Fluvial Landforms & Processes

- River Systems and Fluvial Landforms
- Longitudinal Profile and Equilibrium
- Drainage Basins, classic patterns
- Lakes and Dams
- Mountain Streams
- Straight Rivers
- Braided Rivers
- Meandering Rivers
- Anabranching Rivers
- Gulleys
- River Terraces
- Waterfalls
- Flood plains
- Alluvial Fans

Photo: SCGS

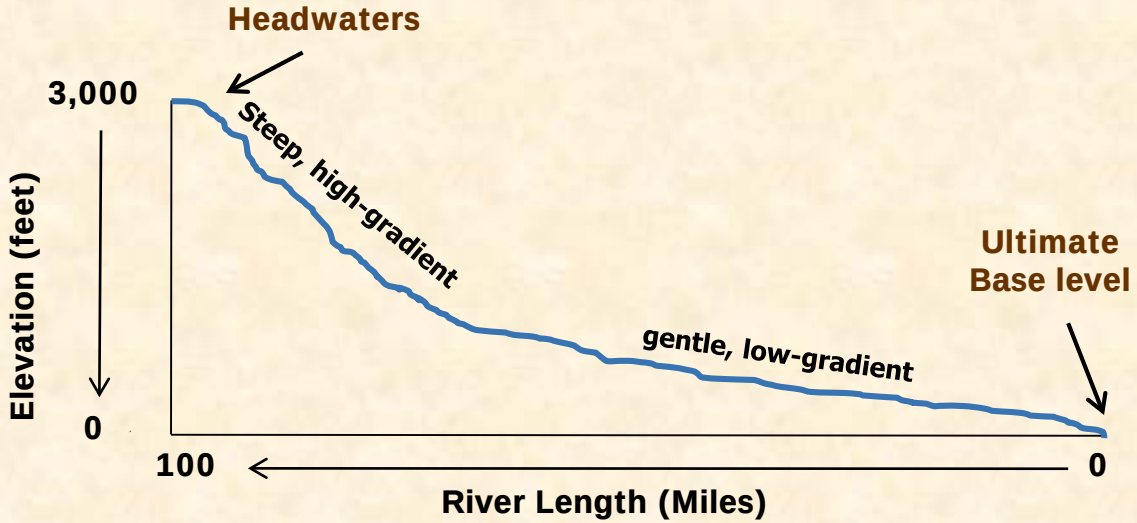
Fluvial Landforms & Processes

- Rivers are one of the most dominant agents of landscape change
- Flowing waters are continually eroding, transporting, and depositing sediments (**Fluvial Processes**).
- River based flooding is among one of the most frequent and widespread natural hazards.




Longitudinal Profile and Watersheds

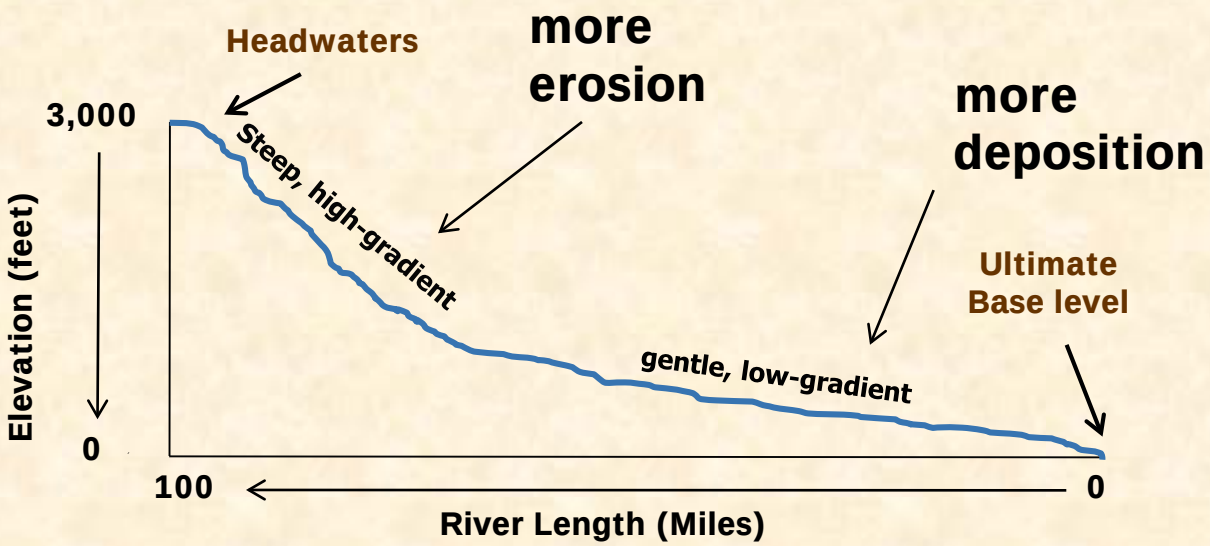
- **longitudinal profile:** an elevation cross-section of the entire watershed from the source of flowing water to the mouth of the stream.
- **headwaters**: the highest elevation where water collects to form a stream network.
- **base level**: the lowest elevation that a stream can erode its channel. Local or temporary base levels may be formed by reservoirs or waterfalls.



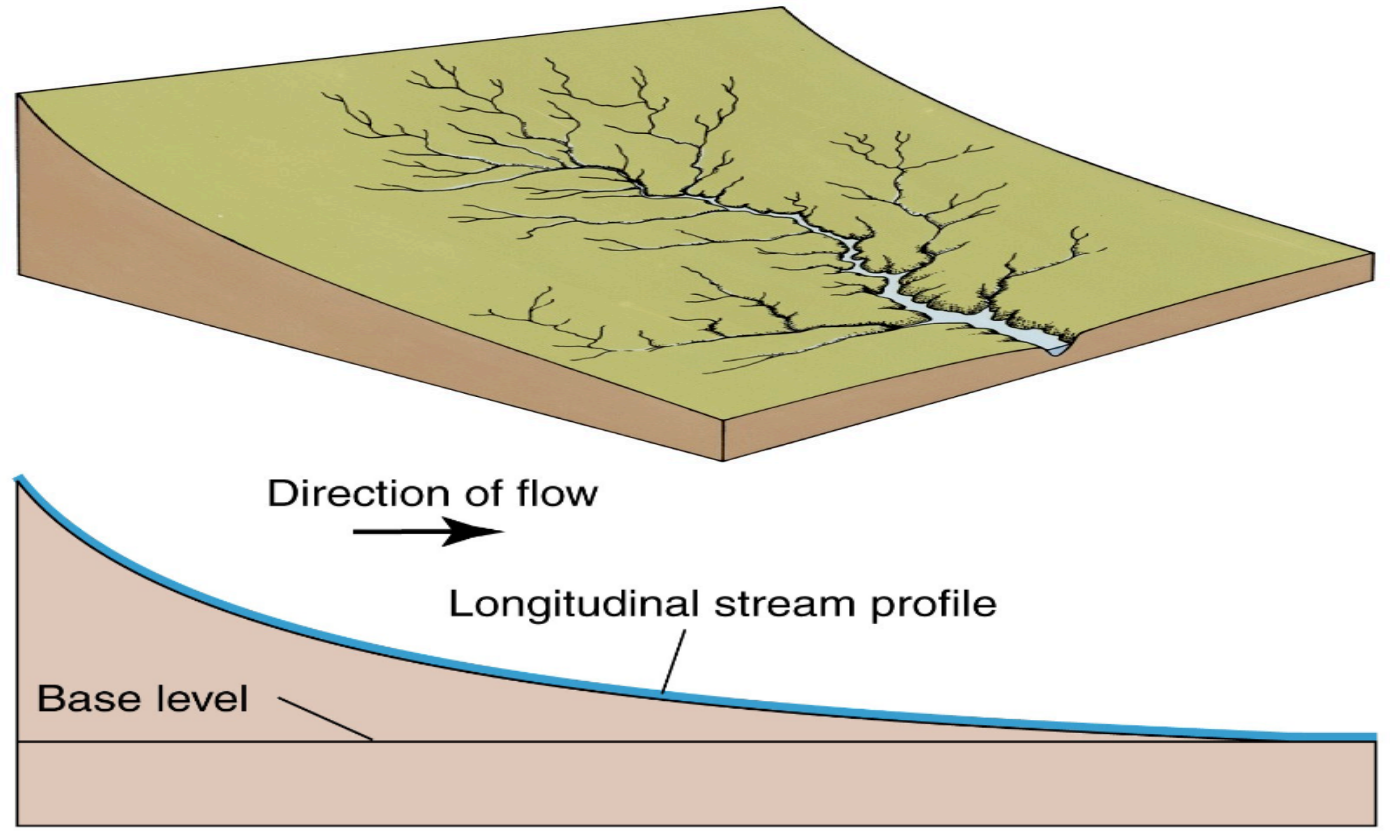
Longitudinal Profile and Watersheds

- A river's gradient (slope) is **steepest near the headwaters** and gentlest near the mouth.

- As rivers flow from their headwaters to their base level they carve valleys into the landscape by eroding, transporting, and depositing weathered rocks, soil, and sediment.

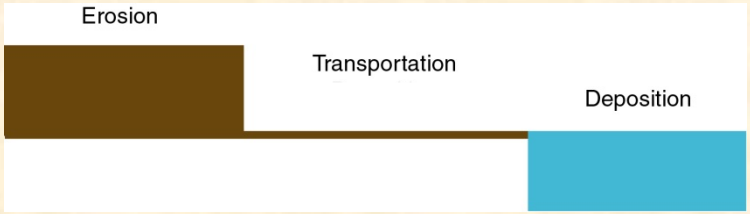


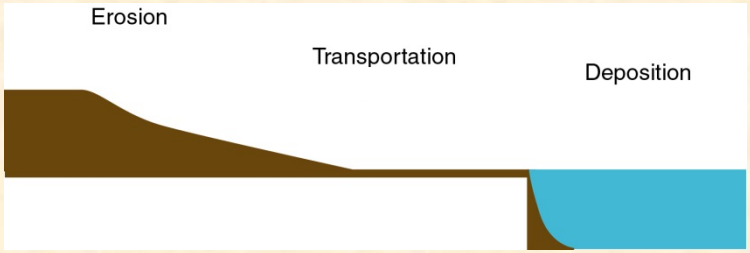
Fluvial Equilibrium

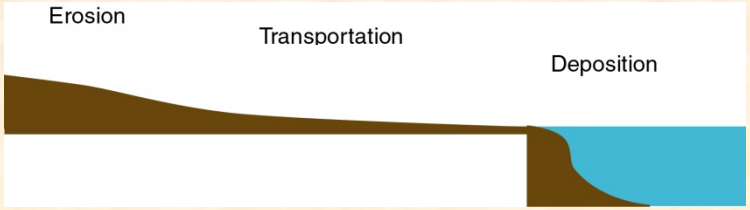


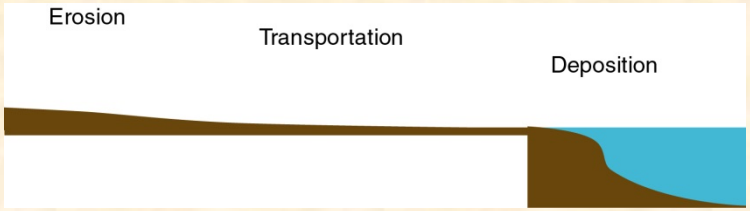
- **Stream gradient is related to water velocity and sediment load**
- **A change in any of these affects the other two.**
- **base level fluctuations (gradient)**
- **precipitation changes (discharge)**
- **sediment character**

Fluvial Equilibrium









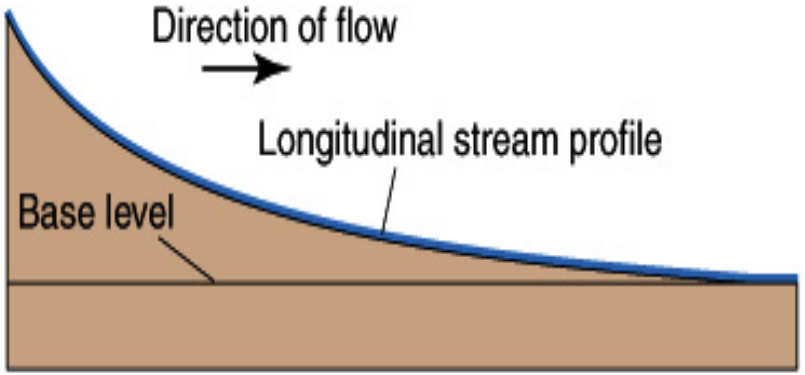
Recent uplift in excess of erosional rates results in a system that is out of equilibrium.

