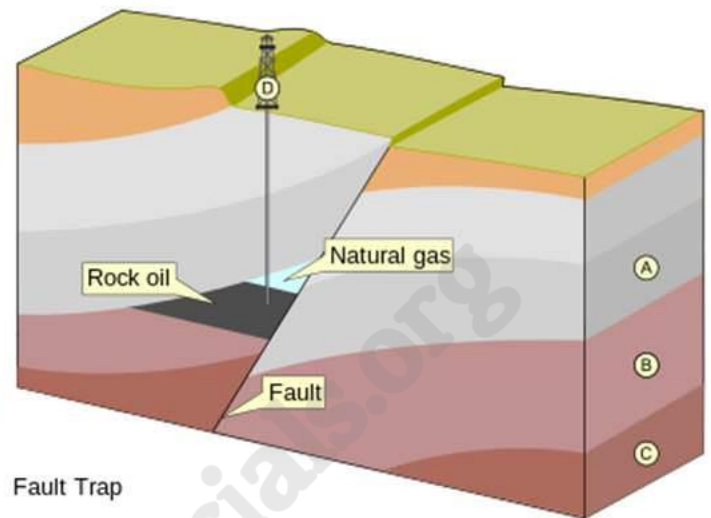
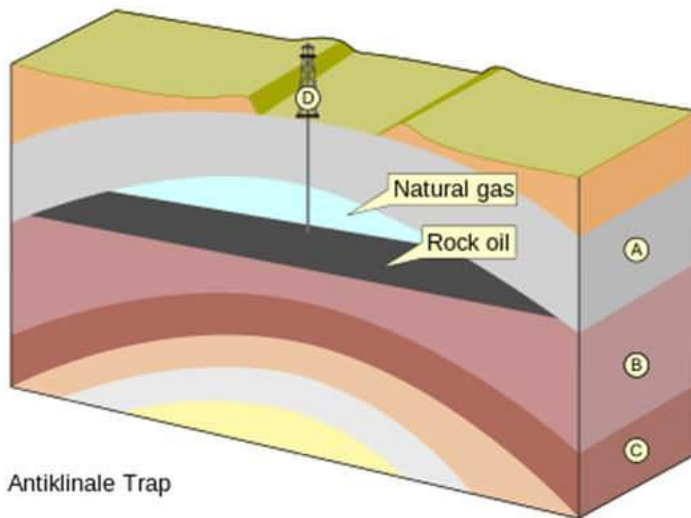
## Marine hydrocarbon deposits

- Generally, large quantities of hydrocarbons can be formed only at depths within **organic-rich layers greater than 1,000 - 2,000 meters**.
- Formation of exploitable reservoirs of hydrocarbons requires migration (from their source rocks) to **geological traps** comprising a **porous reservoir rocks** and **overlain by an impermeable horizon**.



Anticline trap (MagentaGreen, [Wikipedia Commons](#))

- Common geological traps for hydrocarbons include **shales, salt domes (evaporites; also rich in sulphur), and anticlinal folds of permeable and non-permeable strata.**
- In addition to liquid hydrocarbons, natural gas is also common.



Ⓐ = Impermeable Shale clay

Ⓑ = Porous Reservoir rock

Ⓒ = Source rock

Ⓓ = Oil well

*Oil and Gas traps (MagentaGreen, [Wikipedia Commons](#))*

- The estimated reserves of oil worldwide at the beginning of the 21st Century are about one trillion barrels.
- Of this amount, about 252 billion barrels (**25%**) lie in marine environments.
- Similarly, the total worldwide resources of natural gas are estimated at about 4,000 trillion cubic feet, of which about 26 per cent are marine.
- These reserves of oil and gas are located as subsurface deposits almost exclusively on the **continental shelves.**
- The abyssal plains probably contain insufficient thickness of sediments (less than 1 km) to yield hydrocarbon accumulations.

- Of the twenty-five largest offshore production fields, eight are in the Persian Gulf and eight others are in the **North Sea** (here hydrocarbons are available at a shallow depth).

### Challenges in harnessing marine hydrocarbon resources

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- The cost of production from deep marine environments is economically unviable considering the present demand.
- Gas and oil exploration increase the risk of marine pollution from accidental oil spills. Existing response technologies are inadequate to contain and recover spills.

### Mineral deposits found on deep sea floor

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- The deep sea has two main types of mineral deposits of economic importance: **manganese nodules (also called as polymetallic nodules)** and **metalliferous sediments**.

