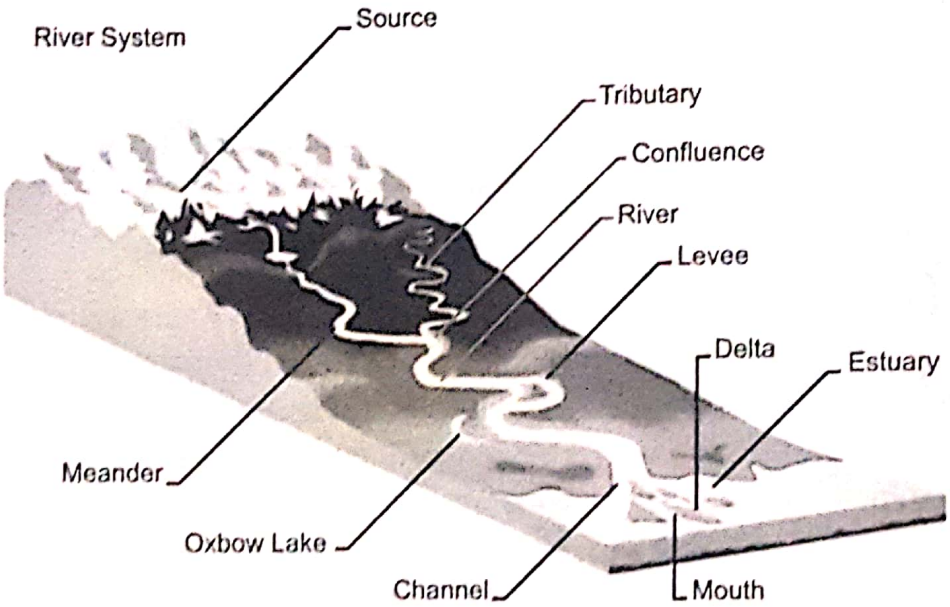
# RIVERS /FLUVIAL LANDFORMS

A *stream* is a body of water that carries rock particles and dissolved ions and flows down slope along a clearly defined path, called a *channel*. Thus, streams may vary in width from a few centimetres to several kilometres.




## STREAM STAGES

Geologists characterize streams as youthful, mature, and old:

A **youthful stream** has a fairly straight channel and a steep gradient. It generally flows in a V-shaped valley in a highland or mountainous area with little shifting of its channel. Its velocity is high, and it is actively lowering its channel through down cutting in order to reach base level. In this stage, a stream has little, if any, floodplain.

A stream in its **mature stage** has a moderate gradient and velocity because it has eroded its bed downward and is closer to base level. Since it has slowed down, the stream begins to meander. While it is still eroding downward, the stream's main force of erosion is lateral (horizontal) as it begins winding back and forth, carving out a valley floor between valley walls or bluffs. Periodically, the stream will flood all or a part of its valley, depositing alluvium on its developing floodplain.

**An old age stream** has nearly reached its base level, and its gradient and velocity are very low. Because its velocity is low, it has lost its ability to erode downward. In fact, it deposits as much material as it erodes. The stream meanders greatly in its nearly flat valley. It has a wide, well-developed floodplain marked with oxbow lakes.

Source Distance Mouth

# EROSIONAL LANDFORMS

- **GORGES**

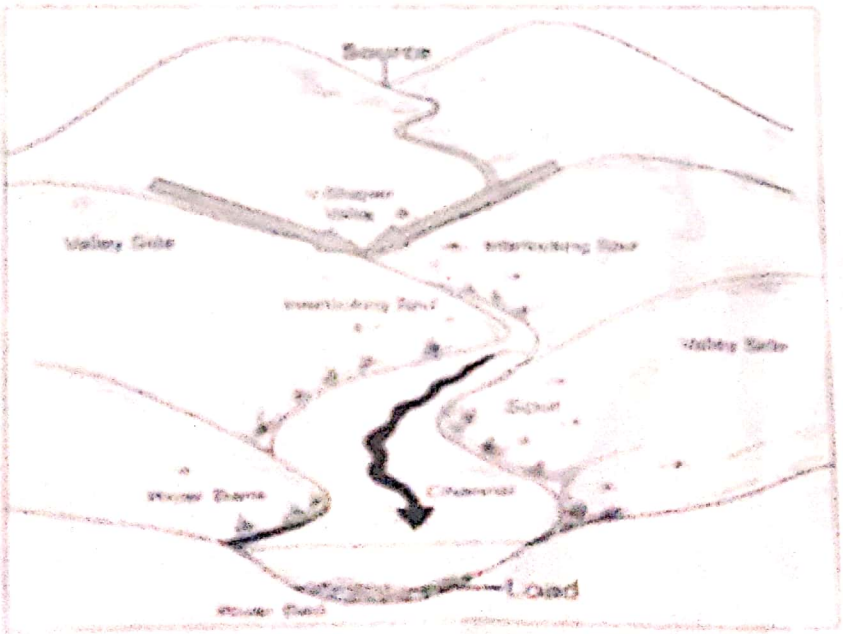
When a river passes through hard rocks in mountainous area, down-cutting takes place so rapidly that lateral corrasion cannot keep pace. This results in the formation of a deep and narrow valley known as gorge. The Sutlej and the Indus have cut deep gorges in their upper course.

- **CANYONS**

This is an enlarged form of a gorge and is found in dry highlands. The best example of a gorge is that of Colorado in USA.

