Chapter No :5

Evolution of Landforms (Erosional and Depositional

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| **Evolution of Landforms (Erosional and Depositional)**: Fluvial, Aeolian, Karst Glacial, and Coastal. |

Unit No 1

**FLUVIAL TOPOGRAPHY**

**WORK OF RIVER/ RIVERINE TOPOGRAPHY**

River is one of the important agents of erosion on the surface of the earth especially in humid region. When rainfall accurs, some part of it evaporate to atmosphere, some parts percolcate down to underground and remaing flow in the from of run off through some narrow stream channels. After the meeting of a number of minor streams, a big stream is formed which is described as river.

Usually the rivers originate from highlands like hills, mountain to sea, they do the work of erosion (wearing & tearing of rocks) transportation of eroded materials & deposition of carried sediment at appropriate place.

**SPECIFIC TERMS OF RIVER**:-

1. ***Source of the river***:-The place where the river takes its origion is called the source of the river or Head of river.
2. ***Mouth of river***:- The place at which the river joins the sea /ocean/lake is know as mouth of the river.
3. ***Valley***:-The path followed by the river on the land surface is called its valley.
4. ***Drainage Basin***:-Many tributary streams join the master stream of river and the entrie area is known as drainage basin.
5. ***Catchment area***:- The area from which the river draws its water is called its catchment area.
6. ***Interfluve***:- An upland dividing two drainage basin is called as a watershed or water divide or interfluves.

**FLUAIAL TOPOGRAPHY:-**

The topography formed by the work of river for runing water is known as flumial topography.

**FORMATION OF RIVER**:-

The water obtained from rain, snow & hail in the froms of small streams. When these small streams join together, they form a big and permanment river.e.g.Amezon river, Nile river, Ganga river, Sindhu, Brahumputra, Missicippi, Misuri, Ho-yang-ho river etc. Amezon river in S.America is the biggest river while Nile river is the longest river in the the world.

**TYPES OF RIVER WORK:-**

A river does three types of work .They are erasion, transportation and the deposition.

***EROSIONAL WORK OF RIVER.***

The ability of river, to scuptrue the country rocks, is controlled by number of factors i.e. velocity, load, discharge and slope of the river. Steeper slope, higher velocity, and more land of river may perfrom grater amount of erosion alone the river may perfrom greater amount of erosion along the river course. In addition to nature of rocks whether hard or soft and chemical composition of water also determine the erosional copability of river.However,under the different sets of condition, the river do the work eroson through different process as below.

* 1. ***Hydraulic process***:-Hydraulic process refers to the breaking down of rocks under the impact of contineous flow of water in river valley.
  2. ***Corrosion or Abrasion***:-The stones from the rocks and boulders are ralled along the bed of the stream.The particles get smothered and rounded as they strike against the sides and bottom of the river vailey.This is known as corrosion&abrasion.
  3. ***Solution***:-Certain rocks have soluble companents which are easily dissolved by the solution.action of work.

*Factors affecting erosional work of a river:-*

Two most important affecting the erosional work of river are volume& velocity of the water.

A river with large volume of water moving all high velocity has great capacity to erode. Erosional work of river also depends upon the nature of rocks. The soft rocks are easily eroded where as hard and resistant rocks with stand erosion for a langer period.(Types of erosional work)

***TRANSOPORTATION:***- The material eroded by the river is carried down the stream by the flow of water. The material which is transportent by the river is called its load. If includes all sorts of material varying from fine particles to big boulders.

***Factors affecting transportantion by river***:-

The most important factor which affects the process of transportion by river is the velocity of water.The greater the velocity of the river, the the greater is capacity of river to transposrt. The capacity is proportianol to sixth power of the velocity of astream.Thus if the velocity is doubled.The transportation capacity will be ( =64 times.

The second important factors is the volume of water if the volume of water in the river is doubled, thetransportion capacity will also be doubled, the transportion capacity will also be doubled. The size of the load is also an important factor.small particles are carried to small distance.

***DEPOSITION WORK OF A RIVER***.

As soon as the river looses its capacity to transport, it starts its depositional work. This happens due to decrease in the volume and velocity of water as well as to increase in the the load of river.Big boulders are first to be deposited. They are followed by pebbles, gravel, sound and silf.Most of the sediments is deposited at the banks, at the bottom of the valley and at the mouth of the river.About one fourth of the total sediments is carried to the sea.

**TYPES OF EROSIONAL WORK ACROSS THE RIVER VALLEY.**

1. **Vertical Erosion** :-When the running water erodes the bottom bed rock of river valley on which it flows, is called as vertical erosion of river.Due to the vertical erosional process of river, the bottom bed rocks are eroded and deeped depression is formed.If the soft rocks came along its flow path, then the deepness of valley is increased due to fast ersion on that rock.
2. **Lateral Erosion**:-When the runninng water erodes the sides of bed rocks along the river valley.it is called as lateral or side erosion of river.Due to lateral erosion, the widens of river valley is formed.

SHORT TERMS:-

1. Erosion- The breaking down or removal of rocks from the surface of the earth is known as erosion or erosicve action of river.
2. Transoportation:- The work in which the river carry away the eroded material from one place to another place is called transportation.
3. Deposition – The work in which the river deposits the transpoted material is called deposition.
4. Vertical erosion- When river erodes the downwards and deepens the valley, it is known as vertical erosion.
5. Lateral erosion- When river erodes the sides and widens the valley.It is known as laterai erosion.

.Load of river:- The eroded materials carried by river is known as land of river.

**LANDFORMS FORMED BY A RIVER**

A river forms a large variety of landfroms right from its source to its mouth.bu its erosional transportational and deposition work.From this point of view, the entrie course of river is divided into three parts,

i)The upper course

ii)The middle course

iii)The lower course

The longitudinal cross section of river valley represents a very smooth curve from the source to the mouth. It is flatlened at to near the mouth and slightly rising upstream. The river represents different nature of denudational and upgradation works along the whole length og the river course.

In the upper course area, the source region, usually have very steep slope resulting higher velocity, dominant erosional activity as especially down cutting of valley. In this part of river valley, depositional work is almost absent. A number landforms like V-shaped valley. gorges , Canyon, Waterfall, rapids, pot holes are formed by the erosional work of the river.

In the middle course of river, the speed of the water is moderate due to the moderate slope of land on which river flows. The erosional and depositional work are constant due to the same down cutting and side of river. Landforms like alluvial cones, alluvial fans, river meandering, and oxbow lakes are formed by the erosional and depositional work of river .

In the lower course of river the speed of water is very very slow or almost zero due to the very gentle slope of that land on which river water flows. The erosional work is almost zero while the depositional work is more in that course. Mainly braided stream, floodplains, natural levees and delta are these landforms are formed in the lower stream due to the depositional work of river.

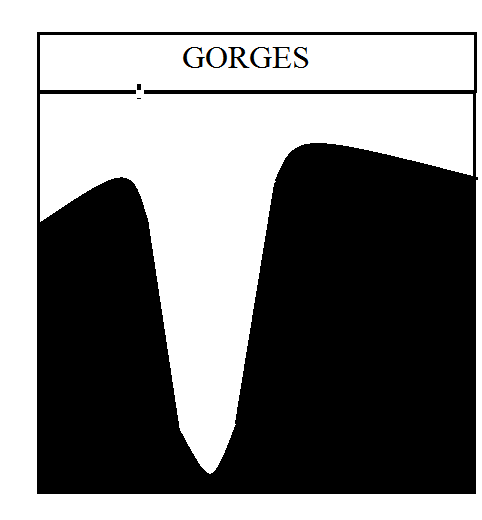
Landforms formed in the upper course of river :-

The upper course of a river starts from its source where erosion is the main work of the river. Following are the main features of the course.

1. **Gorge** :-

Such landforms are formed at initially at near the head of the river in the mountain regions only due to the erosional work of the running water.

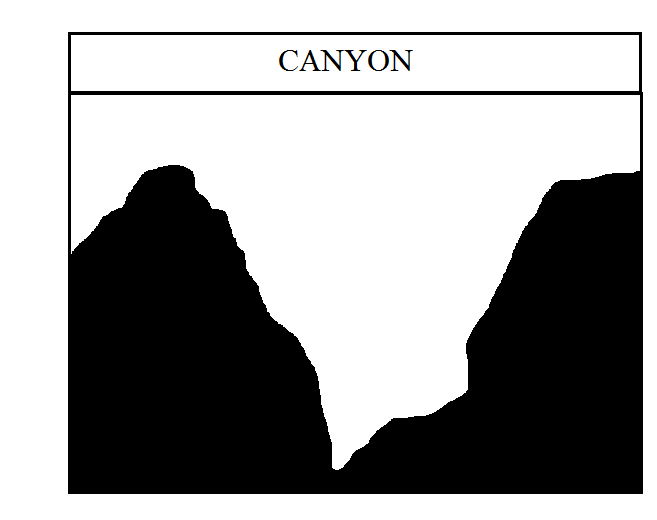
When the river passes through hard rocks in mountain areas, its main erosional work is that of down cutting only while its side cutting is negligibly small due to the very steeper slope of relief land and high velocity of running water this results in the formation of a deep and narrow valley reassembling that I- shaped known as gorges. For example, Sutlej, Indus, Brahmaputra Narmada, Gandak are these rivers have cut a deep gorgeous in their upper course



1. **Canyon :**-

Such landforms are formed in the erosional work of river where downcutting is more active and dominant than the side cutting of the river.

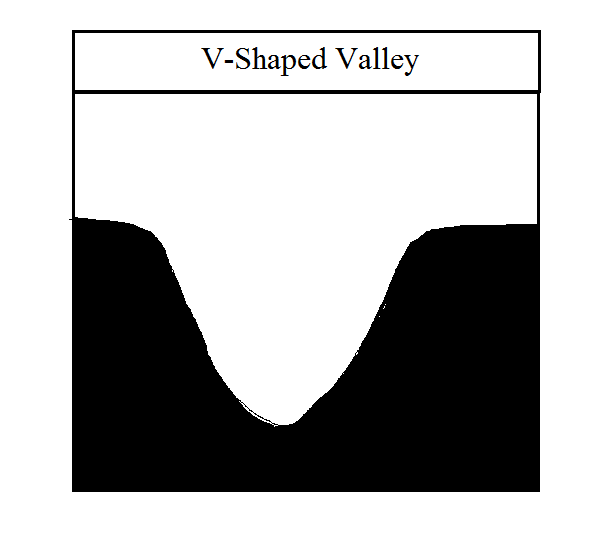
A long and deep gorge is known as Canyon generally it is the enlarged form of gorgeous Canyon. Generally it has high vertical walls on both sides the upper parts of the canyon is wide due to weathering but lower part is narrower due to rapid downcutting. The Grand Canyon made by Colorodo river in USA is the best example of canyon.



1. **V shaped Valley**

Such landforms are formed in all stages of river by the erosional work of running water.

When the down cutting and side cutting of erosional work are take place on soft river rock beds simultaneously. Then dip and widen valley resembling v-shaped is formed. It is known as V shaped Valley. It has steep slopes on both sides. Most rivers of the world have V- shaped valley. Generally the width and the depth are equal in the upper course of river. But its widthness is going on flattening with low depth towards the middle and lower course of river.

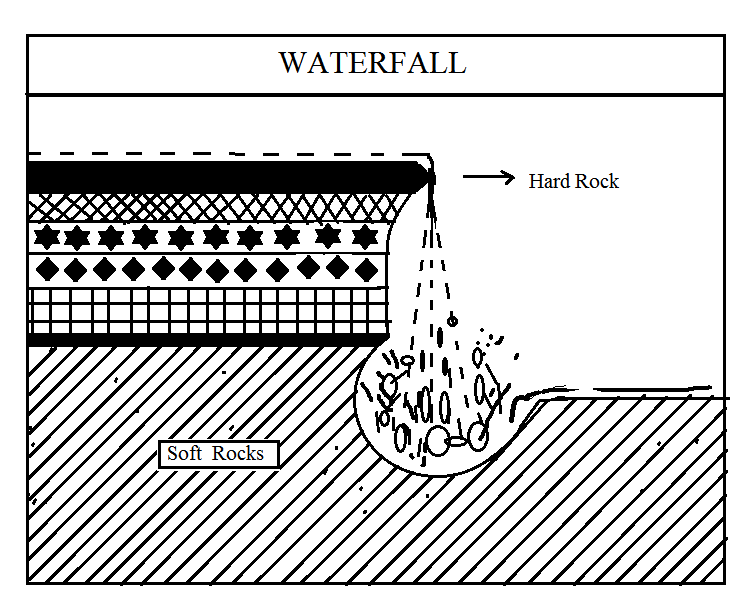


1. Waterfall : -

Such landforms are formed in the upper course of river by the erosional work of running water on the soft and hard rocks. When the river water suddenly falls from a sufficient height, it is said to have formed a waterfall. This is due to the presence of hard and soft rocks across the river valley the soft rocks are easily eroded and hard rocks remains in their position leading to the formation of waterfall. It happens under the following two conditions i.e i) horizontal layer of the soft and hard rocks and ii) vertical layer of soft and hard rock structure.

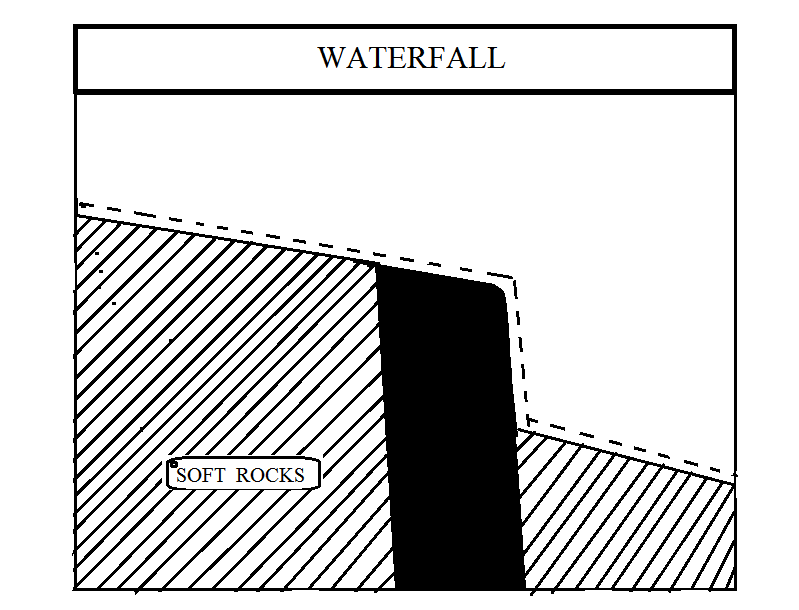
1. **Horizontal layer of soft and hard rocks** :-

When hard and soft rocks are arranged in horizontal layers, the soft rocks are quickly eroded in the level of hard and soft rocks and a waterfall comes into being. The falling water erodes material at its base and a plungo pool to be formed. With the passage of time, the size of that plungo pool increases. Tthe overlying rocks loses its base and falls down resulting in the recession of waterfall ( Shifting of waterfall) so the displacement of location of such waterfall is always takes place.



1. **Vertical layer of soft and hard rocks** :-

Whenever the hard and soft rocks are arranged alternatively in vertical layers, the hard rocks are not easily eroded up to its hardness capacity due to the power of the running water but its next adjacent the soft rocks are easily eroded due to its softness at that situation and the hard rocks stands vertically like as dyke or obstacle across the river . At that time, water falls down from the sufficient height of hard rocks and waterfall is came into being. Here the displacement of location of waterfall is not occurs due to its strong and harder rock base. Under this condition, a number of waterfalls are formed by various rivers in their youth stage in the world i.e. Niagara waterfall, Victoria waterfall and Jog waterfall in India. Niagara waterfall recedes by 1 meter per year.

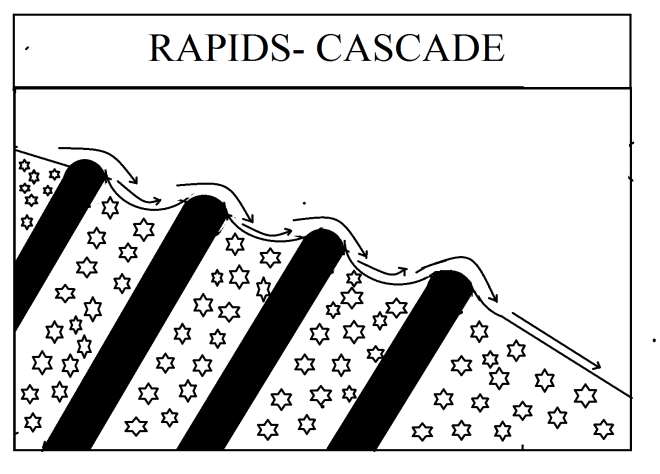


1. **Rapids** :-

Such landforms are formed in the upper course of river by the erosional work of river on series of hard and soft rocks. Sometimes, an alternative series of hard / resistant rocks or and soft rocks came across in the way of river valley, the river erodes the soft rocks and resistance rock remain standing. Thus, the water of river flows through step-like valley falling down from one step to another step. Such type of falling water from relatively lower height as described as a rapids. They are very dangerous for vessel / ship sailing in the river. River Nile has formed a many rapids between Aswan and Khartum.

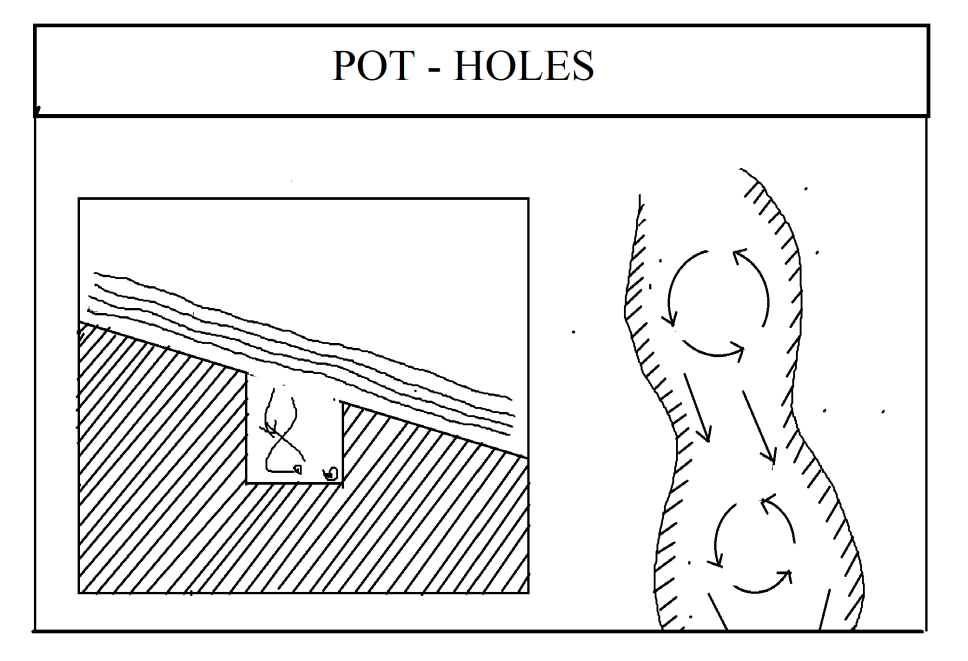
Cascade:-

Sometimes, a large number of continuous rapids is formed across the river and it is known as cascade.



1. **Potholes :-**

Such landforms are formed in the upper course of the river where the velocity of river flow is more and the width of valley became comparatively broader, due to the erosional work of running water. With the running of running water of river, much of the fragmented rocks are present which are brought by river itself from high mountain regions. When this river flows on the beds , some of the fragmented rocks are blocked in the crevices or joints of the river bed. Because of speed of that flowing water, this fragmented rocks make a whirling motion or circular motion along this water. Due to that abrasion action of fragmented rocks with the river bed valley, a circular cylindrical hole has formed on the bed of river. Such, this depression in the bed of river is known as potholes. The diameters of that potholes may vary from few centimetres to metres and depth sometimes reaches up to 7 to 8 metres deep. When the potholes becomes larger and deeper it is known as this plungo pools may remained for longer time if they are formed of resistant rocks and it may for shorter time if they are formed by soft rocks.

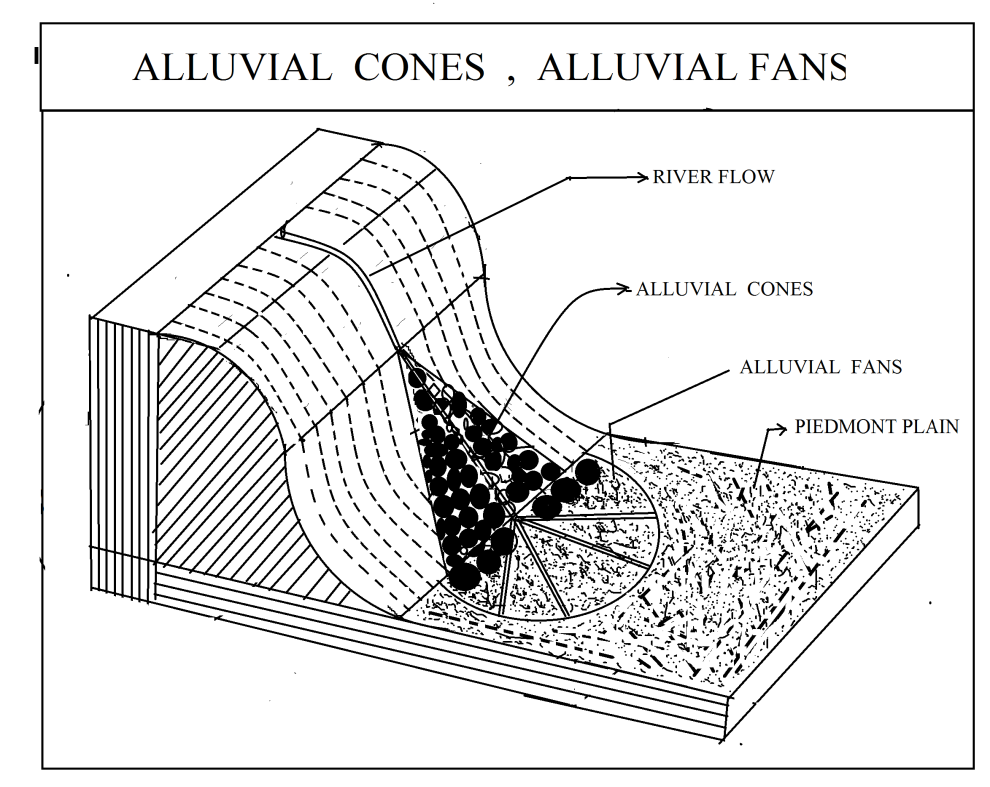


**Landforms formed in the middle middle course of the river**

A River descends down from the highland to the plain regions.In the plain region, the velocity, gradient slope, erosional and transportation capacity of river are reduced to a considerable extent. A number of tributary river joins the mainstream and consequently the discharge of water and loads of river also increases. Lateral erosion and depositional works are taking place and down cutting is relatively slowed down due to decline in gradient of the river. Under this situation of river different kinds of erosional and depositional features formed in the middle course of river.

1. **Alluvial cones and Alluvial fans** :-

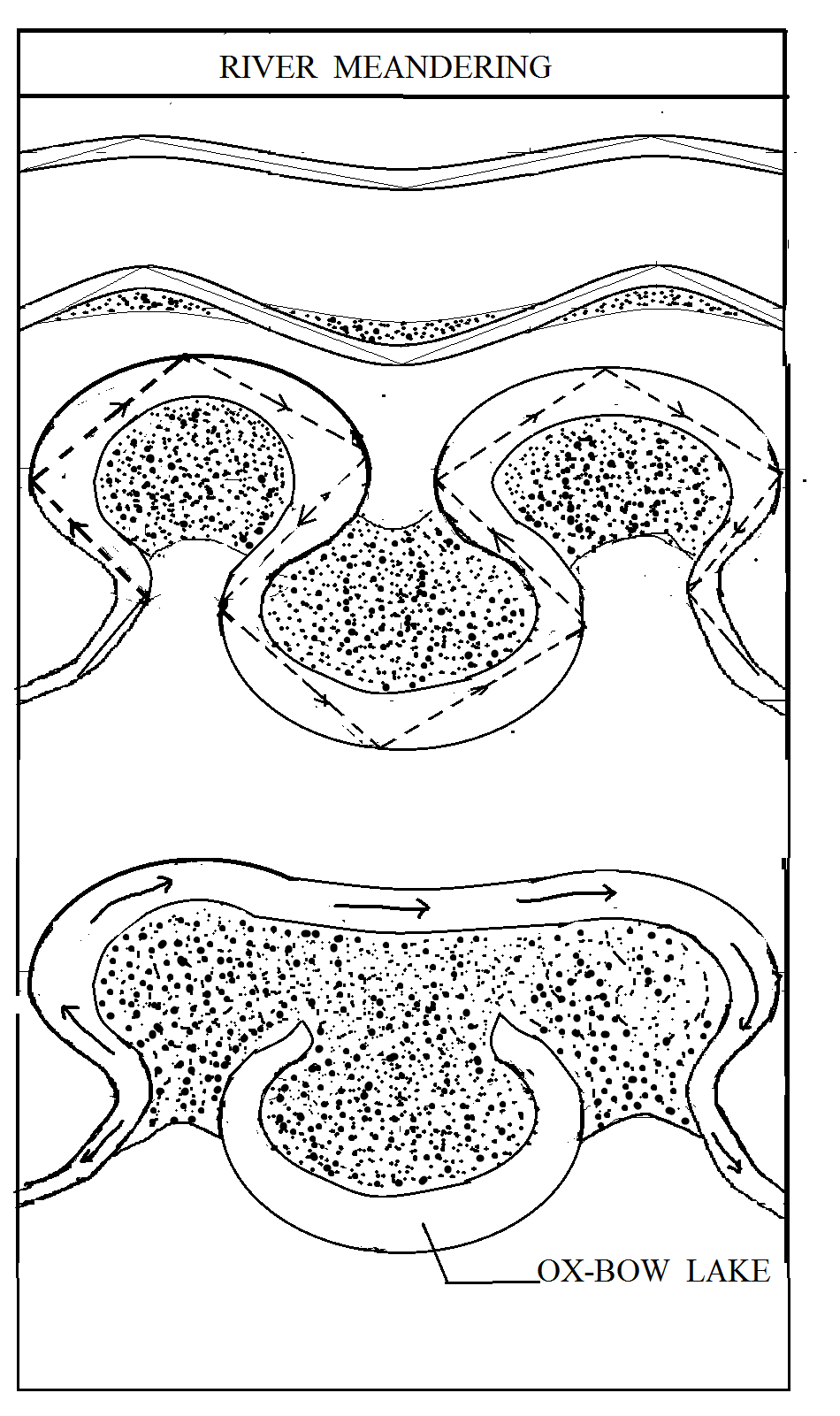
Such landforms are formed at the junction point of hill and plain area due to the partial erosional and depositional work of river in the middle course of it. When the river enters into the plain area from the high mountain course sized sediments was transported by river are deposited along the junction point of mountain and plain. Such type of depositional features along the foot of mountain is known as a alluvial cones at they are having appearance like of cone. It contains less water and more sediment deposits in it. The river water divides the alluvial cone and spread into many channel and forms alluvial fans. It is a fan-shaped mass of sand and gravel with its apex pointing upstreams and its fan formation downstream. It forms when the quantity of water is more than its a sediment deposits. It looks the old typed Kings fan , therefore it is known as alluvial fans and it is contains more volume of water and less sediments.



1. **River meandering :-**

Such landforms are formed in the plain areas where the slope of gradient is gentle and more irregular sediment deposition takes place along the river banks in the middle course of river work.

A river never follows a straight path but curves its way depending upon the relief land. River in the plain area gets more and more loads by different tributaries on the one hand and the carrying capacity of river declines on the other hand due to change in the gradient from steeper to gentler. Due to decrease in the transportation capacity of it, the deposition of sediments along the sides shop on the bed of the valley takes place. When the accumulation of loads on one side becomes greater than other side, the river beds towards the lower side by making erosion and a small turn develops in the river course. With a continuation of this process, this turn develops further and S-shaped course of river is formed. Such feature is known as river meandering. Generally the S-shaped curvature of the river stream in the plain areas due to the irregular deposition along its bed , is known as river meandering. Such landscape is seen in the plain of Uttar Pradesh, Bihar, West Bengal state by Ganga river.



1. **Oxbow lake**

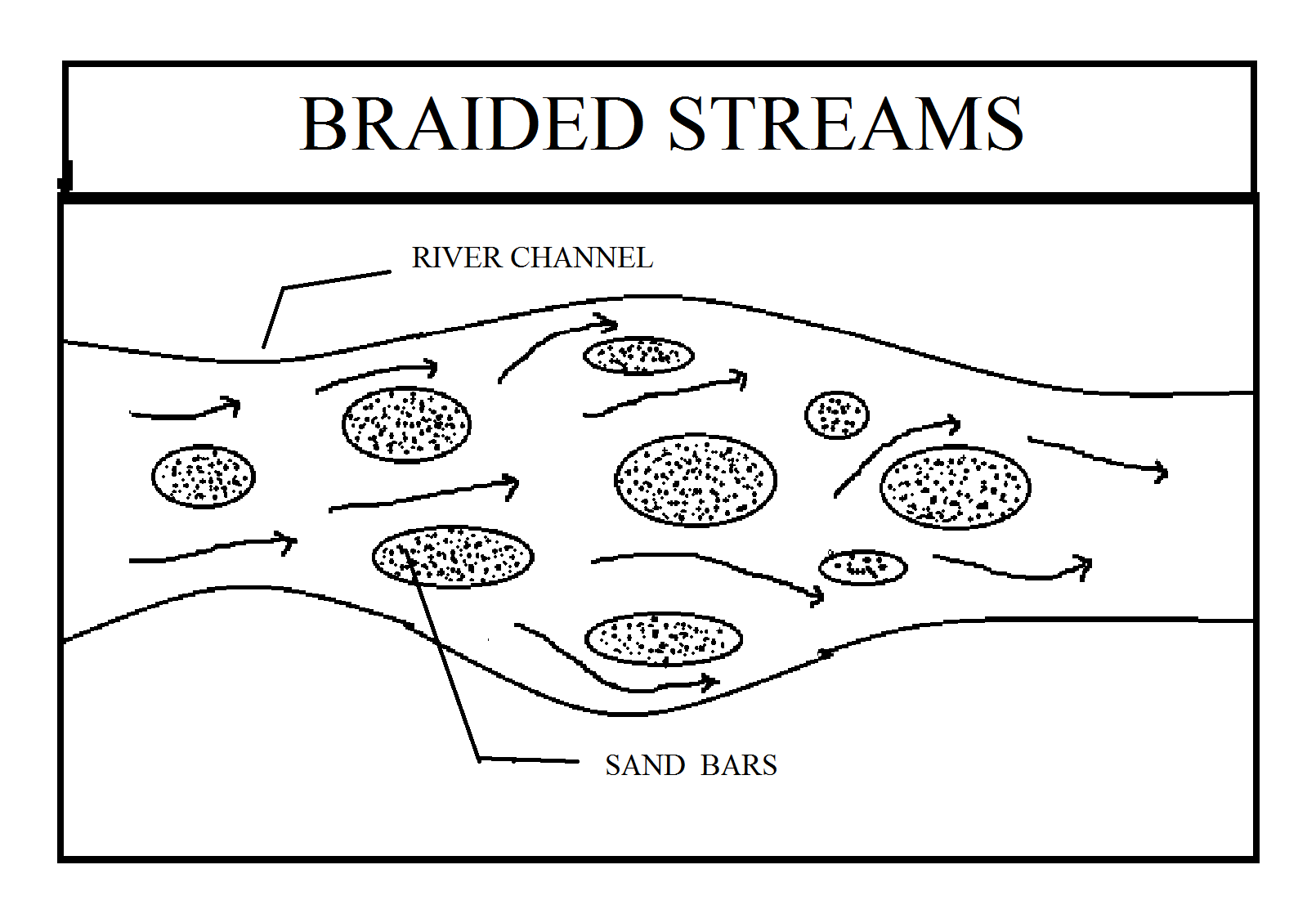
Such landforms are formed in the plain areas from the river meandering in the middle course of river due to the depositional work of river.

