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Component-I (B) Description of Module

Items	Description of Module
Subject Name	**Geography**
Paper Name	**Geomorphology**
Module Name/Title	**Fluvial Processes and Fluvial Landforms**
Module Id	**GEO-21**
Pre-requisites	**Endogenetic and Exogenetic processes, Erosion and Deposition.**
Objectives	**To Know about the processes of erosion, transportation and deposition by the river or stream. To study and understand the landforms produced by erosion and deposition .**
Keywords	**Bedload, Alluvial Fan, Ox Bow Lake, Saltation, Point Bar**

Fluvial Processes and Fluvial Landforms

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Fluvial landforms are those landforms which are **shaped and modified by the running water**. Running water has sculpted most of the land surface across the world in comparison to other agents of erosion like wind or Glacier. Streams are in a constant process of shaping the land surface into newer forms. The running water erodes even the loftiest of mountains and carves deep valleys or gorges into it. Besides erosion it transports heavy load from one place to the other. The present chapter focuses on the landforms produced by fluvial processes. This encompasses both the erosional and depositional landforms produced by the running water.

Whenever any landform is created due to tectonic forces it is attacked constantly by various agents of gradation and thus it undergoes transformation taking new shapes. The running water due to exertion of force on the exposed surface erodes it and carries particles of varying size (ranging from very fine to the size of a boulder) depending on the slope and amount of water discharge.

Erosional processes

Erosion is a process in which the surface of the earth is worn away by various agents of erosion like wind, water or Glacier. The removed material is carried away and deposited elsewhere. Erosion by streams occurs through several processes going together. These processes are Abrasion, Hydraulic action, Solution and Attrition.

Abrasion: Running water when armed with sand, silt and other sediments acts as very effective means of erosion of the river bed. In the upper reaches the river with a steep gradient carries a lot of such materials which act as a tool and are effective in carving huge valleys, gorges and canyons. In contrast if the river is free of these sediments the erosion by abrasion is minimal and the river would take much longer time to erode its bed.

Solution: Pure water seldom exists in natural conditions. It contains various gases and acids in them, the water is charged with the acids and act as an important solvent. It may not be effective on all the rocks but when it comes in contact with limestone, dolomite or chalk it becomes most powerful agent of erosion as it dissolves them much faster. So solution also forms an equally important process of erosion.

Attrition: When the stream loads (pebbles, sand, silt etc) move together, they cause their own wear and tear by colliding with one another. This rounding and shaping of these pebbles and boulders amongst themselves is called attrition.

Hydraulic action (pressure): Running water has enormous force in it, when it strikes the stream bed on its banks it may loosen the rocks, lift it and easily transport it. It acts as a wedge when strikes the crack or fractures in the rock bed by widening and loosening it. Thus, Hydraulic pressure is also reckoned as an important means of erosion. The above discussed processes coupled with other factors give rise to diverse landforms occurring in different parts of the stream course . A brief description of them has been given below.

Erosional landforms

V shaped valley:Deep cutting and erosion by rapid flow of the stream carves out a valley that resembles the English letter V. The V shaped valley has a deep and narrow bottom (or valley) floor with steep valley sides. The shape is an outcome of a number of other factors at interplay; Mass movement and weathering of rocks are effective in shaping the valley.

Gorge: It is a narrow chasm with a very steep precipitous wall. These are common features found very often in mountainous regions. The Himalayas are home to a number of gorges located at different places in its ranges. The **Kali Gandaki Gorge** is one of the deepest gorges in the world. **River Satluj** enters India through a huge gorge near Shipkila pass. Brahmaputra also moves through various gorges and enters Indian Territory. Besides Himalyas the gorges have their presence across the world in most of the continents .

Fig. 1. Gorge **source:** https://pixabay.com/en/gorge-canyon-steep-walls-mythical-1081998/

Waterfalls: It refers to a sudden descend of the flow of the stream or river caused by a variety of factors. They are very picturesque and beautiful features. Waterfalls may result

due to variation in the resistance of rocks, crust deformation, changes in the sea level etc. The different mode of origin has made its classification rather difficult. However, they can broadly be classified into 5to 6 major categories taking into account their origins and distribution across the world.

