GEOMORPHOLOGY

UNIT-III

UNIT III : SYLLABUS

Land Forms Created By Glaciers: Definition of glaciers, formation of glaciers, movement of glaciers. Types: valley glaciers, piedmont glaciers, continental glaciers, Surface features of glaciers. Glacial action: Erosion: plucking, rasping, avalanche, erosional features produced by valley glaciers: cirque, horn, glacial trough, hanging valleys, truncated spurs, glacial boulders, glacial scars, roches mountonnees, fjords. Depositional Features produced by continental ice sheets: crescentic gorges; drumlins. Land Forms Created by Ocean: Shore profile and shoreline development: continental shelf, continental slope, continental rise; Ocean floor-Marine erosion, Features formed by marine reefs — deep sea deposits, abyssal deposits, polygenic sediments, volcanogenic sediments, outline of mid oceanic ridges and submarine canyons.

Glaciers And Oceans

Definition of Glaciers:

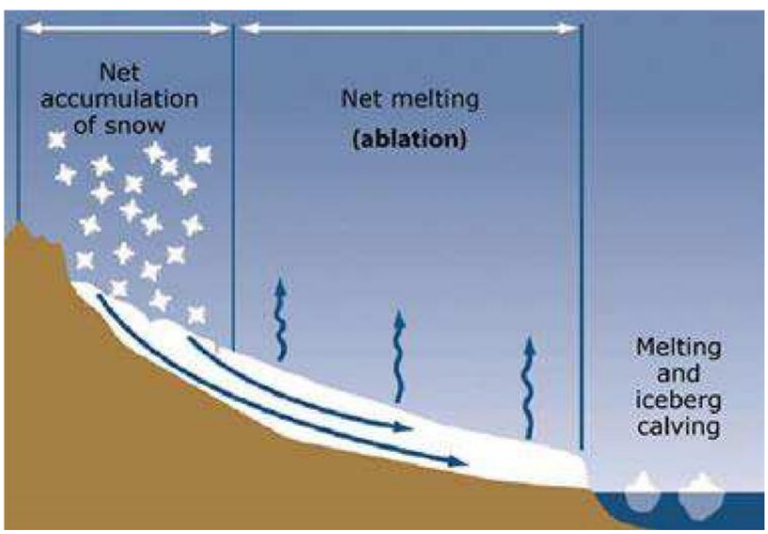
A glacier is a persistent body of dense ice that is constantly moving under its own weight. A glacier forms where the accumulation of snow exceeds its ablation over many years, often centuries. Glaciers slowly deform and flow under stresses induced by their weight, creating crevasses, seracs, and other distinguishing features.

They also abrade rock and debris from their substrate to create landforms such as cirques, moraines, or fjords. Glaciers form only on land and are distinct from the much thinner sea ice and lake ice that forms on the surface of bodies of water.

Glacial ice is the largest reservoir of fresh water on Earth. Many glaciers from temperate, alpine, and seasonal polar climates store water as ice during the colder seasons and release it later in the form of meltwater as warmer summer temperatures cause the glacier to melt, creating a water source that is especially important for plants, animals and human uses when other sources may be scant. Within high-altitude and Antarctic environments, the seasonal temperature difference is often not sufficient to release meltwater.

Formation of Glaciers:

Glaciers form where the accumulation of snow and ice exceeds ablation. Glaciers begin forming in places where more snow piles up each year than melts. Soon after falling, the snow begins to compress or become denser and tightly packed. It slowly changes from light, fluffy crystals to hard, round ice pellets.



A glacier usually originates from a landform called 'cirque' – a typically armchair-shaped geological feature (such as a depression between mountains enclosed by arêtes) – which collects and compresses through gravity the snow that falls into it. This snow collects and is compacted by the weight of the snow falling above it, forming névé. Further crushing of the individual snowflakes and squeezing the air from the snow turns it into "glacial ice". This glacial ice will fill the cirque until it "overflows" through a geological weakness or vacancy, such as the gap between two mountains. When the mass of snow and ice is sufficiently thick, it begins to move by a combination of surface slope, gravity, and pressure. On steeper slopes, this can occur with as little as 15 m (50 ft) of snow-ice.

Movement of Glaciers:

The glacier moves under the pressure from the weight of the overlying ice causes it to deform and flow. Meltwater at the bottom of the glacier helps it to glide over the landscape. Glaciers move very slowly.

Glaciers move by internal deformation of the ice, and by sliding over the rocks and sediments at the base. Internal deformation occurs when the weight and mass of a glacier cause it to spread out due to gravity. Sliding occurs when the glacier slides on a thin layer of water at the bottom of the glacier. This water may come from glacial melting due to the pressure of the overlying ice or from water that has worked its way through cracks in the glacier. Glaciers can also readily slide on a soft sediment bed that has some water in it. This is known as basal sliding and may account for most of the movement of thin, cold glaciers on steep slopes or only 10 to 20 percent of the movement of warm, thick glaciers lying on gentle slopes.

When a glacier moves rapidly around a rock outcrop, flows over a steep area in the bedrock, or accelerates, or over a steep area in the bedrock, internal stresses build up in the ice. These stresses can cause cracks, or crevasses, on the glacier surface.

Types of Glaciers:

1. Valley Glaciers:

Valley glaciers are streams of flowing ice that are confined within steep walled valleys, often following the course of an ancient river valley. The downward erosive action of the ice carves the valley into a broad Ushape, in contrast to the steeper V-shape that is produced during the early stages of erosion by rivers.

Valley glaciers usually start life in either corries or ice sheets. Glacial ice flowing downhill from either of these sources will follow any existing valleys or easy routes, eroding and enlarging them as it moves. Often several corrie glaciers will combine to feed a single valley glacier.

2. Piedmont Glaciers:

A Piedmont glacier is a valley glacier which has spilled out onto relatively flat plains, spreading into bulb-like lobes. The formation of a piedmont glacier happens when ice flows down a steep valley and spills out onto a relatively flat plain.

Piedmont glaciers occur when steep valley glaciers spill into relatively flat plains, where they spread out into bulb-like lobes. Malaspina Glacier in Alaska is one of the most famous examples of this type of glacier, and is the largest piedmont glacier in the world. Spilling out of the Seward Icefield, Malaspina Glacier covers about 3,900 square kilometers (1,500 square miles) as it spreads across the coastal plain.

3. Continental Glaciers:

Continental glaciers are continuous masses of ice that are much larger than alpine glaciers. Small continental glaciers are called ice fields. Big continental glaciers are called ice sheets. Greenland and Antarctica are almost entirely covered with ice sheets that are up to 3500 m (11 500 ft) thick.

Ice sheets, unlike valley glaciers, are not limited to mountainous areas. They form broad domes and spread out from their centers in all directions. As ice sheets spread, they cover everything around them with a thick blanket of ice, including valleys, plains, and even entire mountains. The largest ice sheets, called continental glaciers, spread over vast areas. Today, continental glaciers cover most of Antarctica and the island of Greenland.

Surface features of Glaciers:

Surface features of glacier are **glacial landforms** and **the erosional landforms.**

Glacial landforms are landforms created by the action of glaciers. Most of today's glacial landforms were created by the movement of large ice sheets during the Quaternary glaciations. Some areas, like Fennoscandia and the southern Andes, have extensive occurrences of glacial landforms; other areas, such as the Sahara, display rare and very old fossil glacial landforms.

As the glaciers expand, due to their accumulating weight of snow and ice they crush and abrade and scour surfaces such as rocks and bedrock. The resulting **erosional landforms** include striations, cirques, glacial horns, arêtes, trim lines, U-shaped valleys, roches moutonnées, overdeepenings and hanging valleys.

