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Geomorphology Part I

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Geography is the study of

1. the **physical features** of the earth and its atmosphere,
2. **human activity which affects and is affected by the physical features** of the earth and its atmosphere. (Definition from Oxford Dictionary)

- Human activity which affects and is affected by the physical features include the distribution of populations, distribution of resources and economic activities, and changes in the environment.

Geography, the natural science, is divided into two main branches:

1. **Physical geography:** deals with the study of processes and patterns in the natural environment like the atmosphere, hydrosphere, biosphere, and geosphere.
2. **Human geography:** deals with the environment shaped by human activity.

Physical Geography can be divided into several sub-fields, as follows:

- **Geomorphology** ('geo' meaning earth, 'morphe' meaning form and 'logos' meaning discourse) is the field concerned with understand-

ing the surface of the Earth and the processes by which it is shaped.

- **Climatology** is the study of the climate (weather conditions averaged over a long period).
- **Meteorology** focuses on weather processes and short-term forecasting (in contrast with climatology).
- **Oceanography** is the branch of physical geography that studies the Earth's oceans and seas.
- **Hydrology** is concerned with the amounts and quality of water moving and accumulating on the land surface and in the soils and rocks near the surface and is typified by the hydrological cycle.
- **Biogeography** deals with geographic patterns of species distribution and the processes that determine these patterns.
- **Environmental geography** analyses the spatial aspects of interactions between humans and the natural environment. The branch bridges the divide between human and physical geography.
- **Geomatics** is the field of gathering, storing, processing, and delivering geographic information.

There are many other sub-branches in physical geography.

1. Interior of The Earth

- Understanding the structure of the earth's interior (crust, mantle, core) and various forces (heat, seismic waves) emanating from it is essential to understand the evolution of the earth's surface, its current shape and its future.

1.1 The study of the earth's interior is essential

- to understand the earth's surface
- to understand the geophysical phenomenon like volcanism, earthquakes, etc.
- to understand the earth's magnetic field
- to understand the internal structure of various solar system objects
- to understand the evolution and present composition of the atmosphere
- for mineral exploration

Earth's surface

- Many different geological processes shape the Earth's surface.
- The forces that cause these processes come from both above and beneath the Earth's surface.
- Processes that are caused by forces from within the Earth are **endogenous processes** (Endo meaning "in").
- By contrast, **exogenous processes** (Exo meaning "out") come from forces on or above the Earth's surface.
- The major geological features of the earth's surface like mountains, plateaus, lakes are mostly a result of endogenous processes like folding, faulting that are driven by forces from inside the earth.

Geophysical phenomenon like volcanism, earthquakes

- The forces that cause catastrophic events like earthquakes, volcanic eruptions come from deep below the earth's surface.
- For example, earthquakes occur due to the movement of the tectonic plates and the energy required for this movement is supplied by the **conventional currents in the mantle**.
- Similarly, volcanism occurs through the vents and fissures created by the tectonic movements.

Earth's magnetic field

- Earth's magnetic field is a result of **convection currents in the outer core** of the earth.
- Life on earth would not have been possible if not for the earth's magnetic field which protects the earth's atmosphere from the harmful **solar wind**.

The internal structure of various solar system objects

- The entire solar system was formed from a single nebular cloud, and the process of the formation of every solar system object is believed to be similar to that of the earth.

Evolution and present composition of the atmosphere

- For life to flourish on the surface of the earth, the atmosphere needs to have essential components like oxygen for respiration, CO_2 and other greenhouse gases to maintain the temperature on the surface, ozone to protect life from ultraviolet radiation and the right atmospheric pressure.
- All these components of the earth's atmosphere owe their existence to the **volcanic eruptions** that unlock them from the earth's interior.

Mineral exploration

- Understanding volcanic activity and the nature of rocks is essential for mineral exploration.
- Most of the minerals like **diamonds (form at a depth of 150-800 km in the mantle)** that occur on the earth's surface are formed deep below the earth's surface. They are brought to the surface by **volcanic activity**.

1.2 Direct Sources of information about the interior

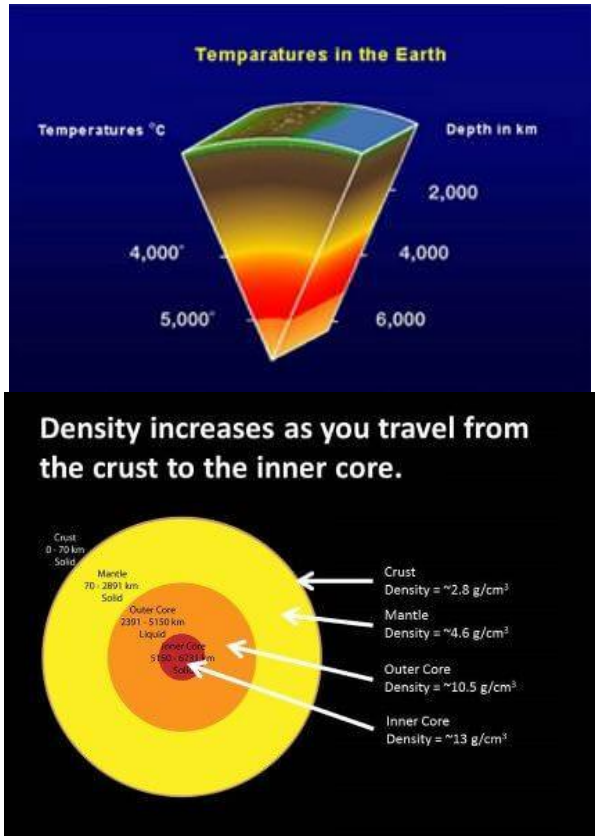
- Deep earth mining and drilling reveal the nature of rocks deep down the surface.
- But as mining and drilling are not practically possible beyond a certain depth, they don't reveal much information about the earth's interior.
- **Mponeng gold mine** (deepest mine in the world) and **TauTona gold mine** (second deepest mine in the world) in South Africa are deepest mines reaching to a depth of only 3.9 km.
- And the deepest drilling is only about 12 km deep hole bored by the Soviet Union in the 1970s over the **Kola Peninsula**.

The Kola Peninsula in north-west Russia. (TUBS, from Wikimedia Commons)

- Volcanic eruption forms another source of obtaining direct information.

1.3 Indirect Sources of information about the interior

- Gravitation and the diameter of the earth help in estimating pressure deep inside.
- Volcanic eruptions and existence of hot springs, geysers etc. point to an interior which is very hot.



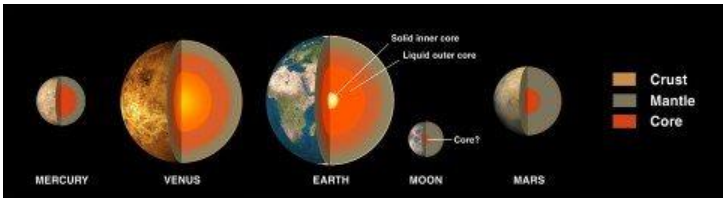
Seismic waves

- They are the most important source available to understand the layered structure of the earth.
- The velocity of seismic waves changes as they travel through materials with different **elasticity** and **density**.
- The **more elastic and denser the material is, the higher is the velocity**.
- They also undergo **refection or refraction** when they come across materials with different densities.
- Earth's internal structure can be understood by analysing the patterns of reflection, refraction

and change in velocity of the seismic waves when they travel through it.

Meteorites

- Meteorites and Earth are born from the same nebular cloud. Thus, they are likely to have a similar internal structure.
- When meteoroids they fall to earth, their outer layer is burnt during their fall due to extreme friction and the inner core is exposed.
- The heavy material composition of their cores confirms the similar composition of the inner core of the earth.



Gravitation

- The gravitation force differs according to the mass of material. The uneven distribution of mass of material within the earth influences this value. Such a difference is called **gravity anomaly**.
- Gravity anomalies give us information about the **distribution of mass** in the crust of the earth.