When a river course begins to bend in large curves, the strong currents srikes to the outer back bank of meander. Thus the outerbank is undercut and steep slope is formed. This eroded steep sloped outer bank of meander is called as cliff of slope. Simultaneously along the inner bank of bend, deposition of sediments takes place and this deposited inner bank known as slip of the slope. Thus the formation of cliff and slip of slope cause the curve of meander to be enlarged and the neck to its narrower. During the flood period, when discharge of water is increased, the river follows straight course and cut it off the r from the neck the detached c-shaped in the loop is known as oxbow lakes for example the oxbow lakes of the Mississippi and more are famous in the world the horse show shape or the c-shaped water strip which was disconnected and detached from that main river meandering due to the deposition is known as oxbow lakes.

**Landforms formed in the lower course of river :-**  river landforms formed In the lower course of a river , the carrying capacity of that river is completely reduced and the entire work of the river is depositional. Following are the important landforms are formed in that course.

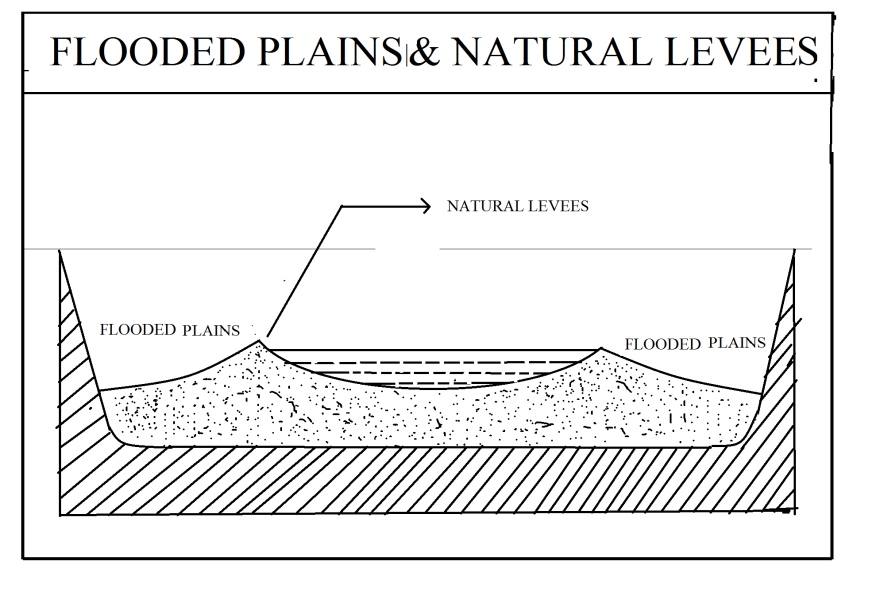
1. **Braided stream** :-

Such landforms are formed in the old stage of the river due to the more and more depositional work of river. In the old stage of river when the river becomes broader the deposition becomes dominant due to the reduction of gradient slope to a considerable extent. Deposition of sediments in the river bed occur into form of sandbars. Due to the inability of river to remove the sandbars, a number of minor streams bifurcated and divided and flow between the sandbars just like of distributaries. Such rivers with sand bars and small distributaries is known as braided streams.



1. **Floodplains and natural Levees** :-

Such landscape is formed in the old stage of river due to the fine sediment deposits found an extensive region by river work in the lower stream. During the monsoon or rainy season, the existing river channel is not enough to adjust the excess rain water in it and the water flows over the banks of the river and spread into a wide area on the either side of the river channel. During the dry season when the water retreats it's channel, deposits of thin layer of fine sediment a left behind on the flooded area. This depositional plain on the both sides of river is known as floodplains.

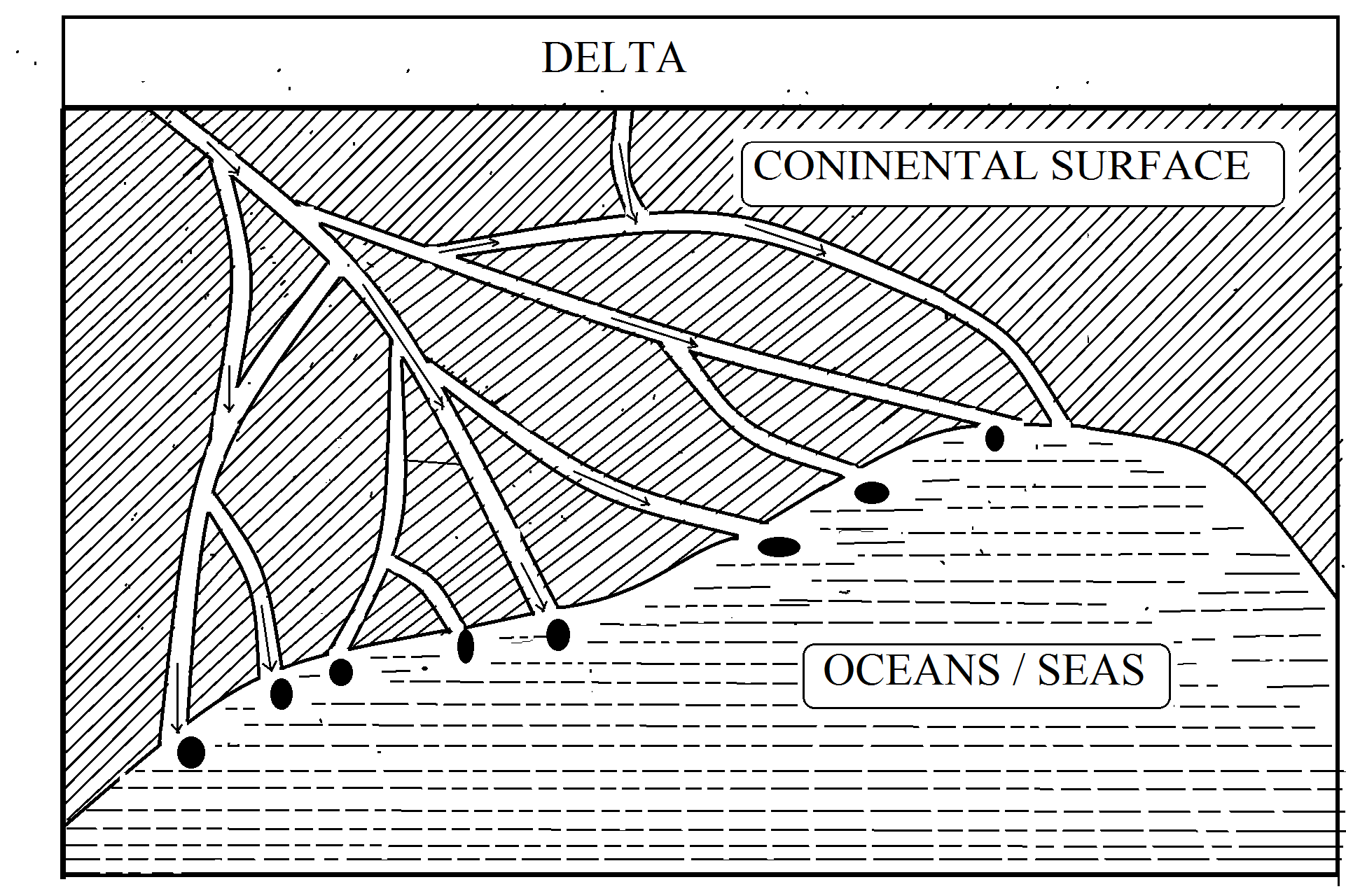


1. **Natural Levee** :-

The speed of the running water is rather slow at the sides and bottom of the river valley because of that retardation due to the friction. In the lower course of river, due to the more and more sedimentation and gentle slope of gradient, the speed of water so decreased that the sediments are not easily transported with the flow water. At that situation, these sediments deposit takes place along the both sides of river and on the bottom of it. After a long period of such deposition, the bed of the river is raised simultaneously the both sided banks of river has also raised due to the continuous fine sediment deposition and a hill or ridge is formed . This ridge like embankment / wall along the sides of river banks is known as naturally levees/ levees.

Successive floods of river, add more sediments to that ridges, so that they grew upward until they are well above the level of flood plain. Sometimes the natural levees are broken up due to the very high flood of that river in monsoon period and many agricultural fields are destroyed on river plain areas. Such landforms are produced in the last stage of river due to more and more **sedimentation** work along the both sides of river.

1. **Delta** :-



Such landforms are formed endly in the last stage of river due to the more and more sediment deposition work at the mouth of river where it meets to the seas or oceans. The river originating from highland ultimately joins to the lake or seas or oceans. At the last stage, when river meet to the oceans or seas , the velocity of river is reduced to almost zero and the transported loads are deposited at the mouth of river forming a triangular strips like Greek letter delta. Due to this reason, the plain at the mouth of river is called the delta. More over the formation of delta is a time taking process. It gradually extends seaward under the some suitable conditions. Gentler coastline, absence of active tides, waves and ocean currents and the larger amount of riverine loads are the most favourable conditions for the better development of delta. Over the time a number of minor streams are flowing over the delta. These streams are formed when the main channel of the river is chock up by the deposition of sediments and this mouth is closed and the water of river bifurcates into different - channels formed over the delta. Such minor streams bifurcating from the main river are known as distributaries. Sundarban delta of Ganga, Brahmaputra, Mississippi, Nile are the best examples of delta formation in the world.

Unit No 5 B

**Aeolian Topography**

**(Work of Wind/ Desert Topography/ Semi-desert Topography)**

About 1/3rd part of the Earth surface is covered by the desert regions. These are two types of deserts found in the world i.e. cold deserts and hot deserts. The major geographical factor of forming desertification in the specific region are that the scarcity of rainfall and sparse vegetation cover present in that region. The hot deserts are found on the western margins of continents between 20 ˚ to 30 ˚North and South latitudes. The large areas of North Africa and Southwest Asia where Sahara , Arabian Bibyan, Syrian Egyption and Thar are important deserts in the World. In addition Kalhari in West Africa, Atacama in South America and the deserts of Australia are also important deserts in world. the temperature of that hot deserts is recorded in daytime period is above more than 40˚C while in the night time it is suddenly falls down below 10˚C and the winds are very hot and dry in nature. The cold deserts are found in the interior of the continents of the temperate zone is specially in the Northern hemisphere these include Gobi and Turkistan desserts in Central Asia and Colorado in the United States of America. The temperature of that cold deserts is recorded below the 10˚C in the day and below the freezing point in the night times and the blowing wind winds of cold deserts are generally dry and cold. The work of wind and is more prominent in hot and dry desert areas that is arid and semi-arid areas due to the scarcity of rainfall and lack of vegetation cover. The dry conditions discourages the binding of the soil particles by water droplets and roots of vegetation the large particles of sand are easily blown away by a strong wind and this causes larger scale . The absence of the vegetation may also expose the weathered rock surface to the blowing wind and insolation. The effectiveness of wind action in these areas is very accurate and powerful due to the absence of stabilizer such as vegetation which cover and protect the rock surface from erosion by friction and reduction of wind velocity near the surface. The work of wind is more powerful and active in the hot and dry regions than the cold and dry deserts.

AEOLIAN TOPOGRAPHY :- The total landscape which is formed due to the action of blowing wind, are known as desert or wind topography or Aeolian topography.

Work of wind: - The work of wind is more prominent in hot and dry areas due to this scarcity of rainfall and lack of vegetation. The loose particles of sand are easily blown away by a strong wind and this causes large scale erosion. Like all are the agents of change wind has three fold action of erosion transportation and deposition.

Erosional work of Wind / Process of Erosion :-

Most of the erosional work of wind is physical or mechanical. Wind has strong physical force with the help of which it blows away sand and dust. Sometimes, even a heavy boulders are carried away by the blowing of wind the causes erosion in the desert areas in the following three ways viz i) Deflation ii) Abrasion and iii) Attrition.

1. Deflation :-

The loose material or sands are picked up by blowing wind and carried away from their original place to another. Consequently the removal of dust particle exposes the hard unweathered the underlying rocks which may be subjected to further erosion by winds. Thus the process of removal of dust particles by blowing winds along this course is known as Deflation.

The particles which are loosened the by weathering and blown by wind is known as the deflation.

1. Abrasion :-

The dust and sand particles present in the air float in the atmosphere. When wind blows very fast, these particles acts as sand tools on the rocks These known as the tools of wind and wear down the rocks by scraping, rubbing, undercutting, scratching scouring and grooving etc. This action is known as the abrasion.

1. Attrition :-

The sand particles in the air also strike against one another and get reduced and rounded by friction this process is known as attrition.

Process of transportation:- The loose particles produced by either mechanical weathering for abrasion and attrition are transported by blowing winds from their original place to some other places. The process of carrying away of loose particles by wind taken in the following ways

1. Saltation:- When the sand particles are moved and transported due to forward movement of grains in a series of jumps, such type of transportation process caused by blowing wind the is known as saltation
2. Suspension :- The finer size of dust particles are hanging with the turbulent winds and these particles do not reach on the earth surface and but along the velocity of blowing winds such type of carrying of dust particles by the wind is known as suspension.

Landforms made by wind erosion :-

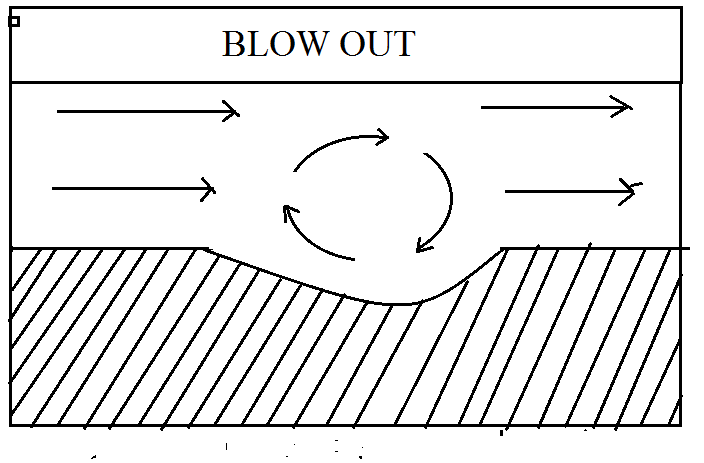
The erosive force of winds is influenced by the amount of sand grains moved by wind either in the form of suspension or saltation, speed of the wind and length of time it continuous to blow. These sand particles wear the rock surface by process of abrasion and polishing the rock surface just like the sand blasting machine. Thus through the deflation and abrasion process, the wind forms different kinds of landforms especially in the desert region such as deflation basin, blow-out, mushroom, Oasis, Domosielle, Stone lattice, Earth pillars, Zuegen , Yardang, Drikanter, Ventifacts, Inselbergs.

1. Defaltion Basin :-

Many depressions are formed by deflation action of wind. These depressions are called as deflation basins.

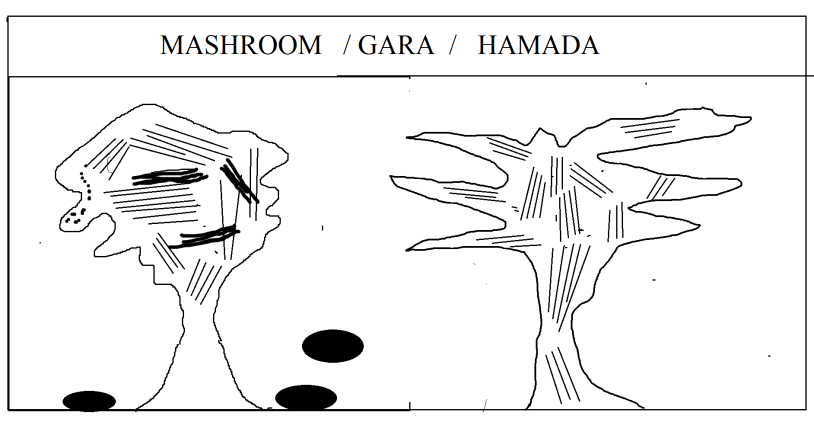
1. Blow Out :- Such landforms are formed in the erosional work of Wind.

In several desert areas which lack vegetation cover, strong winds form eddies and blow away the loose and soft rocks. Consequently a larger irregular shaped depression (Saucer typed ) is formed which is known as blow outs. Sometimes a lake is formed through that blowouts whenever a rainy or underground water accumulates in it. If this Lake has filled up by the fresh water then it become very useful for some other agricultural activities and human settlement takes place to the adjoining areas. Then this blow out filled with freshwater or freshwater lake is known as a OASIS of the desert region. Sometimes a saline water is stored in that blowouts is not useful for other agricultural activities and no human settlements found due to the different type of salts are present in the water. For example, Sambhar Lake is the best example of saline lake in the Rajasthan of Thar desert of India. There are many blow outs in Nebraska and Colorado states of The United States of America, Kalahari Desert region of Africa western parts, Australia Mongolia desert. KATARA is the biggest and depressed blowouts in the world having a depth of 132 metres deep.



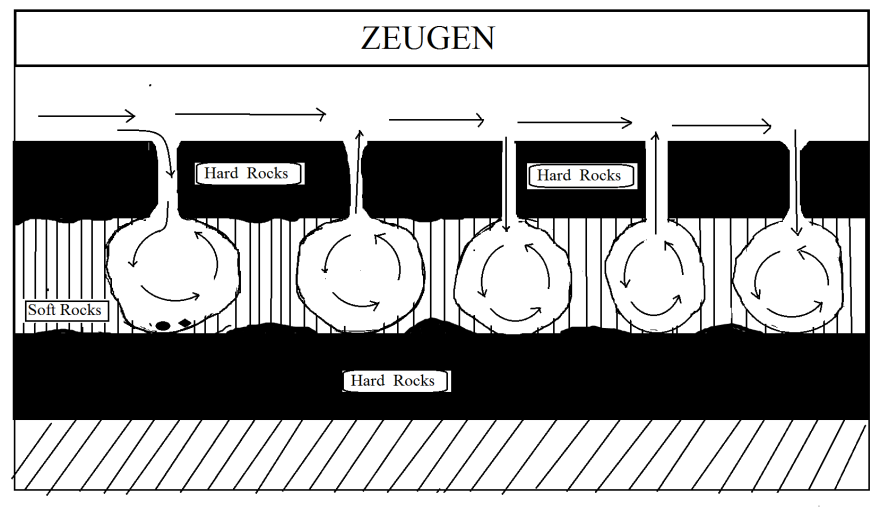
1. Mushroom or Gara :-

Such landforms are formed due to the erosional work of wind in the arid and semi-arid regions. The rock particles which travel with the blowing winds are commonly concentrated near the surface the and the velocity of the wind is also greater above the surface due to absence of friction. Thus the abrasion power of the wind the is greater at low-level slightly above the ground level rather than the upward and downward from this levels. When a column or block hard resistant rocks in this way of blowing wind , the upstanding rock is undercut an abrasion effect is the maximum near the base of the rock. Thus the base of the rock becomes narrower than the upper part of the rocks. Consequently pedestal rock is formed which has wider top supported by comparatively narrower base. This pedestal rock is known as the mushroom rocks or Gara. It is also known as Gara in Arabian language and in Sahara desert is known as the Hamada. These are found in Thar desert of India Sahara desert of Africa continent .



1. Zuegen :-

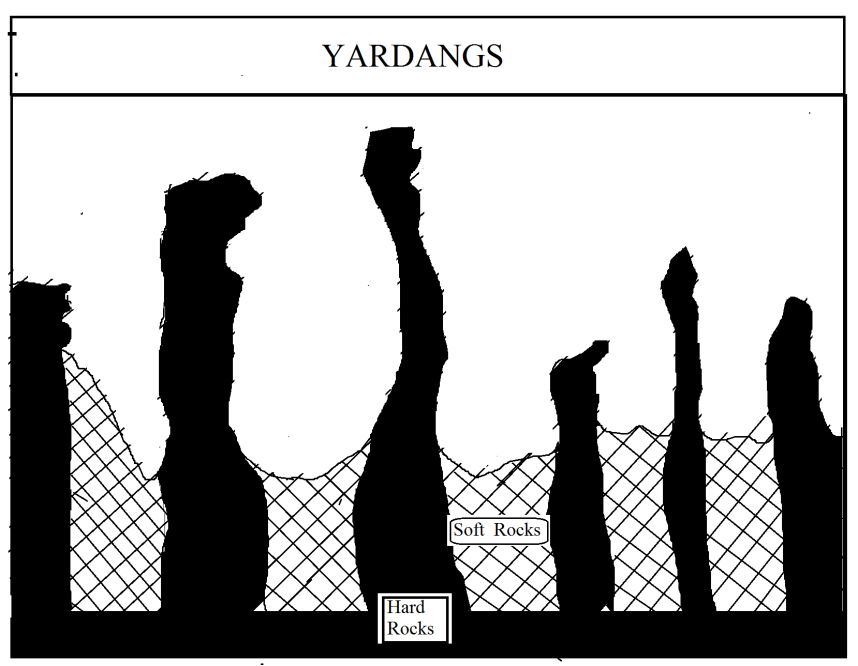
Such landforms are formed due to the abrasion action of wind where the horizontal layers of hard and soft rocks present in the arid topography. Some desert areas has the surface layer of the hard rock underlined by soft rocks, the overlying hard rocks layer is consisting of number of tracks and joints reaching to the underlying soft rocks. The wind the enters into the joints and cracks of hard rocks and reaches upto the soft rocks. Thus winds removes the fragments of the underline soft rocks by the deflation and abrasion process through the rock openings in the overlying the rocks the gaps widen and number of irregular holes(Furrows) are formed in the soft rocks by ridges of hard rocks. They look like a table is put on soft rocks. Such type of Ridge and furrow landscape in desert region is known as Zeugen. This landform are larger in size and the height of them are about 40 to 50 metres high. These are found in Arabian and Egyptian desert.



1. Yardang :-

Such landform are formed due to the abrasion action of wind where the vertically layers of hard and soft rocks present in the arid regions.

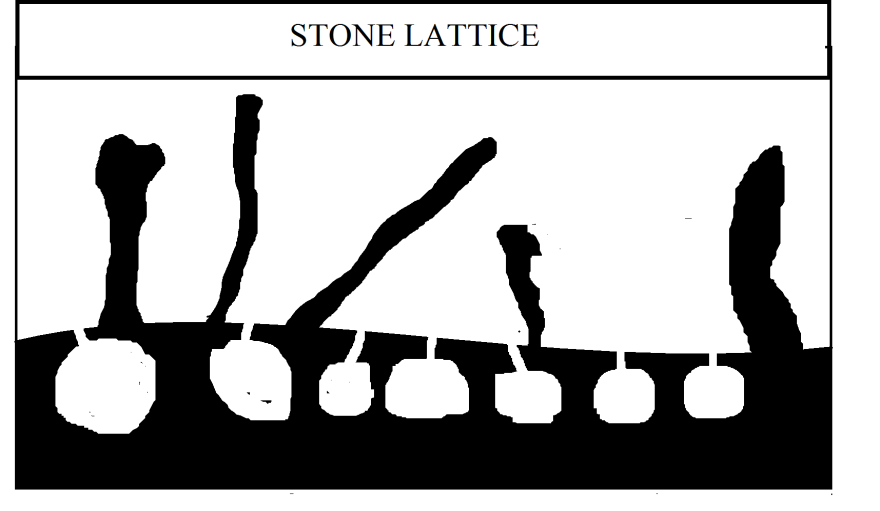
When the desert area is formed of a number of alternate hard and soft rocks which are arranged vertically. The wind erodes the soft rocks easily by the process of deflation and abrasion action rather than the hard rocks. Consequently a number of Furrows and gaps are formed at the place of soft rocks and harder rocks appears as supporters for ridges separating the furrows from one another. Such type of ridges and furrows landscape is known as Yardangs. Many yardangs are found in the desert of Central Asia. These regions of these are not suitable for travel and transport from one place to another.



1. Stone Lattice :-

Sach landforms are formed due to the deflation and abrasion action of wind where the rock with parallel series of hard and soft rock strata areas are arranged the both in horizontal as well as in vertical direction.

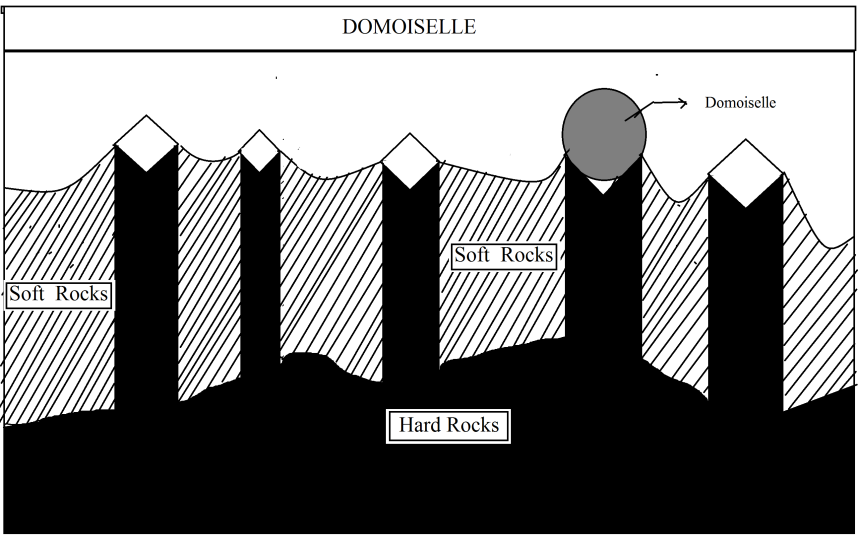
It is the just combination landscape of zuegen and yardang landform of the desert area in the desert region. Some areas has consisting of parallel series of hard and soft rocks are arranged in horizontal as well as in vertical direction. The blowing faster wins erodes the softer rocks easily by the process of deflation and abrasion actions rather than the hard rocks. Thus the widen gaps depression ridges and furrows are formed in the rock status Sach landscape is known as the stone lattice.



1. Earth pillars or Domosielle : -

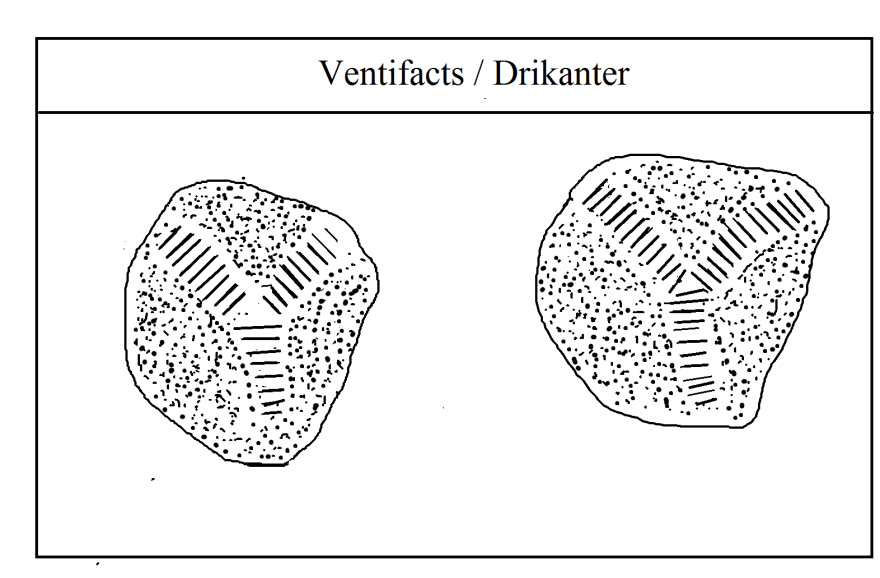
Such landform is formed in the erosional work of wind. There are many areas which are made of hard rocks. Wind subject the upper part of the rocks to abrasion but lower parts of soft rocks remains protected . The protected soft rock stands like a pillar or column below the hard rocks and it is known as the earth Piller or Domosielle. The earth pillars having circular or square in shape .

Domosiello:- Whenever a big stone or boulder has naturally present on the top of the earth pillar then it is known as the Domosiello.



1. Dreikanter / Ventifacts :-

Driekanter are formed in the arid region due to the abrasion action of wind on the stones or boulders. These are also called the stones beveled stones. The stones which is in a certain position and are subjected to abrasion action by wind blowing in one direction, develop one edge shape. When these stone roll away from their position, they develop many shapes. Such stones are known as ventifacts or driekanter becomes smooth and its shape to tetrahedron.