### Marine manganese nodules (Polymetallic nodules) and crusts

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- Manganese nodules are concentrations of **iron and manganese oxides**, that can contain economically valuable concentrations of **manganese (~30%), nickel (1.25-1.5%), copper (~1%) and cobalt (~0.25%)**.
- They are thought to have formed from the precipitation of metals from seawater, hot springs associated with volcanic activity and metal hydroxides through the activity of microorganisms.

### Central Indian Ocean Basin (CIOB)

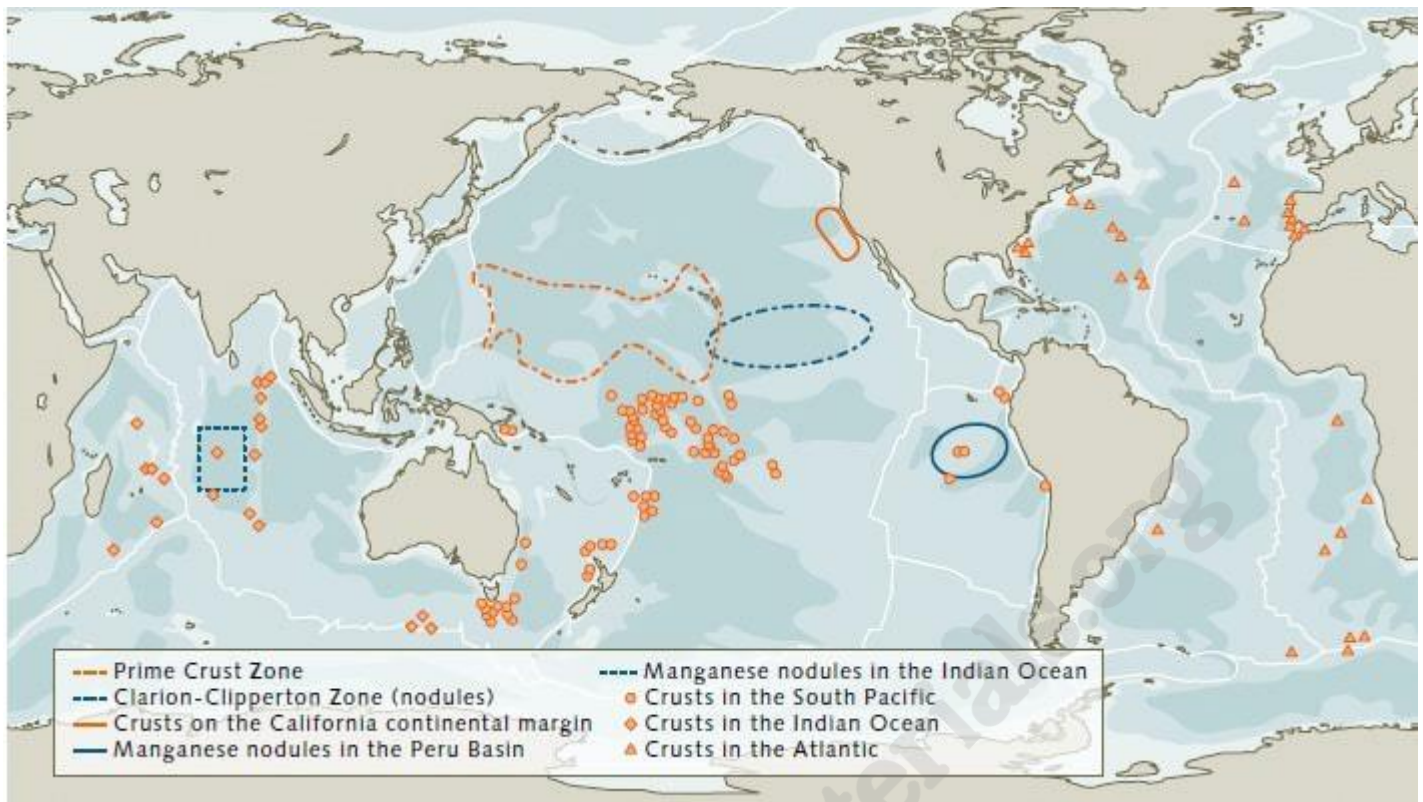
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- Large areas in the basins east of the Central Indian Ridge ([ridge along the Reunion Hotspot](#)) contains nodules with a **high percentage of manganese, nickel and copper**.
- India has exclusive rights to explore polymetallic nodules from seabed in Central Indian Ocean Basin (CIOB).