Magnetic field

- The geodynamo effect helps scientists understand what's happening inside the Earth's core. Shifts in the magnetic field also provide clues to the inaccessible iron core.

Sources of earth's heat

Radioactive decay

- The high temperature below the crust is attributed to the **disintegration of the radioactive substances**.
- **The nuclear decay happens primarily in the crust and the mantle**.
- Scientists believe that uranium could become sufficiently concentrated **at the base of Earth's mantle** to ignite self-sustained **nuclear fission**, as in a human-made reactor.
- The new measurements suggest **radioactive decay provides more than half of Earth's total heat**.

Nuclear fusion doesn't occur inside the earth. *For nuclear fusion to occur there must be far more pressure and temperature inside the earth. The earth is not massive enough to cause such conditions.*

Primordial heat

- The rest is the heat left over from Earth's formation known as the **primordial heat**.
- Primordial heat is the kinetic energy transferred to Earth by external impacts of comets and meteorites and the subsequent effects (**friction** caused by sinking of heavy elements like Fe, rising light elements like Si) and **latent heat of crystallisation released as the core solidified**.

Tidal friction

- The ocean tides are not the only effect of tidal forces (gravitational influence of the moon and the sun on earth; tides are explained in oceanography). The solid body of the Earth also bulges slightly in this way.
- The daily flexing of the Earth (both solid body and the oceans) cause loss of energy of the Earth's rotation, due to friction.
- This energy goes into heat, leading to miniscule increase in the Earth's internal temperature.
- The loss of rotational energy means that the **Earth is slowing down in its rotation rate**, currently by about 0.002 seconds per century.

1.4 Seismic waves

- Seismic: relating to earthquakes or other vibrations of the earth and its crust.
- Seismic waves are waves of energy that travel through the Earth's layers and are a result of earthquakes, volcanic eruptions, magma movement, large landslides and large human-made explosions.
- The refraction or reflection of seismic waves is used for research into the structure of the Earth's interior.
- The terms seismic waves and earthquake waves are often used interchangeably.

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Geomorphology Part II

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1. Volcanism

- A volcano is a vent or a fissure in the crust from which lava (molten rock), ash, gases, rock fragments erupt from a magma chamber below the surface.
- Volcanism is the phenomenon of eruption of molten rock, pyroclastics and volcanic gases to the surface through a vent.

1.1 Causes of Volcanism

- There is a **huge temperature difference** between the inner layers and the outer layers of the earth due to the differential amount of radioactivity.
- This temperature difference gives rise to **convectional currents** in the mantle.
- The convection currents in the mantle create convergent and divergent boundaries (weak zones).
- At the divergent boundary, molten, semi-molten and sometimes gaseous material appears on earth at the first available opportunity.
- The earthquakes here may expose fault zones through which magma may escape (**fissure type volcano**).
- At the convergent boundary, the subduction of denser plate creates magma at high pressure which will escape to the surface in the form of violent eruptions.

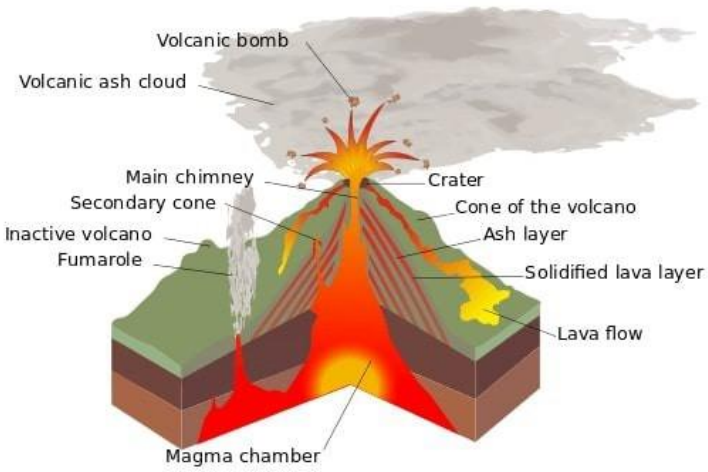
1.2 Lava types

- Magma is composed of molten rock and is stored in the Earth's crust. Lava is magma that reaches the surface through a volcano vent.

Andesitic or Acidic or Composite or Stratovolcanic lava

- These lavas are **highly viscous** with a high melting point.
- They are **light-coloured, of low density, and have a high percentage of silica**.
- They **flow slowly and seldom travel far** before solidifying.
- The resultant volcanic cone is therefore stratified (hence the name **stratovolcano**) and steep-sided.
- The **rapid solidifying of lava** in the vent obstructs the flow of the out-pouring lava, result-

ing in **loud explosions**, throwing out many volcanic **bombs or pyroclasts**.



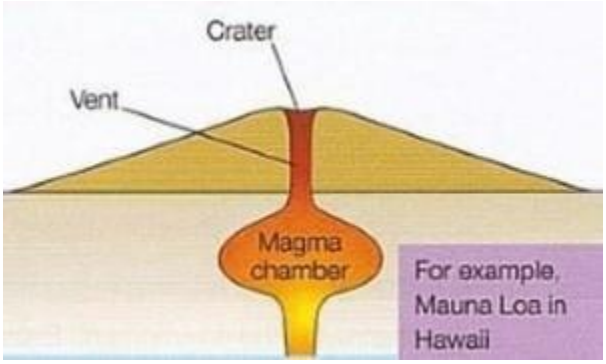
Volcano (Medium69.Cette William Crochot, via Wikimedia Commons)

- Sometimes the lavas are so viscous that they form a **lava plug** at the crater like that of **Mt. Pelée** in Martinique (an island in the Lesser Antilles, Caribbean Islands).
- Andesitic lava flow occurs mostly along the **destructive boundaries** (convergent boundaries).

Lava Plug at the crater

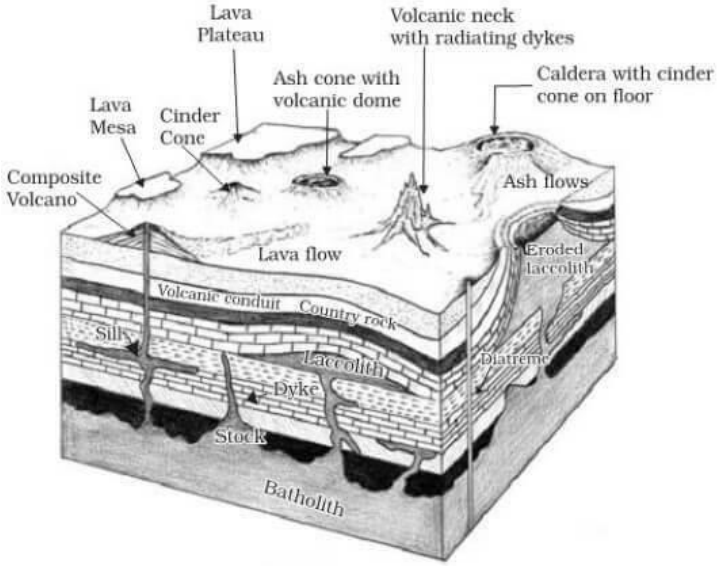
Basic or Basaltic or Shield lava

- These are the **hottest lavas**, about 1,000 °C and are **highly fluid**.
- They are **dark coloured basalt, rich in iron and magnesium but poor in silica**.
- They flow out of volcanic vent **quietly** and are **not very explosive**.
- Due to their **high fluidity**, they flow readily with a speed of 10 to 30 miles per hour.
- They affect extensive areas, spreading out as **thin sheets** over **great distances** before they solidify.
- The resultant volcano is **gently sloping** with a wide diameter and forms a flattened shield or dome.
- Shield type lava flow is common along the **constructive boundaries** (divergent boundary).



1.3 Volcanic Landforms

- Volcanic landforms are divided into **extrusive and intrusive landforms** based on whether magma cools within the crust or above the crust.
- Rocks formed by cooling of magma within the crust are called **Plutonic rocks.**
- Rocks formed by cooling of lava above the surface are called **Igneous rocks**.
- In general, the term 'Igneous rocks' is used to refer all rocks of volcanic origin.



