Section – A

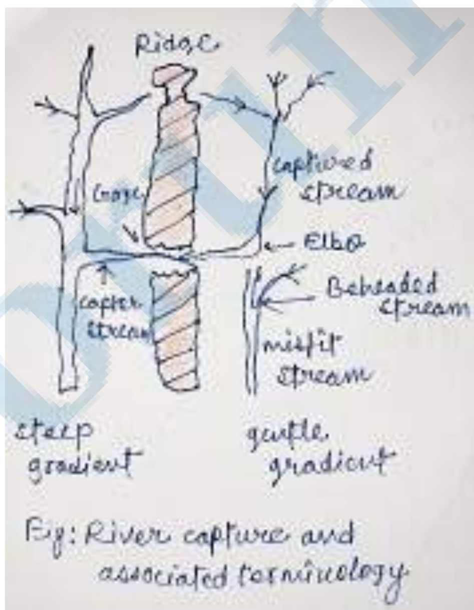
Q.1) Answer the following in about 150 words each:

a) Discuss the phenomena of River capture with suitable examples from across the world?

APPROACH: ***Define river capture phenomenon. Discuss associated processes. Give case studies. Conclude with relevance in geographical studies.***

Introduction:
The diversion of a river's course by another river is known as stream diversion, stream capture, or stream piracy. The river that captures another is called the captor stream, and the diverted river is called the captured stream.

Body: River capture is most common in the youthful stage of valley development when streams actively engage in headward erosion. It can also occur in the mature and senile stages through lateral erosion and meander intersection. Eg: The tributaries once formed the drainage of paleo-Red river are now part of Meckong river in south east Asia.



Processes of river capture:

1. **River Capture Through Headward Erosion:**
   Most captures result from headward erosion as streams and their tributaries shift water divides through active erosion.
   Case Study: The Arun Kosi captured the Phung Cho, a tributary of the Tsangpo River (Brahmaputra's upper part) through active headward erosion.
2. **River Capture Through Lateral Erosion:**
   Lateral erosion narrows water divides between parallel streams on sedimentary plains. Streams with more water and steeper gradients consume smaller tributaries through stream abstraction.

Case Study: The Tigris River in the Mesopotamian plains captured former tributaries of the Euphrates River due to tectonic changes, changes in base level and sedimentation in the Persian Gulf region.

3. **River Capture Through Meander Intersection:**
   As meanders of two close streams erode laterally, they may intersect, allowing the more powerful stream to capture the other.
   Case Study: The Belan River captured the Seoti River near Deoghat through meander intersection.
   Additionally, Tectonic activities and long glacial activities also facilitate river capture in early stages of river streams. Eg: The River Thames, through headward erosion, has captured the upper course of the River Wey during last glacial period.

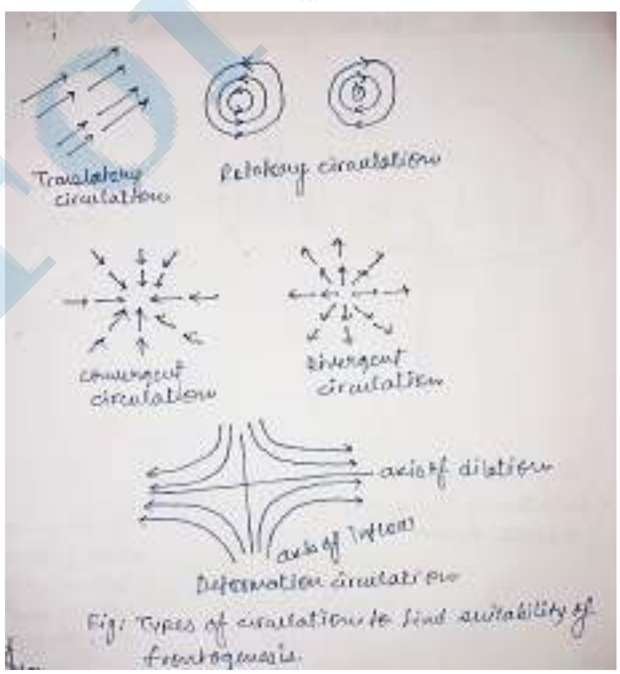
Conclusion: River capture is a dynamic and ongoing geomorphological process that reshapes river systems, often over long geological timescales. The phenomenon has significant impacts on river basins, local hydrology, and even human settlements.

b) Formation of temperate cyclone depends on the condition of axis of dilation. Elucidate?

APPROACH: ***Discuss the pre requisites for formation of temperate cyclones. Explain the deformatory circulations and axis of dilatation and their requirement for frontogenesis. Conclude with the significance of temperate cyclone in climatology.***

Introduction:
Temperate cyclones or extra tropical cyclones are concentrated in the regions of contrasting air masses and front formation. Hence mid latitude regions provide most favourable conditions for frontogenesis.

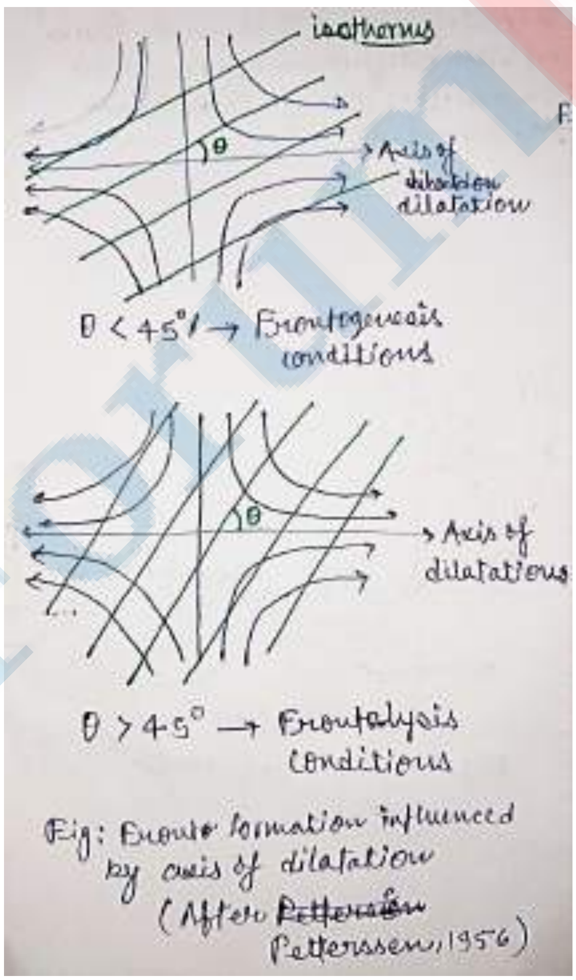
Body: Convergence of two contrasting air masses is a prerequisite condition for frontogenesis because thermal contrast with penetrating air-masses lead to formation of a wave-like front. **Patterson (1956)** studied the suitability of various air circulations for frontogenesis:



1) Translatory circulation involves the horizontal movement of air in the same direction. It doesn't lead to temperature changes because the isotherms are parallel and widely spaced, preventing the formation of fronts.
2) Rotatory circulation refers to the circular motion of air in cyclones or anticyclones. While it causes temperature variations, it does not result in front formation.
3) Convergent and divergent circulation: Convergent circulation brings winds together at a central point, while divergent circulation spreads them outward. Although temperature differences can occur in convergent circulation, fronts do not form as these differences happen at a point rather than along a line.
4) Deformatory circulation results from the convergence of two contrasting air masses, spreading horizontally along a line, known as the axis of outflow or Axis of dilatation. This process is most favorable for front formation.

Frontogenesis and Frontolysis:

When two contrasting air masses converge in deformation circulation, they spread horizontally along the axis of outflow or dialation. In such situation the creation of front depends on the angle between the axis of outflow and isotherms. Fronts do not form when this angle exceeds 45 degrees. As the convergence of air continues, this angle decreases and isotherms try to become parallel to the axis of outflow and frontogenesis is activated.



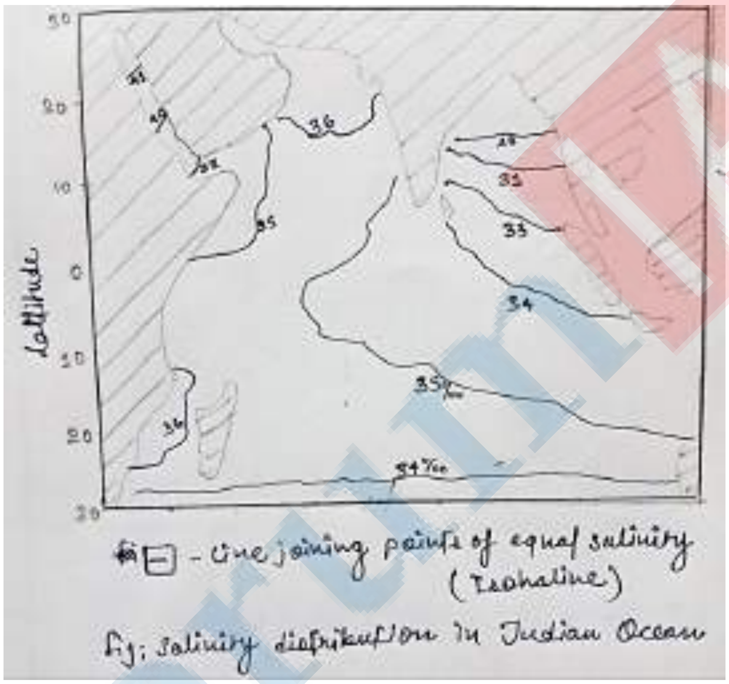
Conclusion: Hence front formation brings instability in local weather facilitating precipitation. Ecosystems like taiga and steppe depend upon frontal precipitation for water requirements.

c) Bring out the salinity pattern of Indian Ocean?

APPROACH: ***Introduce by outlining the uniqueness of Indian Ocean. Explain the distribution of Salinity in Indian Ocean with the help of map. Point out towards temporal variations in salinity in the region. Conclude with significance of this distribution.***

Introduction:
The study of salinity in Indian Ocean is different owing to the proximity with the land. Additionally the northern part is affected with Monsoon and influx of large rivers leading to variations in salinity.

Body:



In Indian Ocean, Isohalines are not parallel to each other in Indian Ocean unlike other Oceans. 35 ‰ (points per thousand) Isohaline divides Indian Ocean into east and west parts. In eastern part which encompasses Bay of Bengal encounters lower salinity. It is also the region with estuaries of major rivers like Ganges, Brahmaputra and Irrawaddy which provides large influx of fresh water into Ocean. Average salinity in eastern part lowers down to 31‰.
In western part salinity becomes high due to high evaporation rate and land locked nature of marginal seas. Red sea observes salinity as high as 40‰.
In the southern Indian Ocean, salinity distribution becomes little uniform. Here the isohalines are parallel and are dictated by latitudinal distribution.