Formation of Waterfalls Due to Structural Variation:

Resistant Rock lain Horizontally

When a hard and resistant rock overlies a very weak rock, the latter wears down quickly and the resistant rock shows deep undercutting. The river bed gets steepened at the point giving rise to waterfalls of larger dimension. **Niagara Fall** is a perfect example of this type of fall where the caprock is a strong dolomite limestone of Silurian age.

The inclination of the resistant rock determines the nature and size of the waterfall. If the overlying hard rock dips downstream it results in the formation of rapids (a waterfall of small dimension). When it dips upstream it gives rise to a precipitous wall and a relatively larger waterfall.

Fig 2. Niagara Falls source: https://pixabay.com/en/photos/niagara%20falls/

Vertical falls: Granitic intrusions (or vertically arranged hard rocks) lying vertical in the course of the river are least affected by the erosion as compared to the adjoining rocks. The differential erosion accentuates the development of a steep slope causing a high water fall. Yellowstone river fall is an example of this type of fall, here a **dike** stands adjoining weaker rocks and Yellowstone River has made a stupendous fall when it flows over it cutting deep gorges as it descends. Such falls do not recede upstream in

comparison to the falls produce on horizontal rocks because there is no undercutting of soft rocks.

Fault and fracture falls: Rivers flowing over faulted rock structure give rise to such type of falls. The fault scarps created during faulting cause the water to fall from a vertical height resulting in waterfalls. The **Victoria Falls** of **river Zambezi** is often cited as an example of this type of fall, because the river flows over a basaltic plateau and crosses the prominent fractures in the plateau thus giving rise to waterfall.

Fig.3. The Victoria Falls source: https://www.flickr.com/photos/i_pinz/1352528624

Falls due to Descend from Uplifted Highlands: when a river flows from the uplifted hard and resistant rocks (like igneous) to the plain region, It gives rise to waterfalls. Such types of falls are noticeable in the **Appalachian regions** where streams have developed numerous falls because of their descent into the Atlantic coastal plain.
Other examples of rivers descending from plateau to the lowlands may also be included in this type of falls. Eg the Livingstone falls, Depict the abrupt break in the flow of river Congo giving rise to an exhilarating waterfall.

Hanging valley falls: The main glaciated valley eroded deeper than their tributary valleys when they were formerly occupied by the glaciers. Post glaciation the glacial valleys were occupied by water and as the tributaries meet the deeply eroded and steep wall of the main glacial valleys they made waterfalls because of their sudden descent into the main valley. There are a lot of waterfalls present in the **Scandinavian region.** Yosemite falls in California lies in this category of waterfall. The stream (tributary of the main river) exhibits a fall over the cliff into the **Merced River** Valley which was previously scoured and deepened by the glacier. This deep valley lies well below the valley of its tributary thus giving rise to hanging valley fall.

Fig 4 Hanging Valley Falls. **source**: https://glaciers1011r1.wikispaces.com/Hanging+Valley

Besides the classification of waterfalls on the basis of their mode of origin, there are a numerous other types of waterfalls, which are classified on the basis of their size, height and flow rate of water.

Sediment transportation:

The stream is an important means of transportation of sediments of varying size and shape to distant lands much away from their source of origin. The sediments are transported in various ways depending upon the size of the material; their composition and volume of water.

Movement in solution: Materials like sulphate, carbonate, and chloride are dissolved in water and carried till the end of the stream. Rivers flowing in arid and semi arid regions show more material in solution.

Movement in suspension: Very fine particles consisting of sand, silt and mud are transported in huge quantities by the rivers. These particles are kept in suspension by the river as the volume of water and its speed does not allow particles to settle. They are always kept in suspension while traveling and therefore are carried for a fairly longer distance than the larger boulder or pebbles which roll along the stream bed.

