1. Details of Module and its structure

Module Detail	
Subject Name	Geography
Course Name	Geography 01 (Class XI, Semester - 1)
Module Name/Title	Landforms — Landforms and their evolution – Part 1
Module Id	kegy_10701
Pre-requisites	Basic Knowledge about Landforms and their evolution
Objectives	After going through this module, the learners will be able to know about : • Acquire the knowledge and understanding of landforms and their evolution. • They will understand the concept of evolution of landforms. • They will understand the concept of erosional and depositional activities of the running water (River). • They will learn about the landforms developed by the erosional and depositional activities of river.
Keywords	Monadnocks, Peneplain, V-Shaped Valleys, Meanders, River Terraces, Alluvial Fans, Distributaries of River, Deltas, Ox-Bow Lakes, Braided Channels

2. Development Team

Role	Name	Affiliation
National MOOC Coordinator (NMC)	Prof. Amarendra P. Behera	CIET, NCERT, New Delhi
Program Coordinator	Dr. Mohd. Mamur Ali	CIET, NCERT, New Delhi
Course Coordinator (CC) / PI	Prof. Aparna Pandey	DESS, NCERT, New Delhi
Course Co-Coordinator / Co-PI	Dr. Archana	CIET, NCERT, New Delhi
Subject Matter Expert (SME)	Dr. Prabuddh Kr. Mishra	NCERT textbook " Fundamentals of Physical Geography" Shivaji College, University of Delhi
Review Team	Dr. Ramashray Prasad	Bhim Rao Ambedkar College, New Delhi

Table of Contents:

Weathering physically breaks up rock and erosion happens when rocks and sediments are picked up and moved to another place by ice, water, wind. The geomorphic agents like glacier, running water (river), wind, ground water, and sea waves form different landforms on the earth. These geomorphic agents also known as agents of erosion acting over long periods of time produce systematic changes, leading to sequential development of landforms. As this module deals with landforms and their evolution 'first' start with the question, what is a landform? In simple words, small to medium tracts or parcels of the earth's surface are called landforms.

If landform is a small to medium sized part of the surface of the earth, what is a landscape? Several related landforms together make landscapes, (large tracts of earth's surface). Each landform has its own physical shape, size, materials, characteristics and is a result of the action of certain geomorphic processes and agent(s). Actions of most of the geomorphic processes and agents are slow, and hence the results take a long time to take shape. Every landform has a beginning. Landforms once formed may change in their shape, size and nature slowly or fast due to continued action of geomorphic processes and agents.

Due to changes in climatic conditions and vertical or horizontal movements of landmasses, either the intensity of processes or the processes themselves might change leading to new modifications in the landforms. Evolution here implies stages of transformation of either a part of the earth's surface from one landform into another or transformation of individual landforms after they are once formed. That means, each and every landform has a history of development and changes through time. A landmass passes through stages of development somewhat comparable to the stages of life — youth, mature and old age.

The evolutionary history of the continually changing surface of the earth is essential to be understood in order to use it effectively without disturbing its balance and diminishing its potential for the future. Geomorphology deals with the reconstruction of the history of the surface of the earth through a study of its forms, the materials of which it is made up of and the processes that shape it.

Changes on the surface of the earth owe mostly to erosion by various geomorphic agents. Of course, the process of deposition too, by covering the land surfaces and filling the basins, valleys or depressions, brings changes in the surface of the land. Deposition follows erosion and the depositional surfaces too are ultimately subjected to erosion. Glaciers, running water, wind, ground-water, and waves are powerful erosional and depositional agents shaping and changing the surface of the earth aided by weathering and mass wasting over long periods of time produce systematic changes leading to sequential development of processes. Each geomorphic agent produces its own assemblage of landforms. Not only this, each geomorphic process and agent leave their distinct imprints on the landforms they produce. You know that most of the geomorphic processes are imperceptible functions and can only be seen and measured through their results. What are the results? These results are nothing but landforms and their characteristics. Hence, a study of landforms will reveal to us the process and agent which has made or has been making those landforms.

As the geomorphic agents are capable of erosion and deposition, two sets — erosional or destructional and depositional or constructional — of landforms are produced by them. Many varieties of landforms develop by the action of each of the geomorphic agents depending upon especially the type and structure i.e. folds, faults, joints, fractures, hardness and softness, permeability and impermeability, etc. There are some other independent controls like (i) stability of sea level; (ii) tectonic stability of landmasses; (iii) climate, which influence the evolution of landforms. Any disturbance in any of these three controlling factors can upset the systematic and sequential stages in the development and evolution of landforms.

