RIVER MORPHOLOGY

About the genesis and behaviour of rivers as determined by natural and anthropogenic factors

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The geomorphologic context

- The river's shape is for a large part determined by the valley topography and the mechanical characteristics of the river basin (geology, soil mechanical properties)
- Rivers have a shape which is the result of a long history of changes in climate, in tectonic activities, in land use, in human interference

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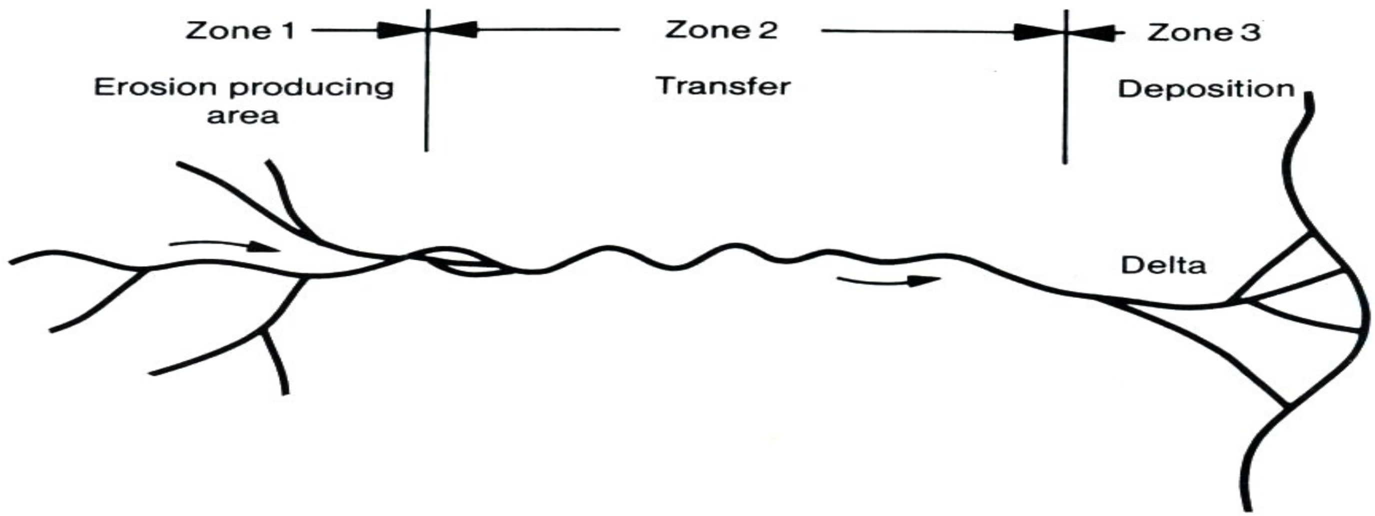
The geomorphology of river basins

In the upper part of the basins, rivers are formed by erosion of the bedrock: their course incises progressively (zone 1). Flow carries the products of the incision and of the soil erosion towards the lower zones. In zone 2 some equilibrium exists between sediment transport capacity of the flow and the sediment supply; it is the transfer zone. In zone 3, the sediments are deposited by lack of transport capacity, in deltas, lagunes or estuaries.



The fluvial system (after Schumm, 1977).

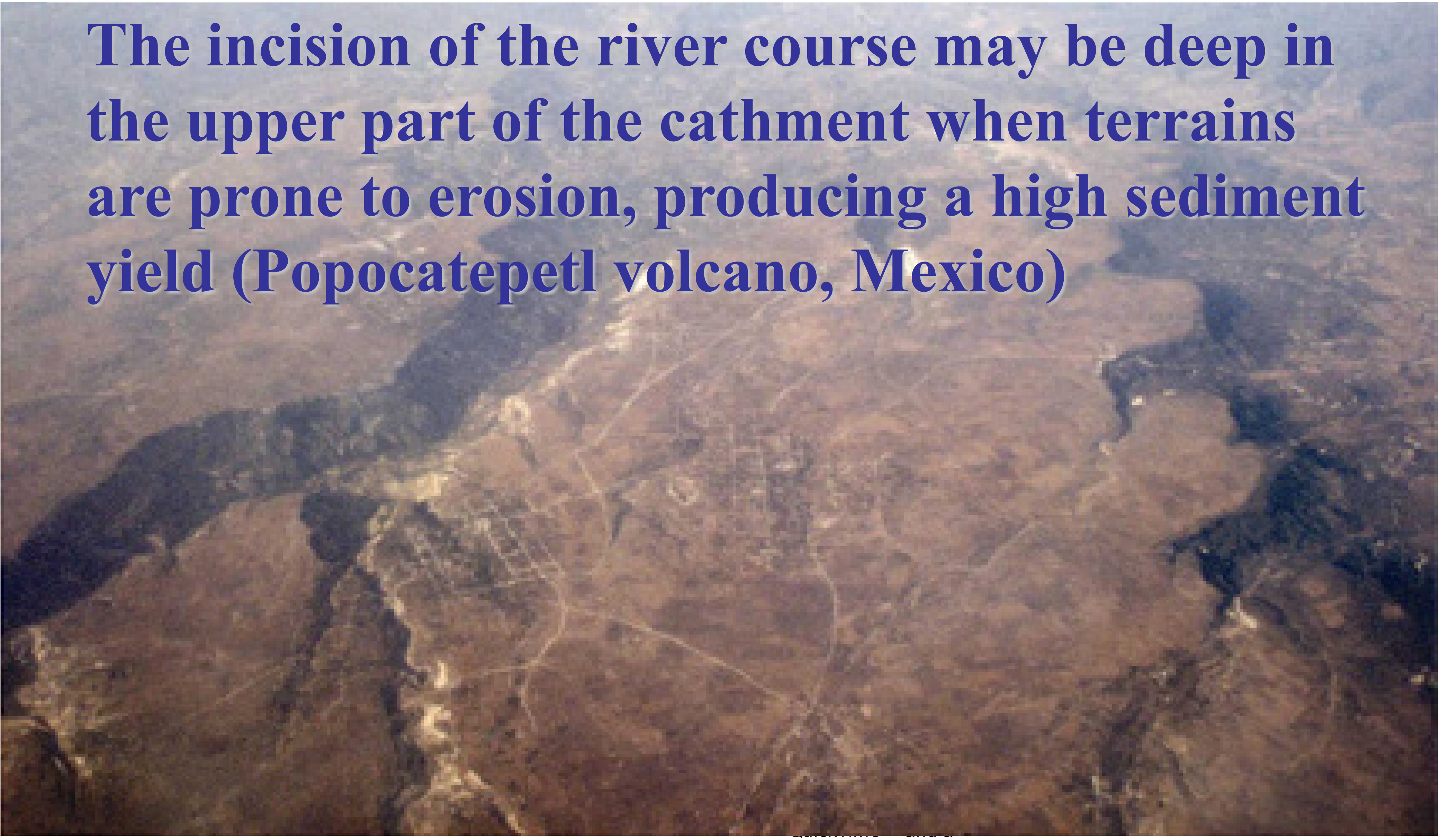
Geomorphic context of upper river basins