Movement by traction: Large boulders and pebbles which are heavier for the stream to carry them by means of suspension or **saltation**, move by rolling along the stream bed. This rolling causes abrasion on the bed and for they are in constant contact with the bed. They emerge as one of the chief erosive agents of stream bed.

Movement by saltation: The particles jump and bounce when uprushing water comes with a force lifting them from the bed to some distance. They cannot be carried long as their weight is more and therefore cannot be kept in suspension. This type of movement is called saltation.

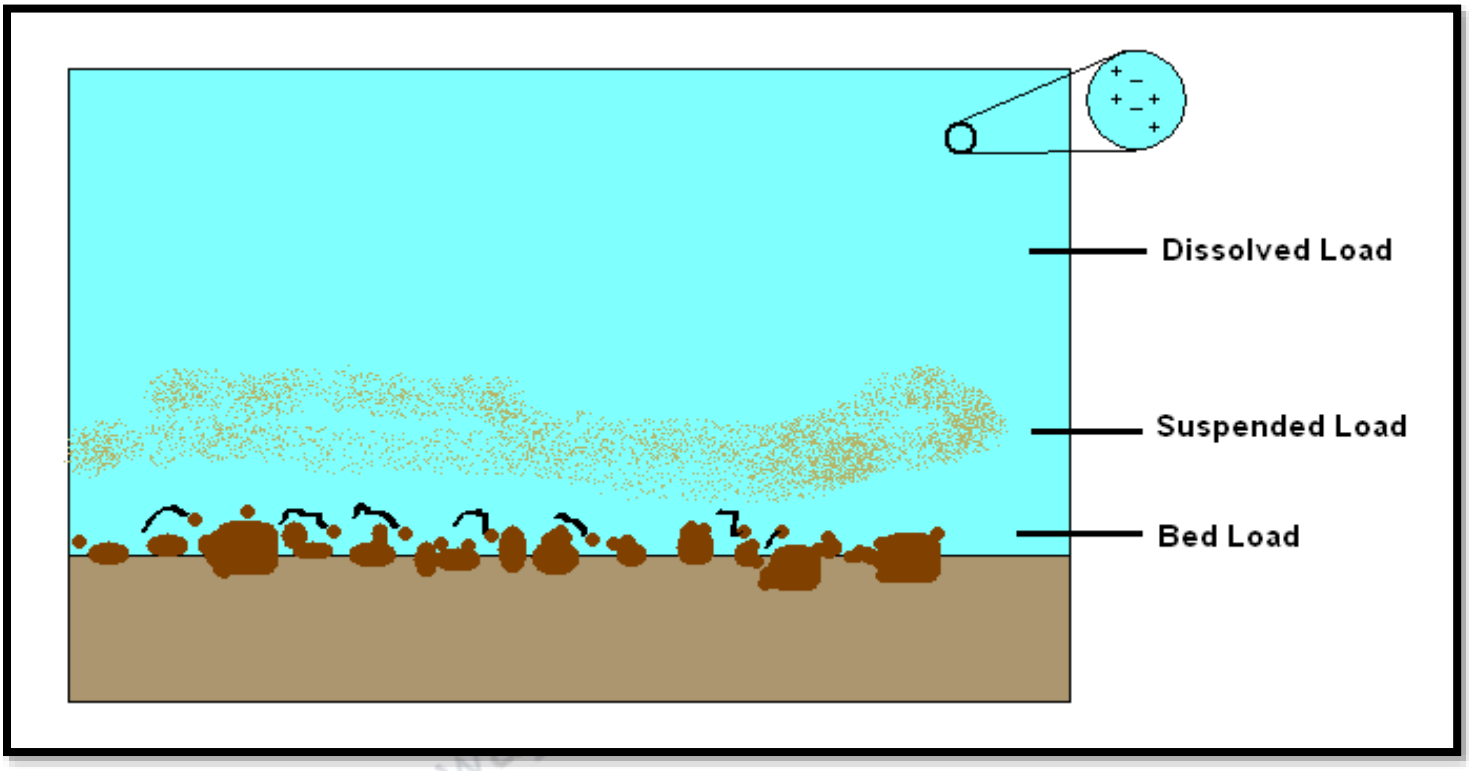

Fig. 5 **source:** https://upload.wikimedia.org/wikipedia/commons/9/9c/Stream_Load.gif