### Challenges

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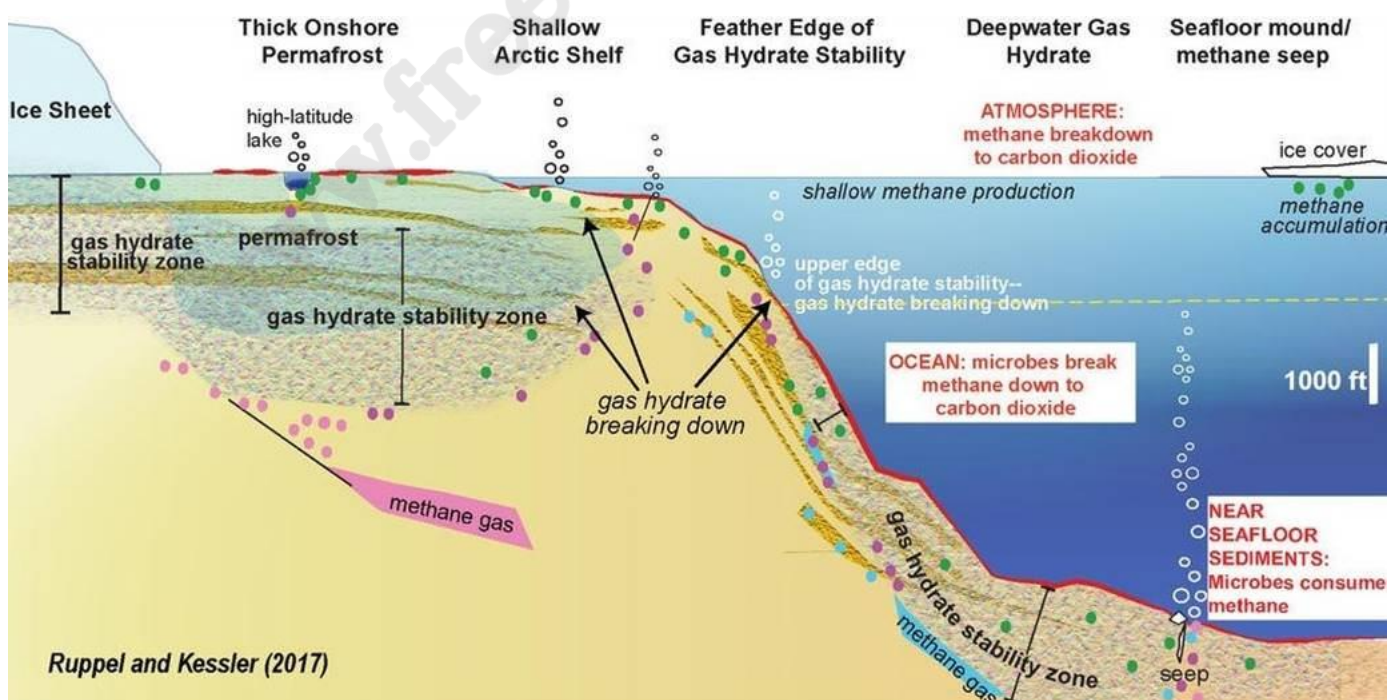
- Continuing availability of the key minerals from land-based sources like **nickel** at market prices.
- Mining is not economically viable for the next two decades.



Locations of known polymetallic nodules. From World Ocean Review 3, (2014) ([Source](#))

## Marine gas hydrate deposits

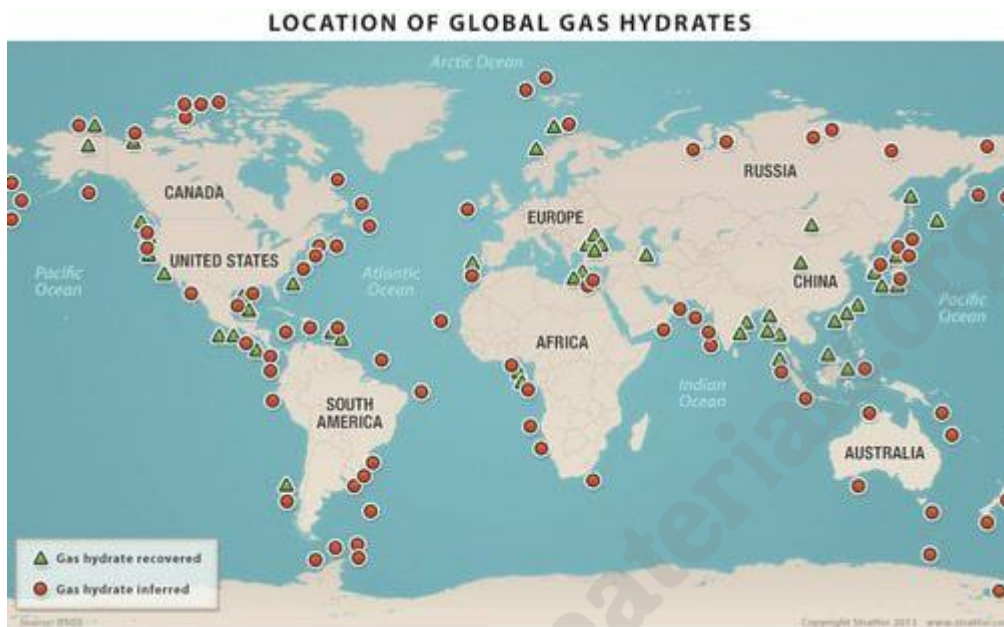
- Gas hydrate is an icy crystalline compound located at great ocean depths and in shallow polar waters.
- It is composed of gas molecules, normally **methane**, encaged within water molecules.