Glacial action:

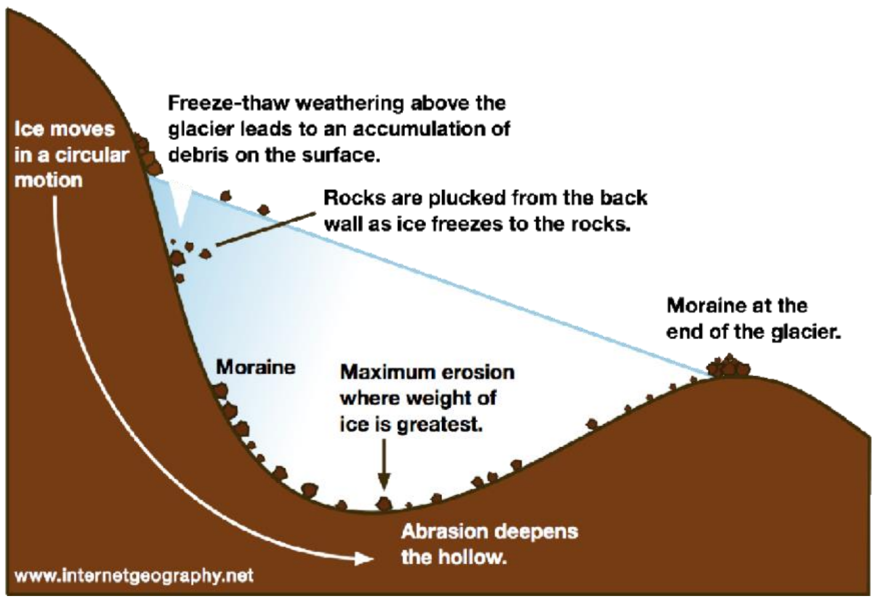
The geological action of glaciers comprises erosion, transportation and deposition which together constitute what is known as glaciation. The geological action of glacier is mainly due to its flow.

Since the piedmont glaciers are intermediate in nature and characters between the valley glaciers on the one hand and continental ice-sheets on the other, the geological action of glaciers can best be studied separately for valley glaciers and continental ice-sheets.

Geological Action of Valley Glaciers:

Erosion:

The erosive action of a glacier takes place due to (i) plucking, (ii) rasping and (iii) avalanching. The erosive action of glacier is more pronounced particularly when the thickness of the ice is great, the pressure on the subglacial floor is high and the glacier ice is heavily charged with rock fragments.



1. Plucking:

This is the process in which the moving ice lifts out blocks of bedrock loosened by the freezing and thawing of water in fractures beneath the ice. Water due to rain or melting often seeps down along the sides of the ice mass filling up the cracks, fissures and pore spaces within the country-rocks along the edges and at the head of the glacier.

When the temperature drops, this water freezes within those openings and exerts enormous pressure on the country rocks due to expansion in volume, breaking them up. The broken blocks are frozen in suspension in the ice and are carried away along with the ice.

Thus, plucking involves two processes-quarrying and frost-wedging.

While frost-wedging causes a shattering of the country- rocks, the quarrying process lifts out the shattered blocks, of rock. The plucking process particularly affects the downstream side of outcrops of welljointed rocks.

Glacial plucking is largely dependent on the amount of stress exerted on a clast overlain by glacial ice. This relationship is a balance between the shear stress exerted on the clast and the normal pressure on the clast by a body of ice. Plucking is increased where there are preexisting fractures in a rock bed. As the glacier slides down a mountain, energy from friction, pressure or geothermal heat causes glacial meltwater to infiltrate the spaces between rocks. This process, known as frost wedging, puts stress on the rock structure as water expands when it freezes. Impacts from large clasts carried in the bedload can cause additional stress to the bedrock. Additionally, plucking can be seen as a positive feedback system in which the increased action of rock removed from the landscape entrained in the glacier causes larger scale fracturing further down the glacier because of a heavier load of force pushing down on the rock bed.

Glacial plucking is the main mechanism of other small scale mechanical glacial erosion such as striation, abrasion and glacial polishing. The heavier the sediment load, the more extreme the erosion of the downhill landscape. Erosion is largely dependent on the amount of water flow and its velocity, the clast size and hardness with relation to the stability of the slope.

2. Rasping:

The process is also known as abrasion or corrosion. Glaciers normally carry considerable quantities of rock fragments in their basal sections. These rock fragments are dragged over rock surfaces, and their sharp points and edges cause characteristic scratches, gougings and grooves in the underlying hard bedrocks.

Since the rock fragments are dragged under great pressure over bedrock, they themselves are scratched and worn down into peculiar facetted stones. The sharp points and edges of the rock fragments are gradually blunted by friction.

Thus, some glacial scratches and grooves which may start by being arrow and deep, gradually become broader, and shallower and finally fade out.

This serves as an indication of the direction of ice movement in a given place; the movement of ice is from the deep and narrow end of the groove towards its broader and shallower end.

Bare rock surfaces are scraped and scoured due to abrasion. If the under surface of the glacier is studded with rock particles consisting of silt or sand grains the rock beneath will be polished; if they are gravel or boulders the rock will be scratched, or striated (if it is softer than the fragments).

While the rock-studded bottom of a glacier functions as an effective file or rasp and polishes, scratches and abrades the surfaces over which it moves, the front edge of the glaciers function like a bulldozer pushing and scraping the ground in front of it and is more effective in soft and semi consolidated sediments.

3.Avalanching

This is a process of mass-wasting. When the valley sides are scraped and the rock debris which are broken off are carried away by the glacier ice, there results a great deal of under-cutting, of the valley side. This leads to mass-wasting, bringing huge amounts of debris onto the top surface of the glacier.

An avalanche (also called a snowslide) is a rapid downward flow of snow over a steep slope that occurs when a cohesive slab of snow lying upon a weaker layer of snow fractures and slides down a steep slope.

Avalanches are typically triggered in a starting zone from a mechanical failure in the snowpack (slab avalanche) when the forces of the snow exceed its strength but sometimes only with gradual widening (loose snow avalanche). After initiation, avalanches usually accelerate rapidly and grow in mass and volume as they entrain more snow. If the avalanche moves fast enough, some of the snow may mix with the air forming a powder snow avalanche, which is a type of gravity current.

Erosional features produced by valley glaciers:

1. Cirque:

Cirque glaciers are glaciers that appear in bowl shaped valley hollows. Snow easily settles in the topographic structure; it is turned to ice as more snow falls and is subsequently compressed. When the glacier melts, a cirque structure is left in its place. Some examples cirque glaciers include:

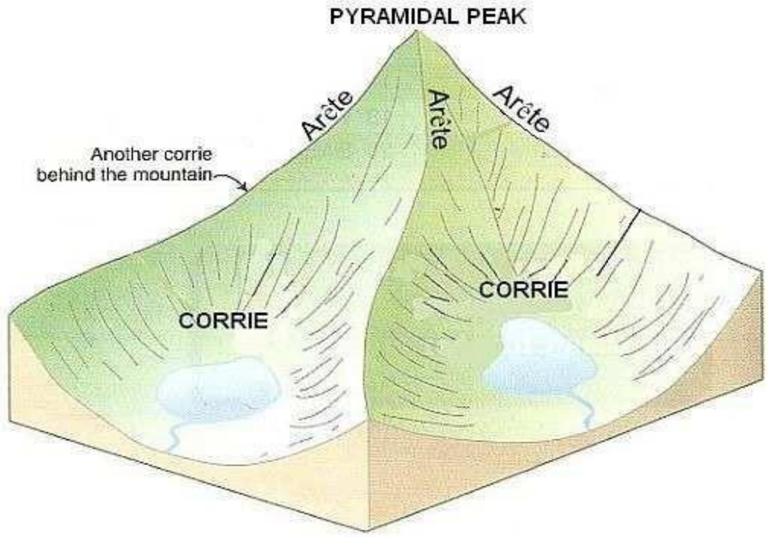
- Lower Curtis Glacier, USA
- Eel Glacier, USA

The concave shape of a glacial cirque is open on the downhill side, while the cupped section is generally steep. Cliff-like slopes, down which ice and glaciated debris combine and converge, form the three or more higher sides. The floor of the cirque ends up bowl-shaped, as it is the complex convergence zone of combining ice flows from multiple directions and their accompanying rock burdens. Hence, it experiences somewhat greater erosion forces and is most often overdeepened below the level of the cirque's low-side outlet (stage) and its down-slope (backstage) valley. If the cirque is subject to seasonal melting, the floor of the cirque most often forms a tarn (small lake) behind a dam, which marks the downstream limit of the glacial overdeepening. The dam itself can be composed of moraine, glacial till, or a lip of the underlying bedrock.