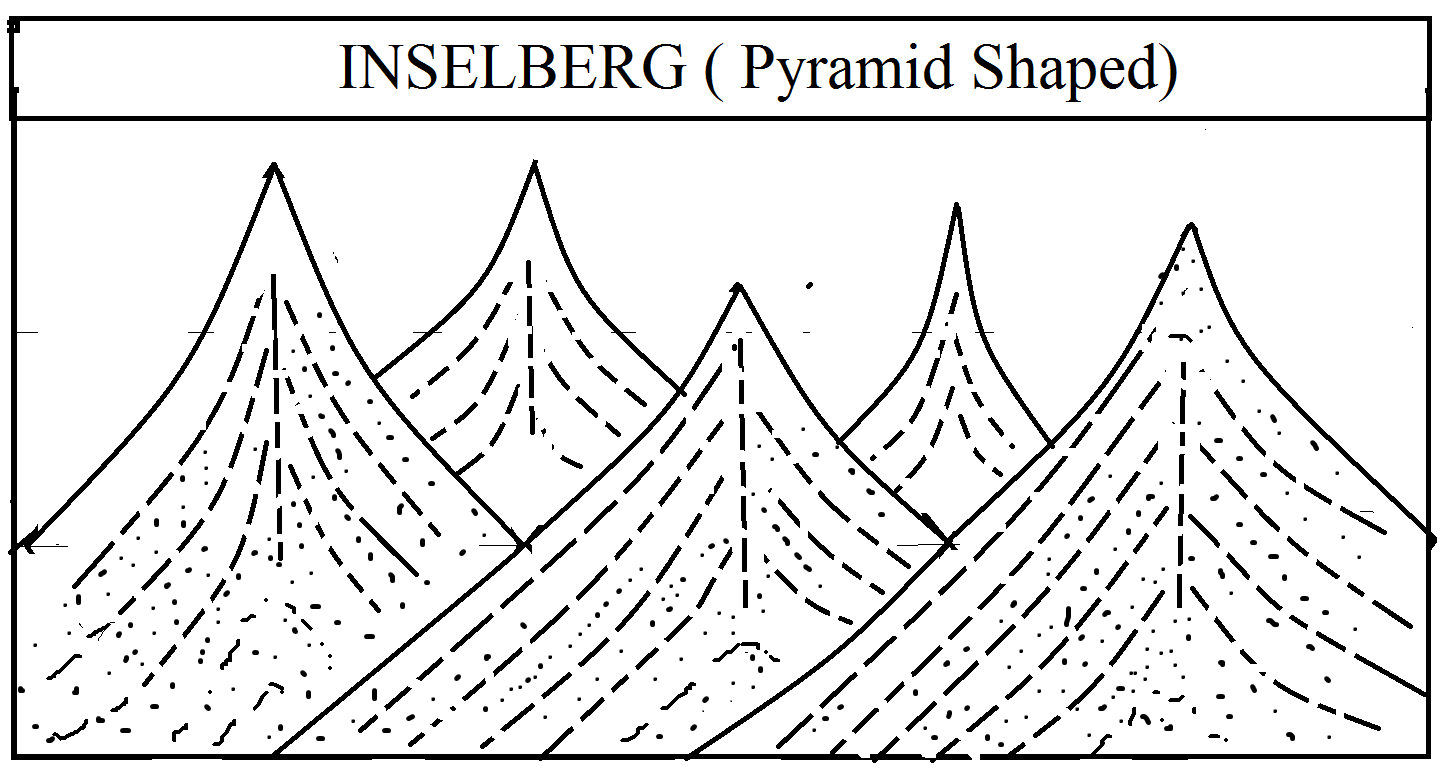


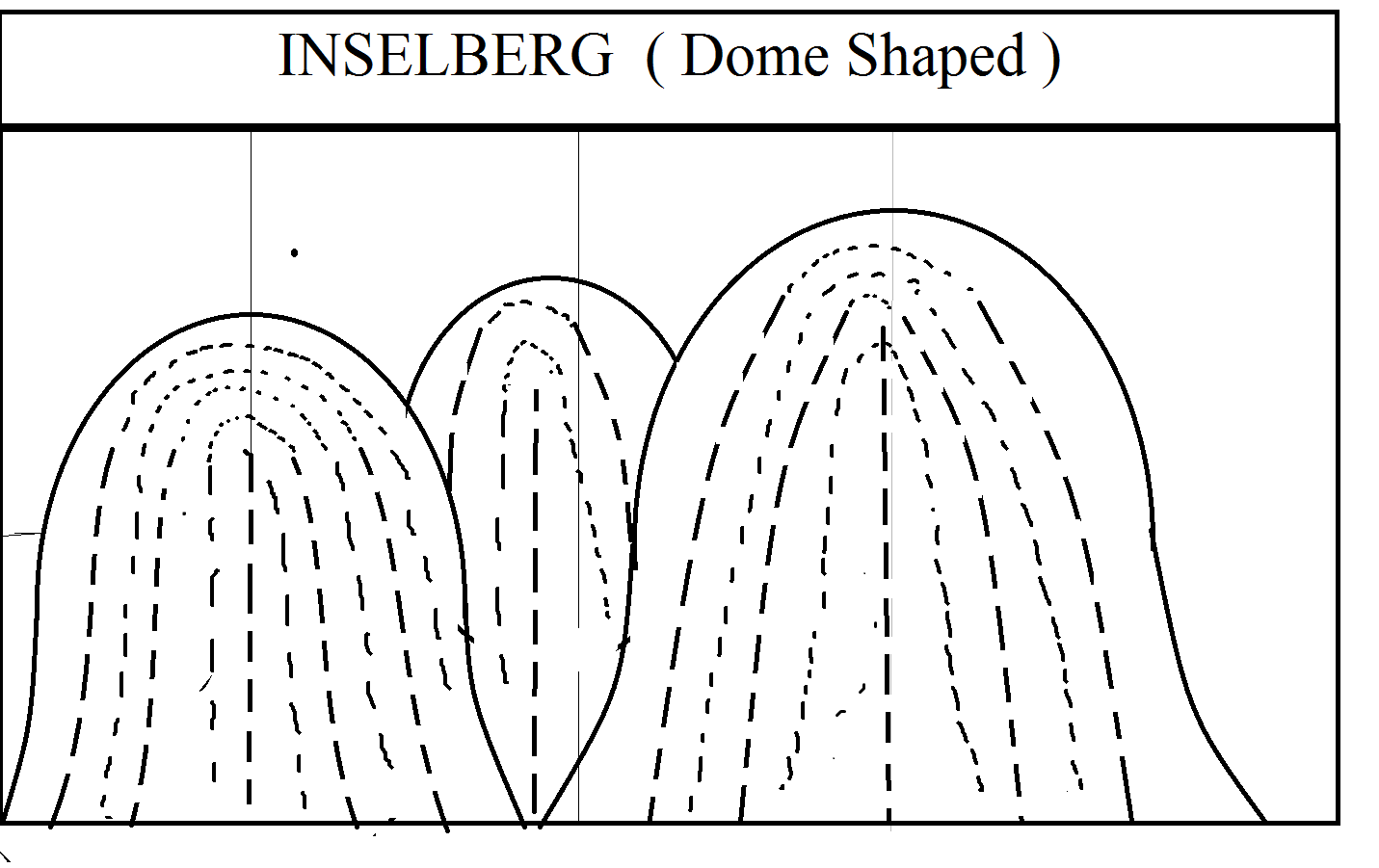
1. Inselberg :-

Such landforms are formed in the erosional work of the wind the in the desert topography. As a result of erosional work of wind much of sand and dust particles is eroded, but some hard rock masses stand out here and there from the surface of the desert. Such an isolated standing of hard rock mass like of hill mountain is known as inselbergs.

Inselberg is a German word which means Island mountain i.e. inselberg looks like ‘Island mountain’ i.e. situated in the seas or oceans. The inselberg are also known as bornhardt after the name of the scientist who first explain their origin. Sometimes these hills like of pyramid like with a cap of hard rocks and sometimes they just like of dome shaped having been made out of the granite.

Pyramid shape inselbergs are formed from hard rocks while dome shaped inselbergs are made from rather soft rocks.





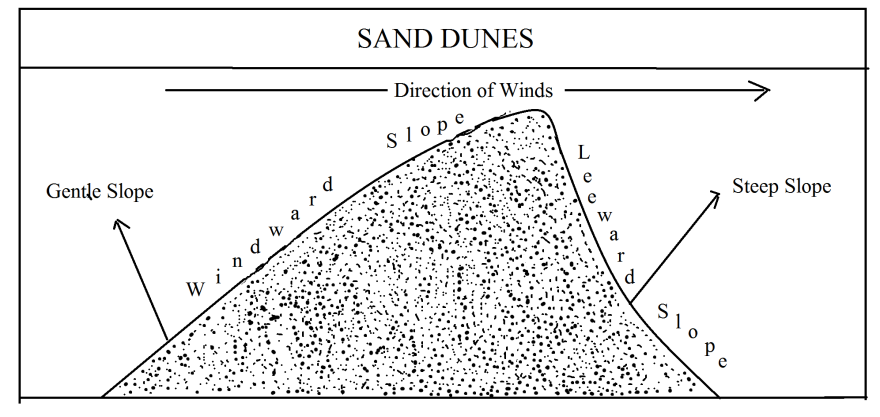
Depositional work of Wind :-

The rock particles carried away by blowing winds begins to deposit at the place where the velocity of wind is reduced to a considerable extent. These deposition occurs either in the form of a hillock or mound in thin horizontal layer, depending upon the size of the particles. Thus the wind the formed deposit vary in great extent so far their nature and size are concerned. The variation in the shape and size of wind formed deposit is controlled by the amount of material deposited, grain size of particles, velocity and directions of the wind blow and the altitude of the place of deposits, However , on the basis of shape and size of the wind deposits, mainly two kinds of landforms are formed viz sand dunes and loess plain.

**Sand dune :**

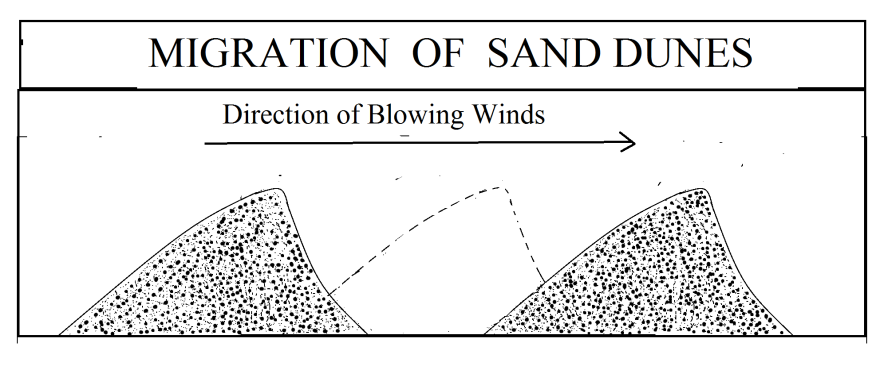
Sanddune is the most important feature formed by the depositional work of wind in the desert areas. Sanddune is a mound , hill or ridge with a crest or definite summit. It is formed when any kind of obstacles i.e bush rise in the ground, skeleton of animals like camels or houses stone or a tuft of grass etc. is found to break the velocity of wind. The reduction in velocity of winds lead to the dropping of transported materials. Thus a mound like deposition is found in the direction of blowing winds. The mound shows gentler slope in windward side while steeper to leeward side. This formation may also occur across the direction of the wind. Such kind of deposits features is known as sand dunes.

The leeward slope is generally called at slip face because along these face, the sand particles slip down and rest on the sand dunes. They vary in their sizes from a few meters to about 150 meters in height. In some deserts, they have been noticed as high as 300 meters. Besides in desert the sand dunes are also found along this sea coastlines and beach wherever a loose sand is available.



**Migration of sand dunes**:-

Sand dunes have a tendency to migrate slowly in the direction of wind by the shifting of sand from the windward to the leeward slope. The rate of migration varies is between 5 metres to 30 metres per year. During the course of migration, they sometimes bury up the woods, pastures , villages and settlements on the way. With the passage of time, these dunes have drifted further on , the buried dead trees, village . Encroachment from local shifting of sand dunes have also been noted in and around Rajasthan desert in dry seasons.



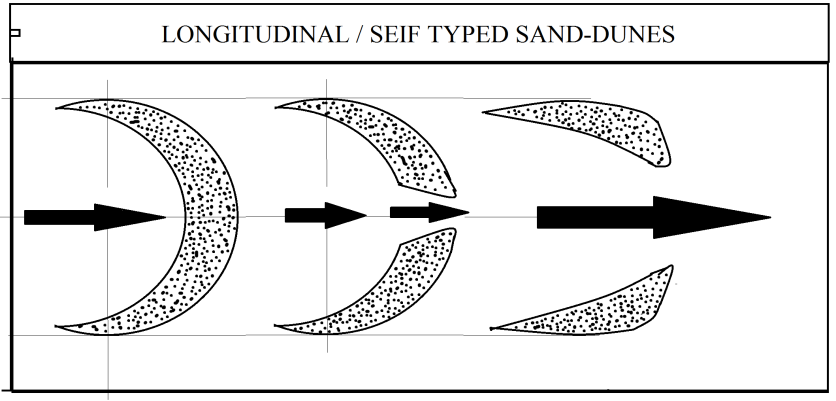
A Sanddunes may be classified into two groups owing to their location with the reference to the direction of blow of winds i.e i) barkhan and ii) Sief or longitudinal sand dunes.

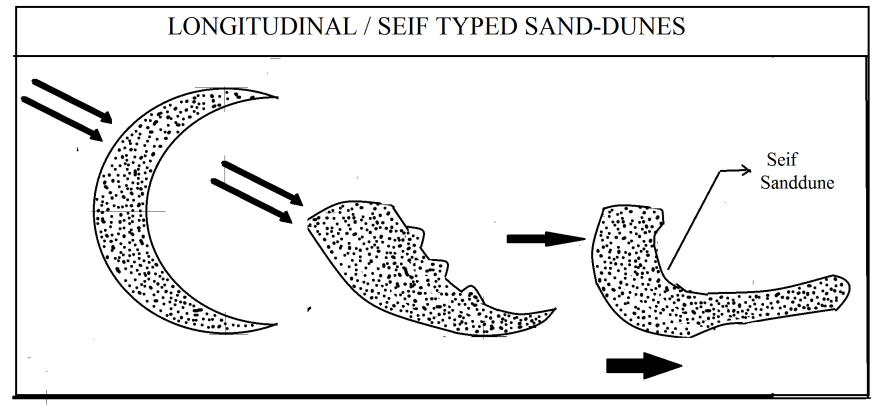
1. **Barkhan** :-

Barkhan is a Turkish word meaning a Sand hill in Kirghiz Steppes. The crescent-shaped sand dunes formed across the direction of blowing wind is known as barkhan. Such a typical type of sand dune is formed due to the constant wind direction and limited supply of windborn materials for the deposition. They are generally convex windward side and projecting two horns on the leeward side. They range in height from few metres to over 300 meters and they may occur single or in groups. They also migrate like an ordinary sand dunes these are commonly found in the deserts of Atacama and Persia desert regions.

1. **Longitudinal sanddunes / Sief Sanddunes** :-

Sief is Arabic word meaning sword to the sharp and narrow nature of sand ridge. The sword shaped sand dune is formed along the direction of blowing of wind and running often to a great distances. The winds blow straight through the corridors between the different parallel sand dunes. They are called as sief because there are resembled the Sword in their shape. Sometimes the sief sanddune is formed when the cross wind blows and persist for longer time and one of the horns of the barkhan is elongated.





**Loess Plain** :-

Such type of landforms are formed in the depositional work of wind in the wind topography. The finest particles, which are carried away by wind in suspension from the desert to a considerable distance are deposited in the desert or out of the desert in a in thin horizontal layer in the form of paper laminae under the favourable conditions. The deposits or the plain formed by deposition of windborn material is called as Loess Plain. Loess is a German word used for deposits of fine-grained, coherent, frible, porus and yellowish dust deposited by wind. As the fine grains have 0.02 mm , the property of clinging together, their deposition and give distinct landforms. The material has no horizontal stratification like others sedimentary rocks, since it is deposited in areas of low rainfall where ground has grasses to bind the particles of dust, the loess stands without being removed further by the wind. The loessic soil are porus and is 15 to 30 meters deep and yellowish or buff in colour. The loess plain found in several parts of Europe, North America, South America and parts of Africa. Initially it has first studied by Von –Rischtofen . It covers an area of nearly 6.5 lakh square kilometer and having a depth top 90 to 300 metres depth. The Loess plain of North China is the best example of loess plains in the world It is yellowish or buff in colour. It has been brought mostly from Gobi desert of Central Asia for many years.

Unit No 5C

**KARST TOPOGRAPHY**

**WORK OF UNDERGROUND WATER**

The water percolates down through the pores and opening of the rocks beneath the earth surface. The percolating water accumulates beneath the surface forming the underground water. The main source of ground water is rainwater and melts water which infiltrates down word through the pore spaces of surface materials and collects in large quantity in aquifers of varying sizes and locations Aquifers refers to the storage pools of ground water lying below the ground surface. The ground water is also called subsurface water of underground water.

**CONDITIONS OR ELEMENTS OF UNDERGROUND WATER**

There are mainly four characteristics which determine the amount of underground water in a particular area. They are porosity and permeability of rocks, climate and topography.

**1) POROSITY**

The porosity of rock refers to the amount of space or voids contained in it and it is stated as percentage of the total volume of material. The percentage of porosity varies with the differential nature of the rocks. The porosity may also vary within the same group of the rocks. For example, loose sand and gravels may have porosity to the extent of 50 percent where as the consolidated sedimentary rocks like limestone is definitely less porous. The igneous rocks rarely have the porosity more than 2 or 3 percent.

**2) PERMEABILITY**

The term permeability indicates the capacity of the rocks to drain the water through it. A rock of high permeability transmits water more rapidly and one with low permeability transmits it slowly. The permeability of rocks is controlled by mainly two factors. 1) Size of rock forming particles and 2) interconnecting among the pores or voids of the rocks. The size of grains of rock is very important element in determining the permeability of rocks. The size of grains of rock is very important element in determining the permeability of rocks, because the size of inter nodular space is directly proportional to the grain size.

For example, coarse grained sedimentary rocks like gravel, which have larger inter nodular openings are more permeable than the fine grained sedimentary rocks. Like silt and clay. If we double the grain size, the permeability will increase by about 7 times.

The inter connection between the pores and voids is another important element to determine the permeability of the rock. The porous rocks are only. Permeable when the pores are interconnected with each other. This is why all porous rocks are not necessarily permeable rocks. But all the permeable rocks are porous rocks because the pores or openings are needed for movement of water.

**3) CLIMATIC CONDITION**

Climatic condition also an important determinant of the amount of underground water. Cold and humid region, due to low evaporation and high prepetition, is having relatively more underground water, if other things being equal. Because more amount of water percolates down to form underground water. In contrast, dry and warm region may have lower volume of underground water because the more evaporation and low precipitation retard the percolation of water downwards.

**4) TOPOGRAPHY**

Nature of terrain or land forms also decides the rate of water percolation. The hilly or slop topography has relatively lower rate of percolation of water as the water from precipitation moves as run-off very rapidly and it does not stand for a longer time for the percolation downwards. While the low lying or plain surface have accumulated water from precipitation for longer duration and consequently more and more water percolates down if other conditions are favorable.

**GEOGRAPHIC TERMS IN UNDERGROUND WATER**

Water Table, Aquifer, Aquiclude and Perched water table Subsurface water Zones-

The water percolates down through the pores and openings in the underlying soil rocks and it accumulates at certain depth where the rock becomes impervious. The region of subsurface water may include two distinct zones viz., (i) Zone of aeration and (ii) Zone of saturation. The zone of saturation refers the region of underground where pores of rocks are fully filled up with water and ground water is formed. Above the zone of saturation, the pores of the rocks are usually partly or entirely filled by air. This is the area through which water moves down word from the ground in wet season. This zone is described as zone of aeration.

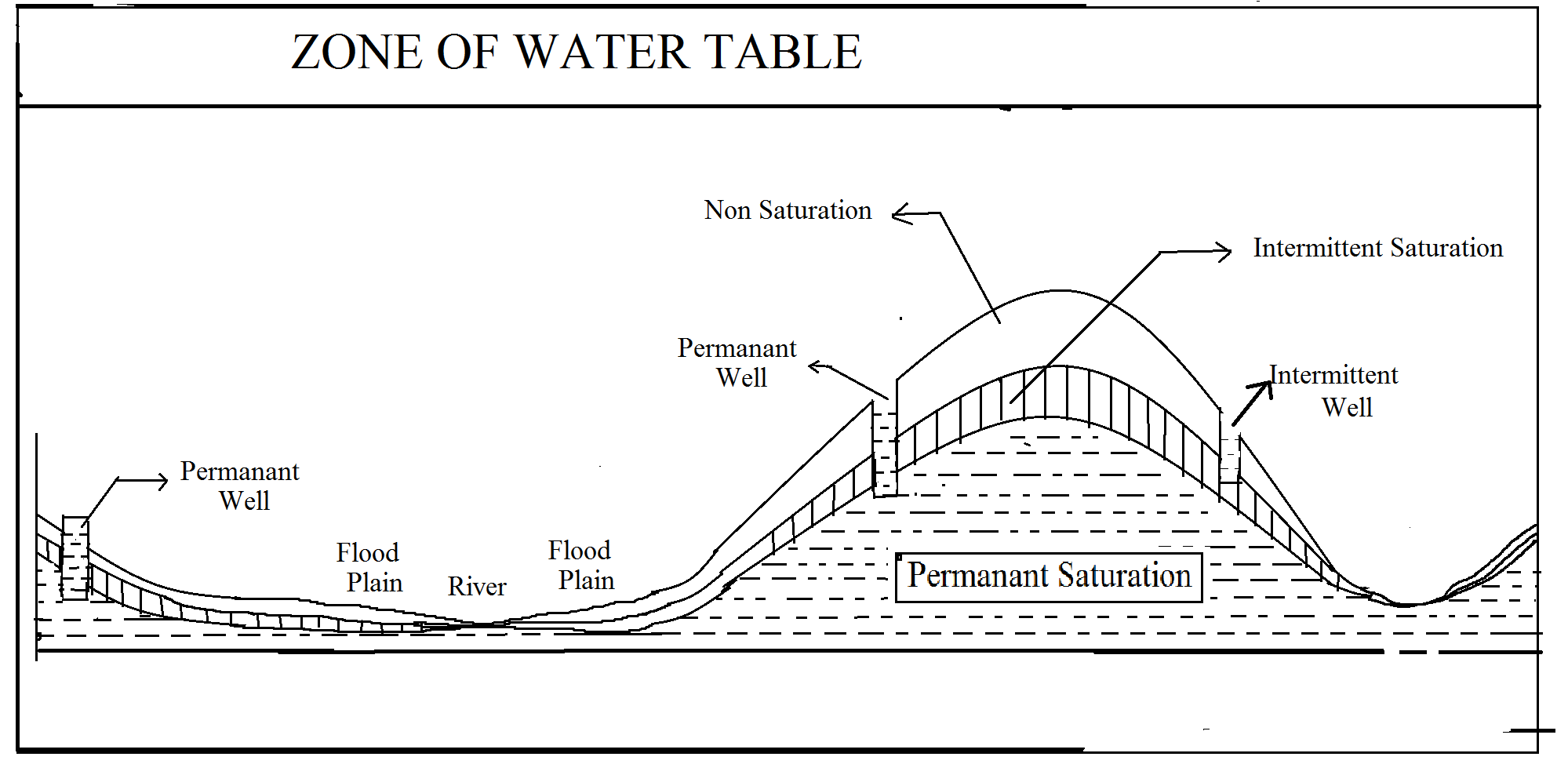
Water Tables, Aquifer, Aquiclude and perched water table. The accumulated water in the zone of saturation, by more and more supply of percolating water, moves upward by filling up the pores of overlying rocks. Thus the upper limit of saturation zone or underground water is known as water table. The water table in any region is seldom a level surface. In most cases it is uneven surface. It is usually seen that water table is highest in highest areas of surface. Namely hill tops and divides but descends down towards the valley where it may appear at surface close to streams, lakes or marshes. The variation in the configuration of water table is due to fact that the water percolating through the zone of aeration tends to raise the water table while the seepage of underground water to the streams, lakes and swamps tends to draw off the underground water and consequently lower the water table.

Moreover, the water table or vertical thickness of saturation zone is dynamic with the season. In the wet season due to more recharge of percolating water, the water table rises up and represents highest height in this season, while in dry season, it is lowest and due to soil moistures looses through evapotranspiration.

The lowest level of water table is also known as permanent water table and the highest level of underground water is called as temporary water table. The area between the permanent and temporary water table is described as intermittent zone of saturation.

Besides, sometimes a thin impervious rock lies above the permanent water table in the zone of aeration. This non-permeable rock effectively blocked of downward percolation of water to the main water table below. Accumulation of water above it (impervious rock) forms an isolated body of underground water within the zone of aeration. The water table of this isolated body of underground water is called ‘perched water table’.

Moreover the area beneath the earth surface is consisting of various kinds of rocks of contrasting physical characterization. The region, consisting of porous and permeable rocks, through which underground water may be stored and moved easily. It is referred as aquifer. E.g. Sand stone is both porous and permeable provides large ground water reservoir through which water may move easily. Contrary to this, the region of rocks of low permeability like shale which restricts the flow of underground water is known as Aquiclude.



**WELL**

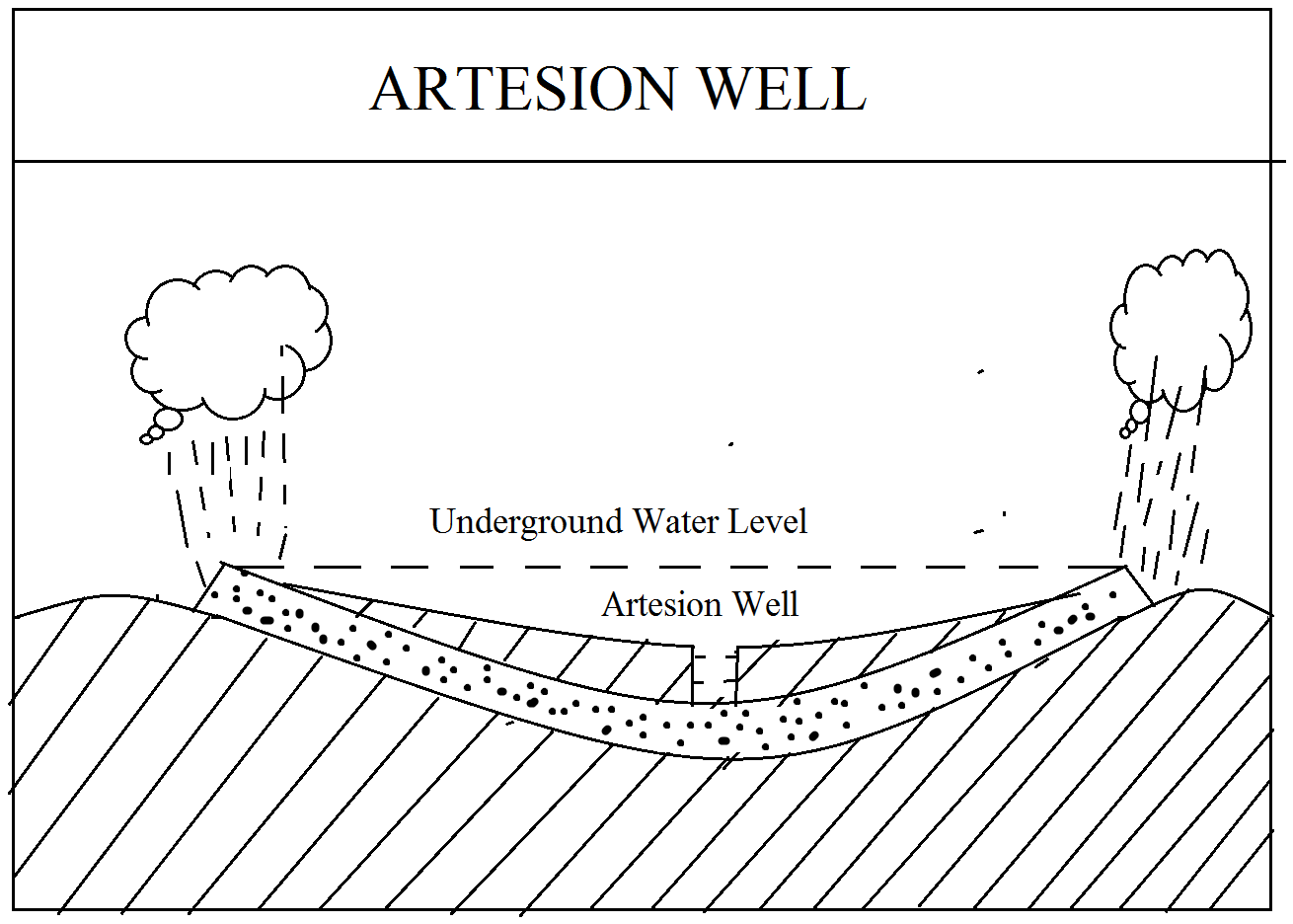
When a hole is dug on the surface through the zone of aeration up to or below the water table the water will seep into it. The hole is described as well. Any water drawn out will be replaced as long as water table remains above the bottom of a hole. Such hole is called as an ordinary well. There are two types of wells. i.e. i) Temporary well ii) Permanent well. Temporary well is one in which water table goes down below the bottom of well in dry season and water cannot be obtained from it in this season. While the permanent well has its bottom always below. The permanent water table so that water may be supplied continuously.

**ARTESIAN WELL**

It is a kind of natural objection or underground water to the surface water through a manmade out let under the pressure of column of underground water. Following conditions are essential for the development of such artesian wells.

1. The rocks should have synclinal or titled structure.
2. Porous and permeable rocks must lie between two non-permeable rock’s layers.
3. At least one extreme or end of the porous and permeable rock should be exposed to the surface so that rainwater can percolate to fill the aquifer zone.
4. Sufficient amount of rainfall should be also in the region.

Moreover, Australia is famous for the artesian wells in the world. Great artesian basin of Australia in eastern interior part with an area of 15,00,000 Sq. Km. is well known for artesian wells. In India such wells are found in alluvial plain of Gujrat, Pondicherry and south Arcott district of Tamil Nadu province.

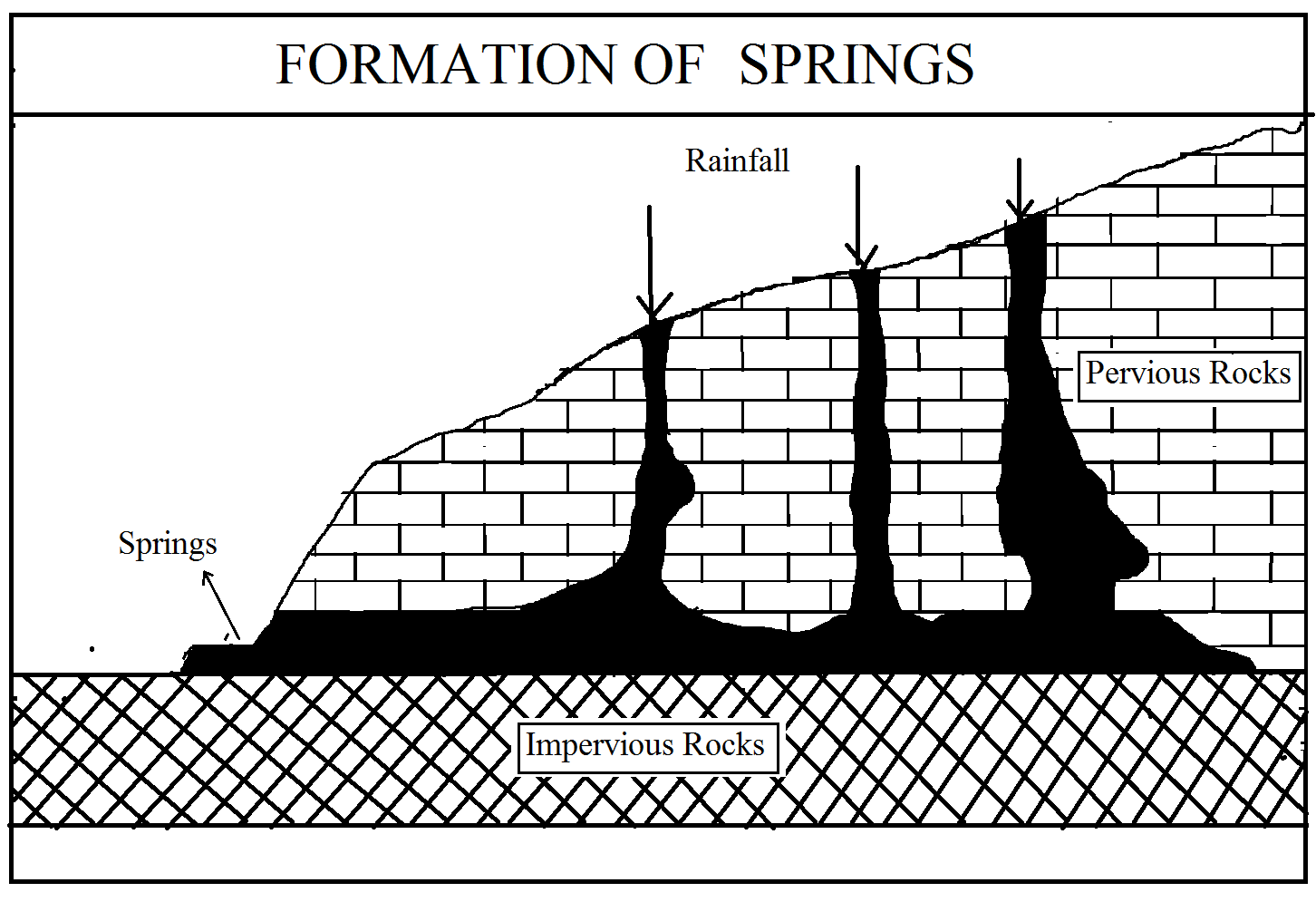


**SPRINGS**

As we know that the water table is always, not regular. Sometimes, when the beds of rock are inclined, the water table may infer sect the surface especially in valley or low lying region and water begins to come up to the surface from the underground water. Thus the flow of water through the natural out lets from the underground water is described as spring. Artesian well is different from the spring in the way rock overlying the aquifer. Spring may be classified into different groups according to the mode of formation and place of their occurrences.

