Channel Avulsion and Sediment Aggradation Rate Controls on Fluvial Sandstone Body Stacking Patterns, Miocene, North Spain*

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Abstract

Determination of the rates of processes responsible for the creation of the architecture of fluvial channel sandstone bodies is generally difficult. However, in the Miocene of the Ebro Basin of North Spain a detailed magnetostratigraphy of a lacustrine succession in a largely undeformed basin-fill provides a means of determining the rate of aggradation of coeval fluvial deposits. The basin was endorheic, so in order to maintain an approximately constant slope of fluvial profile, lacustrine and fluvial aggradation need to have been in balance: for part of the fluvial succession in the early Miocene an aggradation rate of approximately 90 mm/ky can be determined. The succession was formed by a terminal distributive fluvial system (DFS) which can be completely mapped over an area of 1,800 km^2 at the same stratigraphic level. Rates of sediment supply to the DFS can therefore be estimated to be approximately 162,000 m^3/y. This is equivalent to a sediment load of 13.6 kg/s for the Miocene river supplying the DFS.

A timescale for the development of the architecture of channel sandstone bodies and alluvial plain deposits can also be derived. The vertical interval between channel sandstone bodies at a point on the DFS is equivalent to the time interval between events when the river channel occupied the same position on the DFS following episodes of avulsion. These avulsion reoccupation intervals vary from approximately 130 ky in medial areas to 270 ky in distal locations, reflecting the increased spacing of channels distally across the radial planfom of the DFS.

In a system like this a decrease in the proportion of suspended load in the system would result in a decrease in aggradation at the toe of the DFS and hence a relative increase in the proportion of channel deposits (and hence connectedness) at any point across the system. The proportion of channel deposits decreases distally and therefore the relative position on the DFS is also important. The architecture - and sandstone body connectedness - in an endorheic basin is hence determined by sediment supply and in particular the proportion of bedload and suspended load

supplied to the system. Differential subsidence across the basin may modify the profile, but accumulation in an endorheic basin is largely independent of regional subsidence.

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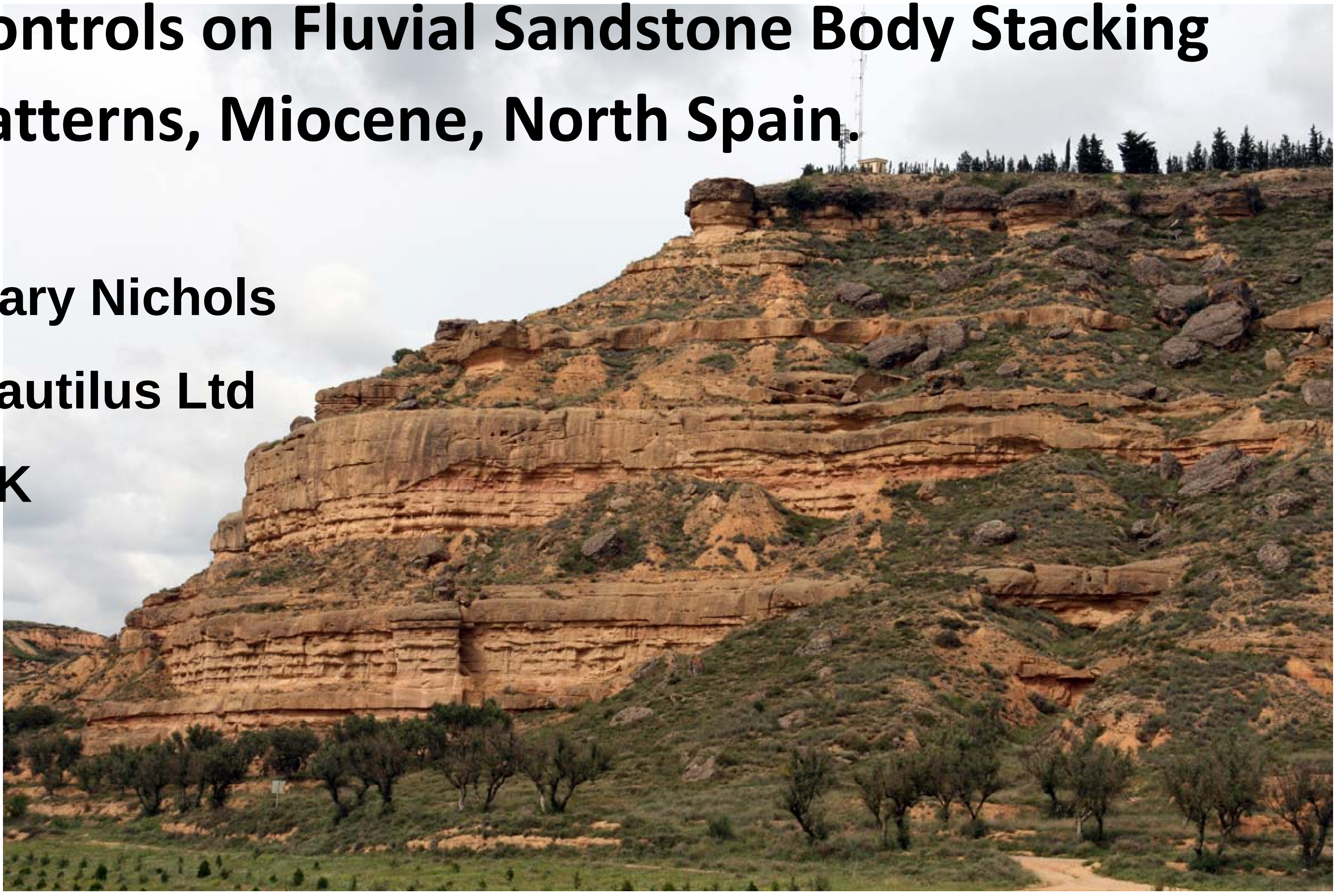

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Question: how long does it take to deposit a succession of channel and overbank deposits like this?

Old answer: I have no idea!

