CHAPTER - IV

CHAPTER FOUR

GEOMORPHOLOGY: A BRIEF ACCOUNT

4. Definition

"Geomorphology" is a branch of geology developed in the late 19th century and is derived from the Greek word "Geo" meaning "earth", "morfe" meaning "form" and "logos" meaning "study" (Chorley et al. 1984)[18]. It is a scientific study of the evolution of the landforms such as plains, plateaus, valleys, mountains etc and the processes which eventually shape and influence them (Summerfield, 1991)[100] and (Worcester, 1939)[104]. In other words, geomorphology deals with the study of the evolution of landforms, which is actually an end product resulted by the interaction of the natural surface agencies and the rock attributes. It depends on three factors: climatic setting, type of the underlying bed rock and its structure and the time span involved in the complete process.

It works on the golden rule "the present is the key to the past" and covers three main branches i.e.

(i) Functional or the process geomorphology which focuses on studying the relationships between the landforms and the processes that are acting upon them and covers two main aspects i.e. forms and processes;

(ii) Applied geomorphology which focuses on the interaction of humans on landforms and its resultant impact and

(iii) Historical geomorphology which studies the evolution of the landforms and its changes over different time scales and relies on the sedimentary record for its database (Huggett, 2003)[36].

The geologic work of running water is of a considerable magnitude and is divided into distinct processes such as 1) hydraulic action, 2) abrasion, 3) attrition, 4) solution, 5) transportation and 6) deposition. Of these all processes the first five are responsible for bringing about degradation whereas under suitable sites and favorable conditions deposition of the eroded and the transported material brings about aggradation (Mukherjee, 1984)[56].

4.1. Geomorphic Processes

4.1.1. Exogenous and Endogenous processes

A geomorphic system has internal and external variables. The internal variables are related to endogenous processes and external variables are related to exogenous process. Endogenous processes have their origin below the surface of earth and exogenous processes take place on the surface of earth. The main endogenous forms are neotectonic and volcanic forms whereas the main exogenous forms are denudational, karsts, fluvial, glacial, coastal, aeolian, anthropogenic and various organic forms (Subramanian)[99]. Exogenic processes mainly involve denudation which results in the removal of material and leads to a reduction in elevation and relief of a landform (Summerfield, 1991)[100]. Geomorphology is primarily concerned with exogenous processes as they play a major role in shaping of the earth's surface but at the same time the internal forces are also necessary to be considered so that the origin of a particular landform can be better studied. These internal forces cause the land to rise and as they do so they are eventually subjected to the external agents such as the effect of temperature, air, water, ice, gravity and other natural as well as artificial agents that brings about weathering of the rock. They are no longer in equilibrium with the environment under which they were formed and thus start to decompose and a completely different landform is evolved. Thus in a given environment the composition

of rocks will decide how they will decompose and which form they will take (Leopold et al. 1995)[45] and (Anderson and Anderson, 2010)[3].

4.2. Fundamental concepts in Geomorphology

Geomorphology works on some fundamental concepts as under:

a) The same physical processes and laws that operate today operated throughout the geologic time, although not necessarily always with the same intensity as now.

b) Geologic structure is a dominant control factor in the evolution of land forms and is reflected in them.

c) To a large degree the earth's surface possess relief because the geomorphic processes operate at differential rates.

d) Geomorphic processes leave their distinctive imprint upon landform, and each geomorphic process develops its own characteristic assemblage of landforms.

e) As the different erosional agents act upon the earth's surface there is produced an orderly sequence of landforms.

f) Complexity of geomorphic evolution is more common than simplicity

g) Little of the earth's topography is older than tertiary and most of it is no older than Pleistocene.

h) Proper interpretation of the present day landscapes is impossible without a full appreciation of the manifold influences of the geologic and climatic changes during the Pleistocene.

i) An appreciation of world climates is necessary to a proper understanding of the varying importance of the different geomorphic processes.

j) Geomorphology, although concerned primarily with present day landscapes, attains its maximum usefulness by historical extension (Thornbury, 1985)[101].