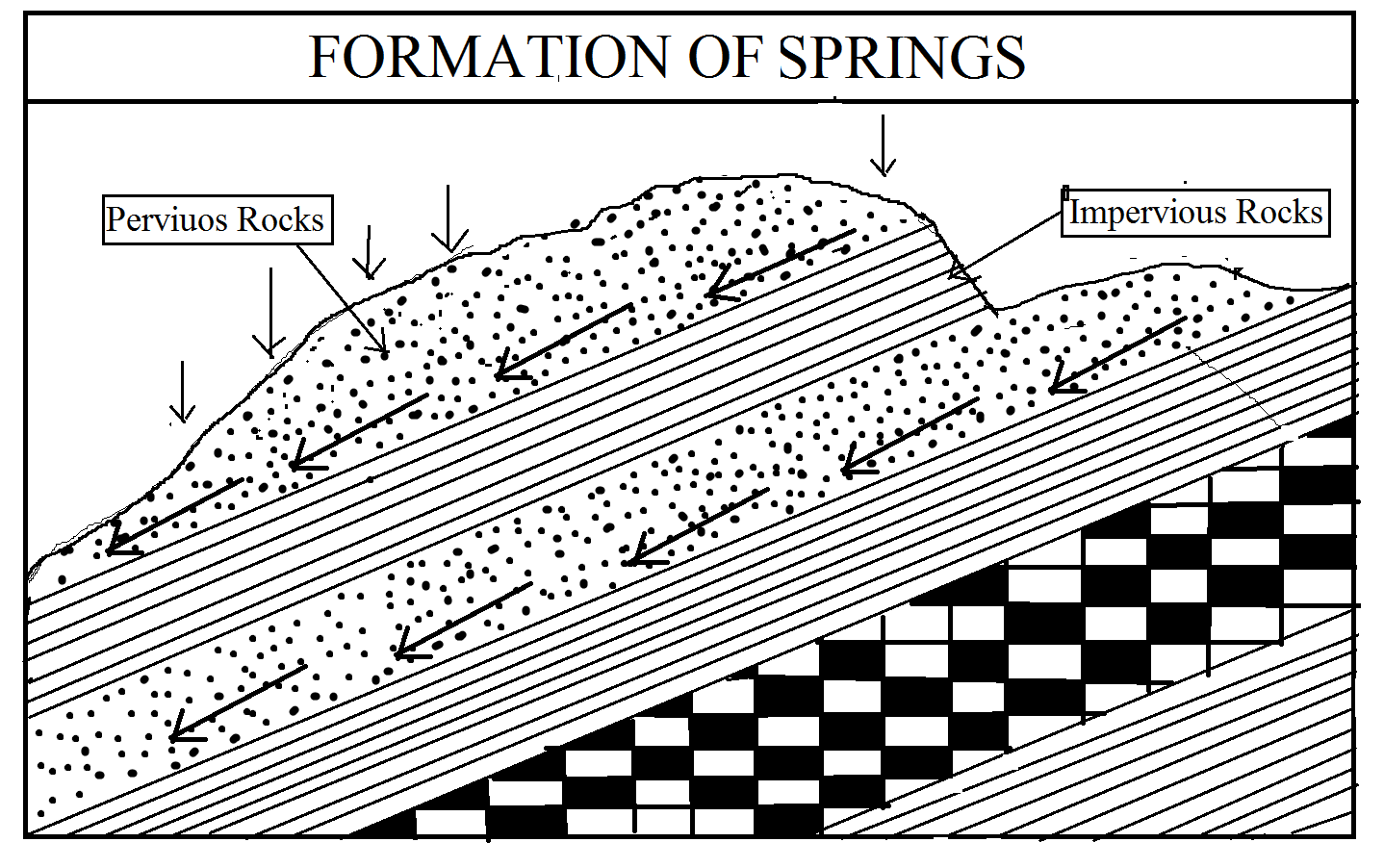
**I) SCRAP FOOT SPRINGS**

Scrap foot springs occur when impervious and pervious / permeable rocks are arranged alternatively, inclined and exposed to the mountain or hill slope. The permeable rock or acquitter is filled up by percolation of rain water. Thus along the scrap foot, at the lowest paint of convergence of aquifer and non porous rocks water begins to gush up as spring under the hydraulic pressure of underground water. Such type of spring is called as scrap foot spring.



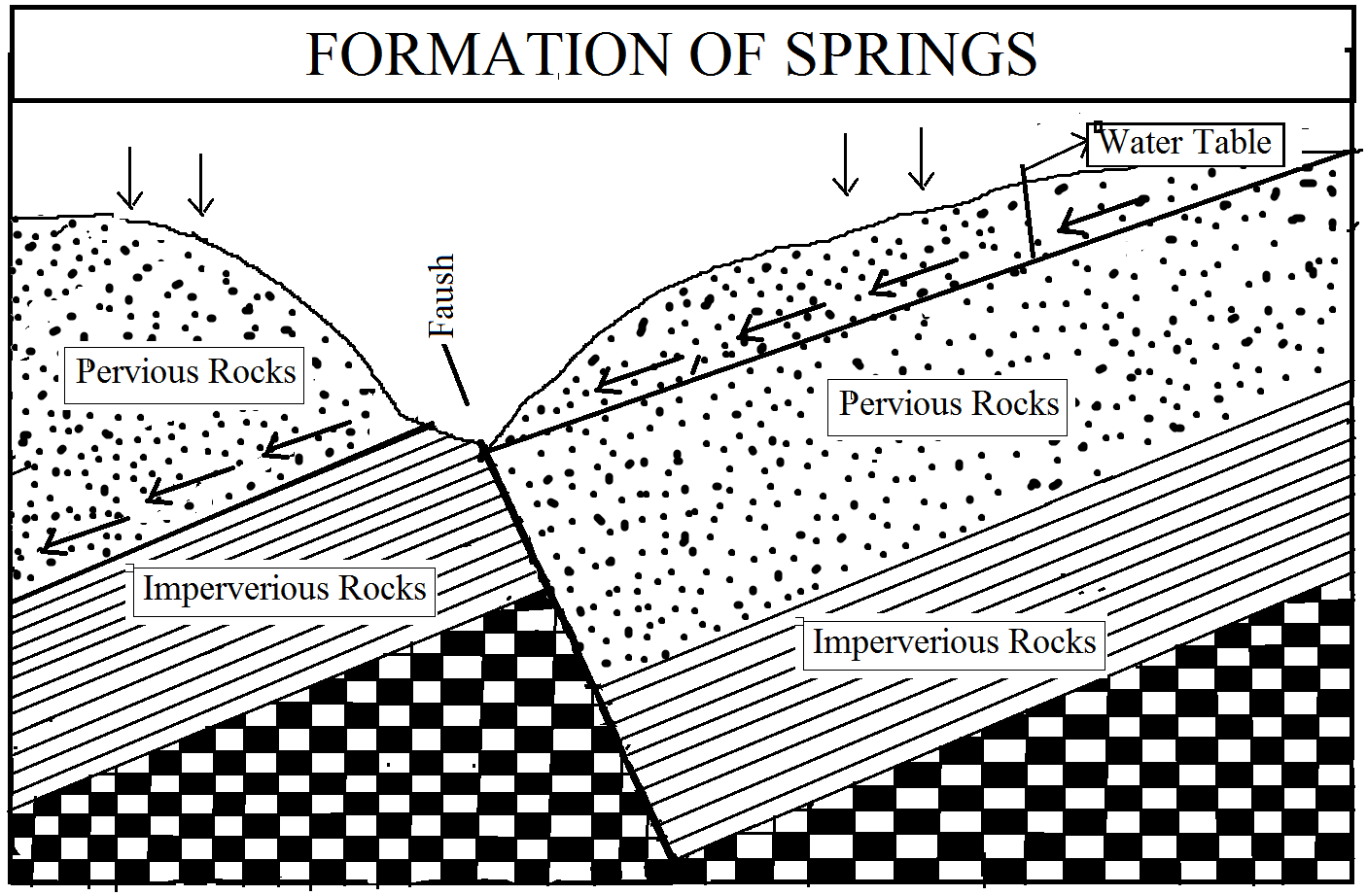
**II) FISSURE SPRINGS**

Ground frequently comes on the surface through a fissure in the bed rock, forming fissure spring. The structure of such spring may be identical with that of an artesian well. The water from fissure springs is usually wholesome, like artesian water. It is rather cold because it comes from greater depth where sun heat does, not penetrate. The flow from such spring is usually constant.



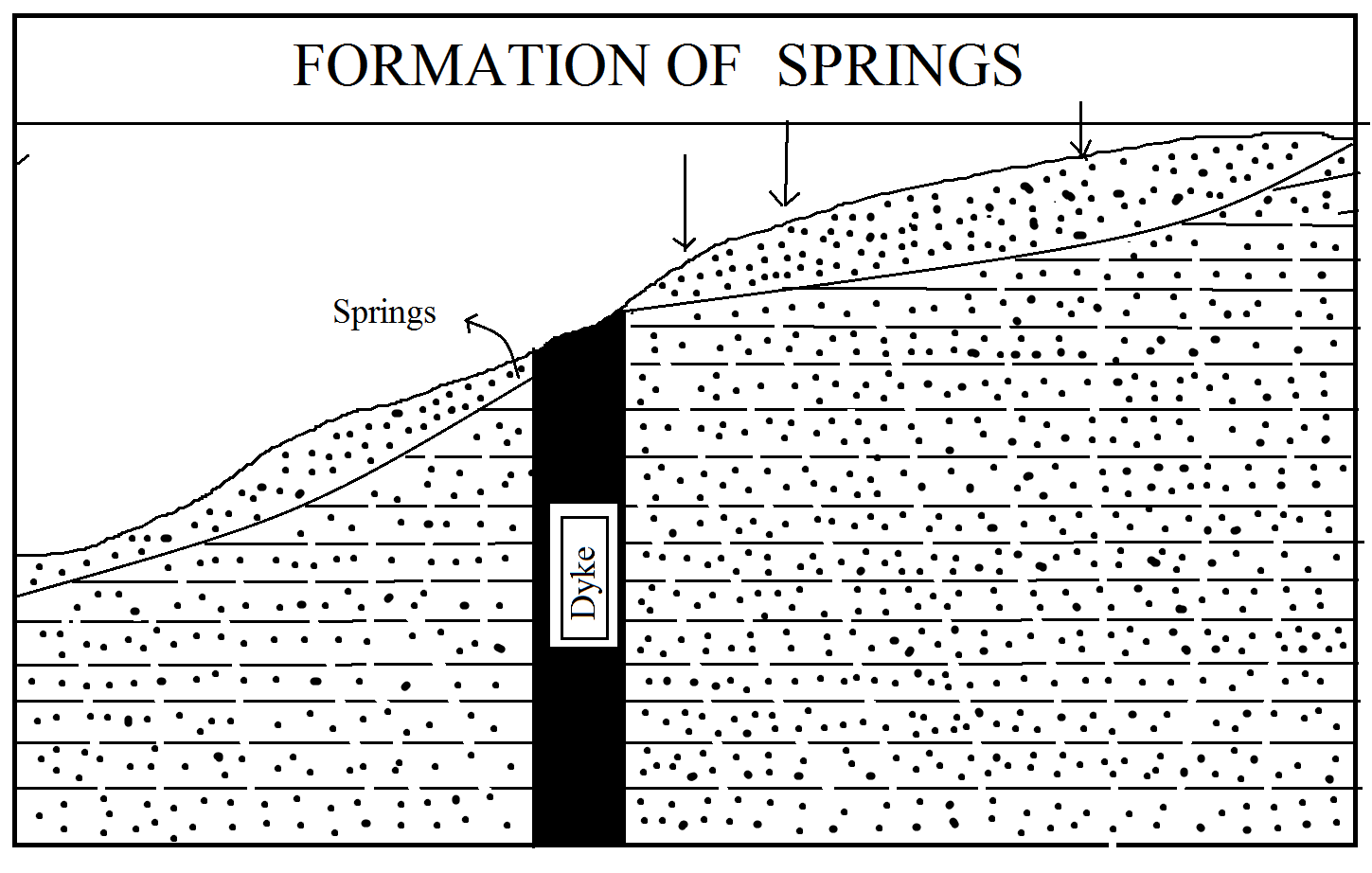
**III) FAULT SPRINGS**

When the rock beds are dislocated or displaced due to formation of fault. Sometimes the permeable rock is set against the non permeable rocks and fault line is exposed to the surface. Due to the percolation of rain water, the permeable rock is filled with water and it moves. Out to the surface through the fault line this kind of spring is described as fault spring.



**IV) DYKE SPRINGS**

If there is a dyke having impervious material exposed at the surface and pervious strata lies on both sides of it. The ground water comes out on the surface through the space along either side of dyke in the form of spring, which is known as dyke spring.



**HOT SPRINGS AND GEYSER**

In the region of volcanic eruption, the underground water is heated in contact with heated or super heated magma inside the earth. The water is heated and converted into steam. Due to expansion of superheated steam in underground cavities, hot water is gushing up with a great for to the surface. Such type of gushing up of underground water is known as hot springs or gufser. Moreover, the hot springs are different from geysers. In the hot springs the simply hot water (not boiled) comes up where as in the case of geysers, boiled water with steam is gushed up with great comes from the geyser, the name of geysers of Iceland. There, are three important areas, i.e. Iceland, the parts of Rockies in USA and North Island of New Zealand, where hot spring and geysers are found in the world.

**LIMESTONE TOPOGRAPHY /KARST TOPOGRAPHY**

Land forms produced by chemical weathering or chemical erosion of carbonate rocks mainly calcium carbonate (cacor) and magnesium carbonate (dolomites) by surface and subsurface waters/ ground water are called Karts topography. This refers to the characteristics landforms produced by chemical erosion of crystalline jointed lime stones of the Karst region of the earst while Yugoslavia situated along the eastern margin of Adriatic Sea.

The Karst region of the earstwhile western Yugoslavia extends for 480 km in length and 80 km in width. The region having folded lime stones rises to the height of 2500 meter a msl. The surface is studded with numerous solution holes, ravines, gullies, clefts, lappies and narrow valley has becomes so corrugated and rough that it becomes practically impossible to walk with bare feet. Thus, the lime stone topography all over the world having characteristic features similar to the Karst region to the earst while Yugoslavia is universally called Karst topography.

**DISTRIBUTION OF KARST AREAS**

Karst topography generally develops in those areas where thick beds of massive limestone lie just below the layer of surfacial materials. Besides, Karst topography develops an dolomite, dolomiatic lime stones and chalks. Besides typical Karst region of the earst while Yugoslavia, Karst topography has well developed in causes region of southern France, Spanish, Andalusia, Western Cuba, Jamaica, Southern Indiana, west central Kentucky, Virginia, Tennessee and central Florida of the U.S.A. These areas are classified as Major Karst areas. Besides, there are a few minor Karst areas e.g. Carlsbad area of USA, chalk area of England, chalk area of France, parts of Jura mountain, some parts of Alps, and Appenies etc.

In India, Most of lime stone of Vindhyan formation are buried under thick covers of sand stones and shale’s. A few area of Karst topography have been identified in the Himalayas J and K, Up (Dehradun), M.P. Bihar and Vishakhapatnam.

**ESSENTIAL CONDITIONS FOR THE DEVELOPMENT OF KARST TOPOGRAPHY**

1. The lime stone must be massive, thickly bedded, hard and tenacious, well cemented, and well jointed.
2. Lime stone should not be porous where in permeability is largely controlled by joints or not mass of rocks because if lime stones are porous, the water may become weak and will collapse. On the other hand, if lime stones are non porous and thickly bedded, water will infiltrate through joints resulting into effective corrosion of lime stones along the joints and solution holes would be formed.
3. The position of lime stone should be above the ground water table so that surface drainage may disappear through sinks, blind valleys, stinking (reeks to have subterranean drainage so that cave, passages and galleries and associated features may be formed.)
4. The lime stone should be widely distributed in both areal and vertical dimensions.
5. The carbonate rocks should be very close to the ground surface so that rainwater may easily and quickly infiltrate into the beds of lime stones and may corrode the rocks to form solution landforms.
6. The lime stones should be highly folded or fractured or faulted.
7. There should be enough rainfall so that required amount of water is available to dissolve carbonate rocks.

**THE GEOMORPHIC WORKS OF GROUNDWATER**

The geological or geomorphic work of ground water includes chemical erosion of soluble rocks at the surface by the surface water and below the surface by percolating and moving ground water, limited transport of eroded materials in suspended forms and deposition of solutes. It may be pointed out that the geological work of ground water is exceedingly slow because of its very rate of movement. Only that part of chemical erosion of carbonate rocks at the ground surface is included in the geological work of ground water which is related to the infiltration of rainwater.

**EROSIONAL WORK**

Besides erosional work, ground water also. Facilitates slumping, debris sides, and landslides on steeply inclined hill slopes because ground water acts as lubricator. The erosional work of groundwater is performed through the mechanism of solution / corrosion, corrosion / abrasion, attraction and hydraulic action. But solution is the most effective process in the denudational work of carbonate rocks only. By the ground water / surface water.

Rainwater mixed with atmospheric carbon dioxide (Co2) and organic Co2 becomes active solvent agent and disintegrates and dissolves at the surface and below the surface to form numerous types of solutional landform. There are seven variables which control lime stone solution viz.

1. Partial pressure of Co2
2. H2Co3 – (carbonic acid)
3. Hco3  – bicarbonate ion
4. Co32– carbonate anion.
5. H+ - Hydrogen ion
6. OH - hydroxyl ion
7. Ca2+ - calcium Cal ion

It may be pointed out that the amount of dissolution of carbonate rocks depends an temperature, portal pressure at atmospheric Co2, Organic Co2, the chemical composition of carbonate rocks, joints of the rocks, nature and rate of flow of ground water, contact time of solvent and carbonate rocks, route of water flow etc.

**DEPOSITIONAL WORK**

As the chemical erosion of carbonate rocks continues, the ground water / solvent receive more and more solutes and become saturated with sediments. Since the movement of ground water exceedingly slow it cannot transport enough materials. Thus chemical erosion and deposition go together. Larger sediments immediately settle down where as suspended fine materials kept in solution. Deposition of sediments takes place at various places in various forms. E.g. i) at the floor of caves ii) along the ceiling of caves iii) in the rock joints etc.

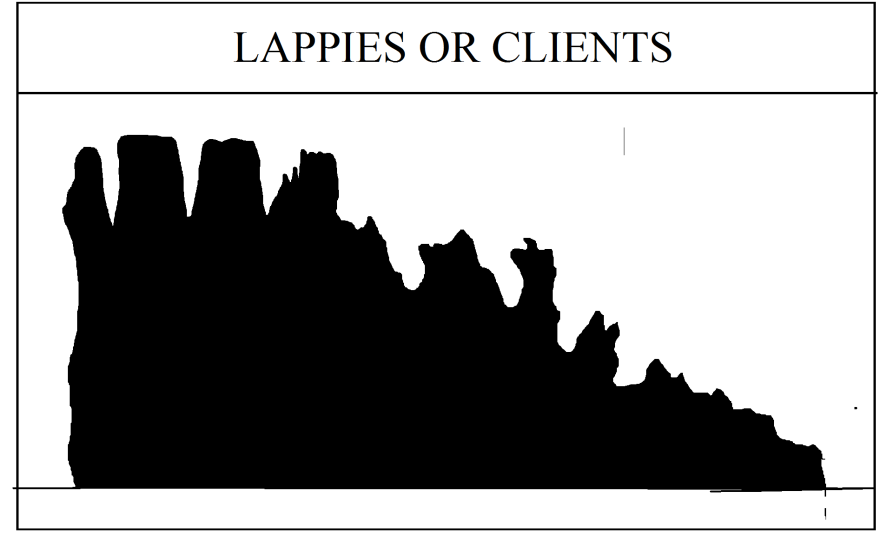
**LANDFORMS FORMED BY EROSIONAL WORK OF UNDERGROUND WATER / EROSIONAL LANDFORMS.**

**1) LAPIS OR CLIENTS**

Such landforms are formed in the erosional work of carbonate rocks by the solution action of surface water on those rocks.

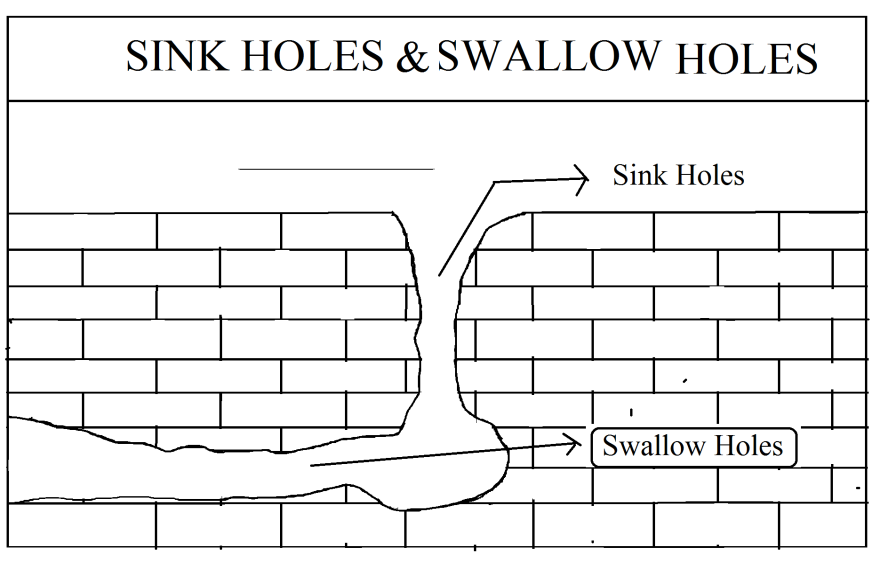
When the water combined with Co2 moves down through the pore spaces of lime stone rock region, a number of long furrows with walls are formed. Such feature consisting of furrows and ridges in line stone ridge region formed by solution action of underground water is called a lapis or clients. OR The highly corrugated and rough surface of lime stone litho logy characterized by low ridges and pinnacles, narrow clefts and numerous solution holes is called lapis.

It is also known as clients / gyres in England, Kerran in Germany, bogaz in earstwhile Yugoslavia. Lapies are generally formed due to corrosion of lime stone along their joints when lime stones are well exposed at the ground surface. The weathering residues left at the surface are called Tera Rosa which means red residual soils or red earth.



**2) SINK HOLES**

Chemically active rainwater dissolves lime stone and other carbonate rocks along their joints and thus numerous types of solution holes are developed at the ground surface when lime stones are directly exposed to the atmospheric processes. Smaller vertical holes or depressions in the lime stone region are called sink holes.



It may be of two types viz. i) funnel shaped sink whole and cylindrical shaped sink holes. The depth of sink holes ranges from a few centimeters to 10 meters but generally average depth remains Between 3 to 10 meters. Area varies from a few square meters to few acres.

E.g. Limestone plateau of Kentucky of USA and southern edge of Meghalaya’s limestone region in India are well known for distribution of sink holes.

**3) SWALLOW HOLES**

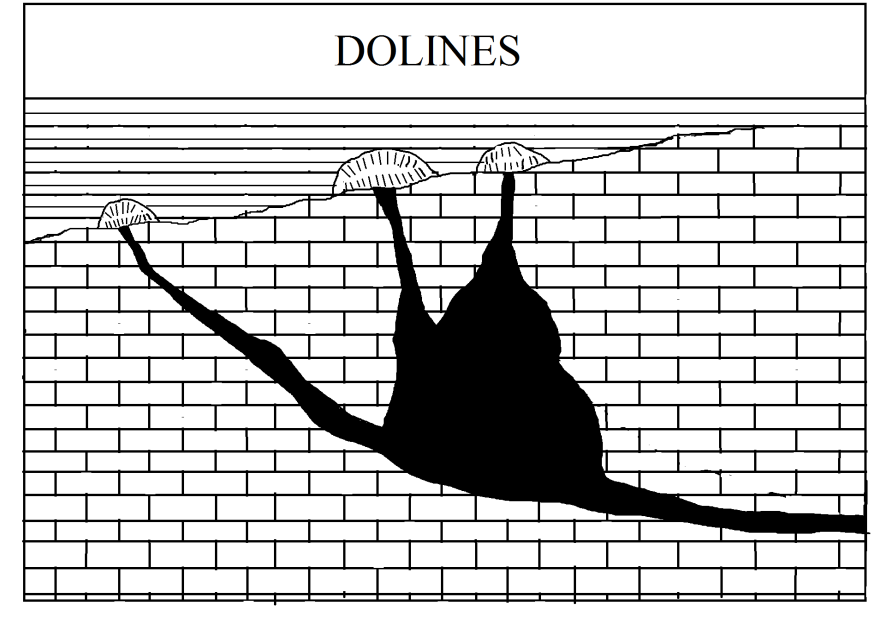
Gradual enlargement of sink holes into one large hole due to continues dissolution of limestone rocks, is known as swallow holes.

**4) DO LINE**

Do lines are huge size of sink holes. They are formed due to solution action of water as the sides of sink holes are laterally eroded and dissolved in solution and they increase in diameters.

The typical do line is found in the Karsts region along the Adriatic Sea. And Serbia and its characteristics feature is funnel shaped top, the diameter being 30 to 100’s of feet. Sometimes, it is deeper than broader. The diameter of do line ranges from a few meter to 1000 meters to 300 meters.

A feature almost similar to do line in appearance but with swallow depth and larger areal extent is called ‘solution pan’. The solution pan of the lost river of Indiana (USA) in 30 acres in area.



**5)KARST LAKES**

Sometimes, the floor of do lines is plugged due to deposition of clay, with the result water cannot percolate downward and thus do line is filled with water. Such do lines full of water are called Karst Lakes.

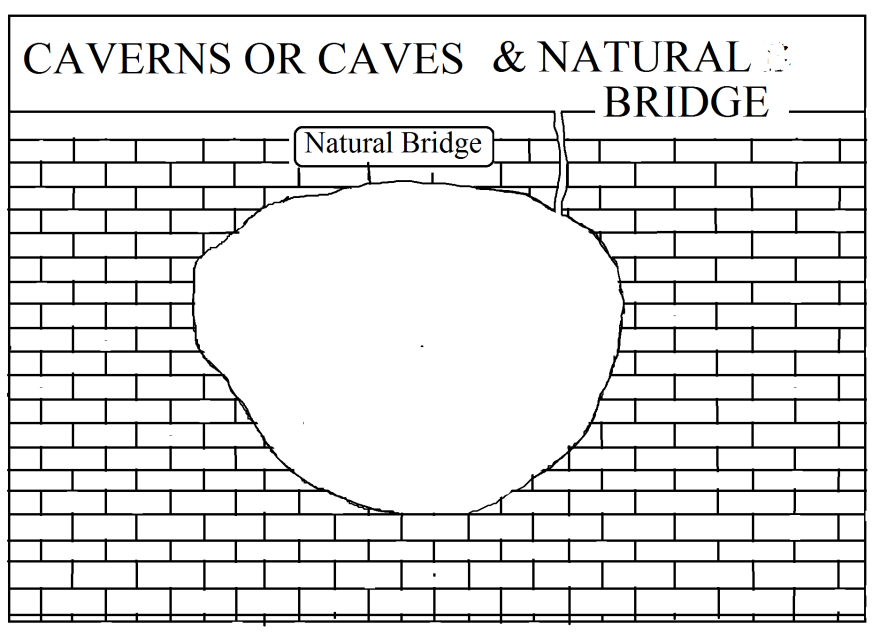
**COCKPITS-** Rock walled steep depressions caused by the collapse of ground surface are called cockpits.

**6) KARST WINDOWS**

Karst windows are formed due to collapse of upper surface of sink holes or do lines. These windows enable the investigators to observe subsurface drainage and other features formed below the round surface.

**7) CAVERNS / CAVES**

Caverns are underground depression with intact roof formed by enlargement of underground opening due to solution action of water. Their floors are irregular although different caverns differ in height, form and size. Caverns are usually above the water table and inter linked with each other by underground channel or passage.



**NATURAL BRIDGE-**

When the roofs of the cavern collapse from two sides leaving the central part standing is known as natural bridge.

**8) U VALES**

Extensive depressions are called Uvalas which are up to one Kilometer across. They are formed in a number of ways e.g. (i) due to coalescence of several do lines due to continuous solution and enlargement of do lines (ii) due to collapse of upper roof of large cavities formed underground. (iii) Due to coalescence of various sinks aligned in a line

Iamas – Smaller Uvalas are called Iamas.

Uvalas are so extensive that surface drainage is lost in them and takes subterranean course. Uvalas are also called as compound sinks because of coalescence of several sink holes. The sides of uvalas are very steep. They are generally dry depression. The floors are generally characterized by the deposition of clay but they are usually of even surface.

**9) POLJES**

Most extensive, larger than do lines, depressions are called poljes. They are characterized by vertical side walls, flat alluvial floors, and independent surface drainage system on their floors, irregular boarders and central lake. Polijes are, in fact, closed basins of elliptical shape having an area up to 258 km2. They are frequently found in Karst region of earstwhile Yugoslavia and in Jamaica. The Livno polje of the Balkan Region of Europe is 64 Km long and 5 to 11 km wide.

**10) PO NORES**

The vertical pipe like chasms or passage that connects the caves and the swallow holes are called ponores in Serbia and ‘avens’ in France. Ponores are termed due to downward extension of sink holes through continuous solution of carbonate rocks. Ponores may be inclined.

**11) VALLEYS OF KARST REGION**

The upper surface having several sink holes in the region of limestone’s having horizontal beds or slightly inclined beds is called Karst plain on which surface drainage system develop various types of valleys and typical landforms. Almost all of the valleys are related to sink holes or swallow holes in one way or the other.

**1) SINKING CREEK**

The surface of the Karsts plain looks like a sieve because of development of closely spaced numerous sinkholes. These sink holes acts as funnel because surface water disappears to go underground through these holes. When surface water disappears through numerous sink holes located in a line, the resultant feature is called ‘sinking creek’ and the point through which water goes downward, is called sink. The water of short rivers disappears through a single sink while that of larger streams disappears through many sinks.

**2) BLIND VALLEY**

Blind valley refers to the valley of that surface stream which disappears in limestone formation through a swallow hole or sink hole. In other words, that valley is called blind valley the flow of which terminates a shallow holes and the valley looks dry valley.

**3) KARST VALLEY**

Surface streams develop their U shaped valleys on limestone formation. Such valleys are always temporary because generally water disappears through swallow holes or sink holes and the valley becomes dry. This valley is also known as ‘solution valleys’ or Karst valleys.