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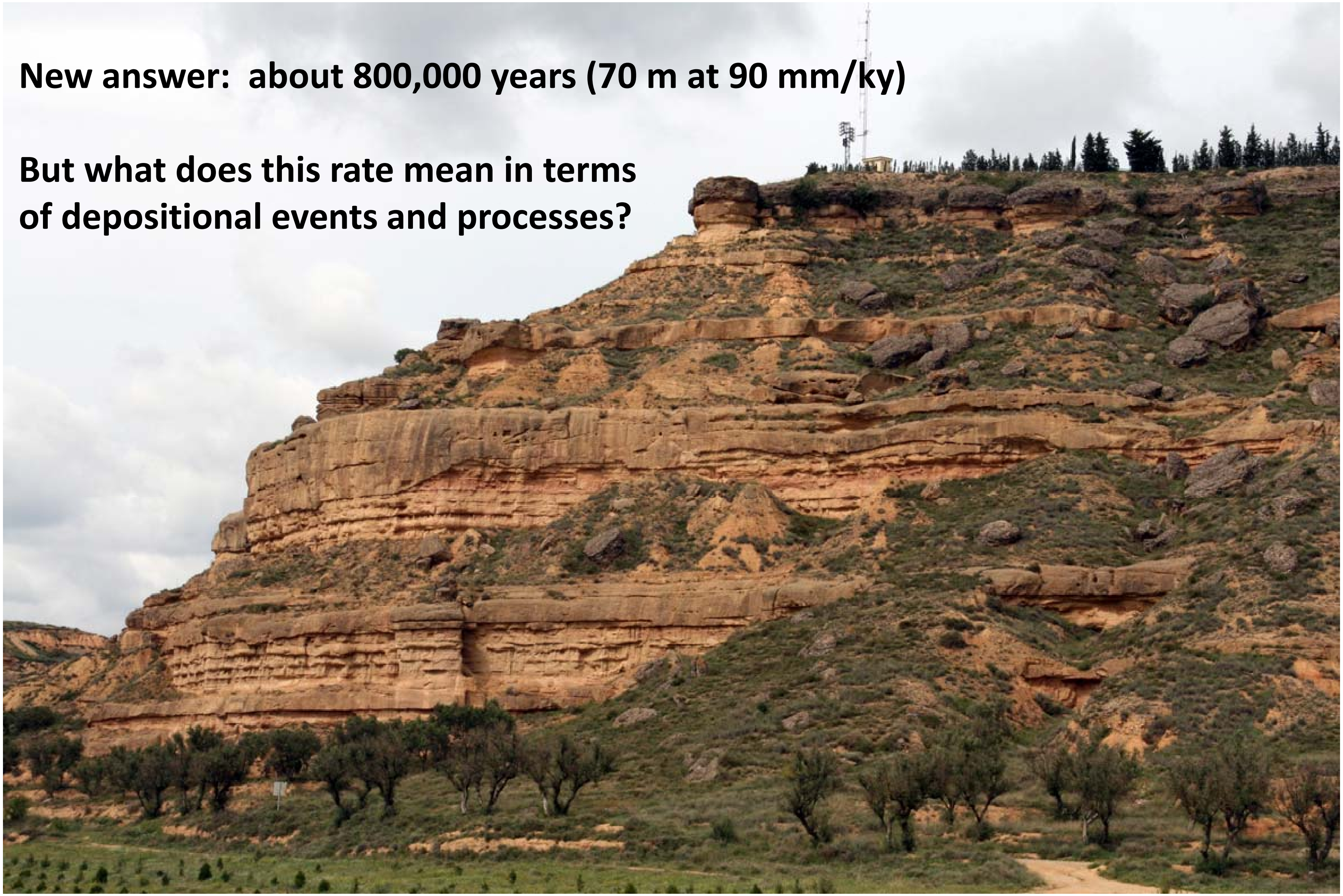
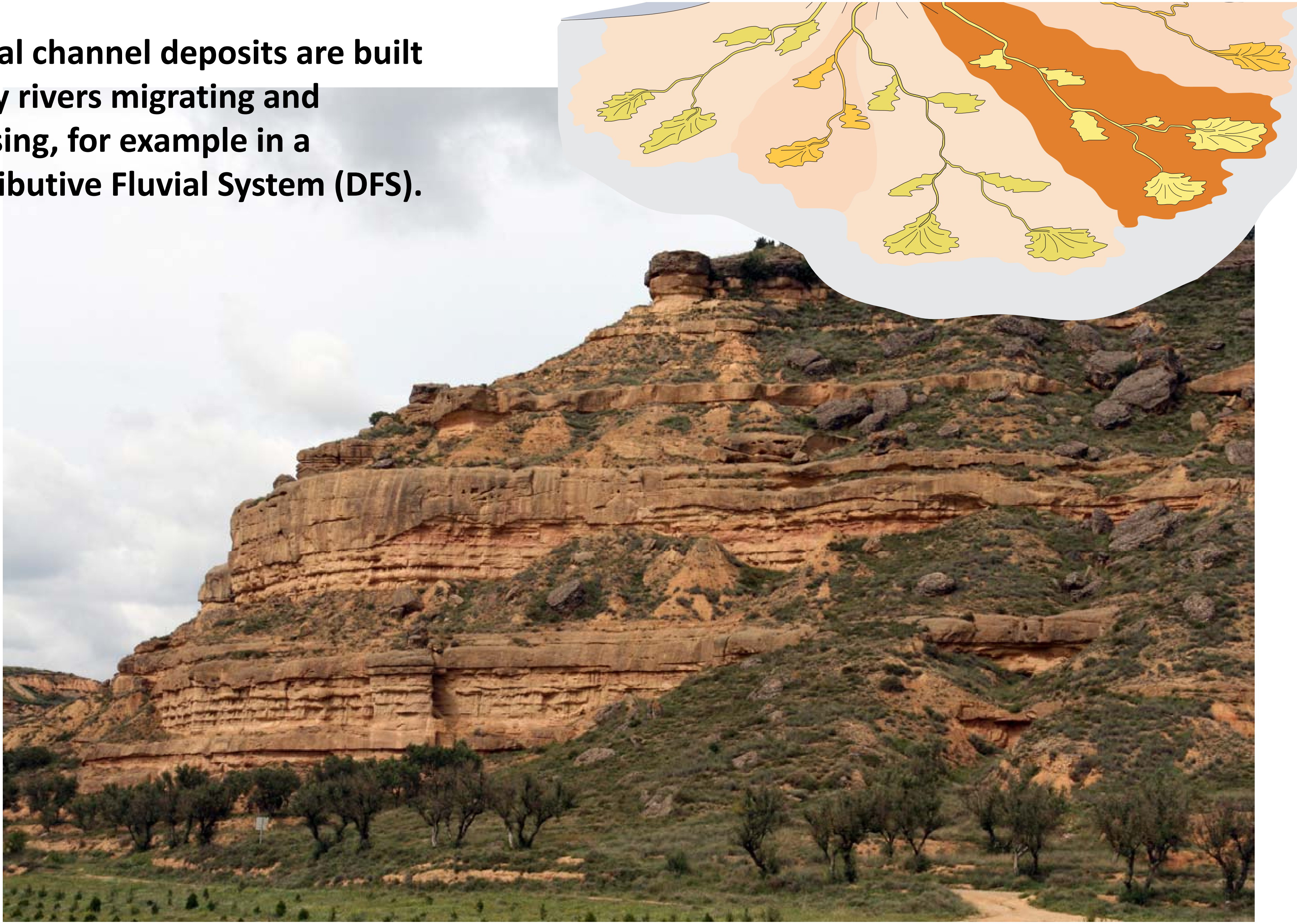


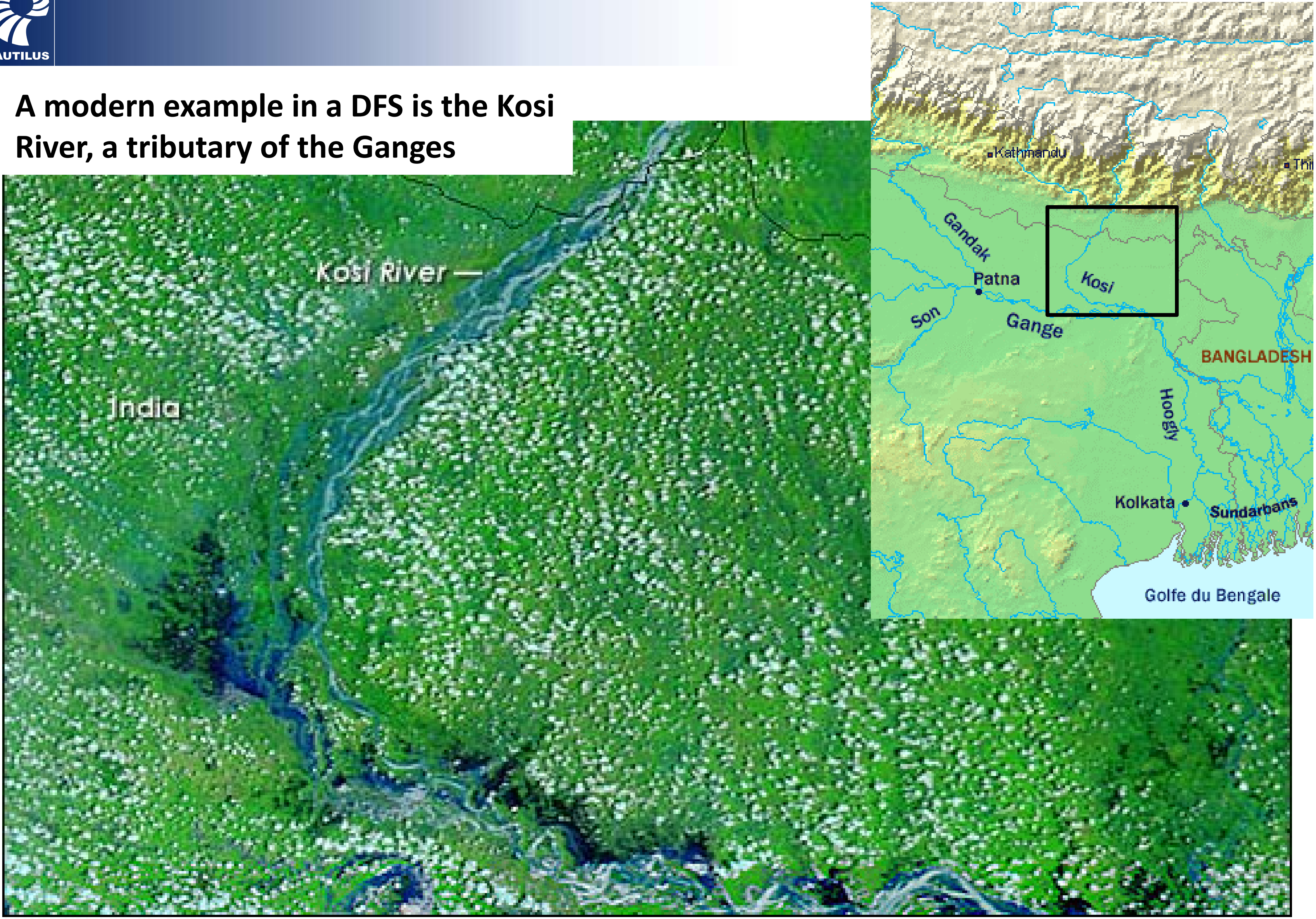
New answer: about 800,000 years (70 m at 90 mm/ky)

But what does this rate mean in terms of depositional events and processes?