4.3. Fluvio-Geomorphology

4.3.1. Principles

Fluvio-geomorphology is one of the most important branches of geomorphology. The term "fluvial" is derived from the Latin word fluvinus meaning river and fluvio-geomorphology is the study of the interactions between the river channel, forms and processes at different time scales (Charlton, 2008)[17]. It focuses on the landforms developed due to river and river systems and how the natural setting and human land use in a watershed determine the shape of the river channel. It also studies the changing pattern of various geomorphic features such as flood-plain, sand-bars, point-bars, river terraces, cut-off meanders, river channel, levees, ox-bow lakes, water-bodies, river islands, meander scars, palaeo meanders etc. and tries to find out the reasons behind the changing scenario. The aim of the fluvio-geomorphological studies is to describe and analyze the different landforms which are created by the effect of flowing water and thereafter to develop an understanding of the ways in which the surface processes operate and control the development of these landforms (Gordon et al. 2004)[28].

According to (Mayer, 1992)[52] and (Marzluff, 2008)[50], the basic principle of fluvio-geomorphology is the equilibrium concept according to which a river form, its cross-sectional shape, planform, and gradient are adjusted to the existing watershed conditions that control the amount of sediment and the water supplied to the river channel. All channels are self adjusting and they change their morphology relative to the changing watershed conditions. The effective discharge in a particular region generally controls the shape and size of the river channel. The discharge at which the channel maintenance is most effective often corresponds to the bankfull stage where water completely fills the channel and starts to spread out into the floodplains which

means the bankfull discharge governs the shape and size of the channel. The effects of extreme flood events persist for a longer time in desertic region because of the absence of sufficient vegetation which helps the channel to recover from the flood effect.

The behavior of a river system can be classified on the basis of their equilibrium states as determined by the balance between three kinds of parameters:

1) **Driving variables:** the inputs of water and sediments, generated from upstream channel and catchment processes

2) **Boundary conditions:** landscape characteristics, e.g. valley slope and bank materials

3) **Adjusting variables:** the characteristics of the channel form determined by the interaction of the driving variables with the boundary conditions. Some rivers are comparatively less dynamic and remain quite steady maintaining their location features over long period of time whereas some rivers are highly dynamic in nature e.g. the Ganges (Pahuja and Goswami, 2006)[60].

According to (Shen, 1971)[80], river channels comprise a small but a very significant part of the earth's landscape. It reflects the geology, climate, hydrology, biology and geomorphology of that particular area and drainage basin which might be extending for hundreds of miles upstream. Geomorphologists group these variables in three main following categories:

Process: It includes different processes acting on the earth' surface that eventually shape a landscape. For different landscapes there are different defining parameters. In case of a river channel the frequency and magnitude of the water runoff is the main defining factor. Climatic conditions and climatic pattern play a very major role since the effects of climate changes are reflected in the erosional and depositional process of the river and ultimately in its landscape and geomorphology. Apart from the erosional

forces acting on the earth's surface, tectonic forces which lead to upliftment or the subsidence of the crust also have a profound effect on the river behavior.

Structure: It includes the type and structure of rocks, its composition, and erosion characteristics of the rock, influence of faults, fractures, joints and other geologic structure and their distribution in the drainage basin. Rivers draining in different physical environment will differ greatly since the type of the rock, the nature of the rock, the hydrologic character of the system and the type and quantity of the sediment load is different.

Stage: the modification of the landform with time is referred as the stage of development of a landscape. In general with time there is a progressive and significant removal of earth materials by erosion and eventually a rugged landscape is reduced to a relatively flat erosional surface e.g. peneplain or a pediplain. Any ideal process of a landform evolution hardly occurs without any interruption by renewed uplift or climatic changes which again have a continuous effect on the type of the landscape produced.

Fluvio-geomorphological studies are carried out mainly by following methods: (Subramanian)[99]

Morphography: It studies and analyses the geomorphological representation of forms and its extent.

Morphogenesis: It studies the origin of a particular relief and the processes responsible for it.

Morphometry: It includes the quantitative aspects of the landforms and its representation.

Morphochronology: Studies the age wise arrangement of various landforms.