2.Horn:

A glacial horn (aka pyramidal peak) is a feature created by glaciers and what exactly this term means is intricately linked with how it formed. A horn is a peak that forms from three arêtes. It is also known as a pyramidal peak.

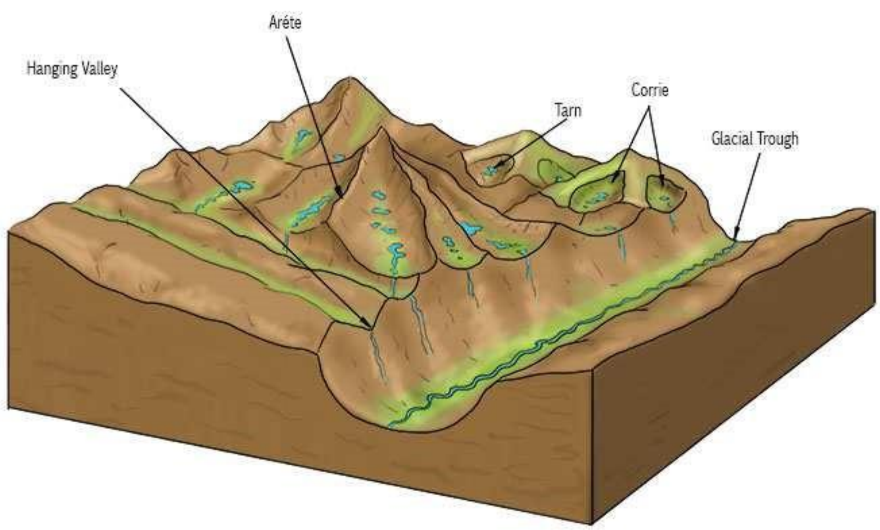
An arête is the edge that forms in the land from cirque erosion, or when two cirque glaciers form up against each other, creating that sharp edge. When more than two arêtes meet, this is a horn.



When three or more of these cirques converge on a central point, they create a pyramid-shaped peak with steep walls. These horns are a common shape for mountain tops in highly glaciated areas. The number of faces of a horn depends on the number of cirques involved in the formation of the peak: three to four is most common. Horns with more than four faces include the Weissmies and the Mönch. A peak with four symmetrical faces is called a Matterhorn (after The Matterhorn).

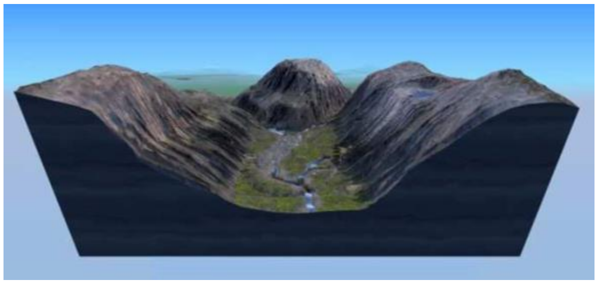
The peak of a glacial horn will often outlast the arêtes on its flanks. As the rock around it erodes, the horn gains in prominence. Eventually, a glacial horn will have near vertical faces on all sides. In the Alps, "horn" is also the name of very exposed peaks with slope inclinations of 45-60° (e.g. Kitzbüheler Horn).

3. Glacial Trough:



U-shaped valleys, trough valleys or glacial troughs, are formed by the process of glaciation. They are characteristic of mountain glaciation in particular. They have a characteristic U-shape in cross-section, with steep, straight sides and a flat or rounded bottom (by contrast, valleys carved by rivers tend to be V-shaped in cross-section). Glaciated valleys are formed when a glacier travels across and down a slope, carving the valley by the action of scouring. When the ice recedes or thaws, the valley remains, often littered with small boulders that were transported within the ice, called glacial till or glacial erratic.

4. Hanging Valleys:



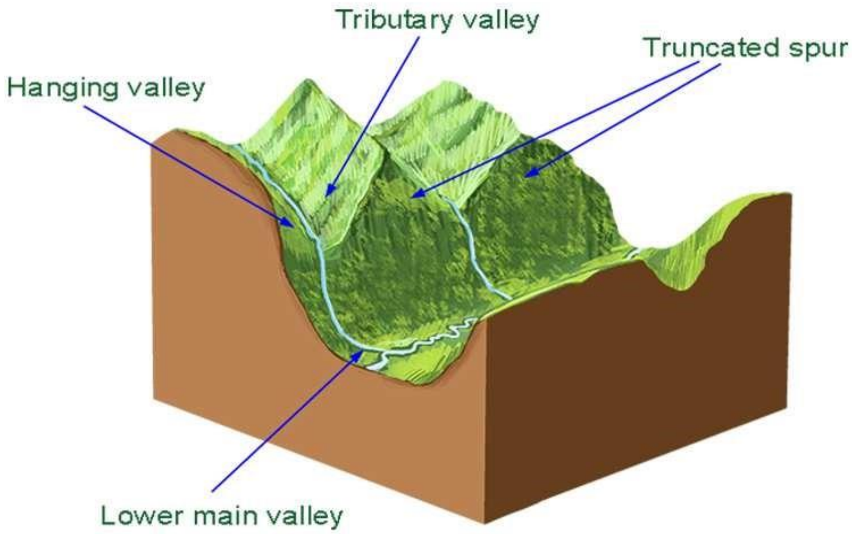
A hanging valley is a tributary valley that is higher than the main valley. They are most commonly associated with U-shaped valleys, where a tributary glacier flows into a glacier of larger volume. The main glacier erodes a deep U-shaped valley with nearly vertical sides, while the tributary glacier, with a smaller volume of ice, makes a shallower Ushaped valley. Since the surfaces of the glaciers were originally at the same elevation, the shallower valley appears to be 'hanging' above the main valley. Often, waterfalls form at or near the outlet of the upper valley.

Hanging valleys also occur in fjord systems under water. The branches of Sognefjord aree much shallower than the main fjord. The mouth of Fjærlandsfjord is about 400 meters deep while the main fjord nearby is 1200 meters deep. The mouth of Ikjefjord is only 50 meters deep while the main fjord is around 1300 meters at the same point.

Glaciated terrain is not the only site of hanging streams and valleys. Hanging valleys are also simply the product of varying rates of erosion of the main valley and the tributary valleys. The varying rates of erosion are associated with the composition of the adjacent rocks in the different valley locations. The tributary valleys are eroded and deepened by glaciers or erosion at a slower rate than that of the main valley floor; thus the difference in the two valleys' depth increases over time. The tributary valley, composed of more resistant rock, then hangs over the main valley.

5. Truncated Spurs:

A truncated spur is a spur, which is a ridge that descends towards a valley floor or coastline from a higher elevation, that ends in an inverted-V face and was produced by the erosional truncation of the spur by the action of either streams, waves, or glaciers. Truncated spurs can be found within mountain ranges, along the walls of river valleys, or along coastlines.