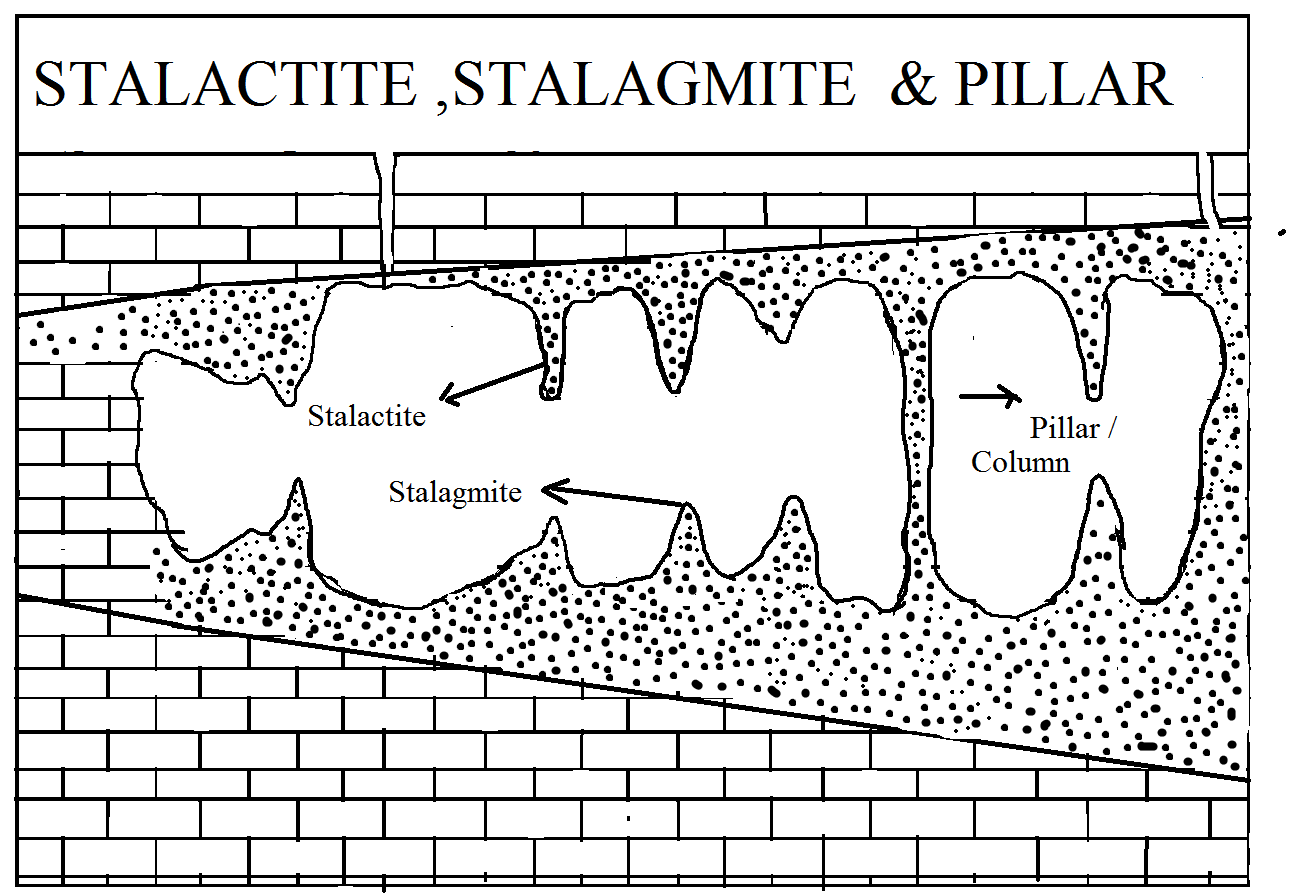
**LANDFORMS FORMED BY DEPOSITIONAL WORK OF UNDERGROUND WATER / DEPOSITIONAL LANDFORMS**

Most of the depositional work of underground water is in the form of calcium carbonate. This leads to the formation of following topographical features.

**1) STALACTITE**

Such landscape is seen in the limestone region, below the earth surface, due to the deposition and petrifaction process by underground water.

The underground water charged with the solution of limestone falls along on the roof of a cavern and drops, drop by drop. During the time a drop is hanging from the roof of the cavern, some of the water evaporates leaving behind a deposition of time and thus deposition of time grows downwards from the roof till it begins to hang like a pointed pillar or finger. This hanging deposit of time in the cavern is known as stalactite.



**2) STALAGMITE**

The percolating underground water also reaches on the floor or the cavern. After the evaporation of water the deposits of the calcium are left on the floor of the cavern. With the passage of time, the deposits move upward like a pillar. This pillar like up standing deports of calcium on the floor of caverns is called stag lag mite.

**3) CAVERN PILLAR**

The calcium carbonate or calcium is deposited on both roofs and floors of the caverns with the passage of time, as the process goes on, these two deposits meet together forming pillar. This pillar is also known as column.

**Unit No 5 D**

**GLACIAL TOPOGRAPHY**

Before 30000 to 40000 years ago, in Pleistocene era, about 1/5 part of the earth surface was covered by glaciated region. This era is known as ice age on the earth surface. About 3108000 Km² area was under glaciated region in which more than half area of North America continent, total Europe continent, Greenland island, Antarctica continent , total Patagonia area, northern part of Asia continent included. Due to changing climate on globe, the glaciated region on the aforesaid parts of the earth, receds towards polar region. According to Salisburg and Chamberlen scientist, the total volume of present glaciated region is 13450000 Km³ on the globe.

Important Glaciated Regions

1. Antarctica Continent - 130, 00000 Km²
2. Greenland island - 19,00000 Km²
3. Spitsbergen - 56000 Km²
4. Iceland - 14000 Km²
5. Norway - 5000 Km²
6. Alps -4000 Km²
7. Caucasus Region 2000 Km²
8. New Zealand 1000 Km²

The moving ice mass down slope under the impact at gravity is called glacier. About 10 % of the earth surface is now covered by glaciers. About 2 to 3 million years B.P. glaciers extended over almost one third of the earth’s lithosphere surface. Glaciers are formed due to accumulation of ice above snowline under extreme cold climate. “***Snow line*** *is generally defined as a zone between permanent and seasonal snow*”. In fact, snow line denotes that height above which there is permanent snow cover and thus it corresponds to the level where average temperature is always below freezing point during the warmest moth of the year. The snow line is at the lowest height (0 meter or sea level) in the polar region and increases equator wards where it tends to occur between 500 to 6000 meter. The snow line is found at the highest elevation in the drier part of the Tibetan plateau and Andes (6500 m) . The estimated number of all types of glaciers all over the world ranges between 70,000 to 2,00,000 numbers.

The snowline is depends upon the following geographical factors :-

1. Latitudinal Variation :- The height of snowline is declined from equator region towards the polar region. That’s why the snow line is above 5400 meters high in equatorial region and it goes to sea level on polar region.
2. Proportion of Snowfall :- Whenever the precipitation takes place in the form of ice and snow , is known as snowfall. The proportion of snowfall is more on polar region and it decreases towards equatorial region.
3. Climatic Condition :- The height of snowline is comparatively more in dry climatic region as compared to humid climatic region. That’s why the snowline on the northern slope of Himalaya mountain is above 5400 meters high due to presence of more dry air as compared to southern slope of Himalaya where it is found above 4800 meters high from MSL due to moist air.
4. Slope of region :- The height of snow line is more in steeply mountain slope as compared to less steeply mountain slope.

The areas of accumulation of huge volume of ice are called snow fields, which generate glaciers of different dimensions. The glaciers grow by gradual transformation of snow into granular snow, then into firn or neve and finally into solid glacial ice. Snow is a fluffy mass of loosely packed snow flakes of very low density having on open feather like appearance. Semi compacted snow due to the weight of overlying snow is transformed into granular snow of denser form. Such granular snow is called firn or neve. Such compaction of granular snow produces pure solid glacial ice.

**TYPES OF GLACIERS**

Glaciers are generally divided into two broad categories viz i) Mountain or valley glaciers and ii) continental glaciers. H.W. Ahlmann classified world glacier into three broad categories and into eleven sub type’s category.

1. Glaciers without geomorphologic constraints or glaciers of extensive ice-sheets characterized by glacial movement’s in all directions.

i) Continental glaciers

ii) Ice cops

iii) High land glaciers.

2. Glaciers with geomorphologic constraints / confined to more or less marked courses.

iv) Valley glaciers of Alpine type.

v) Cirque glaciers

vi) Glacier tongues.

vii) Wall Sided glaciers.

viii) Transaction glaciers.

3. Cake like Ice-sheets.

ix) Piedmont glaciers.

x) Foot glaciers.

xi) Shelf ice.

1. **Ice Sheets or Ice Caps.**

The biggest glaciers on the earth’s land surface are called ice sheets which are broad dome with flattened cross- section covering thousands of square kilometers area . These are hundreds of kilometer in width. They submerge underlying topography. Ice radiates outward from the centre of the ice–mass. These radiating ice-masses are called Ice-sheets.

The difference between ice-sheets and ice-caps is that of a real extent e.g. down shaped ice masses spreading over more than 50,000 km2 are called ice-sheets while small ice-sheet with are area less than 50,000 km2 is called ice-cap. The central part of an ice cap / a sheet is called ice-down. The most extensive Ice-sheets are Antarctic and Greenland ice-sheet.

1. **Continental Glaciers**

Continental glaciers are in fact, extensive ice-sheets. These are called continental because they cover most part of the continents. Extensive Ice sheets radiates outward from the centre and move down slope. At present the biggest continental glaciers are Antarctica and Green land ice sheet. The Antarctica continental glacier having an average thickness of 400 meter covers an area of 80 lakh Km2 and the ice sheets rise about 4500 meter above mean sea level. The Greenland continental glacier with the thickness of 3000 meter of its central dome is spread over an area of 13 lakh km2 which is about 3/4th of the island.

1. **Mountain And Valley Glacier**

The body of ice moving down slope under the impact of gravity through the valley bordered by rock valley walls in the mountains is called mountain glacier / Valley Glacier / Alpine glacier. The length of these glacier ranges from a few kilo meters to 2000 Kms. They are located generally above the snow line as they are ablated while desending down the snowline. E.g. Himalayan glaciers Rupal (16 Km), Punmach (27 Km) Hispar (60 Km) Gangotri (25 Km), Kosa (11 Km), Zemu (25 Km), Kanchanganga (16 Km)

1. **Piedmont Glaciers**

The glaciers formed due to coalescence at several mountain or valley glaciers at the foothill zone are called piedmont glaciers such glaciers are found only in colder areas and not in the tropical or temperate regions because they melt when they reach the foothill zone. Milaspina glacier at Alska (USA) is typical example of piedmont glacier.

1. **Ice Shelf**

Ice shelf is a floating thick ice sheet or ice cap attached to the east, since there is no friction of ice bed and ice can spread freely such glaciers are abundantly found along the Antarctica coasts e.g. Ross ice shelf.

1. **Ice Field**

Ice field is comparatively flat and extensive mass of ice sheets.

1. **Cirque Glacier**

The ice occupying an armchair shaped cirque in the mountains is called cirque glacier.

1. **Niche Glacier**

Niche glacier represents a small upland ice mass which rests upon a sloping rock face.

**MOVEMENT OF GLACIERS**

Glaciers move under the impact of force of gravity which is the result of the thickness of ice mass and the gradient of the bed. In technical terms glacier advances because it deforms to stress set up in the ice mass because the weight of overlying ice. Hydrostatic pressure and shear stresses are the two mean components of internal stress. The hydrostatic pressure representing the weight of overlying ice is the same in all directions of the ice mass. Thus it is the shear stress which, being the outcome of the weight of the super incumbent ice and surface slope of the glacier causes the particles of ice to slip past one another.

* 1. They are three types of movement of glaciers viz.
  2. By sliding over bedrock.
  3. By internal deformation (creep) of the ice.
  4. By alternate compression and extension of the ice mass.

The rate of movement of glacier depends on the thickness of glacial ice and its slope e.g. the greater the thickness of glacial ice, and steeper its slope. The faster the movement of the glacier and vice versa. The rate of movement of glacial ice decreases from the centre line towards the side or edges of the glaciers because the friction of the ice against rock walls retards the flow from the surface towards the bottom or the bed. The average velocity of the most of glaciers range Between 3 meter to 300 meter per year. The internal deformation of the ice makes the glacier sluggish in their movement. More active basal sliding of the ice causes higher velocity of the glaciers.

The longest glacier ‘Fedronko’ is found on glaciated Pamir plateau have a length of 70 Km long. Alesh is a 16 Kms long glacier found in Switzerland ,

**ADVANCEMENT, RETREAT AND ABLATION OF GLACIERS**

The forward movement of glacier is called advancement of glaciers. While withdrawl of glacier is known as retreat of glacier. The destruction of glacial front due to melting of ice consequent upon increase of temperature is called ablation of glacier.

**WORK OF GLACIER**

In polar areas and in high mountain regions, the temperature always remains below the freezing point and precipitation takes place in the form of snow instead of rainfall. Snow accumulates after the snow fall and give rise to snowfield. The snowfield lies above the snow line. The snowline is defined as a lowest level above which continuous snow field is found. Due to the increasing weight of accumulated overlying snow, the loose snowflakes convert into hard solid crystalline ice. The underlying compact solid ice is called as Neve or firn. When the ice becomes so thick that the lower layer becomes like plastic and consequently moves outwards or down hills under the influence of overlying pressure of accumulated snow. Thus the mass of ice moves either lateral or downhill, is called as glacier.

**DEFINATION**

1. A glacier is a mass of snow and ice that moves slowly over the land away from its place of accumulation.

2. The moving mass of ice is known as glacier.

1. **LENGTH AND SPEED OF THE GLACIER**

Generally the length of the glacier is very short as compared to the length of the river. The length of the glacier is depends on the climatic zone of the earth and the altitude of the mountain range or hill. Some glaciers having a length of 70 Km while some glaciers having a length of 2 to 3 Km long only. e.g. Siachean Glacier in Karakoram range is 72 Km long. These glaciers are melted below the snow field line and it converts into running water or river due to the increasing temperature above freezing point or 00 C at that point. i.e. In the Himalayan range, Ganga river originates from Gangotri glacier.

The speed of the glacier is very slow as compared to the speed of the running water. The movement or the speed of the glacier is directly depends upon the thickness of glacier, temperature of that region and slope of relief land on which glacier move. On the Antarctica continents, the movement of glacier is very slow i.e. 50 to 60 meter per day. In India, Sikkim’s Zemu glacier moves at the speed of 22 cm per day.

1. **SNOW LINE**

There are many areas in the world where the temperature remains below freezing point and the snow remains unmelted there. The ice keeps on accumulating year or after year. The lower limit of the accumulating year o after year. The lower limit of the accumulating ice is called as snow line. In other words, snow line is that line above which snow does not melt even in summer. The snow line is found at different heights in different climatic zones. It may be as high as 6000 meters in the tropical zone where as it may be found even at sea level in the polar region.

1. **SNOW FIELD**

The areas the snow line is known as snow field. In such areas the amount of winter snowfall is more than the amount of summer snow melt. Snow fields are found in areas of high altitude and latitude. There are several examples of snow fields in the Himalayas, Rockies, Alps, and in the polar areas.

1. **NEVE OR FIRN**

The underlying compact solid ice is called as Neve / firn.

**TYPES OF GLACIER**

Glaciers are widely spread in the area where temperature lies below freezing point. Glaciers are found in every continent except Australia. The source of the glaciers i.e. snow field occurs above the snow line. The height of this line varies from region to region. It is at over 5000 meter in equatorial region and at the sea level in polar region. Glaciers are found at different localities and spread into different forms on the basis of their occurrences and dimension. They may be grouped as

1. Valley glacier
2. Continental glacier.
3. Piedmont glacier.

iv) Ice cap.

**i) Valley glacier or Mountain glacier**

A glacier rising from a neve and flowing down a valley is called as valley glacier.

These glaciers are formed at high altitude regions in any climatic zones. They are long and narrow because they occupy previously formed river valleys and they move down slope from colder climate to the warmer climate where glaciers begin to melt. Due to their location in mountainous region. They are also called as mountain or alpine glaciers. Such glaciers are commonly found in Himalayan ranges and Alps Mountain. Siachen (72 Km) and Gangotri (25.5 Km long) are important Himalayan glaciers.

**ii) Continental Glaciers**

An extensive sheet of ice is called as continental glacier. Or glaciers covering vast areas of a continent are known as continental glaciers. These are also known as ice sheets due to their vast extent region. Such types of glaciers are generally found in polar regions mainly on the Arctic and the Antarctica regions and Greenland island. These regions are completely covered by glaciations.

**iii) Ice Caps**

Smaller ice sheets are known as ice caps. They give rise to many glaciers in the mountain area. Many peaks rise above the ice caps.

**iv) Piedmont Glacier**

When the ice are accumulated along the foothill is known as piedmont glacier. Many mountain glaciers descend down the snow line and flow in the plains formed at the base of the mountain. e.g. The Melaspina of Alaska is an example of a piedmont glacier.

**WORK OF GLACIER**

Like the other agents of denudation, it also does the work of erosion, transportation and deposition. Different kinds of landforms are formed by these works of the glaciers especially in cold regions.

1. **WORK OF EROSION**

The mobile blocks of ice catch up the rock fragments found in the way of glaciers and these caught p materials work as tool of erosion by glaciers. The following processes are involved in the erosional works of the glacier.

**i) Frost Wedging**

The process of wearing and tearing of the rock blocks along the pores or opening due to the melting of ice and freezing of water in that particular openings at the day and night respectively are known as frost wedging / frost weathering.

**ii) The Plucking / Quarrying**

The plucking process is one in which the broken and shattered rock fragments are caught up by mass of ice are carried away from their original place to other place by glaciers.

**iii) Abrasion**

The glaciers erode their valleys with the help of plucked materials with them. Such process is desorbed as the Abrasion process.

1. **TRANSPORTATION**

The broken or weathered rocks are caught up by the mass of ice within it, and they are plucked and transported from their original place. These carried materials and firmly caught up till the time when the glaciers begin to melt. After the thawing (melting) of ice the catch up materials are dropped down and deposited at suitable places.

1. **DEPOSITION**

The materials removed by the valley glaciers through plucking, scratching or abrading are dropped down and deposited reroute at its terminal point. These glacial deposited materials are unsorted, un stratified and angular unlike these sediments deposited by stream. Such kind of all glacial deposits are called as ‘Glacial drift or tills’.

**LANDFORMS FORMED IN THE EROSIONAL WORK OF GLACIER**

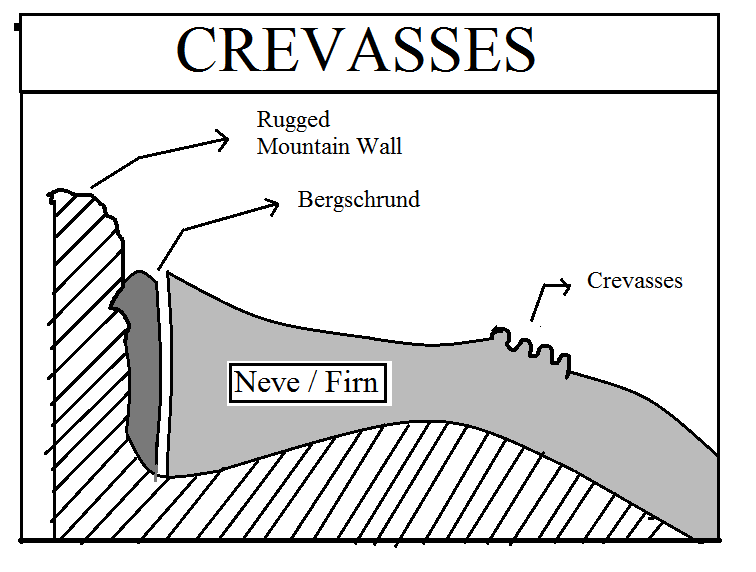
Pure ice, like pure water, does not do any erosional work. Rather it is the rock material consisting of drift, boulder, boulder clay, and pebbles etc. which do the erosional work in the form of abrasion and plucking action. Before rising of glacier and in the erosional work of glacier, some of the important landforms are formed e.g. It includes crevasses, Bergs chrund, Neve, Cirque, Tarn, Horn, Col / pass. Arete / comb ridge, U shaped valley, hanging valley. Sheep rocks, crag and tail etc.

**1. Crevasses**

The invisible and hidden interior cavities or cracks formed in the glacier body due to the unequal movements of ice within the glacier are known as crevasses.

The movement of ice is different in different parts of the glacier. As a result of unequal movement of ice within a glacier. The top glacier part with least amount of friction moves much faster than the base. The cracks marked on the glacier because of the splitting up of ice as a result of its unequal movement are known as crevasses. These crevasses are formed along the flow of glacier and across the entire glacier due to the unequal movement of ice blocks within glacier.

Many more crevasses are formed across the entire glacier where the slope of its bed i.e. the floor of the valley becomes suddenly steeper. At that situation, the ice can not keep pace (adjust) with its faster movement and the glacier breaks up into separate blocks on such steeper slopes. At the downwards where the gradient is gentler again, crevasses gradually joins into unite block of ice and glacier becomes smoother.

The crevasses in the direction of flow usually develop when a glacier becomes wide on leaving a narrow valley. The crevasses on the glacier are dangerous to the travelers when hidden by fresh snow since many of them are from 1 to 2 meters wide and may be 50 to 200 meters deep. 

**2. Bergschrund**

When the upper end of a valley glacier comes out of the ice field, a deep and wide crack is developed in the glacier which is known as bergschrund. According to some scholars, the vertical broad crevasses are called as bergschrund.

**3. Neve or Firn**

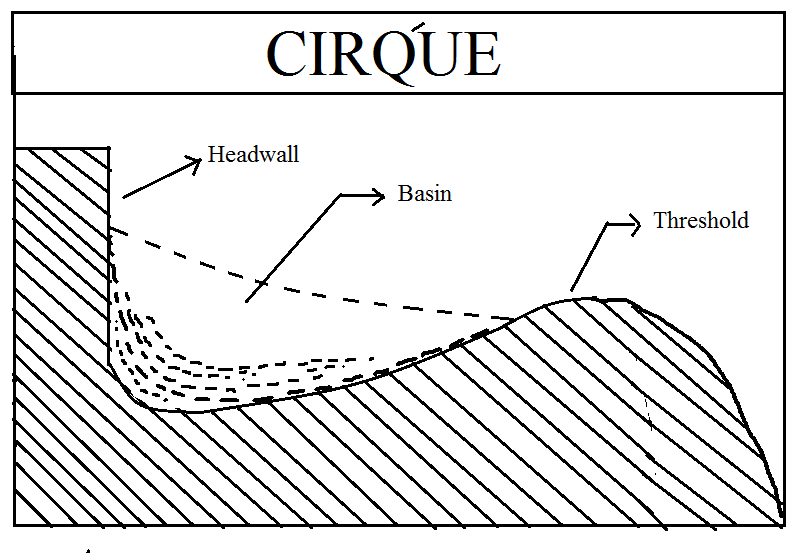
When the snow and ice accumulates in a deep basin or hollow, it becomes hard due to pressure of ice layer lying above. This is known as firn in German or Neve in French.

**4. Cirque**

Such land scope is formed before the rising of glacier at the top mountain ranges where snowflakes falls down.

A large circular depression on the mountain tops which are covered with snow and ice are called cirques. They have looks like of amphitheatre or arm chair type of hollow cut into the mountain ridge. It is open at one end, has a flat bottom and very steep rocky slopes on three side. It is slightly higher ground. The frost weathering and the plucking action of ice starts the formation of a cirque.

A cirque is known as Corril in Scotland; karren is Germany, coom in Wales, Both in Norway and Kessel in Scandinavia.



**5. Tarn**

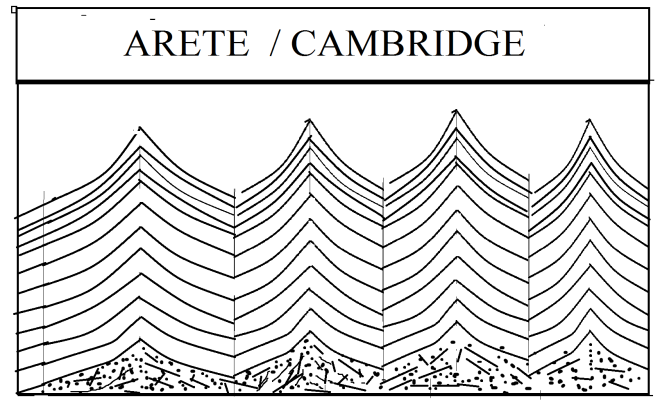
After the melting of ice, the cirque or depression is filled by water and converted into a lake. Such lake is known as Tarn.

**6. Arete or Combridge**

When an adjacent cirque grows up along the opposite slopes of mountain, the wall between these two cirques, gradually becomes narrower and pointed due to the head ward erosion by them. Such sharp and irregular ridge is known as Aretes / Com Bridge.

When three or more cirques develop on various sides of the mountain, are known as Com Bridge.

A sharp edge ridge separating to the continuous cirques is called Arete. It is developed by the lateral erosion on both sides by the continuous glaciers.

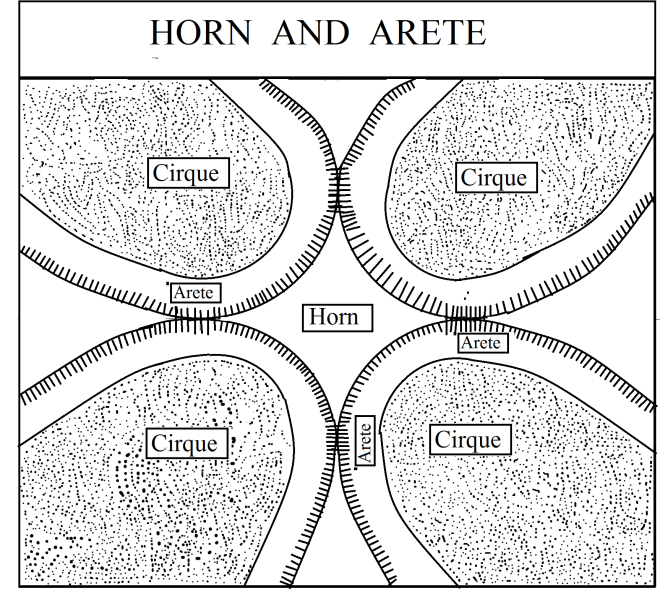


**7. Horn**

The various arêtes form a pointed peak at the top of mountain from different cirques. This pointed peaks shows pyramid shape, which is called as horn.

The matter horn peak of Swiss Alps is the famous example of horn.

When the ice over the horn melts, it leaves the peak exposed and free from ice cover. Then it is known as Nunatak.



**NUNATAK**

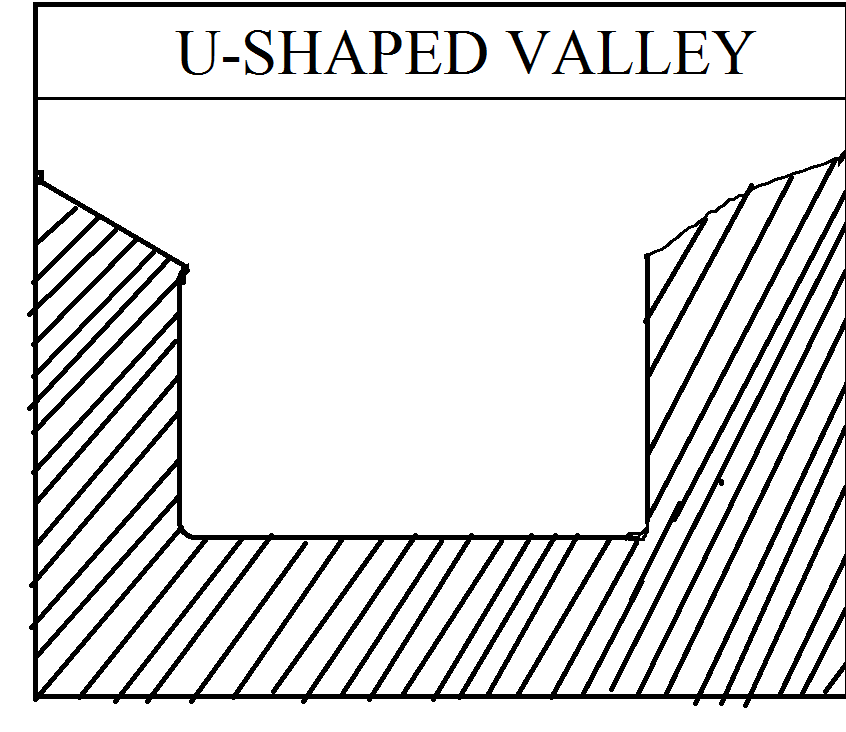
It is also formed when a glacier passes over pointed parts. These pointed parts are completely free from ice but it is surrounded by ice, are known as Nunatak.

**8. Col or Pass**

When the cirques from the opposite but frontal sides of a mountain develop and melt each other, the summit line is lowered and a Col or pass is formed.

Many cols in the Alps have been formed by the glacier in this way.

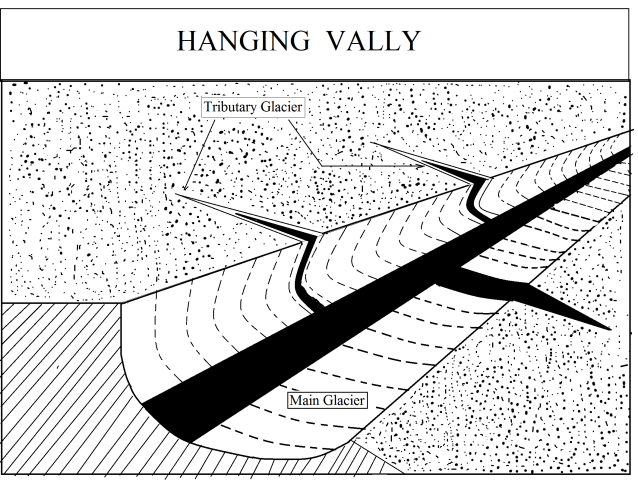
**9. ‘U’ Shaped Valley**

Such special types of landforms are formed in the erosional work of the glacier. Initially the glacier moves in the pre-existing ‘v’ shaped river valley. This glacier moves very slowly and does not follow the sharp and acute bends found in the course of valley but it straightens up its course and cut the topographic projections. This ‘v’ shaped valley is deformed into steep walled, flat based and deep valleys such type of valleys are known as ‘U’ Shaped Valleys. 

**10. Hanging Valleys**

Such special types of land forms are formed in the erosional work of the glacier where the small or tributary glacier meets to the big or main glacier as like of river.

The glaciers have the tributaries just as the tributaries of a river. The main glacier has deeper valleys as compared to its tributary glacier’s valley. Hence at the confluence of main and the tributary valley, their bases are not coming in the same base level i.e. a discordant junction is formed. In other words, tributary valley of glacier is higher than that of the main valley of glacier. When the ice melts, the tributary valleys look hanging over the main valley and are known as hanging valleys.

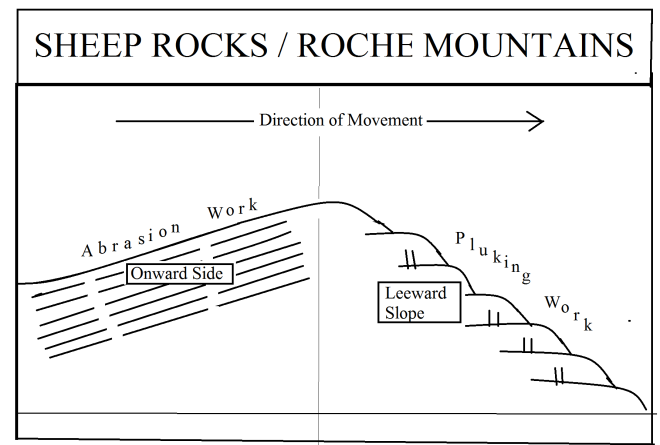


**11. Sheep Rocks or Roche Mountains**

Such landscape is formed in the erosional work of the glacier where abrasion action is takes place on the onward side of slope and plucking action is on leeward side of slope of rock.

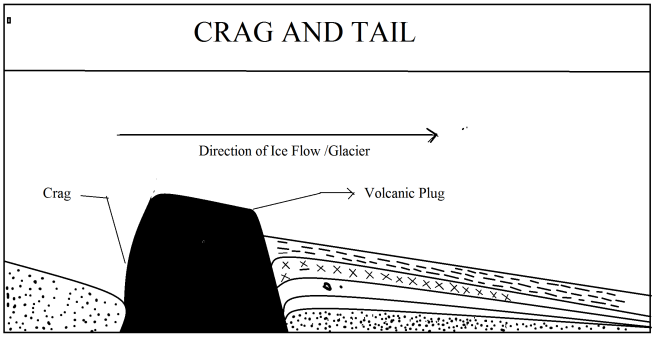
Unlike the running water, the glacier does not diverted from its path (route) by slight barriers or hummock comes in the way of glacier, the glacier rides over the rock and then descends on the other side. When the glacier rides over the rock, it is smoothed and polished due to the abrasion action by the glacier. The onward slope becomes gentle. But when the glacier descends the leeward slope it becomes rugged and rough due to the plucking action of the glacier. Such a rock swell which has gentle and smooth slope towards the direction of movements of ice and steep and rough slope away from the direction of movement of ice is known as Rochec mountainees.