Gas Hydrate deposits ([Source](#))



- On dissociation at standard atmospheric pressure, gas hydrate yields approximately 164 times its own volume of methane gas.
- Gas hydrates are estimated to **hold many times more methane than presently exists in the atmosphere and up to twice the amount of energy of all fossil carbon-based fuels combined.**



### Challenges in economic exploitation of gas hydrate deposits

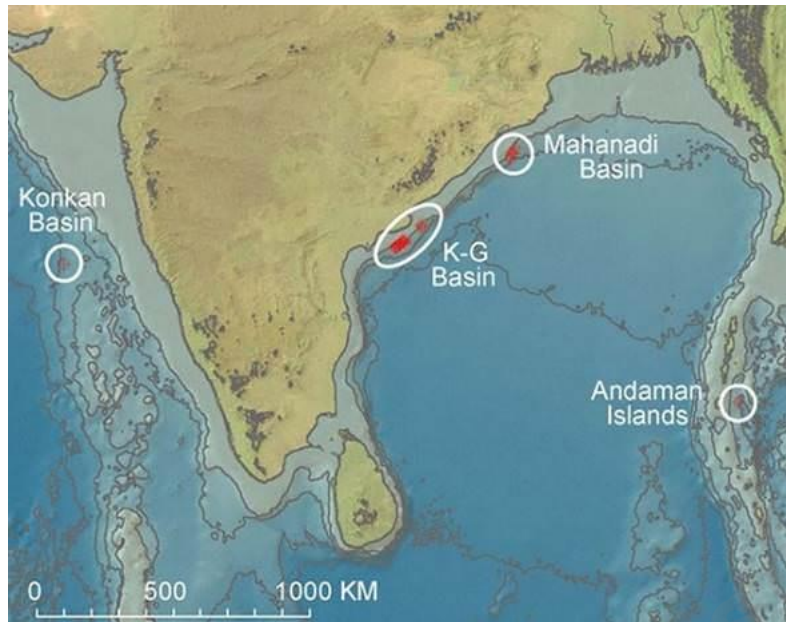
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Methane is a greenhouse gas that traps heat **twenty times** more proficiently than carbon dioxide

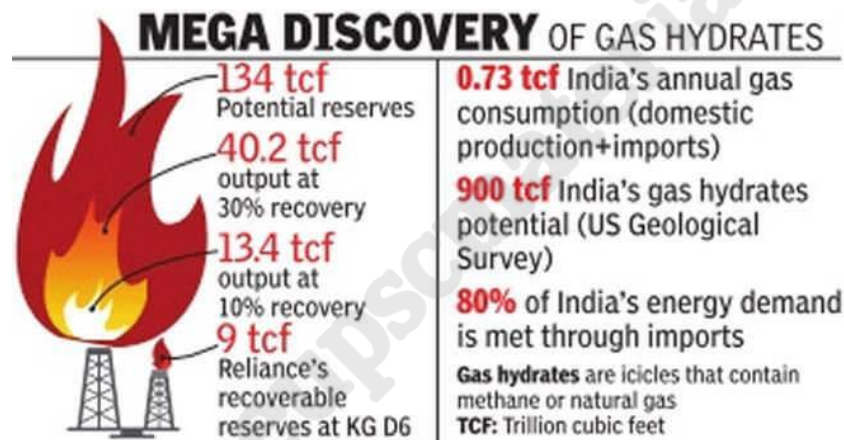
### Natural gas hydrate in North Indian Ocean

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- 2016: [ONGC discovered](#) large, highly enriched accumulations of natural gas hydrate in the Bay of Bengal.