- **V-SHAPED VALLEYS**

V-Shaped valleys are found in the upper course of the river and are a result of both erosion by the river and weathering. V-Shaped valleys are deep river valleys with steep sides that look like a letter V when a cross section of them is taken, hence the name.



- **POTHOLES**

One interesting form produced by river abrasion is the pothole, a cylindrical hole carved into the hard bedrock of a swiftly moving river. They're found in the upper course of a river where it has enough potential energy to erode vertically and its flow is turbulent. Pebbles which are trapped in hollows on the river bed are swirled about in turbulence. Potholes range in diameter from a few inches to several feet; the larger ones may be many feet deep. Pebbles will only be able to erode a river's bed though if the rock the pebble's made of is stronger than the rock the river bed is made of.

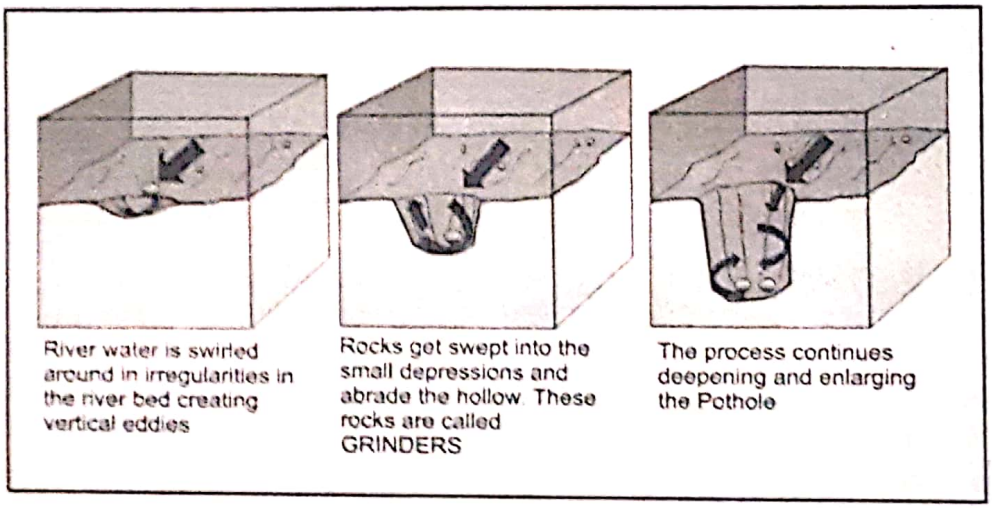



**Figure: Creation of potholes**

- **INTERLOCKING SPURS**

As the river erodes the landscape in the upper course, it winds and bends to avoid areas of hard rock. This creates **interlocking spurs**, which look a bit like the interlocking parts of a zip. In this upper stage the river erodes vertically rather than laterally.

- **WATERFALLS**

A waterfall is the steep descent of a river over a rocky ledge. The descent is so fast that the water, together with the rock debris it carries, quickly wears off the rocks at the base. Further processes of abrasion and corrosion create a plunge pool strewn with boulders and pebbles.

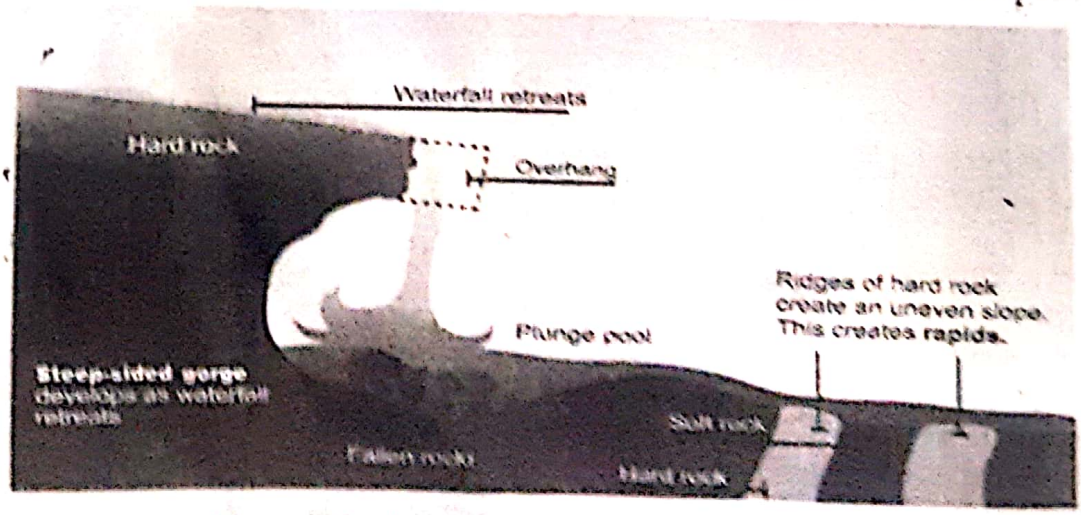



**Figure: The formation of waterfalls and rapids**

There are many ways in which a waterfall may be formed:

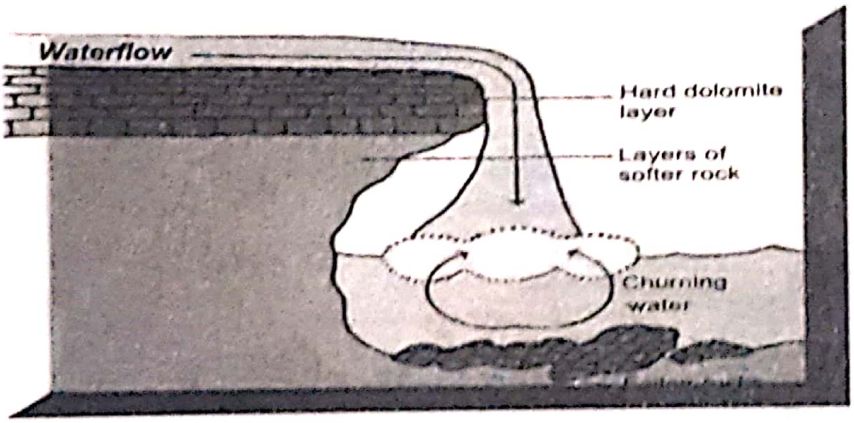
i. When a bar of more resistant rock lies transversely across a river valley, e.g. Niagara Falls on the USA, Canada border.

ii. When a river plunges down the edge of a plateau, e.g. Livingstone Falls in Zaire, Africa.

iii. When a stream plunges down a hanging valley in a glaciated upland area, e.g. Yosemite Falls in Yosemite National Park, USA.

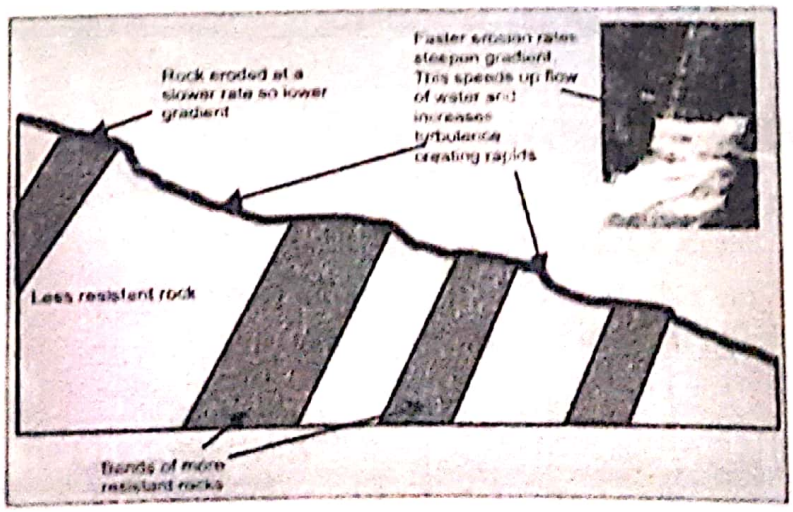
- **PLUNGE POOLS**

At the foot of waterfalls 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. Plunge pool is further deepened by hydraulic action of the plunging water.




- **RAPIDS**

i. When a river flows through an area of alternating strata of hard and soft rock, the softer rocks are worn out faster, giving rise to a sudden change in gradient, where the water tumbles over the rock ledges as cataracts or rapids.



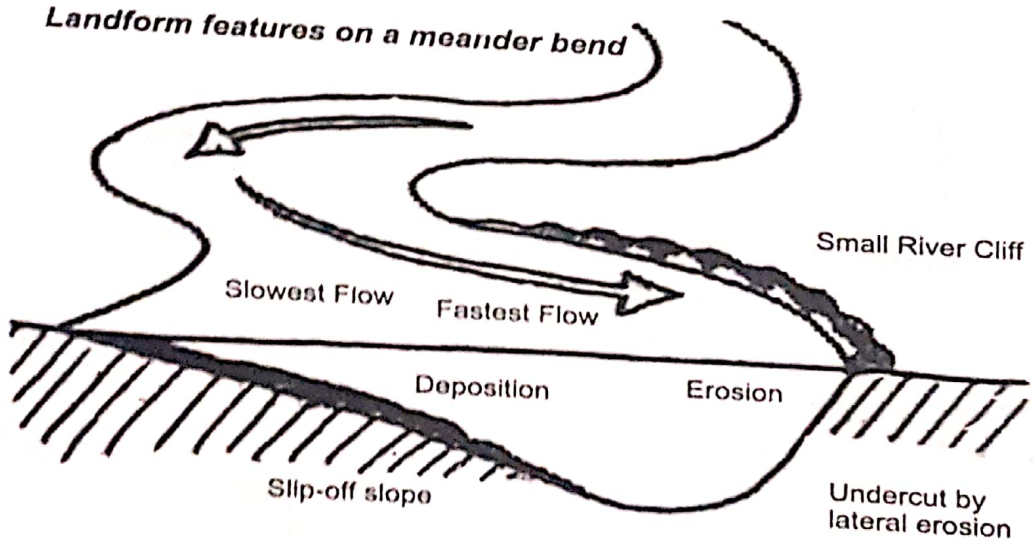

ii. Some rapids may occur as a series of steps in midstream where the fast flowing water has to make a quick descent. This interrupts smooth navigation by boats along the river.

iii. Rapids are also called series of little waterfalls. Due to the roughness of the channel, flow is turbulent and known as white water.

- **MEANDERS**

These are bends in the river. Lateral erosion of the river channel results in the river forming a winding pattern.

- As the river erodes laterally, to the right side then the left side, it forms large bends, and then horseshoe-like loops called **meanders**.
- The formation of meanders is due to both deposition and erosion and meanders gradually migrate downstream.
- The force of the water **erodes** and undercuts the river bank on the **outside** of the bend where water flow has most energy due to decreased friction.
- On the **inside** of the bend, where the river flow is slower, material is **deposited**, as there is more friction.
- Over time the horseshoe become tighter, until the ends become very close together. As the river breaks through, e.g. during a flood when the river has a higher discharge and more energy, and the ends join, the loop is cut-off from the main channel. The cut-off loop is called an **oxbow lake**.