Depositional landforms

Alluvial fans: When a stream carrying heavy load descends from a narrow mountain valley onto a plain, it leaves behind its load in the form of a fan or a cone. This deposit at the base of a mountain occurs due to sudden drop in the velocity of the stream which cannot carry further such a heavy load on a plain region as it lacks gradient that earlier provided velocity to the stream enabling it to carry enormous load with much ease.
The alluvial fans show a thick deposit at the mouth of valley and gradually descend in height away from it. The size of material deposit also show a gradual decline from large to small away from the mountain front. The slope of fans vary due to variation in the size of the grains. Where there is abundance of coarse sediments there is development of fans with steeper slopes whereas fans having finer sediments have gentler slopes. The alluvial fans in comparison to cones have a wider spread making an arc (or fan) in shape, while

cones are relatively less extensive in their spread and have a steeper gradient. These two terms are often used together to denote the deposit at the mountain front. In India one can see a fan on **river Kosi** at the base of the Himalyas. It is a large and gently sloping fan with a width of about 140 kilimetres.

Fig 6. Alluvial Fan source: https://commons.wikimedia.org/wiki/File:Alluvial_fan_01.JPG

Floodplains: Floodplain is a very gently sloping flat region bordering the stream. It is covered with fine silt, mud sand etc. brought down by the river and deposited in the adjoining region due to its regular flooding. This regular flooding enriches the soil and makes it a very good fertile land suitable for cultivation. River flowing across a floodplain may either form meanders in its course or develop numerous channels due to deposition of the sediment load on its bed. It also gives rise to embankment known as "Natural Levees" running along it for a fairly long distance. All the said features of floodplains are discussed below in detail.

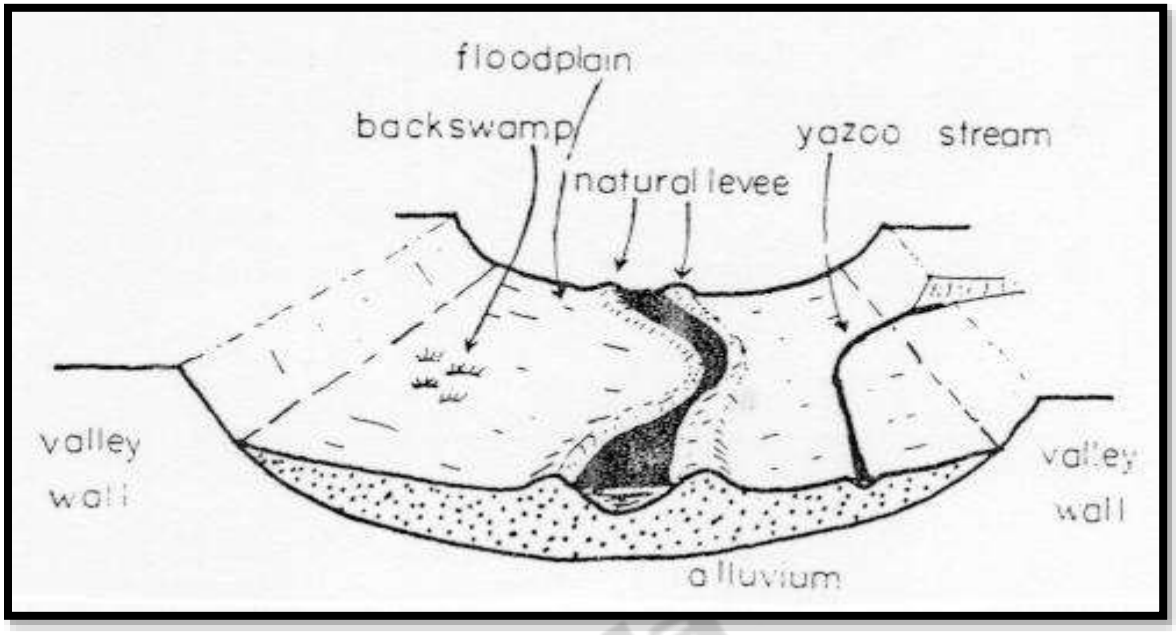

Fig.7. Floodplain and Levees. **Source**: https://commons.wikimedia.org/wiki/File:Yazoooo.jpg