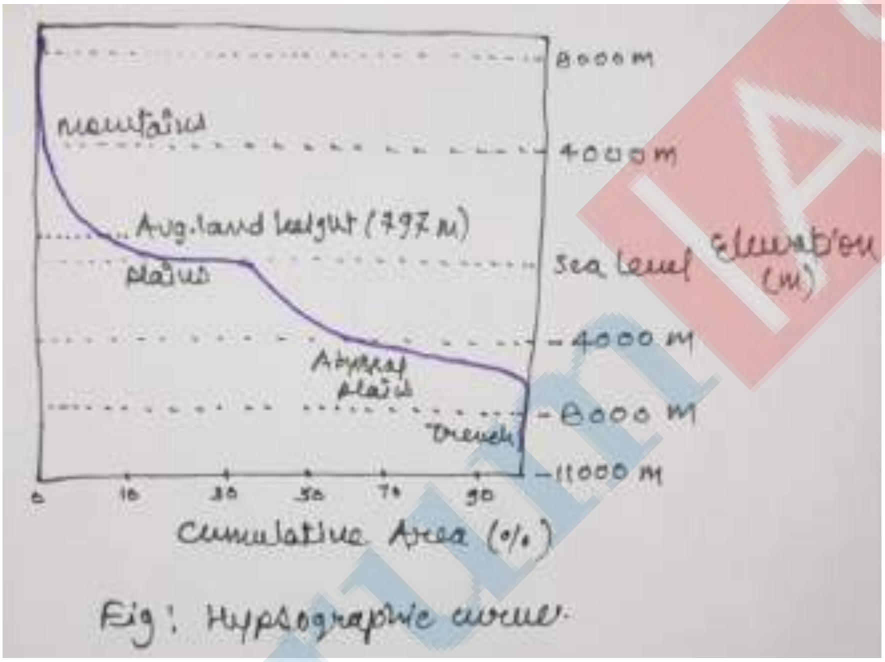
Temporal variations: South west monsoon leads to lower the salinity level in some regions like Bay of Bengal region. Similarly events like Indian Ocean dipole also have sufficient correlation with the surface level salinity variations especially in northern Indian Ocean.
Conclusion: This unique pattern of salinity in Indian Ocean help in thermo-haline circulations and guides movements of marine organisms.

d) Write a short note on Hypsographic curve?

APPROACH: Define Hypsographic curve. Explain the diagram. Describe its utility.

Introduction: A hypsometric curve, also known as an altimetric curve, is a graph of the distribution of Earth's surface. They are typically constructed using data from maps or geospatial data from satellites.

Body: The hypsographic curve is a graphical representation that shows the distribution of the Earth's surface elevations relative to sea level. It plots elevation (or depth) on the vertical axis and the corresponding percentage of Earth's surface area at that elevation on the horizontal axis. This curve is essential in understanding the topography of the planet.



Typically, the curve reveals two primary zones: the continental crust and the oceanic crust. The continental areas generally lie above sea level, while the ocean basins are below it. The distribution presented by Hypsographic curves:

Elevation Distribution:

- 29% of Earth's surface lies below sea level
- 21% between 0-200 meters
- 15% between 200-1,000 meters
- 12% between 1,000-2,500 meters
- 10% between 2,500-4,500 meters
- 5% above 4,500 meters

Applications of Hypsographic Curve Analysis:

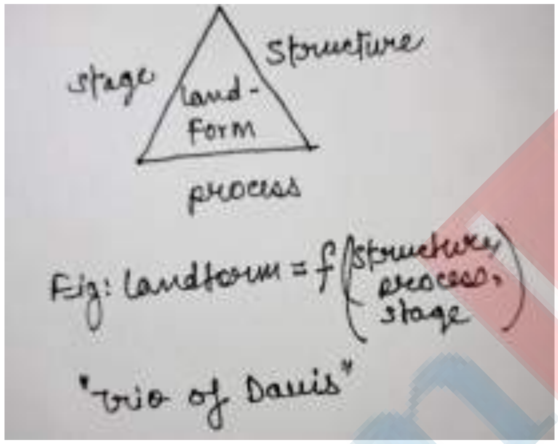
- Geological Research: Understanding Earth's surface processes and evolution.
- Environmental Studies: Assessing climate change impacts on sea levels and land distribution.
- Urban Planning: Informing land use decisions and infrastructure development.

Conclusion: The hypsographic curve is useful in various fields, including geology, oceanography, and environmental science, as it helps scientists understand Earth's structure, the extent of ocean coverage, and the effects of sea-level changes on land distribution.

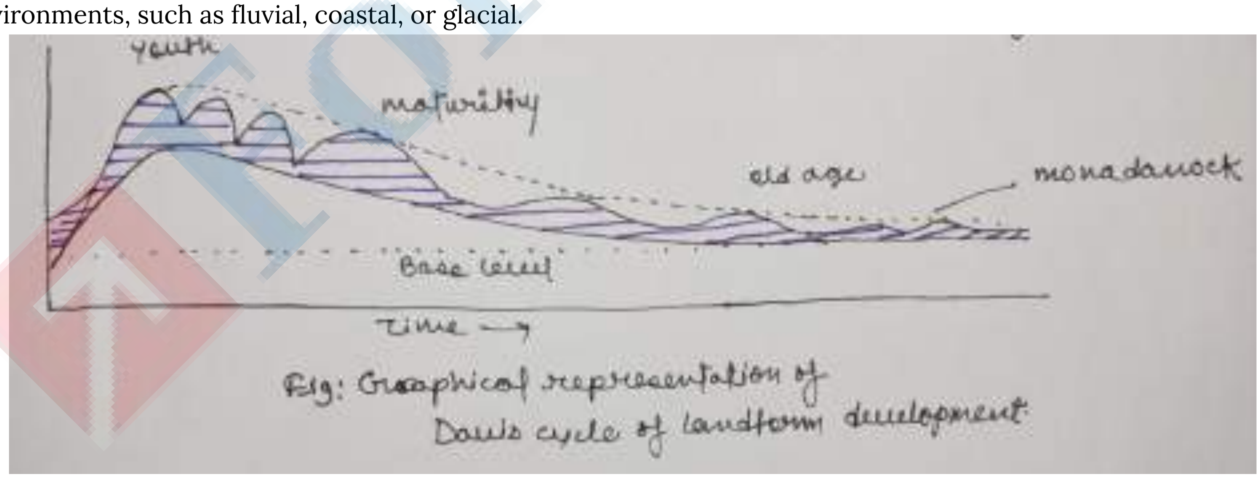
e) "Landscape is a function of structure, process and stage". Critique the statement?

APPROACH: Introduce the sequential landscape development model of Davis. Mention the positives and negatives of this model. Mention the applicability of this model.

Introduction: W.M. Davis in 1899 propounded 'Normal Cycle of erosion' through a model which is described as framework for the sequential landscape evolution through erosion.
Body: The statement "Landscape is a function of structure, process, and stage" is a fundamental concept in geomorphology.



The Model gained widespread popularity due to:
Strengths:
- **Comprehensive framework**: The statement acknowledges the interplay between three critical factors that shape landscapes: structure (lithology, tectonics), process (erosion, deposition), and stage (time, evolutionary history).
- **Simple and useful in pedagogical interaction**: Simplifies complex processes for students and researchers (Summerfield, 1991).
- **Applicability**: This framework can be applied to various spatial scales, from local to regional, and across different environments, such as fluvial, coastal, or glacial.



However, this framework has some limitations:
- Oversimplification: The statement oversimplifies the complex interactions and non-linear processes happening in actual landform development. (Bennett & Glasser, 2009).
- Lack of specificity: The terms "structure," "process," and "stage" are broad and require clearer definitions to facilitate precise application.

- o Determinism: The framework Implies a fixed, predictable sequential development of landforms, whereas actual landscape evolution is more dynamic (Kennedy, 2006).
- o Time and spatial scales: The concept of "stage" may not fully capture the diverse temporal and spatial scales at which landscape changes occur.
- o Lack of Quantification: No clear time scales or erosion rates are provided (Schumm, 1977).
- o Human and social factors: The statement neglects the significant impact of human activities and social processes on landscape evolution.

Impact:

- The framework is considered as Foundation for Geomorphology (Chorley et al., 1973).
- Sequential development models Inspired subsequent models, such as process-form relationships (Church, 2017).

Conclusion: The statement "Landscape is a function of structure, process, and stage" provides a foundational framework for understanding landscape evolution. However, it should be refined to acknowledge additional factors, clarify definitions, and account for complex interactions and scales.

Q.2) a) Examine the recent views on mountain building process and divide the world mountains on the basis of their genesis?

APPROACH: *Enlist various theories of Mountain building from older to recent ones. Explain the recent plate tectonic theory on mountain building. Categorise various mountains on the basis of their Genesis.*

Introduction:

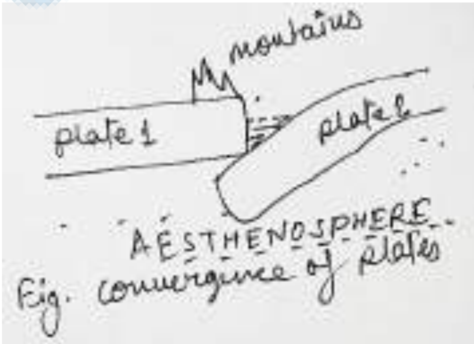
Older theories like Geosyncline by Kober and Continental Drift Theory by Alfred Wegner did not satisfactorily explain the mountain building processes leading to newer Quantitative and Geological Data Models.

Body:

New Approaches in explaining 'Orogeny' are:

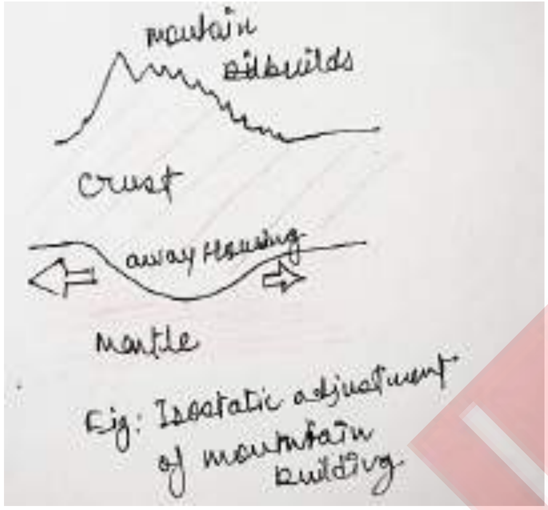
1. **Plate Tectonics and Convergence:**

   Convergent Boundaries: Most mountains form at convergent plate boundaries where tectonic plates collide. The collision of continental plates leads to crustal thickening, while the collision of oceanic and continental plates results in subduction zones.



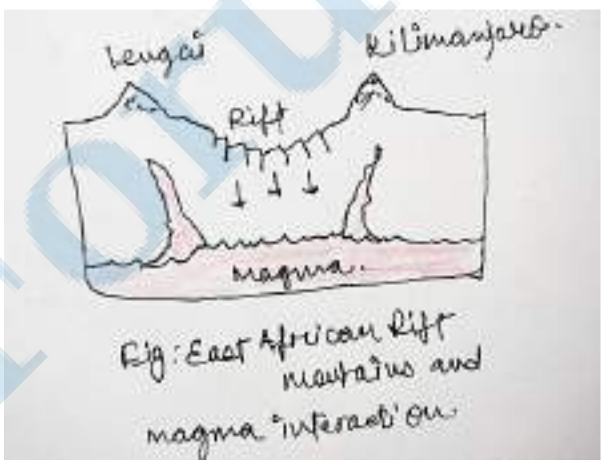
   Recent Views: The role of micro-plates and continental fragments has been recognized in shaping mountain ranges. Studies also highlight the importance of mantle plumes and asthenosphere dynamics in modulating crustal deformation and uplift.

2. **Isostasy and Crustal Thickening:**
Isostasy: The Earth's crust floats on the denser mantle, and the thickening of the crust (through tectonic forces) leads to vertical uplift, which is balanced by the principle of isostasy.



Recent Views: Isostatic rebound due to glacial melting and erosion is seen as an active mechanism, especially in regions like Scandinavia and the Canadian Shield, where post-glacial rebound continues to elevate mountains and highlands.

3. **Mantle and Lithosphere Dynamics:**
Mantle Convection: The movement of molten rock in the mantle influences surface processes. Mantle upwelling in certain regions is believed to contribute to localized uplift and mountain formation, such as in the case of East Africa's rift mountains.



Recent Views: Advances in geophysical imaging suggest that mountain building is influenced by lithospheric flexure and mantle-driven tectonics, particularly in intraplate settings where tectonic activity occurs away from traditional plate boundaries.