## DEPOSITIONAL LANDFORMS OF RIVER

- **FLOODPLAINS AND LEVEES**

A floodplain is the area around a river that is covered in times of flood. A floodplain is a very fertile area due to the rich *alluvium*, sediment deposited by rivers. This makes floodplains a good place for agriculture. A build up of alluvium on the banks of a river can create levees, ridges formed by deposits of alluvium left behind by the periodic flooding of rivers, which raise the river bank.

Because of the sudden decrease in velocity, the coarser grained suspended sediment will be deposited along the riverbank, eventually building up a natural levee. Natural levees provide some protection from flooding because with each flood, the levee is built higher and therefore discharge must be higher for the next flood to occur.

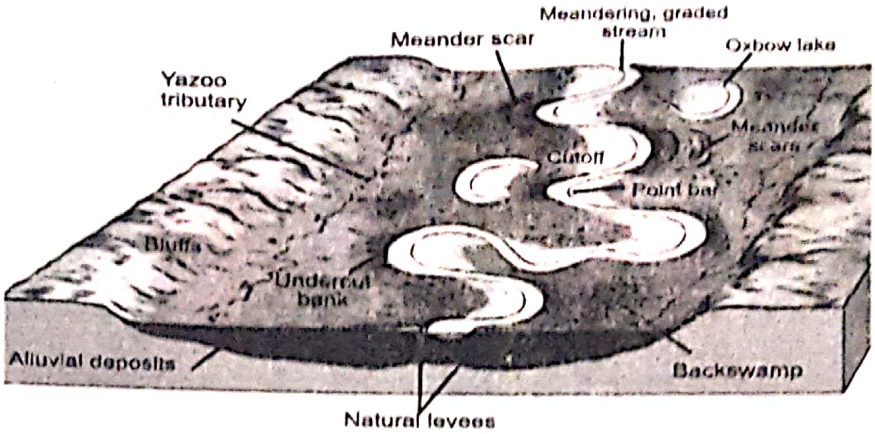
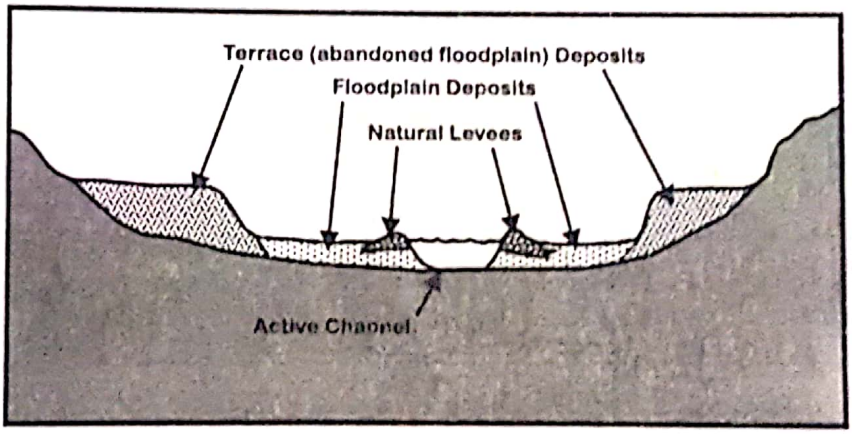



**Figure: Mature River Floodplain and its Components**

- **TERRACES**

Terraces are exposed former floodplain deposits that result when the stream begins down cutting into its flood plain (this is usually caused by regional uplift or by lowering the regional base level).




- **ALLUVIAL CONES AND ALLUVIAL FANS**

The sudden decrease in velocity of the river entering in a plain area, after leaving a hilly area, results in abrupt reduction in its capacity of carrying and transporting load. Hence the river deposits much of its sediments at the foothill to form alluvial cones. The river divides the alluvial cones into many channels and forms alluvial fans. Which is a fan shaped mass of sand and gravel with its apex pointing upstream and its fan formation downstream.

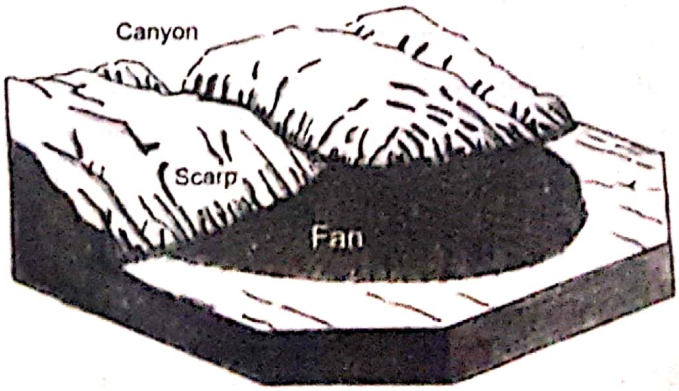
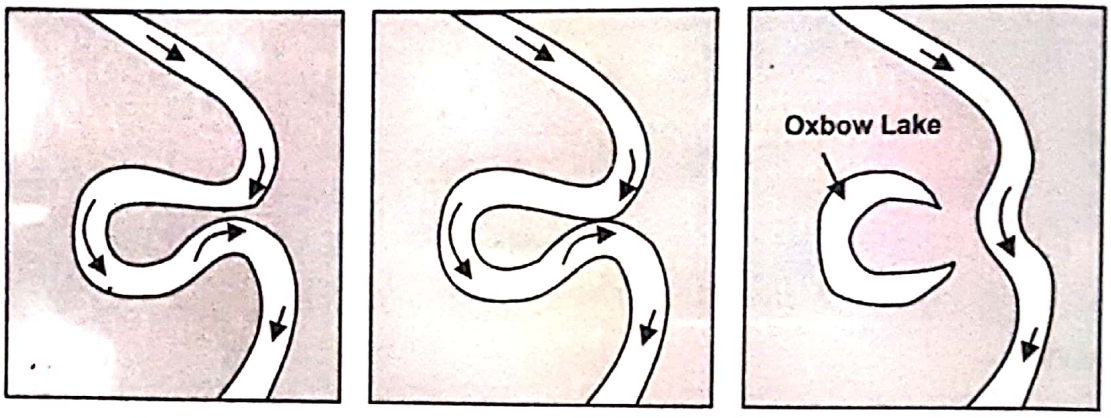