In the next section, the erosional and depositional work of running water is presented as to how landmasses are reduced in their relief through erosion and then, development of some of the erosional and depositional landforms is dealt with.

Do You Know

Denudation is the combined action of the various processes that causes the wearing away of the Earth's surface and causes a general lowering and levelling out of the surface. It is carried out in four phases- *weathering, transportation, erosion and deposition*.

Running Water (Fluvial Topography)

In humid regions, which receive heavy rainfall running water is considered the most important of the geomorphic agents in bringing about the degradation of the land surface.

The adjective 'fluvial' (from Latin fluvius river) refers to the work of rivers but in the context of landscape development, it includes the work of both overland flow and stream flow. Thus landforms shaped by running water (i.e. by the fluvial processes of overland flow and stream flow) are called fluvial landforms. Fluvial landforms and processes dominate the continental land surface. Rivers and their associated streams undertake some important physical functions:

a) By draining the land surface they dispose the super fulvous water brought by precipitation.
b) They are responsible for much of the denudation of the land surface over large parts of the earth.
c) They dissolve and erode the rocks over which they flow.
d) They transport the matter which they have dissolved. They deposit some of the materials which they have carried in suspension or roll along stream bed.

As a result of all this, certain topographic features are produced which are called fluvial topography, and sediment entering is balanced by leaving.

The Process of River Action

When a river flows, it carries with it eroded materials. These comprise the river's load, and may be divided into three distinct types.

1. ***Material in solution***- these are minerals which are dissolved in the water.
2. ***Materials in suspension***- sand, silt and mud are carried along suspended in the water as the stream flows.
3. ***The Traction load***- this includes coarser materials such as pebbles, stones, rocks and boulders, which are rolled along the river bed.

It has been estimated that for every square mile of earth's surface, more than 200 tons of solid materials in suspension and more than 50 tonnes of materials in solution are being carried off by running water every year. During the floods the amount of rock debris swept off by rivers is very much greater. We can see this mud that colours the river water during a heavy rain. The ability of river to move the various grades of materials depends greatly upon the volume of the water, the velocity of the flow and lastly the size, shape and weight of the load. It is said that by doubling the velocity of a river, its transporting power is increased by more than 10 times. The movement of rivers is thus intermittent, acting vigorously in certain parts of the year and remaining less active at other times.

Erosive Work of River

In rivers, erosion and transportation go on simultaneously, comprising the following inter-acting processes. The erosional work of running water acts in several different ways.

Solution or corrosion i.e., the solvent action of water as it flows over the rock. Solution is particularly well developed in lime stone regions. But it should be remembered that most rocks contain minerals which are soluble in water, and solution of rocks in tropical humid regions is especially important.

Hydraulic Action: is performed by lifting and quarrying effect of rushing water. The force of moving water dislodges the rocks. It is also able to weaken solid rocks by surging into cracks in the rock. But hydraulic action effects very little erosion if the river has little or no load.

Abrasion: Rock particles carried by a river are thrown against the sides of the channel and are dragged along the rock bed. This causes further erosion further erosion which adds to load. The larger the particles of the load, the more rapid are the erosion.

Attrition: This is the wear and tears of the transported materials themselves when they roll and collide into one another. The courser boulder is broken down into smaller pieces/stones. However it is not uncommon to find angular particles of large size in the lower sections of a river course.

Fluvial Processes

These above mentioned four processes together make up river erosion which enables a river to cut a channel into the land. River erosion operates or streams erode by three ways:

1. **Headward erosion**

   It is also known as *channel extension*. Headward or regressive erosion by streams and gullies, by which river increases its length.
2. **Vertical erosion**

   Channel deepening or by down cutting of the streambed.
3. **Lateral erosion**

Channel widening through bank caving or undercutting. This is particularly effective along the outside banks of meanders.

River Valley Characteristics and Landforms

Usually a river has its source in a lake or spring or a glacier, some of the world's very large rivers originate from lakes, namely, the Brahmaputra and the Indus from Lake Mansarowar. In its upper course the river flows through mountains or hilly areas. Here the slope is steep and the velocity of river water is great. This stage is also called the youthful stages. The rivers assume a high speed. So the most prominent feature in this stage is vertical erosion. River in its middle and lower course produce variety of landforms as listed in Table 1.