Weathering and erosion dominate headland areas with removed material being transported to a depositional basin.

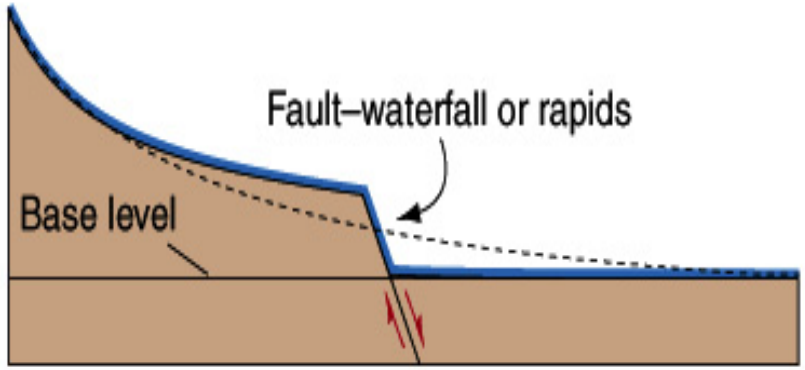
As headlands recede, both erosional and depositional rates decrease.

If the region remains stable for an extended period, equilibrium, where erosional and depositional rates are equal, might be achieved: Graded Stream.

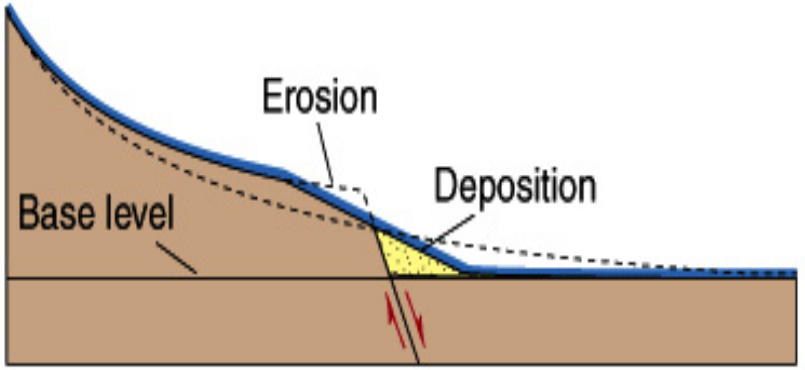
Fluvial Equilibrium



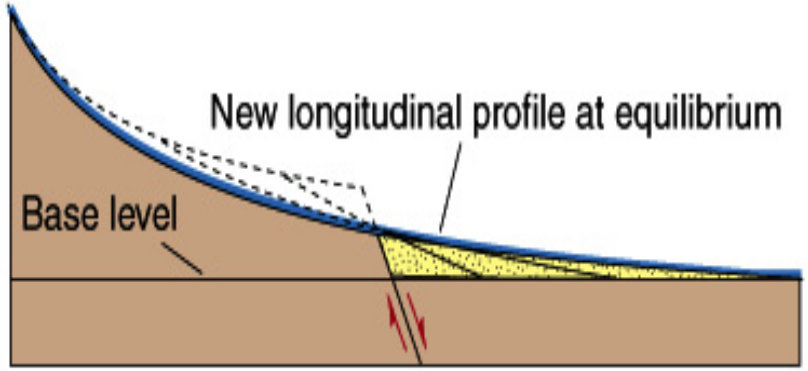
(A) Initially, when the stream profile is at equilibrium, the velocity, load, gradient, and volume of water are in balance. Neither erosion nor deposition occurs.



(B) Faulting disrupts equilibrium by decreasing the gradient downstream and increasing the gradient at the fault line.



(C) Erosion proceeds upstream from the fault, and deposition occurs downstream and a new stream profile starts to develop.

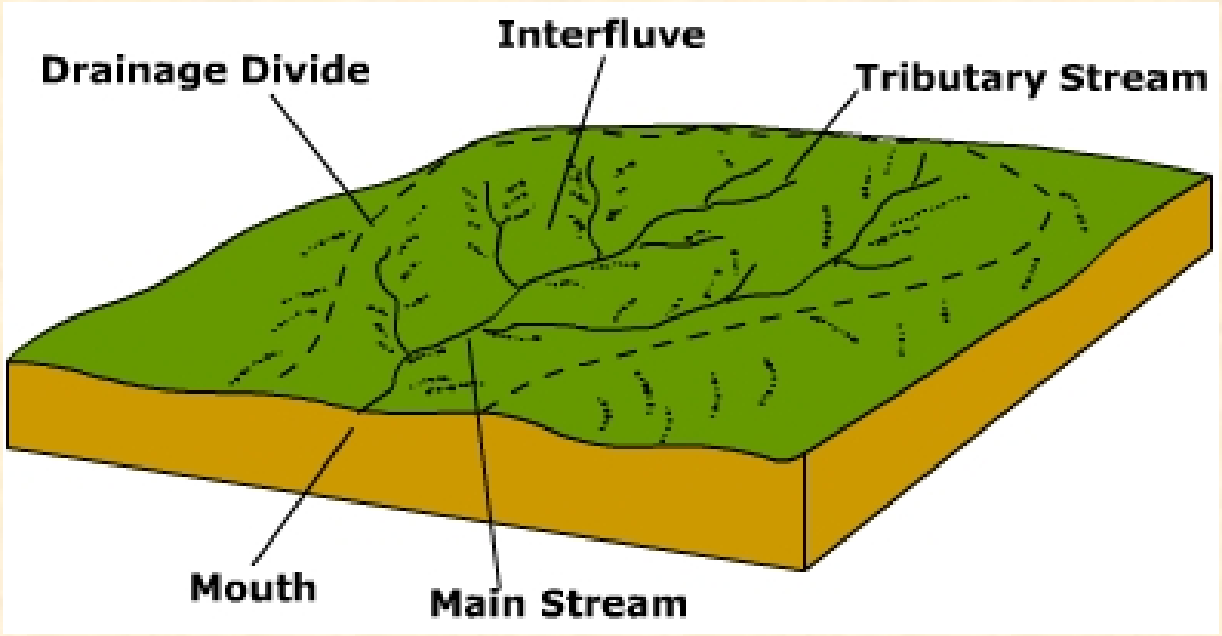


(D) Erosion and deposition eventually develop a new stream profile at which the velocity, load, gradient, and volume of water will be in balance so that neither erosion nor deposition occurs.

Longitudinal Profile and Watersheds

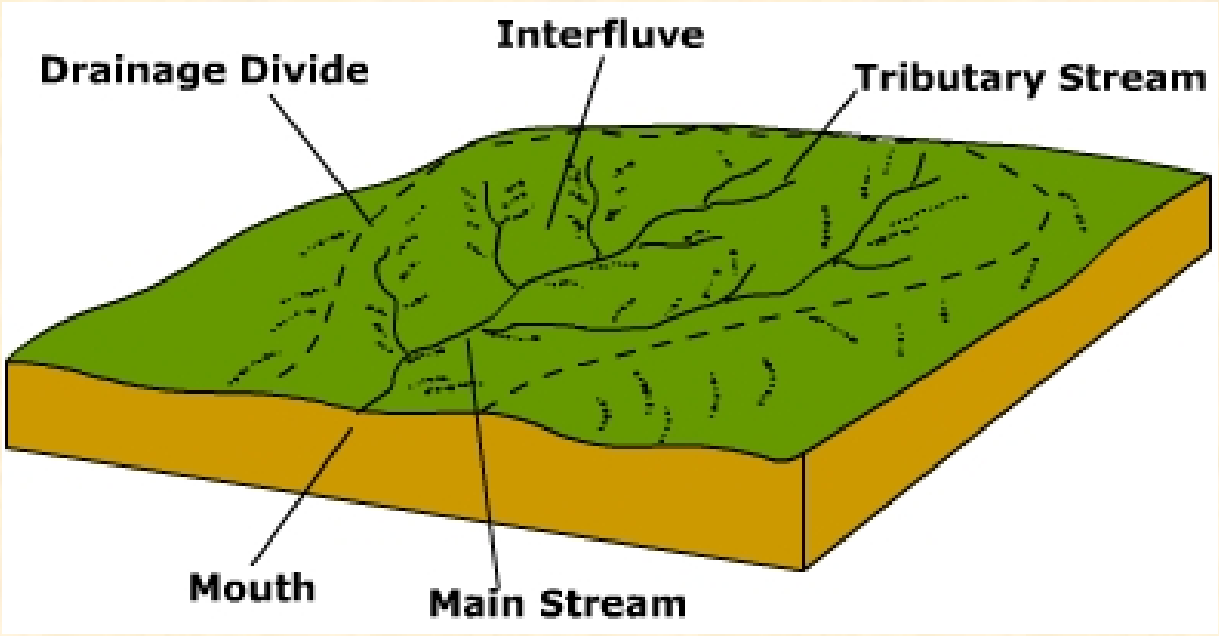
- A **watershed** or **basin** is the area of land bound by a **drainage divide**, where all the water within that area drains downstream from its headwaters to a single outflow location.

- This will include all **overland flow**, channelized **stream flow** and any **groundwater** contribution

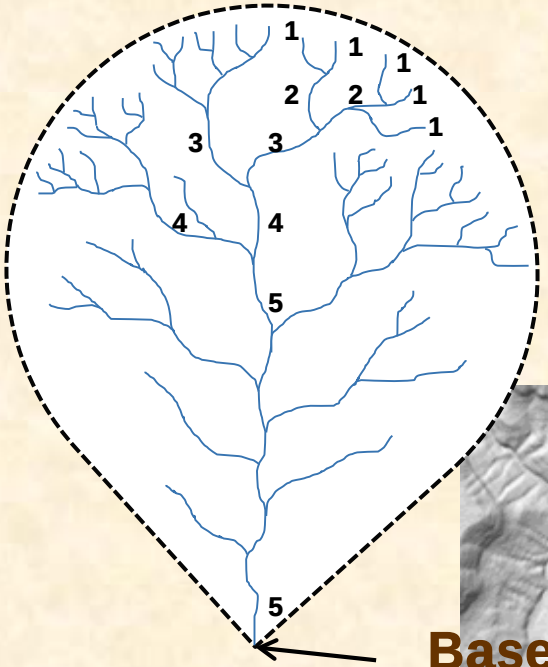


Longitudinal Profile and Watersheds

- **Drainage divides:** high elevation ridges that separate watersheds
- **Valleys:** section of the basin with a clearly established drainage system
- **Interfluves:** regions separating the valleys, mostly overland flow, no clear drainage pattern established,
- Nested hierarchy of drainage basins.