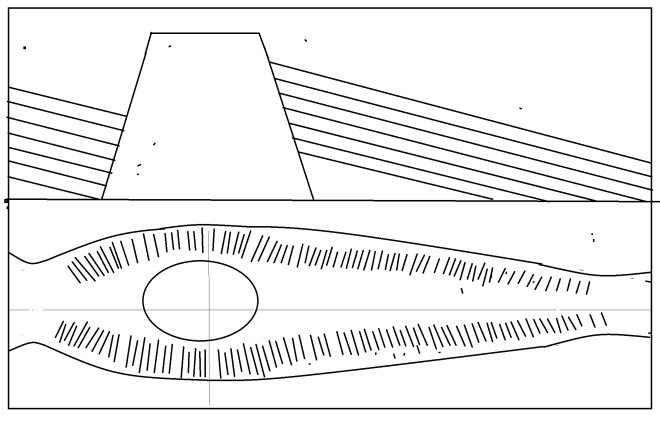
From a distance, these rock swells look like back of sitting sheep. Hence they are also known as sheep rocks.



**12. Crag and tail**

Crag and Tail is a special feature of glacial erosion. Sometimes, a resistant granite or basalt volcanic plug occurs in path of a advancing glacier. This volcanic plug is surrounded by soft sedimentary rocks of especially shale or clay. The layer of soft rocks on the sides from which the glacier come is removed by glacier and the glacier rides over the sleeps slope of the side. The soft layer on the descending side is protected by ice and there is a gently slope on this side. Thus the ice front side shows steeps and rough slope and leeward side is gentler unlike the rochee mountaineers. Such feature is called as crag and tail.





**DEPOSITIONAL WORK OF A GLACIER**

The materials, removed by valley glaciers through plucking, scratching or abrading are dropped down and deposited enroute and at its terminal point. These glacial deposited materials are unsorted, unstratified and angular unlike the sediments deposited by stream. Such kinds of all glacial deposits are called as “glacial drift or tills”.

The deposition of glacial derived material takes place at different locations along the valley glacier. According to the mode of occurrence, the glacial deposits may be grouped as follows.

1. Moraines 2. Drum lines

**1. Moraines**

When the glacier melt or recedes they deposit rock material of various shapes and sizes. Thus hillocks of heterogeneous character and formed along the glacier which are known as moraines. The material ranges from fine rock flour to big boulders. The material thus deposited is loose and has no connection with the original rock of the region where they now lie.

There are several types of moraines. These are as below.

**i) Lateral Moraines**

Lateral moraines are those ridges of loose and broken rock material that are formed on the sides of glacier valley. These ridges are several meters high and are formed due to the slow speed of the glacier as well as due to the dissipation (melting) of ice on its sides.

**ii) Medial Moraines**

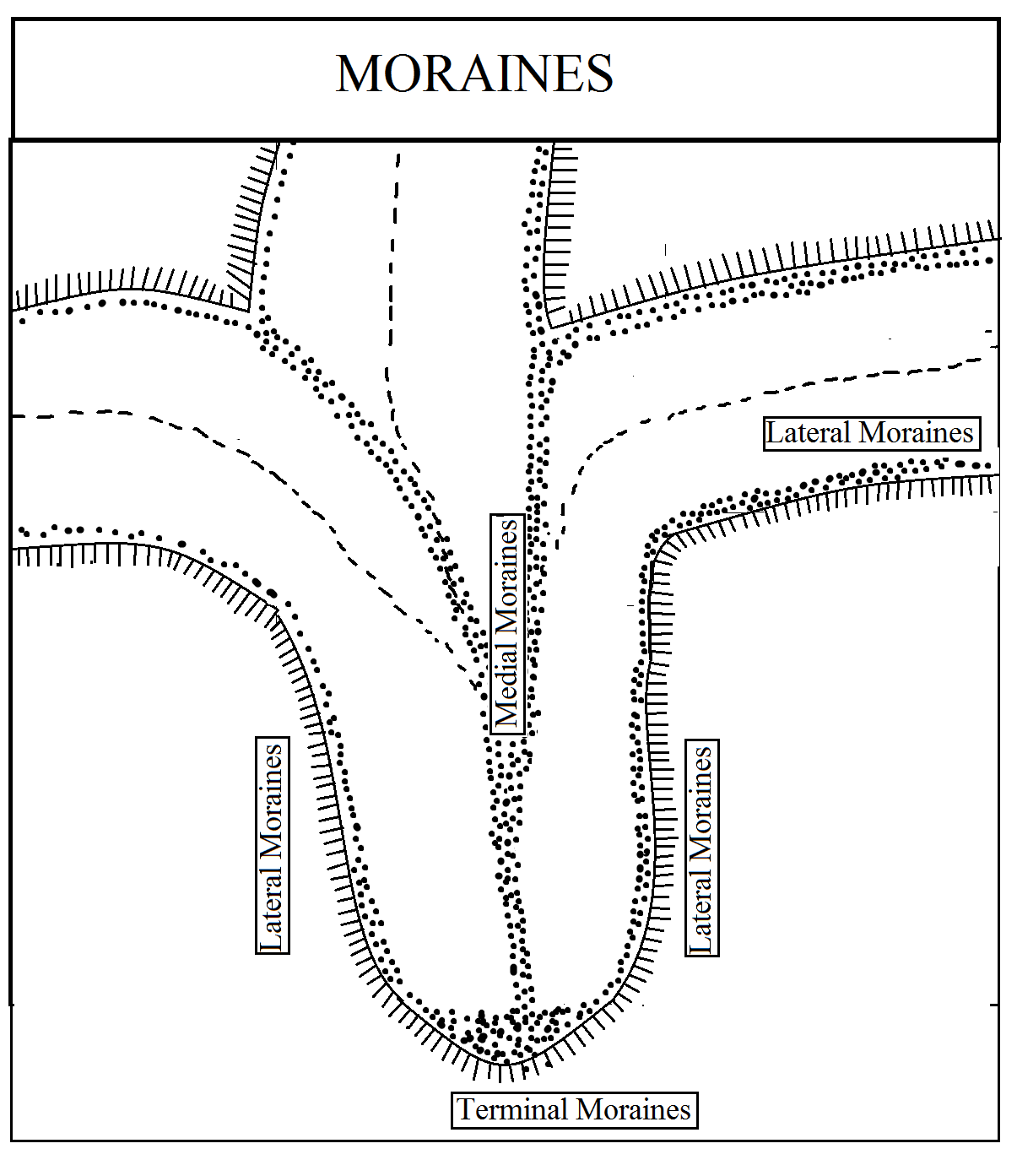
The glacial origin materials are also deposited at the junction of two glaciers and it continuous down the central part of valley. Such deposit of till is known as medial moraine.

**iii) Terminal Moraines**

The deposits of glacial origin material at the end of the valley glacier due to the melting of front of the glacier.

**iv) Ground Moraines**

When the glacial deposits is found on the bottom of glacial valley is called as ‘Ground moraine’.

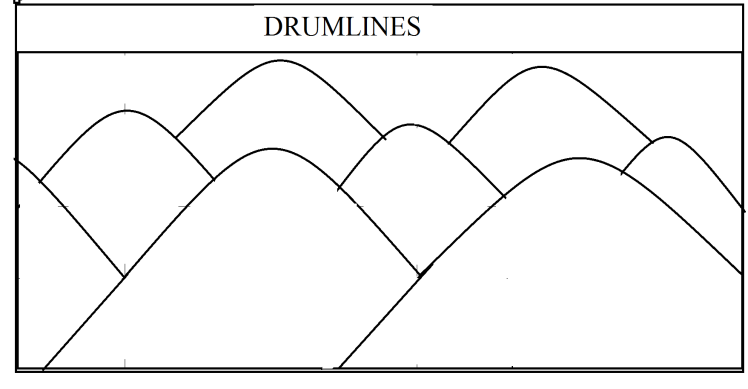


**2. Drum Lines**

Such type of land forms / land scope are formed in the depositional work of the glacier.

Drum lines are continuous chain age type of hills like a half eggs split lengthwise and from a distance look like eggs put in a basket. Hence it is often termed as ‘Basket of eggs Topography’. They also appear like an inverted boat in shape.

Drum lines are composed of boulder clays and their long axis is in the direction of ice movement. Their size varies from 80 to 100 meters high. Usually they are found in groups and radially arrangement. Drumlines are found in large numbers in North island, Nisconsin (USA) and Finland.

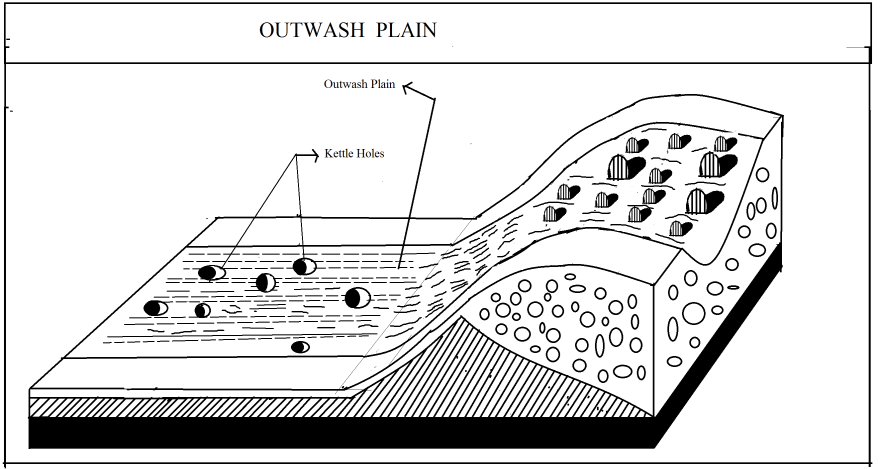


**GLACIO- FLUVIAL DEPOSITS OR FLUVIO GLACIAL DEPOSITS**

At the end of glacier, the ice melts into water and a stream flows from the glacier’s front. Fine particles of sediments are carried away by the stream and deposited after the terminal moraine. The deposited material are sorted and stratified and they are collectively known as fluvio -glocial deposits. Such deposits are of several types as given below.

**1. Outwash Plain**

Stratified and sorted sediments are occurring down the valley beyond the terminal moraines. These materials are deposited by streams, originated form the end of the valley glacier after the melting of ice. These deposits form an extensive plain having the characteristics of flood plains. Such land form formed by fluvio - glacial deposit is called ‘outwash plain’

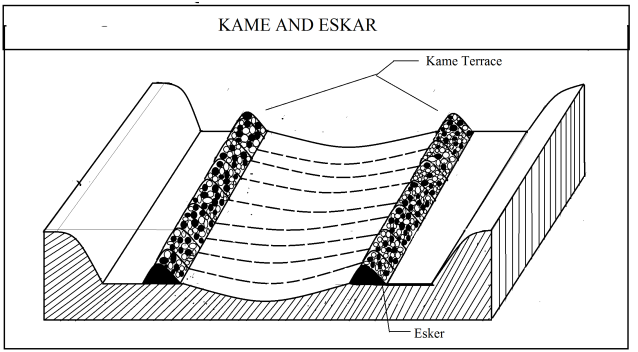


**2. Kettle Holes.**

Kettle holes are said to be formed by due to enclosure or burial of block of ice within glaciate drift and with the passage of time the arrested blocks of ice are melted and consequently a number of hollows or depressions are formed on the outwash plain. Such hollows are described as kettle holes. They are either circular or elongated in shape and vary in size and dimension considerably.

**3. Kame**

A lot of material is deposited at the mouth of the glacier where ice melts. It takes the shape of an elongated steep ridge and is called Kame. It is made up of sand and graval laid down by melt water along the ice sheet.



**4. Kame Tarrace.**

The tarrace which is formed along the sides of a valley is called Kame tarrance. Its upper part is contact with ice where as its lower part has a river valley at the end.

**5. Esker.**

These are long winding ranges to till formed by the sub glacial streams. From a distance, they look like natural levees. They are usually 40 to 80 meters high and 20 to 35 km long. These are very useful for constructing railways and roads.

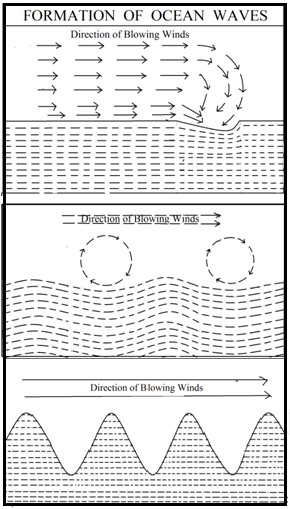
**Unit No 5 E**

**COASTAL GEOMORPHOLOGY**

**WORK OF OCEAN WAVES**

The extensive bodies of water like lake, sea and oceans are not in stationery positions. Tide, Ocean currents and waves are common phenomena. These oceanic features are used by number of factors. Tides are caused by gravitational force of the sun, moon on the earth while ocean currents caused by variation in sea temperature and the Ocean waves are caused to due to blowing winds over the water surface. The waves are regarded as oscillatory movement of the water particles in which the surface of water is deter med into troughs and crest.

**FORMATION OF WAVES**

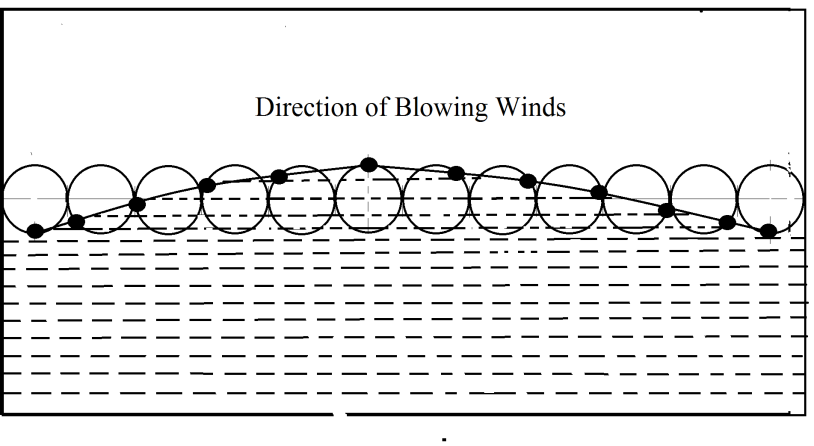


The blowing winds over the water surface cause the friction and pressure. The friction exerted on water by the movement of overlying air is rather reducing with the height. The top layer of the air experiences at least friction and consequently moves with faster rate. Due to the unequal rate of movement of air at different depths, the air of top layer moves ahead and tumble forward. Due to the absence of base of underlying layers of slow moving air, top layer falls down on the surface of water and consequently water is pressed down at its front. The down pressed water moves backward as subsurface water and pressed up at the rear of the blowing air (wind) and water level is rise up. When the surface water is disturbed in the wave form.

However, the wave, which is formed in the sea, is consisting of many parts. The highest part of the wave is known as crest and the lower part is called as trough. The vertical distance between the crest and trough is wave height or amplitude. The horizontal distance between either two crest or two troughs is described as wavelength.

**MOVEMENTS OF WATER PARTICLES IN THE SEA WAVE MOTION.**

The water shows the different trends and behavior with different kinds of motion in the sea. Ocean currents, fide and waves are common features of sea water.



**1) Ocean Currents**

Ocean current is the continuous flow of huge amount of water in the sea, ocean, caused by the variation in temperature from place to place. This ocean current displace the huge amount of water horizontally in a detonate direction from on region to another. Ocean currents referred as the horizontal movement of water / water particles in / from ocean / sea.

**2) Ocean Tides**

Ocean tides are the vertical rise and fall of ocean / sea water after a fixed interval everyday under the attraction of the sun and the moon on earth. It is also referred as the vertical motion of ocean water/ water particles.

**3) Ocean Waves**

Ocean / sea waves are defined as undulations of sea water characterized by well developed crests and trough. In the ocean / sea waves, the water particles do not move ahead with this wave but oscillates ups and down at the same place in circular form at all depth especially in deep water. At the crest, the movement of particle is forward, at the middle of hinder slopes downwards at the trough backward and the middle of front slope upward. As the wave move into shallow zone of water, the velocity decreases. The circular motion of particle is distorted into elliptical form. Gradually the elliptical form becomes horizontal. Consequently, the crest of wave becomes steeper and higher and the trough is flattened. Finally the crest loops out and falls down in the form of wave break. It is also known as surf / breaker in which the movement of water particles takes place horizontally.

**TYPE OF WAVES**

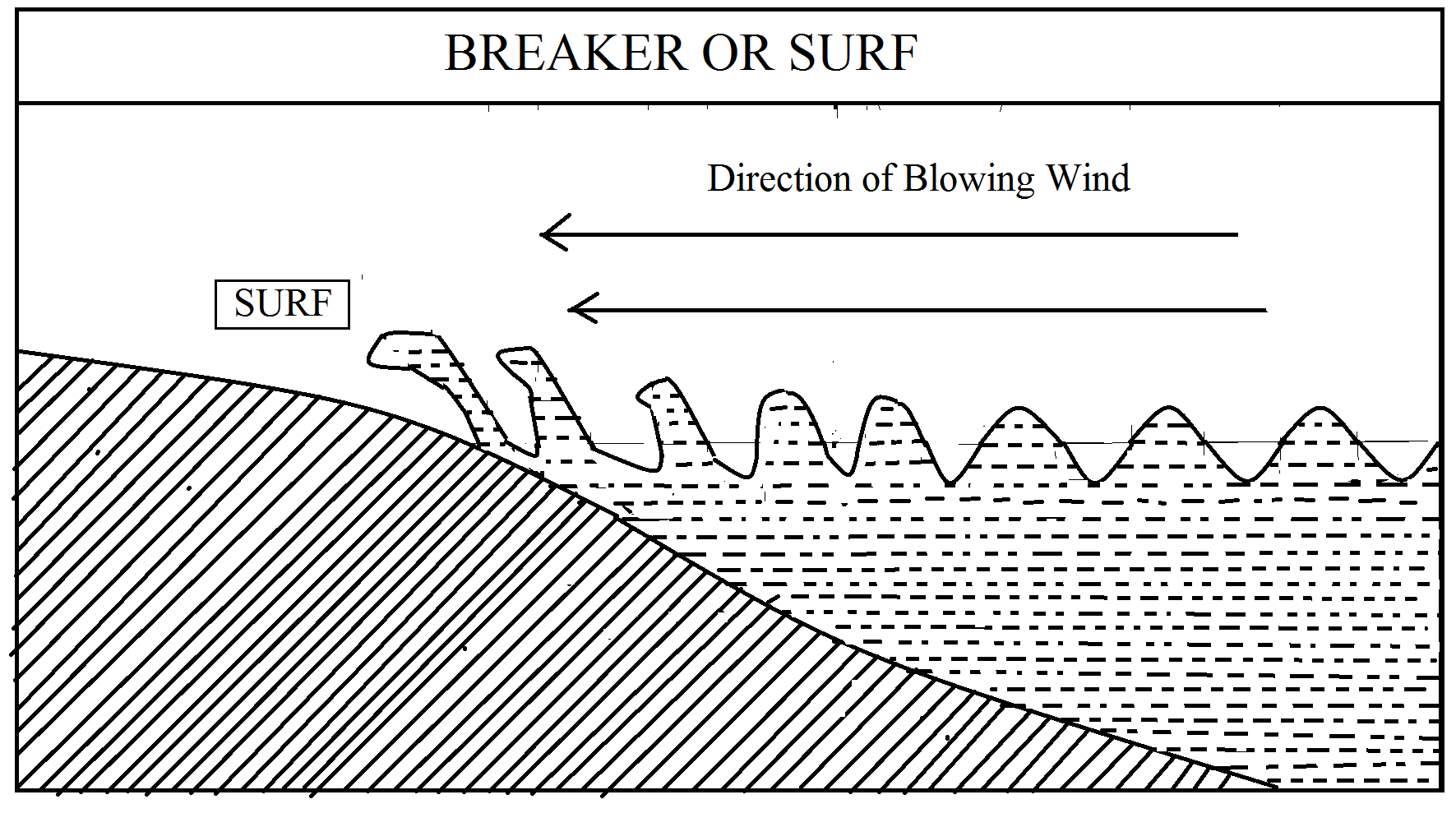
The physical characteristics like the size and the velocity of ocean / sea waves are determined by mainly three elements or the height of wind generated sea / ocean waves depends on i) Velocity of wind ii) The duration of wind from one direction iii) The extent of fetch which represents the length of water surface over which e.g. Deep and extensive water with faster rates winds experience stronger and high waves and vice versa. Thus the waves are known by different names according to their location, shapes, strength along their courses of travel.

1. **Seas**

When the wave originates in the deeper parts of sea water, it is very stronger and valiant. Sea water appears very high. Such stronger waves are known as seas.

1. **Breaker or Surf**

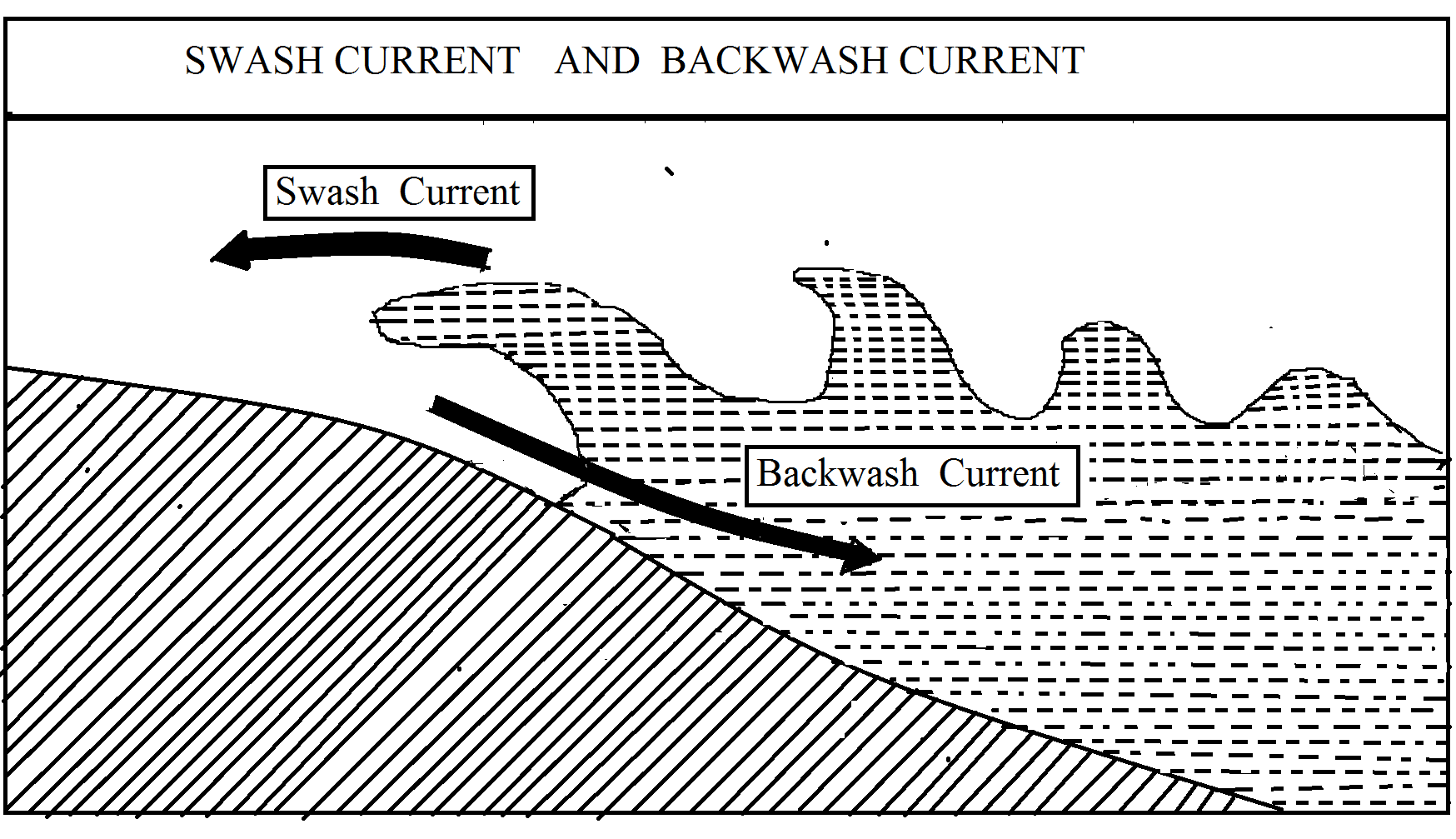
When the sea waves move into shallow water the velocity and wavelength of ocean waves are decreased. Height of waves increases as the water particles orbital movement becomes elliptical and horizontal at the sea bottom due to decline in depth of water body. The trough of the wave’s touches with bottom and move at rather slower rate as compared to the crest. The advancing crests of the wave gradually develop in concave form and fall down and rush the coast. Thus the wave after breaking up in shallow zone of water is known as breaker of surf.



**iii). Swash And Backwash Current**

After the breaking up of waves near the shore zone in shallow water, a huge amount of sea water moves over the shore zones to strike the coast line. This upward (landward) / turbulent forward moving flow of sea water is described as swash current / up rush currents.

The breakers / swash / surf after reaching the sloping beach return towards the sea is described as backwash current / under few currents or rip currents.



**PLUNGE LINE**

The distance from the shore where the ocean / sea waves break is called plunge line, where the depth of water and the wave height are approximately equal.

It may be pointed out that surf / swash or bracers and undertow / rip / backwash currents are more active geomorphic agents only when they touch the bottom ocean surface at the plunge line.

**iv) Ocillatory Waves And Translatory Waves**

Sea / Ocean waves are classified into two types on the basis of depth of oceanic water viz i) Waves in deep water are called oscillatory waves and ii) Waves of shallow water are called translator waves.

**Oscillatory Waves**

In oscillatory waves, water particles move in circular orbit and they return very nearly to their original position after the passage of waves.

**Translatory Waves**

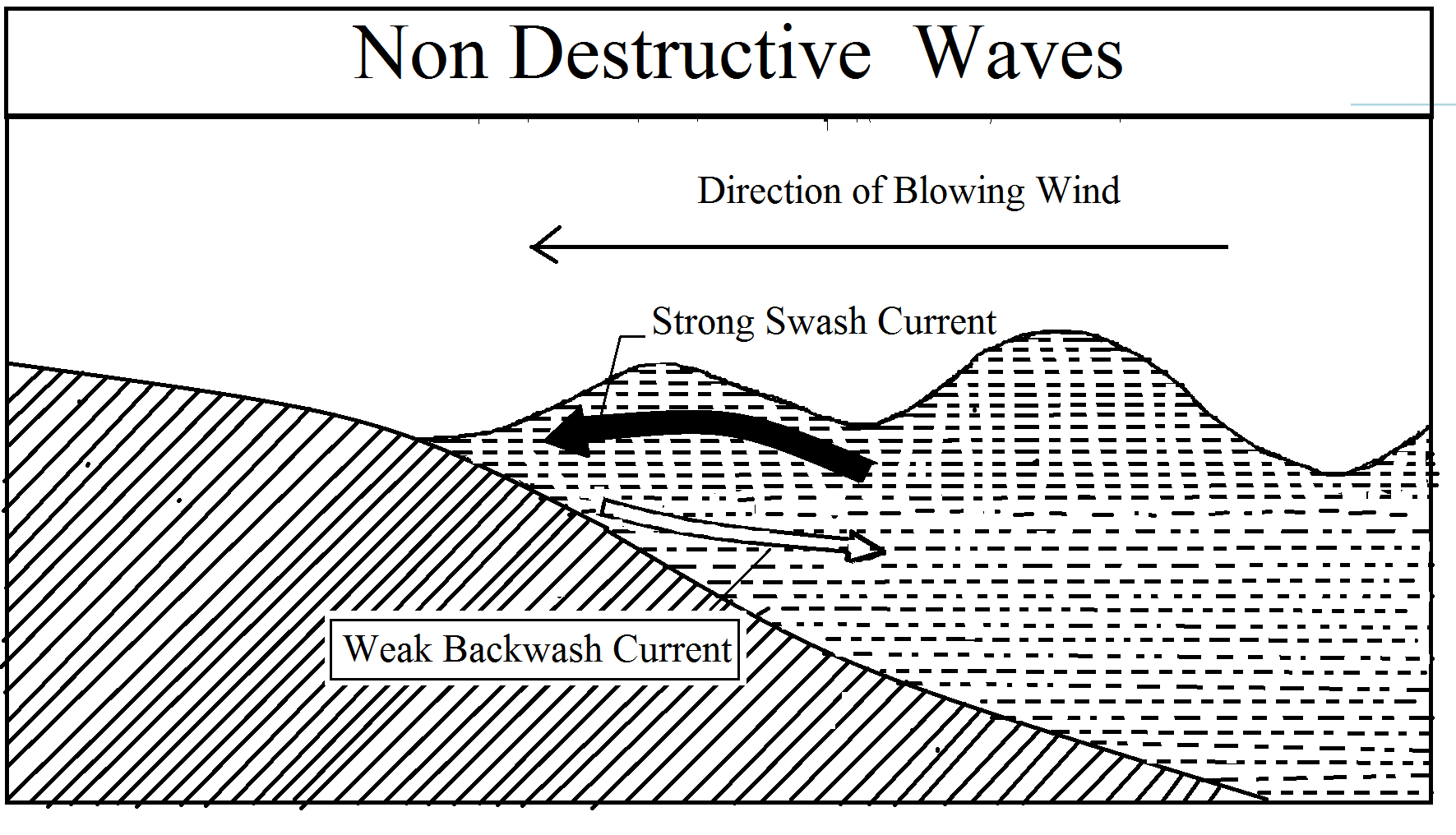
In translatory waves , water particles move forward approximately at the same velocity as the wave form

1. **Constructive And Destructive Waves**

On the basis of the strength and function of the swash and backwash currents waves can be grouped into two types.