Table 1. Distinct Course of River

The Upper Mountain Course	The Middle or Valley Course	The lower or Plain Course
Erosional Topographic Features • V- Shaped Valley • Gorge-Canyon • Cataract • Waterfalls and Rapids • Plunge Pool • Structural Benches • River Cliff • Slip off Slopes	Lateral corrasion tends to replace vertical corrasion. Transposition and Deposition. River slope is gentle compared to youthful valley. • Truncated Spurs • U-shaped valleys • Meandering • Meander Terraces • Flood Plain • Riffle	*Depositional Features* • Levees • Crevasse splays • Ox-bow lake • Delta

In the early stages, down-cutting dominates during which irregularities such as waterfalls and cascades will be removed. In the middle stages, streams cut their beds slower, and lateral erosion of valley sides becomes severe. Gradually, the valley sides are reduced to lower and lower slopes. The divides between drainage basins are likewise lowered until they are almost completely flattened leaving finally, lowland of faint relief with some low resistant remnants called *monadnocks* standing out here and there. This type of plain forming as a result of stream erosion is called a *peneplain* (an almost plain). The characteristics of each of the stages of landscapes developing in running water regimes may be summarised as follows:

Youth

Streams are few during this stage with poor integration and flow over original slopes showing shallow V-shaped valleys with no floodplains or with very narrow floodplains along trunk streams. Streams divides are broad and flat with marshes, swamp and lakes. Meanders if present develop over these broad upland surfaces. These meanders may eventually entrench themselves into the uplands. Waterfalls and rapids may exist where local hard rock bodies are exposed.

Mature

During this stage streams are plenty with good integration. The valleys are still V-shaped but deep; trunk streams are broad enough to have wider floodplains within which streams may flow in meanders confined within the valley. The flat and broad inter stream areas and swamps and marshes of youth disappear and stream divides turn sharp. Waterfalls and rapids disappear.

Old

Smaller tributaries during old age are few with gentle gradients. Streams meander freely overvast floodplains showing natural levees, oxbow lakes, etc. Divides are broad and flat with lakes, swamps and marshes. Most of the landscape is at or slightly above sea level.

Erosional Landforms

Valleys

Valleys start as small and narrow rills; the rills will gradually develop into long and wide gullies; the gullies will further deepen, widen and lengthen to give rise to valleys. Depending upon dimensions and shape, many types of valleys like *V-shaped valley, gorge, canyon,* etc. can be recognised. A gorge is a deep valley with very steep to straight sides (Figure 7.1) and a canyon is characterised by steep step-like side slopes (Figure 7.2) and may be as deep as a gorge. A gorge is almost equal in width at its top as well as its bottom. In contrast, a canyon is wider at its top than at its bottom. In fact, a canyon is a variant of gorge. Valley types depend upon the type and structure of rocks in which they form. For example, canyons commonly form in horizontal bedded sedimentary rocks and gorges form in hard rocks.

The V-shaped valley usually exhibits definite characteristics in the initial stage. The valley is narrow and deep V; shaped in Transverse profile. Resemblance to English letter 'V', produced by rapid cutting and deepening stream floor, comparatively narrow (vertical corrasion) and the steepy rising valley sides. Down-cutting takes place so rapidly that lateral erosion cannot keep place. In some cases where rocks are very resistant, the valley is so narrow and the sides are so steep that gorges are formed e.g., the Indus gorge of Kashmir. Grand Canyon in southwestern USA is also a classic example of V-shaped valley. The Colorado River has deeply cut the Colorado Plateau through ages, which gave rise to this Grand Canyon.

Fig 1 **V shaped valley, Carding Mill Valley**

http://s0.geograph.org.uk/geophotos/02/26/07/2260729_85d52a2f.jpg

The U-shaped valley symbolizes the English letter ‘U’. These valleys are steep-sided with curves at the valley floor. The floors are generally is broad and flat. This valley type is found in the middle course of the river where lateral erosion is predominant than the vertical erosion. These valleys are also formed out of the glacial erosion, when huge mountain glaciers moved down slowly from the mountain slopes during last glaciations. These valleys are also called as glacial troughs when formed with glaciers. When glaciers (especially the alpine glaciers) move down slowly from the mountains along the pre-existing river or the v-shaped valleys, they turn these valleys into U-shaped, resulting in wider and deeper valleys. One of the examples of this type of valley is Yosemite Valley in California, USA.

Fig. 2 U-Shaped river Valley Giacier National Park Montana

https://c1.staticflickr.com/1/26/66252669_e521e00dcf_b.jpg

The flat-floored valleys are formed in the 'matured 'stage of the river course. Here the stream channel becomes gentler. A stream flowing at a moderate to low gradient tends to erode the sides of the river rather than the bottom of it. Thus, the river soon forms S-shaped bends in the valley floors known as meanders. Thus, with time the steep-sided v-shaped valley turns into a broad, flat floored river valley. An excellent example of this type of valley is Nile River Valley.