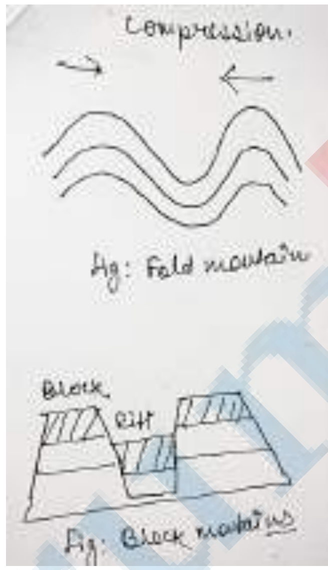
4. **Climate-Tectonic Feedback:**
Erosion and Uplift: Climate has been recognized as a significant factor in the mountain-building process. High rates of erosion can influence the rates of tectonic uplift by reducing the load on the Earth's crust.
Recent Views: Feedback mechanisms between climate (particularly precipitation and glaciation) and tectonics are gaining attention. In the Himalayas, for example, intense monsoonal erosion is linked to ongoing tectonic activity.

Classification of Mountains Based on Their Mode of Origin:

1. **Primary or Tectonic Mountains:**
These mountains result from tectonic activity driven by endogenic forces from deep within the Earth's interior. They are categorized into four distinct types based on the tectonic processes involved in their formation:
(i) Fold Mountains

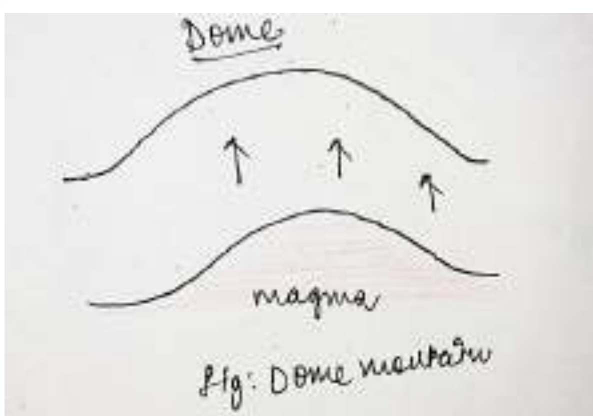
Formed primarily through compressional stress, fold mountains are further classified into three categories based on their age and development:

a) Young Fold Mountains: Characterized by sharp, high peaks, such as the Himalayas and the Andes.
b) Mature Fold Mountains: Mountains that have undergone significant erosion, but still retain considerable elevation, such as the Appalachian Mountains.
c) Old Fold Mountains: These are ancient, eroded structures with subdued topography, like the Aravalli Range.



(ii) Block Mountains:
Formed by extensional tectonics, where tensional forces create fault-blocks leading to the uplift of large crustal segments. These are also referred to as horst mountains, with examples including the Sierra Nevada and the Black Forest.

(iii) Dome Mountains:
Dome mountains result from the upwarping of the Earth's crust due to magma intrusion beneath the surface without eruption. This leads to the formation of structures like batholithic and laccolithic domes. Examples include the Adirondack Mountains and the Black Hills.



(iv) Volcanic Mountains:

These mountains are created by the accumulation of volcanic materials such as lava, ash, and pyroclastic deposits. They are often associated with different types of volcanic formations, including stratovolcanoes, shield volcanoes, and cinder cones. Notable examples include Mount Fuji and Mauna Loa.

2. **Erosional or Residual Mountains:**
   These mountains have formed through the denudation of once higher elevations, shaped by prolonged weathering and erosion. Often referred to as relict mountains, examples in India include the Vindhyachal, Aravalli, Satpura, Eastern Ghats, and Western Ghats ranges.

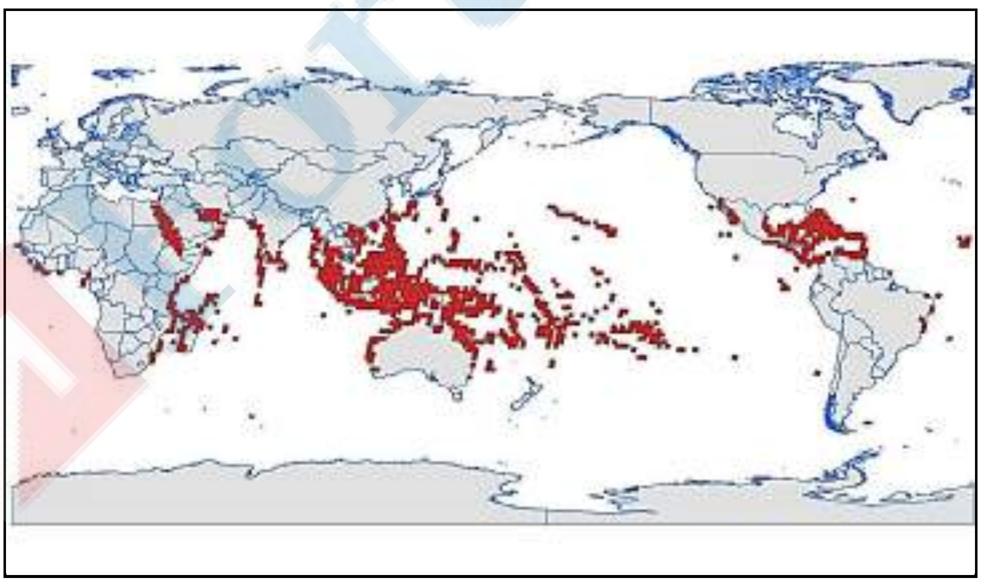
Conclusion: Orogenesis is a fundamental mechanism that shapes the Earth's surface through complex interactions between tectonic plates. Recent advances in geological understanding, such as plate tectonics and mantle dynamics, have deepened our comprehension of how mountains form over geological time.

b) Compare the subsidence and glacial control theories on the formation of coral reefs.

Approach: Introduce with meaning of coral reef then show distribution of coral reef on world map. Contrast the meaning of subsidence and glacial control theories of coral formation. Conclude with currently accepted synthesis of two.

Corals are marine invertebrates or animals which do not possess a spine. They are the largest living structures on the planet. Each coral is called a polyp and thousands of such polyps live together to form a colony, which grow when polyps multiply to make copies of themselves.

The tubular skeletons grow upwards and outwards as a cemented calcareous rocky mass collectively called corals. The shallow rock created by these depositions is called a reef. These reefs, later on, evolve into islands.

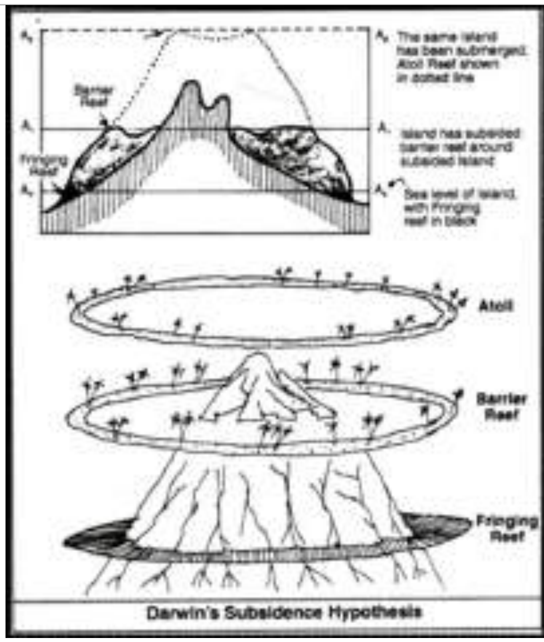


Distribution of coral reef:

Various theories have been put forth to explain the mode of origin of coral reefs, taking into account the fluctuation of the Pleistocene Sea level and the stability of the land concerned. The latter fact analyses three conditions—a subsiding island, a stationary island and an emerging land with reefs along them.

The subsidence theory vs. glacial control theories on the formation of coral reefs.

• **Subsidence Theory-** This theory was put forth by Charles Darwin in 1837 and modified in 1842, during his voyage on the Beagle when it became clear to him that coral polyp could grow only in shallow waters. He published the concept in **The Structure and Distribution of Coral Reefs in 1842**	**Glacial control Theory-** Daly propounded his theory of coral formation in the year 1915 after he was convinced that coral reefs were formed after Pleistocene Ice Age.
• Darwin assumes that along a suitable platform, coral polyps flocked together and grew upward towards a low water level. • The resulting reef, in this stable condition, would be a fringing reef. But, at the same time, Darwin assumes, the seafloor and the projecting land in coral seas started submerging, and the living corals found themselves in deeper waters. Hence, an urge to grow upward and outward would be balanced by the subsidence of the land.	• According to him sea-level fell by 33 to 38 fathoms (198 feet to 228 feet) due to glaciation (confinement of sea water in the form of ice on the continents) during Pleistocene Ice Age. The existing corals died due to lowering of temperature of marine water. • Wave-cut platforms were formed along continental coasts and islands due to abrasion by a sea wave. After the end of ice age, the sea-level again rose by 33 to 38 fathoms due to return of sea water which was imprisoned on the continents in the form of ice during the ice age. In other words, the ice melted due to rise of temperature and the melt- water after reaching the oceans raised their levels to previous stage. • Thus, the wave-cut platforms were submerged under sea water up to the depth of 33 to 38 fathoms. The corals which could survive during the glacial period and new coral polyps began to grow and establish their colonies on the seaward edges of submerged platforms.
• Thus, he supports tectonic subsidence of landform unlike Murray's stability-based standstill theory. • Darwin postulated that the fringing reef, barrier reefs, and atolls are only three stages in the evolutionary growth of a reef. • Fringe reef were formed during stable condition. • As the land subsides, the fringing reef would grow upwards and outwards, resulting in the formation of a barrier reef • Further subsidence would convert it into atoll with wide and comparatively deeper lagoon.	• Thus, it is based on eustatic changes and relationship between temperature and coral polyps. • Thus, fringing reefs were formed on narrow wave-cut platforms. • Barrier reefs were formed on broad wave-eroded platforms. • Atolls were formed around isolated wave eroded island peaks.



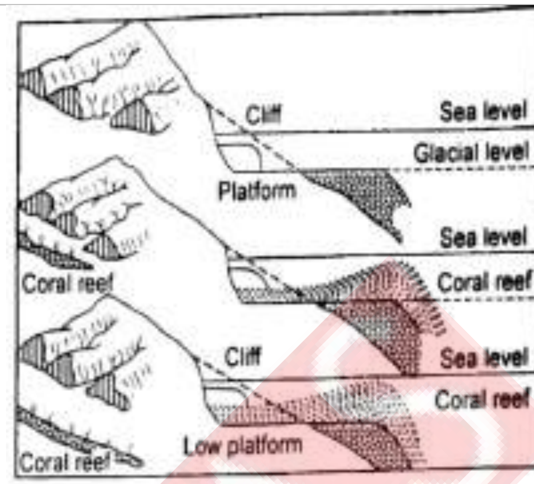


Fig. 13.9 : Origin of coral reefs according to R.A. Daly.

• the depth of lagoon does not increase in spite of gradual subsidence of land because there is continuous sedimentation in the lagoon.	• → Lagoons of uniform depth were formed between the reefs and the land because of uniform lowering of sea-level due to glaciation during Pleistocene Ice Age.

<u>Evidence in Support of the Darwin's Subsidence Theory:</u>

- There is much evidence of subsidence in coral areas. For example, submerged valleys in the east of Indonesia and the coastal areas of Queensland. Had there been no subsidence, the sediment produced by the erosion of coral reefs would have filled the lagoons and caused the death of corals.
- The material produced by erosion gets continuously accumulated at the subsiding lagoon bottom. That is why the lagoons are shallow. During an experimental boring, done to a depth of 340 m in the island atoll of Funafuti, dead corals were discovered at these depths.
- Only subsidence can explain the existence of corals at this depth because, generally, corals cannot grow below 100 meters. Also, these dead corals showed evidence of their having got 'dolomitised' which is possible only in shallow waters. All this evidence goes to prove the subsidence theory.