(a) Meanders: A stream flowing on a flat or a gently sloping surface seldom flows straight; it tends to take a sinuous course. While flowing it makes gentle loops in its flows commonly referred to as meander. There is no unanimity on the reason leading to formation of meanders.

The water flowing in the stream when strike the banks causes erosion at the site, which in turn leads to development of bend in the channel. The repeated striking of water and resultant erosion accentuates the bend and makes it more prominent. This prominent bend takes the form of meander.

The meander represents the process of erosion and deposition going together on its banks. The outer side of the bend shows erosion and referred to as **cut off bank** while the inner side of the meander where the flow of the water is slow gives rise to deposition at the site of the bend known as **point bar.**

These two processes going on together cause the meanders to shift laterally. So meandering also leads to the formation of floodplain.

As has been said the process of erosion and deposition continues it tends to accentuate the meander leading to formation of a complete circle. The river then cuts across the meander loops and takes a straighter course. The abandoned meander loops form **ox bow** lakes in the flood plains.

Fig.8. a Meanders
Source: https://commons.wikimedia.org/wiki/File:RiverWampool(SimonLedingham)Sep2004.jpg

Fig.8. b Meanders and ox Bow lake
Source: https://www.flickr.com/photos/mollystevens/3397960888

(b) Natural Levees: They are embankments formed on both the sides of the river. They owe their origin to the regular flooding of the river. During floods the river overflowing its bank leaves behind a good amount of material. The material due to regular occurrence consolidates into small embankments known as Natural Levees. These Levees sometimes rise very high as they grow with each successive flood.

Braided streams: The streams when get overloaded with sediments do not carry them along and leave the excess material on the river floor in the form of sand bars. These deposits cause the stream to split into several channels. The braided stream is a common occurrence in the region which are relatively dry and arid and where the supply of water is not steady.

Fig: 9 . **Braided Stream** **source**:https://www.flickr.com/photos/jsjgeology/20061304082

Alluvial Terrace: Alluvial terraces are the sites of former floodplains which are deeply eroded by the stream due to its rejuvenation. Its process of formation is explained in the following stages.

a) A stream is creating its valley by erosion.
b) The stream with decline in its gradient tends to deposit its load in adjoining areas creating extensive floodplain.
c) Due to fall in the base level (because of fall in sea level) or upliftment of the region over which the stream flows, rejuvenation of stream takes place. The rejuvenated stream gets actively involved in downcutting of the floodplain resulting in development of terraces on both the sides. New terraces can also be created by further erosion on the newly established floodplain. Thus, lowering of Base Level either due to fall in sea level or upliftment of the land surface causes the formation of alluvial terraces.

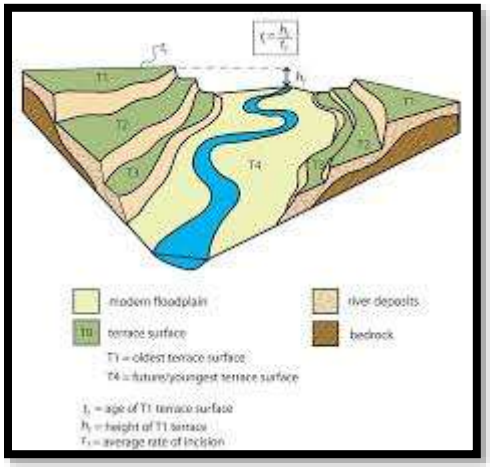

Fig: 10 (a) River Terrace
Source: https://commons.wikimedia.org/wiki/File:A_series_of_paired_river_terraces.jpg