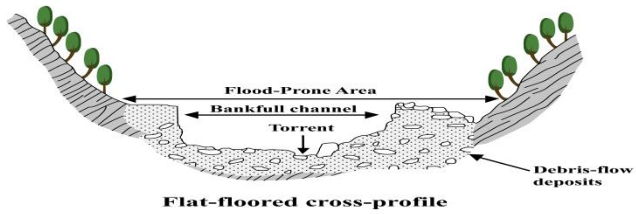


Fig 3: Flat Floored river valley

Fig 4: The Aigas Gorge

http://s0.geograph.org.uk/geophotos/04/64/10/4641040_22260e36.jpg

Over the rocky beds of hill-streams more or less circular depressions called *potholes* formbecause of stream erosion aided by the abrasion of rock fragments. Once a small and shallow depression forms, pebbles and boulders get collected in those depressions and get rotated by flowing water and consequently the depressions grow in dimensions. A series of such depressions eventually join and the stream valley gets deepened. At the foot of waterfalls also, large potholes, quite deep and wide, form because of the sheer impact of water and rotation of boulders. Such large and deep holes at the base of waterfalls are called *plunge pools*. These pools also help in the deepening of valleys. Waterfalls are also transitory like any other landform and will recede gradually and bring the floor of the valley above waterfalls to the level below.

Fig-5 Potholes

https://upload.wikimedia.org/wikipedia/commons/f/f6/Bourke%27s_Luck_Potholes_at_the_Blyde_River_Canyon_Nature_Reserve.JPG

Potholes and Plunge Pools

Incised or Entrenched Meanders

In streams that flow rapidly over steep gradients, normally erosion is concentrated on the bottom of the stream channel. Also, in the case of steep gradient streams, lateral erosion on the sides of the valleys is not much when compared to the streams flowing on low and gentle slopes. Because of active lateral erosion, streams flowing over gentle slopes develop sinuous or meandering courses. It is common to find meandering courses over floodplains and delta plains where stream gradients are very gentle. But very deep and wide meanders can also be found cut in hard rocks. Such meanders are called *incised or entrenchedmeanders* (Figure-6). Meander loops develop over original gentle surfaces in the initial stages of development of streams and the same loops get entrenched into the rocks normally due to erosion or slow, continued uplift of the land over which they start. They widen and deepen over time and can be found as deep gorges and canyons in hard rock areas. They give an indication on the status of original land surfaces over which streams have developed. What are the differences between incised meanders and meanders over flood and delta plains?

Fig 6. An entrenched meander loop of river Colorado in USA showing step-like side slopes of its valley typical of a canyon

Fig 6a: Meandering River

https://upload.wikimedia.org/wikipedia/commons/1/1f/Nowitna_river.jpg

River Terraces

River terraces are surfaces marking old valley floor or floodplain levels. They may be bedrock surfaces without any alluvial cover or alluvial terraces consisting of stream deposits. River terraces are basically products of erosion as they result due to vertical erosion by the stream into its own depositional floodplain. There can be a number of such terraces at different heights indicating former river bed levels. The river terraces may occur at the same elevation on either side of the rivers in which case theyare called *paired terraces* (Figure 7).

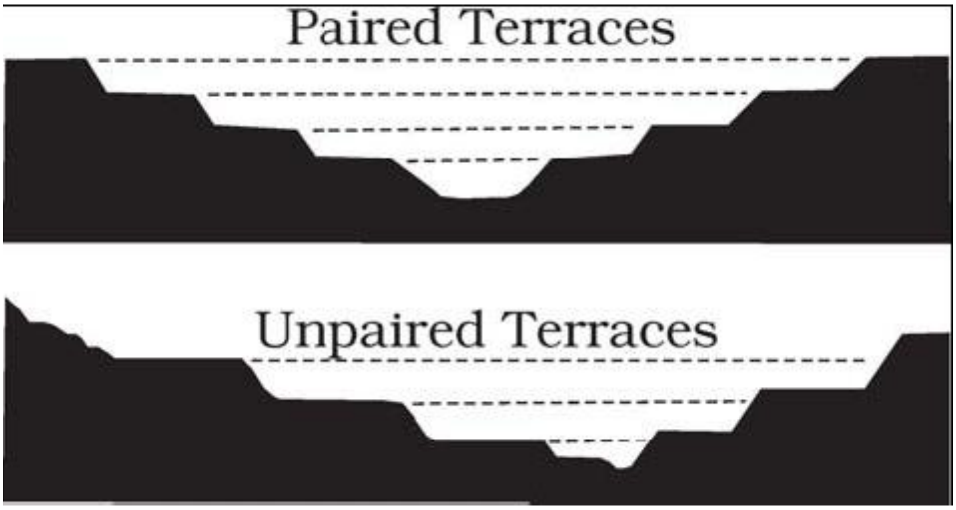


Fig 7 : Paired and unpaired river terraces

When a terrace is present only on one side of the stream and with none on the other sideor one at quite a different elevation on the other side, the terraces are called *unpaired terraces*. Unpaired terraces are typical in areas of slow uplift of land or where the water column changes are not uniform along both the banks. The terraces may result due to (i) receding water after a peak flow; (ii) change in hydrological regime due to climatic changes; (iii) tectonic uplift of land; (iv) sea level changes in case of rivers closer to the sea.