Extrusive and Intrusive volcanic landforms

Extrusive Volcanic Landforms

- Extrusive landforms are formed from material thrown out to the surface during volcanic activity.
- The materials thrown out include lava flows, pyroclastic debris, volcanic bombs, ash, dust and gases such as **nitrogen compounds, sulphur compounds** and minor amounts of **chlorine, hydrogen** and **argon**.

Conical Vent and Fissure Vent

Fissure vent

- A fissure vent (volcanic fissure) is a narrow, linear volcanic vent through which lava erupts, **usually without any explosive activity**.
- The vent is often a few meters wide and may be many kilometres long.
- Fissure vents are common in **basaltic volcanism** (**shield type volcanoes**).

Conical vent

- A conical vent is a narrow cylindrical vent through which magma flows out violently.
- Conical vents are common in **andesitic volcanism** (**composite or stratovolcano**).

Mid-Ocean Ridges

- The system of mid-ocean ridges stretches for more than 70,000 km across all the ocean basins.
- The central portion of the mid-ocean ridges experiences frequent eruptions.
- The lava is **basaltic** (less silica and hence less viscous) and causes the **spreading of the seafloor**.

Composite Type Volcanic Landforms

- They are conical or central type volcanic landforms.
- Along with andesitic lava, large quantities of pyroclastic material and ashes find their way to the surface.
- **Andesitic lava** along with pyroclastic material accumulates in the vicinity of the vent openings leading to the formation of layers, and this makes the mounts appear as a **composite volcano or a stratovolcano** (divided into layers).

- The highest and most common volcanoes have composite cones.
- **Mount Stromboli (the Lighthouse of the Mediterranean)**, Mount Vesuvius, Mount Fuji are examples.

Shield Type Volcanic Landforms

- The **Hawaiian volcanoes** are the most familiar examples.
- These volcanoes are mostly made up of **basaltic lava** (very fluid).
- These volcanoes are not steep.
- They become explosive if somehow water gets into the vent; otherwise, they are less explosive.
- Example: Hawaiian volcanoes **Mauna Loa** (active shield volcano) and **Mauna Kea** (dormant shield volcano).

Fissure Type Flood Basalt Landforms (Lava Plateaus)

- Sometimes, a very thin magma escapes through cracks and fissures in the earth's surface and

flows after intervals for a **long time**, **spreading over a vast area**, finally producing a **layered, undulating (wave-like), flat surface**.

- Example: **Siberian Traps**, **Deccan Traps**, **Snake Basin, Icelandic Shield, Canadian Shield**.

Crater

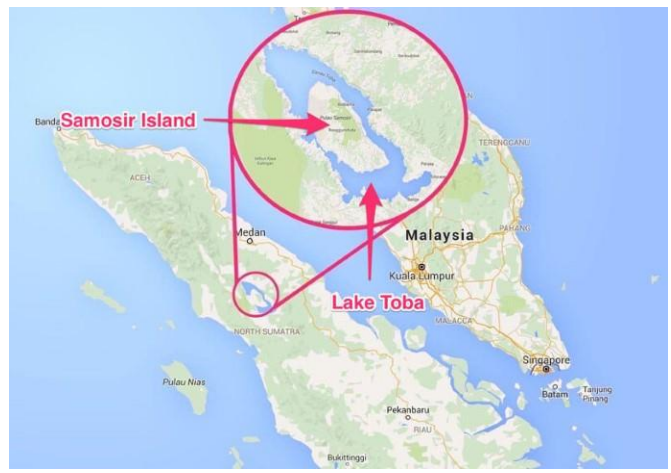
- A crater is an inverted cone-shaped vent through which the magma flows out. When the volcano is not active the crater appears as a bowl-shaped depression.

The crater of Mount Fuji, Japan

- When water from rain or melted snow gets accumulated in the crater, it becomes a **crater lake**.

Caldera

- In some volcanoes, the magma chamber below the surface may be emptied after volcanic eruptions.
- The volcanic material above the chamber **collapses** into the empty magma chamber, and the collapsed surface appears like a large cauldron-like hollow (tub shaped) called the caldera.
- When water from rain or melted snow gets accumulated in the caldera, it becomes a **caldera lake** (in general, the caldera lakes are also called crater lakes).
- Due to their unstable environments, some crater lakes exist only intermittently. Caldera lakes, in contrast, can be quite **large and long-lasting**.
- For example, **Lake Toba (Indonesia)** formed after its supervolcanic eruption around 75,000 years ago. It is the **largest crater lake in the world**.



- Mount Mazama (Cascade Volcanic Arc, USA) collapsed into a caldera, which was filled with water to form Crater Lake (the literal name of the lake formed by the collapse of Mount Mazama is 'Crater Lake'!).

Caldera lake of Mount Mazama

A crater lake, in general, could be of volcanic origin (volcanic crater lake, volcanic caldera lake) or due to a meteorite impact (meteor

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Climatology Part I

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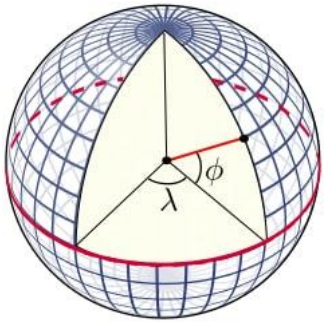
1. Latitudes and Longitudes

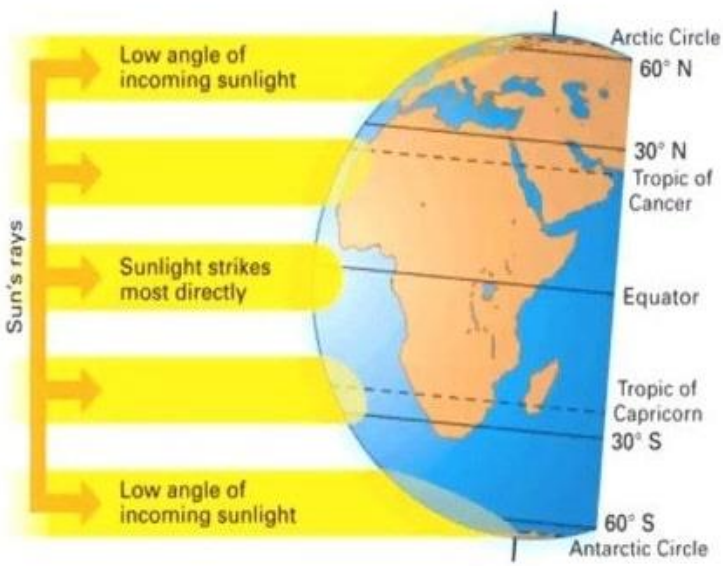
- Latitudes and Longitudes (coordinate system) are imaginary lines used to determine the location of a place on earth.
- Example: The location of New Delhi is 28° N Latitude, 77° E Longitude.



Latitude (ϕ) and longitude (λ) are defined on a perspective spherical modal (Wikipedia)

1.1 Latitude or Parallel

- Latitude is the angular distance of a place north or south of the equator measured in degrees from the centre of the earth.
- As the earth is **slightly flattened at the poles**, the **linear distance of a degree of latitude at the pole is a little longer than that at the equator**.
- For example, at the equator linear distance of a degree of latitude is 110.57 km (68.7 miles), at 45° it is 111.13 km (69 miles), and at the poles, it is 111.7 km (69.4 miles). The average is taken as **111 km (69 miles)**.