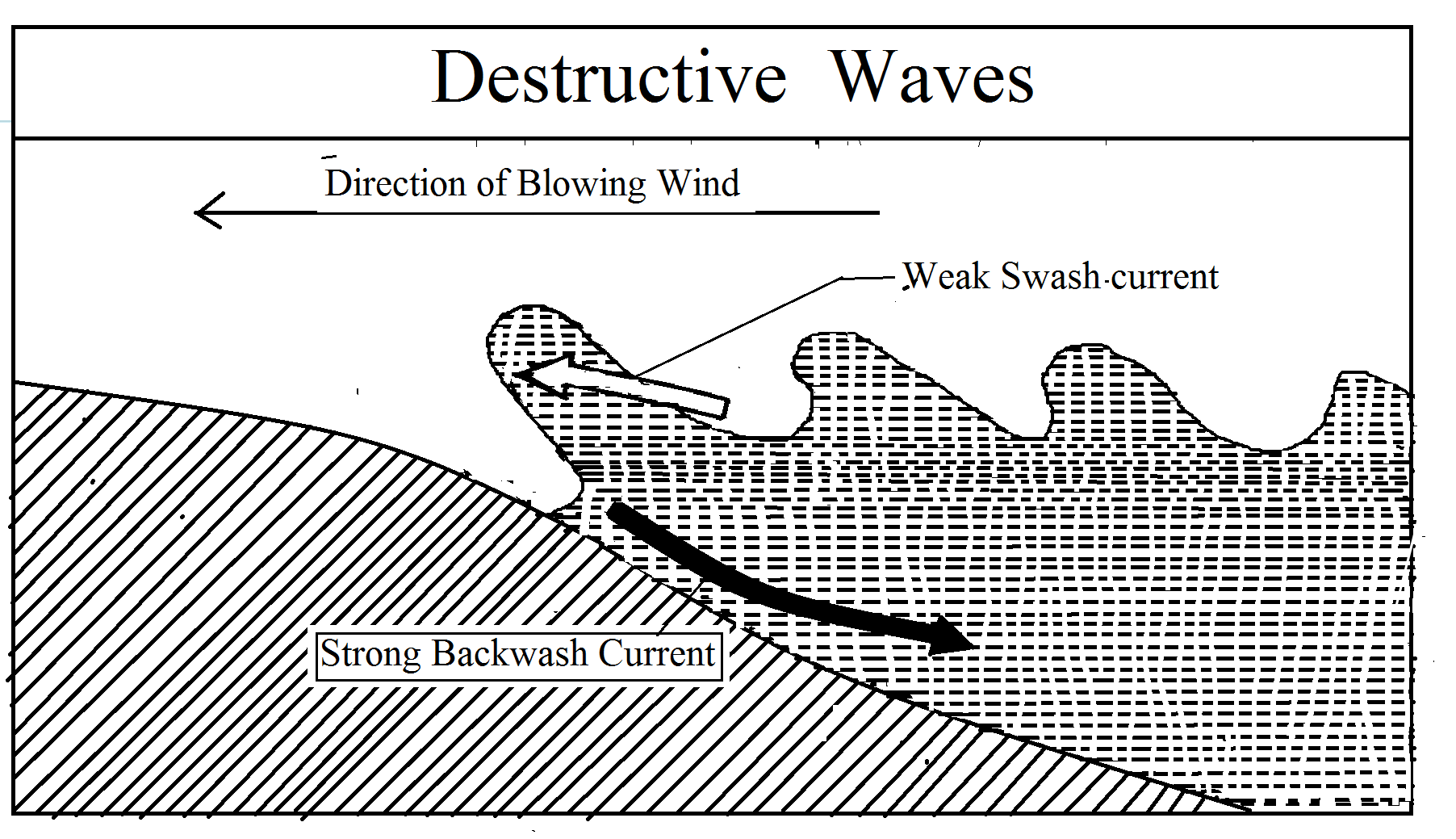
1. **Constructive Waves**

Low frequency waves approaching the share and beach are constructive waves in character because they lose volume and energy rapidly while moving up the beach because water percolates in the shingles and other beach materials and thus the backwash is weakened. It is, thus, obvious that low frequency with high wavelength haven helps in the building of beaches.



1. **Destructive Waves**

High frequency with short wavelength waves and high wave crests occurring on a more steeply sloping shore are destructive in character because instead of spilling they plunge and generates a powerful backwash which combs down the beach (removes the beach materials and transport them towards the sea).

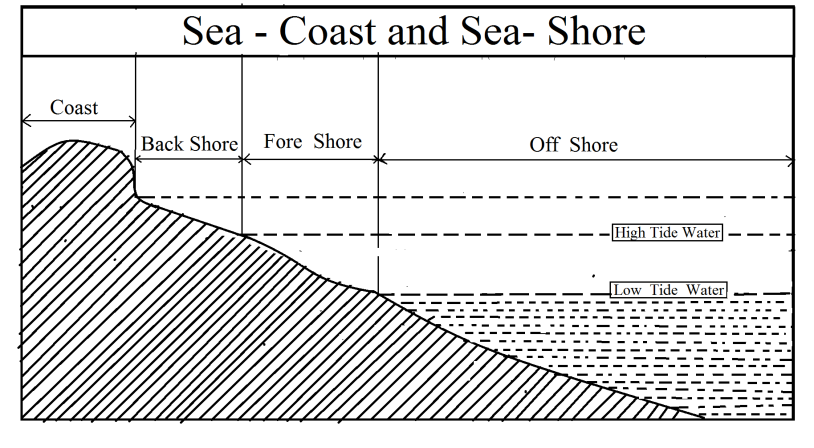


1. **Littoral / Long Spore Currents**

Wave refraction results in the formation of littoral / long share currents which mave parallel to the coast.

**SEA COAST AND SEA SHORE**

Generally, sea coast and sea shore are taken as synonym but geomorphologically these two terms have quite different meaning. Sea shore represents the zone of land between high tide water (HTW) and low tide water (LTW) while the shoreline represents the actual landward limit of sea water at a given moment of time. The shoreline is the line of demarcation between land and water. It fluctuates from moment to moment influenced by waves and tides. The coast represents the land zone immediately behind the cliff. The coast line represents the cliff- line or the margin of land rising above the sea water. The shore zone / simply shore are divided into 3 zones viz.



**I) BACK SHORE**

Represents the beach zone starting from the limit of frequent storm waves to the cliff base.

**II) FORE SHORE**

Fore share extends from low tide water to high tide water.

**III) Off shore**

Off shore extends from low tide water to inward sea water. Off shore represents the zone of shallow bottom of the continental slope.

**PROCESSES AND MECHANISMS OF MARINE EROSION**

Sea waves resort to erosion of the coastal land and back shore zone through the processes and mechanism of hydraulic action. Corrosion / abrasion, attrition, corrosion / solution and water pressure. When the sea waves break at plunge line, the potential energy and the resultant breakers / swash / surf currents strike the coast land with enormous power and erode the geomaterials in different manner as stated above. It may be pointed out that the coastal rocks are immensely attested by weathering processes resulting into disintegration and decomposition and thus weakening of rock. Such weakened rocks are easily plucked and eroded away by hydraulic pressure and turbulence of treating waves (swab).

The nature and magnitude of coastal erosion are affected and determined by the following factors- (1) Wave length, wave velocity, wave frequency and wave period. Long enduring waves with longer wave length and high velocity becomes effective erosive agent. (2) structure and composition of bed rocks of coast land. Rock types determine the nature of erosion. (3) More / Less stable coast line is subjected to more erosion than unstable coastline. The erosional actions by the sea waters are performed by following processes.

**1) HYDRAULIC ACTION**

It refers to the impact of moving water on the coastal rocks. Large strong waves attack the coastal rocks with enormous hammer blow amounting to 50 kg / cm2. Repeated blows of striking sea waves enlarge the incipient points, fracture patterns and thus help in breaking the rocks into smaller point bounded blocks. The waves are capable of dislodging larger fragment of rocks weighing several tones in weight. This process of displacement of rock fragments is also called as quarrying and plucking.

**2) ABRASION / CORROSION**

The broken fragments of rocks produced by hydraulic action commonly travel with the advancing waves and strike against share. The rocks of the share are subjected to further erosion due to rubbing effect of impinging rock fragments. Thus the process of wearing and tearing of coastal rocks, due to grinding effects of invading rocks, is called as abrasion.

**3) ATTRITION**

The broken fragments of rocks are moved up and down the share zone by swash and backwash currents. During the movement, the boulders and pebbles are broken further into finer particles due to collision among themselves. Such process of wearing and tearing of rocks is described as attrition.

**4) CORROSION / SOLUTION**

The rocks of sea cost, consisting of some soluble constituents, are attacked by sea waves. The solvent action of water dissolves the rock and removes them in the form of solution. Such process of disintegration of rocks of sea coast is called as solution.

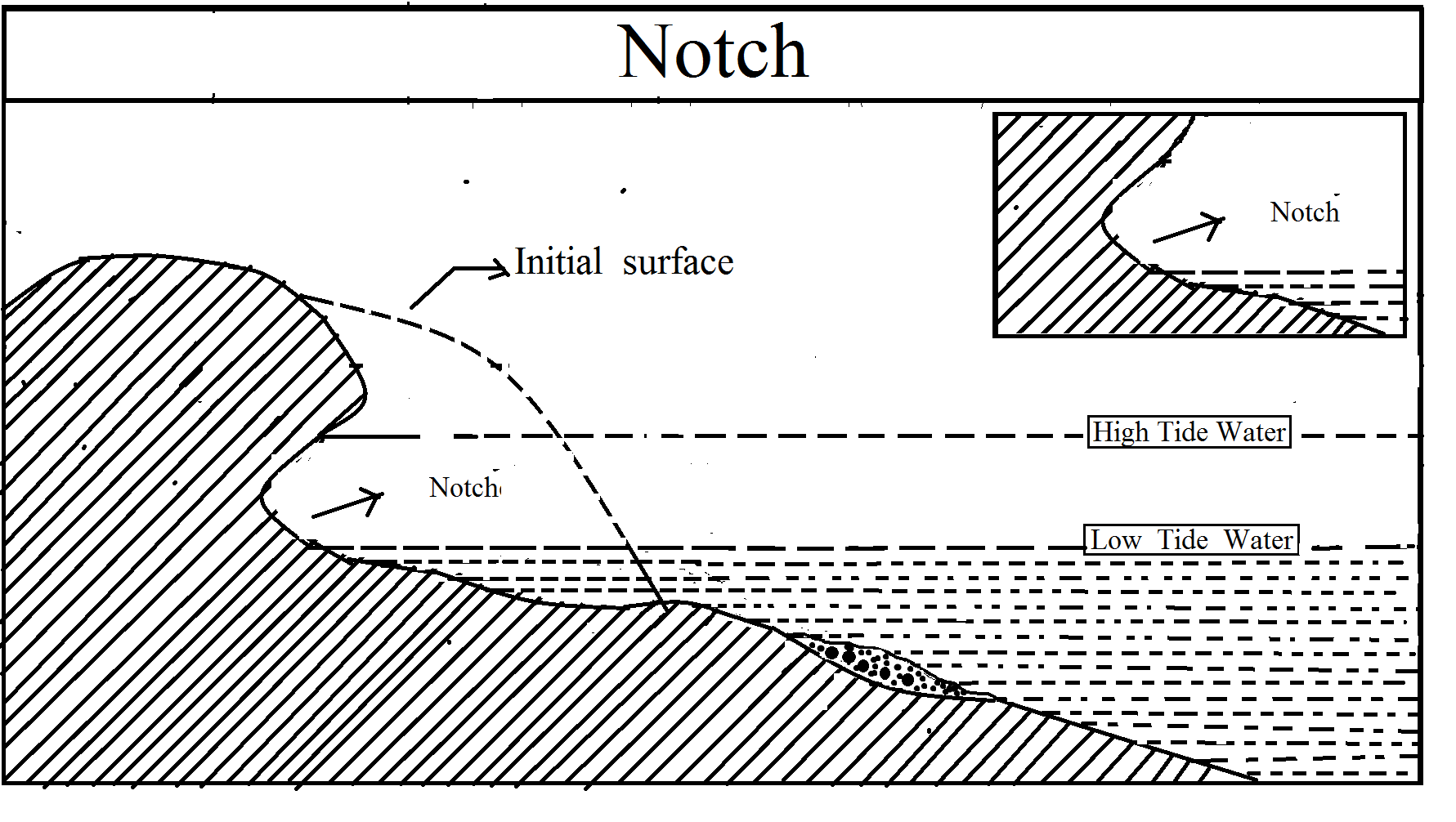
**EROSIONAL LANDFORMS FORMED BY SEA WAVES**

Significant coastal features formed due to marine erosion by sea waves and other currents and solution processes include notch, cliffs, coves, caves, indented coastline, stacks, chimneys, arch, inlets and wave cut plat forms.

**1) NOTCH**

Such land features are formed in the erosional work of Ocean / sea waves.

Swash / surf currents strikes on the exposed coastal rocks and the rocks are weakened, loosened, and shattered of at variable height depending upon the level of wave water. Thus the rock are undercut and small hallow is constructed along the coast especially of softer rocks. The overlying resistant rock projects in the sea and hangs over hollow. Such marine eroded hollow is called as notch.



**2) CLIFFS**

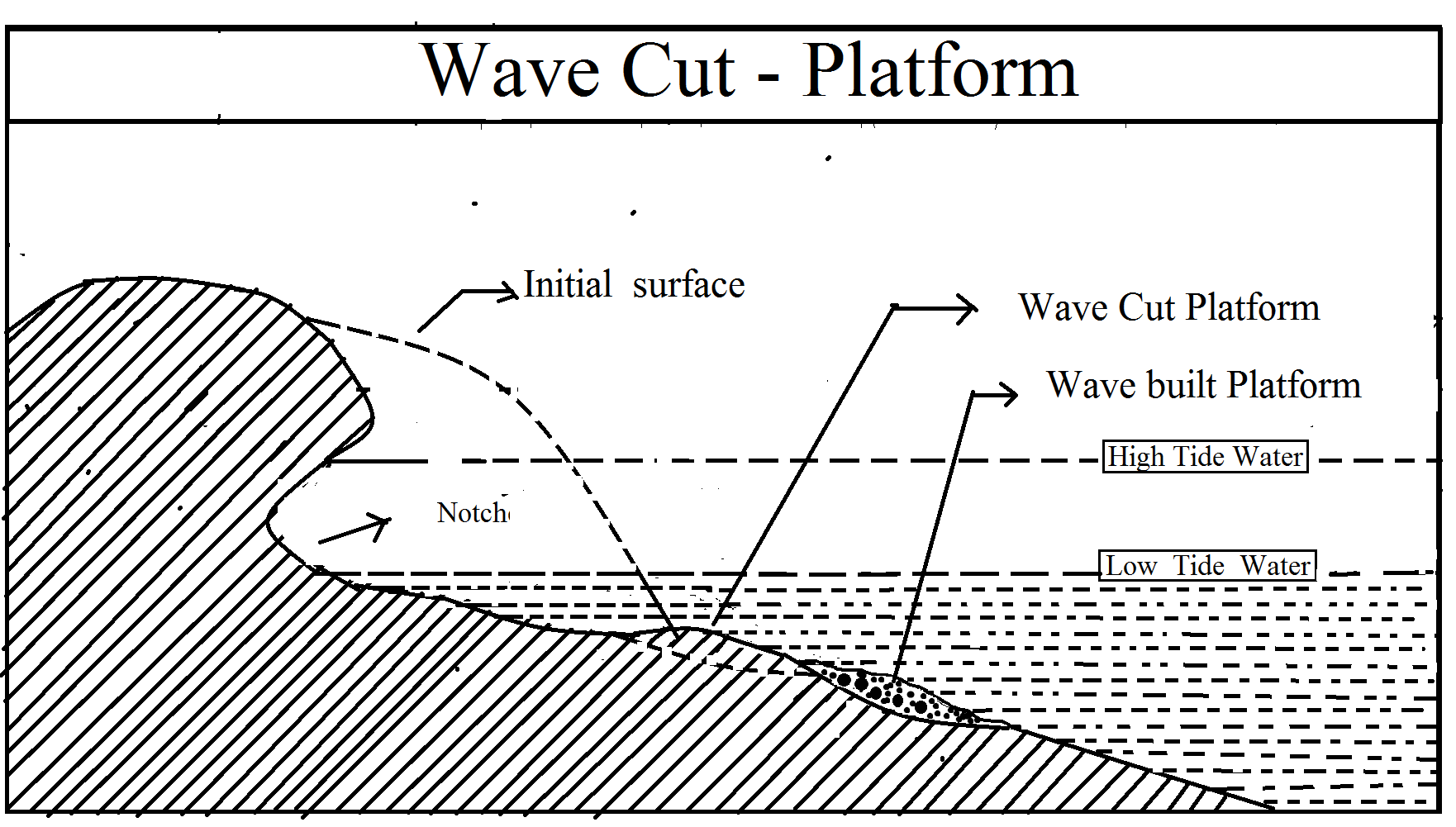
Such type of landforms is formed in the erosional work of Ocean waves on the coastline where hard resistant rocks are present.

Steep rocky coast rising almost vertically above sea water is called sea cliff which is very precipitous with overhanging crest. The steepness of the true vertical cliffs depends on variation of litho logy and geological structure and relative rate of sub aerial weathering and erosion of cliff face and crest and marine erosion of cliff base. If the marine erosion at the base of cliff is much faster than the sub aerial weathering of cliff face and crest, overhanging cliff with steep vertical face is formed.

The formation of sea cliff begins with the erosion of coastal rocks through the mechanism of hydraulic actions and abrasion by breaker waves. This results in the formation of notch and the coast becomes vertical. There is gradual extension of notch landward due to continuous wave attack with the result the crest of the cliff overhangs the notch. If the notch at the base of the cliff is extended landward to such an extent that the support to the cliff crest is weakened, overhanging head of the cliff breaks and falls down resulting into gradual recession of the cliffs landward.

**3) WAVE CUT PLATFORMS**

Such type of land forms are formed due to the erosional work of Ocean waves on flat rock surfaces which are present in front of the cliffs.



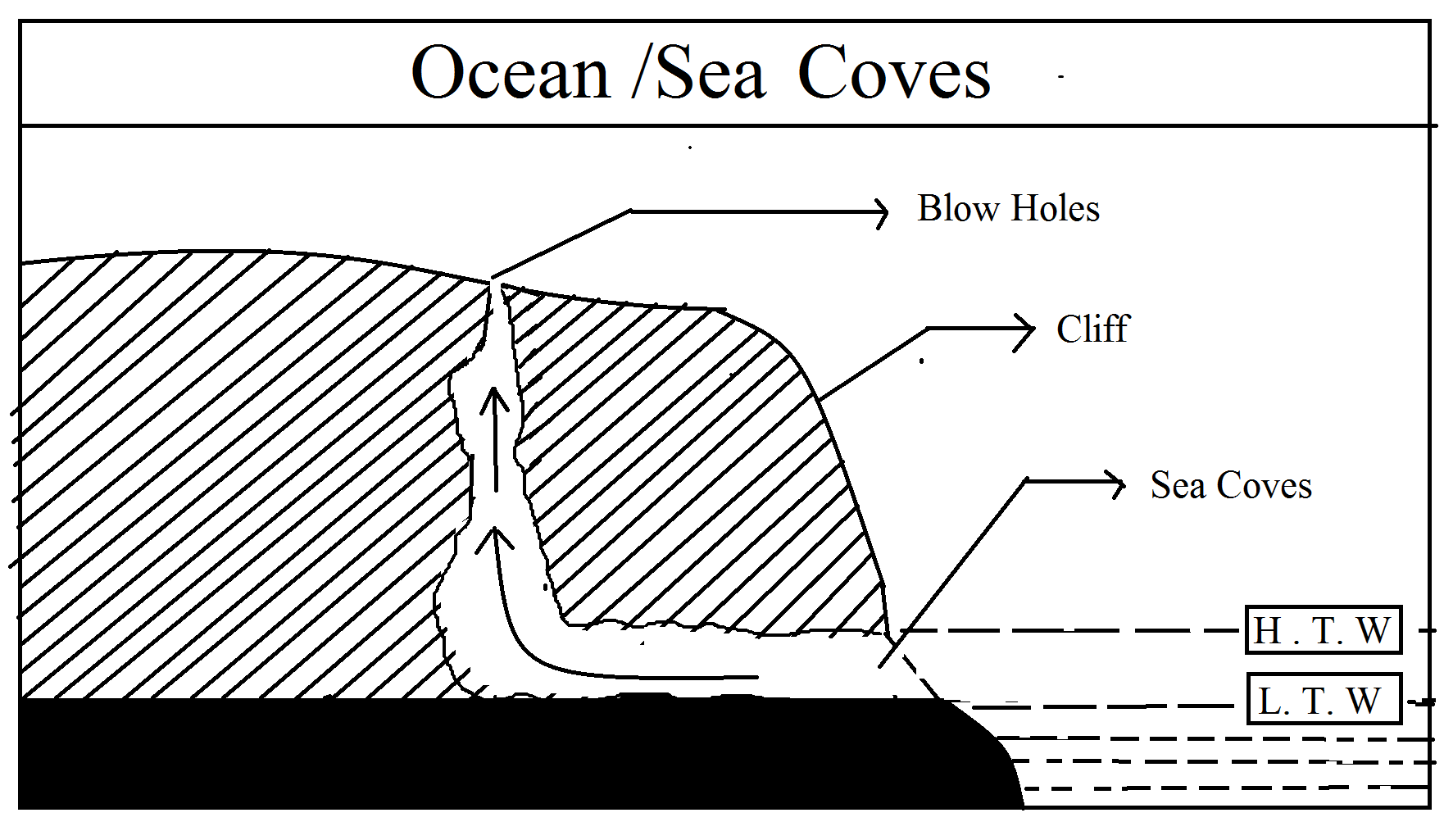
Rock cut flat surfaces in front of cliffs are called wave cut platforms or simply share platforms which are slightly concave upward. The origin and development of wave cut platforms is related to cliff recession. These are also called wave cut benches. Share platforms are formed where cliff recession is active due to powerful bombardment of cliff base by up rushing breaker waves and effective removal of eroded materials by backwash. The forms of wave cut platform depend on geological factors. Extensive platforms are developed where the rock are least resistant to wave erosion.

Wave cut platforms are generally divided into three zones. Viz. (1) Mesa littoral zone between high and low tide water. (2) Supra littoral zone above high tide but within the range of spray (3) sub littoral zone below low tide water.

**4) OCEAN / SEA CAVES**

Such landscape is formed along the coastline due to erosional work of ocean waves.

Sea cliff or the sea coast is formed of rocks of differential hardness and the rocks are associated with a number of joints, fractures and zone of weakness. Due to prolonged wave action a cylindrical or funnel shaped hole is formed at the base of sea cliff along the line of weakness. Such type of wave cut formation is described as sea cave. It generally occurs when the overhanging rock is enough strong to stand without any support from below. The diameter of the cave decreases from entrance to the end.



**5) BLOW HOLES**

Such landscape is formed in the roofs of the sea coves due to the action of surf current on the mouth of that cove.

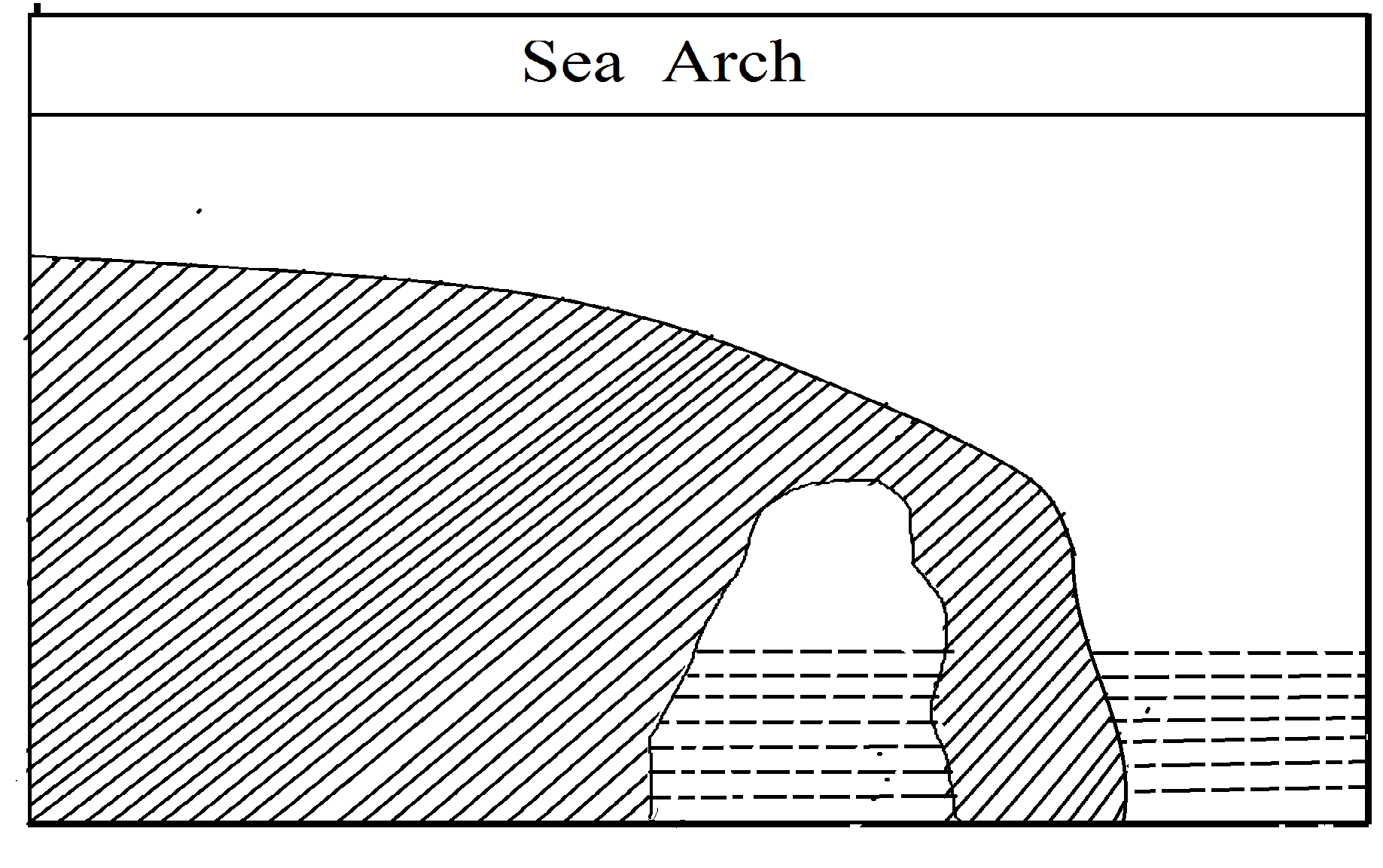
Ocean caves are the cylindrical / funnel shaped hole or cavities in the sea cliff / coast line rocks. The air in the sea coves is / was / being compressed due to the continuous striking of swash currents at the mouth of coves and sometimes its mouth is / was closed due to rising of water walls in front of it. At that time, if the pressure of inside closed compressed air increased to some extent, then this compressed air to be well try to gushes out with a great force through the enlarged joints found in their intact roofs. Thus this outgoing pressurized air forms a hole / way out in the roofs. This landscape is known as blow holes.

When the size of the blow holes increases to a great extent or much of blow holes are formed in the cove’s roof, then it would be weakened and after some period of time, it collapsed. It is also known as ‘Natural chimneys’ because if produces a specific sound like of industrial cyber, when water gushes in caves and wind blows out from blowholes after closing of mouth of caves.

**6) SEA ARCH**

Such landscape is formed in the projected head lands by the erosional work of ocean waves.

Along the irregular coastline a number of resistant headlands are projecting in the sea. The projected head lands are eroded by waves from both directions of the exposure. Thus two caves develop from opposite sides. With the passage of time these caves meet together and a hole is formed across the projected head land. Natural Bridge is formed connecting two sea caves. This bridge is generally known as sea arch.

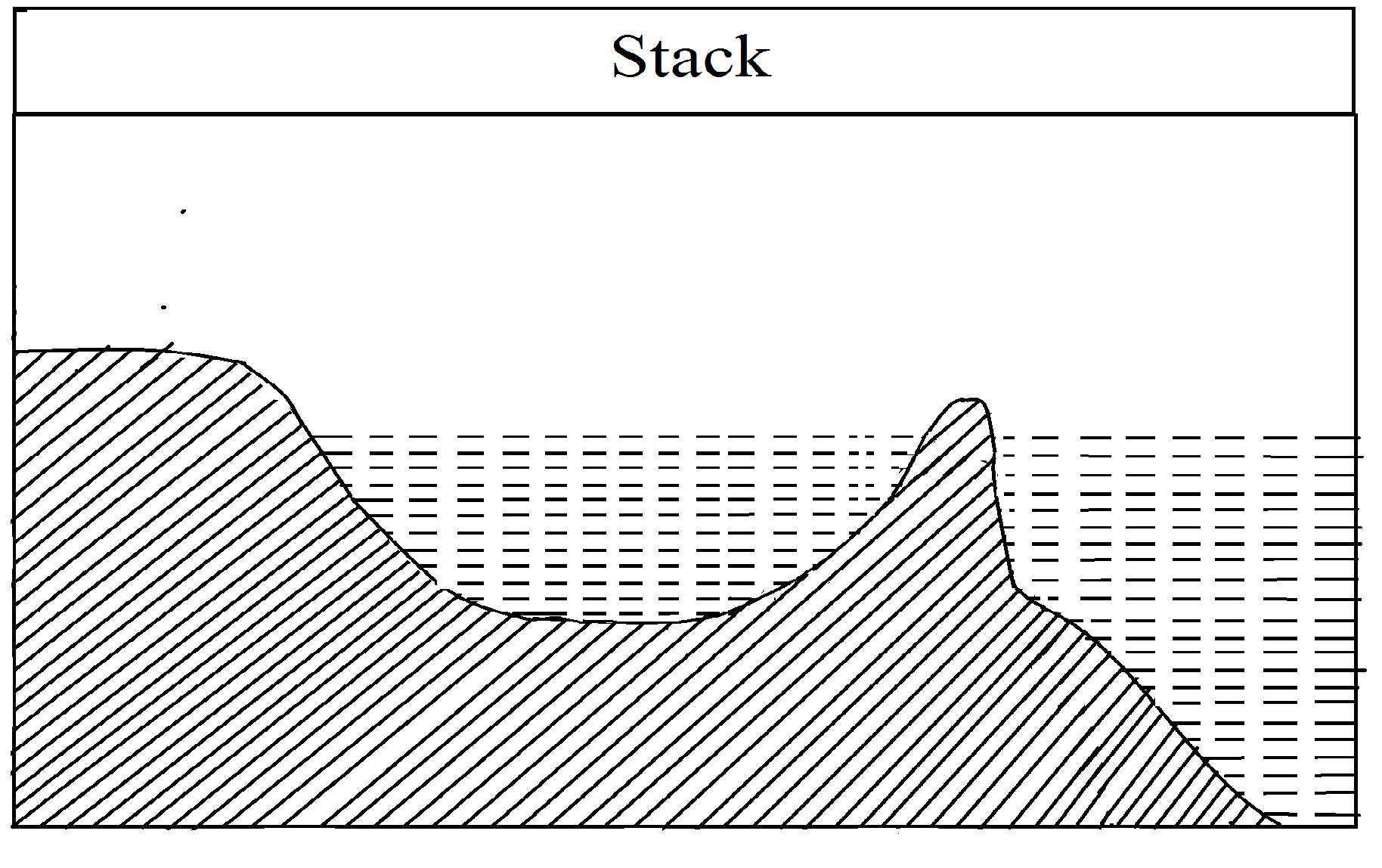


**7) STACK**

Such landscape is formed from collapsing of roof of sea arc due to the erosional work of ocean waves that which always strikes on that roof.