**Figure: A simple alluvial fan**

- **OX-BOW LAKES**

This is a truncated (cut off) section of a meander in the river channel which forms a 'c' shape. This is formed by the loops in a meander eroding the flood plain until eventually the loop in the meander is left cut off from the main river channel.

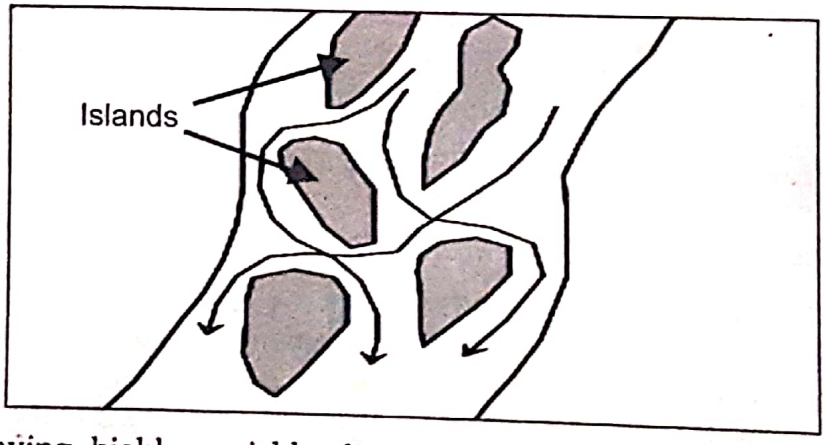



If erosion on the outside meander bends continues to take place, eventually a meander bend can become cut off from the rest of the stream. When this occurs, the cut-off meander bend because it is still a depression, will collect water and form a type of lake called an *oxbow lake*.

- **BRAIDED CHANNELS**

A braided channel is a type of channel that is divided into smaller sub-channels by small, temporary islands called eyots.

Braided Channel




In streams having highly variable discharge and easily-eroded banks, sediment gets deposited to form bars and islands that are exposed during periods of low discharge. In such a stream, the water flows in a braided pattern around the islands and bars, dividing and reuniting as it flows downstream. Such a channel is termed a braided channel. During periods of high discharge, the entire stream channel may contain water and the islands are covered to become submerged bars. During such high discharge, some of the islands could erode, but the sediment would be re-deposited as the discharge decreases, forming new islands or submerged bars. Islands may become resistant to erosion if they become inhabited by vegetation.

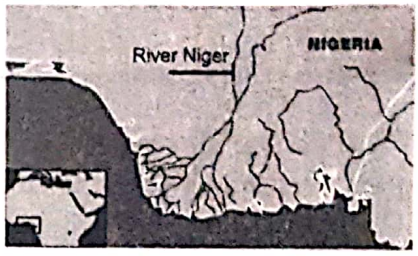
- **DELTAS**

When a stream enters a standing body of water such as a lake or ocean, again there is a sudden decrease in velocity and the stream deposits its sediment in a deposit called a delta.

Deltas build outward from the coastline, but will only survive if the ocean currents are not strong enough to remove the sediment. As the velocity of a stream decreases on entering the delta, the stream becomes choked with sediment and conditions become favourable to those of a braided stream channel, but instead of braiding, the stream breaks into many smaller streams called distributary streams.

Deltas are found at the mouth of large rivers - for example, the Mississippi. There are three main types of delta, named after the shape they create:

## THREE MAIN TYPES OF DELTA

| Type of delta | Example |
|---|---|
| **Arcuate or fan-shaped** - the land around the river mouth arches out into the sea and the river splits many times on the way to the sea, creating a fan effect.<br>Example: River Niger Delta |  <br>Figure: The Niger Delta(Egypt) |
| **Cuspate** - the land around the mouth of the river juts out arrow-like into the sea.<br>Example: Ebro River delta Spain. |  <br>Figure: The Ebro Delta(Spain) |
| **Bird's foot** - the river splits on the way to the sea, each part of the river juts out into the sea, rather like a bird's foot.<br>Mississippi USA. |  <br>Figure: The Mississippi Delta(USA) |