Fig: 10 (b) . **Alluvial Terrace**
source: http://www.coolgeography.co.uk/ALevel/AQA/Year%2012/Rivers_Floods/Rejuvenation

Deltas: Deltas are an arcuate or fan shaped feature at the mouth of the river formed by regular deposition of the sediments. The name owes its origin to **Greek letter Δ.** The process of formation of delta begins with the deposition of sediments as soon as the river enters sea or lake. First the river would shed its coarse sediments which are heavier in comparison to the finer light particles. The finer particles are carried forward by the distributaries to some distance where they come in contact with the saline water, get coagulated and settle. It is clear that delta formation follows a series of steps.

The longitudinal cross section of delta shows three depositional units: bottom set bed, foreset bed and topset bed (Gilbert,1890)

a) Bottom set beds: This is a layer of fine material on the bottom of sea or lake beyond the delta.

b) Foreset beds: They are inclined beds lying between the top set beds and the bottom set beds. They are inclined because the sediments accumulate near the delta front resulting in its sliding from the frontal slope of the delta.

C) Top set beds: They lie on the delta surface and as the name suggest they lie on the top of all the above mentioned beds.

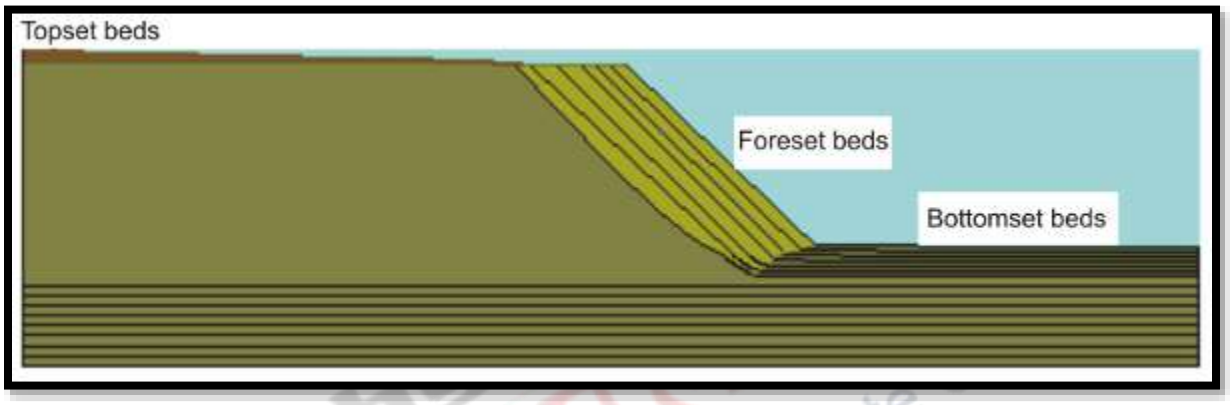

Fig: 11 source: https://upload.wikimedia.org/wikipedia/commons/f/fe/Delta_beds.png

Conditions for Delta formation

Delta formation is an outcome of a number of factors operating together with variable rate. Delta formation takes place in those parts of the coast which are relatively protected from high tides and destructive waves. So a comparatively calm sea or lake is a precondition for delta formation. The second important factor at play is the presence of abundant load in the stream which can settle at the mouth of the river. The rate of deposition of bedload should exceed the rate of its destruction. When these two conditions appear favourable delta formation takes place. Delta is not a stable feature and is regularly modified by the waves which often redistribute the deposited material at different places along the coast. Further the fluctuations in the volume of water and the amount of load a river carries also cause modification in the shape and extent of delta. Therefore, there is no uniformity in the shape and size of delta across the world, though arcuate delta is very commonly observed.

The shape of the deltas can be classified into (a) River dominated (b) Wave dominated and (c) Tide dominated (coleman et. Al, 1986; Galloway and Hobday, 1996)

Given below are few deltas which have been categorized on the basis of their shape.