Fig 7a : River Terraces

http://s0.geograph.org.uk/geophotos/05/12/14/5121477_a2c6a483.jpg

Depositional Landforms

Alluvial Fans

Alluvial fans (Figure 7.4) are formed when streams flowing from higher levels break into foot slope plains of low gradient. Normally very coarse load is carried by streams flowing over mountain slopes. This load becomes too heavy for the streams to be carried over gentler gradients and gets dumped and spread as a broad low to high cone shaped deposit called *alluvial fan*. Usually, the streams which flow over fans are not confined to their original channels for long and shift their position across the fan forming many channels called *distributaries*. Alluvial fans in humid areas show normally low cones with gentle slope from head to toe and they appear as high cones with steep slope in arid and semi-arid climates.

Fig 8: An alluvial fan deposited by a hill stream on the way to Amarnath, J and K

Deltas

Deltas are like alluvial fans but develop at a different location. The depositional feature of almost triangular shape at the mouth of a river debouching either in a lake or a sea is called delta. The word delta has been derived from a Greek letter. The size of delta of major and small rivers all over the world varies from a few sq kilometer to 1000 sq. kilometer (eg. the Ganga Delta in India and Bangladesh). The size of delta depends on the rock characteristics, vegetal cover, rate of erosion etc.

Fig 9 Deltas

https://upload.wikimedia.org/wikipedia/commons/c/c7/River_Deltas%2C_Lake_Ayakum%2C_Tibet.JPG

The ideal condition for the formation and growth of delta includes:

1) Suitable place in the form of shallow sea and lake shores,
2) Long courses of the river
3) Medium size of sediments
4) Relatively calm or sheltered sea at the mouth of the rivers.
5) Large amount of sediments supply.
6) Accelerated rate of erosion in the catchment area of the concerned river
7) Almost stable condition of sea coast and oceanic bottom

As deposition goes on the river is forced to divide into several channels each of which repeated by divides. All these channels are called distributaries. Stretches of sea or lake become surrounded by deposited sediments and these are filled in with sediments when they may persist for sometimes as swamps.

Nature and rate of delta growth depends on a variety of factors e.g.,

a. Velocity of the steam flow
b. Native of sea waves
c. Supply of Sediments
d. Oceanic currents
e. Slope and heights of deltas

Floodplains, Natural Levees and Point Bars

Floodplain is a depositional feature by large quantities of sediments carried by rivers in their lower course. Deposition develops a floodplain just as erosion makes valleys. Floodplain is a major landform of river deposition. Large sized materials are deposited first when stream channel breaks into a gentle slope. Thus, normally, fine sized materials like sand, silt and clay are carried by relatively slow moving waters in gentler channels usually found in the plains and deposited over the bed and when the waters spill over the banks during flooding above the bed. A river bed made of river deposits is the active floodplain. The floodplain above the bank is inactive floodplain. Inactive floodplain above the banks basically contain two types of deposits — flood deposits and channel deposits. In plains, channels shift laterally and change their courses occasionally leaving cut-off courses which get filled up gradually. Such areas over flood plains built up by abandoned or cut-off channels contain coarse deposits. The flood deposits of spilled waters carry relatively finer materials like silt and clay. The flood plains in a delta are called *delta plains*.