## EXPECTED QUESTIONS

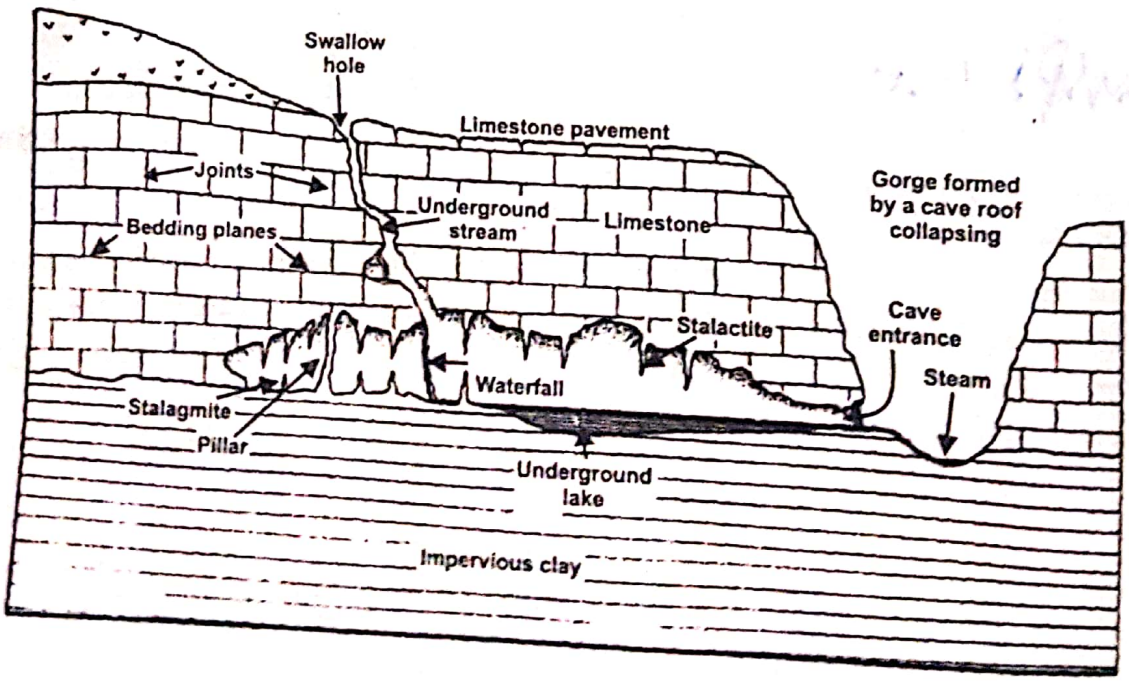
1. Discuss the depositional landforms shaped by a river and describe their importance.
2. Discuss the chief landforms resulting from river erosion and deposition in humid regions.
3. Outline the processes by which a river produces various land features describing its mode of transportation.
4. Write in detail on the action of the river in its youth, maturity and old age.

# KARST LANDFORMS/ LANDFORMS MADE BY UNDER GROUND WATER/ LANDFORMS OF LIMESTONE REGION

Karst is a German name for an unusual and distinct limestone terrain in Slovenia, called Kras. The karst region in Slovenia, located just north of the Adriatic Sea, is an area of barren, white, fretted rock. The main feature of a karst region is the absence of surface water flow. Rainfall and surface waters (streams, for example) disappear into a drainage system produced in karst areas. Another feature is the lack of topsoil or vegetation. In geology, the term karst topography is used to describe areas similar to that found in Kras. The most remarkable feature of karst regions is the formation of caves.

## CHEMISTRY OF KARST LANDSCAPES

Karst landforms are generally the result of mildly acidic water acting on soluble bedrock such as limestone or dolostone. The carbonic acid that causes these features is formed as rain passes through the atmosphere picking up $CO_2$, which dissolves in the water. Once the rain reaches the ground, it may pass through soil that may provide further $CO_2$ to form a weak carbonic acid solution: $H_2O + CO_2 \rightarrow H_2CO_3$. Recent studies of sulphates in karst waters suggest sulphuric and hydrosulfuric acids may also play an important role in karst formation.

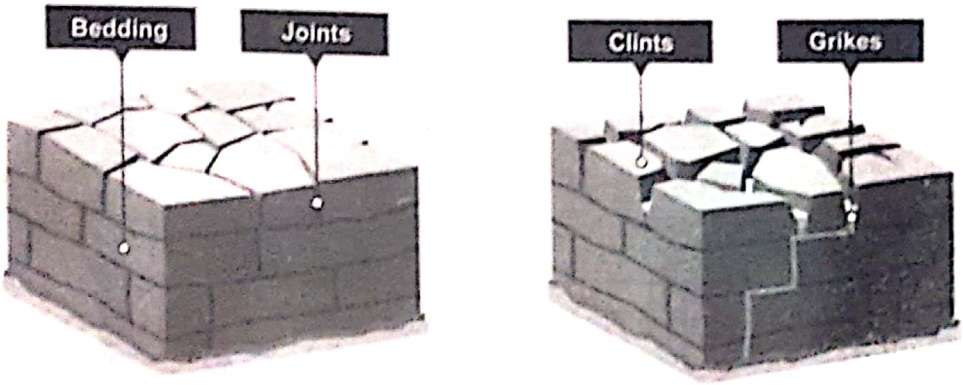


This mildly acidic water begins to dissolve the surface and any fractures or bedding planes in the limestone bedrock. Over time, these fractures enlarge as the bedrock continues to dissolve. Openings in the rock increase in size, and an underground drainage system begins to develop, allowing more water to pass through and accelerating the formation of underground karst features.

## EROSIONAL / DEGRADATIONAL LANDFORMS

### 1. CLINTS AND GRIKES

Due to the solubility of limestone, limestone pavements are associated with some very curious and unusual landforms.