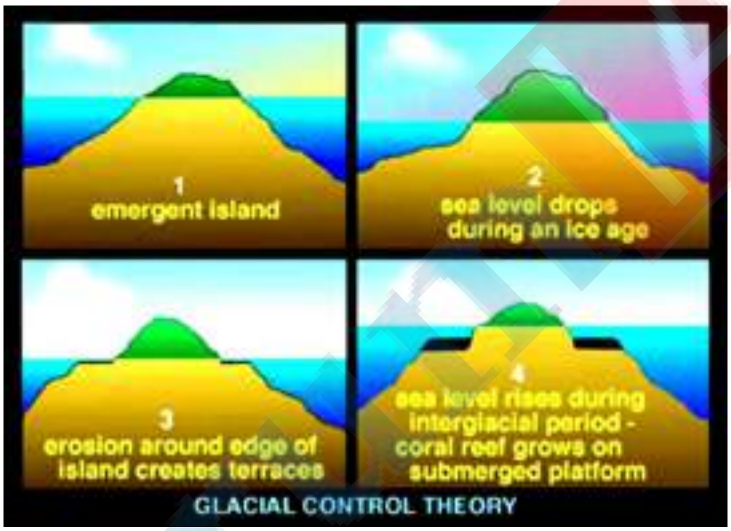
<u>Evidence against the Subsidence Theory:</u>

- Many scientists, like Agassiz and Semper, have argued that the corals have developed in places where there is no evidence of subsidence. Timor is one such area. Similarly, lagoons, with depths of 40m to 45m and many kilometers wide, cannot be explained on the basis of subsidence.
- Also, the question arises as to why there is uniform subsidence in the tropical and sub-tropical areas and not so in other areas. Kuenen has described some areas where the fringing and barrier reefs are found close to each other.
- This is not possible if the subsidence has been a continuous process. Finally, if it is supposed that the coral islands are a product of subsidence, we will have to assume the existence of a vast area in the Pacific Ocean which has submerged, leaving behind corals as islands. There is no evidence of the existence of such a vast land area in the Pacific Ocean that existed in ancient times.
- Rapid outward growth of the reef and the deposition of coral debris along it. The last stage of submergence (comparable to thousands of feet) results in partial or complete disappearance of the land and the existence of a coral ring enclosing a lagoon.

- In spite of continued subsidence, Darwin maintains that the shallowness of the lagoon would be due to the deposition of the sediment from the nearby subsiding land. Hence, the lagoon always remains flat and shallow.
- The theory, though simple in its presentation, implies that the barrier reef and atoll can occur only in the areas of submergence, and the great amount of vertical thickness of coral material is primarily due to the subsidence of land and consequent upward growth of coral polyps.

Evidence in Support of Daly's Glacial Control Theory:

- The experimental borings done on the Funafuti atoll provide evidence in support of Daly's hypothesis. Also, in the ice age, all the platforms were cut down to the sea level by marine erosion. Hence, the depth of these platforms and that of lagoons with barrier reefs and coral atolls were almost equal.
- Study shows that the depths of the platforms and of lagoons are equal at all places. The greatest merit of this hypothesis is that it needs no subsidence of the crust, as is the case with Darwin's hypothesis. Finally, the sea waves and currents could have easily cut down the islands and converted them into low platforms.



Evidence against Daly's Hypothesis:

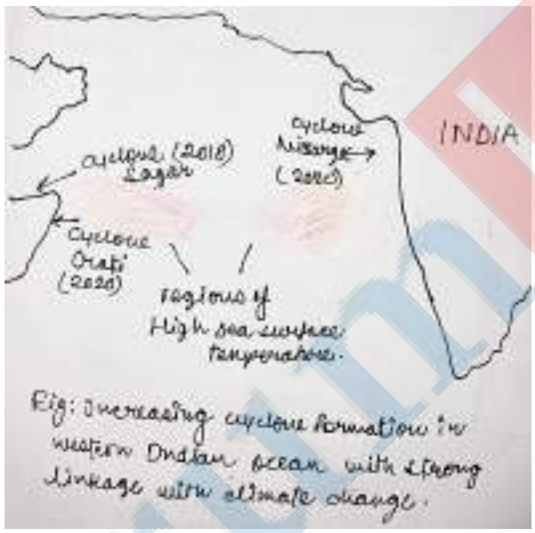
- There are some platforms which are so long and broad that their formation cannot be considered as the work of marine erosion alone. One such platform is the Nazareth Platform—350 km long and 100 km wide. It is about 600 m high everywhere.
- Also, Daly could not explain the existence s of coral colonies at depths of 100 meters. He had to admit local subsidence to be able to explain coral colonies in some deeper areas. Daly had also calculated that the fall of sea level during the ice age was around 80 meters.
- It appears that this calculation is not correct. In fact, the fall of sea level can be correctly measured by the angle of walls of submerged V-shaped valleys. If calculation is done on this basis, the sea level should have fallen by more than 80m. Finally, Daly had stated that the temperature was lowered during the ice age. It must have caused the death of corals, but there is no evidence of this phenomenon.
- From the above discussion, it appears that the hypotheses of Darwin and Daly are not contradictory but complementary. Both together throw a lot of light on the phenomenon.
  These theories are in reality complimentary and not contradictory. Hence the 3D theory (Darwin-Davis-Daly) of the reef formation is the most accepted synthesis.

c) Bring out the various reasons for the rise of tropical cyclones in the non-traditional areas of the Indian Ocean region with suitable examples?

APPROACH: *Explain the changing trends of tropical cyclones in areas of Indian Ocean. Give reason for these changes in the existing trends. Explain the wider effect of these changing trends.*

<u>Introduction</u>:
Tropical cyclones, historically confined to specific regions within the Indian Ocean, have increasingly been observed in non-traditional areas. This trend has raised concerns due to the environmental, economic, and social impacts these cyclones have on areas not accustomed to such extreme weather events.

Body:



Several factors contribute to the rise of tropical cyclones in non-traditional areas of the Indian Ocean region:

1. **Rising Sea Surface Temperatures (SSTs):** One of the primary drivers of the increase in tropical cyclones in new areas is the warming of the Indian Ocean. Cyclones require warm ocean waters (above 26.5°C) to form. As global temperatures rise due to climate change, previously cooler areas of the ocean are now reaching temperatures conducive to cyclone development. This expansion of warm waters into non-traditional regions allows cyclones to form and intensify in areas where they were rare or non-existent.
   Example: Cyclone Gati (2020), which made landfall in Somalia, a region rarely affected by tropical cyclones, is attributed to unusually warm SSTs in the western Indian Ocean.
2. **Weakening of Vertical Wind Shear:** Vertical wind shear (the change in wind speed and direction with height) plays a crucial role in preventing the formation of cyclones. In some non-traditional areas, the weakening of wind shear, possibly due to climate change, is making conditions more favorable for cyclones to develop.
3. **Altered Monsoon Patterns:** Changes in monsoonal winds and pressure systems in the Indian Ocean, partly driven by climate change, are influencing cyclone paths. Monsoon systems, which typically inhibit cyclone formation in certain areas, are shifting, leading to cyclones forming outside traditional regions.
   Example: Cyclone Sagar (2018) affected the Gulf of Aden and Yemen, a region typically not associated with tropical cyclones. Changing wind patterns contributed to its formation in this unusual area.
4. **Indian Ocean Dipole (IOD) Variability :** an irregular oscillation of sea surface temperatures in the Indian Ocean, influences the formation and distribution of cyclones. Positive IOD events lead to warmer waters in the western Indian Ocean and cooler waters in the eastern part. This shift can cause an increase in cyclonic activity in areas that usually do not experience such events.

Example: During the positive IOD phase of 2019, cyclones such as Kyarr and Maha formed in the Arabian Sea, which traditionally sees fewer cyclones compared to the Bay of Bengal.

5. **La Niña and El Niño Events:** El Niño-Southern Oscillation (ENSO) events significantly impact cyclone formation in the Indian Ocean. During El Niño, the Indian Ocean's western parts become warmer, favoring cyclone formation in non-traditional areas like the western Arabian Sea. La Niña conditions can lead to an increase in cyclonic activity in the Bay of Bengal and other parts of the northern Indian Ocean.
   Example: The 2019 La Niña event contributed to an active cyclone season in the Arabian Sea, including Cyclones Vayu and Hikaa, which impacted western India and Oman, areas that typically see fewer storms.
6. **Increased Oceanic Heat Content:** Beyond surface temperatures, the heat content of deeper layers of the ocean is increasing, providing more energy to fuel tropical cyclones. Even in non-traditional areas, the increased oceanic heat content supports the intensification of cyclones, making them stronger and longer-lasting.
   Example: Cyclone Luban (2018), which impacted Oman and Yemen, rapidly intensified due to the unusually high ocean heat content in the western Indian Ocean.
7. **Anthropogenic Activities:** Human activities, including greenhouse gas emissions, deforestation, and urbanization, have altered regional climates and exacerbated extreme weather patterns. These changes can disrupt local climate systems and create favorable conditions for tropical cyclones to form in previously unaffected regions.
   Example: Coastal areas of Somalia and Yemen, which have historically experienced low cyclone activity, have seen an increase in cyclones in recent years, linked to broader environmental changes triggered by human activities.
8. **Shifts in Cyclone Tracks:** Historically, the Bay of Bengal has been the most active cyclone region in the Indian Ocean. However, there has been a noticeable shift in cyclone tracks towards the Arabian Sea and western Indian Ocean, leading to increased cyclonic activity in these areas.
   Example: Cyclone Chapala (2015), which struck Yemen, was an unusual event as cyclones rarely make landfall in this region. This shift in track is linked to changing oceanic and atmospheric conditions, including warmer waters and altered wind patterns.

Conclusion : The rise of tropical cyclones in non-traditional areas of the Indian Ocean is primarily driven by global warming, changing ocean temperatures, shifts in atmospheric patterns, and climate variability (like IOD and ENSO events). A better understanding of these patterns is essential for improving preparedness and adaptation measures in vulnerable regions.

Q.3) a) The development of coastal landforms depends on the configuration of coast, lithology and structure of coastal rocks and nature and energy of sea waves. Explain the statement through marine cycle of erosion along a shoreline of emergence and submergence.

APPROACH: ***Introduce with mentioning the determinants of development of coastal landforms. In the body, explain how configuration of coast, lithology and structure of coastal rocks and nature and energy of sea waves influence the development of the coastal landforms and conclude.***

The development of coastal landforms is influenced by several factors including the configuration of the coast, the lithology and structure of coastal rocks, and the nature and energy of sea waves. To understand how these factors interact, it is useful to examine the marine cycle of erosion along shorelines of emergence and submergence.

Marine Cycle of Erosion:

The marine cycle of erosion describes the stages of coastal development influenced by erosional and depositional processes. This cycle can be observed in shorelines of emergence and submergence, each characterized by different features.

Interaction of Factors:

1. **Configuration of the Coast**
   - Determines the initial shape and features of the coastline, influencing how wave energy is distributed.
2. **Lithology and Structure of Coastal Rocks**
   - Resistant rocks form prominent features like headlands and cliffs.
   - Less resistant rocks erode faster, leading to bays and inlets.
3. **Nature and Energy of Sea Waves**
   - High-energy waves erode coastal features more rapidly, leading to faster cliff retreat and the formation of wave-cut platforms.
   - Low-energy waves contribute more to sediment deposition, forming beaches and barrier islands.

Shoreline of Emergence:

A shoreline of emergence occurs when land previously below sea level is exposed due to a relative drop in sea level or uplift of the land. This can result from tectonic activity or a decrease in sea level. Key processes and landforms include:

1. **Initial Stage: Cliff Formation:**
   - **Configuration of Coast:** Initially, the coast may be irregular with promontories and bays.
   - **Lithology and Structure:** Resistant rocks form headlands, while less resistant rocks erode to create bays.
   - **Wave Energy:** High-energy waves erode the base of cliffs, leading to the formation of wave-cut notches and platforms.