Fluvial channel deposits are built up by rivers migrating and avulsing, for example in a Distributive Fluvial System (DFS).



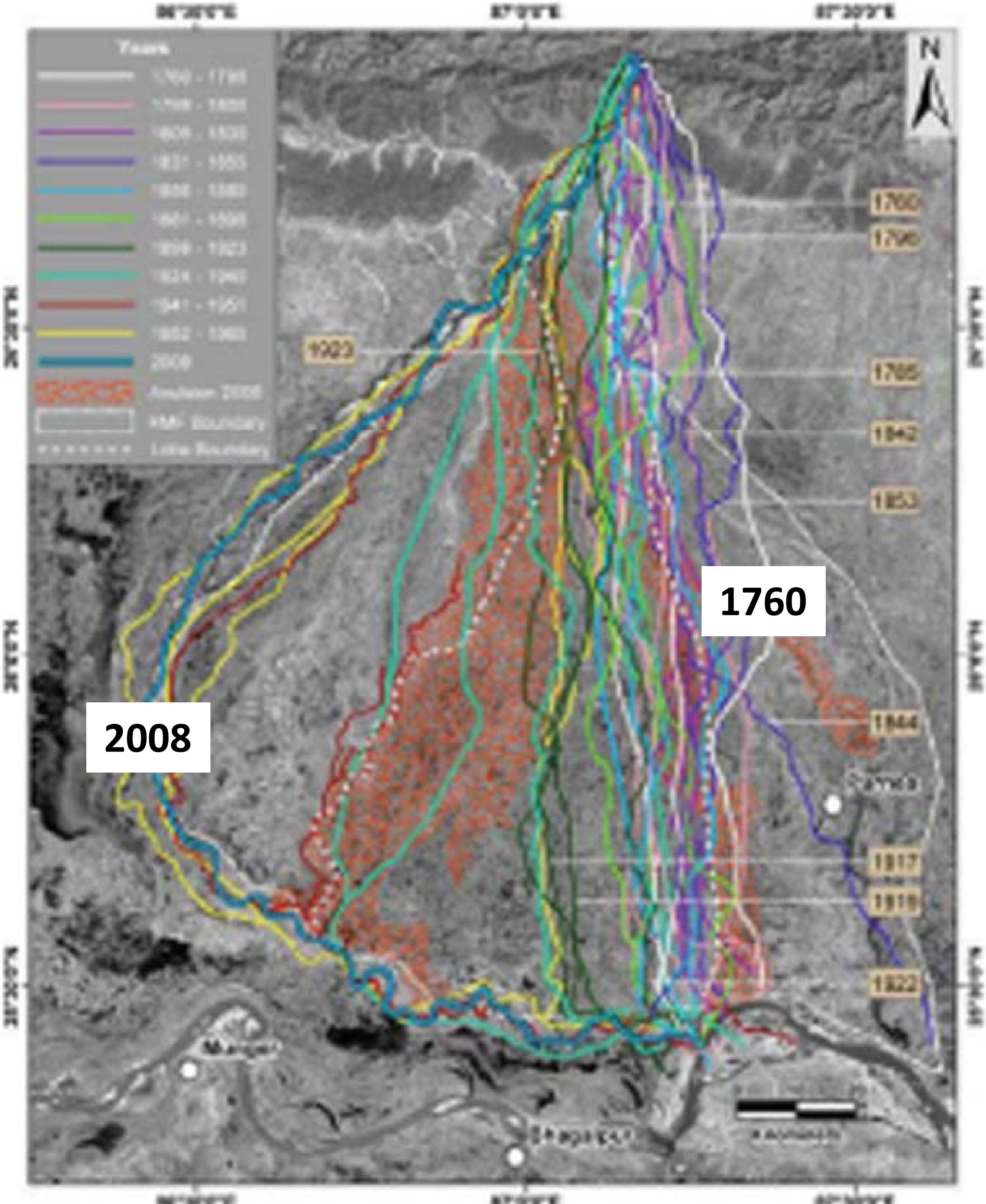
A modern example in a DFS is the Kosi River, a tributary of the Ganges



August 8, 2008

Channels on the Kosi River have migrated laterally across the Distributive Fluvial System since 1760.

Approx 100 km of lateral migration in 250 years



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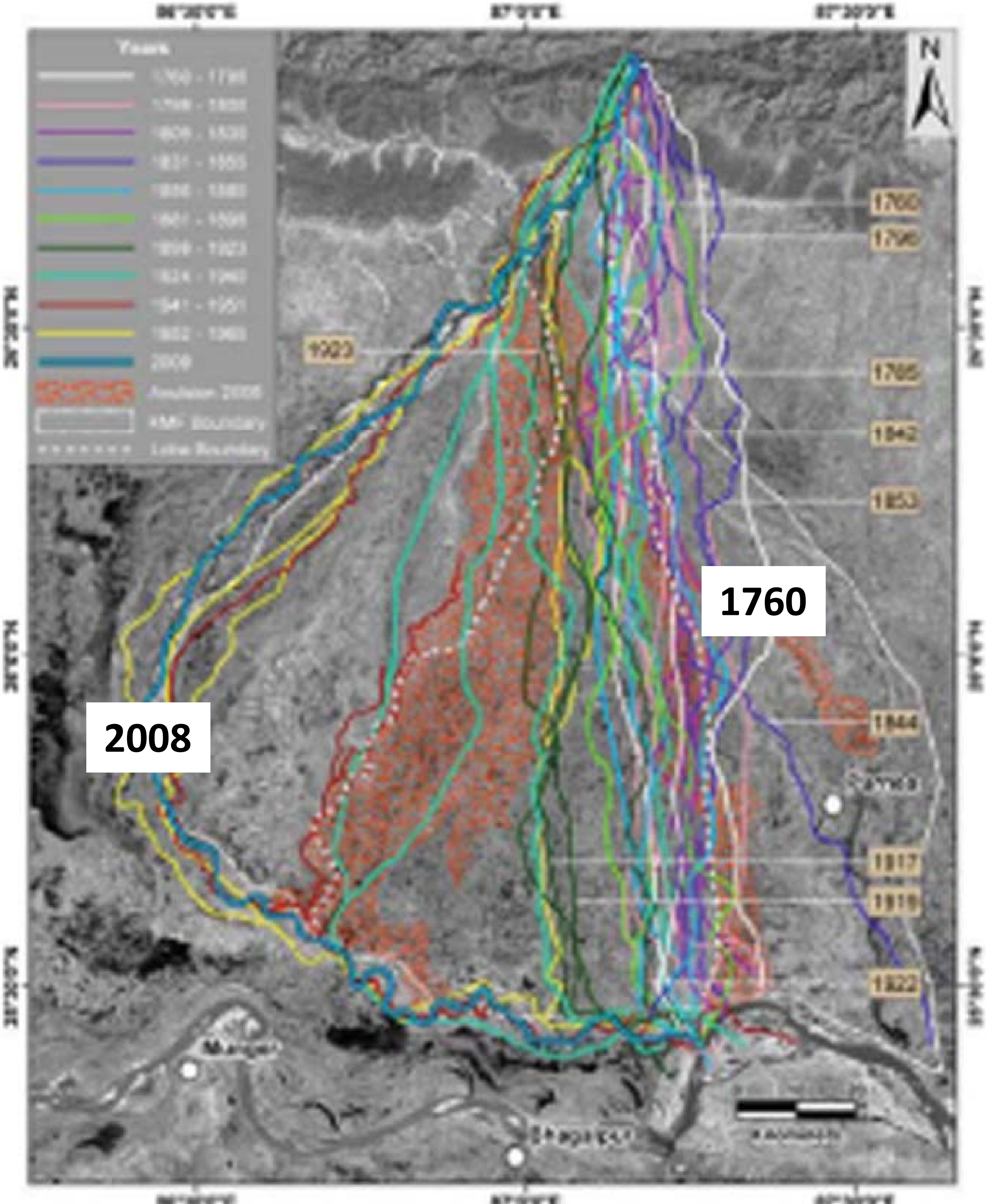
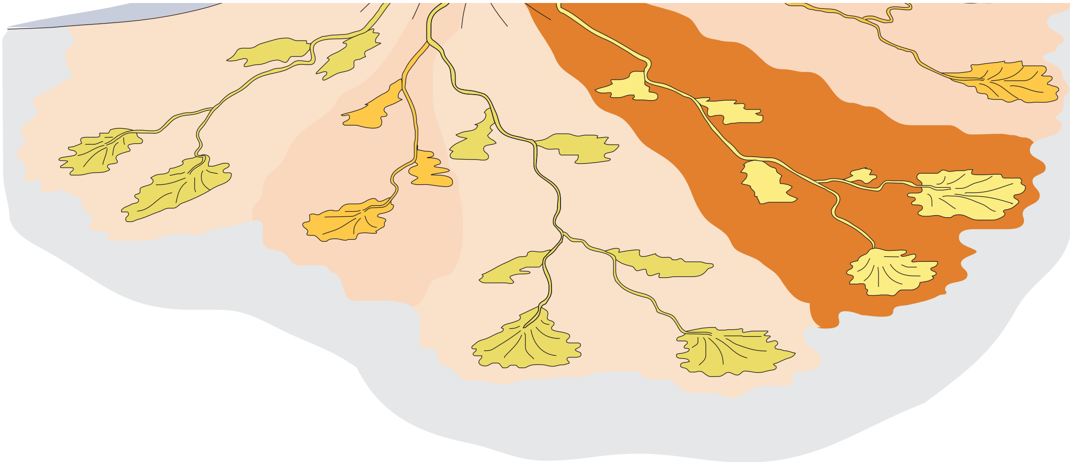
Approx 100 km of lateral migration in 250 years

But are these rates typical for the stratigraphic record of fluvial deposits ?