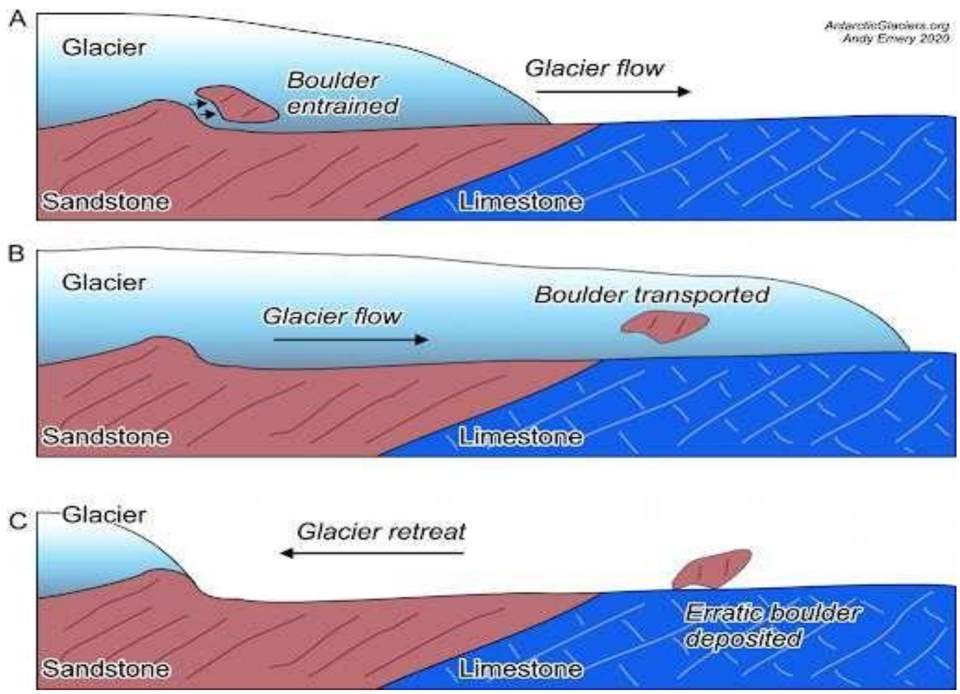


Before glaciation, relatively immature rivers display a pattern of interlocking spurs. A valley glacier cannot avoid the interlocking spurs as a river can. As the valley glacier moves, abrasion and plucking erode the protruding tips of the spurs, leaving steep cliff-like truncated spurs. Hanging valleys are found in between truncated spurs as they join the main glacial valley from the side. It is common for waterfalls to form from them, where they fall into the main valley. Such truncated spurs can be found in mountainous regions. The Mer de Glace, in the European Alps, is a valley through which a glacier currently flows. This is a geologically active process where the glacier continues to gradually erode the valley sides.

6. Glacial Boulders:

A glacial boulders (aka erratic) is glacially-deposited rock differing from the size and type of rock native to the area in which it rests. "Erratics" take their name from the Latin word errare (to wander), and are carried by glacial ice, often over distances of hundreds of kilometers. Erratics can range in size from pebbles to large boulders such as Big Rock

(16,500 tonnes or 18,200 short tons) in Alberta.
Glacial boulders are formed by glacial ice erosion resulting from the movement of ice. Glaciers erode by multiple processes: abrasion / scouring, plucking, ice thrusting and glacially-induced spalling.



A boulder is a rock fragment with size greater than 256 millimeters (10.1 in) in diameter. Smaller pieces are called cobbles and pebbles. While a boulder may be small enough to move or roll manually, others are extremely massive. In common usage, a boulder is too large for a person to move.

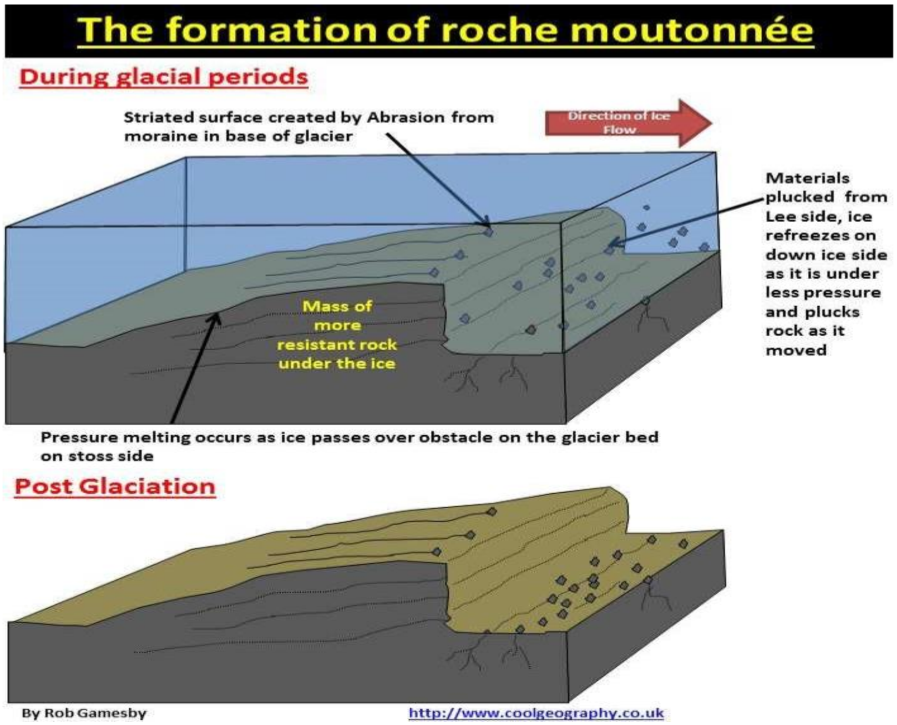
7. Glacial Scars:

Glacial scars (aka striations or striae) are scratches or gouges cut into bedrock by glacial abrasion. These scratches and gouges were first recognized as the result of a moving glacier in the late 18th century when Swiss alpinists first associated them with moving glaciers. They also noted that if they were visible today that the glaciers must also be receding.

Glacial striations are usually multiple, straight, and parallel, representing the movement of the glacier using rock fragments and sand grains, embedded in the base of the glacier, as cutting tools. Large amounts of coarse gravel and boulders carried along underneath the glacier provide the abrasive power to cut trough-like glacial grooves. Finer sediments also in the base of the moving glacier further scour and polish the bedrock surface, forming a glacial pavement. Ice itself is not a hard enough material to change the shape of rock but because the ice has rock embedded in the basal surface it can effectively abrade the bedrock.

Most glacial striations were exposed by the retreat of glaciers since the Last Glacial Maximum or the more recent Little Ice Age. As well as indicating the direction of flow of the glacial ice, the depth and extent of weathering of the striations may be used to estimate the duration of postglacier exposure of the rock.

8. Roches Mountonnees:



A **roche moutonnée** (or **sheepback**) is a rock formation created by the passing of a glacier. The passage of glacial ice over underlying bedrock often results in asymmetric erosional forms as a result of abrasion on the "stoss" (upstream) side of the rock and plucking on the "lee" (downstream) side. These erosional features are seen on scales of less than a metre to several hundred metres.

The contrasting appearance of the erosional stoss and lee aspects is very defined on roches moutonnées; all the sides and edges have been smoothed and eroded in the direction travelled by the glacier that once passed over it. It is often marked with glacial striations.

The rough and craggy down-ice (leeward) side is formed by plucking or quarrying, an erosional process initiated when ice melts slightly by pressure and seeps into cracks in the rock. When the water refreezes, the rock becomes attached to the glacier. But as the glacier continues its forward progress it subjects the stone to frost shattering, ripping pieces away from the rock formation. Studies show that the plucking of the lee side is a much more significant erosional process than the abrasion of the stoss side.

The side profile of a stoss and lee glaciated, bedrock knob (an erosional feature) is opposite to that of a drumlin (a depositional feature). In a drumlin, the steep side is facing the approaching glacier, rather than trailing it.

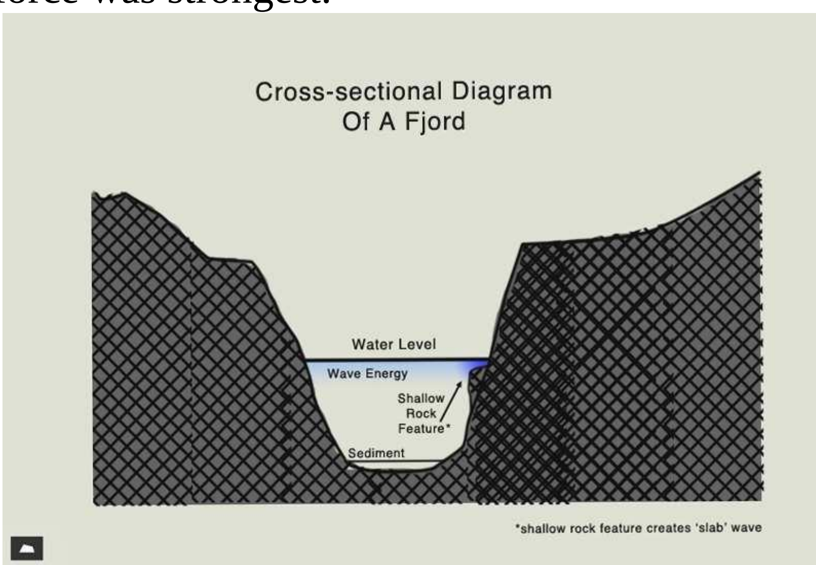
9. Fjords:

A fjord is a long, deep, narrow body of water that reaches far inland. Fjords are often set in a U-shaped valley with steep walls of rock on either side.