4.4. Fluvial Landforms

A fluvial action mainly involves constructive and destructive processes such as erosion and deposition. Landforms associated with fluvial erosion are gorges, canyons, V-shaped valleys, steep hill slopes, waterfalls, pediments, river terraces, etc whereas the landforms formed due to river deposition process are mainly alluvial fans, cones, alluvial plains, flood-plains, natural levees, meander scars, point-bars, channel fills, back swamps, deltas, river terrace etc. (Gupta, 2003)[33].

Some common terminologies related to fluvio-geomorphology

A fluvial action mainly involves constructive and destructive processes such as depositional and erosional processes. Different landforms are formed by these processes. Some of the major and most commonly found fluvio-geomorphological features are described below: (Bates and Jackson, 1980)[8], (Bates and Jackson, 1984)[9], (Kearey, 2001)[42], (Goudie, 2004)[30], (Neuendorf et al. 2005)[59], and (Arya et al. 2009)[5].

Abandoned channel: These are the channels where run-off no longer prevails since it is cut-off from the main channel e.g. Drainage on an alluvial fan and an ox-bow lake.

Aggraded bed: A river bed on which sediment has accumulated is termed as an aggraded bed.

Bank: It is the margin of the ground bordering a river/stream with water during normal course of flow. Banklines are termed as right and left banks as it would appear to an observer facing downstream.

Alluvium: It is a fine-grained fertile soil consisting of mud, silt, clay and sand deposited by flowing water on flood plains, in river beds, and in estuaries.

Alluvial plain: It is formed by the extensive deposition of alluvial materials mainly comprising of sand, silt and clay by major river systems. Topographically it is normally flat to gently undulating and usually adjacent to the river that periodically overflows its

banks. Ones which are formed due to the early cycle of deposition and occupying higher elevation are referred as older and upper alluvium. Similarly the ones which are formed during the late cycle of deposition and occupying lower elevation are referred as younger and lower alluvial plains.

Alluvial fan: It is a low cone shaped sediment deposit formed where a stream undergoes reduction in its slope.

Flood-plain: Topographically it is the most dynamic surface formed adjacent to the river or a stream. Geomorphologically it consists of unconsolidated fluvial sediments such as gravels, sand, silt, and clay transported by the river/stream. Hydrologically, it is the landform which is subjected to periodic flooding by the parent river or we can say it is the region of maximum inundation during the floods or is the area of land which is flooded when a river overflows its banks. In this area layers of alluvium are laid down. The soils are thus thick and fertile.

River Island: Land which is completely surrounded by water in normal condition in a river. Sometimes an elevated piece of land which is surrounded by swamp, marsh and is isolated by high waters or floods is also referred as an island.

Cut-off meander: A cut-off is formed when a stream cuts through a meander neck. A cut-off meander is a new and relatively short channel formed when a stream cuts through a narrow strip of land and thereby shortens the length of its channel. The crescent shaped body of water separated from the main stream by cut-off.

Meander scar: It is a concave or a crescent shape mark on the face of the valley wall formed by the lateral planation of the meandering stream. The meandering stream under cuts the valley wall which indicates the abandoned route of the river channel.

Natural Levee: A river or stream develops an elongated embankment or a broad low ridge made up of sand and silt and deposits along the banks of a river channel during

times of flood. Each levee is a low, wide sand and silt ridge situated immediately adjacent to the river channel and can be either big or small in size (plate 4.1a-b). A delta levee is a term used for an advancing delta formed between sandbars or natural levees and exist at the mouths of the distributaries.

Ox-bow lake: A crescent-shaped lake formed when a meander of a river or stream is cut off from the main channel. An ox-bow lake is often ephemeral in nature and located in abandoned meandering channel present in the flood-plain. It is also defined as single meander loop which is isolated from the main stream by natural or human process (plate 4.2).

Palaeo-channels: They are the remnants of river and stream channels that have been filled with sediments and are overlain by younger units or younger rocks. It is also referred as buried stream channel.