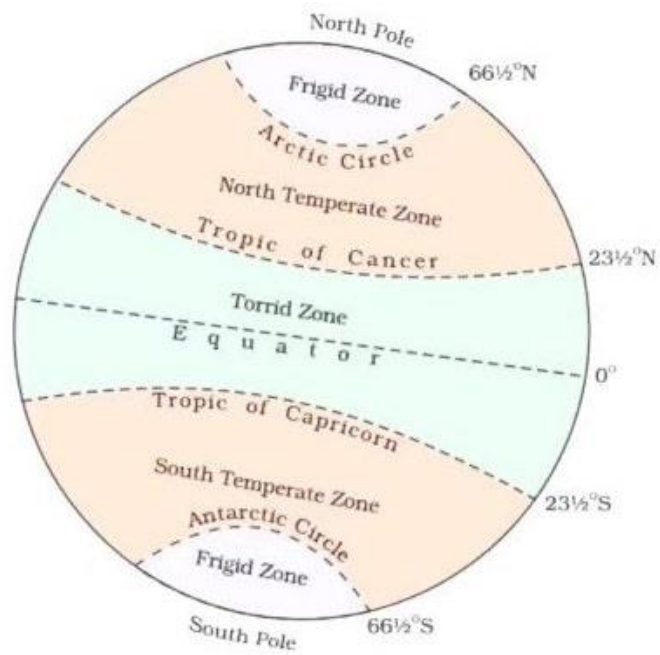
Latitudinal Heat zones of the earth

- The mid-day sun is exactly overhead at least once a year on all latitudes in between the Tropic of Cancer and the Tropic of Capricorn. This area, therefore, receives the maximum heat and is called the **torrid zone**.
- The mid-day sun never shines overhead on any latitude beyond the Tropic of Cancer and the Tropic of Capricorn. The angle of the sun's rays goes on decreasing towards the poles.
- As such, the areas bounded by the Tropic of Cancer and the Arctic circle, and the Tropic of Capricorn and the Antarctic circle, have moderate temperatures. These are, therefore, called **temperate zones**.
- Areas lying beyond the Arctic circle and the Antarctic circle are very cold. Here the sun does not rise much above the horizon. Therefore, its rays are always slanting. These are, therefore, called **frigid zones**.

Important parallels of latitudes

- Besides the **equator (0°)**, the **north pole (90° N)** and the **south pole (90° S)**, there are four important parallels of latitudes:
  1. The **Tropic of Cancer (23½° N)** in the northern hemisphere.
  2. The **Tropic of Capricorn (23½° S)** in the southern hemisphere.
  3. The **Arctic circle (66½° N)** in the northern hemisphere.
  4. The **Antarctic circle is (66½° S)** in the southern hemisphere.

Latitudinal Heat zones of the earth



1.2 Longitude or Meridian

- Longitude is an angular distance of a place east or west of the **Prime (First) Meridian** measured in degrees from the centre of the earth.

- On the globe, longitude is shown as a series of semi-circles that run from pole to pole passing through the equator. Such lines are also called **meridians**.
- It was decided in 1884 to choose the meridian which passes through the Royal Astronomical Observatory at **Greenwich, near London**, as the **zero meridian or prime meridian**.
- All other meridians radiate eastwards and westwards of the prime meridian up to 180°.
- Unlike the parallels of latitude, the meridians of longitude are of **equal length**.
- The meridians of longitude have one very important function; they determine local time in relation to **Greenwich Mean Time (GMT)**, which is sometimes referred to as **World Time**.

Longitude and Time

- Since the earth makes one complete rotation of 360° in one day or 24 hours, it passes through **15° in one hour** or **1° in 4 minutes**.
- The earth rotates from west to east, so **every 15° we go eastwards, local time is advanced by 1 hour**.
- Conversely, **if we go westwards by 15°, local time is retarded by 1 hour**.
- Thus, the **places east of Greenwich gain time**, whereas **places west of Greenwich lose time**.
- A traveller going eastwards gains time from Greenwich until he reaches the meridian 180° E when he will be 12 hours ahead of GMT (GMT+12).
- Similarly, in going westwards, he loses 12 hours when he reaches 180° W. There is thus a total difference of 24 hours or a whole day between the two sides of the 180° meridian.

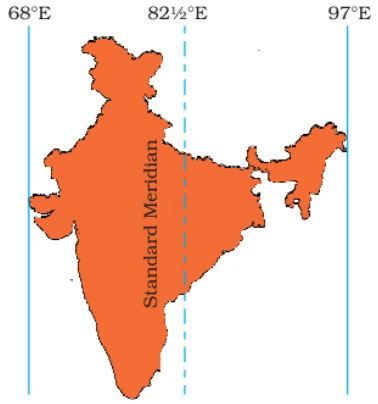
180° E and 180° W correspond to the same longitude. The difference is the direction of travel.

Standard Time and Time Zones

- Standard Time is the time corresponding to a certain longitude or longitudes as chosen by a country.
- Most countries adopt their standard time from the central meridian of their countries. E.g. **IST corresponds to the time at 82.5° E longitude**.
- In countries that have a very **large longitudinal extent** (**large east-west span**), such as Canada, USA, Russia, it would be inconvenient to have a single time zone. So, such countries have multiple time zones.
- For example, Russia has nine time zones, and Canada and USA have six time zones each.

Indian Standard Time

- Indian Standard Time (IST) is taken as the time at **82.5° E longitude** (passing close to the east of **Prayagraj or Allahabad**). Which means, **IST is 5 hours 30 mins ahead of GMT** (**IST = GMT+5:30**).