A fluvial succession aggrades where there is available accommodation.

Channels laterally migrate and avulse over the DFS, eventually returning to a former position



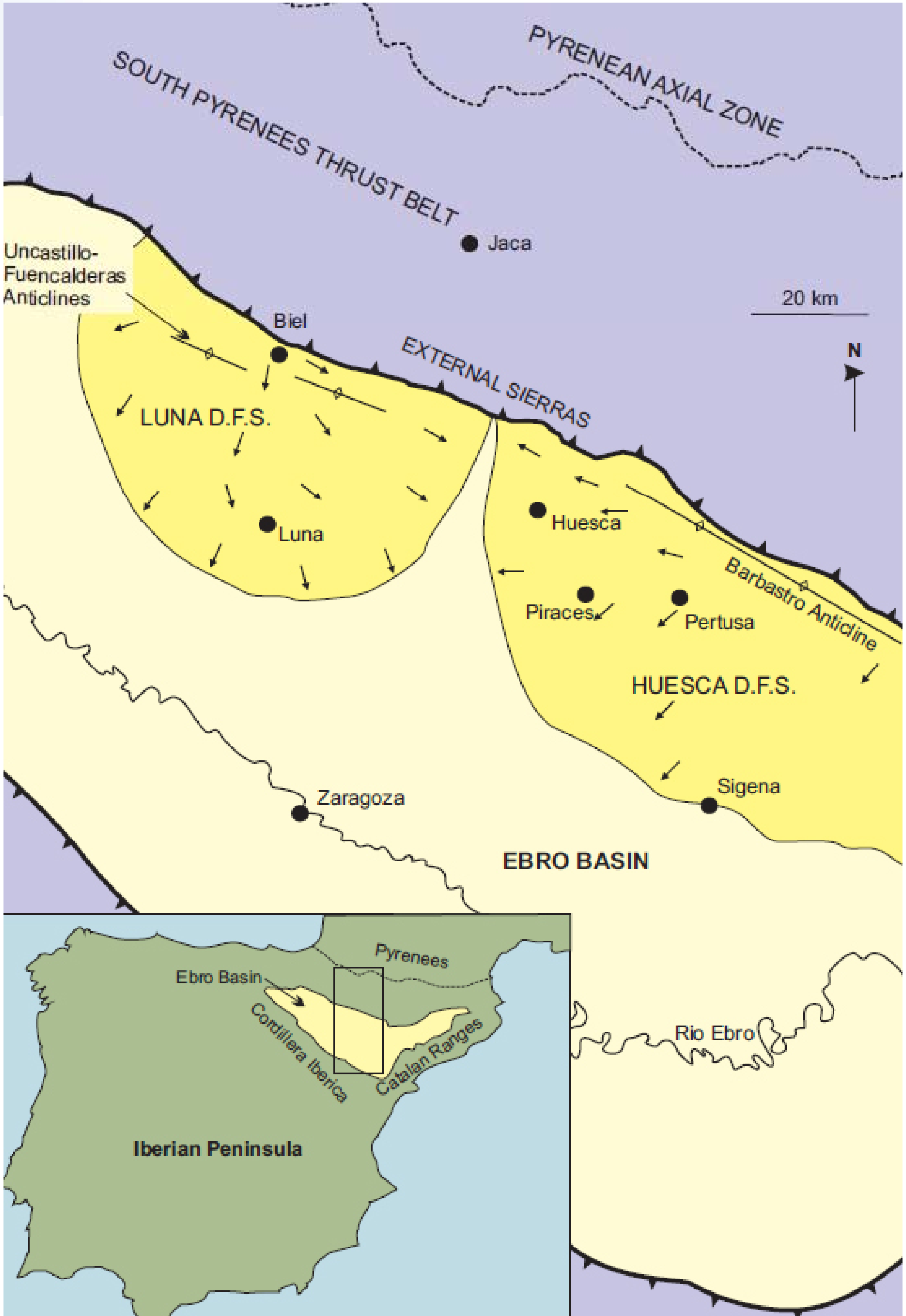
If the rates of aggradation are known, the frequency of return to former position can be determined.

Fluvial strata in the Miocene of the Ebro Basin provide a suitable case study.

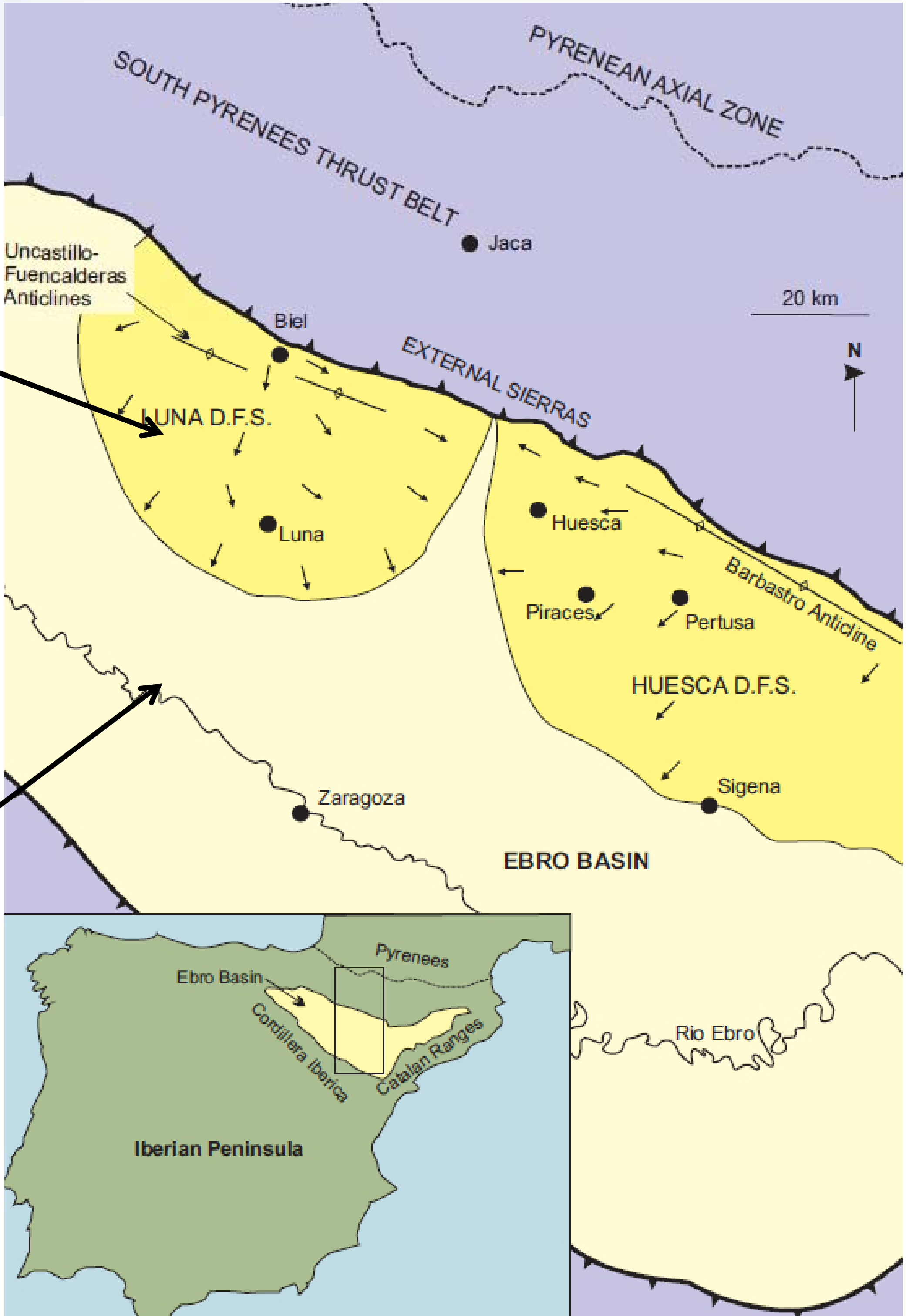
The Ebro Basin in northern Spain is the foreland basin of the southern Pyrenees.