River terraces: These are areas of flat land located on either side of the flood plains, and raised above the flood plain. Earlier they used to be the flood plain but after that the river has cut down deeper and formed a new flood plain at a lower level. They are formed by the fluvial processes of deposition and erosion. The erosional terraces are formed by eroding the pre-existing formations and depositional terraces are formed by the accumulation of river sediments. River terrace consists of river borne deposits mainly alluvium comprised of sand, gravel, clay and silt. During different stages of cycles of erosion-deposition, the alluvium of the river valley cut into series of alluvial terrace and gets arranged at different levels along the sides of the valley thus forming a series of surfaces in the stream valley (plate 4.3).

Sand-bars: It is a bar or ridge of sand that borders the shore and forms near water surface by water currents in a river. It forms on the depositional bank of the river because of the deposition of the sediments carried by the river water.

Point-bars: They are series of low more or less arcuate ridges of sand and gravel developed on an inside area of a growing meander by the slow process of accretion. This process is accompanied by the migration of the channel towards the outer bank (plate 4.4).

River bed/stream bed: The channel which is containing or which formerly used to contain river water.

Water-body: It is a body of water having significant amount of accumulated water. They can be artificially made but most of them are natural.

Back Swamp: It is the section of a floodplain where deposits of fine silts and clays get settled after a floods. Back swamps usually lie behind a stream's natural levees.

Riffles: It is a shallow stretch of a river or stream, where the current is above the average stream velocity and the region where the water forms small ripple waves. Ripples are formed in shallow areas by coarser materials such as gravel deposits over which water flows.

Delta: It is a landform that is created at the mouth of a river where that river flows into an ocean, sea, estuary, lake, reservoir or another river. Deltas are formed from the deposition of the sediment carried by the river as the flow leaves the mouth of the river.

4.4.1. Types of river patterns

Channel patterns are used to describe the plan view of a river reach. There are three main types of river courses or river patterns (Leopold and Wolman, 1957)[44]

1) Straight
2) Meandering and
3) Braided

Throughout the river course we may come across to reaches of each of these three types at various points, sometimes making it very difficult to separate one pattern from the other. The type of the river pattern in turn depends on the geology of the area. For e.g. if the geology of the region is such that there are number of faults, then the course of the river will be quite a controlled one i.e. it will be almost a **straight pattern.**

Meandering pattern: A meander is a curve or an extreme U-shaped bend usually occurring in series in a water course which is developed due to the flow characteristics of water. A meander is formed when the moving water in a river erodes the outer banks and widens its valley. A stream of any volume may assume a meandering course, alternatively eroding sediments from one side of the water course and depositing them on the other side. Usually meanders are formed in the lower course of the river, where the erosion as well as the water velocity is higher on the outer side of the U-shaped bend whereas deposition occurs on the inner side of the bend. An ox-bow lake is formed when a meander gets cut-off from the main stream (plate 4.5).

Braided pattern: Braided streams are characterized by a network of smaller streams which continuously part to flow around islands and then again rejoin further downstream. It is a stream that divides into number of interlacing network of several smaller branches and reuniting shallow channels which were separated from each other by branch islands. Such a stream generally indicates an inability of the channel to carry any further sediment load (plate 4.6) (Arya et al. 2009)[5].

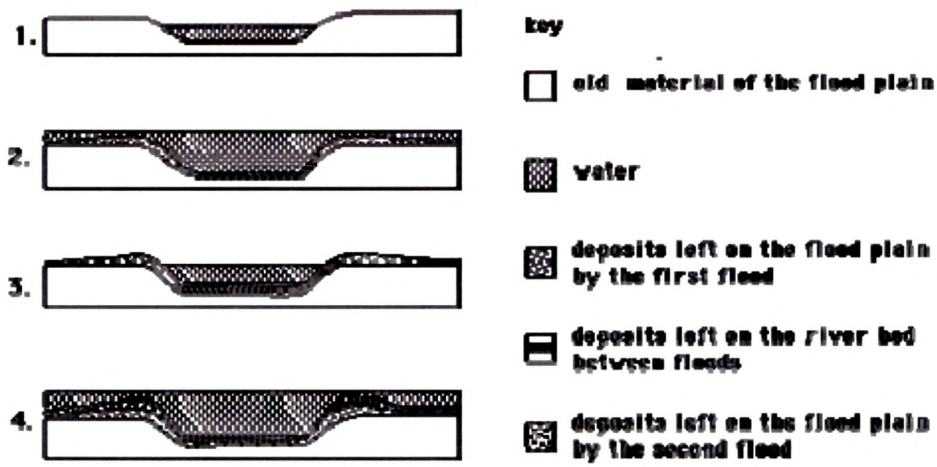

Plate 4.1 (a)