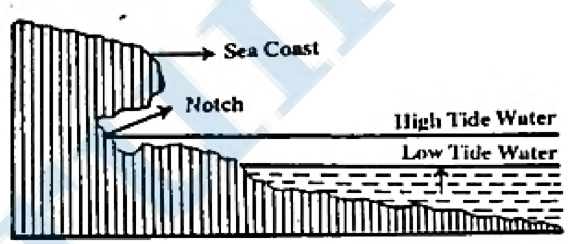


Fig. 24.4 : An example of sea cliff.

2. **Mature Stage: Wave-Cut Platforms and Cliffs**
   - **Wave-Cut Platforms:** Continued erosion at the base of cliffs extends the wave-cut platform.
   - **Cliff Retreat:** Cliffs continue to retreat landward due to undercutting by wave action.

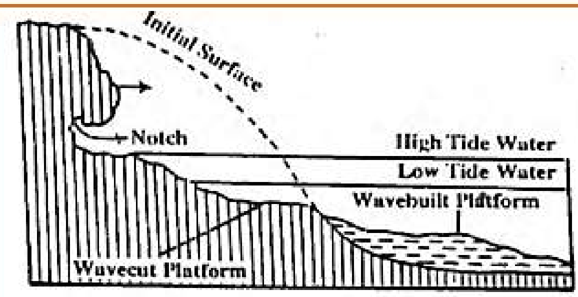


Fig. 24.6 : Wave-cut and wave-built platforms.

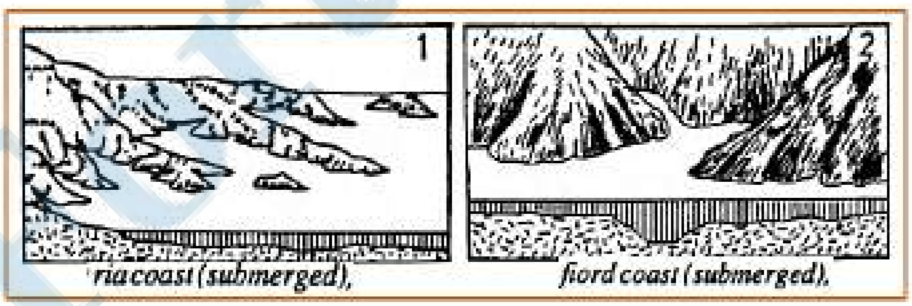
3. **Old Stage: Erosion and Deposition**
   - **Erosion Dominates:** Headlands are progressively eroded, and the coast becomes more linear.
   - **Deposition in Bays:** Sediments eroded from cliffs are deposited in bays, forming beaches, bars, spits etc.

Fig. 24.11 : Offshore bars and spits.

Shoreline of Submergence:

A shoreline of submergence forms when land previously above sea level is inundated due to a relative rise in sea level or subsidence of the land. This can result from tectonic subsidence or an increase in sea level. Key processes and landforms include:

1. **Initial Stage: Drowned River Valleys**
   - **Configuration of Coast**: River valleys and glacial troughs are flooded, creating rias and fjords.
   - **Lithology and Structure:** Valleys carved in less resistant rocks are more prominent.
   - **Wave Energy:** Waves begin to erode the newly formed coastline, focusing on headlands and sheltered bays.



2. **Mature Stage: Estuarine Development**
   - **Rias and Fjords:** These features become more pronounced as sea levels stabilize.
   - **Sedimentation:** Sediment deposition occurs in sheltered areas, leading to the formation of estuaries.
3. **Old Stage: Barrier Islands and Lagoon Formation**
   - **Barrier Islands:** Offshore bars and barrier islands may form from deposited sediments.
   - **Lagoons:** Lagoons develop behind barrier islands as areas become more protected from wave action.

The development of coastal landforms through the marine cycle of erosion is a dynamic process influenced by the interplay of coastal configuration, rock lithology and structure, and wave energy. Understanding these interactions helps explain the evolution of diverse coastal landscapes along shorelines of emergence and submergence.

b) Describe the configuration of the Pacific Ocean floor?

Ans. Pacific Ocean is the largest and deepest Ocean, extending from arctic in north to Antarctica in south. It was formed when Pangea broke away (200 million years ago) in Mesozoic Period.

CONFIGURATION OF PACIFIC OCEAN:
Bottom topography of Pacific Ocean is a function of evolutionary history, age and contemporary process.

CONTINENTAL MARGINS
Pacific Ocean generally has active margins located at convergent plate boundaries particularly along western Americas and eastern Asia, having presence of numerous Trenches and Volcanic arcs, therefore most of its area is covered with continental shelves and slopes but continental rise would remain missing.

1. Continental shelf: Narrow continental shelf due to tectonic activity especially off the coasts of south America, Japan and Alaska where sea floor drops quickly.
    - The average width is 80 km having wide shelf which found at north west Pacific (Eurasian coast) which is also called back arc Basins.
    - Several islands are seated on these broad continental shelves (viz. Kuriles, Japanese islands, Philippines, Indonesia, New Zealand etc.).

2. Continental slope: narrow slopes having active subduction and tectonic forces are common, which are mostly Depositional slopes.
3. Continental rise: found only on passive margins where trenches have become inactive.

DEEP OCEANIC FEATURES

1. Mid oceanic ridge: Pacific Ocean doesn't have central ridge but ridge is found along east Pacific. The east pacific rise is a prominent mid – ocean ridge runs along eastern side of Pacific, where sea floor spreading is occurring very fast (7-11) cm / year.
    - It throws several minor Ridges Like Galapagos ridge. The New Zealand Ridge, the Hawaiian rise, The Nazca ridge etc as shown in fig.
    - Its is wide like a plateau due fast spreading rate.
    - The eastern branch merges with Chilean coast while the other branch moves southward in the name of Eastern Island rise.

2. Ocean Basin: There are numerous Basin in Pacific Ocean which are separated by rise:
   Fiji basin, Philippine basin, east Australian basin, Peru basin, south western pacific basin etc. Most of the basin are geopolitical in nature.
3. Ocean Deeps: Numerous trenches and deeps in the Pacific Ocean along subduction zone in convergent boundaries are found having depth of around (4000m – 5000m) like Aleutian, Kurile, Japanese, Mariana, Philippines, Bougainville, Tonga, Karma Dec, Peru- Chile etc.

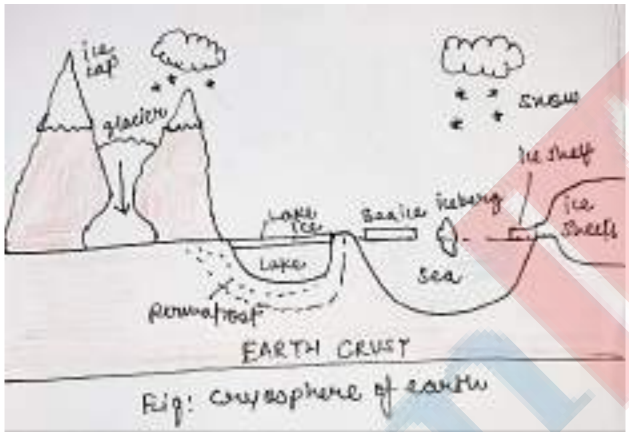
4. Abyssal floor: comparatively less flat due to presence of active margins. Since terrigenous sediments are unable to reach and bury the undulating topography at the ocean bottom floor. Therefore, large number of sea mounts, abyssal hills, rise and island above sea level are found.
   Like three groups Islands: Micronesia group, Polynesia group, Melanesia group.

In contemporary times, configuration of Pacific Ocean is changing due to high subduction rates and ongoing climate change phenomenon. This manifests statement of Hutton i.e. “No vestige of a beginning and no prospect of an end”.

c) Examine the various consequences of the climate change on the cryosphere of the world with suitable examples?

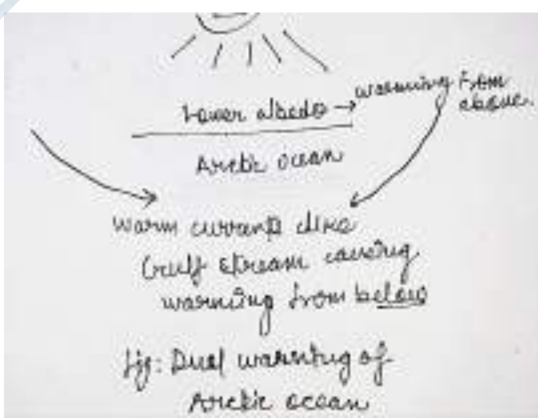
APPROACH: ***Define cryosphere. Explain various consequences of climate change on cryosphere and impact on communities.***

Introduction:
The cryosphere refers to the portion of the Earth's surface where water is in its solid form, primarily as ice and snow. This includes various components such as glaciers, ice caps, sea ice, permafrost, and snow cover.



Body: The cryosphere, comprising all the frozen water on Earth (glaciers, ice caps, sea ice, permafrost, and snow), is highly sensitive to climate change. As global temperatures rise, the cryosphere is experiencing significant alterations:

1. **Glacier Retreat:** Many glaciers around the world are shrinking due to rising global temperatures. This leads to reduced water availability for rivers and ecosystems that depend on glacial meltwater.
   Case Study: In the Andes of South America, the glaciers that supply water to cities like Lima, Peru, are shrinking. This threatens agriculture and hydropower, as well as the livelihoods of people who depend on glacial runoff.
2. **Sea Ice Loss:** Melting Arctic sea ice is one of the most visible indicators of climate change. The loss of sea ice disrupts ecosystems, reduces habitat for species like polar bears, and accelerates warming due to reduced albedo (reflectivity).
   Case Study: Arctic Sea is facing 'Atlantification' i.e. warming of arctic and extension of Atlantic like conditions deep in polar regions.



3. **Permafrost Thaw:** Rising temperatures are causing permafrost–frozen ground in the Arctic and sub-Arctic regions–to thaw. This releases trapped greenhouse gases (CO_2 and methane) into the atmosphere, further accelerating climate change.
   Case Study: In Alaska, infrastructure such as roads and pipelines is being damaged as the ground beneath them thaws. The town of Newtok is relocating due to severe land erosion linked to permafrost melt and coastal flooding.
4. **Sea Level Rise:** Melting glaciers and ice sheets contribute directly to rising sea levels, threatening coastal populations worldwide. Low-lying islands and coastal cities are particularly vulnerable.
   Eg: In Kiribati, an island nation in the Pacific, rising sea levels are leading to increased flooding and saltwater intrusion, jeopardizing freshwater supplies and forcing some communities to consider relocating.
5. **Loss of Snow Cover:** Reduced snow cover affects freshwater availability, ecosystems, and winter tourism. Snowpack in mountainous regions serves as a natural reservoir, slowly releasing water during warmer months.
6. **Impacts on Biodiversity:** As the cryosphere shrinks, species that depend on cold environments are at risk of extinction or displacement. Changes in ice cover also affect ocean circulation and marine ecosystems.
   Case Study: The Adélie penguin population in Antarctica has been declining as sea ice melts earlier in the season, reducing their access to feeding grounds during critical periods of breeding.
   Increased Glacier Lake Outburst Floods (GLOFs): As glaciers retreat, they leave behind unstable moraine-dammed lakes that can burst, causing catastrophic floods downstream.
7. **Example:** The Imja Lake in Nepal, formed by the retreating Imja Glacier, poses a serious threat of a GLOF event that could impact downstream communities.

Conclusion: The consequences of climate change on the cryosphere are far-reaching, affecting global water resources, biodiversity, and human societies. Mitigating these impacts requires a concerted effort to reduce greenhouse gas emissions, adapt to changing environments, and invest in sustainable development strategies.