The Cenozoic deposits are a thick succession of continental strata

The basin was endorheic – it had internal drainage and no connection to the sea



The Miocene deposits are undeformed and can be traced laterally over large areas



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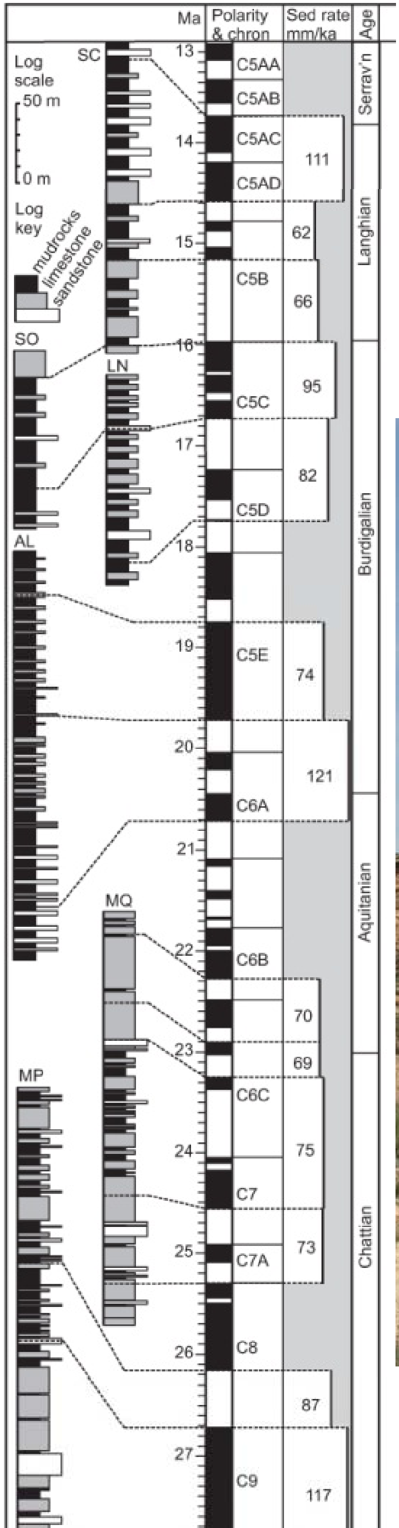
Reversals in lacustrine successions

A palaeomagnetic reversal stratigraphy has been established in the lacustrine succession by geologists from Barcelona *(e.g. Perez-Rivares et al 2002, 2004)*

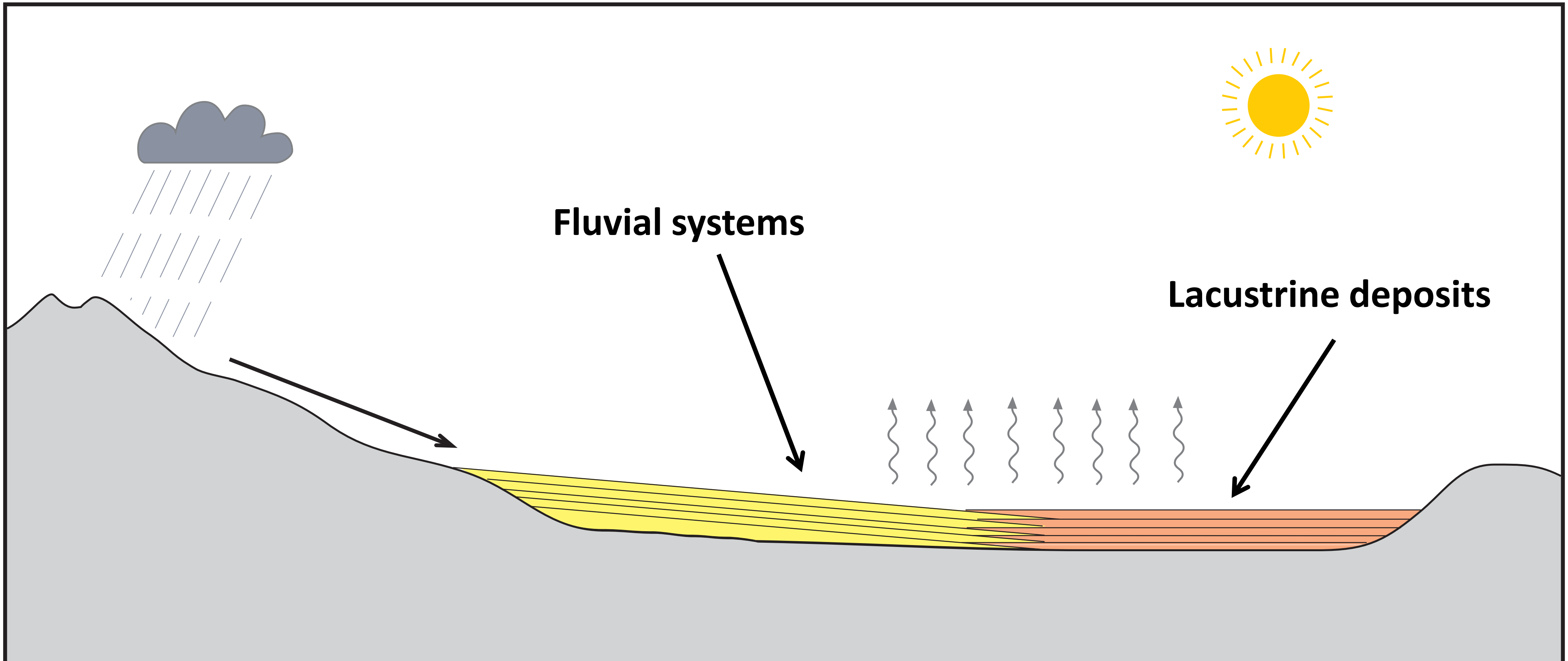


Semi-continuous record for 15 My in late Oligocene and early Miocene

Average rate of deposition = 90 mm/ky

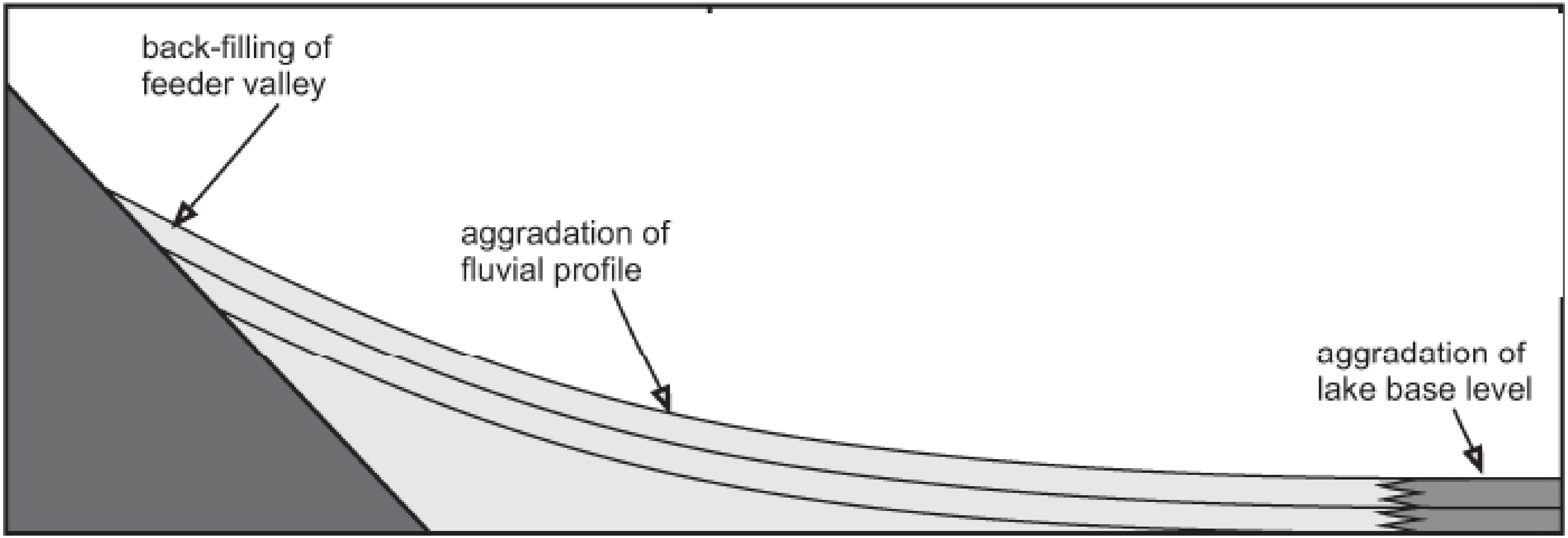
In a basin of internal drainage sedimentation results in aggradation of both fluvial and lacustrine deposits