(a) Arcuate Delta: These Deltas resemble arc of a circle. This is the most common shape of the delta found across the world. The distributaries of the main river spread the load in large proportion as they arrive close to the sea and the deposited material coalesce to give a triangle like appearance. The **Nile Delta** is an ideal example of arcuate delta. It is also an example of wave dominated delta.

It has barriers that enclose several lagoons. Niger delta, Ganga delta, Rhone delta, Indus delta, Po delta are all examples of arcuate delta.

Fig. 12. Nile Delta Source: https://commons.wikimedia.org/wiki/File:Nile_delta_landsat_false_color.jpg

(b) Cuspate Delta: Cuspate delta gives a pointed tooth like appearance. It is formed on a straight shoreline where waves are in a predominant position modifying regularly the deposited sediments by redistributing it along the shoreline. The site of the river meeting the ocean looks like a protrusion in the water. Tiber River forms cuspate delta at its mouth.

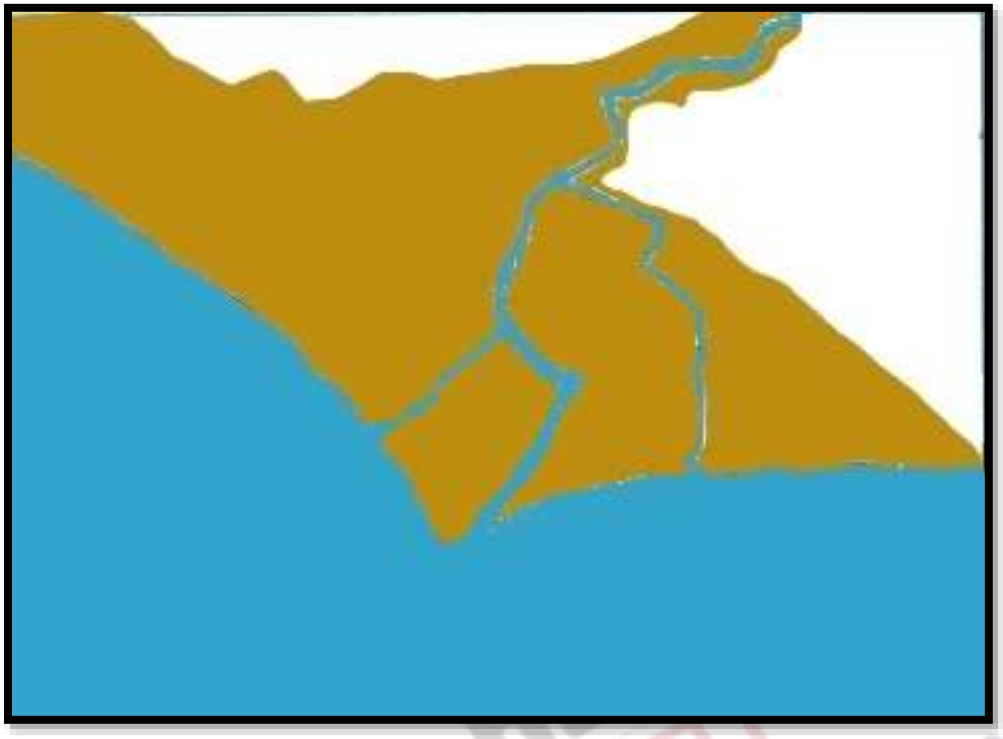

Fig. 13 Cuspate Delta

(c) Birdfoot Delta : The delta derives its name from the shape that resembles the claws of bird. The delta has its tributary channels projecting into the sea. The fine load carried by the distributaries is deposited along them in a linear form making small levees. These channels appear penetrating into the sea in narrow finger like shape. The Mississippi river is a perfect example of river dominated delta. It is a river of North America that forms grand bird foot delta when it falls in the Gulf of Mexico. This type of delta is usually formed when a large river joins a relatively shallow gulf or lake.

Fig. 14. Mississippi delta Source:
https://www.jpl.nasa.gov/spaceimages/details.php?id=PIA03497

Truncated delta, Eastuarine delta, Abandoned delta are examples of some other types of delta besides these three major types of deltas