Stream Orders



Headwaters: multiple low-order streams near drainage divide

Base level: single outflow and highest order stream

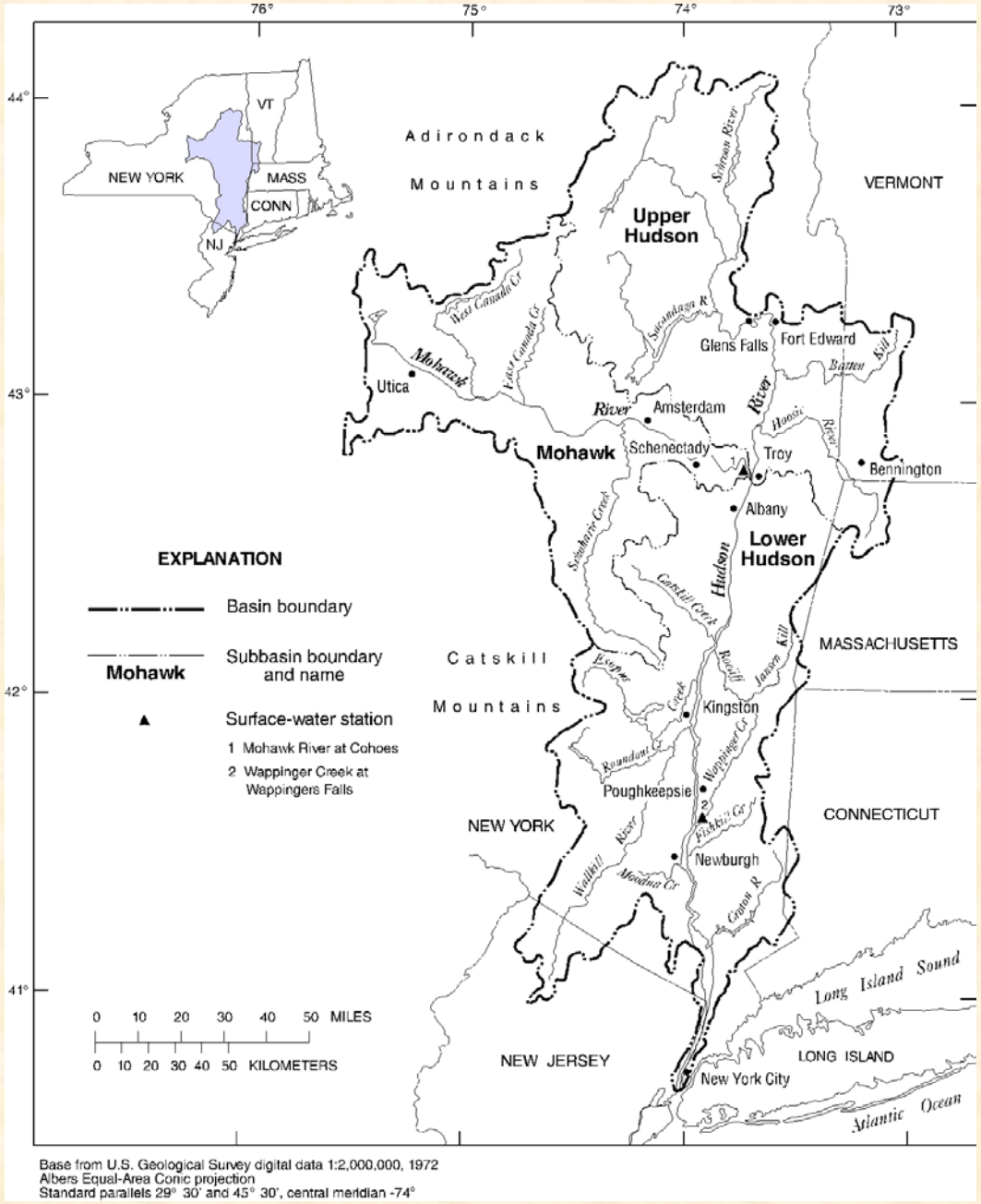
Stream Order:

1st order and 1st order = 2nd order
2nd order and 2nd order = 3rd order
3rd order and 3rd order = 4th order
4th order and 4th order = 5th order
And so on, 5 and 5 =6, 6 and 6 =7th order…

Mississippi River Drainage Basin

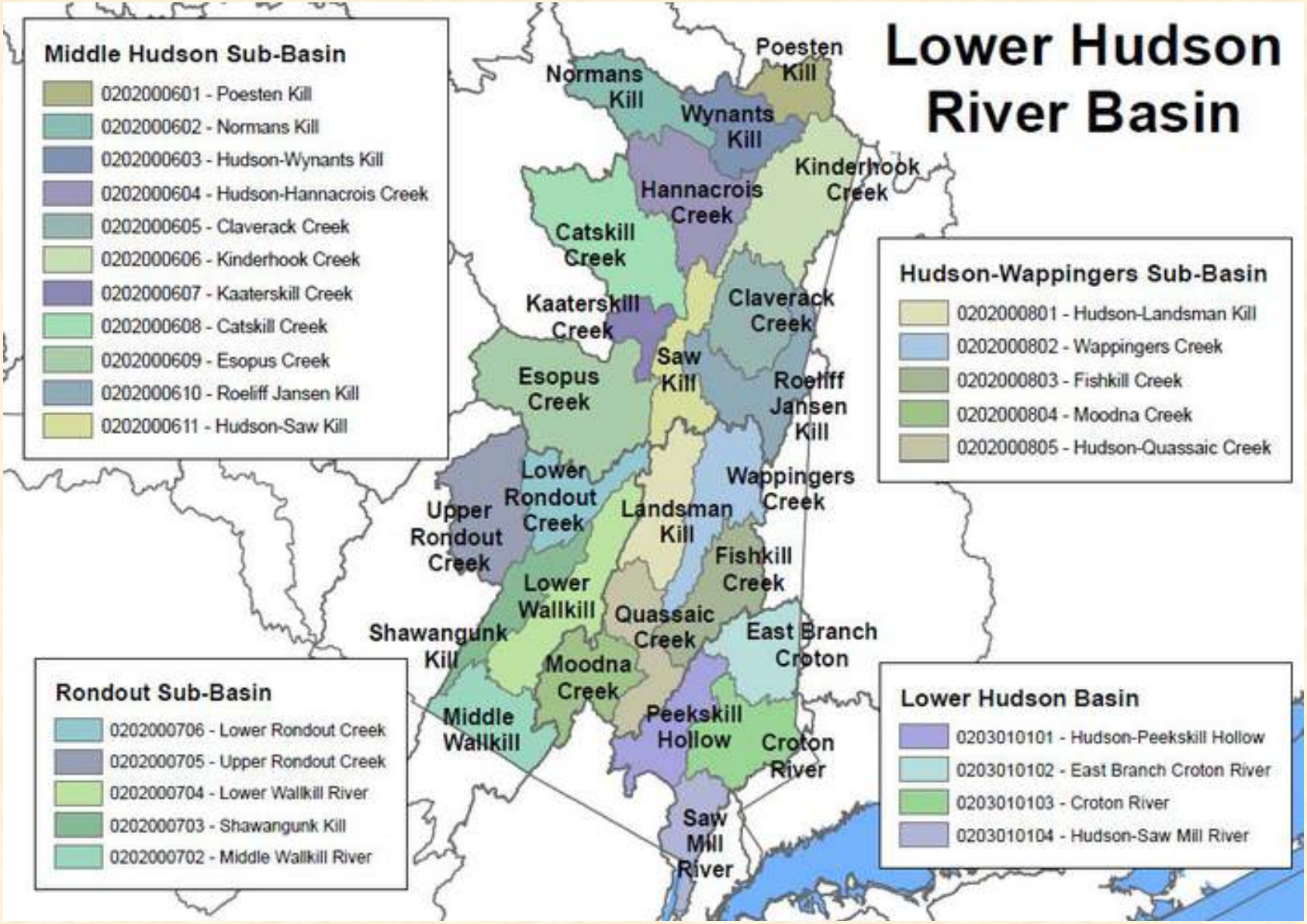
Mississippi River Drainage Basin

Hudson River Basin



Hierarchy of drainage basins

USGS: monitoring of major rivers and tributaries falls under USGS jurisdiction.


Lower Hudson River Basin
Middle Hudson Sub-Basin
0202000601 - Poesten Kill
0202000602 - Normans Kill
0202000603 - Hudson-Wynants Kill
0202000604 - Hudson-Hannacrois Creek
0202000605 - Claverack Creek
0202000606 - Kinderhook Creek
0202000607 - Kaaterskill Creek
0202000608 - Catskill Creek
0202000609 - Esopus Creek
0202000610 - Roeliff Jansen Kill
0202000611 - Hudson-Saw Kill
Hudson-Wappingers Sub-Basin
0202000801 - Hudson-Landsman Kill
0202000802 - Wappingers Creek
0202000803 - Fishkill Creek
0202000804 - Moodna Creek
0202000805 - Hudson-Quassaic Creek
Rondout Sub-Basin
0202000706 - Lower Rondout Creek
0202000705 - Upper Rondout Creek
0202000704 - Lower Wallkill River
0202000703 - Shawangunk Kill
0202000702 - Middle Wallkill River
Lower Hudson Basin
0203010101 - Hudson-Peekskill Hollow
0203010102 - East Branch Croton River
0203010103 - Croton River
0203010104 - Hudson-Saw Mill River
Poesten Kill
Normans Kill
Wynants Kill
Kinderhook Creek
Hannacrois Creek
Catskill Creek
Kaaterskill Creek
Claverack Creek
Saw Kill
Esopus Creek
Roeliff Jansen Kill
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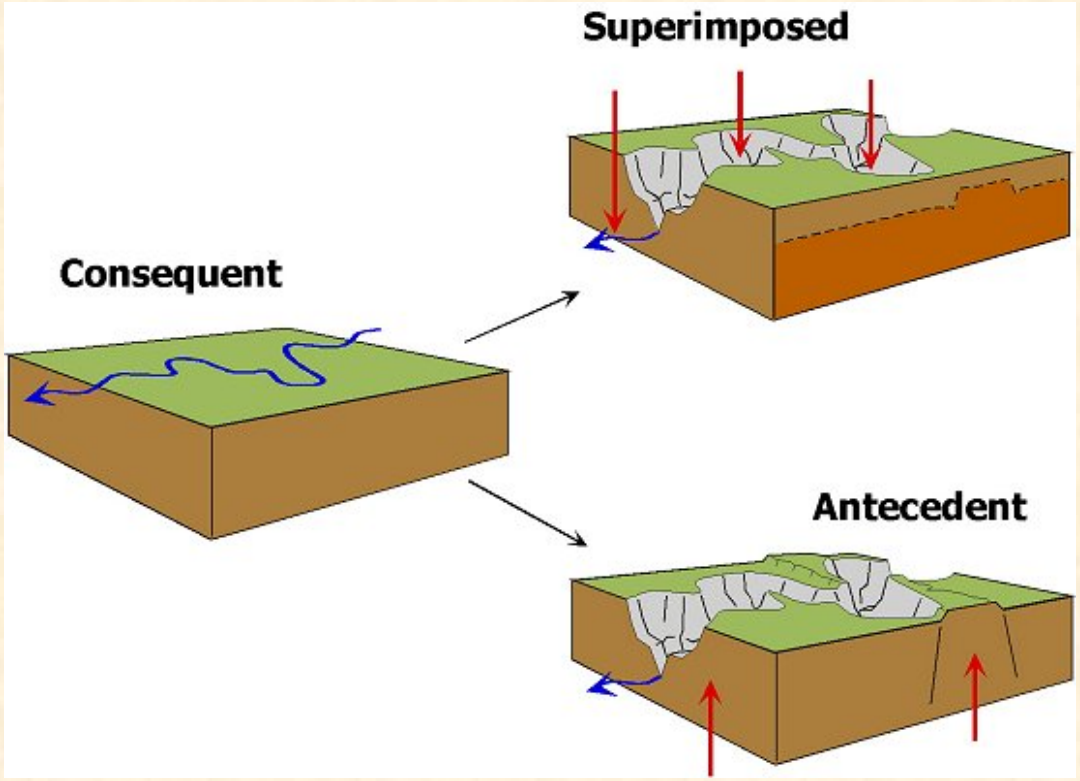
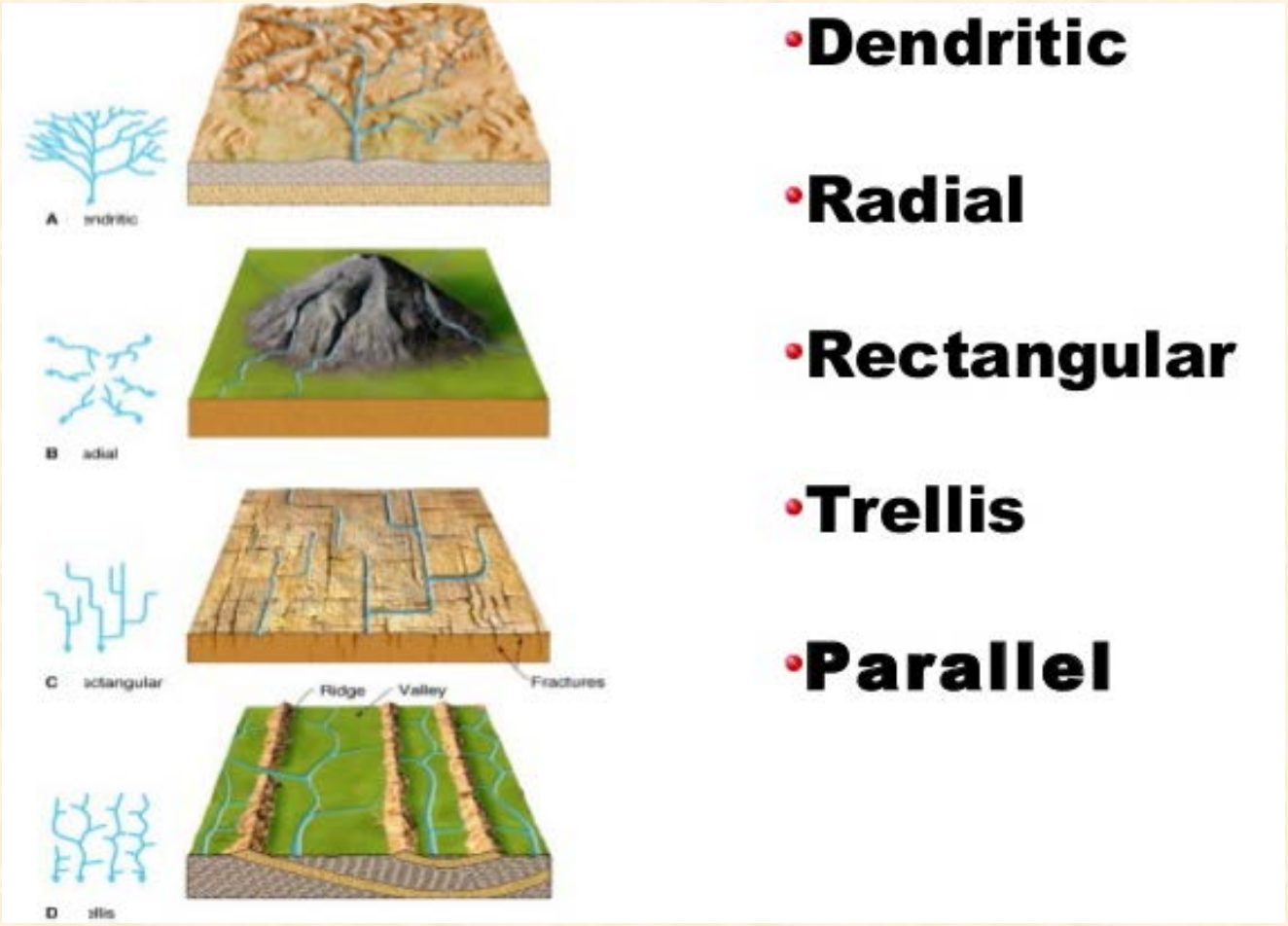
Wappingers Creek
Fishkill Creek
Lower Wallkill
Quassaic Creek
Shawangunk Kill
Moodna Creek
East Branch Croton
Middle Wallkill
Peekskill Hollow
Croton River
Saw Mill River