Longitudinal extent of India

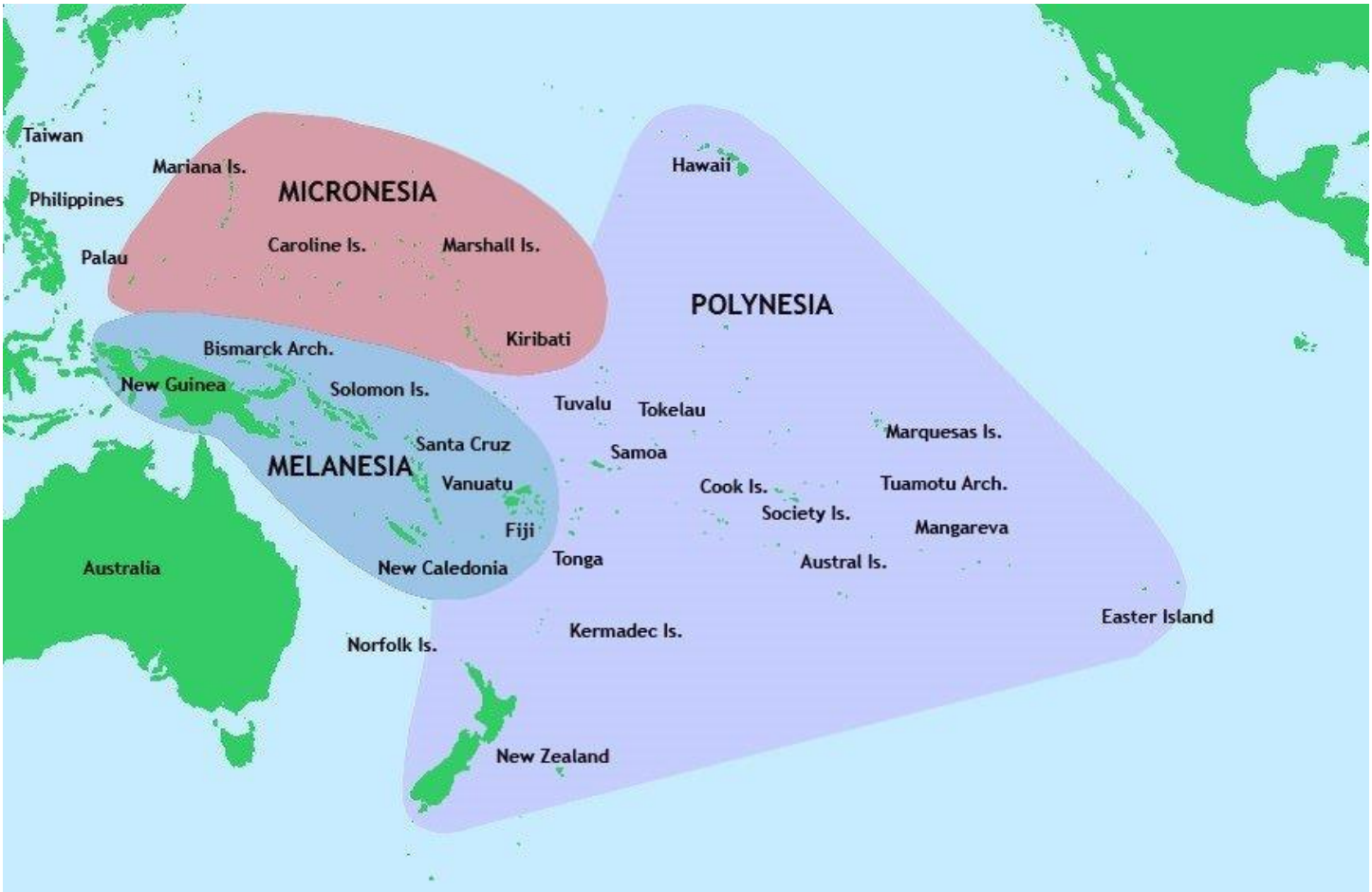
Chaibagaan Time

- One hundred fifty years ago, British colonialists introduced "Chaibagaan time" or "Bagaan time", a schedule observed by tea planters, which was **one hour ahead of IST**.
- This was done to improve productivity by optimising the usage of daytime.
- After Independence, Assam, along with the rest of India, has been following IST.
- The administration of the Indian state of Assam put forward a proposal to change its time zone back to Chaibagaan time to conserve energy and improve productivity.
- Indian government refused to accept such a proposal.

The International Date Line

- The International Date Line (IDL) an imaginary line that passes through the Pacific Ocean.

Time Zones and International Date Line



The Island Groups of Australia, Polynesia, Melanesia and Micronesia

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Climatology Part II

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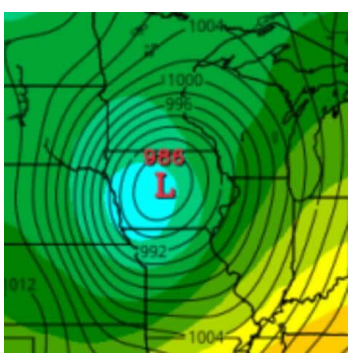
1. Tropical Cyclones

- Tropical cyclones originate over oceans in **tropical areas in late summers**.
- They are rapidly rotating violent storms characterised by
  - ✓ a **closed low-pressure centre with steep pressure gradients** (category 1 cyclones have a barometric pressure of greater than 980 millibars; category 5 cyclones can have central barometric pressure of **less than 920 millibars**),



Closed Isobars in a Tropical Cyclone

  - ✓ a **closed low-level atmospheric circulation** (winds converging from all directions — cyclonic circulation),
  - ✓ **strong winds** (squalls — a sudden violent gust of wind), and
  - ✓ a **spiral arrangement of thunderstorms** that produce very heavy rain **(torrential rainfall**).
- The low-pressure at the centre is responsible for the wind speeds.
- The closed air circulation (cyclonic circulation) is a result of **rapid upward movement of hot moist air** which is subjected to **Coriolis force**.

1.1 Conditions necessary for the Formation of a Tropical Cyclone

- **Large sea surface with temperature higher than 27° C.**
- **Presence of the Coriolis force enough to create a cyclonic vortex.**
- **A pre-existing weak low-pressure area or low-level-cyclonic circulation.**
- **Low wind shear.**
- **Upper-level divergence.**

Good Source of Latent Heat

- Ocean waters having temperatures of **27° C** and depth of warm water extending for **60-70 m** deep supply enough moisture, and hence **latent heat of condensation**, to generate and drive a tropical storm.
- Thick layer of warm water ensures that the deep convection currents within the water do not churn and mix the cooler water below with the warmer water near the surface.

Why tropical cyclones form mostly on the western margins of the oceans?

- Because of **warm ocean currents** (easterly trade winds drag ocean waters towards west) that flow from east towards west forming a thick layer of warm water with temperatures greater than 27°C.

Why are tropical cyclones very rare on the eastern margins of the oceans?

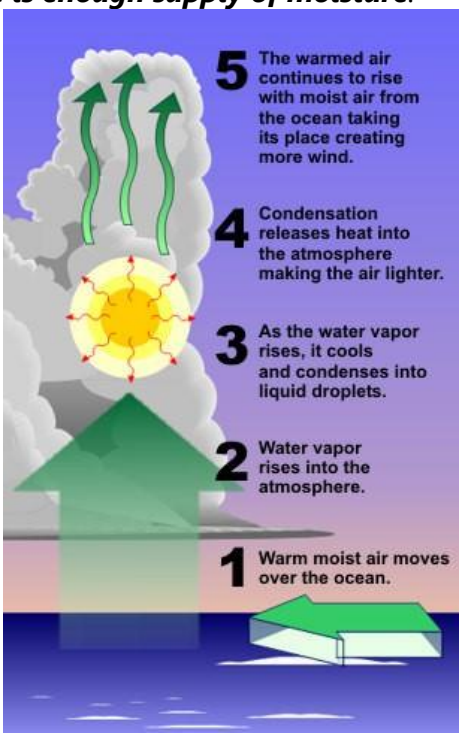
- The **cold currents** lower the surface temperatures of the eastern parts of the tropical oceans making them unfit for the breeding of cyclonic storms.

*Exceptional case: During **strong El Nino years**, strong hurricanes occur in the eastern Pacific. This is due to the accumulation of warm waters in the eastern Pacific due to **weak Walker Cell**.*

Why do tropical cyclones weaken on landfall?

- On landfall, the storm is cut-off from adequate moisture supply and hence it is deprived of latent heat of condensation. Thus, the storm dissipates (weakens or dies off) on landfall.

*Rising of humid air parcel ➔ ambient pressure on the air parcel decreases with altitude ➔ adiabatic lapse rate (fall in temperature of air parcel) ➔ condensation of moisture in air parcel due to low temperature ➔ **latent heat of condensation** is released in the process ➔ air parcel is heated further due to the release of latent heat of condensation and becomes less denser ➔ air parcel is further uplifted ➔ more air comes in to fill the gap ➔ new moisture is available for condensation ➔ latent heat of condensation is released. **The cycle repeats as long as there is enough supply of moisture**.*



Coriolis Force

- The **Coriolis force is zero at the equator,** but it increases with latitude.
- Coriolis force at 5° latitude is significant enough to create a storm (cyclonic vortex).
- About 65 per cent of cyclonic activity occurs between **10° and 20° latitude**.
- The cyclonic circulation is **anti-clockwise (counterclockwise) in the northern hemisphere** and **clockwise in the southern hemisphere**.

Why cyclones occur mostly in late summers?

1. Due to high specific heat of water, and mixing, the **ocean waters in northern hemisphere attain maximum temperatures in August** (in contract continents attain maximum temperatures in June-July).
2. Whirling motion (cyclonic vortex) is enhanced when the **doldrums** (region within ITCZ) over oceans are farthest from the equator (**Coriolis force increases with distance from the equator**).

Why do 'tropical cyclones' winds rotate counter-clockwise in the Northern Hemisphere?

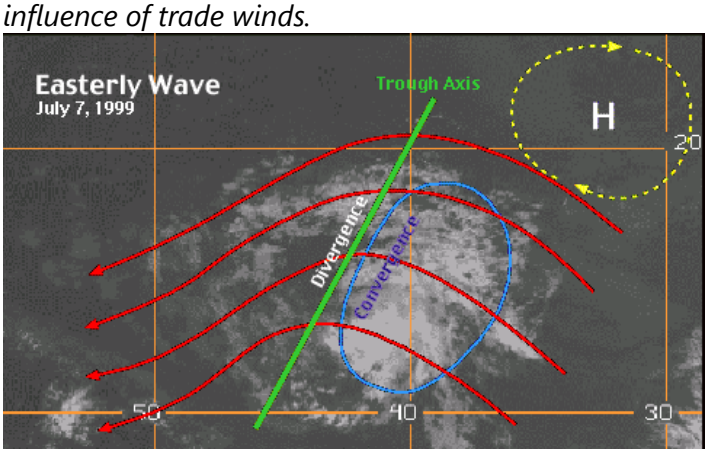
- As the earth's rotation sets up an apparent force (called the Coriolis force) that pulls the winds to the **right** in the Northern Hemisphere (and to the left in the Southern Hemisphere).
- So, when a low-pressure starts to form over north of the equator, the surface winds will flow inward trying to fill in the low and will be deflected to the right, and a **counter-clockwise rotation** will be initiated.
- The opposite (a deflection to the left and a clockwise rotation) will occur south of the equator.