The most characteristic surface feature of limestone pavements is their division into blocks, called clints, bounded by deep vertical fissures known as grikes. Clints and grikes form under relatively deep cover of soil where water, carrying carbonic acid which is formed from dissolved carbon dioxide as well as organic acids from decaying vegetation, picks out vertical lines of weakness (joints) in the rock. These fissures widen over the years as the acidic water preferentially attacks the lines of weakness.

### 2. LAPIES

As rainwater mixed with $CO_2$ proceeds over a region of limestone rock, it begins to dissolve certain portions of the rock. The system of joints is widened by solution and the surface is fretted and fluted. This is known as Lapies in French, Karrens in German and Bogaz in the Serbian language.

### 3. SINKHOLES AND SWALLOW HOLES

Gradually, lapies are further widened to form sink holes and swallow holes, through which surface streams disappear, and begin to flow beneath the ground. Sinkholes form where rock has been removed by dissolution, forming an underground void. Where these underground voids have collapsed, a closed depression, or sinkhole, is formed at the surface. The density of sinkholes in some karst regions may reach hundreds per square mile.

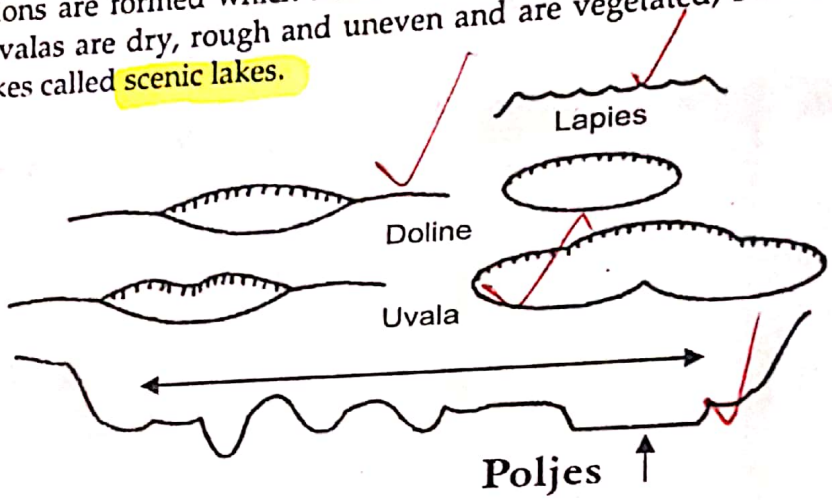
Cylindrical structure below sink hole is called swallow hole. The surface stream that often sinks suddenly disappears through swallow hole, because these holes are linked with underground lakes.

### 4. DOLINES

If the dissolution is very intense, the sink holes may become very wide and such wide and deep funnel-shaped sink holes are called Dolines. The typical doline is found in the Karst Region along the Adriatic Sea and its characteristic feature is a funnel-shaped top, the diameter being thirty to hundreds of feet.

### 5. UVALAS

Due to the collapse of cavern roofs and coalescence of dolines and swallow holes, often very vast depressions are formed which are known as Uvalas. They can reach even 1.5 Km in diameter. Some Uvalas are dry, rough and uneven and are vegetated, but some are filled with water and form lakes called scenic lakes.




### 6. POLJES

Poljes are elongated basin having a flat floor and steep walls; it is formed by the coalescence of several sinkholes. The basins often cover 250 square km (about 100 square miles) and may expose "disappearing streams." Most such basins have steep enclosing walls that range from 50 to 100 m (165 to 330 feet) in height, giving rise to the name "blind valley." The flat floor of a polje is characteristically covered with a soil composed of the residues of limestone solution. These areas may constitute the only arable part of the rock wasteland in a karst region.

### 7. LIMESTONE CAVERNS

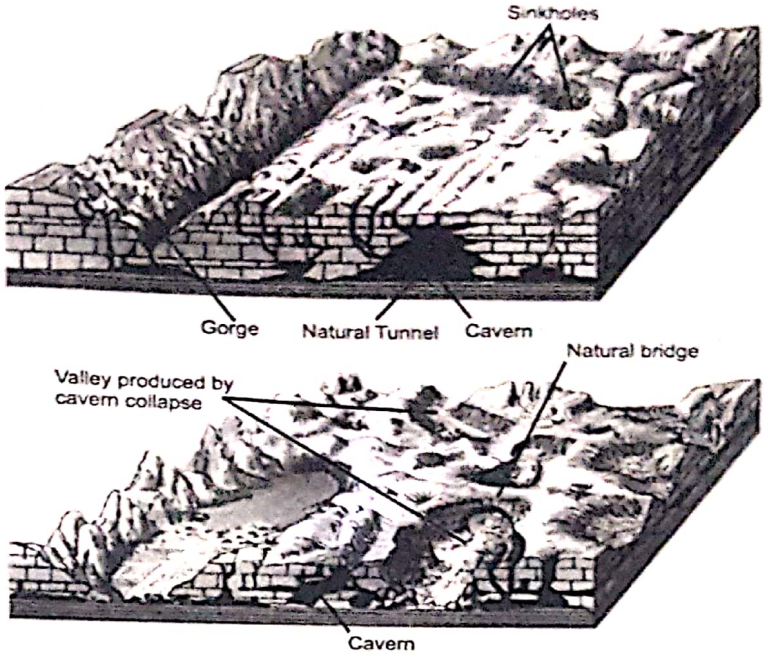
Among the most spectacular results of groundwater's erosional handiwork is the creation of limestone caverns. Most are relatively small, yet some have spectacular dimensions. In the United States, Carlsbad Caverns in south-eastern New Mexico and Mammoth Cave in Kentucky are famous examples.