Structural Relationship

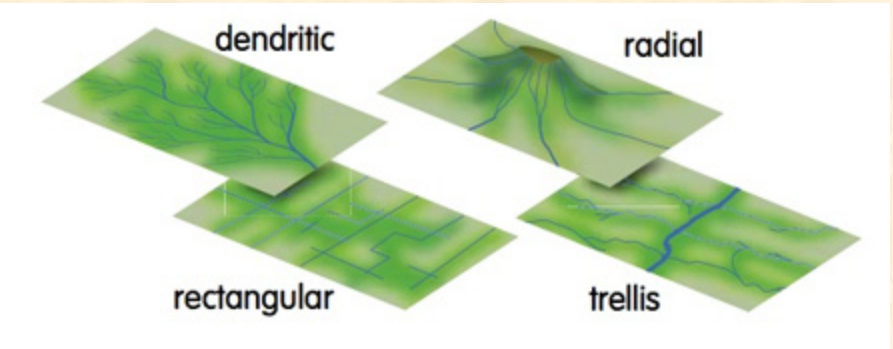


- **Consequent Stream:** follow the initial slope of the land.
  - **Subsequent streams**: exploit zones of structural weakness
- **Antecedent Streams:** predate geologic activity, was able to down cut and keep pace with the uplift
  - **Superimposed stream**: initial structure controlling the drainage has been eroded, no resemblance to current surface structure.

Drainage Patterns

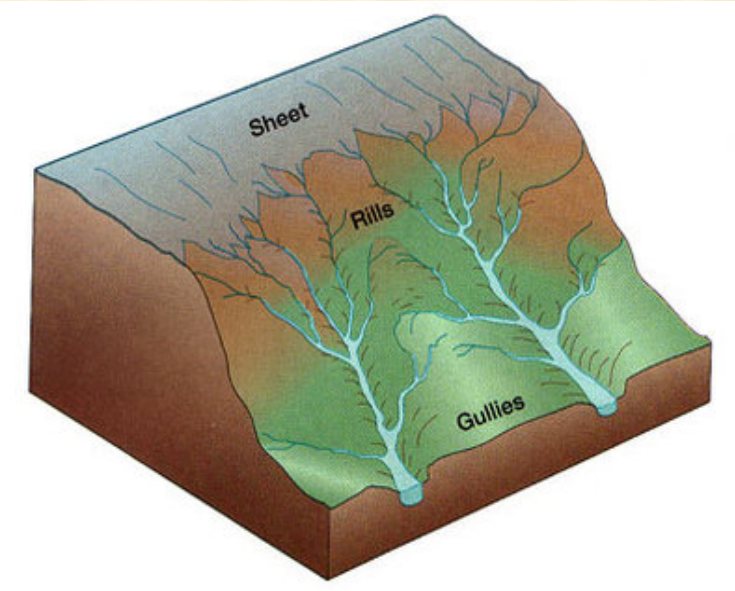


- Dendritic
- Radial
- Rectangular
- Trellis
- Parallel



Fluvial Erosion

- 3 distinct categories:
  - **Rain splash erosion** occurs when the impact of a rain drop loosens and mobilizes particles.
  - **Sheet erosion** is a process where particles loosened buy rain-splash erosion are transported by runoff water down the slope of a surface.
  - **Rill erosion** occurs when water concentrates during sheet erosion and erodes small rills or **gullys** into the surface that channel flow down slope.



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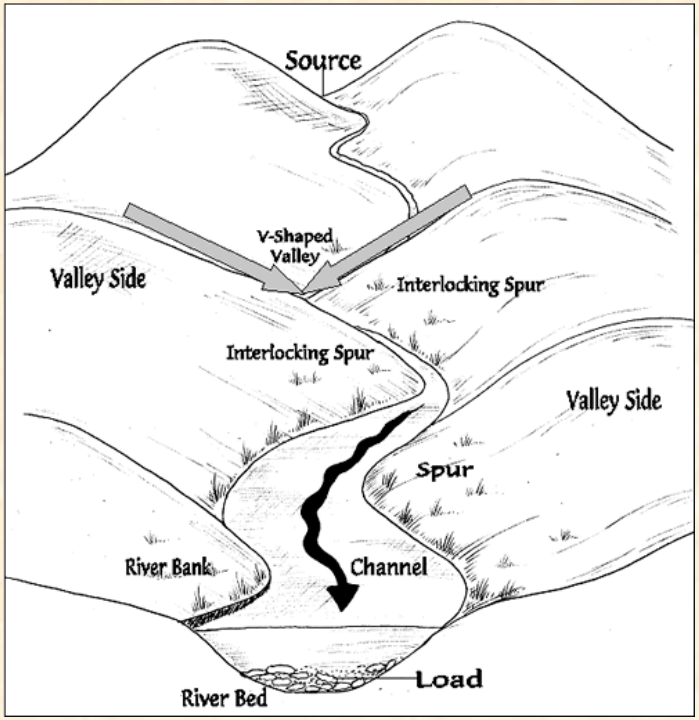
Fluvial Erosion

- Rills & Gullys are the first examples of semi-organized/channelized drainage.
- When multiple gullys form they produce a **disconnected network of headwater channels** that dissect the hillslope and increase soil erosion.
- Gullys are most common on disturbed hillslopes (vegetation free).
- Erosion-extension typically proceeds upslope
- Erosion-downcutting: steep gradients, increased flow velocities

Fluvial Erosion

- Rainfall events, melt-water runoff, or ground water percolation.
- Transported as **suspended load**, **bed load** (rolling along the bottom), or bounced by **saltation**.
- The accumulation of fluvial erosion and associated processes over a large area forms pathways for surface and groundwater flow and carves **v-shaped river valleys** that continue to erode, transport, and deposit weathered sediments across the landscape.
- **Interlocking Spurs**



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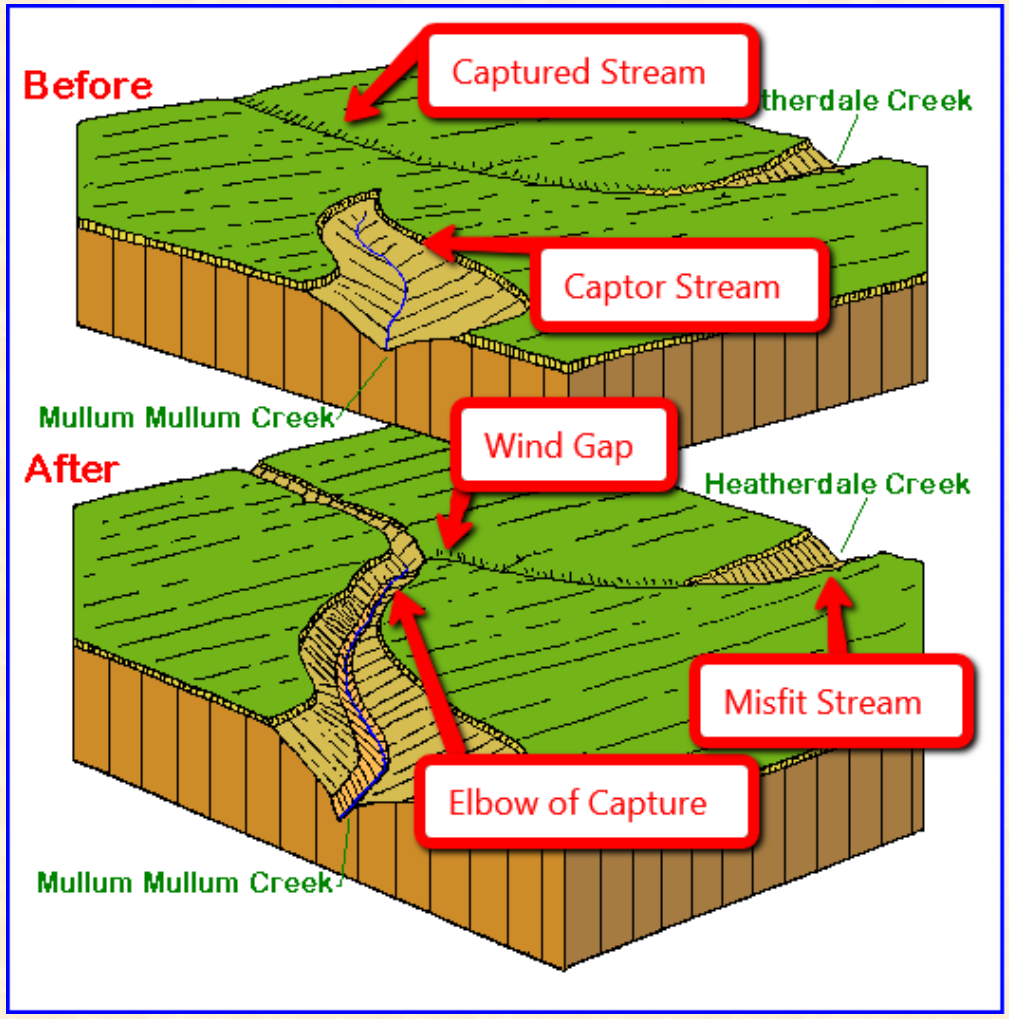
River Capture or Stream Piracy

Abstraction: unequal erosion of a drainage divide, flow transferred to the more energetic side; or **Headward Erosion** of a tributary



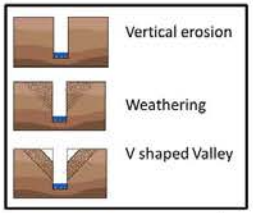
Intercision: intersection of meanders or lateral movement of two separate streams

- **Anabranching Systems**

Upper Course

Upper Course

flows with high velocity
V-shaped valley
vertical erosion dominates
waterfalls, rapids, gorges etc.