Fjords are found mainly in Norway, Chile, New Zealand, Canada, Greenland, and the U.S. state of Alaska. Sognefjorden, a fjord in Norway, is more than 160 kilometers (nearly 100 miles) long.

Fjords were created by glaciers. In the Earth's last ice age, glaciers covered just about everything. Glaciers move very slowly over time, and can greatly alter the landscape once they have moved through an area. This process is called glaciation.

Glaciation carves deep valleys. This is why fjords can be thousands of meters deep. Fjords are usually deepest farther inland, where the glacial force was strongest.



Some features of fjords include coral reefs and rocky islands called skerries.

Some of the largest coral reefs are found at the bottom of fjords in Norway. They are home to several types of fish, plankton and sea anemones. Some coral reefs are also found in New Zealand. Scientists know much less about these deep, cold-water reefs than they do about tropical coral reefs. But they have learned that the living things in cold-water reefs prefer total darkness. Organisms in cold-water reefs have also adapted to life under high pressure. At the bottom of a fjord, the water pressure can be hundreds or even thousands of kilograms per square meter. Few organisms can survive in this cold, dark habitat.

Skerries are also found around fjords. A skerry is a small, rocky island created through glaciation. Most of the Scandinavian coastline is cut into thousands of little blocks of land. These jagged bits of coastline are skerries. The U.S. states of Washington and Alaska also have skerries.

Even though skerries can be hard to get around in a boat, fjords are generally calm and protected. This makes them popular harbors for ships.

Depositional features produced by continental ice sheets:

1. Crecentic gouges:

Cresentic gouges are formed on the bed rock where rock fragments moving in the ice encounter obstructions in their path and eventually chips off pieces of the bedrock. The chatter marks which are in the form of a series of curved cracks along the direction of glacier movement, are produced when sharp pointed rock fragments dragged over the surface of the bedrock by the moving ice. It is to be noted that the curvature of the cresentic gouges are opposite to the curvatues of the chatter marks.

2.Drumlins:

Drumlin, oval or elongated hill believed to have been formed by the streamlined movement of glacial ice sheets across rock debris, or till. The name is derived from the gaelic word druim ("rounded hill," or "mound") and first appeared in 1833.

Drumlins are generally found in broad lowland regions, with their long axes roughly parallel to the path of glacial flow. Although they come in a variety of shapes, the glacier side is always high and steep, while the lee side is smooth and tapers gently in the direction of ice movement. Drumlins can vary widely in size, with lengths from 1 to 2 km (0.6 to 1.2 miles), heights from 15 to 30 m (50 to 100 feet), and widths from 400 to 600 m.

Most drumlins are composed of till, but they may vary greatly in their composition. Some contain significant amounts of gravels, whereas others are made up of rock underlying the surface till (rock drumlins). Drumlins are often associated with smaller, glacially streamlined bedrock forms known as roches moutonnées.

Drumlins are commonly found in clusters numbering in the thousands. Often arranged in belts, they disrupt drainage so that small lakes and swamps may form between them. Large drumlin fields are located in central wisconsin and in central new york; in northwestern canada; in southwestern nova scotia; and in ireland.

Landforms created by ocean:

1. Shore profile and Shoreline development:

The shoreline is the coastal zone that lies between low tide and high tide. This perpetually changing landscape is subjected to the continuous action of the sea, rivers and the wind. It can assume highly varied forms, depending on the coast’s geological makeup.

They are two types of coasts. A rocky coast is eroded by waves, which hit its cliffs with considerable force (3 metric tons per cubic meter, and up to 50 metric tons per cubic meter during storms). Rock broken off from the coast in this manner is gradually reduced to finer particles, which are deposited on coasts and mix with fluvial sediment to form another type of shoreline.

From cliff to reef

Some parts of the coast are eroded more quickly than others, depending on the type of rock that makes them up. For instance. Cliffs jutting into the sea form capes. The water carves out these exposed areas, transforming fissures into sea caves. When two sea caves meet on either side of a cape, they form a sea arch. As they are crushed, they leave a needle-shaped landmass that is subsequently transformed into an islet or reef. There where the bedrock is softer, the shoreline features a hollow, called a bay.

Beaches and marshes

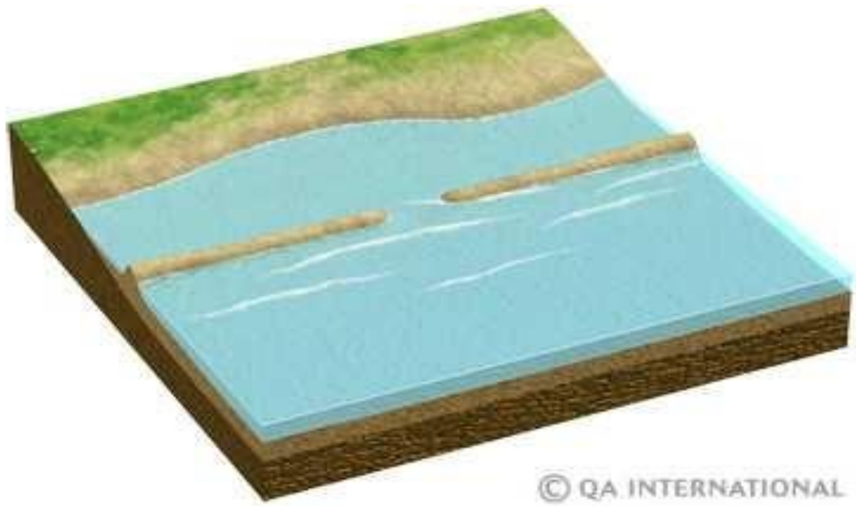
The sand and pebbles produced by the erosion of the rock face accumulate along the coast, forming a beach. A sand spit can close off a bay, forming a lagoon; when it links an island to a coast, it is called a trombola. At the mouths of rivers there may be partially flooded lowlands, called marshes.

Longshore drift

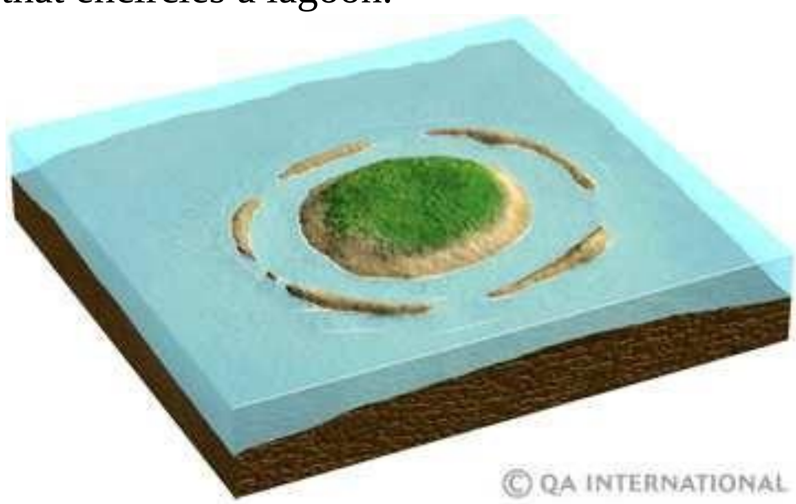
The grains of sand and pebbles deposited on the coast do not settle there permanently; they are agitated by the waves, which push them onto the shore obliquely, and then sweep them perpendicularly in the ebb, before drawing them back to shore again at an angle. This zigzag shift, called longshore drift, sets a pattern in which the sediment is moved in a precise direction.