Section – B

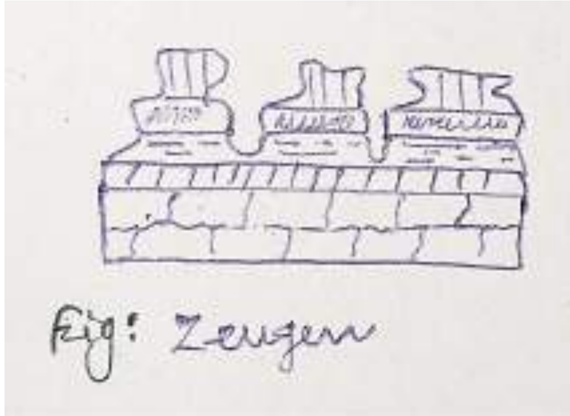
Q.4) Answer the following in about 150 words each:

a) Differentiate between Zeuden and Yardang with suitable sketches?

APPROACH: ***Introduce with the aeolian processes of erosion. Explain the morphologies of zeuden and yardang. Enlist various differences and significance.***

Introduction:
Wind erosion in the arid and semi-arid regions is assisted by mechanical weathering. Differential Expansion and contraction combined with mechanical action by wind produces an assemblage of erosional landforms.

Body: Zeugen and Yardangs are both geomorphological features formed by the processes of erosion in arid environments, particularly influenced by wind activity.
Zeugen: Zeugen are rock masses with a tabular form, resembling capped inkpots, standing on softer rock pedestals like shale or mudstone.



Characteristics:

Formation Process: The alternate freeze and thaw of moisture causes expansion and contraction, leading to rock disintegration along joints. The finer disintegrated material is blown away by wind. Repeated cycles of this process result in the formation of zeugen.

Appearance: Zeugen typically appear as a series of elongated ridges with flat tops. The ridges are usually parallel to the prevailing winds, and the base of the structure is broader than the top.

Location: They form in desert areas where nighttime temperatures drop low enough for moisture in rock joints and crevices to freeze.

Yardang:

Yardangs are steep-sided, deeply undercut rock ridges, separated by long grooves or corridors, often found in desert floors with relatively softer rocks.

Characteristics:

Formation Process: Yardangs form where alternating bands of hard and soft rock are inclined or vertical. Softer rock layers are eroded and abraded, with the material being removed by the deflation process.

Appearance: Yardangs have a streamlined shape, with steep sides and a tapered end pointing in the direction of prevailing winds. They are notable for their parallelism.

Location: Typically found in areas with consistent, directional winds.

Conclusion: zeugen and yardangs differ significantly in their formation processes, appearances, and geological contexts. While Zeugen due to differential layering find utility in stratigraphic studies, Yardangs are considered as natural communication routes.

b) What is a twister? Why are the majority of twisters observed in areas around the Gulf of Mexico?

APPROACH: ***Define a twister. Explain the formation of twister with the help of diagram. Explain the suitability of Gulf of Mexico region for formation of tornadoes.***

Introduction:
A "twister" is an informal term for a 'tornado' characterized by a violent, whirling wind, often appearing as a funnel-shaped cloud. These are concentrated mostly in mid latitude regions especially in United States near Gulf of Mexico region.

Body: A **tornado** is a rapidly rotating column of air in contact with both the surface of the Earth and a cumulonimbus or, in rare cases, a cumulus cloud. Very violent winds reaching upto 450 to 575 km per hour lead to catastrophic impact on region.

Formation:

- **Instability in the Atmosphere**: Tornado formation begins with a combination of warm, moist air at the surface and cold, dry air in the upper atmosphere creating significant atmospheric instability.
- **Wind Shear**: causes the air in the storm to rotate horizontally, creating a rolling motion in the lower atmosphere. This rotation is a critical precursor for tornado development.
- **Updrafts**: strong updrafts lift the rotating air from horizontal to vertical. The rising warm, moist air causes the rotating column of air to stretch, which intensifies its spin due to the conservation of angular momentum.
- **Formation of a Mesocyclone**: The vertical rotating air column, known as a mesocyclone, forms within the storm. This mesocyclone often becomes the core of the developing tornado.
- **Tornado Development**: The visible part of the tornado, often a funnel cloud, becomes apparent as the rotation picks up debris or as water vapor condenses within the low-pressure vortex.
- **Maturation and Dissipation**: Once the tornado touches the ground, it can grow stronger as it draws in more air, expanding and intensifying. Tornadoes can last from a few minutes to over an hour before weakening due to loss of instability or disruption in the storm's updrafts, eventually dissipating.

Reasons for concentration in Gulf of Mexico Region:

- Warm, Moist Air from the Gulf: The Gulf of Mexico consistently supplies warm, moist air to the lower atmosphere. This air mass is crucial for the formation of thunderstorms, which are precursors to tornadoes.
- Cold, Dry Air from the Rockies: Cold, dry air masses from the Rocky Mountains or Canada often meet the warm, humid air from the Gulf in the central U.S. This collision creates significant atmospheric instability, fostering the development of severe thunderstorms, which can spawn tornadoes.
- Jet Stream Influence: The jet stream frequently dips southward over this region, enhancing wind shear—an essential factor in tornado formation—by increasing the variation in wind speed and direction at different altitudes.
- Favorable Terrain: The flat topography of the central U.S., particularly around Tornado Alley (Texas, Oklahoma, Kansas, and nearby states), allows air masses to collide unimpeded, heightening the risk of severe weather and tornadoes.
- Wind Shear: Strong wind shear, characterized by changes in wind speed and direction with altitude, is prevalent in the Gulf region. It contributes to the formation of rotating thunderstorms, known as supercells. Tornadoes often emerge from these supercells when rotating air columns are stretched and intensified by updrafts.

Case Study: The Tri-State Tornado (1925): One of the deadliest tornadoes in U.S. history, this event affected Missouri, Illinois, and Indiana, illustrating the catastrophic potential of such storms in areas near the Gulf's influence.

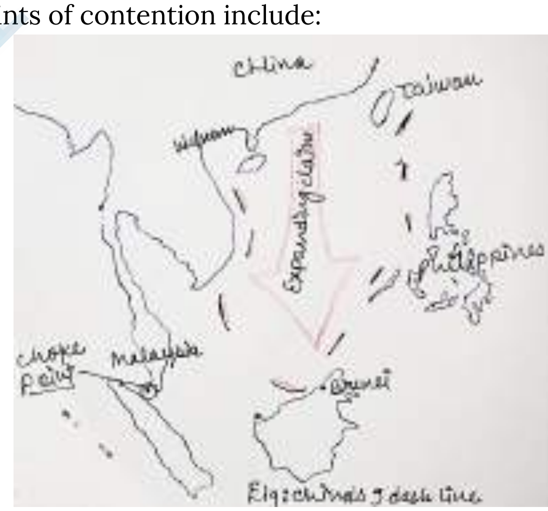
Conclusion: The Gulf of Mexico region is particularly vulnerable to tornadoes due to the combination of factors. These unique geographical and meteorological conditions increase the frequency and severity of tornadoes, making this area one of the most tornado-prone regions in the world.

c) What is South China Sea Dispute and how will it impact India's interest in the ASEAN region?

APPROACH: *Give the background of South China sea dispute. Enlist various impacts on India specifically in context of ASEAN region*

<u>Introduction</u>:
The South China Sea dispute is a complex territorial and maritime conflict involving several nations in Southeast Asia, with China at the center of the controversy with far reaching effects involving India an ASEAN countries.

Body: Several countries, including China, Vietnam, Philippines, Malaysia, Brunei, and Taiwan, claim overlapping parts of the South China Sea. The key points of contention include:



- China's "Nine-Dash Line": China claims about 90% of the South China Sea based on historical maps, marked by the so-called "Nine-Dash Line," which extends deep into waters also claimed by other Southeast Asian nations.
- UNCLOS and Exclusive Economic Zones (EEZs): The United Nations Convention on the Law of the Sea (UNCLOS) gives countries rights to resources within 200 nautical miles of their coastline, known as an EEZ. However, China's claims go beyond these limits, infringing on the EEZs of other nations like Vietnam and the Philippines.
- Strategic Importance: The South China Sea is one of the world's busiest maritime corridors, with a third of global shipping passing through it making it a strategic region.

Impacts on India's Interests in the ASEAN Region: India views the ASEAN region as part of its broader "Act East Policy," aimed at strengthening economic, security, and cultural ties with Southeast Asia. Hence the dispute has wider repercussions owing to tensed relation with China:

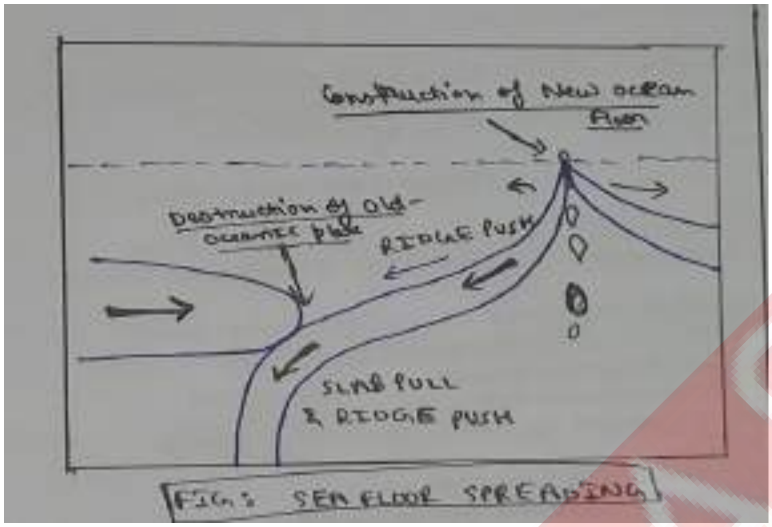
1. **Freedom of Navigation and Trade:** more than 55% of India's trade passes through the South China Sea, making the freedom of navigation in this region vital for India's economic interests. Any conflict or militarization in the South China Sea could disrupt global shipping routes harming India's interests.
2. **Strategic Security Concerns:** India has been deepening its strategic relations with ASEAN countries as part of its broader Indo-Pacific vision. Security and peace of every region are interconnected.
   Eg: India's Diamond necklace policy to counter China's String of Pearls and attain regional security.
3. **India's Energy Interests:** India has significant energy investments in Southeast Asia, particularly in Vietnam where ONGC Videsh has been involved in joint exploration with Vietnam in oil blocks within Vietnam's EEZ.
4. **Geopolitical and Diplomatic Stakes:** India aims to delocalize the relations with China and foresees to counter the hegemony claimed by China in Indo-Pacific region.
   Case Study: India and Philippines issuing joint statement calling for UNCLOS based order and adherence to International Court of Justice 2016 award regarding china was a departure from India's earlier approach in wake of Galwan Valley clashes.
5. **Defense Cooperation with ASEAN:** The ongoing dispute has prompted ASEAN countries to seek closer defense ties with other powers to counterbalance China's influence. India has been stepping up its defense diplomacy in the region, including joint naval exercises, maritime domain awareness cooperation, and port visits. Eg: Gifting of fully operational INS Kirpan to Vietnam by India with defence line of credit.

Conclusion: New Delhi's advocacy for a rules-based international maritime order, especially its emphasis on UNCLOS and wider collaborations with ASEAN countries reflects a stance against unilateral actions that threaten regional stability.