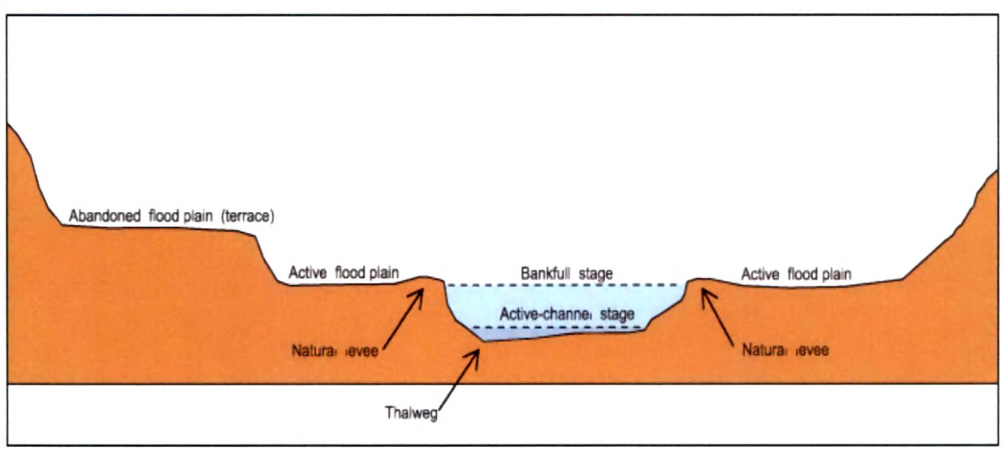

Plate 4.1 (b): Formation of a natural levee

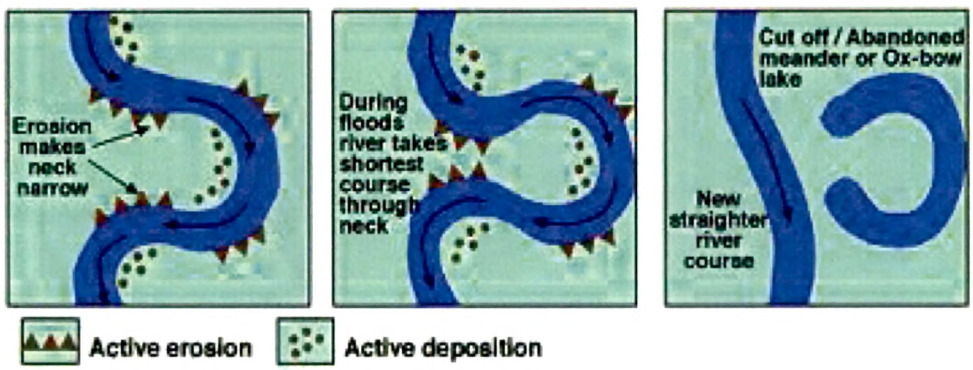

Plate 4.2: Formation of an ox-bow lake

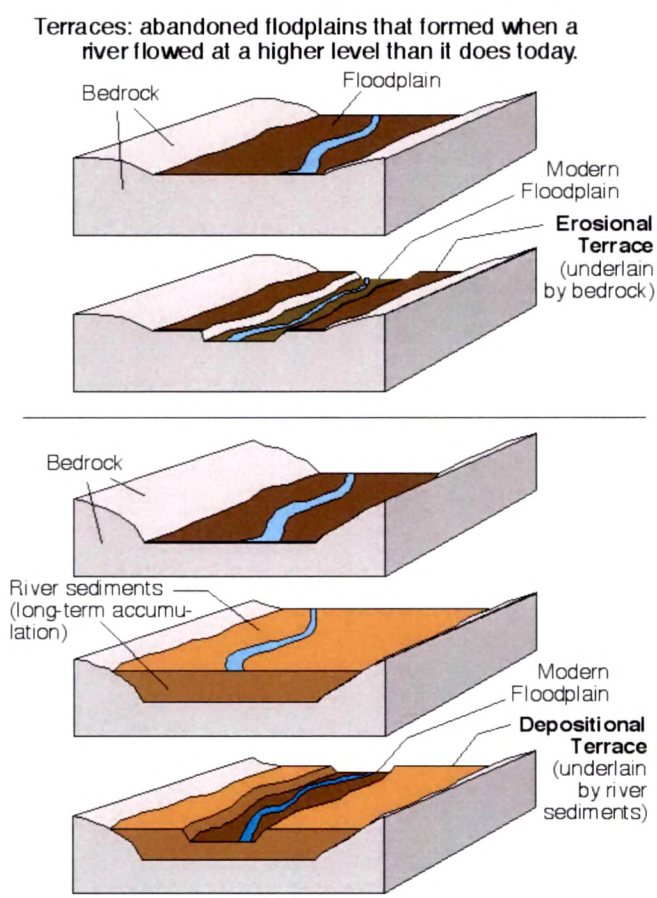