Accumulations of natural gas hydrate in North Indian Ocean



[Source](#)

## Marine Polymetallic sulphides

- Deep seabed Poly-Metallic Sulphides (PMS) containing **iron, copper, zinc, silver, gold, platinum** in variable constitutions.
- They are formed due to the **precipitation of hot fluids from upwelling hot magma** discharged along the mid-ocean ridges.
- Considerable interest has been sparked by the discovery of **polymetallic sulphides in Western Indian Ocean**.
- India has received a 15 years contract from International Seabed Authority (ISA) for exploration of PMS in the area of 10,000 sq km in parts of Central and South - West Indian Ridges (SWIR).
- In the SWIR, PMS found near the [Galapagos rift system](#) contain 48 per cent sulphur, 43 per cent iron, 11 per cent copper and smaller quantities of **zinc, tin, molybdenum, lead and silver**.

## 7.3 Fresh Water

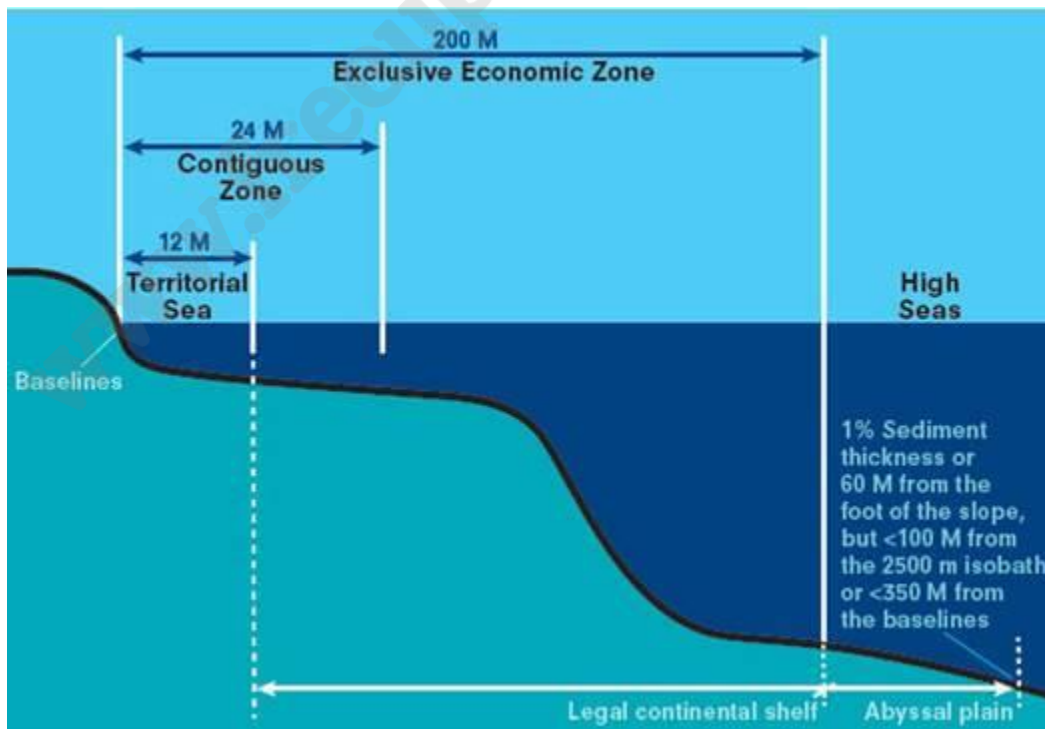
- Several desalination technologies are in operation, but as yet they are not being used on a large scale, as they are costly.

### Technologies adopted in desalinization of sea water

- Electrodialysis** employs iron-selective membranes for the desalination of brackish water.
- Flash distillation** technique is in use in Saudi Arabia, Kuwait, Island, Pakistan, Chile, and India.
- Reverse osmosis** is the most widely used method. Suitable osmotic membranes are used which reject salts and allow water to pass through when sea water is put under high pressure.

## 7.4 United Nations International Conferences on the Law of the Sea (UNCLOS)

- UNCLOS is an **international agreement** that defines the **rights and responsibilities of nations** where **use of the oceans' waters** by them is concerned.
- As of today, it has been signed by more than 150 countries.
- The **USA has signed the treaty but has not ratified it.**
- Four main decisions have been widely accepted since 1978.



UNCLOS Coastal Zones

## Territorial waters

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- Territorial waters are those waters over which a state has full sovereignty
- Territorial waters extend for 19 km (**12 miles**) from the coast.