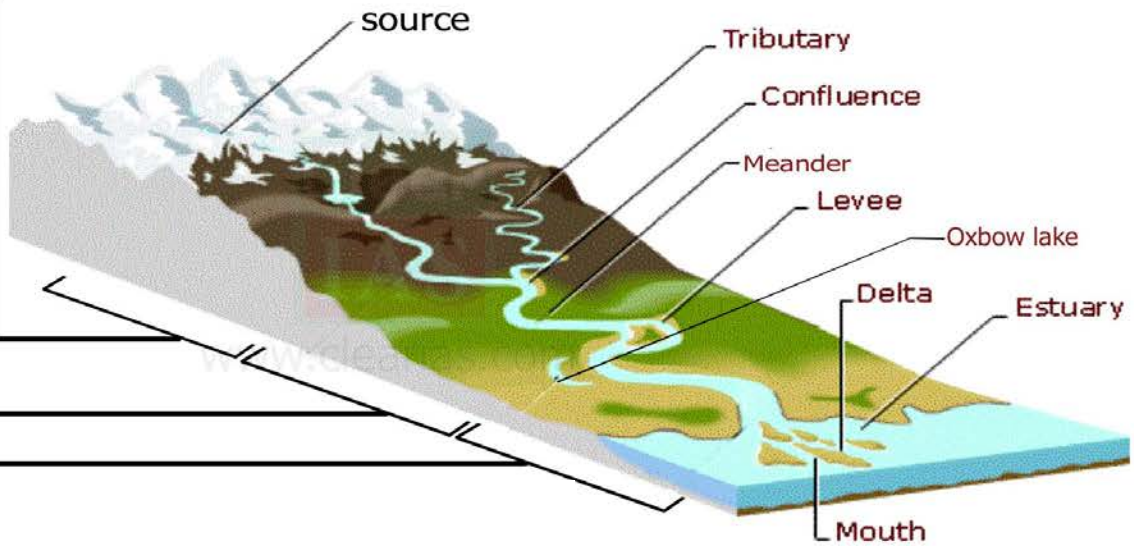


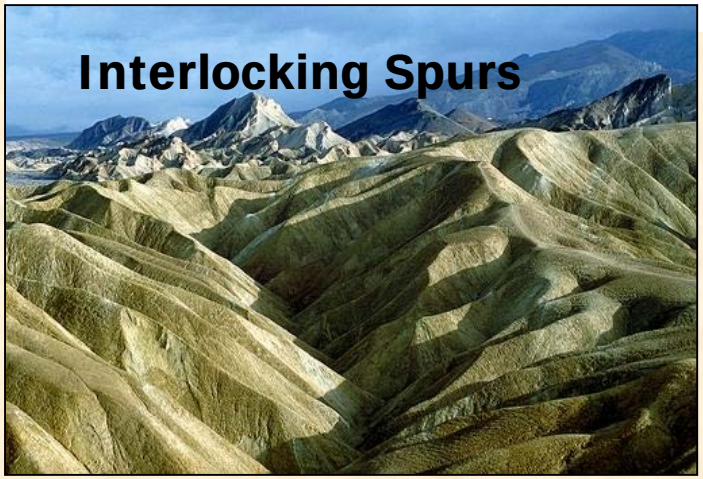
Middle Course

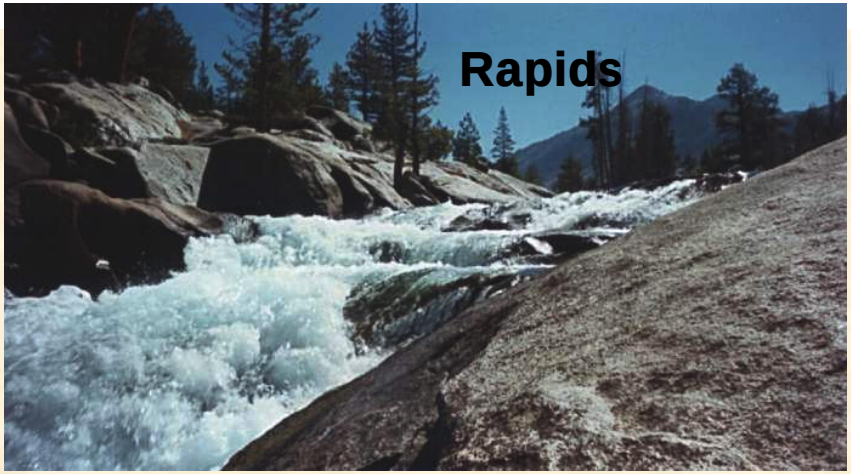
flows with moderate velocity
vertical and lateral erosion
plenty of streams
meanders, alluvial fans etc.

Lower Course

flows with low velocity
lateral erosion dominates &
wide channels
extensive flood plains
braided channels,
levees, oxbow lakes, meanders, deltas etc.

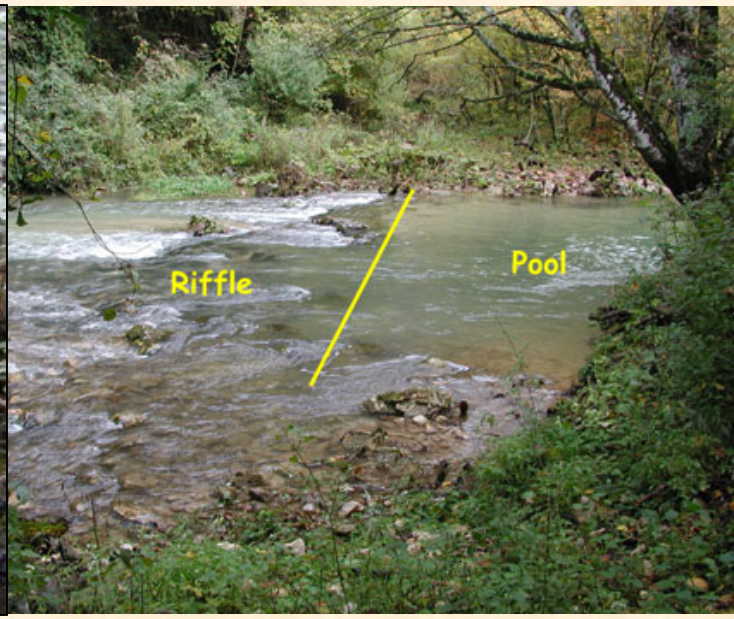






Upper Course: Mountain Streams

- high-gradient, low-order, sourced from springs, rainfall, or snowmelt.
- v-shaped valley, bedrock bottom, rapids, waterfalls, narrow flood plain.
- contain the largest sediment sizes (boulders, cobbles, gravel, etc.)
- localized pools upstream and or downstream of small elevation drops, this pattern is referred to as a step-pool sequence.



Upper Course: Waterfalls

- resistant bedrock, changes in bedrock resistance, fractures or faults.
- differential weathering creates stair-stepped ledges.
- less resistant rocks may form pools between waterfalls.
- faults and fractures provide pathways for the downslope movement of water.
- "**knick-point**": slowly migrate upstream.

This waterfall was formed by differential weathering between the softer shale and harder more resistant limestone.

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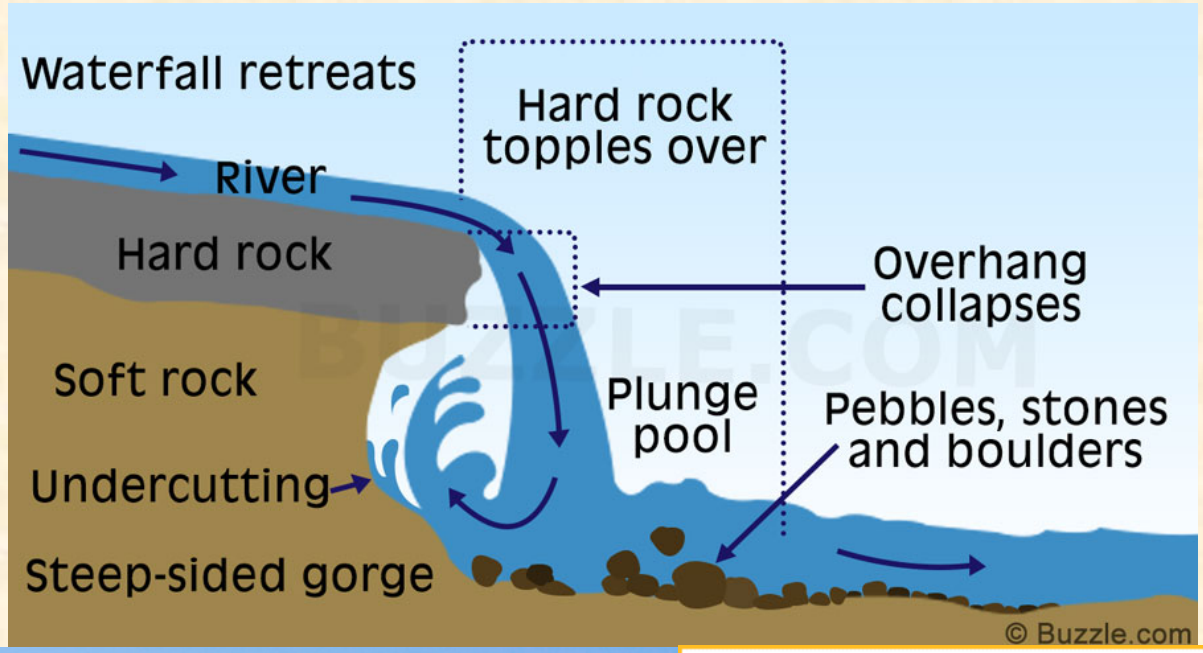
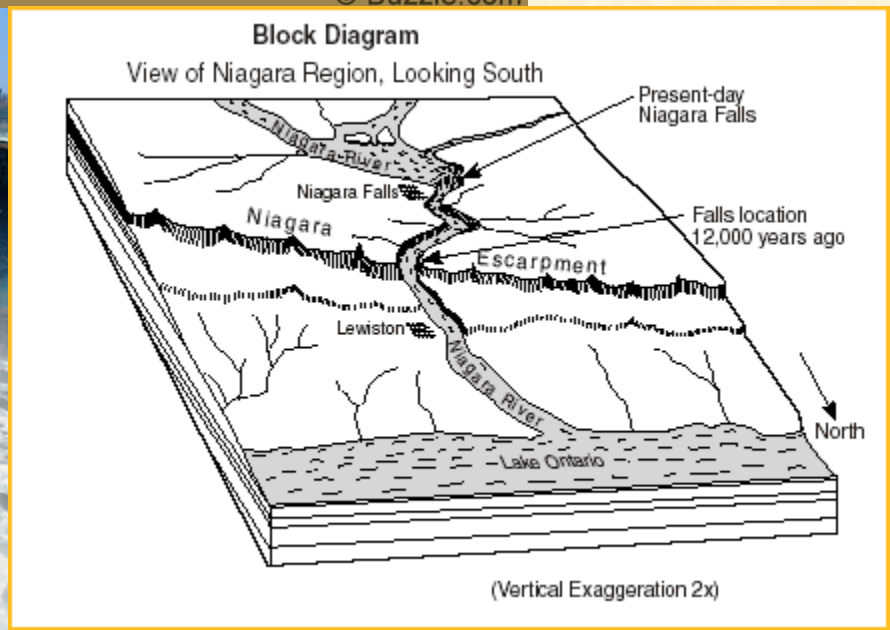
Photo: SCGS

Lower White Water Falls in the Jocassee Gorges area of South Carolina drops nearly 200 ft. Here, the Toxaway Gneiss forms a resistant bedrock that the Lower White Water River flows over before draining into Lake Jocasse.

Upper Course: Waterfalls





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Upper Course

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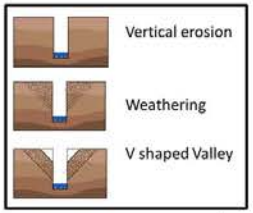
V-shaped valley
vertical erosion dominates
waterfalls, rapids, gorges etc.