Plate 4.3: Erosional and depositional terrace

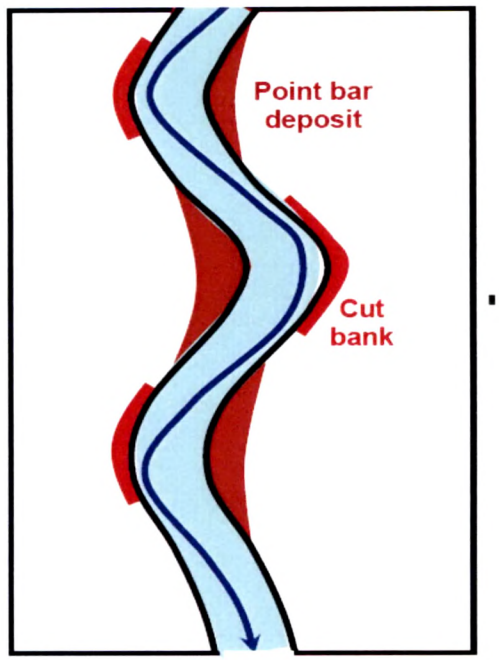

Plate 4.4: Point bar deposit

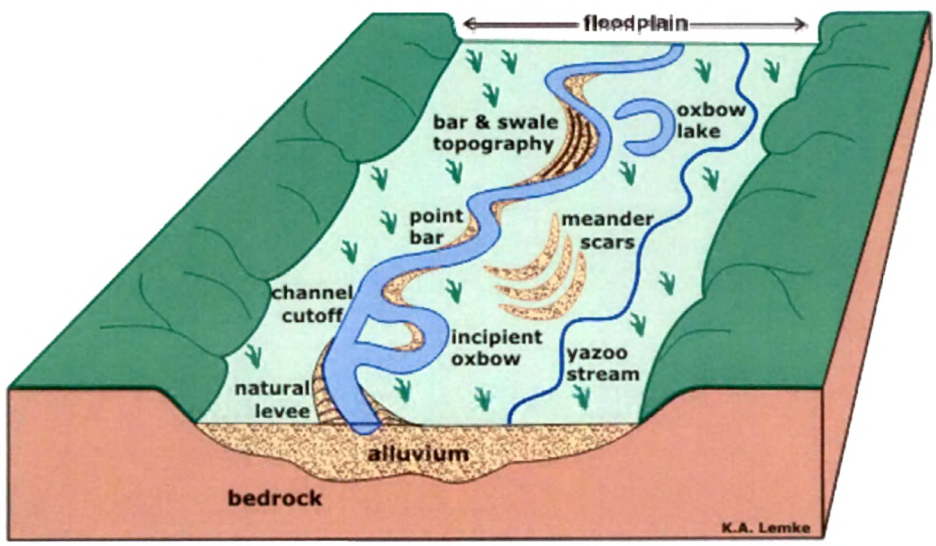

Plate 4.5: Figure showing few fluvial landforms