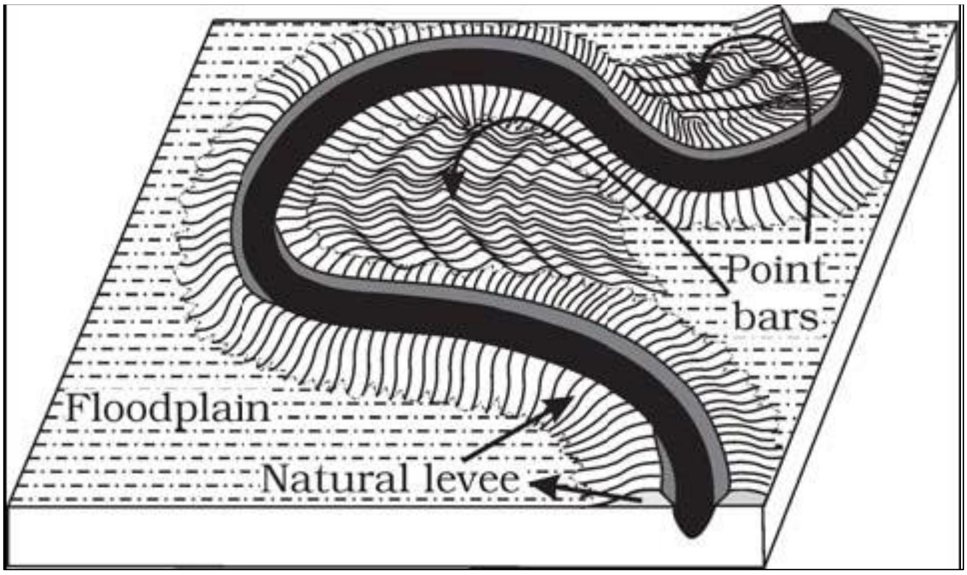


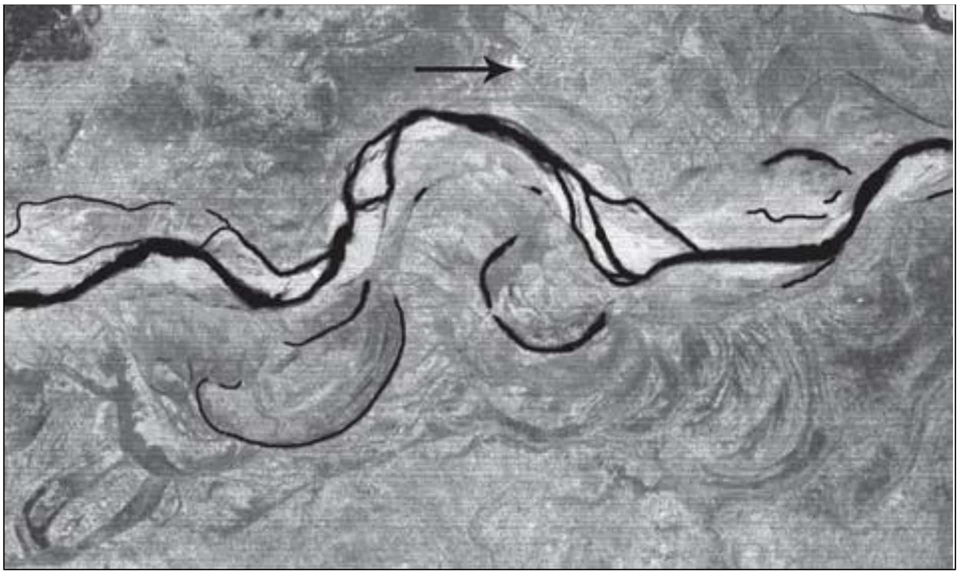
Fig 11 : Natural levee and point bars

Natural levees and point bars (Figure 11) are some of the important landforms found associated with floodplains. *Natural levees* are found along the banks of large rivers. They are low, linear and parallel ridges of coarse deposits along the banks of rivers, quite often cut into individual mounds. During flooding as the water spills over the bank, the velocity of the water comes down and large sized and high specific gravity materials get dumped in the immediate vicinity of the bank as ridges. They are high nearer the banks and slope gently away from the river. The levee deposits are coarser than the deposits spread by flood waters away from the river. When rivers shift laterally, a series of natural levees can form.

Point bars are also known as *meander bars*. They are found on the convex side of meanders of large rivers and are sediments deposited in a linear fashion by flowing waters along the bank. They are almost uniform in profile and in width and contain mixed sizes of sediments. If there more than one ridge, narrow and elongated depressions are found in between the point bars. Rivers build a series of them depending upon the water flow and supply of sediment. As the rivers build the point bars on the convex side, the bank on the concave side will erode actively. In what way do natural levees differ from point bars?

Meanders

In large flood and delta plains, rivers rarely flow in straight courses. Loop-like channel patternscalled *meanders* develop over flood and delta plains (Figure 12).



Fig, 12 : A satellite scene showing meandering BurhiGandak river near Muzaffarpur, Bihar, showing a number of oxbow lakes and cut-offs

Meander is not a landform but is only a type of channel pattern. This is because of (i) propensity of water flowing over very gentle gradients to work laterally on the banks; (ii) unconsolidated nature of alluvial deposits making up the banks with many irregularities which can be used by water exerting pressure laterally; (iii) coriolis force acting on the fluid water deflecting it like it deflects the wind. When the gradient of the channel becomes extremely low, water flows leisurely and starts working laterally. Slight irregularities along the banks slowly get transformed into a small curvature in the banks; the curvature deepens due to deposition on the inside of the curve and erosion along the bank on the outside. If there is no deposition and no erosion or undercutting, the tendency to meander is reduced. Normally, in meanders of large rivers, there is active deposition along the convex bank and undercutting along the concave bank.