## Contiguous Zone or Pursuit Zone

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- A further contiguous zone of 19 km is recognized in which the coastal state can act against those who break the law (smugglers, pirates, illegal immigrants etc.) within the true territorial waters.
- This, in other words, is a **pursuit zone**.

## Exclusive Economic Zone (EEZ)

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- Exclusive economic zone (EEZ) starts at the same baseline as the territorial waters.
- EEZ extend for 320-km (**200-mile**) from the baseline.
- Within the EEZ the coastal state has the right to **exploit all economic resources** — fish, minerals, oil and gas and energy production.

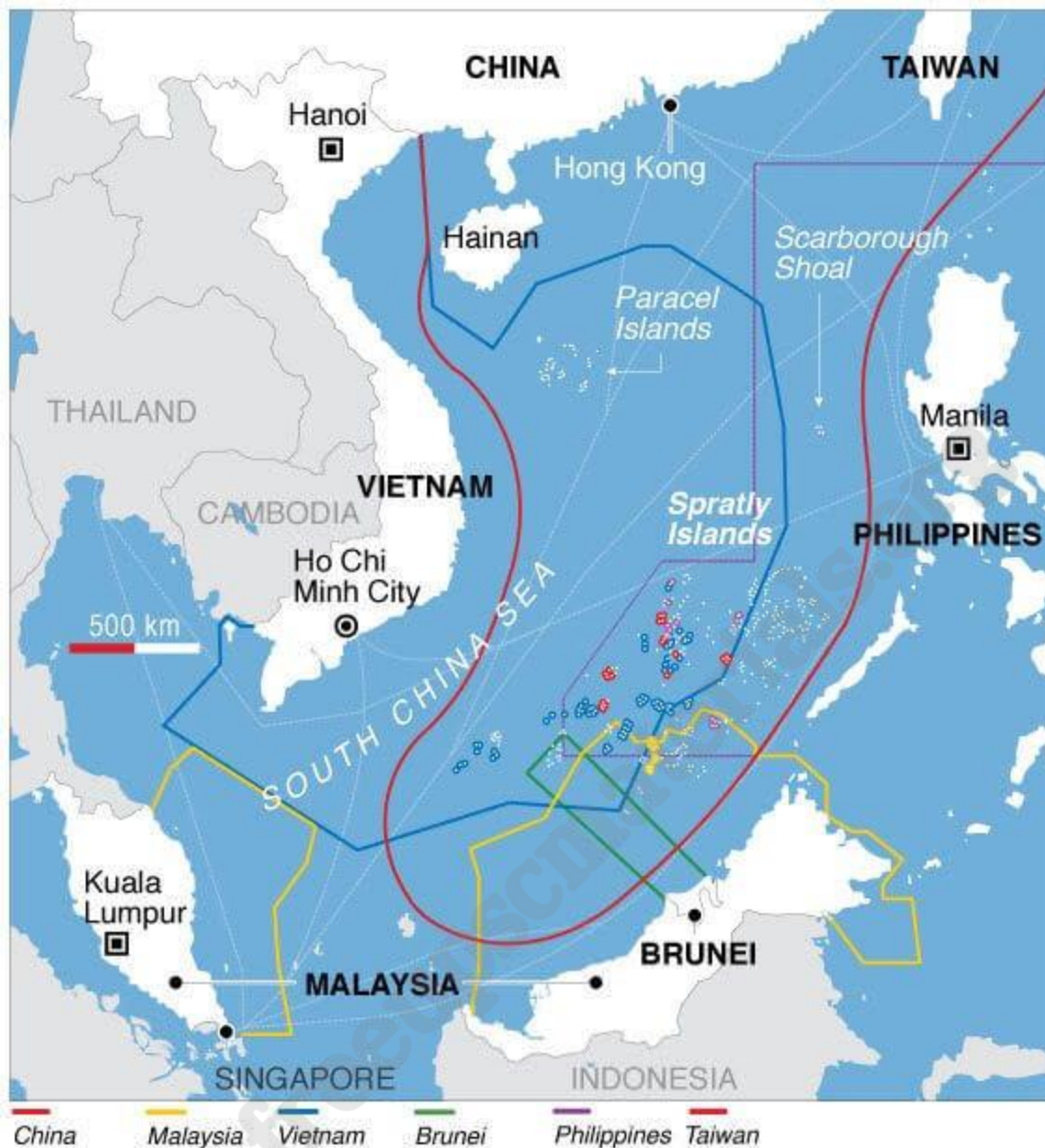
## High Seas

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- Beyond all the zones in which individual countries can claim control are the high seas.
- The high seas are **free for navigation** by vessels of all nations.
- The oceans may also be used freely for the laying of submarine cables, and the airspace over them is also free.