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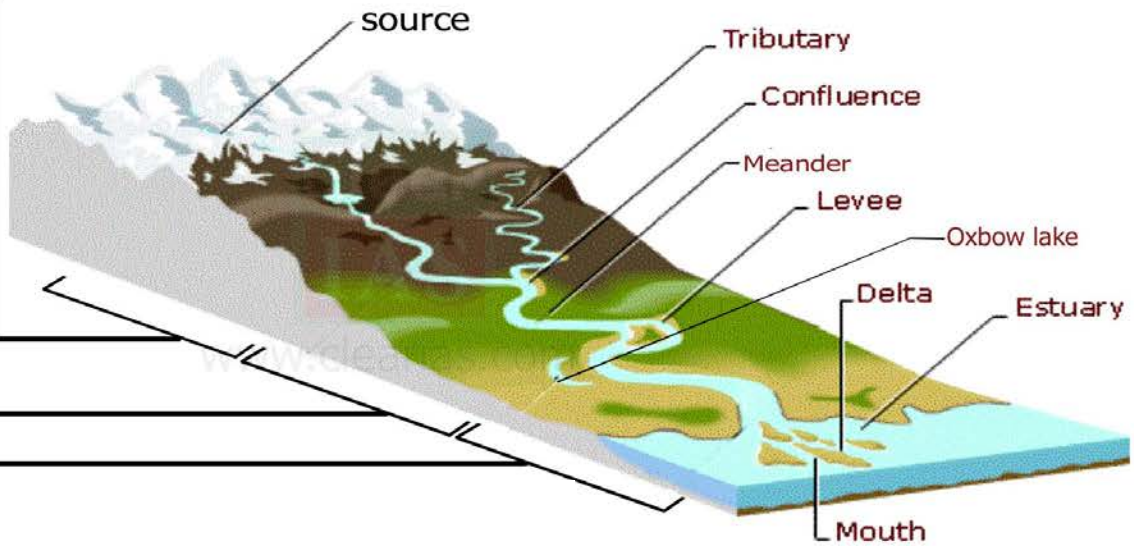

Middle Course: Alluvial Fans

- fan-shaped fluvial deposits that accumulate at the base of stream where it flows out from a steep gradient and enters into a lower-gradient flood plain or valley setting.
- change in fluid velocity reduces sediment load, forces deposition.
- common in arid environments with a high sediment load and minimal vegetation.
- form from a single high-flow event or composite from multiple events.

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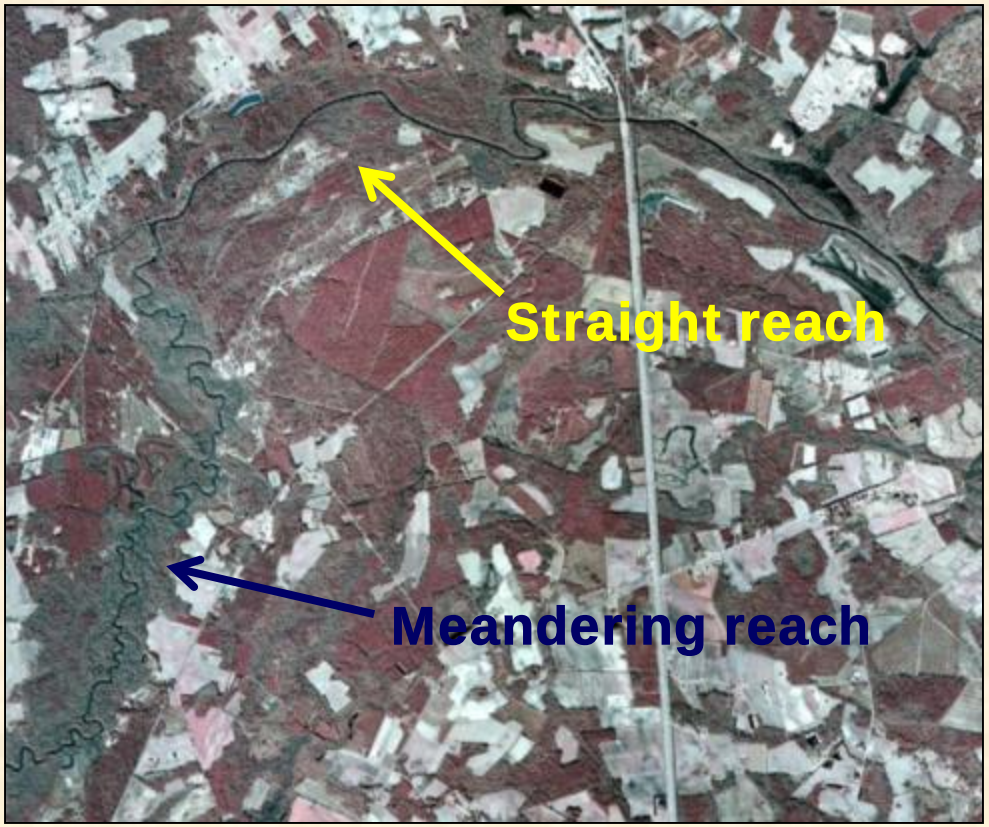
This alluvial fan is carrying a high sediment load from material weathered from the mountains. The dark line along the edge of the fan is a road. Because the road is not buried by recent deposits it suggest that this fan is not currently as active as it was in the past.

Middle Course: Straight Reach

- geologically controlled (incised into bedrock, follow geologic structure)
- not as common as meandering or braided streams
- associated with higher flow velocities and down cutting of the channel
- provide insight into bedrock controls or changes in stream gradient



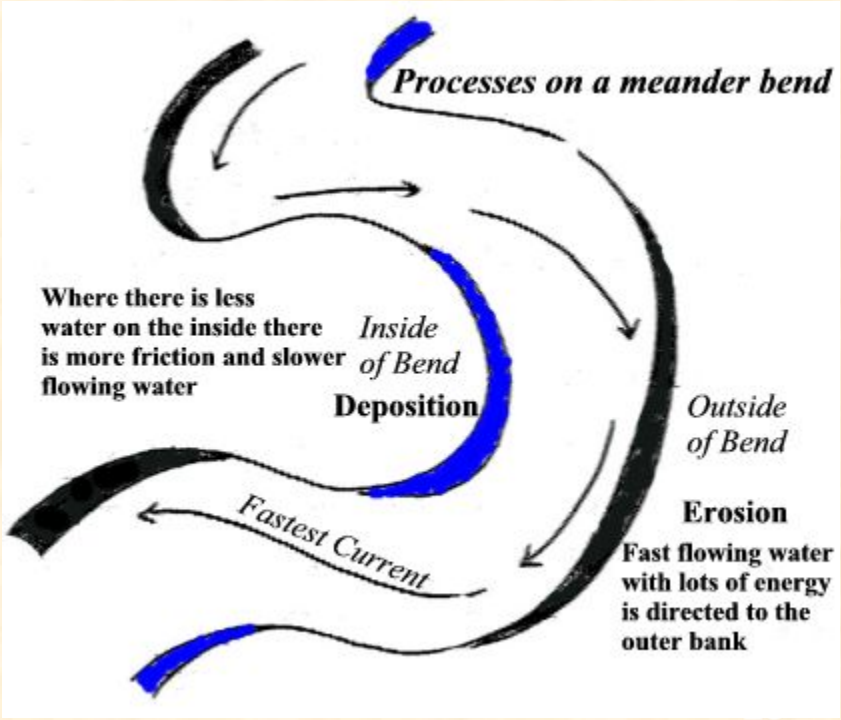
Data source: www.dnr.sc.gov/gis.html

- **Straight reach is incised in limestone bedrock**
- **Meandering reach is reworking through the flood plain**

Middle Course: Meandering

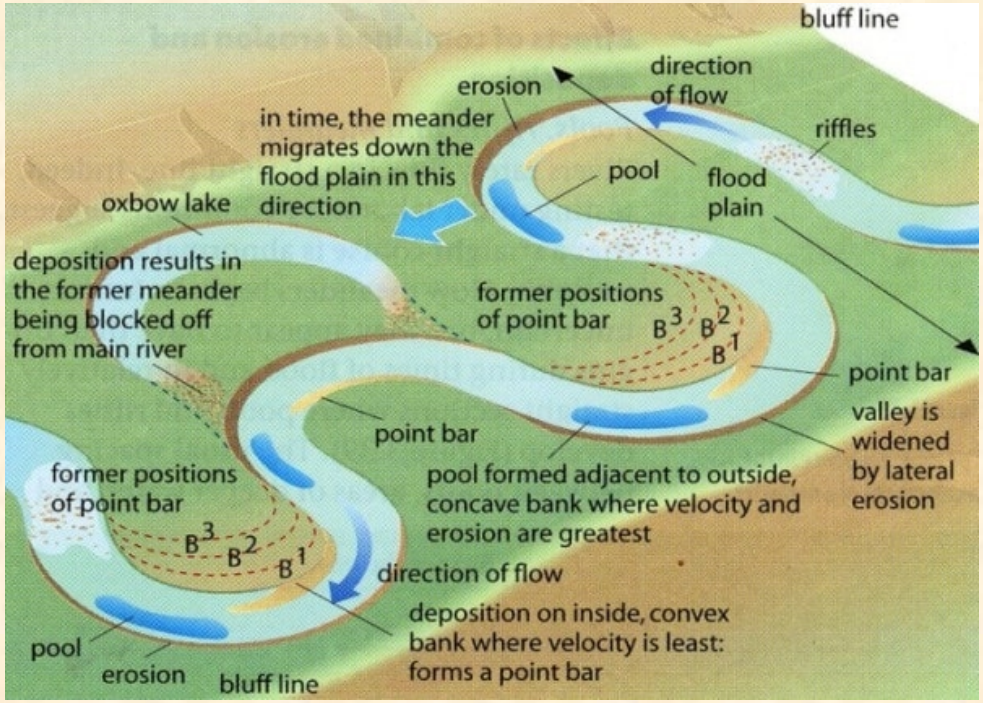
- lower-gradient, sinuous channels
- multiple, individual meander bends that laterally migrating across the flood plain.
- continuously eroding, transporting, and depositing alluvial sediments.
- variety of depositional and erosional landform features
  - collectively form the **flood plain valley**.

2006 Aerial imagery: http://www.dnr.sc.gov/GIS/gisdata.html



Middle Course: Meandering

- aggrading **pointbar** deposit on the inside of a meander bend
- eroding **cut bank** along the outside of the bend
- as the channel migrates laterally across the flood plain, sediments are eroded from the outer cutbank and deposited on the inner pointbar.
- when meandering channels cut-off entire meander bends **oxbow lakes** or in-filled channels are formed.



Middle Course: Entrenched Meanders

- Lateral migration is inhibited by geology
- Down-cutting becomes the dominant erosion mechanism
- The Colorado River flowing through the Grand Canyon in Arizona, provides a classic example of entrenched meanders.
  - Down cutting began as the Colorado Plateau was uplifted ~5 mya

Below are the entrenched meanders of the Colorado River and to the right is the first geologic interpretation of the numerous geologic units exposed by the down cutting river.