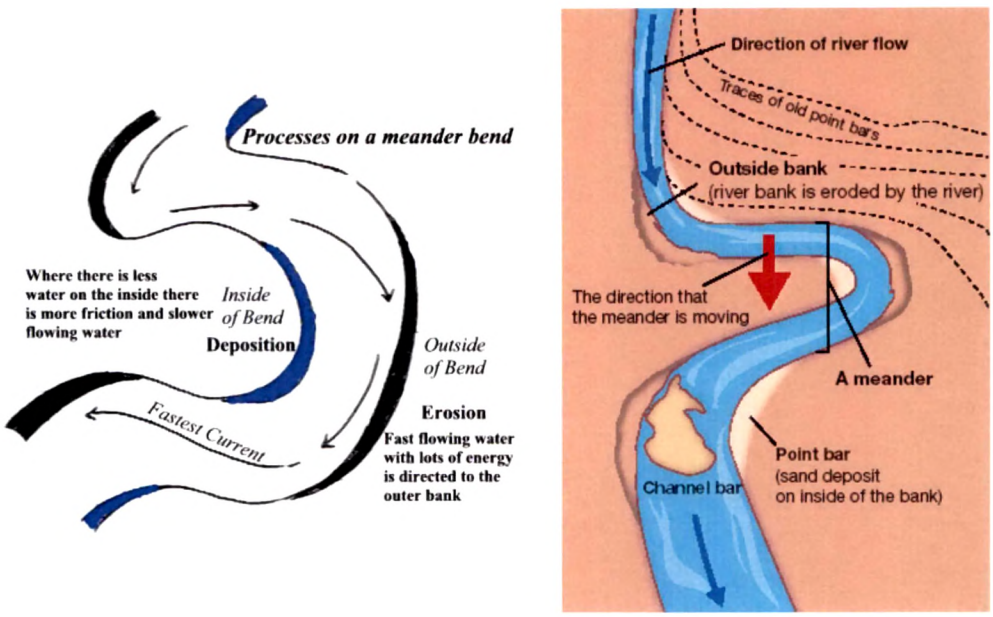

Plate 4.6: Formation of a meander

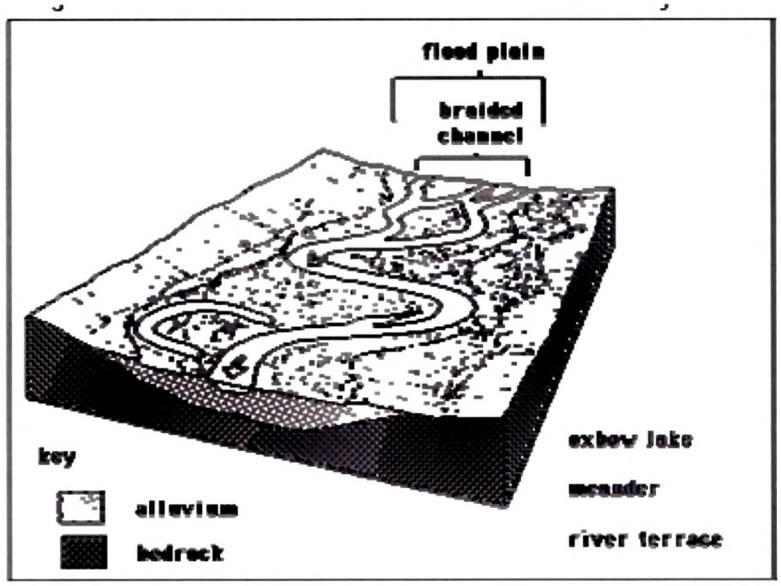

Plate 4.7: Braided pattern

4.5. Fluvial Processes

Fluvial Erosion:

Landforms associated with fluvial erosion are gorges, canyons, V-shaped valleys, steep hill slopes, waterfalls, pediments, river terraces, etc. Running water is capable of carrying out two types of processes erosion and corrosion which gives rise to different landscapes. Erosion is a hydraulic action derived from the energy of flowing water. Gravels, pebbles and similar other coarser and finer materials which are being carried by the running water erodes the channel and removes the sediments from the river bed, due to which slowly and gradually the channel becomes wider and deeper. This type of erosion is termed as lateral erosion and deepening erosion respectively. Now if deepening erosion predominates then that gives rise to a "canyon". Sometimes the flowing water undergoes a chemical reaction with the river bed rocks and dissolves them, and this process is called as corrosion which gradually gives rise to Karst topography or the Karst landforms which is mainly composed of calcareous limestone. In the same way deep V-shaped valleys and steep slopes are also a result of stream action as well as other processes such as weathering. The rocks composing the slopes gradually undergo weathering over a long period of time and become rock fragments which under the action of gravity along with heavy rainfall cause them to fall down into the valley bottom. This process results in downstream extension of the valley and retreat of the upper slopes. The material which is deposited in the valley bottom are scoured by the action of river water and carried to the lower reaches (Matsuda, 2004)[51]. Depending on the factors responsible for degradation, river bed degradation can occur downstream as well as upstream. The causes of downstream progressing degradation are primarily related to changes in independent river channel variables, such as increase in water discharge, decrease in size of bed material, and decrease in bed material

discharge. The causes of upstream progressing degradation are all related to an imposed increase in river slope which can occur as a result of natural river behavior or by man-made changes (Galay, 1983)[26].

Fluvial Transportation

Higher the water velocity higher will be the sediment transport capacity of the river. River transport their load in mainly four different ways traction, saltation, suspension and by solution. In the process of Saltation bigger rock material or boulders move as bed load material close to the channel floor either by sliding or rolling. Here it is important to note that the bed load always touches the floor whereas traction involves the transportation of pebbles, gravels, cobbles and boulders. The process of saltation involves transport through water currents whereby the coarse load moves downwards by the method of hopping or jumping and this is a very slow process whereas the finer and medium materials remain suspended in water due to the effect of buoyancy. This load is called as the suspended load and due to its finer grain size they are usually carried for a longer distance by the river water. Suspended materials cause turbidity of the stream water. In the corrosion or the solution process the stream water undergoes a chemical reaction with the rocks and creates a solution. The materials are dissolved and become invisible and since such materials are transported in solution, the mechanism is called transportation by solution (Singh, 2006)[87].

Fluvial Deposition

Depositional landforms are also termed as constructional landforms and they include alluvial fans and cones, natural levees, flood plains, sand-bars, deltas etc. Deposition of the load carried by the stream can be effected due to various reasons such as decrease in the channel gradient, spreading of stream water over larger area, obstruction in channel flow, decrease in the volume and discharge of water, decrease in

the stream velocity, increase in the sediment load etc. Floods carry huge volume of sediment load from hills to the plains and as they do so during the transport process since the carrying capacity greatly reduces from hills to plain regions, the sediment gradually gets deposited relative to the order of their size giving rise to alluvial fans. Alluvial fans and cones are formed due to the accumulation of gravels size materials at the base of the foothills where there is a sudden decrease in the gradient and also in the transport capacity of the streams due to the decrease in the velocity of the flowing water. Thus at the base finer to coarser as well as bigger grained size material accumulate and get deposited. Sorting of material is observed in alluvial fans (Singh, 2006)[87]. The streams flowing through alluvial fan are generally interconnected giving rise to a braided channel. During heavy flood episodes the channels flowing through an alluvial fan often change their course giving rise to a new channel. The former channel in such cases becomes an abandoned river channel which gets water only through ground water. Now if the channel is rejuvenated, the channel gradually begins to deepen and a gorge is formed in the alluvial plain. Due to this the surface of the former alluvial plain becomes higher then the river bed and the river water no more flows into it. Here the former alluvial plain forms the river terrace (Matsuda, 2004). In the same way a delta is formed near the mouth of a river which is composed of fine materials and sand. A delta is formed due to the combined interaction of fluvial and marine processes. Natural levees are composed of sand and silt. They are arcuate low ridges of sand formed due to the deposition of sediments during heavy flood episodes when the water overtops the river banks and spreads over the adjoining flood-plains. Because of this long, low ridges of sand are formed which are parallel to the river valleys.