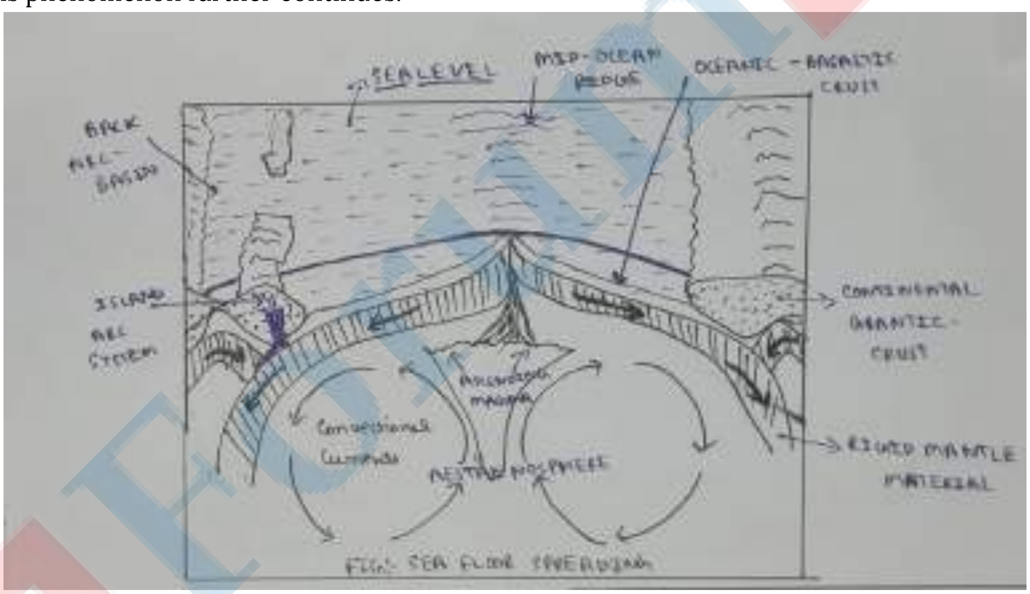
d) Write short on sea floor spreading Theory?

Ans. Sea floor spreading hypothesis was proposed by American geographer Harry H. Hess in 1960.During post-world war II, Ocean floors were extensively surveyed and following facts were collected

- There are thousands of kilometers long mountain ridges are situated on ocean floor.
- The crust of these ridges is characterized by continuous ejection of basaltic magma.
- Near margins of the ocean, long narrow and steep sided depressions are founded, these depressions are known as trenches.
- The rocks of ocean crust are much younger than rocks of continental crust.
- Also, it was found that age of rocks near oceanic crust are much younger and age of rocks increase as one moves away from mid oceanic ridge.



On the basis of these findings harry Hess, propounded sea floor spreading theory. He propounded that; crust of oceanic ridges is situated above ascending thermal convection currents. The ascending currents generates tensional stress and rupture the oceanic crust due to divergence of currents at the oceanic crust, leading to formation of fissures along mid oceanic ridge, from where magma upwells upwards and new oceanic crust is formed. This further gets diverged away from the centre and this phenomenon further continues.



This whole phenomenon is called sea floor spreading.
He used maps created by solar readings of the ocean floor.
Sea floor spreading became theory as more scientific evidence continued to support it.
Hess proposed that it was seafloor itself that was pushing continents apart. wherein, he believed that the location and topography of mid oceanic ridge (Atlantic Ocean) was not coincidence. The ridge was found where new seafloor was being added to the earth's lithosphere, which in turn pushed the continents apart. Hess called it sea floor spreading.

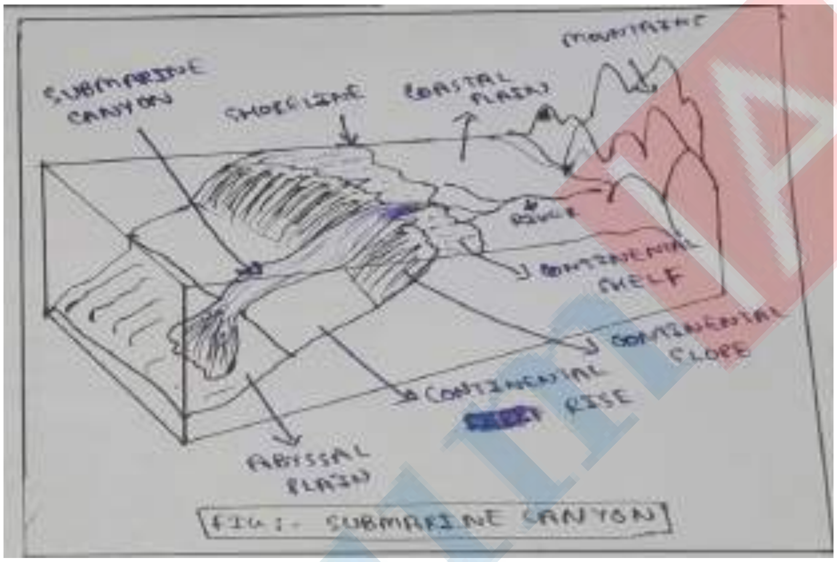
EVIDENCE TO SUPPORT THE THEORY:

SEAFLOOR MAGNETISM: It was found that magma containing magnetic material solidifies due to cooling below curie temperature, this magnetic material acquires contemporary magnetic properties and these properties gets locked in the igneous rocks. Such magnetism can be locked in the sedimentary rocks with lithification.

MAGNETIC STRIPES: symmetrical magnetic patterns on either side of mid oceanic ridges indicate crust formation and outward spread.
CRUST AGE: oceanic crust is younger near ridges and older farther away, showing new crust formation and outward spread.
Sea floor spreading theory further supported foundations of plate tectonic theory and revolutionized our understanding of geomorphological features on earth.

e) Examine the theories related to formation of submarine canyons?

Ans. Submarine canyons are deep narrow valleys of the continents extending inside oceans. They are mostly located at continental shelves and slopes. Some are associated with river mouth and some are not connected with any rivers.
FORMATION OF SUBMARINE CANYONS



Many theories have been proposed for the formation and origin of submarine canyons. Majority of them consider that these are of recent age of Cenozoic era and quaternary period. Major theories put forward and their analysis is presented as:

1. **DIASTROPHIC THEORY**: This theory explains the origins due to tectonic movements of rocks like faulting, warping and sinking of sea floor. Due to tensional forces, faulting on continental margins creates troughs. these troughs may be later on become submarine canyons.
   But tectonic activity alone may not be sufficient to explain the canyon's characteristics depth and width, so it likely combines with processes like turbidity.
2. **SUBAERIAL EROSION THEORY:** this theory was put forwarded on the basis of resemblance of these canyons to continental canyons in shape and depositional patterns. As suggested by scientists during period of low sea level, rivers extended across the continental shelves and deep cutting action of rivers carved valleys that became submarine canyons when sea level rose again.
   However, this theory doesn't explain canyons formed away from river sources or those found in deep-sea environment, which rivers would have little direct impact.
3. **TURBIDITY CURRENT THEORY:** this theory is widely accepted and it proposed that underwater landslides, or turbidity currents (dense, sediments -laden currents) flows downslope and performs erosional work repeatedly. these muddy torrents lead to major force in excavation of submarine canyons.
   However, it may not explain the initial formation of some canyons, suggesting turbidity currents might play a primary role.
4. **SUBMARINE DENSITY CURRENT THEORY:** wave and tidal action may contribute to submarine canyon formation, especially near the continental shelf's edge, though this is a typically secondary process.
   While this process could modify existing canyon, it cannot account for their initial formation, as waves and tides lack enough energy to cut deep into seabed for canyon formation.

However, in reality, combination of all these theories would better explain formation of submarine canyons. Turbidity currents primarily deepen and maintain canyon, while river erosion, tectonic forces, and glacial influence may contribute to their initial formation or impact certain regions based on local conditions.

Q.5) a) Compare and contrast the tropical cyclones with that of temperate cyclones?

APPROACH: ***Define Tropical and Temperate cyclones. Mention various aspects of similarities and differences between these two. Mention case studies. Mention the impact of these cyclones.***

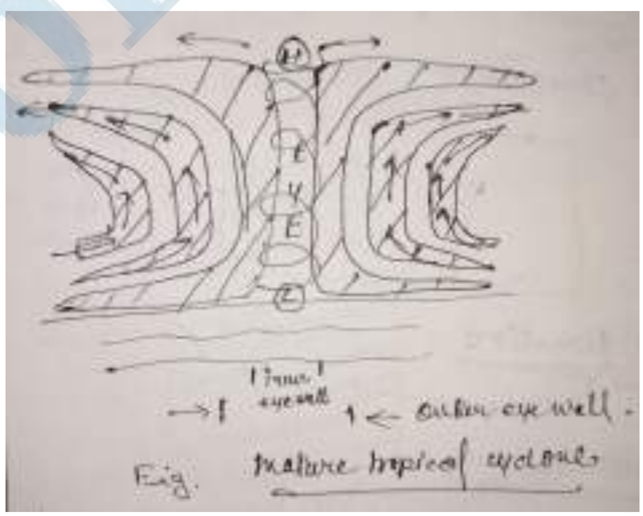
Introduction: A cyclone is a large-scale rotating air mass with low atmospheric pressure at its center, typically accompanied by strong winds, heavy rainfall, and thunderstorms.
Body: Tropical cyclones and temperate cyclones are two distinct types of low-pressure systems that differ in their formation, characteristics, and impacts.

Similarities:

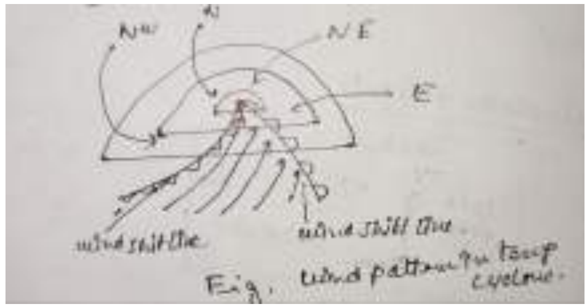
- Low-pressure systems: Both tropical and temperate cyclones are low-pressure systems with rotating air masses.
- Wind circulation: Both exhibits inward-spiraling winds that rotate around a central eye.
- Formation from instability: Both form from areas of atmospheric instability.

Differences:

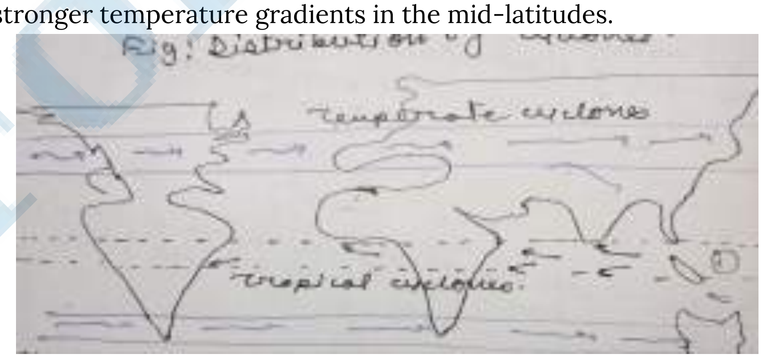
- Origin and Formation
  - Tropical Cyclones: Form in the warm tropical oceans, primarily between 5° and 20° latitude in both hemispheres. Require warm sea surface temperatures (at least 26.5°C) and high humidity for formation. Rely on the Coriolis effect for rotation, which is weak at the equator, so tropical cyclones rarely form close to it.
  - Temperate Cyclones: Develop in mid-latitudes (30° to 60° latitude) due to the interaction of warm and cold air masses. Form along the polar front, where cold polar air meets warm tropical air. Depend less on sea surface temperature and more on frontal activity and upper-level westerlies.
- Structure
  - Tropical Cyclones: **Symmetrical** and circular in shape, with a **distinct eye** at the center, surrounded by the eye wall, which has the most intense winds and rainfall. Driven by convection and fueled by **latent heat** from warm ocean water.



  - Temperate Cyclones: **Asymmetrical**, with distinct warm and cold fronts extending outwards from the center. Lacks a clear eye or eye wall and is marked by a more complex frontal structure. Primarily **driven by temperature contrasts** and upper-level wind patterns, not latent heat.