- In the upper catchments, geology and tectonic movements, faults and plication determine the shape of river courses
- Caving and landslides contribute significantly to the river's sediment load

- Vegetation controls soil erosion, while agriculture (slope tillage, roads and other works induce soil erosion)

Geomorphic context of upper river basins

The incision of the river course may be deep in the upper part of the cathment when terrains are prone to erosion, producing a high sediment yield (Popocatepetl volcano, Mexico)



Geomorphic context river channels

- **Entrenched channel**: channel bordered on either side by banks higher than the highest flood level. This type of channel is usually degrading when bedrock can be eroding, i.e. incising always deeper its course in the valley

- **Partly entrenched channel**: channel bordered occasionally by discontinuous segments of flood plain. Some degradation and lateral shifting may be taking place (Middle reach of the Var river)

Geomorphic context river channels

- **<u>Confined channel</u>**: channel is either stable (vertically) or aggrading and frequently impinges on the valley walls. The channel pattern is controlled by the narrow valley

- **<u>Partly confined channel</u>**: channel is occasionally confined by valley walls. There is usually sufficient room for complete development of channel pattern

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Partly confined channel (Piraï river, Bolivia).
Example of river course affected by bank caving

Geomorphic context lower reaches

- Geomorphologic context may be quite diversified, depending on the topography and sediment sources and sorting

- When slopes change rapidly, sediment deposits on the riverbed may be coarse or fine, depending on the local slopes (selective deposition with the varying velocities and slopes) (Think about the different reaches of the Var)

Geomorphic context river mouths

- The type of river mouth will depend on the relative importance of sea (lake) and river
- Streams carrying large amounts of solids to the sea form deltas
- When tides and or waves at sea are strong, sediments will be transported along the coast, forming lagoons, separated from the sea by a sandbar
- Streams with little solid load to the sea (lake) with strong tidal currents create estuaries

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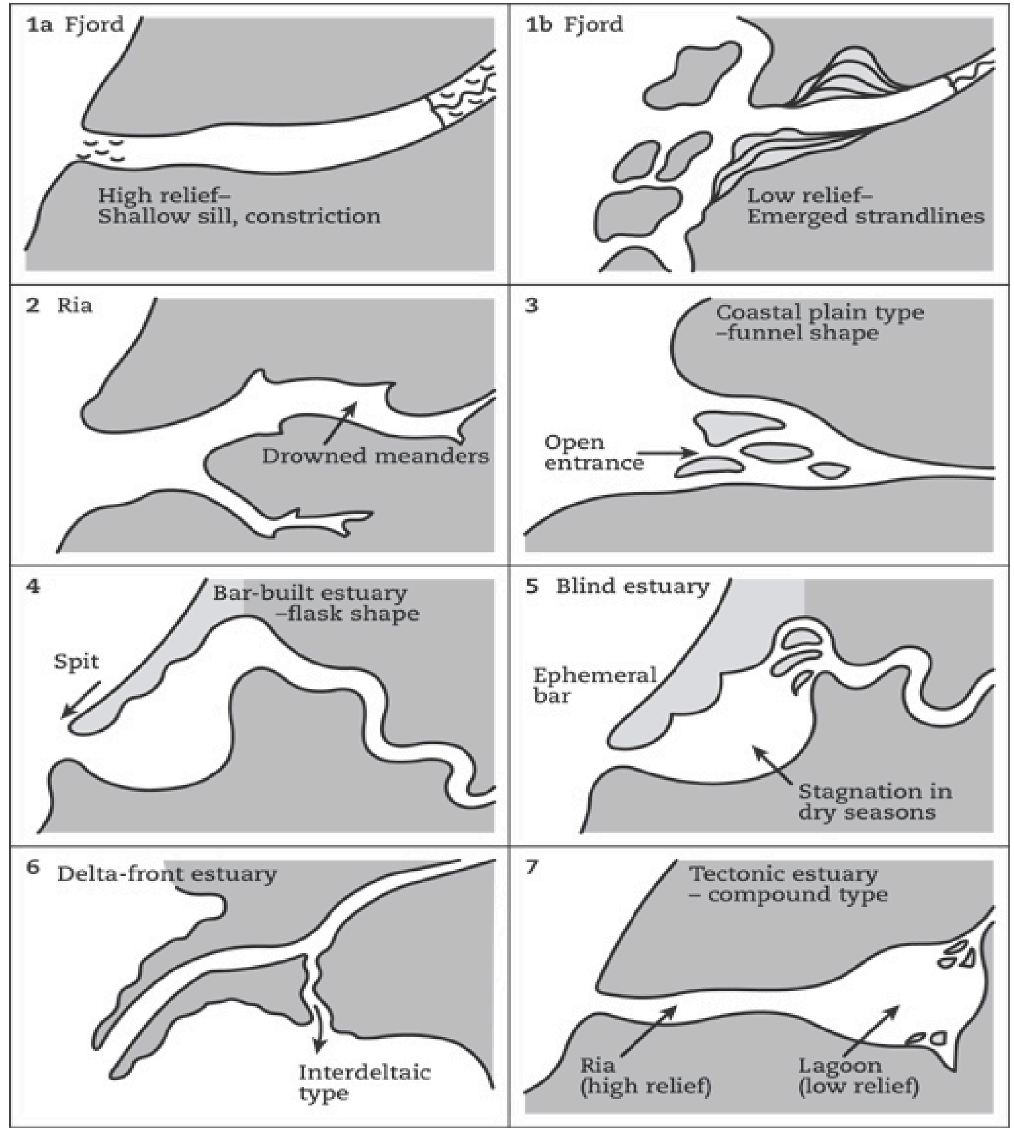
Geomorphic context river mouths