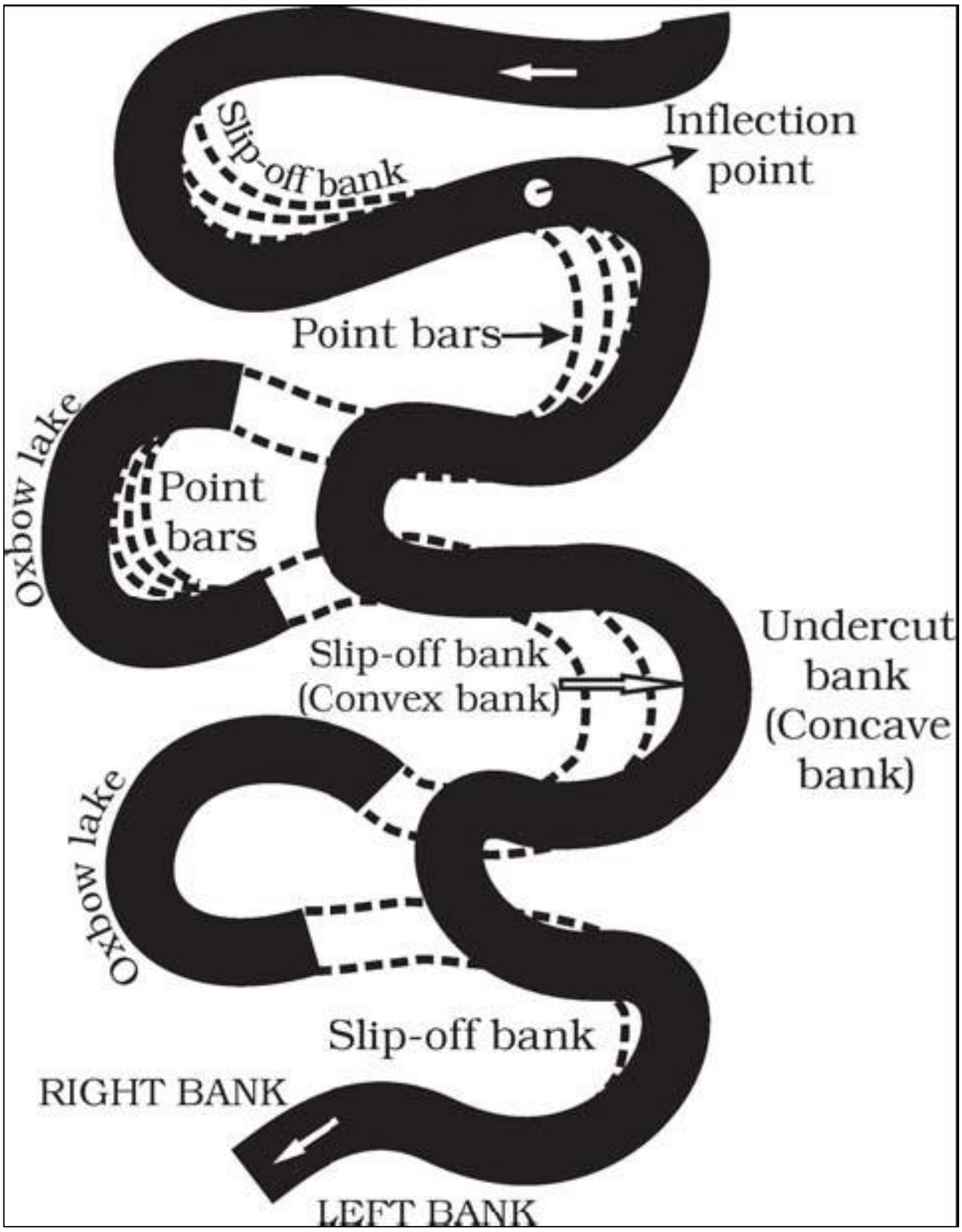


Figure 12a : Meander growth and cut-off loops and slip-off and undercut banks

The concave bank is known as cut-off bank which shows up as a steep scarp and the convex bank presents a long, gentle profile and is known as slip-off bank (Figure 12a). As meanders grow into deep loops, the same may get cut-off due to erosion at the inflection points and are left as *ox-bow lakes*.