Fluvial and lacustrine deposits should therefore aggrade at the same rate – an average rate of 90 mm/ky



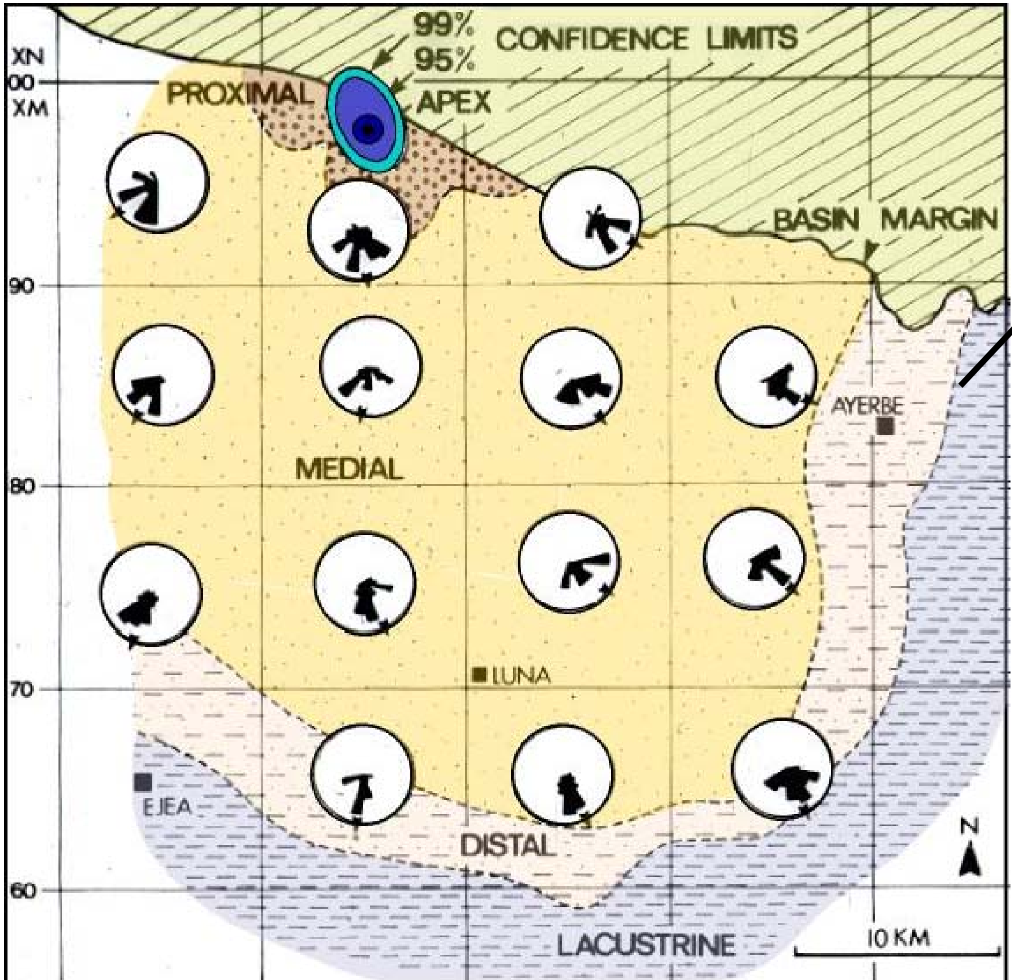
If there was any difference in the rate of aggradation of fluvial and lacustrine deposits the fluvial profile would change, resulting in changes in the fluvial architecture in a vertical section

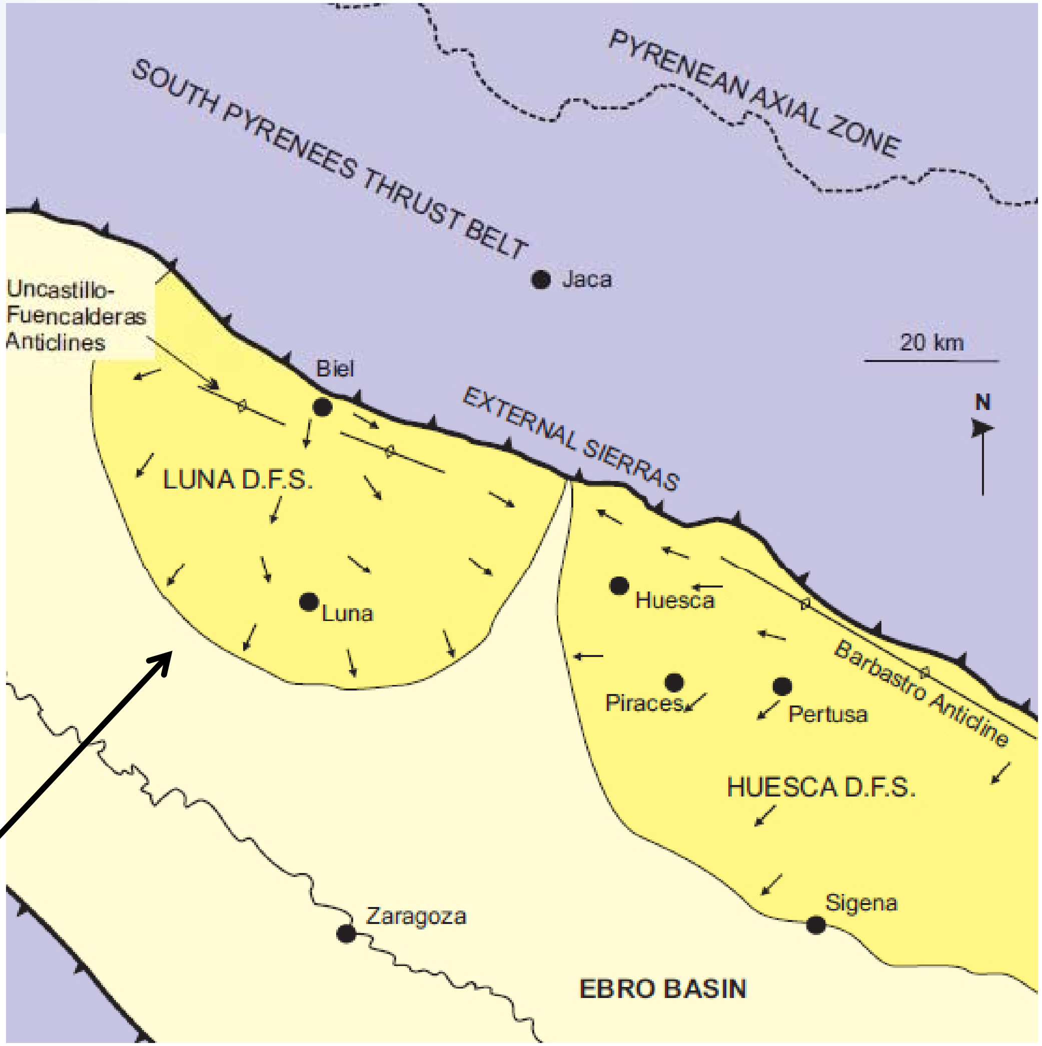
There is no sign of changes in fluvial architecture through >100 m of succession



The Miocene fluvial deposits have been mapped out as radial, terminal systems – the deposits of a Distributive Fluvial System