## Land Disputes in South China Sea: Parcel Islands and Spratly Islands

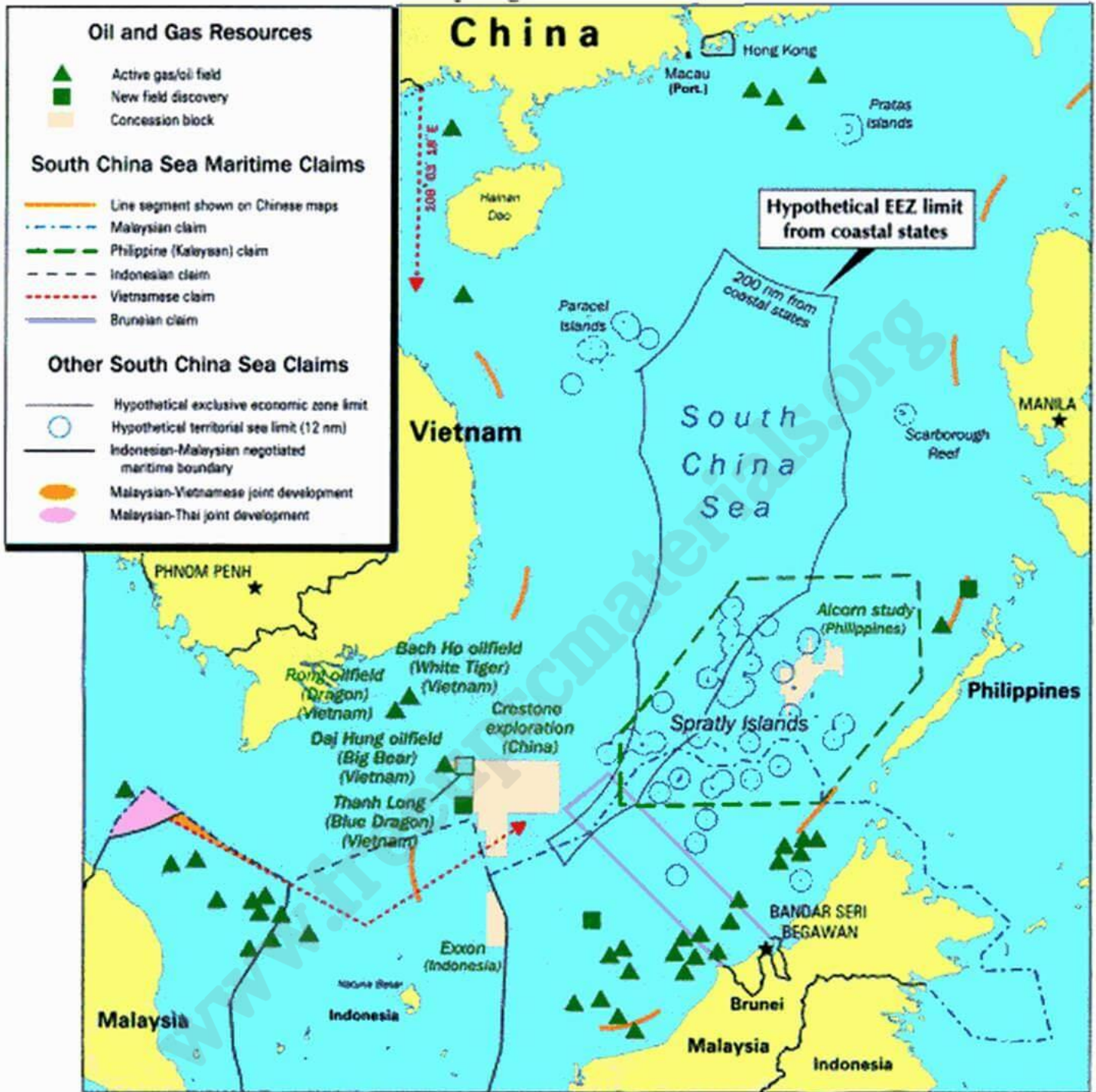
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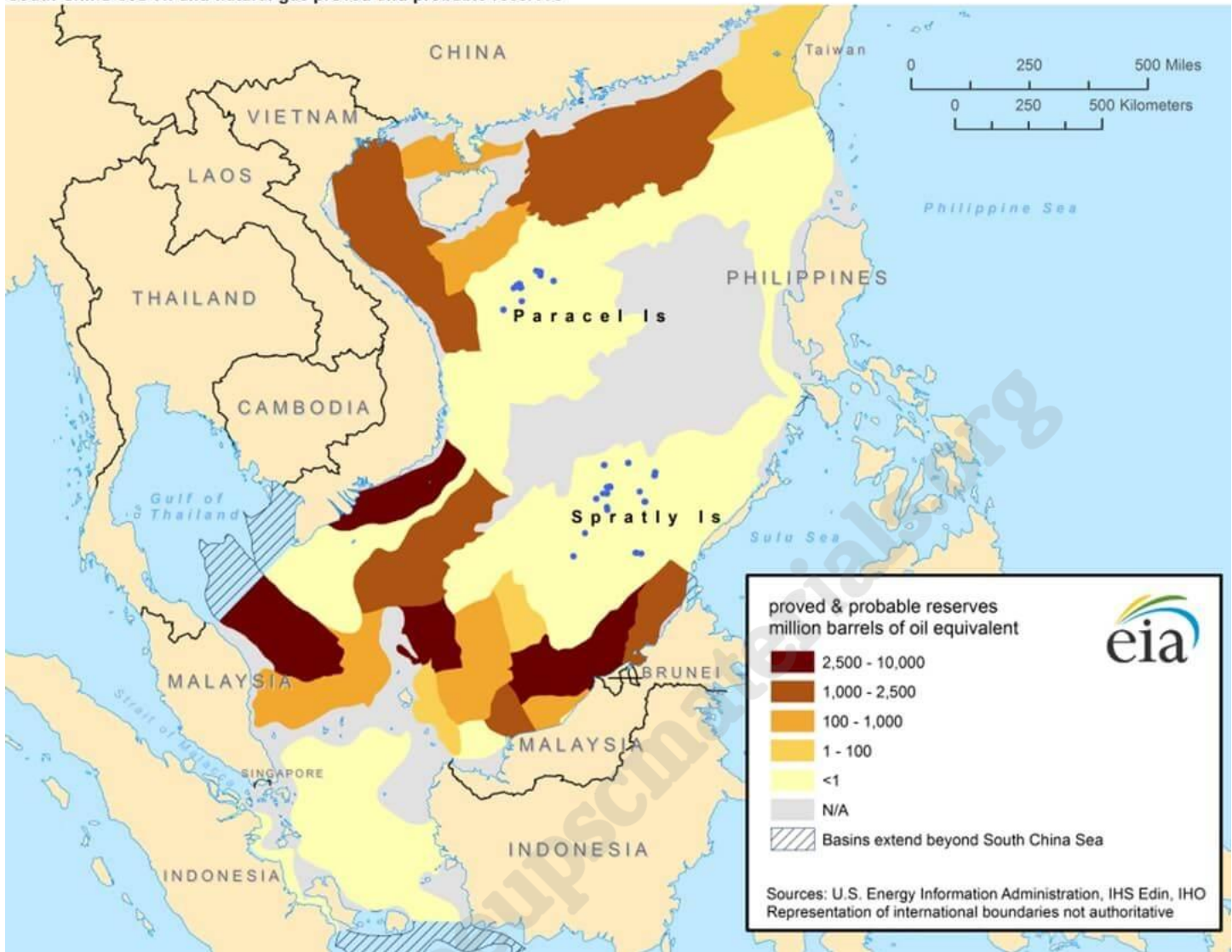
Parcel Islands and Spratly Islands in South China Sea (Voice of America, [Wikipedia](#))

- The **Spratly Islands and Paracel Islands** are two of the most contested areas in the South China Sea.
- However, unlike other parts of the South China Sea, these areas do not hold large resources of oil and natural gas.
- Most fields containing discovered oil and natural gas are clustered in uncontested parts of the South China Sea, close to shorelines of the coastal countries.
- Under the UNCLOS, ownership of habitable islands can, however, extend the exclusive access of a country to surrounding energy resources (**200 mile EEZ**).

### Competing Claims in the South China Sea



South China Sea oil and natural gas proved and probable reserves

Oil and Gas reserves around Spratly Islands and Parcel Islands ([Source](#))

### Economic and Strategic importance of South China Sea

- 10% of world's fisheries.
- 30% of global shipping trade.
- Population is 2.2 billion in the region.
- 11 billion barrels of oil.
- 190 trillion cubic feet of natural gas.

[Source](#)