Braided Channels

When rivers carry coarse material, there can be selective deposition of coarser materials causing formation of a central bar which diverts the flow towards the banks; and this flow increases lateral erosion on the banks. As the valley widens, the water column is reduced and more and more materials get deposited as islands and lateral bars developing a number of separate channels of water flow. Deposition and lateral erosion of banks are essential for the formation of braided pattern. Or, alternatively, when discharge is less and load is more in the valley, channel bars and islands of sand, gravel and pebbles develop on the floor of the channel and the water flow is divided into multiple threads. These thread-like streams of water rejoin and subdivide repeatedly to give a typical braided pattern (Figure 12).

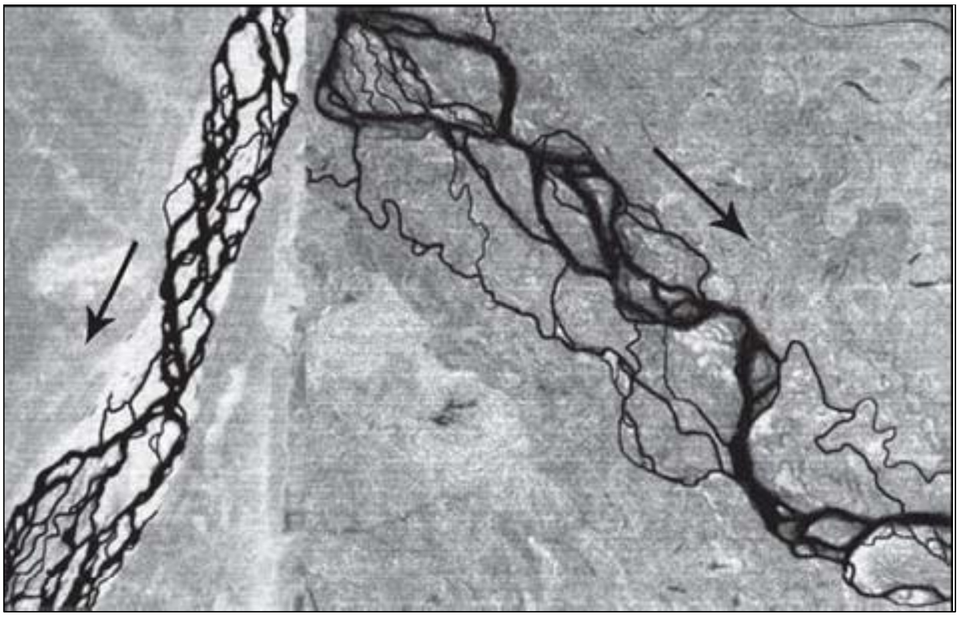


Fig. 13 : Satellite scenes showing braided channel segments of Gandak (right) and Son (left) rivers (Arrows show the direction of flow)

Summary

A river system can be divided into three subsystems

- *Collecting system* (branches) -- consisting of a network of tributaries in the headwater region, collects and funnels water and sediment to the main stream
- *Transporting system* (trunk) -- the main trunk stream, which functions as a channel way through which water and sediment move from the collecting area toward the ocean? (Erosion and deposition also occur in a river's transporting system)
- *Dispersing system* (roots) -- consists of a network of distributaries at the mouth of a river (delta), where sediment and water are dispersed into an ocean, a lake, or a dry basin
- Rivers are agent of erosion, transportation and deposition. They are the most important agents of transportation. Weathering, downslope movements and rivers shape the landscape.

- All the material carried by a river is called its load. This is carried along by saltation, suspension and solution.
- A river's flow comes from its energy, and its energy is related to gradient, volume and channel shape.
- A river erodes by the processes of attrition, abrasion, hydraulic action, and solution.
- The slope of a river channel is adjusted by erosion and deposition to attain a state of grade.
- River erosion deepens, lengthens and widens the valley. Headward erosion is the down cutting at the head of the stream; it lengthens the valley. The valley widens by creep and landsliding and by lateral cutting by the stream.
- River erosion produces minor features such as pot holes, plunge pools, river cliffs, knick points, and major features such as valley, gorge, waterfalls, rapids, canyons and interlocking spurs (usually in conjunction with rock structure).
- River deposition produces minor features such as levees and slip-offs slopes, and major features flood plains and delta.
- A river's velocity is increased if the gradient steepens and is decreased when the river enters a lake or the sea.
- Base level is limit to which a river can erode the elevation of its mouth.
- Distinctive curves, called meanders form, which distribute the river's loss of energy most uniformly. Developing meanders may intersect, cutting off a stretch of a river, forming ox-bow lake.