The Luna System





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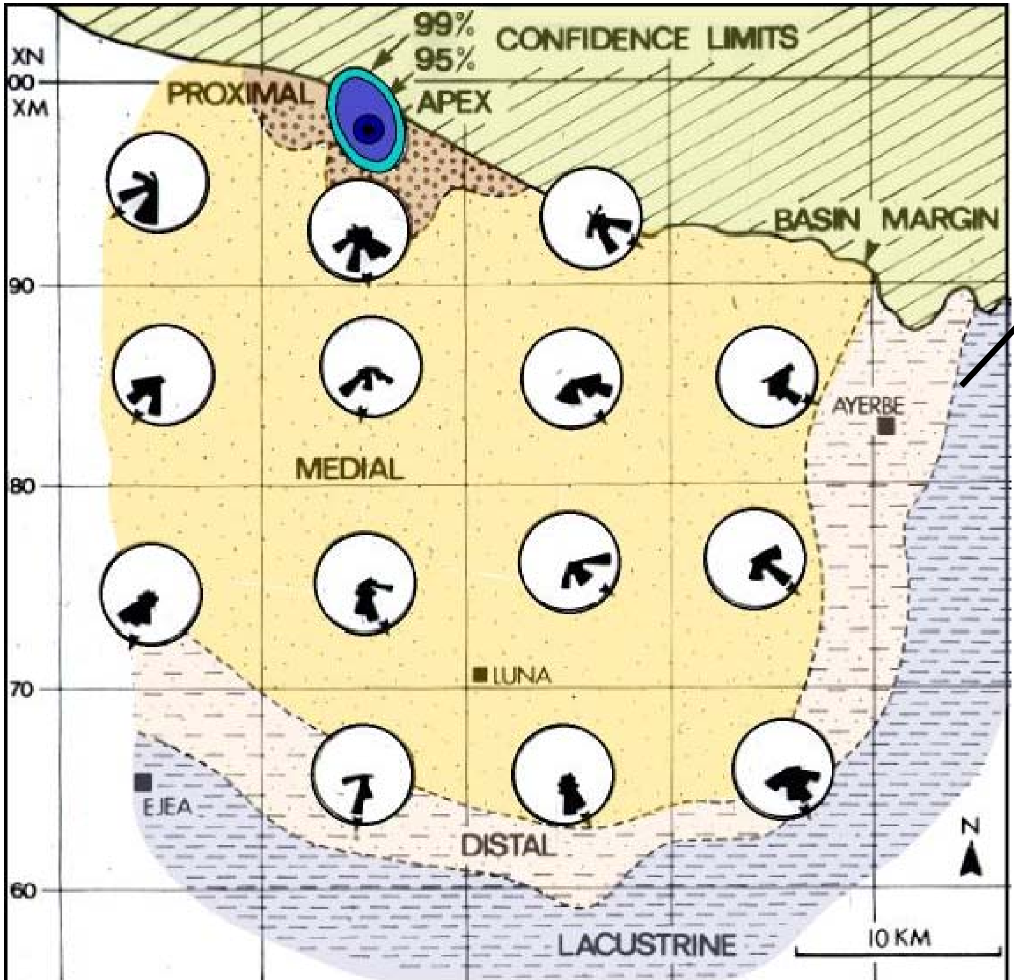
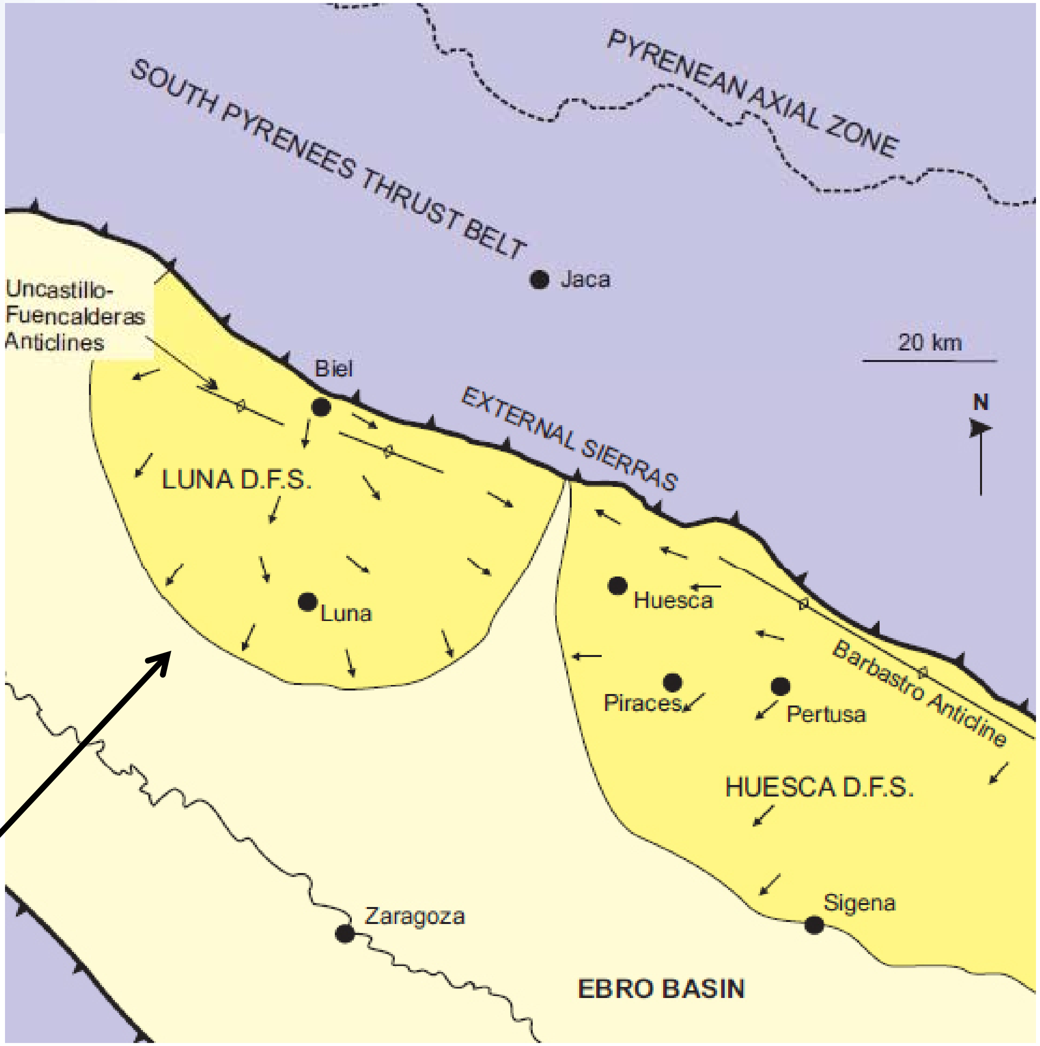


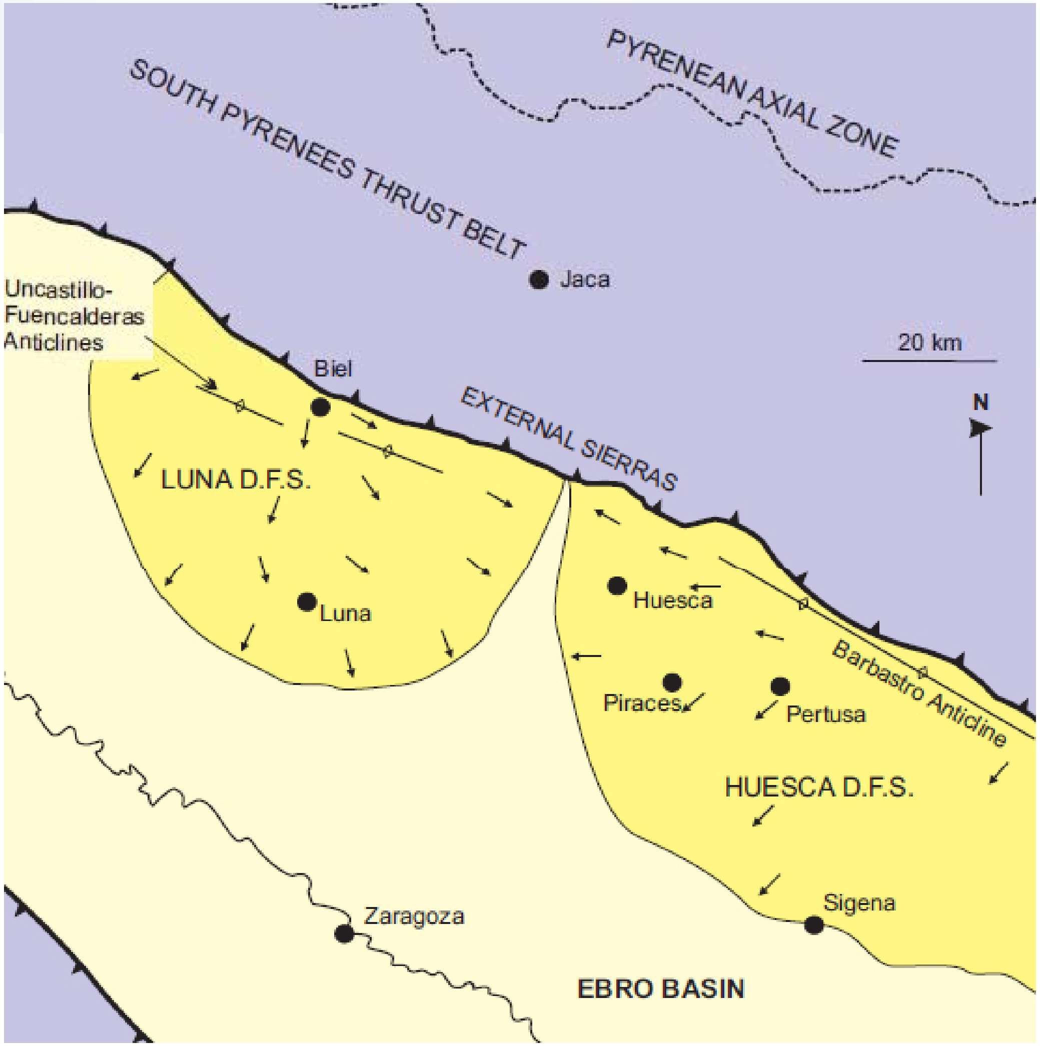


The area of the Luna System is mapped out as c. 1,800 km^2

At aggradation rate of 90 mm/ky the rate of sediment supply to the Luna System calculated to be 162,000 m^3/yr