Coriolis force is too tiny to effect rotation in water that is going down the drains of sinks and toilets. The rotation in those will be determined by the geometry of the container and the original motion of the water.

Low-level Disturbances

- Low-level disturbance is a **low-pressure trough (an extended region of low-pressure)** that moves from east to west in the form of **easterly wave disturbances** in the Inter-Tropical Convergence Zone (ITCZ).

A disturbance is a persistent group of thunderstorms with heavy rains and strong wind gusts.
Easterly wave disturbances: *it is a convective trough (thermal origin) — a persistent group of thunderstorms travelling together in east to west direction (westward traveling disturbances) under the influence of trade winds.*



Easterly wave disturbances

- Easterly wave disturbances act as **seedling circulations (birthplace)** for a large number of tropical cyclones. However, not all disturbances develop into cyclones.

Temperature Contrast Between Air Masses

- The convergence of air masses of different temperatures results in instability causing low-level disturbances which are a prerequisite for the origin and growth of violent tropical storms.
- Trade winds from both the hemispheres meet along the inter-tropical front (ITCZ). Temperature contrasts between these air masses must exist when the ITCZ is farthest from the equator so that the low-level disturbances can intensify into a depression (intensifying low-pressure cell).

Wind Shear

- Wind Shear is the difference between wind speeds at different altitudes.
- Tropical cyclones develop when the wind is uniform.

Why is convective cyclogenesis (tropical cyclogenesis) confined to tropics?

- **Because of weak vertical wind shear, cyclone formation processes are limited to latitude equatorward of the subtropical jet stream.**
- In the temperate regions, wind shear is high due to westerlies, and this inhibits convective cyclogenesis.

Why there are very few Tropical Cyclones during southwest monsoon season?

Large vertical wind shear

- The southwest monsoon is characterized by the presence of strong westerly winds (south-west monsoon winds) in the lower troposphere (below 3 km) and strong easterly winds in the upper troposphere (above 9 km). This results **in large vertical wind shear**. **Strong vertical wind shear inhibits cyclone development**.

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Oceanography

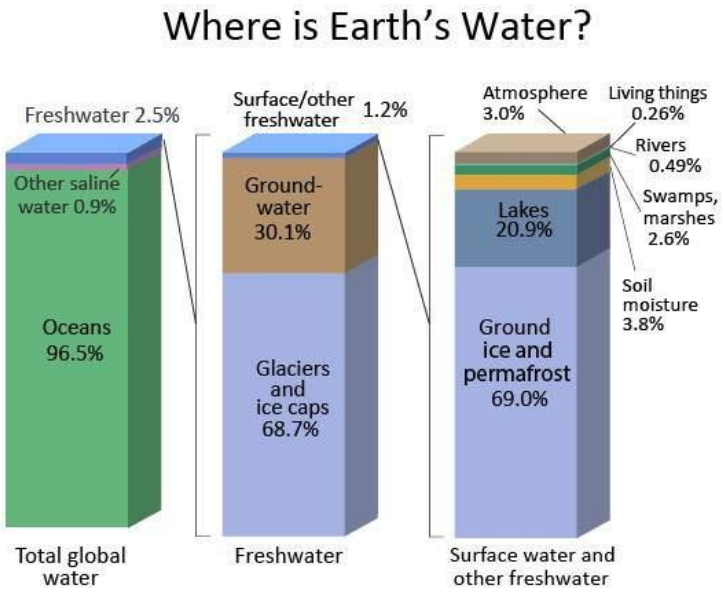
Print Friendly PDF

World Water Day – March 22

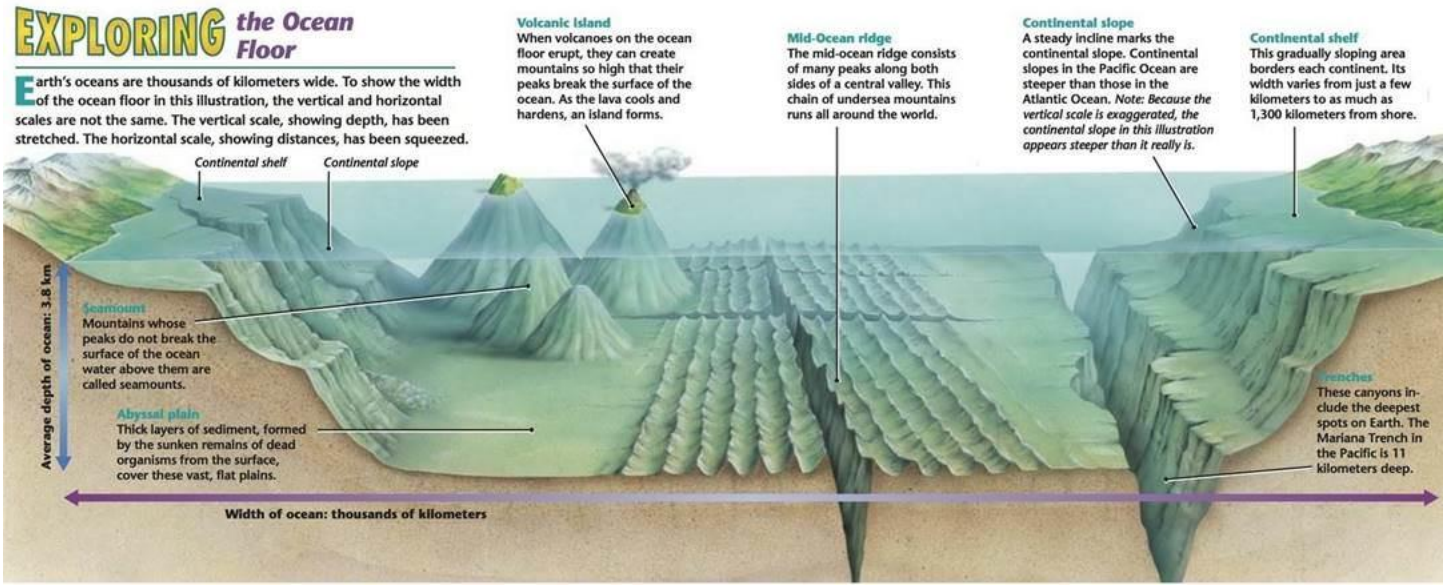
Water on the Earth's surface

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

- Water on earth in liquid form came into existence in Hadean Eon (4,540 – 4,000 mya).
- During the Hadean Eon, temperature on earth was extremely hot, and much of the Earth was molten.
- **Volcanic outgassing** created the primordial atmosphere which consisted of various gases along with water vapour.
- Over time, the Earth cooled, causing the formation of a **solid crust**.
- The water vapour condensed to form rain and rainwater gradually filled the depressions on the newly solidified crust.
- The water in the depressions merged to give rise to mighty oceans.
- During the Hadean Eon, the atmospheric pressure was **27 times greater** than it is today and hence even at a surface temperature of close to 200° C water remained liquid in the oceans.
- Over time, both temperature and atmospheric pressure dropped, and water continues to stay as liquid in the oceans.



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.