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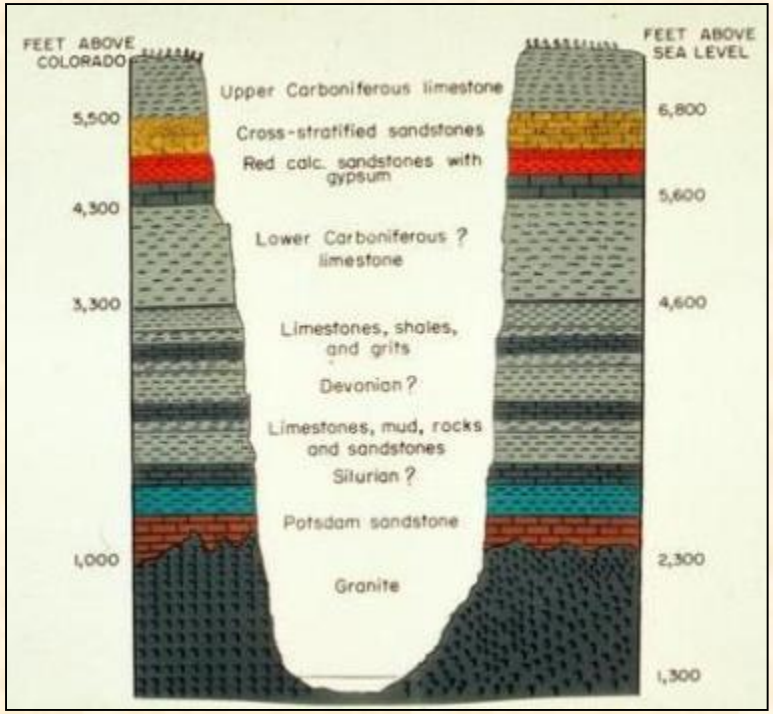

Courtesy USGS Photographic Library

Lower Course

Upper Course

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V-shaped valley
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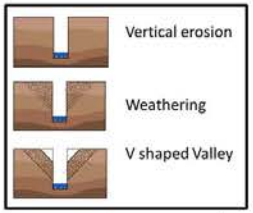

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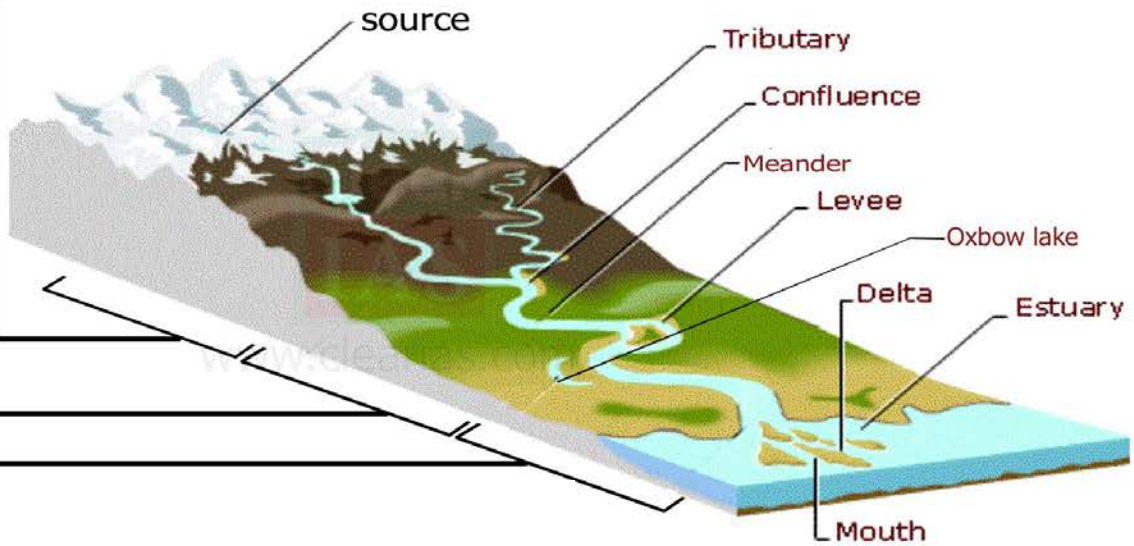

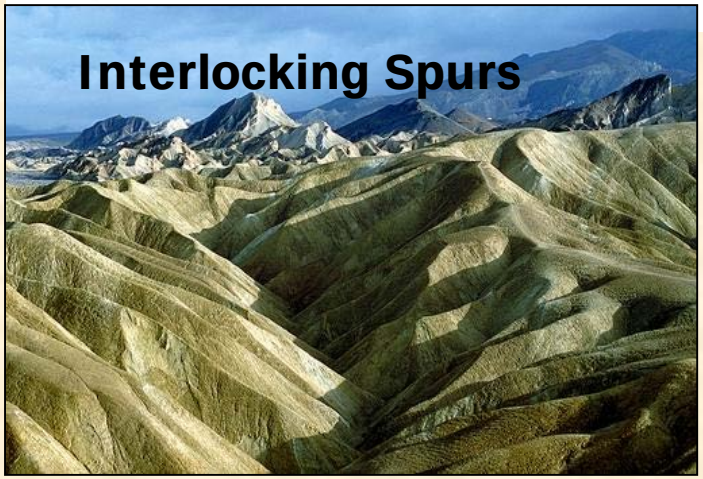

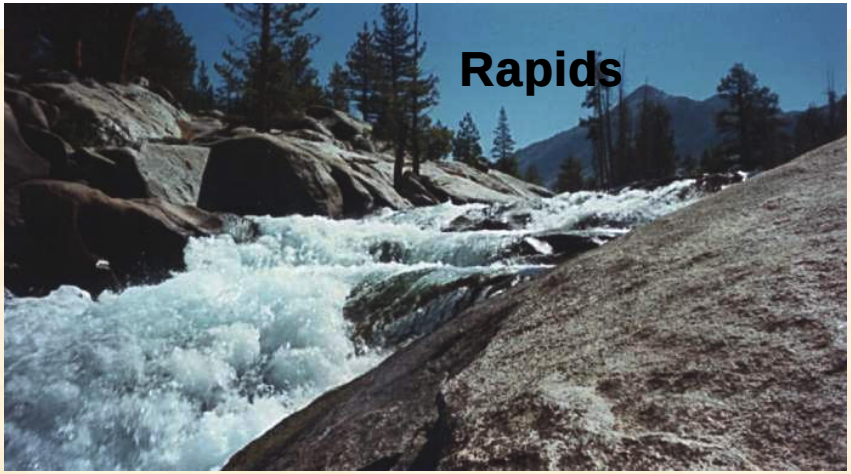

Lower Course: Braided

- **sediment load exceeds carrying capacity**
- as carrying capacity decreases, sediment is deposited on channel bed
- river forced to carve new path, creating an interwoven network of channels
- islands between the braided channels are ephemeral and dynamic
- sediments are continually remobilized, transported and deposited
- occur downstream of areas with high sediment loads
- composition varies from silts, sands, and gravels

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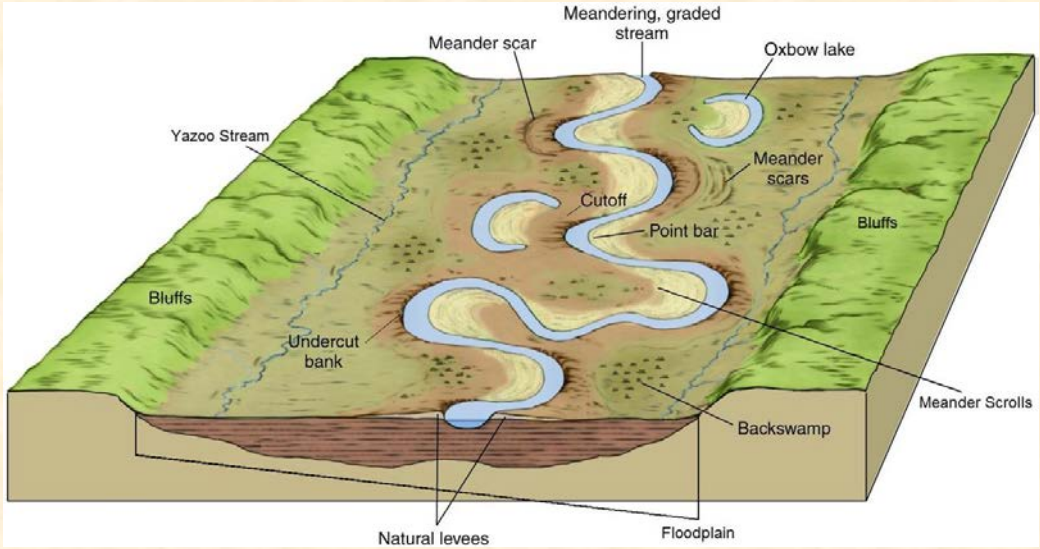
This is the braided Resurrection River in Alaska. The sediment load consists primarily of silt that has been eroded and weathered from glacial debris. Braided river patterns may also be referred to as anastomosing.

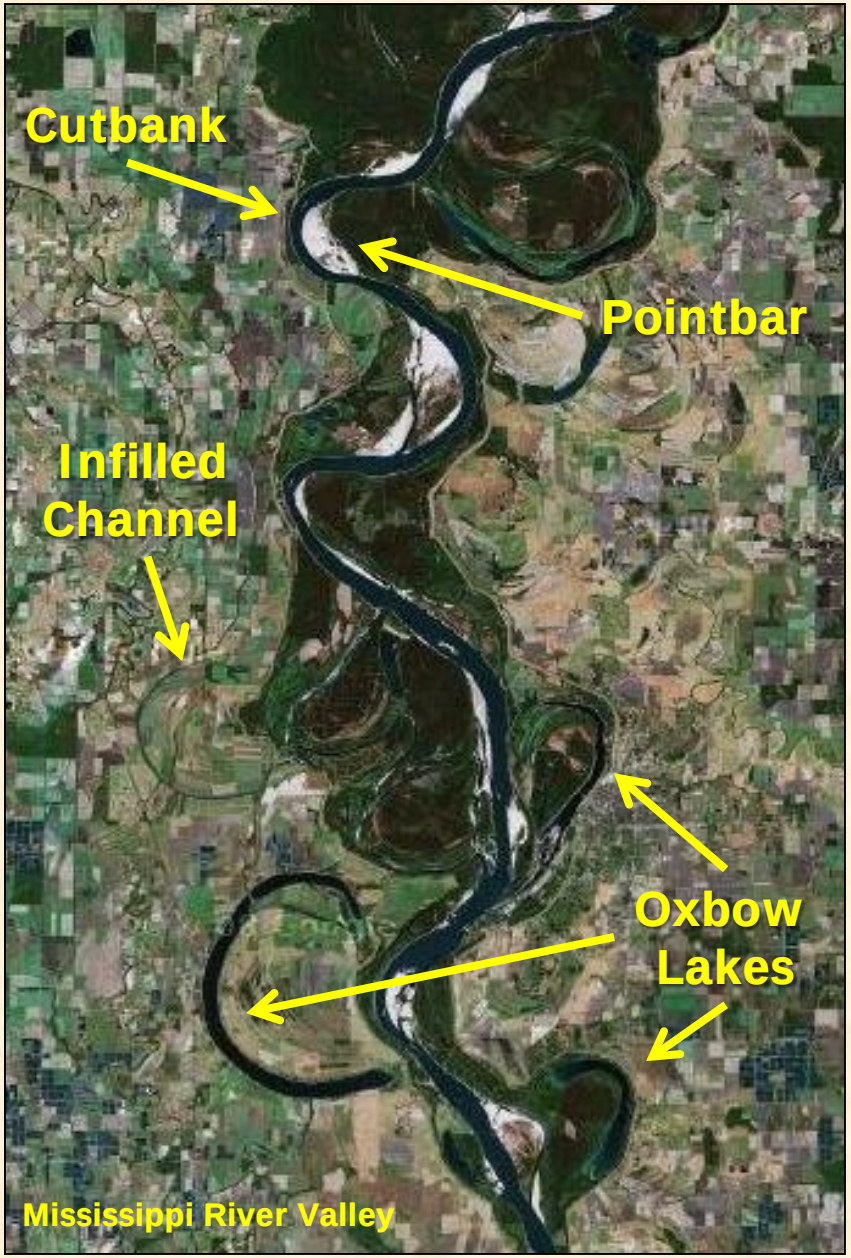
Lower Course: Anabranching

- multiple channels that weave through semi-permanent alluvial vegetated islands.
- formed through **meander bend cutoffs**, channel avulsions (abandonment of an entire channel segment), or mid-channel deposition and subsequent vegetation.