- Most river mouths have estuaries, which type depends on the relative importance of sea (lake) and river:
  - open entrance: Fjord, ria, coastal plain (funnel shape)
  - constricted entrance, bar built, blind (Var)
- Delta's develop with high solid discharges



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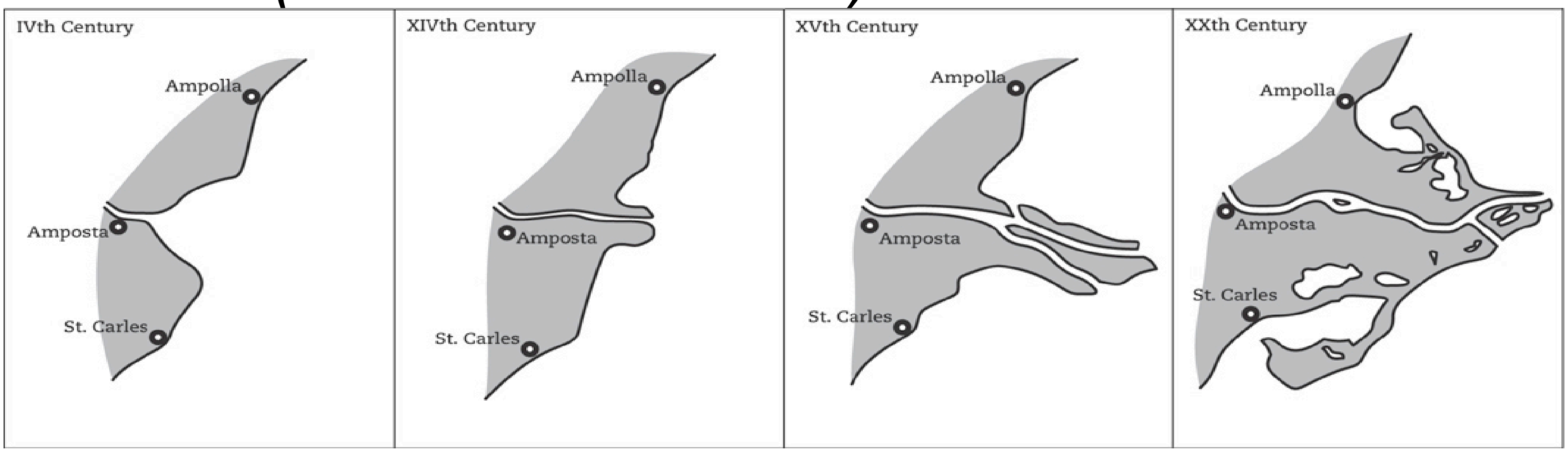
Geomorphic context river mouths

- Rivers with high sediment load:
  - in a first phase fill up the drowned valley
  - then deposit sediment beyond the coastline, creating the delta *(from Greek letter Δ)*