The different types of coast

- A **barrier reef** (or barrier island) is a sandbar that stretches parallel to the coast, at a distance of a few kilometers to a few dozen kilometers. A lagoon forms behind this reef.



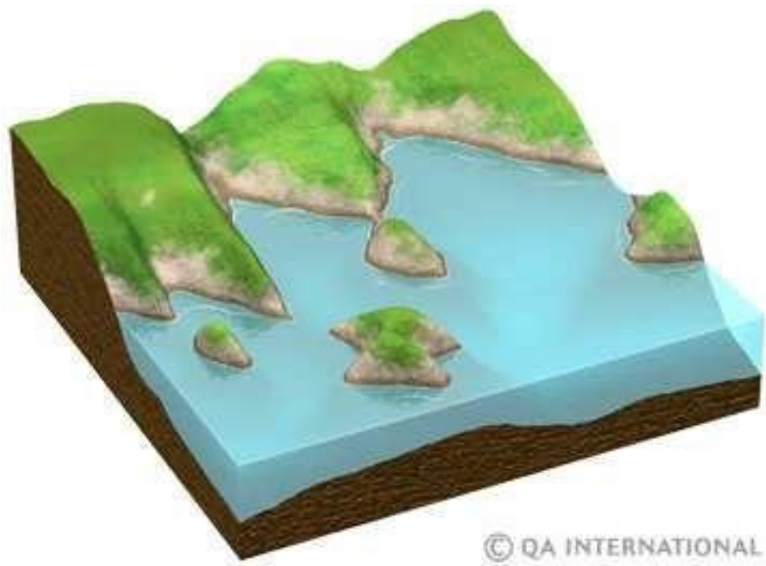
- Some shorelines are the result of volcanic eruptions. The coral reef or **atoll** that forms around a volcanic island presents a ring shape that encircles a lagoon.



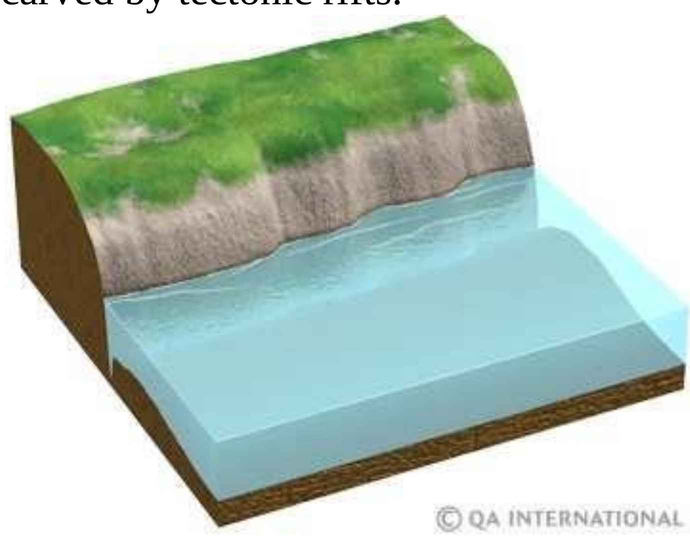
- **Fjords** (a word that means “long arms of the sea” in norwegian) are valleys that were carved out by glaciers long ago and then flooded by water. They are found in abundance along the norwegian coast.

- **Deltas** form at the mouths of rivers. They result from the accumulation and deposit of sediment transported by rivers flowing to the sea.

- Fluvial valleys that are submerged following a rise in sea level or sinking land, forming a group of inlets cut into the coastline, are called **rias.**



- Geological events have sometimes modified the coast, producing rifts. Such is the case of very high **shore cliffs** that have been carved by tectonic rifts.



Continental shelf:

A continental shelf is a portion of a continent that is submerged under an area of relatively shallow water known as a shelf sea. Much of these shelves were exposed by drops in sea level during glacial periods. The shelf surrounding an island is known as an insular shelf.

The continental margin, between the continental shelf and the abyssal plain, comprises a steep continental slope, surrounded by the flatter continental rise, in which sediment from the continent above cascades down the slope and accumulates as a pile of sediment at the base of the slope. Extending as far as 500 km (310 mi) from the slope, it consists of thick sediments deposited by turbidity currents from the shelf and slope. The continental rise's gradient is intermediate between the gradients of the slope and the shelf.

Continental slopes:

A continental slope is defined by the iho as “the **slope** seaward from the shelf to the upper edge of a **continental** rise or the point where there is a general reduction of **slope**.

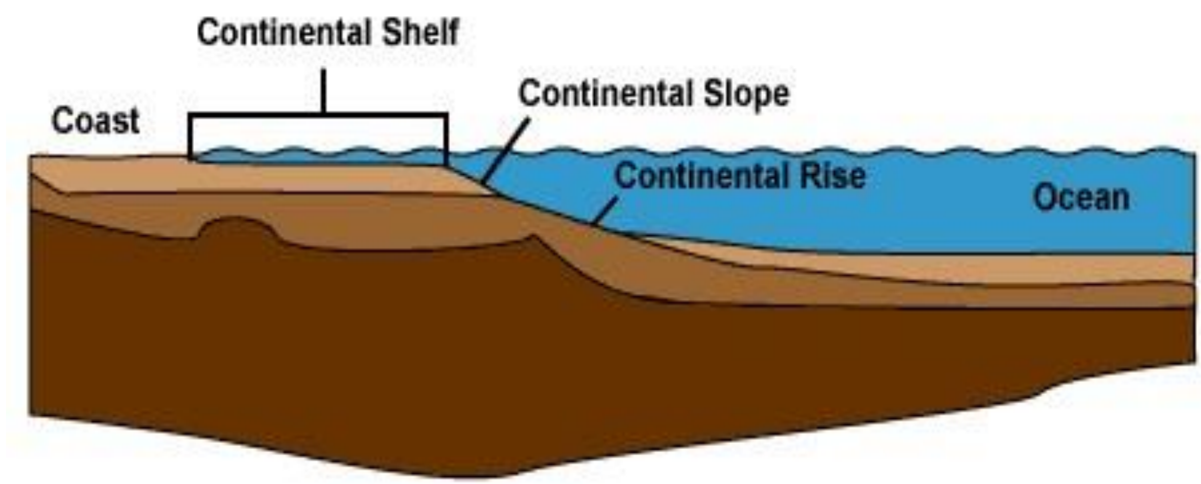
Continental slope, seaward border of the continental shelf. The world’s combined continental slope has a total length of approximately 300,000 km (200,000 miles) and descends at an average angle in excess of 4° from the shelf break at the edge of the continental shelf to the beginning of the ocean basins at depths of 100 to 3,200 metres (330 to 10,500 feet).

The gradient of the slope is lowest off stable coasts without major rivers and highest off coasts with young mountain ranges and narrow continental shelves. Most pacific slopes are steeper than atlantic slopes. Gradients are flattest in the indian ocean. About one-half of all continental slopes descend into deep-sea trenches or shallower depressions, and most of the remainder terminate in fans of marine sediment or in continental rises. The transition from continental crust to oceanic crust usually occurs below the continental slope.about 8.5% of the ocean floor is covered by the continental slope-rise system.

Continental rise:

The **continental rise** is a sediment underwater feature found between the continental slope and the abyssal plain. This feature can be found all around the world, and it represents the final stage in the boundary between continents and the deepest part of the ocean. The environment in the continental rise is quite unique, and many oceanographers study it extensively in the hopes of learning more about the ocean and geologic history.

At the bottom of the continental slope, one will find the continental rise, an underwater hill composed of tons of accumulated sediments. The general slope of the continental rise is between 0.5 degrees and 1.0 degrees. Deposition of sediments at the mouth of submarine canyons may form enormous fan-shaped accumulations called submarine fans on both the continental slope and continental rise. Beyond the continental rise stretches the abyssal plain, an extremely deep and flat area of the sea floor .the abyssal plain hosts many unique life forms which are uniquely adapted to survival in its cold, high pressure, and dark conditions .the flatness of the abyssal plain is interrupted by massive underwater mountain chains near the tectonic boundaries of the earth's plates .the sediments are mostly sand and pieces of coral or rock.