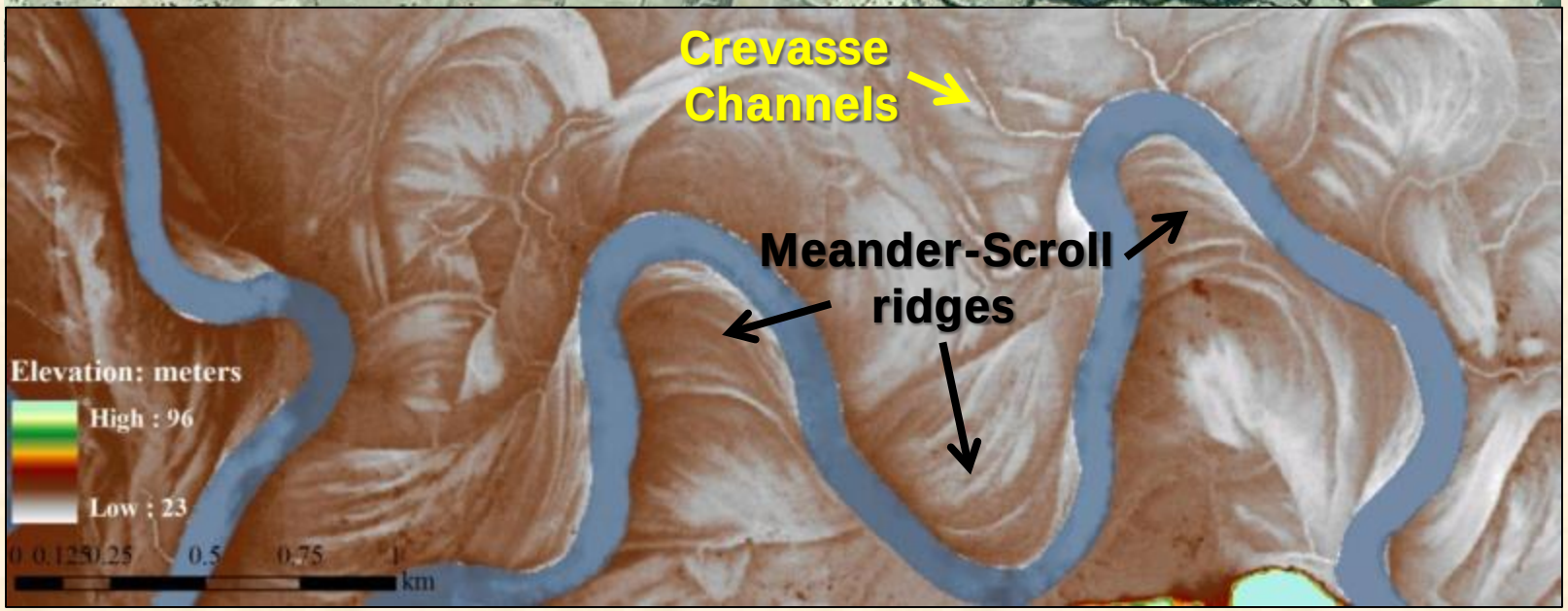
Lower Course: Flood Plains

- region influenced by modern fluvial processes
- mosaic of landform features: **cutbanks**, **pointbars**, **natural levees**, **crevasse channels** and **crevasse splays**, **infilled channels** and **oxbow lakes**, **backswamps**, and occasionally yazoo tributaries etc.





Flood Plains

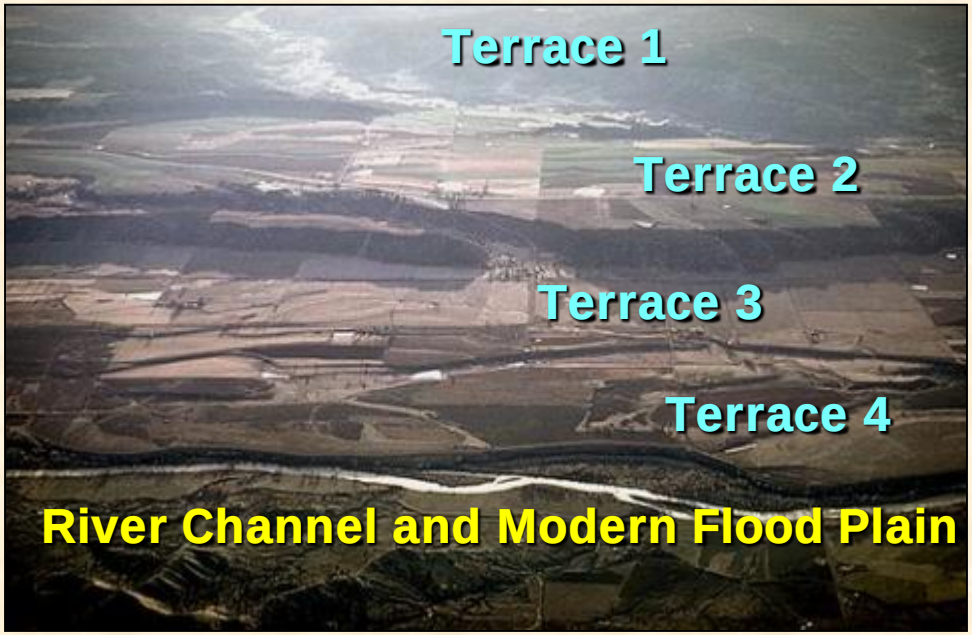


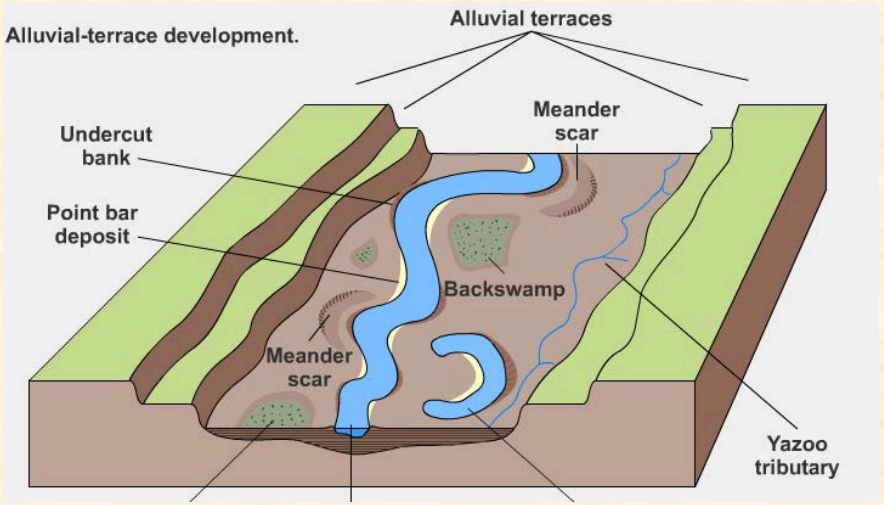
Flood Plains: Notes

- **Cutbanks** form along the outer convex margin of meander bends. Cutbanks , unlike most floodplain landforms are actually erosional features formed by the lateral movement of the channel across the flood plain. Flood plain sediments are eroded from the cutbank and deposited on pointbar surfaces.
- **Pointbars** are concave, depositional landforms that form opposite of the eroding cutbanks, and they develop in concert with the laterally migrating river channel. Pointbars are typically composed of sands, gravel, silts, and clay deposits, that form arcuate, **meander-scroll ridges**.
- **Natural levees** are depositional landforms formed from the vertical accumulation of sediments deposited during flood events. Natural levees form topographically higher surfaces adjacent to the river channel, that generally consist of stratified, well-sorted sands, silts, and clays. Natural levees deposits are thickest and coarsest close to the channel and they become progressively thinner, and finer with increasing distance from the channel.
- **Crevasse channels and splays** are breaches in the natural levee that result in the fan-shaped deposition of flood deposits, beyond or over levee deposits. Crevasse channels can produce flooding in backswamp areas, even before the levees are submerged by floodwaters.
- **Oxbow lakes** or **infilled channels** form when a meander bend is cut off from the main river and abandoned in the floodplain. Abandoned meanders can occur in various stages from flooded oxbow lakes to being completely infilled with sediment deposits.
- **Backswamps** are typically low-lying areas of the floodplain beyond the natural levee deposits. Backswamps contain the finest-textured flood plain deposits and may even develop organic-rich soils from the forest litter. They often form along the margins or edge of the floodplain, and are usually influenced by connections to the groundwater.
- **Yazoo tributaries** are stream networks that enter the floodplain but the natural levee prevents the stream from flowing into the river. As a result the yazoo tributary flows parallel to the mainstem river before reaching a breach in the levee or occupying the course of an abandoned meander that allows the stream to cross the levee deposits and flow into the river.

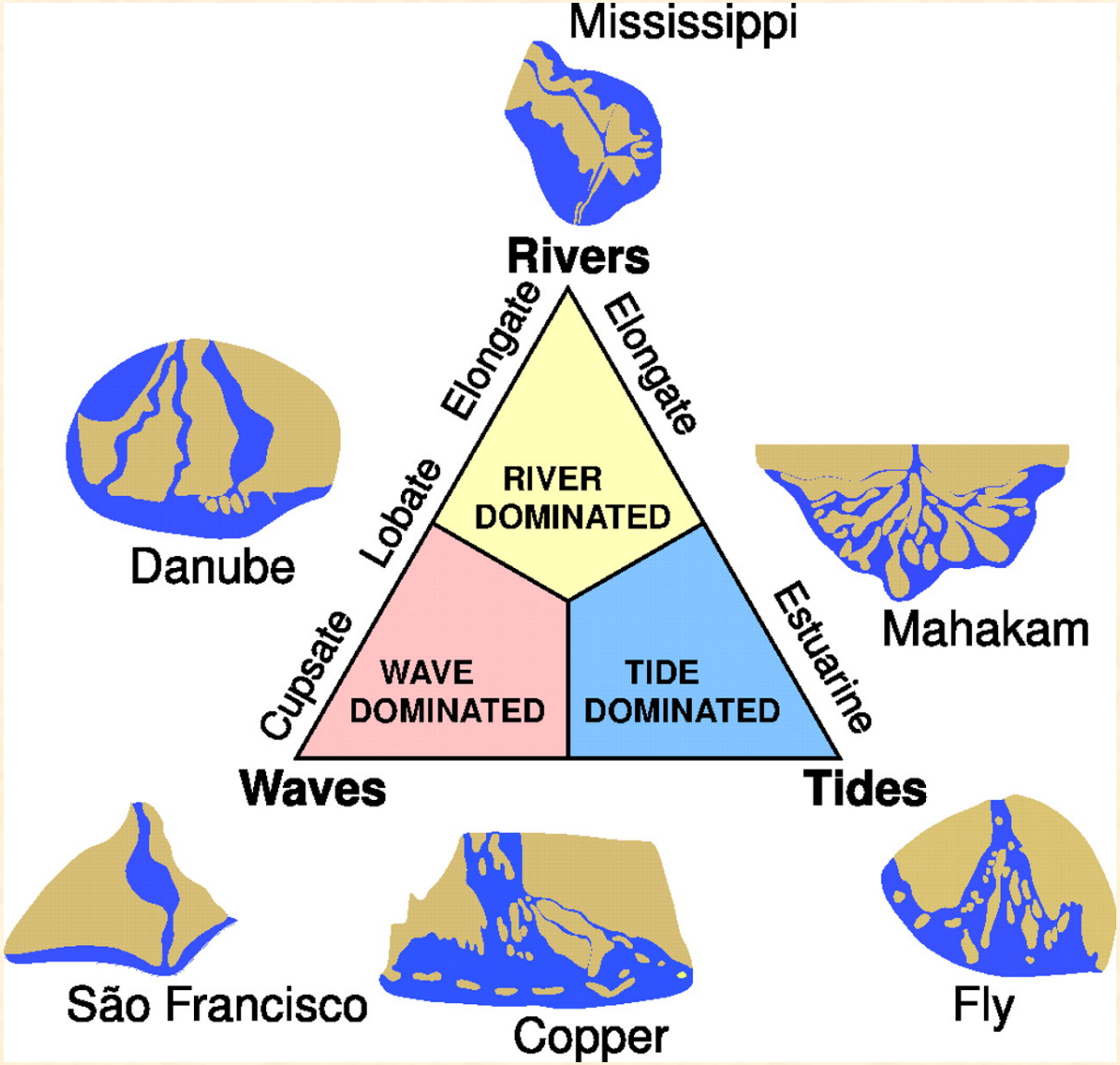
Lower Course: River Terraces

- older remnant flood plain surfaces, higher in elevation
- they may occur on one or both sides of the valley
- Formation mechanisms vary:
  - Hydraulic or sedimentary changes in the headwaters
  - Valley gradient changed in response to lowered base-level
  - Tectonic and valley uplift
- **Stream rejuvenation**: a river is said to be rejuvenated when it is eroding the landscape in response to a lowering of its base level.





Lower Course: Delta



- Coastal Geomorph
- Controls
  - Discharge
  - Tides
  - Waves
  - Sediment Characteristics

Lower Course: Delta