Evolution of the EBRO river mouth (Spain), from estuary to delta

- When rivers have rather low sediment load, their estuaries remain as such

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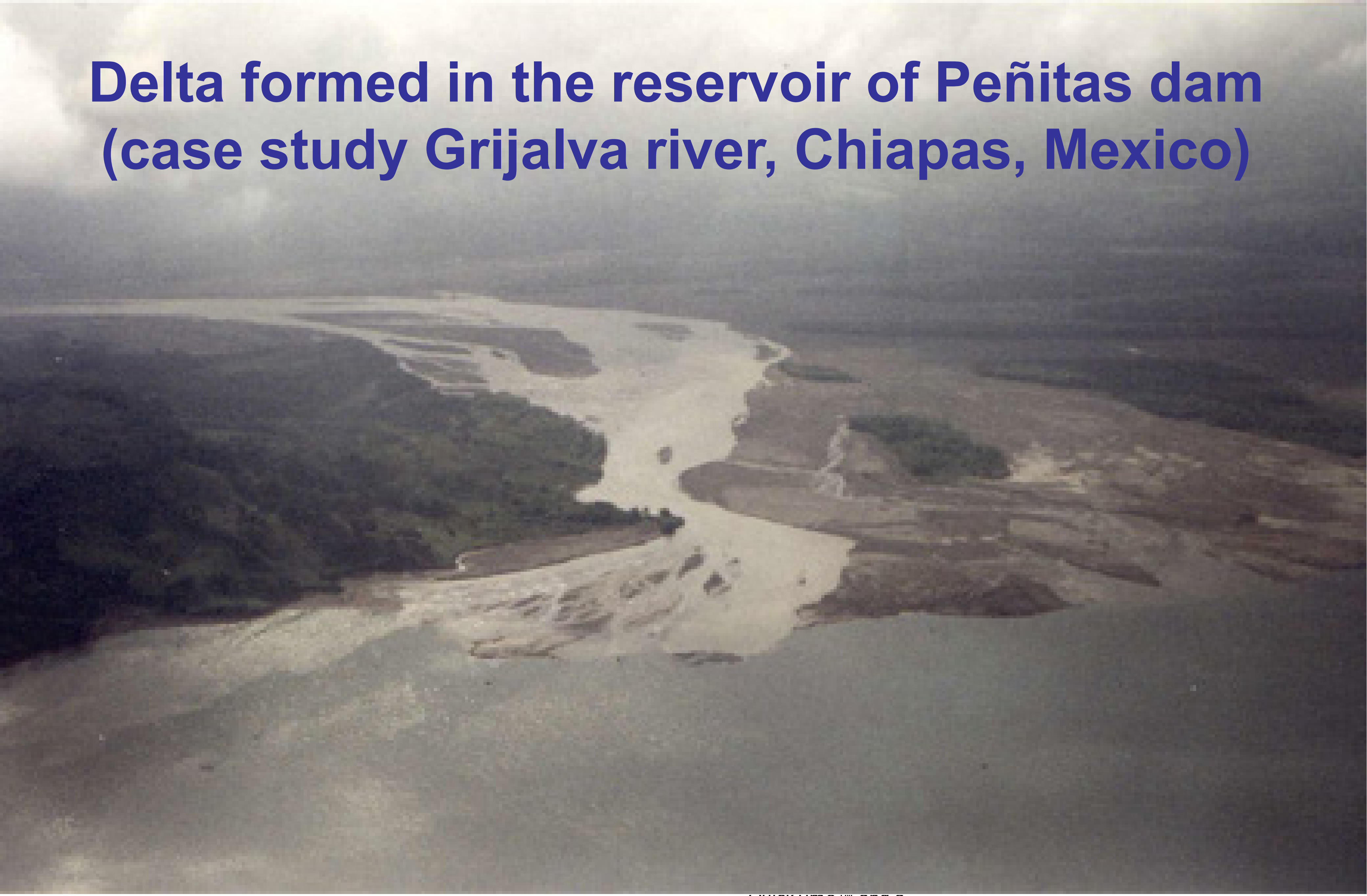
Delta formed in the reservoir of Peñitas dam (case study Grijalva river, Chiapas, Mexico)



Impacts of climatic changes

- Climate has always changed
- Over the past 3000 years, the final phase of the Holocene, climate has been exceptionally stable
- On the short term, recent climatic changes mainly affect the upper catchments
- Changes in climate and hydro-meteorology affect soil erosion, hydraulic regime (discharges and sediment transport) and evolution of the river courses
- In the Holocene period, the variation in sea level (±125 metres) strongly affected coastal rivers

Geomorphic context - Conclusions

- Today, most rivers and streams still experience the influence of morphologic changes induced by natural factors : tectonic, climatic, hydrologic, sedimentological, and other
- Some rivers have reached a kind of ‘maturity’, other not yet an equilibrium
- ***<u>Consequently, one (and certainly the river engineer) should acknowledge that rivers may not be managed or trained if their natural evolution is not properly recognised</u>***

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Geomorphic context - Conclusions

- River projects should start with a diagnostic phase in which the geomorphic situation has to be central
- The study should evaluate the influence of human activities on the morphological changes (morphological impact assessment)
- River engineering must take into account the likely river "response" to the project, so that it would remain effective even when new morphological changes would appear

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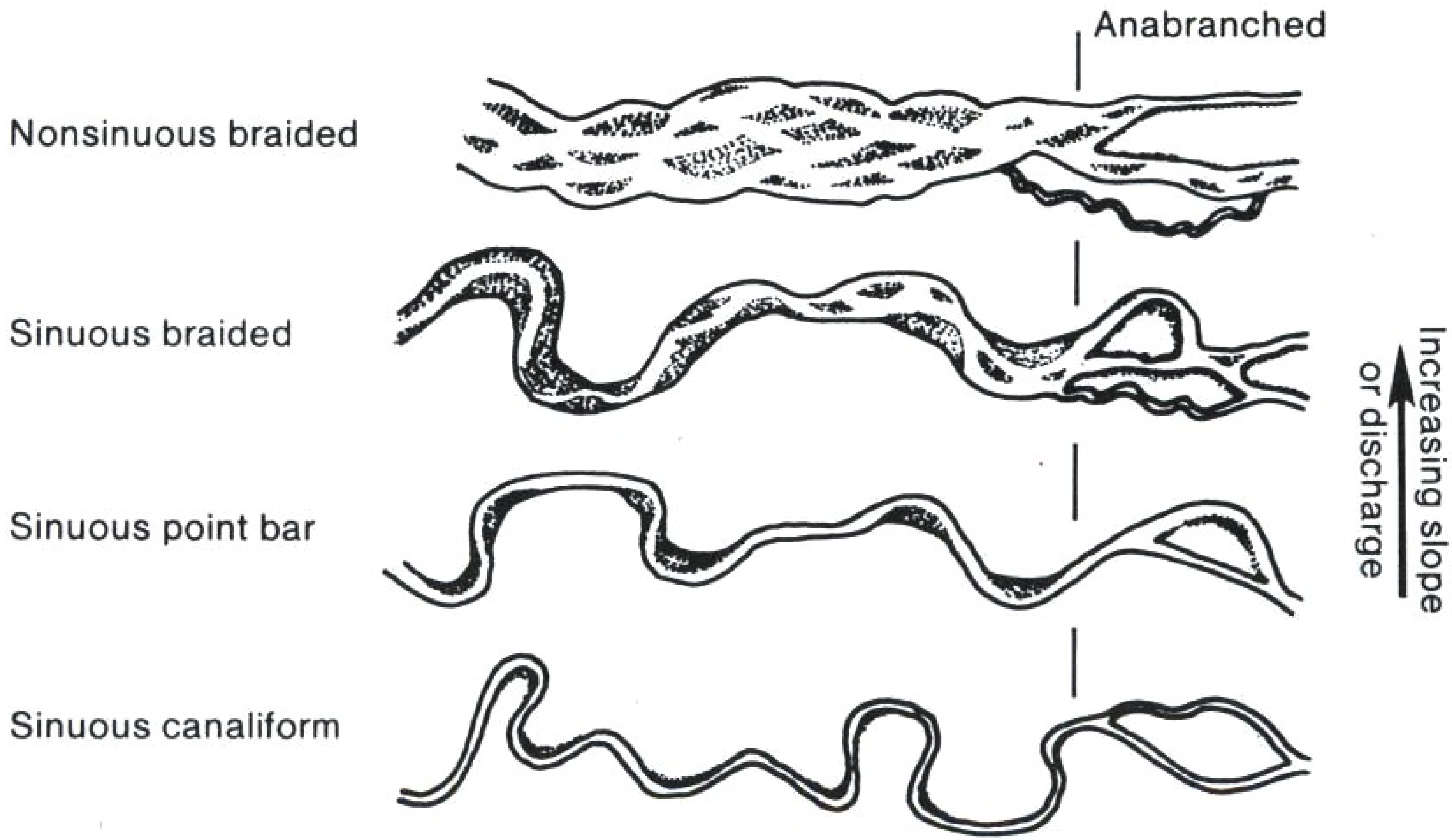
Geomorphic context - Conclusions