Ocean floor marine erosion:

The ocean floor (also known as the seafloor, sea floor, or sea bed) is the bottom of the ocean, no matter how deep. All floors of the ocean are known as ocean floor.

Most of the oceans have a common structure, created by common physical phenomena, mainly from tectonic movement, and sediment from various sources. The structure of the oceans, starting with the continents, begins usually with a continental shelf, continues to the continental slope – which is a steep descent into the ocean, until reaching the abyssal plain – a topographic plain, the beginning of the seabed, and its main area. The border between the continental slope and the abyssal plain usually has a more gradual descent, and is called the continental rise, which is caused by sediment cascading down the continental slope.

The mid-ocean ridge, as its name implies, is a mountainous rise through the middle of all the oceans, between the continents. Typically a rift runs along the edge of this ridge. Along tectonic plate edges there are typically oceanic trenches – deep valleys, created by the mantle circulation movement from the mid-ocean mountain ridge to the oceanic trench.

Hotspot volcanic island ridges are created by volcanic activity, erupting periodically, as the tectonic plates pass over a hotspot. In areas with volcanic activity and in the oceanic trenches there are hydrothermal vents – releasing high pressure and extremely hot water and chemicals into the typically freezing water around it.

Deep ocean water is divided into layers or zones, each with typical features of salinity, pressure, temperature and marine life, according to their depth. Lying along the top of the abyssal plain is the abyssal zone, whose lower boundary lies at about 6,000 m (20,000 ft). The hadal zone – which includes the oceanic trenches, lies between 6,000–11,000 metres (20,000–36,000 ft) and is the deepest oceanic zone.

Features formed by marine reefs:

Coral reefs are made of the calcium carbonate skeletons of corals – small immobile animals closely related to jellyfish. Though individual corals can be quite small, they live with millions of other individuals, and over the course of hundreds of thousands of years, they build reefs that are absolutely enormous. The largest coral reef in the world, the great barrier reef in australia, can be seen by astronauts in outer space. Unlike rocky reefs, where the reef structure is created by geological processes, the reef structure on coral reefs is created by biological processes – the growth and death of reef-building corals, sponges, and other immobile marine animals. This structure provides holes, crevices, and even caves for all sorts of other animals, including shrimps, crabs, clams, snails, fishes, and many more. Numerous species are perfectly adapted to a coral reef lifestyle.

Corals prefer warm, clear, shallow water, and these reefs are found throughout the tropics. Different species of corals live in different ocean basins, so reefs in the tropical western atlantic ocean can look different than reefs in the indo-pacific ocean.

Furthermore, scientists have different names for coral reefs based on the way in which they grow: fringing reefs are those directly attached to the shore; barrier reefs are separated from shore by a lagoon; patch reefs are small reefs that occur throughout a lagoon but do not form part of the barrier reef; and atolls are circular reefs surrounding a lagoon that no longer includes a central island.

In addition to being home to countless marine animals, coral reefs are very important ecosystems for coastal peoples. They are often the first line of defense against strong tropical storms for coastal communities, and at least 400 million people rely on coral reef fisheries for income and food. Furthermore, high value tourism in many places relies on healthy, intact coral reefs to attract visitors to remote parts of the world. These services, and others, combine to make coral reefs extremely valuable to nearby communities. Unfortunately, coral reefs face numerous threats to their continued survival.

Destructive fishing practices, pollution, and invasive species threaten local coral reefs in populated areas. Climate change and ocean acidification threaten all coral reefs around the world. Without careful management of human activities and an active reversal of global threats, entire coral reefs may be lost.

Deposits and sediments:

1. Deposit is sediment or rock that is not native to its present location or is different from the surrounding material sometimes refers to ore or gem.

The ocean deposits can broadly be divided into two types—the terrigenous deposits and the pelagic deposits. The terrigenous deposits are those which are found on the continental shelves and slopes and mainly consist of the rock material derived because of wear and tear. The pelagic deposits are those which are found over deep-seaplains and the deeps.

These deposits mainly consist of organic remains of plants and animals. But this distinction between the two types of deposits is not absolute.

Terrigenous deposits (abyssal deposits):

Terrigenous deposits are derived from the wear and tear of land and volcanic and organic products. The greater part of the deposits on the continental shelf and slopes is derived from rock material let loose by disintegration and decomposition by the agents of weathering and carried to sea by the agents of erosion, such as running water, wind, etc.

The process and extent of disintegration depends on the nature of rock material, climate and time taken. The larger particles of the terrigenous deposits are found near the shore and the finer ones carried deeper. The extent to which they are carried outwards depends on the size of rock material and the strength of sea waves and currents.

On the basis of size of particles, the terrigenous deposits may be categorized into three classes mud, sand and gravel. Mud refers to the finest particles which comprise the minute particles of rock forming minerals, principally quartz. Murray has classified the mud deposits into blue, green and red types, based on the colour of constituents. Sand refers to the coarser particles, while gravel has even bigger particles.

Pelagic deposits (deep sea deposits):

Pelagic deposits are the most conspicuous of all deposits—covering about 75% of the total sea floor. This is because, except for fine volcanic ash, little terrigenous material is carried into the deeps. The pelagic deposits consist of both organic and inorganic material.

- **Organic material:**

This is in the form of a kind of liquid mud, called ooze, which contains shells and skeletons of various marine organisms. The ooze is said to be calcareous when the shell is made of calcium carbonate. The calcareous ooze may be either pteropod ooze or globogerina ooze. Most parts of the indian and atlantic oceans have calcareous ooze as deposits (fig. 3.13). When the shell is made of silica, the ooze is said to be siliceous ooze, which can be either the diatom type or the radiolarian type of ooze. The southern fringes of the indian and the atlantic oceans have the siliceous type of ooze.

- **Inorganic material:**

This is in the form of red clay, which is apparently of a volcanic origin. The chief constituents of red clay are silicon and aluminium dioxide, while other constituents include iron, manganese, phosphorus and radium. The red clay is the most widely spread pelagic deposit and covers 38% of the sea floor. The red clay covers more than half of the pacific floor

2. Sediment is a collection of small particles, particularly dirt, that precipitates from a river or other body of water.

Pelagic sediments:

Pelagic sediment is a fine-grained sediment that accumulates as the result of the settling of particles to the floor of the open ocean, far from land. These particles consist primarily of either the microscopic, calcareous or siliceous shells of phytoplankton or zooplankton; clay-size siliciclastic sediment; or some mixture of these. Trace amounts of meteoric dust and variable amounts of volcanic ash also occur within pelagic sediments. Based upon the composition of the ooze, there are three main types of pelagic sediments: siliceous oozes, calcareous oozes, and red clays.

The composition of pelagic sediments is controlled by three main factors. The first factor is the distance from major landmasses, which affects their dilution by terrigenous, or land-derived, sediment. The second factor is water depth, which affects the preservation of both siliceous and calcareous biogenic particles as they settle to the ocean bottom. The final factor is ocean fertility, which controls the amount of biogenic particles produced in surface waters.

- **Oozes**

In case of marine sediments, ooze does not refer to a sediment's consistency, but to its composition, which directly reflects its origin. Ooze is pelagic sediment that consists of at least 30% of microscopic remains of either calcareous or siliceous planktonic debris organisms. The remainder typically consists almost entirely of clayminerals. As a result, the grain size of oozes is often bimodal with a well-defined biogenic silt- to sand-size fraction and siliciclastic clay-size fraction. Oozes can be defined by and classified according to the predominate organism that compose them. For example, there are diatom, coccolith, foraminifera, globigerina, pteropod, and radiolarian oozes. Oozes are also classified and named according to their mineralogy, i.e. calcareous or siliceous oozes. Whatever their composition, all oozes accumulate extremely slowly, at no more than a few centimeters per millennium.

Calcareous ooze is ooze that is composed of at least 30% of the calcareous microscopic shells—also known as tests—of foraminifera, coccolithophores, and pteropods. This is the most common pelagic sediment by area, covering 48% of the world ocean's floor. This type of ooze accumulates on the ocean floor at depths above the carbonate compensation depth.