Ocean Relief Features

1. Ocean Relief

- Ocean relief is largely due to **tectonic, volcanic, erosional and depositional processes and their interactions.**
- Ocean relief controls the **motion of seawater.**
- The oceanic movement in the form of currents, in turn, causes many variations in both oceans and atmosphere.
- The bottom relief of oceans also influences **navigation and fishing.**

Ocean relief features are divided into major and minor 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

- Continental Shelf is the gently sloping (**gradient of 1° or less**) seaward **extension of a continental plate**.
- Continental Shelves cover **7.5%** of the total area of the oceans.
- **Shallow seas** and **gulfs** are found along the continental shelves.
- The shelf typically ends at a very steep slope, called the **shelf break.**
- Examples of continental shelves: Continental Shelf of South-East Asia (Sunda Plate), Grand Banks around Newfoundland, Submerged region between Australia and New Guinea, etc.

Formation

- 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

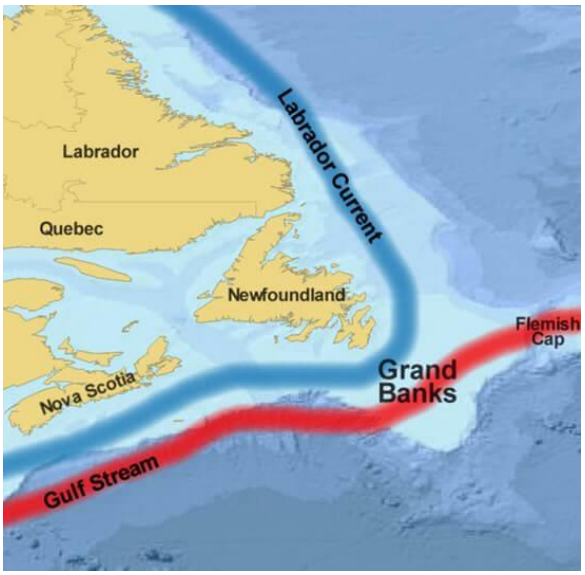
- Continental shelves have an average width of **70-80 km.**
- The shelves are almost absent or very narrow along a convergent boundary. E.g. coasts of Chile.
- The width of continental shelf of eastern coast of USA varies between 100-300 km.
- **Siberian shelf** in the Arctic Ocean is the largest in the world and stretches up to 1,500 km from the coast.

Width of various continental shelves

- Continental shelves may be as shallow as 30 m in some areas while in some areas it is as deep as 600 m.

Importance of continental shelves

- 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

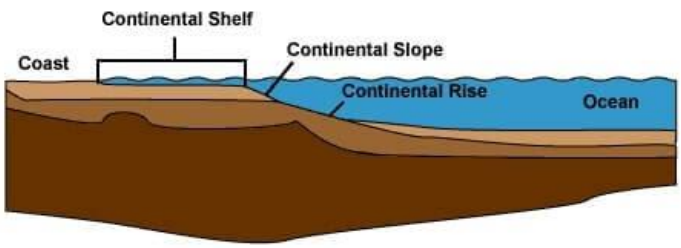
- Marine food comes almost entirely from continental shelves.
- They are sites for **placer deposits** and **phosphorites** (explained in Ocean Resources).

Continental Slope

- The gradient of the slope region varies between **2-5°.**
- The continental slope connects the continental shelf and the ocean basins.
- The depth of the slope region varies between 200 and 3,000 m.
- The seaward edge of the continental slope loses gradient at this depth and gives rise to **continental rise.**
- The **continental slope boundary indicates the end of the continents**.
- Canyons and trenches are observed in this region.

Continental Rise

- The continental slope **gradually** loses its steepness with depth.
- When the slope reaches a level of between **0.5° and 1°**, it is referred to as the continental rise.
- With increasing depth, the rise becomes virtually flat and merges with the **abyssal plain.**



Shelf, Slope and Rise (Wikipedia)

Deep Sea Plain or Abyssal Plain

- Deep sea planes are gently sloping areas of the ocean basins.
- These are the **flattest** and smoothest regions of the world because of **terrigenous** (marine sediment eroded from the land) **and shallow water sediments** that buries the irregular topography.
- It covers nearly **40%** of the ocean floor.
- The depths vary between 3,000 and 6,000 m.
- These plains are covered with fine-grained sediments like clay and silt.

1.2 Minor Ocean Relief Features

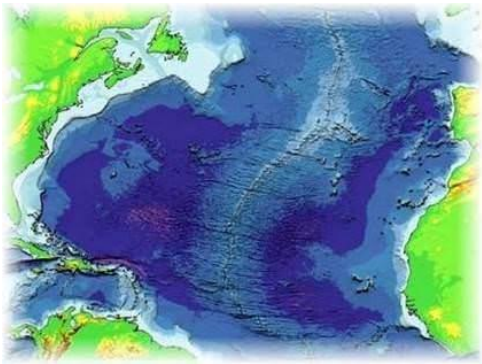
- Ridges (along a divergent boundary),
- Abyssal Hills (submerged volcanic mountains): Seamounts and Guyots,
- Trenches (along a convergent boundary),
- Canyons (erosional landform),
- Island arcs (formed due to volcanism along a convergent boundary or hotspot volcanism),
- Atolls and Coral reefs.

Oceanic Deeps or Trenches

- The trenches are relatively steep-sided, narrow basins (Depressions).
- These areas are the deepest parts of the oceans.
- They are of tectonic origin and are formed during ocean-ocean convergence and ocean-continent convergence.
- They are some 3-5 km deeper than the surrounding ocean floor.
- The trenches lie **along the fringes of the deep-sea plain** at the bases of continental slopes and along island arcs.
- The trenches run **parallel to the bordering fold mountains** or the **island chains**.
- The trenches are very common in the Pacific Ocean and form an almost continuous ring along the western and eastern margins of the Pacific.
- The **Mariana Trench off the Guam Islands** in the Pacific Ocean is the deepest trench with, a depth of more than **11 kilometres.**
- Trenches are associated with **active volcanoes** and **strong earthquakes** (like in Japan).
- Majority of the trenches are in the Pacific Ocean followed by the Atlantic Ocean and Indian Ocean.

Mid-Oceanic Ridges or Submarine Ridges

- A mid-oceanic ridge is composed of two chains of mountains separated by a large depression (divergent boundary).
- The mountain ranges can have peaks as high as 2,500 m and some even reach above the ocean's surface.
- Running for a total length of **75,000 km**, these ridges form the **largest mountain systems on earth.**



Mid Ocean Ridge

- The ridges are either broad, like a plateau, gently sloping or in the form of steep-sided narrow mountains.

Abyssal Hills

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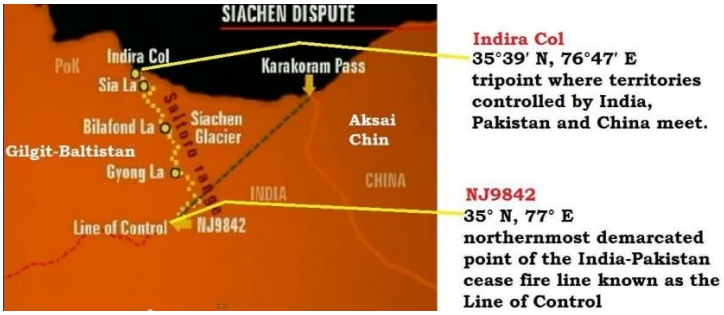
1. India as a Geographical Unit

Map of Jammu and Kashmir showing the occupied regions



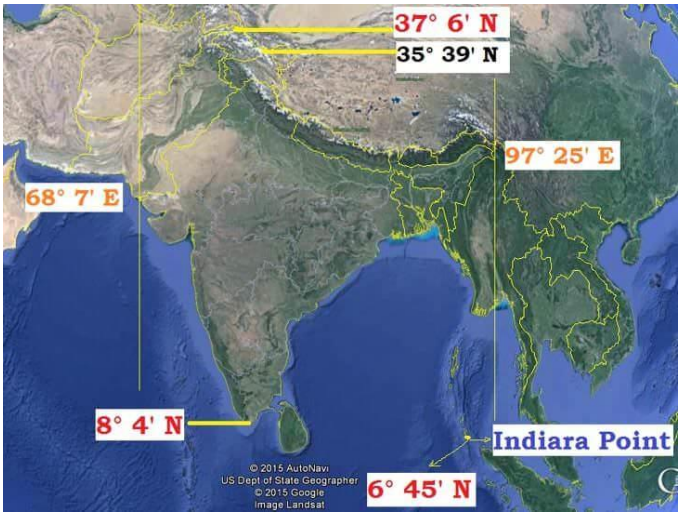
Location: Indira Col and NJ9842

- The southernmost point of the country is the **Pygmalion Point, or Indira Point** is located at **6° 45' N latitude**.
- North-south extent from **Indira Col** in Kashmir to Kanyakumari is **3,214 km**.
- East-west width from the Rann of Kutch to Arunachal Pradesh is **2,933 km**.