- River engineers should recognize all the processes responsible for the morphological changes, not only hydraulics and sediment transport
- The morphology of a river course must be understood through the processes, not by making river categories
- Developing specific tools tools per river category is dangerous, because reality is much more complex than theory

Morphology of rivers

- Typology of rivers can be based on the plan view shape of the river course, on the existence and types of sandbars and islands
- The physical processes responsible for developing one or another type are still not understood; however, engineering can not wait till this knowledge would become available
- Besides (or instead of) classifying rivers morphologically, one should start with a diagnostic, based on all available data and information

Typology of rivers based on plan view



River classification (Brice, 1983).

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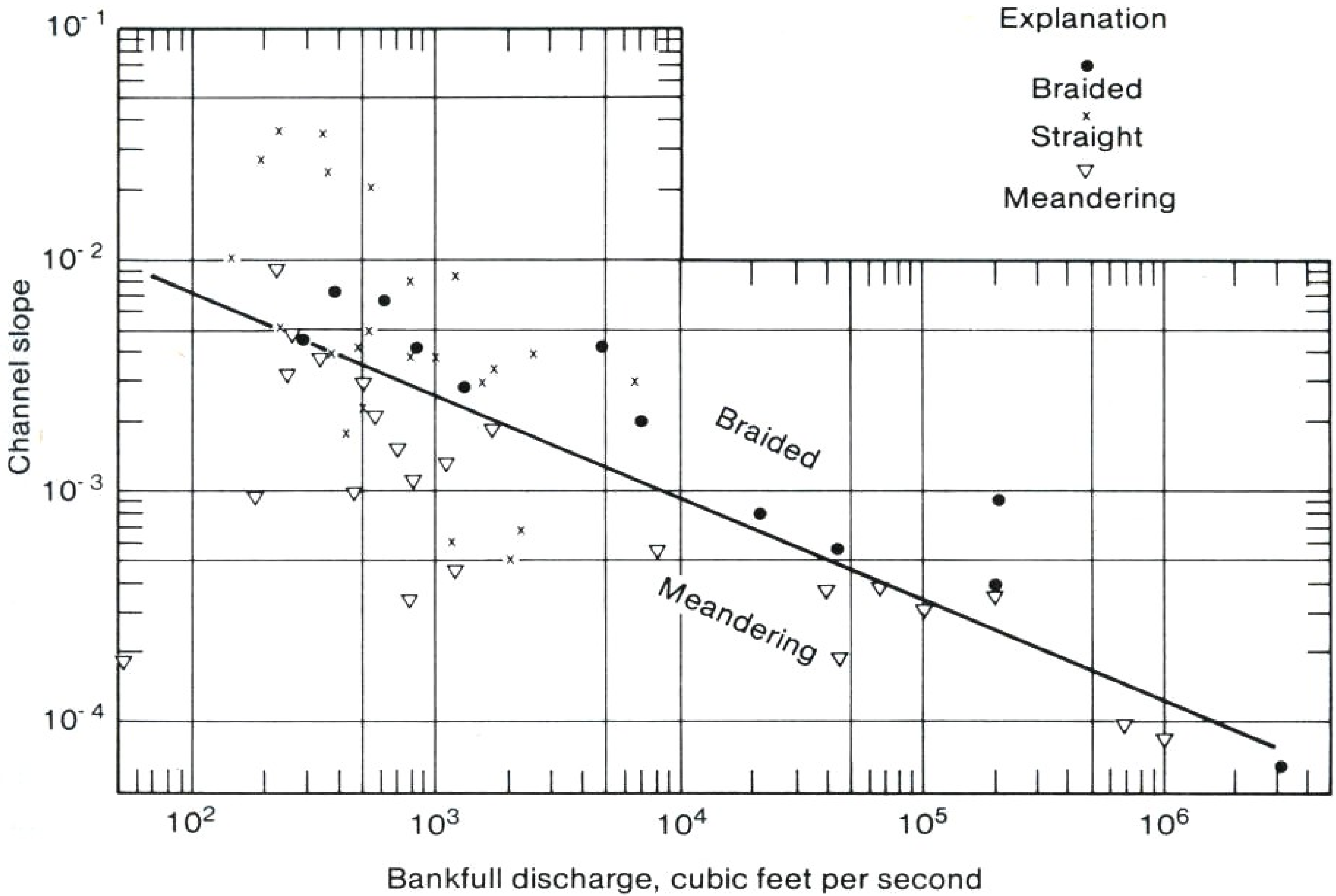
Braided or meandering?