### 8. NATURAL BRIDGE

Beneath the surface of the earth, the underground drainage is able to dissolve out very long and wide caverns. Sometimes, roofs of such caverns are in caved, and rock bridges may be formed. These are known as natural bridges and are circular in outlines.

### 9. NATURAL TUNNELS

When a considerable portion of the roof of the tunnel is retained over the valleys (originally cavern), it is called a Natural Tunnel.




### 10. KARST GULF

The collapse of a cavern over a large area can create a feature referred to as a solution valley or basin, sometimes referred to as a **karst gulf,** which from the air resembles a huge sinkhole. These depressions may reach hundreds of metres across and may contain numerous smaller, local sinkholes.

### 11. KARST TOWERS

Continued dissolution of rock leads to a mature karst, where pinnacles of limestone protrude above a relatively flat plane. This type of topography is called tower karst, after the characteristic steep-sided limestone remnants.

### 12. HUMS

In the midst of Uvalas and Poljes, residual masses of limestone rise here and there. These are known as Hums.

### 13. GORGES

When the roof of cave collapses, narrow, steep sided valley also called gorges, are formed. The collapse of a cave roof is only one way in which gorges may be formed.

## DEPOSITIONAL/ AGGRADATIONAL LANDFORMS ASSOCIATED WITH GROUNDWATER

Depositional work by the groundwater goes on in the caverns.

### DRIP STONES

The features that arouse the greatest curiosity for most cavern visitors are the stone formations that often exhibit quite bizarre patterns and give some caverns a wonderland appearance. These features are created by seemingly endless dripping of water over great spans of time. The calcite, which is left behind, produces the lime stone we call Travertine. These cave deposits, however, are also commonly called drip stones, an obvious reference to their mode of origin.

## Stalactite

Of the various drip stone features found in caverns, perhaps the more familiar are stalactites. These icicles-like (ice cube like) pendants hang from the ceiling of the cavern and from where water seeps through crater above. The water containing limestone drops from the roof of the cavern. As the water evaporates, it leaves behind solidified calcium carbonate ($CaCO_3$). The stalactites are sharp, slender, downward growing pinnacles that hang from the cave roof. They look like a set of concentric rings of $CaCO_3$ placed over one another with the broadest one at the roof and the narrowest being at the downward extremity.

## Stalagmites

The drops of water that fall on the floor of the cavern after trickling down the roof still contain some lime which is left behind on the floor after the water has evaporated. Thus on the same lines as a stalactite, a pillar begins to rise upwards from the floor.

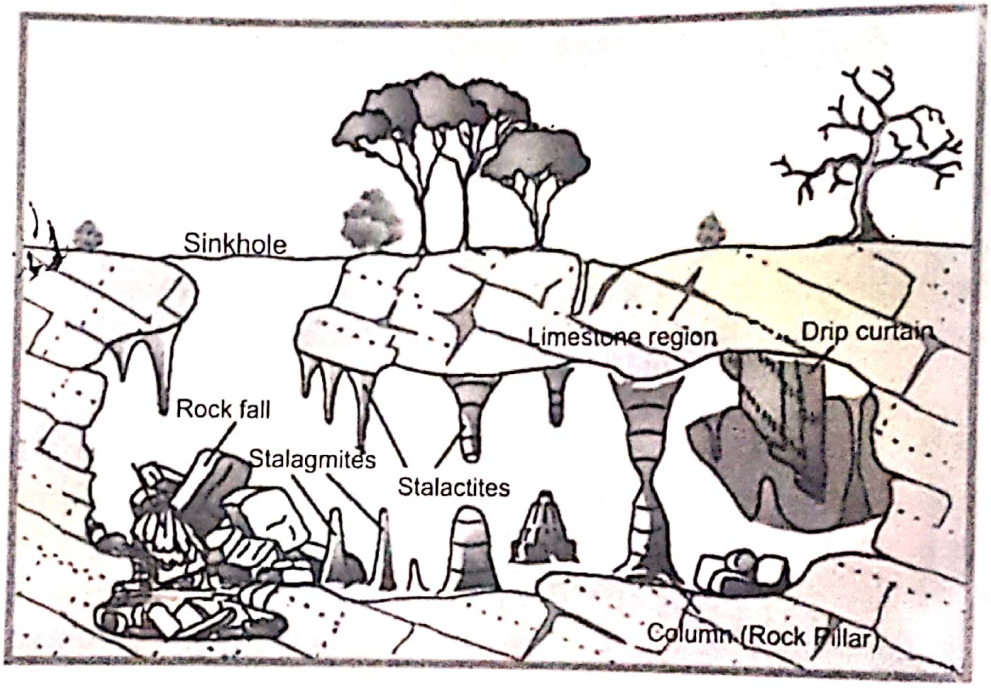



**Figure: Stalactites and stalagmites in a limestone cave**

This is known as stalagmite. It is conical in shape and comparatively thicker. Because the drops, as they fall down the roof, are scattered away, the stalagmite is blunt and irregular in form but at its top it has generally a crater-like depression.

## Rock Pillars / Column

Over a long period, the stalactite hanging from the roof is eventually joined to the stalagmite growing from the floor to form a cavern pillar or rock pillar. It is known as column.

## DRAPES OR CURTAINS

Drapes or curtains are numerous needle shaped dripstones hanging from the cave ceiling.

KARST CYCLE