- Size and Duration
  - Tropical Cyclones: Generally smaller, ranging from 100 to 1,000 kilometers in diameter. Can last from a few days up to two weeks, depending on favorable conditions.
  - Temperate Cyclones: Larger, usually extending from 1,000 to 4,000 kilometers across. Typically last 3–7 days, but some systems can last longer due to continuous supply of cold and warm air.
- Wind Speed and Intensity
  - Tropical Cyclones: Characterized by very high wind speeds (up to 300 km/h or more in severe cases) around the eye wall. Categories range from tropical depressions to Category 5 hurricanes, typhoons, or cyclones, depending on wind speed.
  - Temperate Cyclones: Usually have lower wind speeds, typically up to 120 km/h, although some severe storms can produce hurricane-force winds. Intensity is generally lower, but storms can still cause significant damage due to sustained winds, large size, and associated fronts.
- Weather Patterns and Precipitation
  - Tropical Cyclones: Bring intense rainfall, thunderstorms, and high winds concentrated around the eye and eye wall. Often produce storm surges, coastal flooding, and heavy rain-induced inland flooding.
  - Temperate Cyclones: Associated with a mix of weather due to warm and cold fronts, leading to varied precipitation patterns, including rain, snow, sleet, or freezing rain. Heavy snowfall and blizzards are common in winter storms, especially when cold fronts are involved.
- Seasonality
  - Tropical Cyclones: Have specific seasons based on ocean temperatures. For example, the Atlantic hurricane season runs from June to November, with a peak around September.
  - Temperate Cyclones: Occur year-round, but are more frequent and intense in late autumn, winter, and early spring due to stronger temperature gradients in the mid-latitudes.



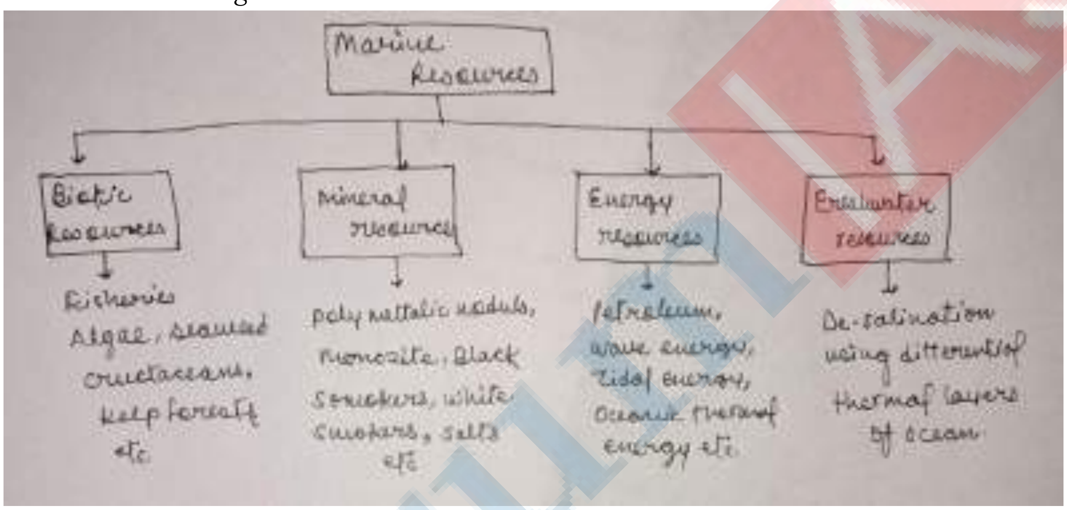
- Energy Source
  - Tropical Cyclones: Primarily powered by the latent heat released from warm ocean water, which evaporates and condenses in the storm system.
  - Temperate Cyclones: Derive energy from the horizontal temperature gradient between air masses, known as baroclinic instability.
- Impact and Damage
  - Tropical Cyclones: Cause catastrophic damage in coastal areas due to high winds, intense rainfall, and storm surges. The concentrated energy can lead to severe flooding and infrastructure damage.
  - Temperate Cyclones: While generally less intense, they can still cause extensive damage, especially during winter storms and blizzards. Flooding, snow, and ice accumulation pose major hazards.

Conclusion: Tropical cyclones are intense, localized systems fueled by warm ocean waters, while temperate cyclones are larger, less intense systems driven by temperature contrasts. Understanding these differences is crucial for predicting and preparing for the unique impacts of each type of cyclone.

b) Give an account of marine resources and discuss their present-day utilization?

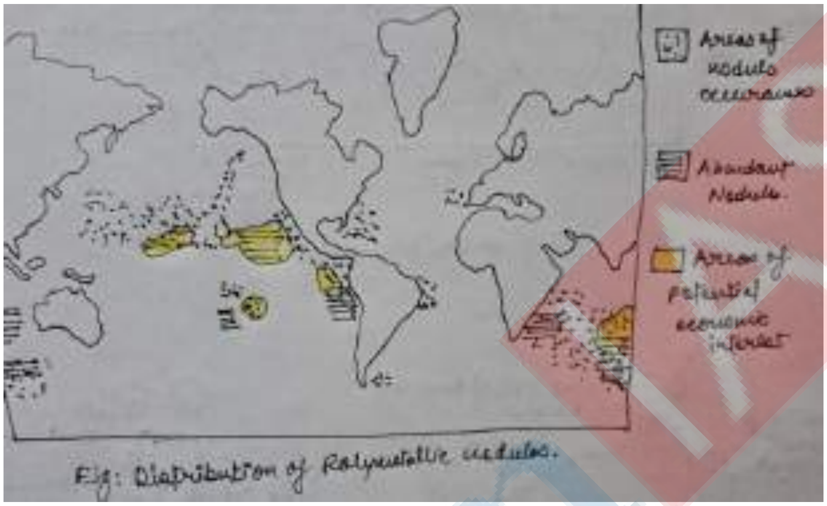
APPROACH: *Define Marine resources. Mention various types of marine resources. Explain distribution and usefulness of these resources. Explain potential and utilization citing case studies.*

Introduction: Marine resources encompass the vast array of natural resources found within ocean and sea environments, extending across living organisms, mineral deposits, energy sources, and freshwater. Covering over 70% of Earth's surface, marine resources provide essential materials and support for a wide range of industries, livelihoods, and ecological services.
Body: Marine resources can be categorized into:



- **Biotic Resources**: Biotic resources refer to the living components of marine ecosystems, including fish, seaweed, corals, and other marine organisms.
  Distribution: These resources are found throughout the world's oceans, with the richest fisheries located in coastal zones and upwelling areas, like those off the coasts of Peru, Japan, and the northwest Atlantic.
  Utilization: Biotic resources are critical for global food security, providing protein, oils, and other nutrients over 3.5 billion people dependent on seafood as a primary protein source. Marine organisms also contribute to medicine, with compounds found in sponges, algae, and corals used in pharmaceuticals. Also it is vital for Ecological services. Eg: **Iron Enrichment** of oceans for promoting growth of phytoplankton is vital for **carbon sequestration**.
  Case Study: The Norwegian fishing industry is a global leader, with sustainable practices such as quota systems and marine protected areas (MPAs) to manage fish stocks like cod and herring.
- **Energy Resources:** Energy resources include both traditional fossil fuels (oil and natural gas) and renewable sources (wave, wind, and tidal energy) found in marine settings.
  Distribution: Major reserves of oil and gas exist on continental shelves, such as in the Gulf of Mexico, the North Sea, and the South China Sea. Renewable energy potential is highest in regions with strong tidal currents or consistent winds, like the North Sea and the coastal areas of the United Kingdom and China.
  Utilization: Fossil fuels extracted from marine environments are major sources of global energy, though they contribute to greenhouse gas emissions. Renewable energy sources offer sustainable alternatives to meet rising energy demands. Global tidal energy potential is estimated to be around **1 terawatt (TW)** of power capacity whereas Global methane hydrate reserves are estimated to be around **15,000 to 30,000 trillion cubic meters**.
  Case Study: Gulf of Khambhat in Gujarat has a significant tidal energy potential, estimated at around 7,000 MW, which could power nearby coastal villages.

- **Mineral Resources**: Seabed mining could meet the demand for critical metals needed in high-tech industries, especially with growing reliance on digital and renewable technologies. Eg: Sulfide deposits from Black smokers and white smokers areas.
  Utilization: Currently, most deep-sea mining is exploratory. However, Japan's rare earth extraction from seabed deposits shows potential for reducing dependency on land-based mining.
  Case Study: Polymetallic nodules with wide distribution across ocean floor present significant harvesting opportunities across concentration regions.



- **Freshwater Resources:** Desalination technology advancements could make seawater desalination more affordable, helping to address freshwater scarcity in more regions.
  Utilization: Countries like Israel have achieved near self-sufficiency through desalination, providing over 50% of the country's drinking water.

Conclusion: Marine resources are vital for human well-being, but their utilization must balance economic benefits with environmental sustainability. Sustainable management initiatives and international cooperation ensures the long-term health of marine ecosystems.

c) "Geomorphological changes are largely responsible for the environmental hazards in the Himalayan region". Comment with relevant examples?

Himalayan region consists of young fold mountains wherein tectonic forces are still active, and this makes this region prone to hazards. However, further geomorphological changes due to interplay of tectonic forces, glacial dynamics, erosion and human interventions continuously reshapes this landscape, leading to various environmental hazards.
Geomorphological changes leading to environmental hazards in Himalayan region are:

- **Mountain Ranges and Valleys:** The Himalayas consist of high mountain ranges and deep valleys formed by tectonic uplift and erosion. The steep slopes, are highly susceptible to landslides, especially during monsoon seasons.
  For Instance, Chamoli landslide 2021 led to huge loss of infrastructure, human settlements etc.
- **Glacier region:** global warming of the region leading to glaciers melting like Siachen glacier and Gangotri glacier. This melting contributes to formation of glacial lake, which can pose severe risk of GLOF phenomena.
  Example: GLOF phenomena in 2021 in Nubra valley, Ladakh.
  Also, as glaciers retreat, moraines can become unstable and failure of moraine dame can create catastrophic floods. Example: recent Gangotri glacier flooding
- Peri glacial features: destabilization of **Talus slope** for construction purpose frequently leads to rockfalls and landslides, threatening nearby settlements.
  Also, permafrost thawing due to global warming is leading to ground instability, increasing risk of landslides and erosion.

- Erosion: increased heavy rainfall, deforestation, agriculture practise like slash and burn agriculture increases erosion rates which modifies geomorphic feature of landscape and intensifies erosion in the region. This makes steep slopes vulnerable to frequent landslides and mass wasting and often exacerbates in flooding.
- Urbanisation and increased settlements: rapid urbanization is promoting commercial activities like industrialisation, settlements etc which destabilises the natural slopes and exacerbates vulnerability of the region for various environmental hazards like mass wasting, erosion, flooding etc

Although geomorphological changes make this region susceptible for hazards but its pertinent to note that naturally also this region is prone to environmental hazards. Since:

1. Active tectonics: ongoing collision between Eurasian and Indian plate creates significant geological stress, leading to frequent earthquakes and subsequent hazards.
2. This region also lies in zone 5^{th} of earthquake prone zones in India.
3. Climate change: Himalayan region is warming at faster rate due to global warming, this changes glacial and peri glacier dynamics and triggers glacial retreat, GLOF phenomena.
4. Monsoon climate: which brings intense rainfall during July to September in this region. this along with steep terrain significantly increases the risk of various environmental hazards like landslides.
5. Anthropogenic threat: like deforestation, unsustainable development due to technocratic approach further exacerbates environmental threat in this region.

Therefore, effective disaster risk management approach must consider both geomorphological processes and the natural features that make the Himalayas susceptible to such challenges. Sustainable land use practice, improved monitoring system, and community participation and preparedness is essential to mitigate impacts of these hazards in this region.