- There are no universally accepted theories to explain the reasons for braiding and meandering of rivers
- Well accepted is the influence of discharge and slope on the channel patterns, while the role of sediment transport is not clear
- Analysis of a large number of rivers in terms of channel slope and bankfull discharge was made by Leopold and Wolman (1957)
- Straight rivers however, as given in the graph, can only exist due to the geomorphic setting

Braided or meandering?



Values of slope and bankfull discharge for natural channels as well as a threshold distinguishing braided from meandering rivers (Leopold and Wolman, 1957).

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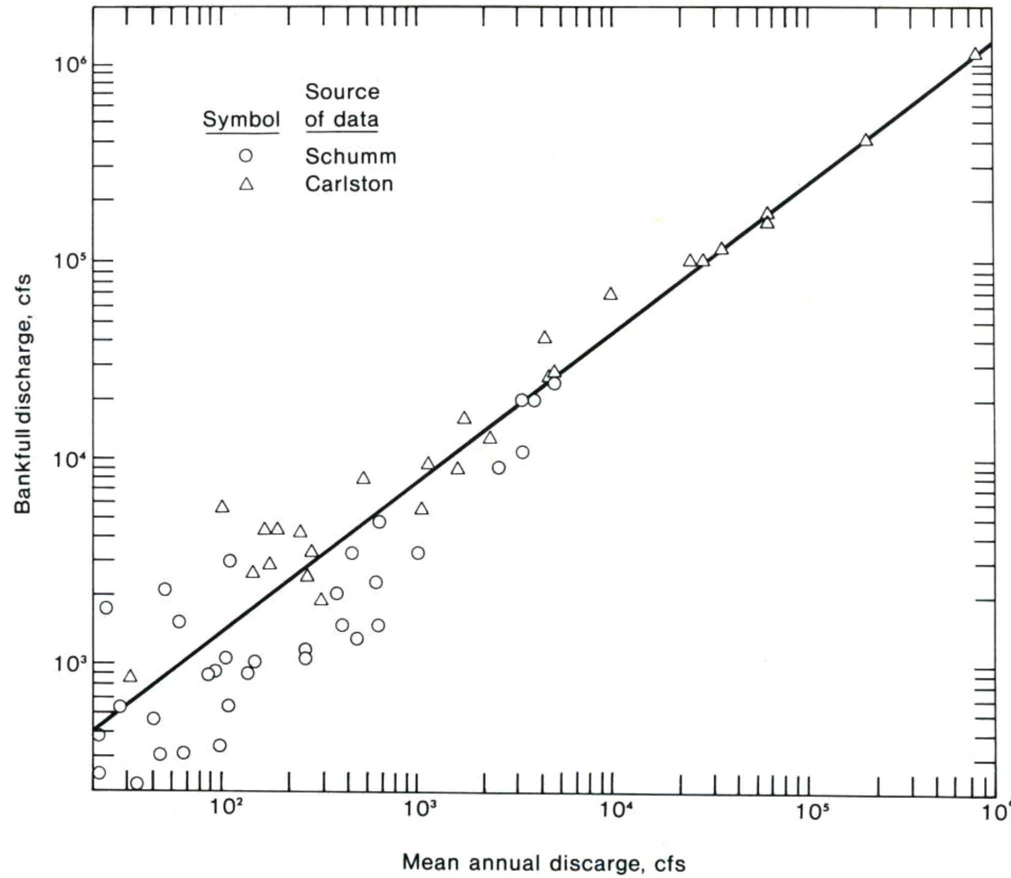
Braided or meandering?

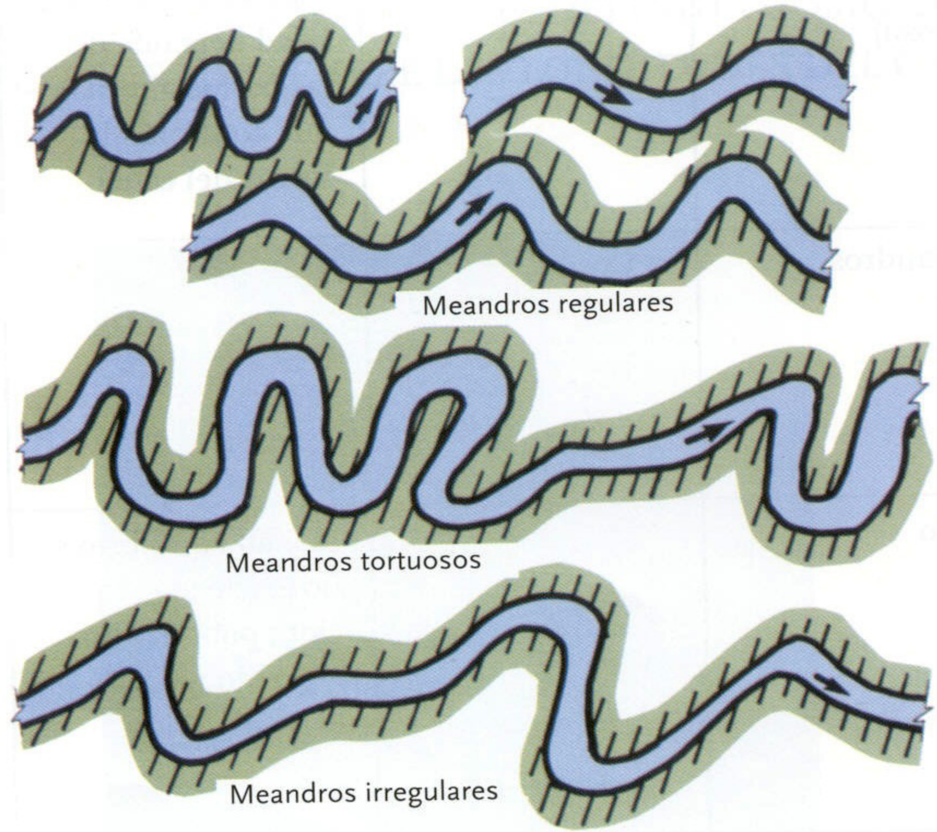
- Many experts believe that exists a channel-forming discharge, usually taken as bankfull, somehow related to mean annual discharge