Siliceous ooze is ooze that is composed of at least 30% of the siliceous microscopic "shells" of plankton, such as diatoms and radiolaria. Siliceous oozes often contain lesser proportions of either sponge spicules, silicoflagellates or both. This type of ooze accumulates on the ocean floor at depths below the carbonate compensation depth. Its distribution is also limited to areas with high biological productivity, such as the polar oceans, and upwelling zones near the equator. The least common type of sediment, it covers only 15% of the ocean floor. It accumulates at a slower rate than calcareous ooze: 0.2–1 cm/1000 yr.

- **Red and brown clays:**

Red clay, also known as either brown clay or pelagic clay, accumulates in the deepest and most remote areas of the ocean. It covers 38% of the ocean floor and accumulates more slowly than any other sediment type, at only 0.1–0.5 cm/1000 yr.[1] containing less than 30% biogenic material, it consists of sediment that remains after the dissolution of both calcareous and siliceous biogenic particles while they settled through the water column. These sediments consist of aeolian quartz, clay minerals, volcanic ash, subordinate residue of siliceous microfossils, and authigenic minerals such as zeolites, limonite and manganese oxides. The bulk of red clay consists of eolian dust. Accessory constituents found in red clay include meteorite dust, fish bones and teeth, whale ear bones, and manganese micro-nodules.

These pelagic sediments are typically bright red to chocolate brown in color. The color results from coatings of iron and manganese oxide on the sediment particles. In the absence of organic carbon, iron and manganese remain in their oxidized states and these clays remain brown after burial. When more deeply buried, brown clay may change into red clay due to the conversion of iron-hydroxides to hematite.

Volcanogenic sediments

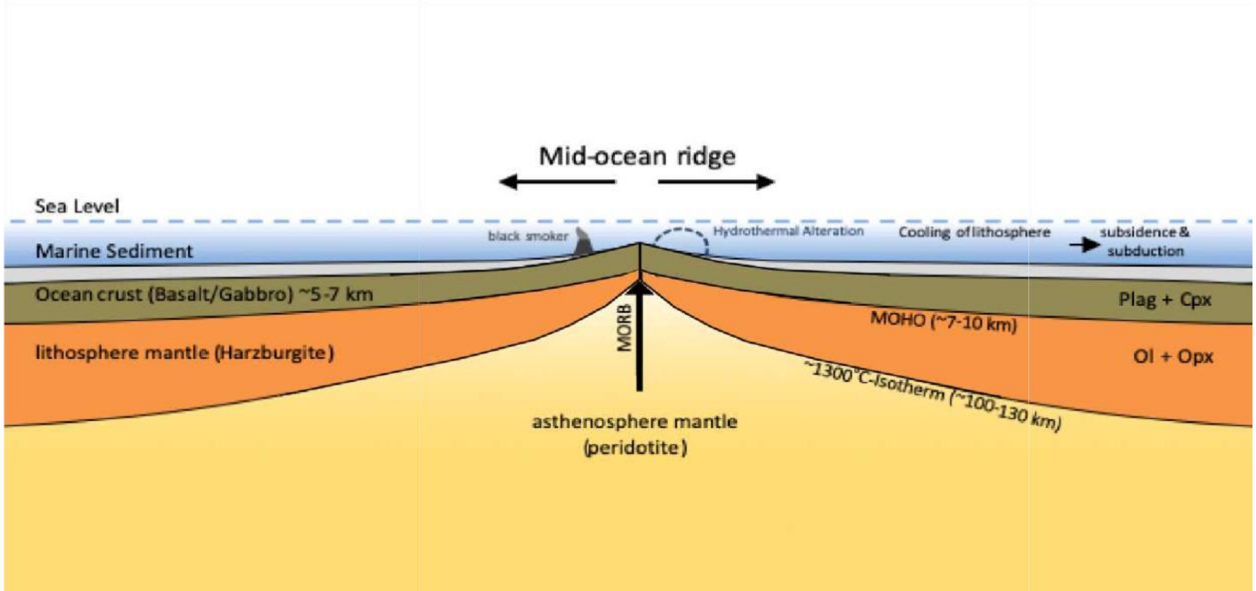
Mineral deposits occurring in cases of the entry into ancient and modern sea and ocean basins of mineral products formedduring volcanic eruptions on the sea floor, on islands, and along the shores and upon the precipitation of these products inthe form of strata and nodules. The mineral products entered the areas of sedimentary accumulation in solutions of volcanicgases and hot waters of volcanic origin, in a state of adsorption on the surface of volcanic ash, or upon decomposition ofcooled lavas and ash by sea water as a result of their leaching and removal from lava and ash by volcanic gaseous andliquid solutions.

Volcanogenic sedimentary deposits include large stratified deposits of iron and manganese ores composed of silicates,carbonates, oxides, and hydroxides of the above metals, as well as pyrite ores containing sulfide compounds of iron, copper,and zinc and occasionally lead, barite, and gypsum. Certain investigators believe that some phosphorite and bauxite depositsare also volcanogenic sedimentary deposits. They are deposited in layers of rock consisting of lavas, ash, and strata ofsiliceous rocks alternating with normal marine deposits.

Accumulations of nodular iron and manganese ores, which are foundon the bottom of the pacific, atlantic, and indian oceans and contain admixtures of cobalt, nickel, molybdenum, and othervaluable metals, may also have been produced as a result of submarine eruptions of youngvolcanoes .

Volcanogenicsedimentary deposits of ancient and modern geological periods are known.

Mid oceanic ridges:



A **mid-ocean ridge (MOR)** is a seafloor mountain system formed by plate tectonics. It typically has a depth of ~ 2,600 meters (8,500 ft) and rises about two kilometers above the deepest portion of an ocean basin. This feature is where seafloor spreading takes place along a divergent plate boundary. The rate of seafloor spreading determines the morphology of the crest of the mid-ocean ridge and its width in an ocean basin. The production of new seafloorand oceanic lithosphere results from mantle upwelling in response to plate separation. The melt rises as magma at the linear weakness between the separating plates, and emerges as lava, creating new oceanic crust and lithosphere upon cooling. The first discovered mid-ocean ridge was the mid-atlantic ridge, which is a spreading center that bisects the north and south atlantic basins; hence the origin of the name 'mid-ocean ridge'. Most oceanic spreading centers are not in the middle of their hosting ocean basis but regardless, are traditionally called mid-ocean ridges. Midocean ridges around the globe are linked by plate tectonic boundaries and the trace of the ridges across the ocean floor appears similar to the seam of a baseball. The mid-ocean ridge system thus is the longest mountain range on earth, reaching about 65,000 km (40,000 mi).

Submarine canyon:

A submarine canyon is a steep-sided valley cut into the seabed of the continental slope, sometimes extending well onto the continental shelf, having nearly vertical walls, and occasionally having canyon wall heights of up to 5 km, from canyon floor to canyon rim, as with the great bahama canyon.

Just as above-sea-level canyons serve as channels for the flow of water across land, submarine canyons serve as channels for the flow of turbidity currents across the seafloor. Turbidity currents are flows of dense, sediment laden waters that are supplied by rivers, or generated on the seabed by storms, submarine landslides, earthquakes, and other soil disturbances. Turbidity currents travel down slope at great speed (as much as 70 km/h), eroding the continental slope and finally depositing sediment onto the abyssal plain, where the particles settle out.

About 3% of submarine canyons include shelf valleys that have cut transversely across continental shelves, and which begin with their upstream ends in alignment with and sometimes within the mouths of large rivers, such as the congo river and the hudson canyon. About 8.5% of submarine canyons cut back into the edge of the continental shelf, whereas the majority (about 68.5%) of submarine canyons have not managed at all to cut significantly across their continental shelves, having their upstream beginnings or "heads" on the continental slope, below the edge of continental shelves.

The formation of submarine canyons is believed to occur as the result of at least two main process:

1) erosion by turbidity current erosion; and

2) slumping and mass wasting of the continental slope.

While at first glance the erosion patterns of submarine canyons may appear to mimic those of river-canyons on land, several markedly different processes have been found to take place at the soil/water interface.

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