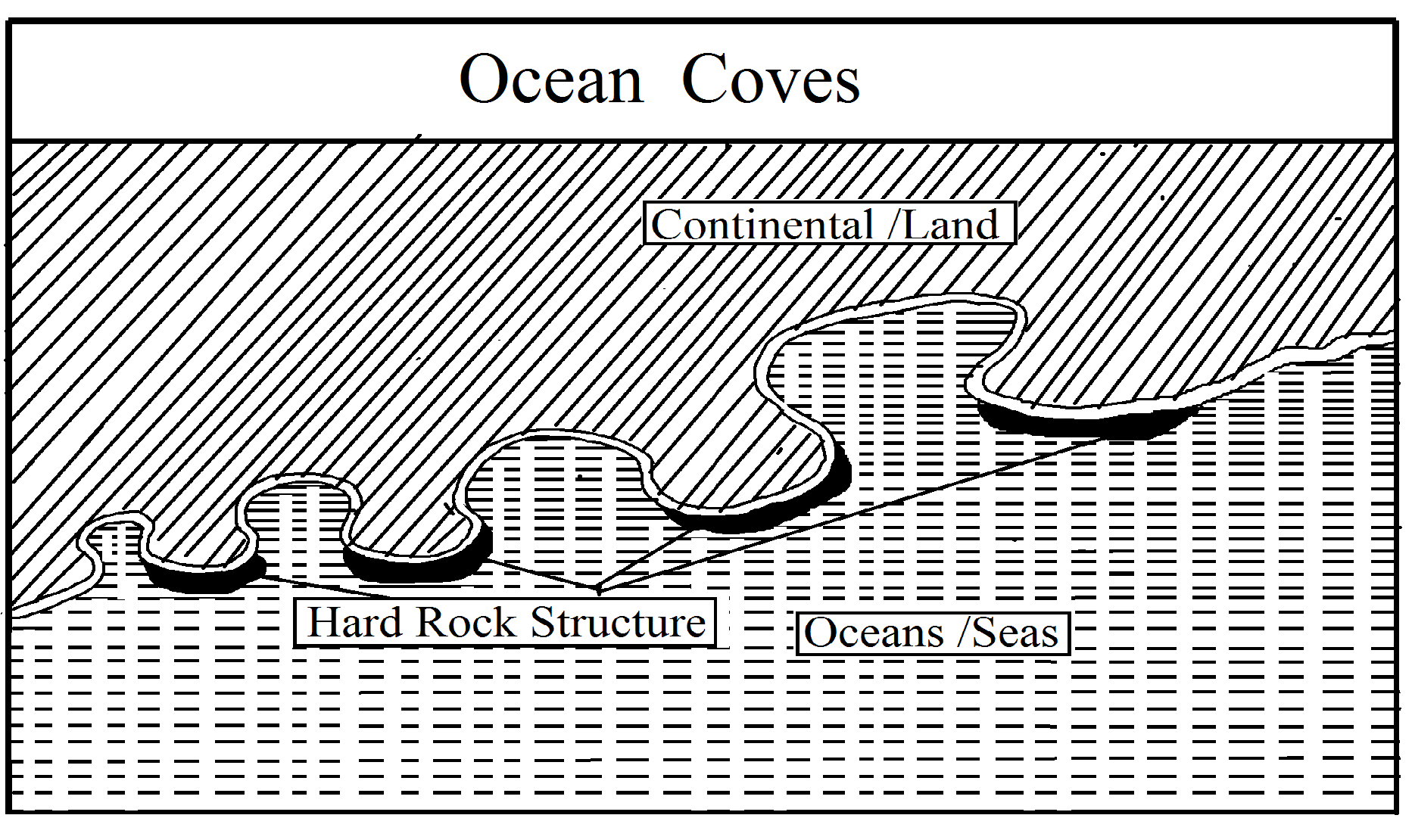
The natural arcs are not permanently landscape in the coastal topography because the roof, after becoming very thin, collapses and the seaward part of the arch stands detached from the cast. Such isolated remnant of head land projecting well above sea level is called stack. This is also called as ‘chimney rock’. Stacks are also called needles, columns, pillars, skerries etc.

The old man at Hoy (137 meter high) in the Orkney island of British isle is widely quoted example of sea stack.



**8) COVES**

Along the irregular coastline a number of hard resistant rocks are alternated by softer rocks sequentially one by one. The enforced swash current erodes the softer rocks fastly rather than the hard resistant rock. After passing time, vertically viewed, elliptical shaped hollows are formed in between the out coming projected hard resistant rock. Such landscape is termed as ‘Sea coves’ or ‘mini bays’.



**TRANSPORTATIONAL WORK**

The eroded materials are transported by sea waves in different manner but the transformational work of sea waves varies significantly from other agents of erosion and transportation. For example, the backwash currents pick up the eroded materials and transport them sea ward but the up rushing breaker waves / surf currents pick up these materials and bring them again to the coast and beaches. Thus, the transportation of materials takes place from coastland towards the sea and from the sea forwards the coast.

When oblique waves strike the coast, long share currents are generated. These long share currents transport the materials parallel to the share line. The materials involved in the transportation by sea waves include sands, silts, gravels, pebbles, cobbles and sometimes boulders. When there is up rushing breaker waves and removal of sediments by backwash currents on the wave cut platform, a profile of equilibrium is achieved.

If the wave cut platform is characterized by steep sloped toward the oceanic slope, the destructive waves becomes very active and thus resultant powerful backwash removes the materials from the landward side so that the slope of the platform is lessened. On the other hand, if the slope of wave cut platform is less steep, constructive waves becomes more effective as they favor sedimentation and beach deposition on the landward side so that the slope of the platforms becomes steeper.

The surface is therefore continually modified, and in such a way that at each point it tends to acquire just the right slope to ensure that incoming supplies of sediments can be carried away just as fast as they are received. A profile, is so adjusted that this fluctuating state of balance is approximately achieved is called a ‘’profile of equilibrant’

**DEPOSITIONAL LANDFORMS**

Significant depositional landforms developed by sea waves include sea beaches, bars and barriers, off share, and long share bars, looped bars, tombola, barrier island, tidal inlets, winged head land, pro gradation, wave built platforms etc.

**1) BEACH / BEACHES**

Such landscape is formed along the shore line due to the continuous deposition of various sized particles by ocean waves.

Temporary or short lived deposits of marine sediments consisting of sands, singles, cobbles etc. on the sea shore are called beaches. Beaches are deposited by breaker waves between high and low tide waters. Beaches are, in fact, wedge shaped sediment deposits on sea shore. In width beaches vary from a few meters to several kilometers. Beaches are generally formed when sea is calm and winds are of low velocity. Beach material consists of fine to coarse sands, shingles (pebbles), cobbles and boulders. The major sources of the supply of beach materials are erosion of headlands and cliffs, sediments brought by the river and nallas at their mouths, mass wasting and mass movement of cliffs.

The stronger backwash current removes the sediment from beach area to the sea water, and the beach is reduced. It is attractive place for the tourists.

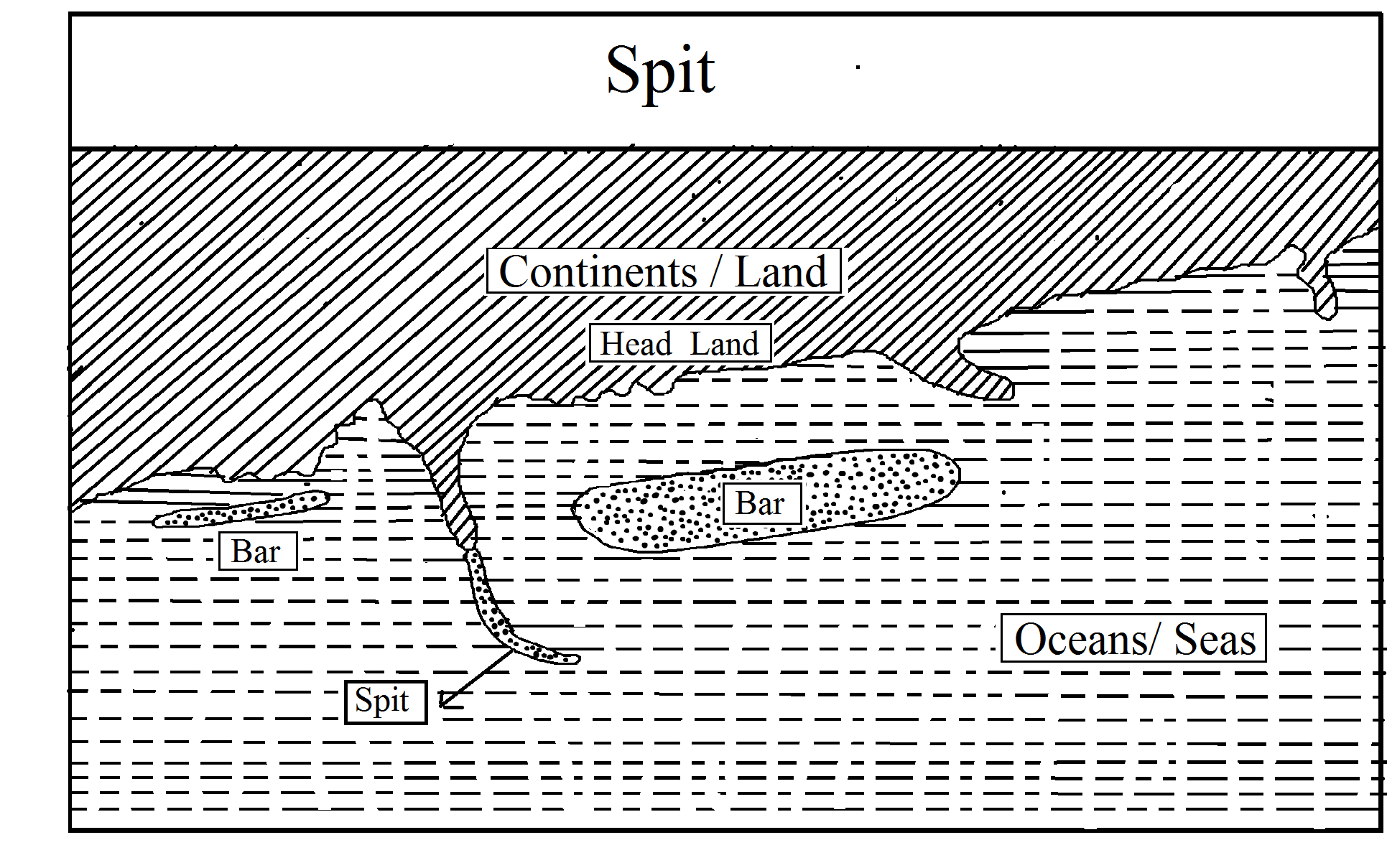
And ideal beach consists of two main elements e.g. upper beach and lower beach and several minor elements e.g. storm beach, bench ridge, bench cilsps, small channels, ripples, ridges and runnels etc. The upper beach representing the landward section of the beach is composed of coarser and larger materials such as pebbles, cobbles and boulders and the slope ranges Between 100 to 200. On the other hand, the lower beach representing the seaward section of the beach is composed of sands and has low gradient of 20 or even levs. The storm beach is a semi permanent ridge. Which stands well above the level of highest spring tide? The successive low ridges built by constructive waves parallel to the coastline and below the level of high spring tides are called beach ridge or berms.

Beaches are generally classified on the basis of beach materials into (1) sand beach (sand grains ranging in size between 0.5 to 2mm) (2) shingle beach (composed of pebbles ranging in size from 2mm to 100mm) and (3) boulder beach (more than 100mm in diameter). The regular increase in width of Seal Beach towards the sea is called pro gradation while depletion of beach endues to erosion and thus narrowing of beach cutting is called retro gradation.

**2) SPIT**

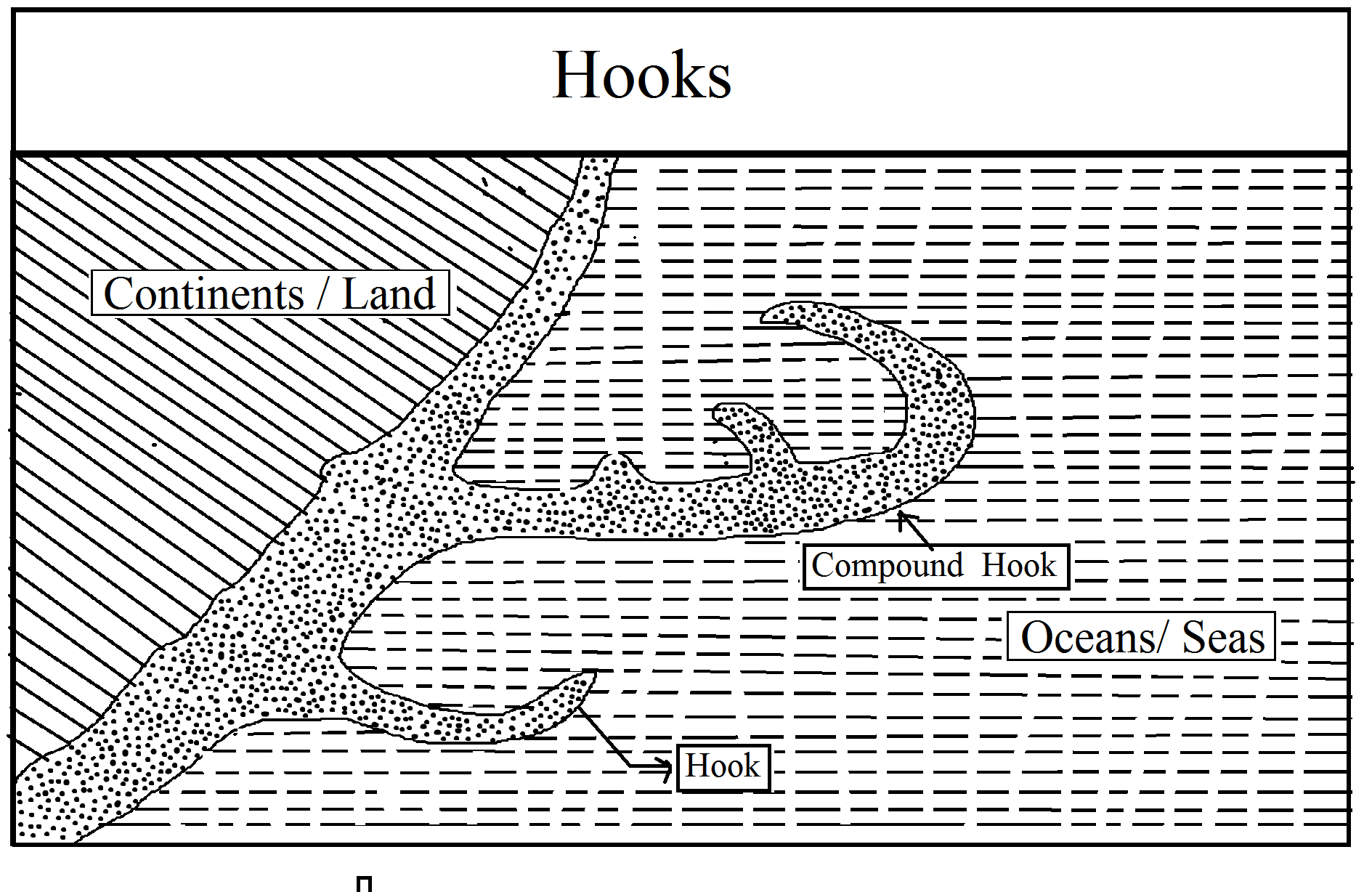
Such landscape is formed nearly perpendicular to the head land or coastline due to the growing of sedimentation by ocean waves. The pebbles and sands, transported by backwash currents are deposited in the shallow sea water. Gradually the deposited materials extend upward, sideward and seaward and develop in the form of a long narrow ridge like formation, connected with head land / main land or island by at least one end it projects in the sea, is called spit.

A few spits have been reported from the eastern and western coast of India. E.g. 50 km long spit in the mouth of Chilka lake, 16 km long spit near Kalinagapatnam a well developed spit at the rate of 12 km / century to the east of Kakinada Bay, 60 km long spit to the east of palikat lake are the good examples of spits found in India.



**3) HOOKS**

Such landscape is formed form the spit when it bends towards the coast due to the action of ocean currents in its depositional work.

High energy strong waves very often modify the shape of spits by bending them towards the coast. The curved spits assume the shape of hook and such spits are called hooked spits or simply hooks. Hooks are stabilized when there is equilibrium between constructive and destructive waves. 

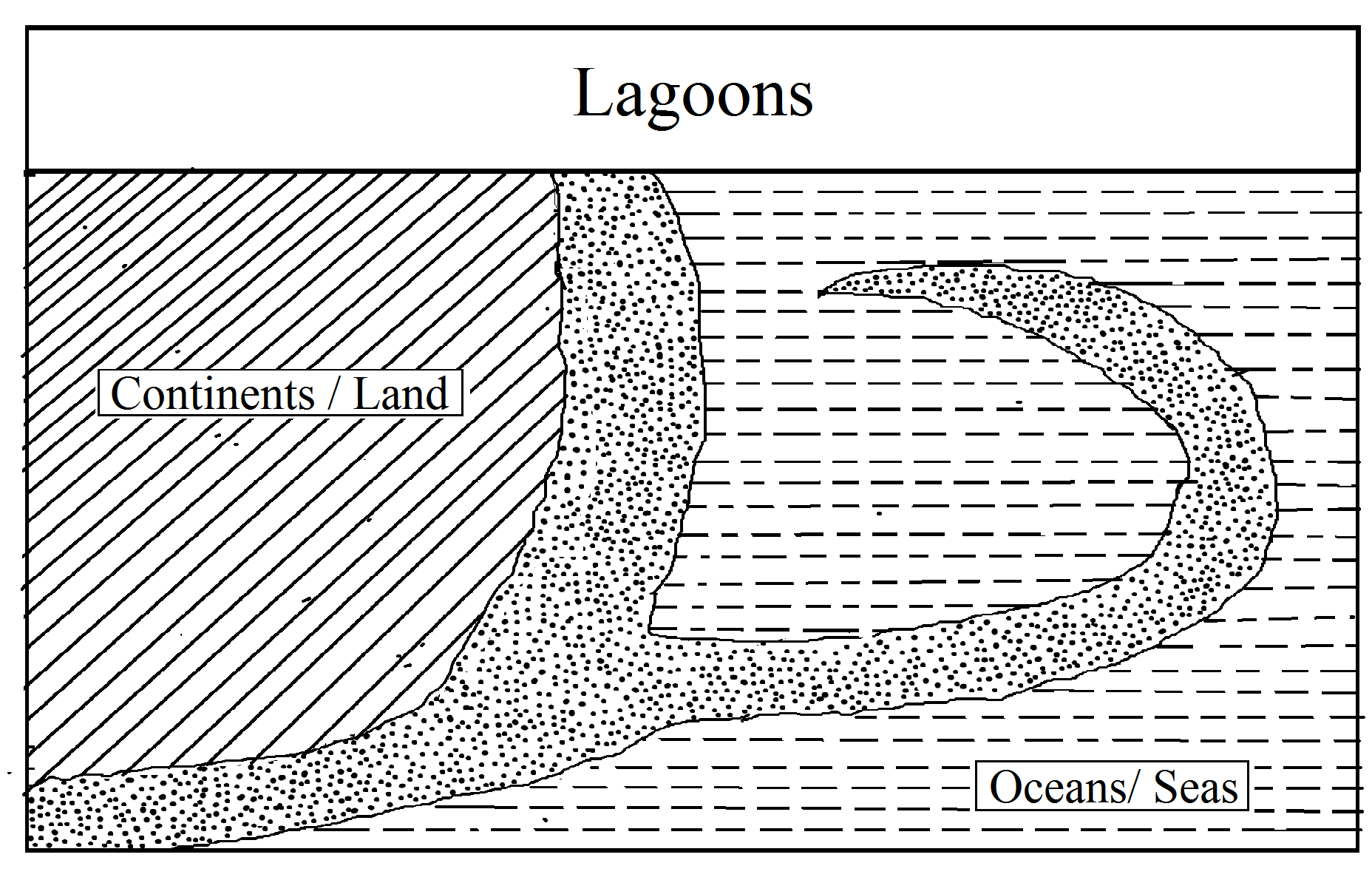
**COMPOUND HOOKS**

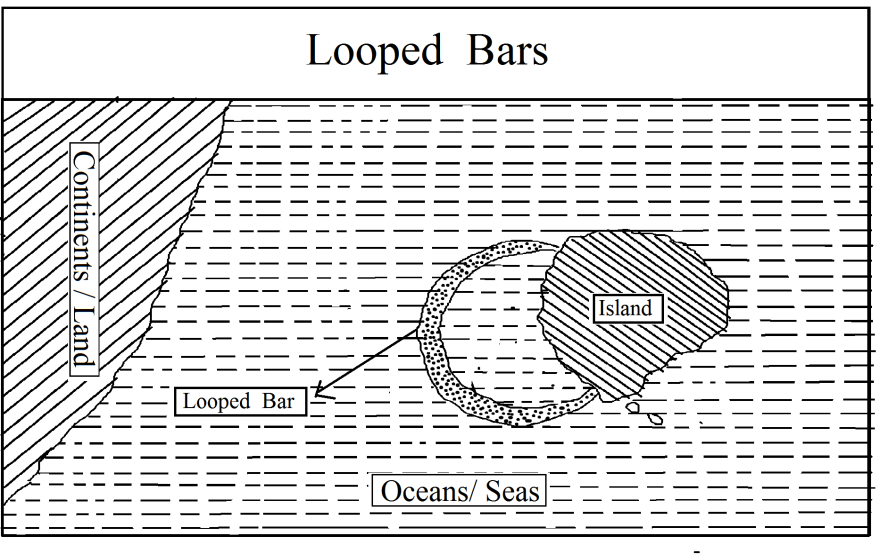
When the two or more hook is formed from a single spit, then it is termed as compound hooks.

**4) LAGOONS**

Such landscape is formed from the spit when it so bends towards the coast that joins / connects to that coastline and completes a loop, by the work of strum waves.

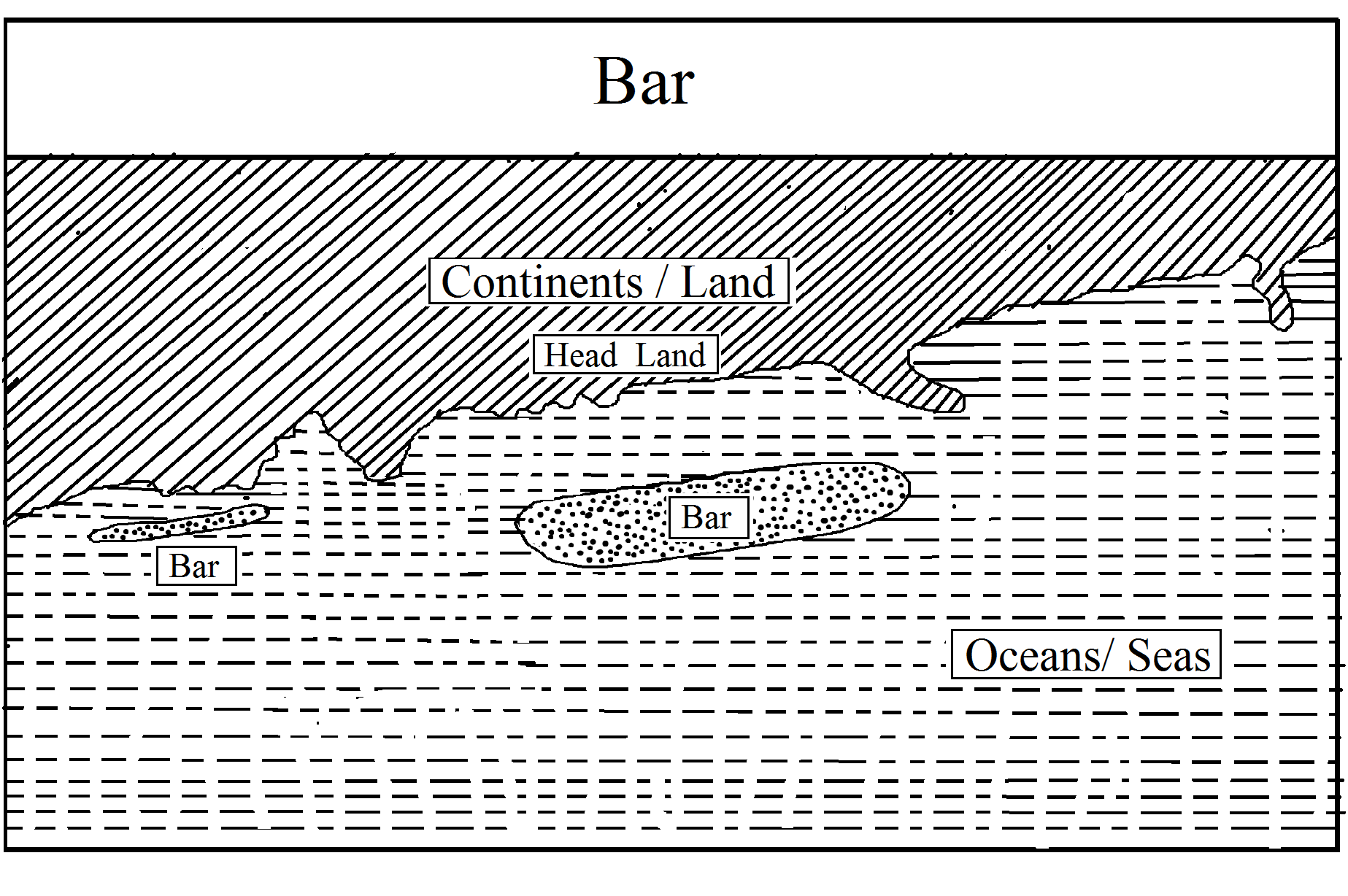
When the opposing currents becomes more dominant than the littoral currents, the spits are bent to such an extent that they are attached to the main land (wart) and thus form complete loop which encloses sea water in the form of lagoons. Such form of a spit is called loop. When such loop is formed around an island, it is called looped bar.





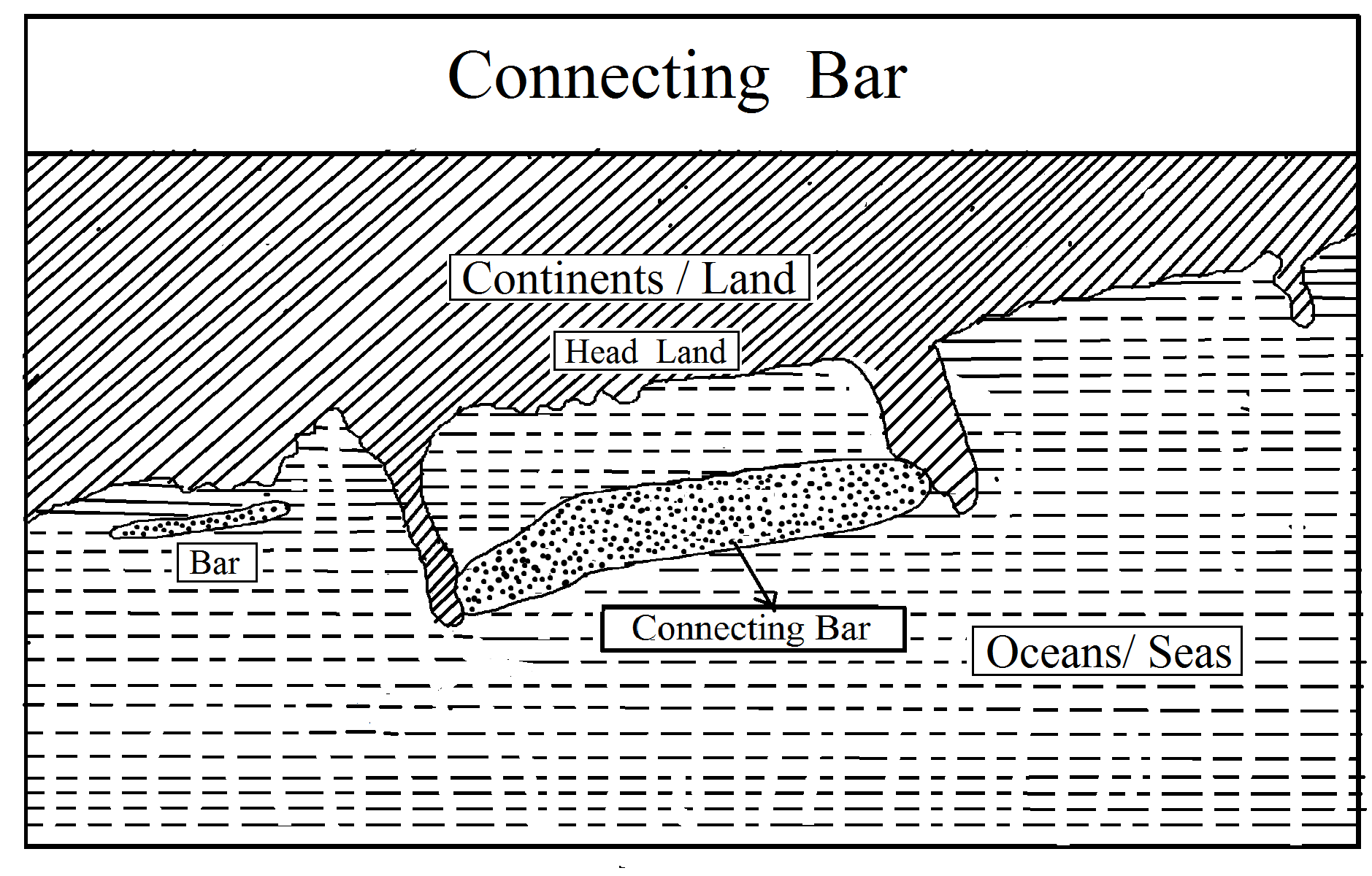
**5) BAR**

The ridges, embankments or mound of sands formed by sedimentation through seas waves parallel to the share line are called bars. The larger forms of bars are called barriers. The formation of bars and barriers starts with the development of shoals due to deposition of sands. These shoals grow in height by addition of sediments until they appear above sea level. Bars and barriers may be formed near the coast or away from the coast, parallel to the coastline or transverse to the coast. There are different forms of sand bars and barriers. If the barriers / bars are formed in such way that they are parallel to the coast but are not attached to the land, they are called off share / long share bars.



**6) CONNECTING BAR**

Connecting bars are formed when bars are so extended that they either join two head lands or two islands. Connecting bars are variously named on the basis of their shape and forms.

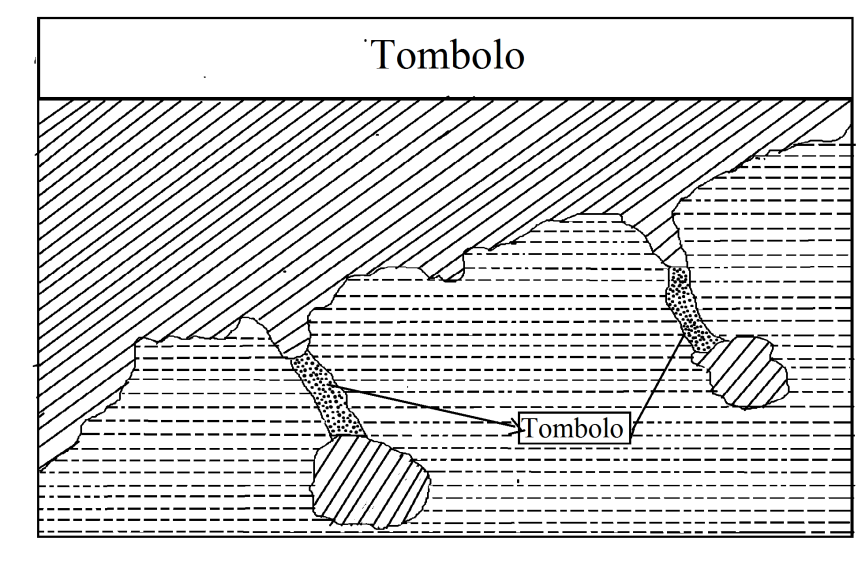


**7) TOMBOLO**

When a sand bar is extended in between the headland and island or island to main land, then it is known as tombola.

Tombola acts as a bridge between the coast and an island.

A few examples of tombola are observed along the western coast of India between Ratnagiri and Naidiv.



**8) WINGED HEAD LAND**

When bars of pebbles or cobbles are formed on either side of a head land, such headland is called a winged headland.

Questions

1. Describe the various landforms formed in the erosional work of river.
2. Describe the various landforms formed in the depositional work of river
3. Describe the various landforms formed in the erosional work of wind.
4. Describe the various landforms formed in the depositional work of wind
5. Describe the various landforms formed in the erosional work of underground water.
6. Describe the various landforms formed in the depositional work of underground water.
7. Describe the various landforms formed in the erosional work of oceanic waves.
8. Describe the various landforms formed in the depositional work of oceanic waves.
9. Describe the various landforms formed in the erosional work of glacier.
10. Describe the various landforms formed in the depositional work of glacier
11. Describe the various landforms formed in the glacio--fluvio work
12. State the migration process of sand dunes in desert topography.

Short Notes

1. V-shaped valley.
2. Canyon
3. Alluvial cones and Alluvial fans
4. River meandering
5. Oxbow Lake
6. Floodplain and natural levees
7. Delta
8. Mashroom
9. Yardang
10. Stone Lattice
11. Types of Sand dunes
12. Loess Plain
13. Doline
14. Cavern
15. Stalacite
16. Moraines
17. Valley Glacier
18. Crevasses
19. Cirque
20. Horn
21. U-shaped valley
22. Outwash plains
23. Esker
24. Bar
25. Wave cut platform