East-West Extent (~30°)	***68° 7' East to 97° 25' East longitude***
South-North Extent of mainland India (Including POK) (~29°)	***8° 4' North to 37° 6' North latitude***
South-North Extent of India (Including POK and the Andaman and Nicobar Islands) (~31°)	***6° 45' North to 37° 6' North latitude***

Top 10 Largest Countries in the World by Area

Rank	Country	Capital City	Continent	Area (km^2)
1	Russia	Moscow	Europe	1,70,98,242
2	Canada	Ottawa	North America	99,84,670
3	USA	Washington DC	North America	98,26,675
4	China	Beijing	Asia	95,96,961
5	Brazil	Brasilia	South America	85,14,877
6	Australia	Canberra	Oceania	77,41,220
7	**India**	**New Delhi**	**Asia**	**32,87,263**
8	Argentina	Buenos Aires	South America	27,80,400
9	Kazakhstan	Astana	Asia	27,24,900
10	Algeria	Algiers	Africa	23,81,741



Locational Extent of India

- With an area of **32,87,263 km²**, India is the **seventh largest** country in the world.
- India accounts for about **2.4 per cent** of the total surface area of the world.
- The Tropic of Cancer passes through the middle of the country dividing it into two latitudinal halves.
- The area to the north of Tropic of Cancer is **near twice** the area which lies to the south of it.
- South of 22° north latitude, the country tapers off over 800 km into the Indian Ocean as a peninsula.
- East-West time difference is nearly **2 hrs**. (A difference of 1° longitude will make a difference of 4 minutes in time. ~30 x 4 = ~120 minutes or ~2 hours).

India, Tropical or Temperate Country?

- The temperate part (north of Tropic of Cancer) is twice the area of the tropical part.
- But India has always been treated as a tropical country for two different reasons – physical and cultural.

Physical Geographical (Climatic) Reasons

- The country is separated from the rest of Asia by the Himalayas.
- The tropical monsoons dominate its climate.
- Himalayas blocks the cold temperate air masses.
- Although winter night temperatures are low, yet clear skies and intense insolation raise the day temperatures to a tropical level.

Cultural Geographical Reasons

- Settlements, diseases, agricultural and primary economic activities are all tropical in nature.

It is primarily because of the Himalayas that India is a predominantly tropical country.

1.2 India's Frontiers

Data from the **Ministry of Home Affairs (Department of Border Management)**

- India has **15106.7 Km** of land border running through **17 States**.
- Indian has a coastline of **7516.6 Km (6100 km of mainland coastline + coastline of 1197 Indian islands)** touching 13 States and Union Territories (UTs).
- Barring Telangana, Madhya Pradesh, Chhattisgarh, Jharkhand, Delhi and Haryana, all other States in the country have one or more international borders or a coastline and can be regarded as **frontline States** from the point of view of border management.
- India's **longest border** is with **Bangladesh** while the shortest border is with Afghanistan.
- The length of India's land borders with neighbouring countries is given in the table below.

Neighbour	Length of the border (in Km)
1) Bangladesh	**4,096.7**
2) China	**3,488**
3) Pakistan	**3,323**
4) Nepal	1,751
5) Myanmar	1,643
6) Bhutan	699
7) Afghanistan	106
	15,106.7

Border with China

- This is the **second longest border of India**, next only to its border with Bangladesh.

- Five Indian states, namely Jammu and Kashmir, Himachal Pradesh, Uttarakhand, Sikkim and Arunachal Pradesh touch the Indian boundary with China.
- The Sino-Indian border is generally divided into three sectors namely: (i) the Western sector, (ii) the Middle sector, and (iii) the Eastern sector.

The Western Sector

- Separates Jammu and Kashmir state of India from the Xinjiang province of China.
- The western sector boundary is largely the outcome of the British policy towards the state of Jammu and Kashmir.
- China claims the **Aksai Chin, the Changmo valley, Pangong Tso and the Sponggar Tso area of north-east Ladakh**.
- China also claims a part of **Huza-Gilgit** area in **North Kashmir** (**ceded to it in 1963 by Pakistan**).

The Middle Sector

- Two Indian states of Himachal Pradesh and Uttarakhand touch this border.

The Eastern Sector

- The 1,140 km long boundary between India and China runs from the eastern limit of Bhutan to a point near **Diphu pass (Talu-Pass)** at the **tri-junction of India, Tibet and Myanmar**.

Diphu Pass *is a mountain pass around the area of the disputed tri-point borders of India, China, and Myanmar.*
It is ***Talu pass*** *on the Burmese side, and* ***Diphu pass*** *on the Indian (Tibetan) side.*

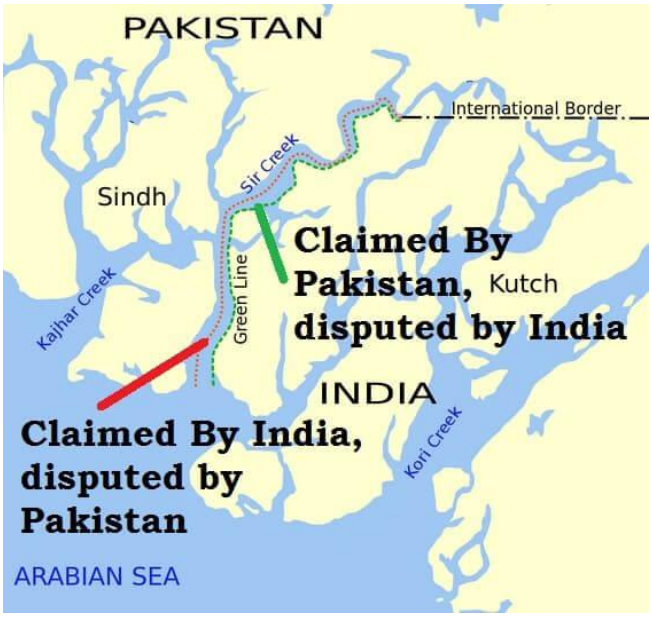
- This line is usually referred to as the **Mc Mahon Line** after Sir Henry Mc Mahon, then foreign secretary of British India, who negotiated the boundary agreement between Great Britain and Tibet at **Shimla accord in 1913-14**.

The India-Nepal Boundary

- Five states of India, namely Uttarakhand, Uttar Pradesh, Bihar, West Bengal and Sikkim touch the Nepalese border with India.
- The border is a **porous** one with an unrestricted movement of goods and people between Indian and Nepal.
- Major portion of Indo-Nepalese border runs in the east-west direction almost along the foothill of the **Shiwalik Range**.

The Indo-Pakistan Boundary

- The Indo-Pakistan boundary is the result of the partition of the country in 1947 under the **Radcliffe award** of which Sir Cyril Radcliffe was the chairman.
- Jammu and Kashmir, **Sir Creek** are the major disputed regions.



Creeks in the Kutch Region

The India-Bangladesh Border

- India's 4,096 km long border with Bangladesh is the **longest**.
- This boundary has been determined under the **Radcliffe Award** which divided the erstwhile province of Bengal into two parts.

India-Myanmar Boundary

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Coming Soon...