- We however believe that in most cases, the river morphology depends on the variation with time (flood shape and history)

Meandering channels

- Channels may be classified depending on the regularity of the meanders
- Regular meanders exist, though they are the exception
- Shape of tortuous and irregular meanders is mostly caused by differences in riverbed and banks composition (geology and relief)



(Fuente: "Erosion and Sedimentation in the Nepal Himalaya" Vic Galay, 1987)

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Meandering channels

Ichilo river, Bolivian Amazon

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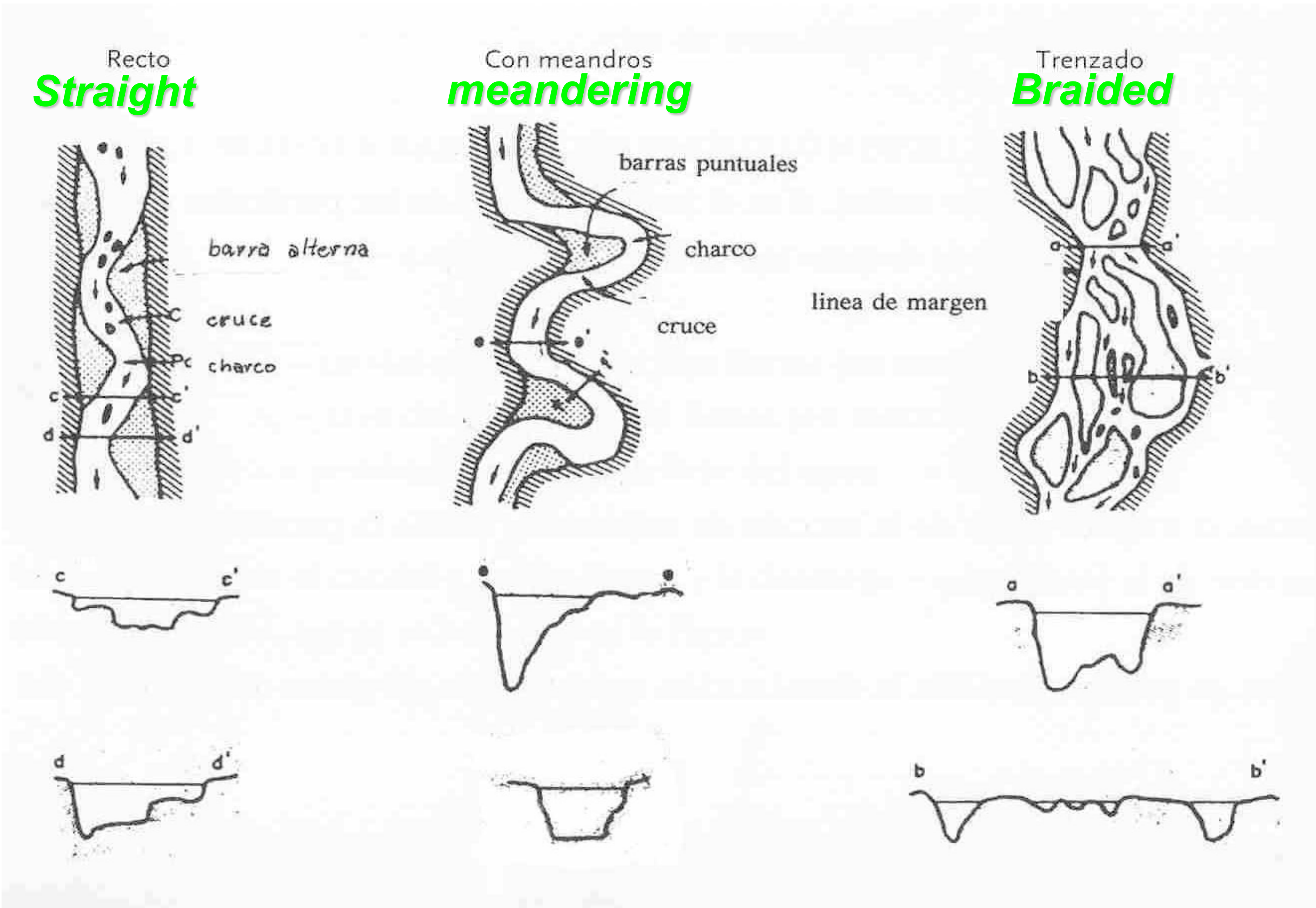
Meandering channels

Shape of river courses



Braided rivers (Pirai river, Bolivia)

- The islands are unstable and change shape at each flood
- Several channels are present in all cross-sections
- Some bars remain stable during a sufficient time to allow vegetation growing
- The riverbanks have irregular shapes

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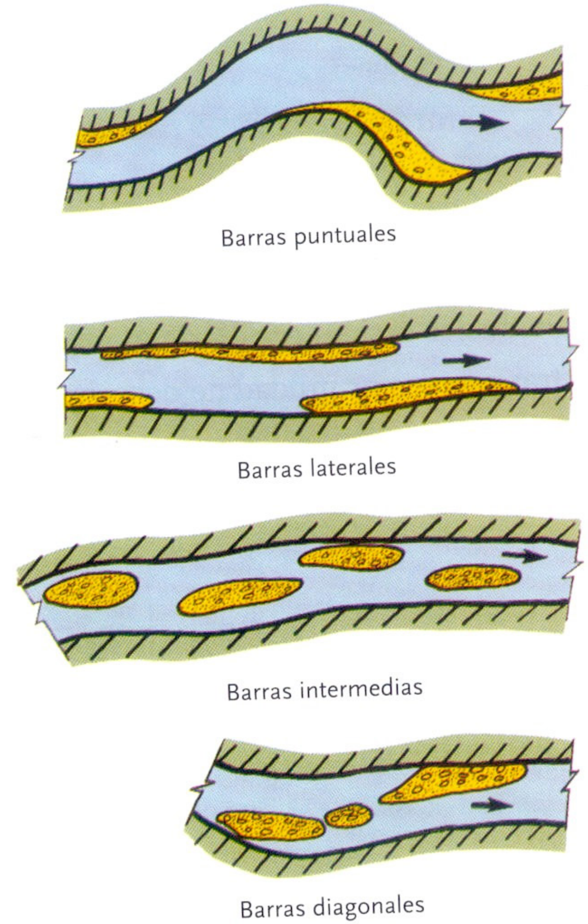
Channel bars

- Point bars are located at the inside of the bend
- Side bars, adjacent to the banks, usually in straight channel reach
- Mid-channel bars,with no connection to either bank
- Diagonal bars, extending across a channel at a definite angle to the river bank; flow spills over the bar in the form of a riffle (or rapid) which can be seen in the Var



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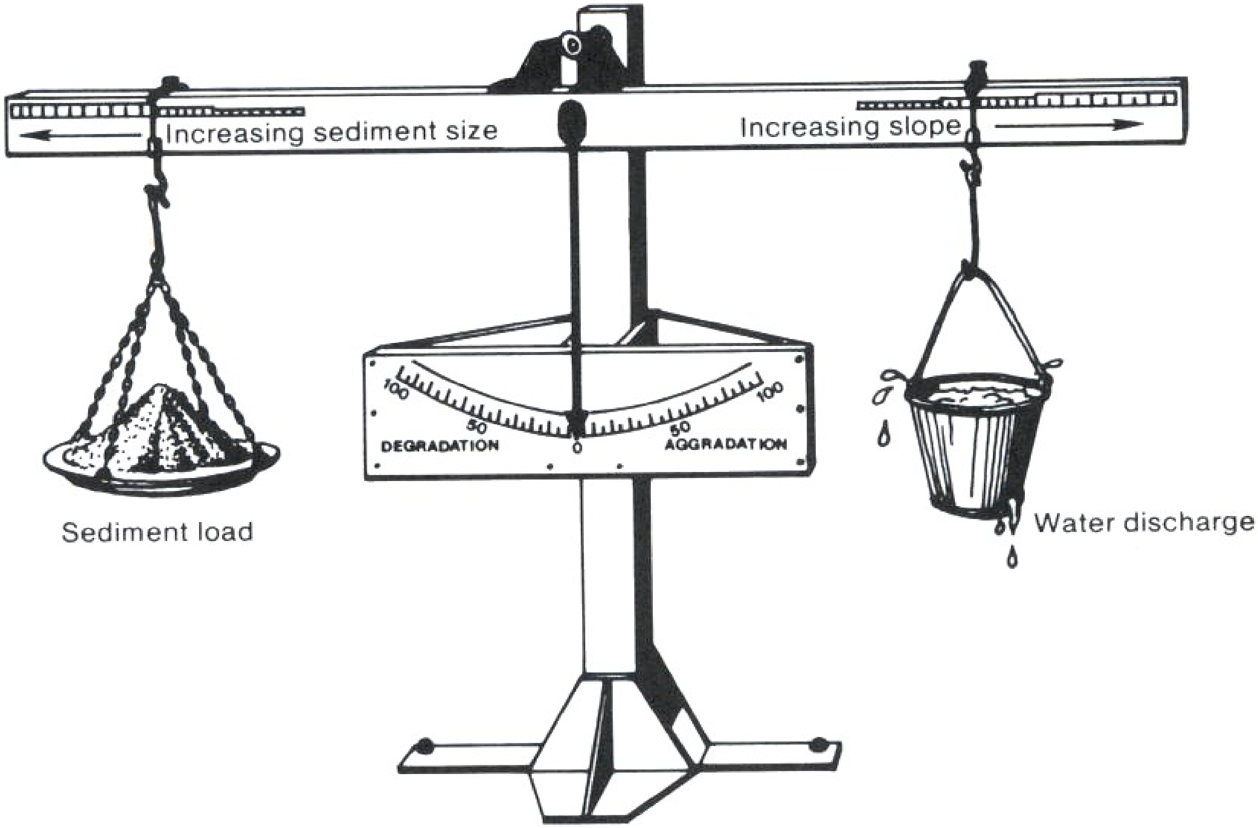
Channel equilibrium



Stable channel balance (after Lane, 1955).

There is a long-term adaptation of the river morphology to flow and sediment. Lane showed that product of the flow discharge times flow slope is proportional to the product of the sediment load times sediment size

This can be used to asses the river response to changes in hydrologic and sedimentological regime of a river (e.g. Var)

Morphology - Conclusions

- Most important is to comprehend how the observed river morphology was created, so that could be ***set up a good concept, before constructing physical or numerical models***
- To comprehend fluvial processes, we do not need to know all the mathematical formulations, nor understand all the physical processes
- Understanding the mechanisms governing the river behaviour must go through field surveys, observations and measurements which became extremely powerful with the new technologies


END OF RIVER MORPHOLOGY