Equivalent to a river sediment load of 13 kg/s

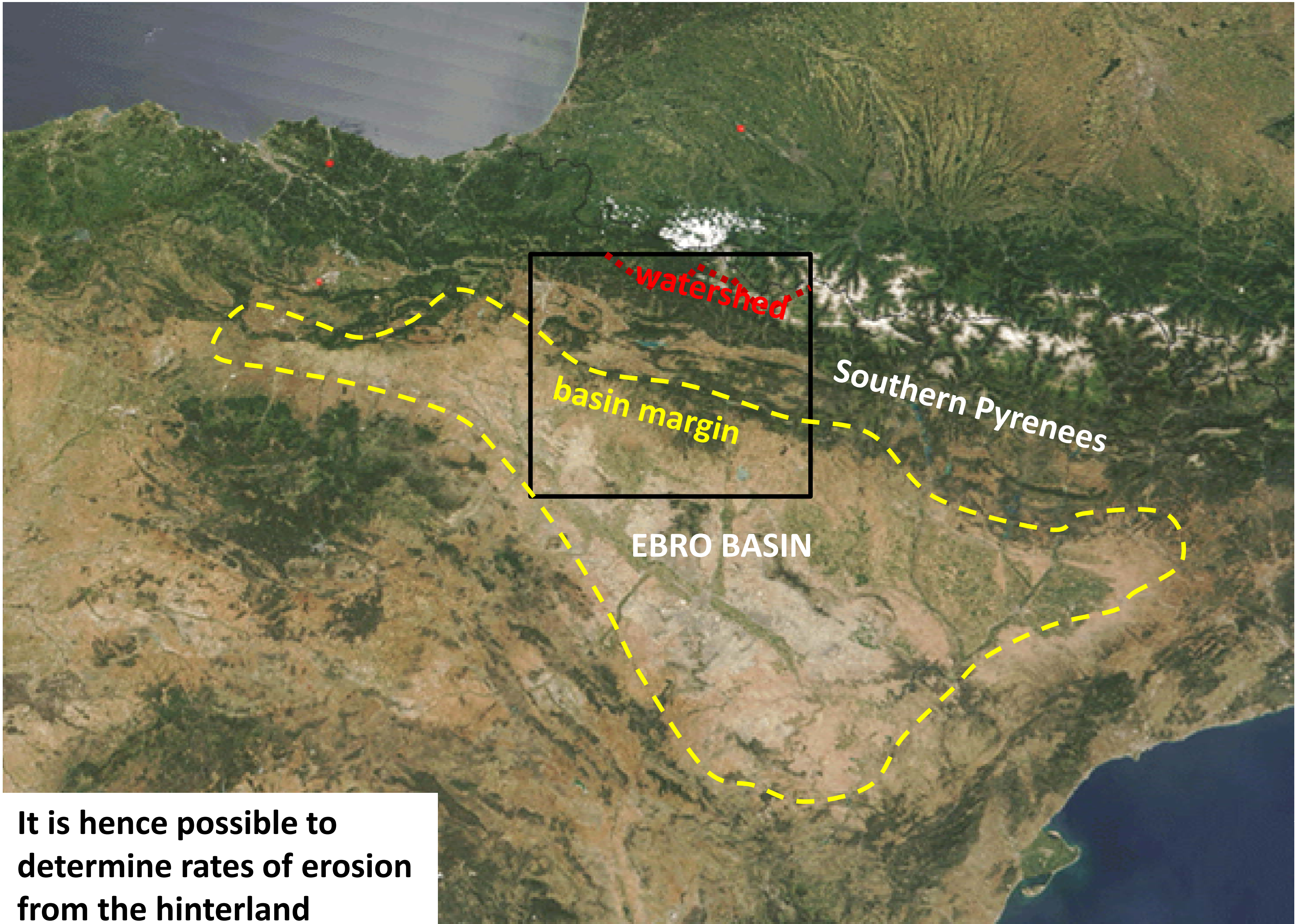
Check: are these results consistent with other data on rates of processes?



Knowing the rate of sediment supply to the Luna System makes it possible to determine rates of erosion.

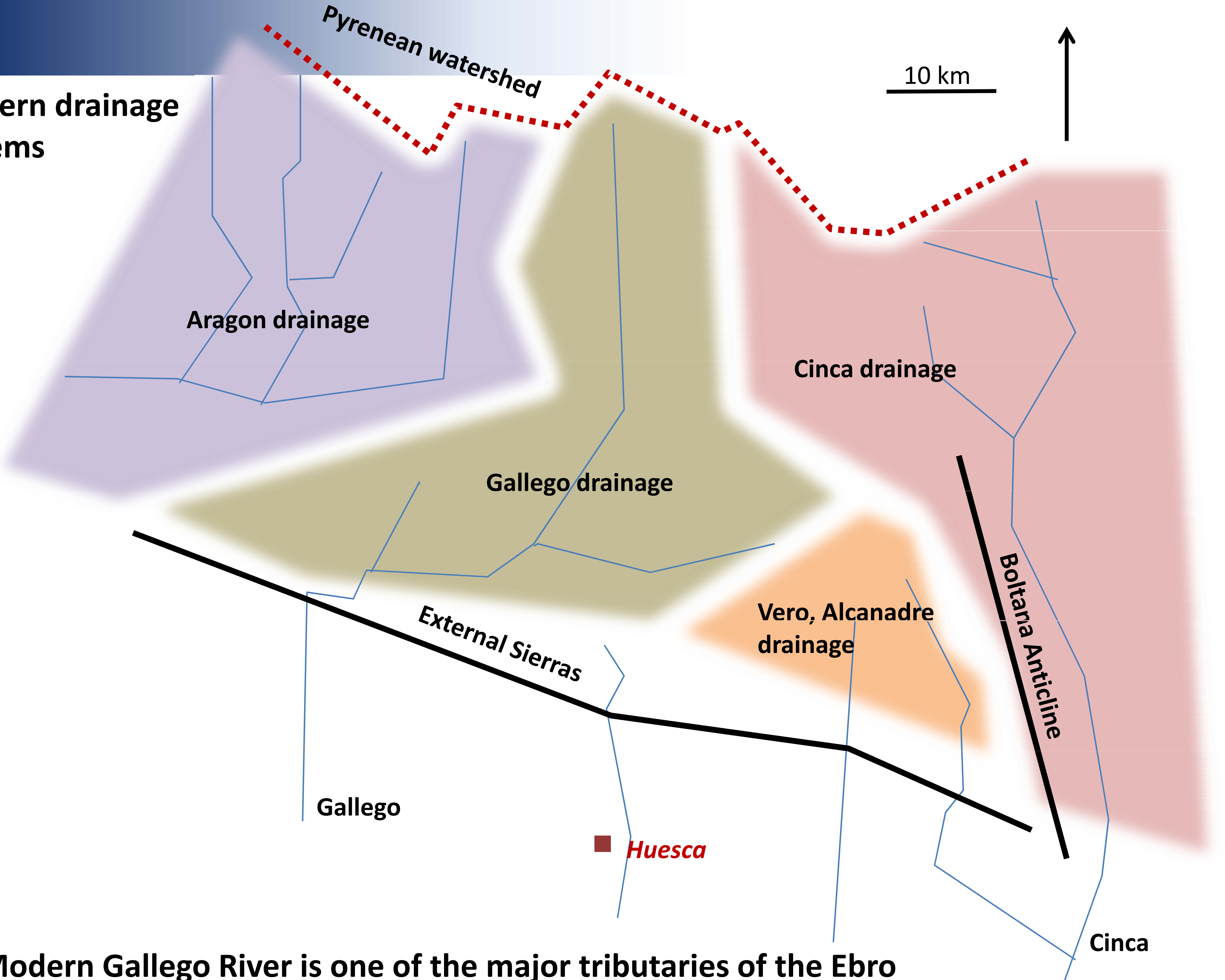
This requires reconstruction of the Miocene drainage pattern in the adjacent part of the southern Pyrenees

Drainage networks have evolved through the Neogene, but relicts of the Early Miocene drainage patterns still remain



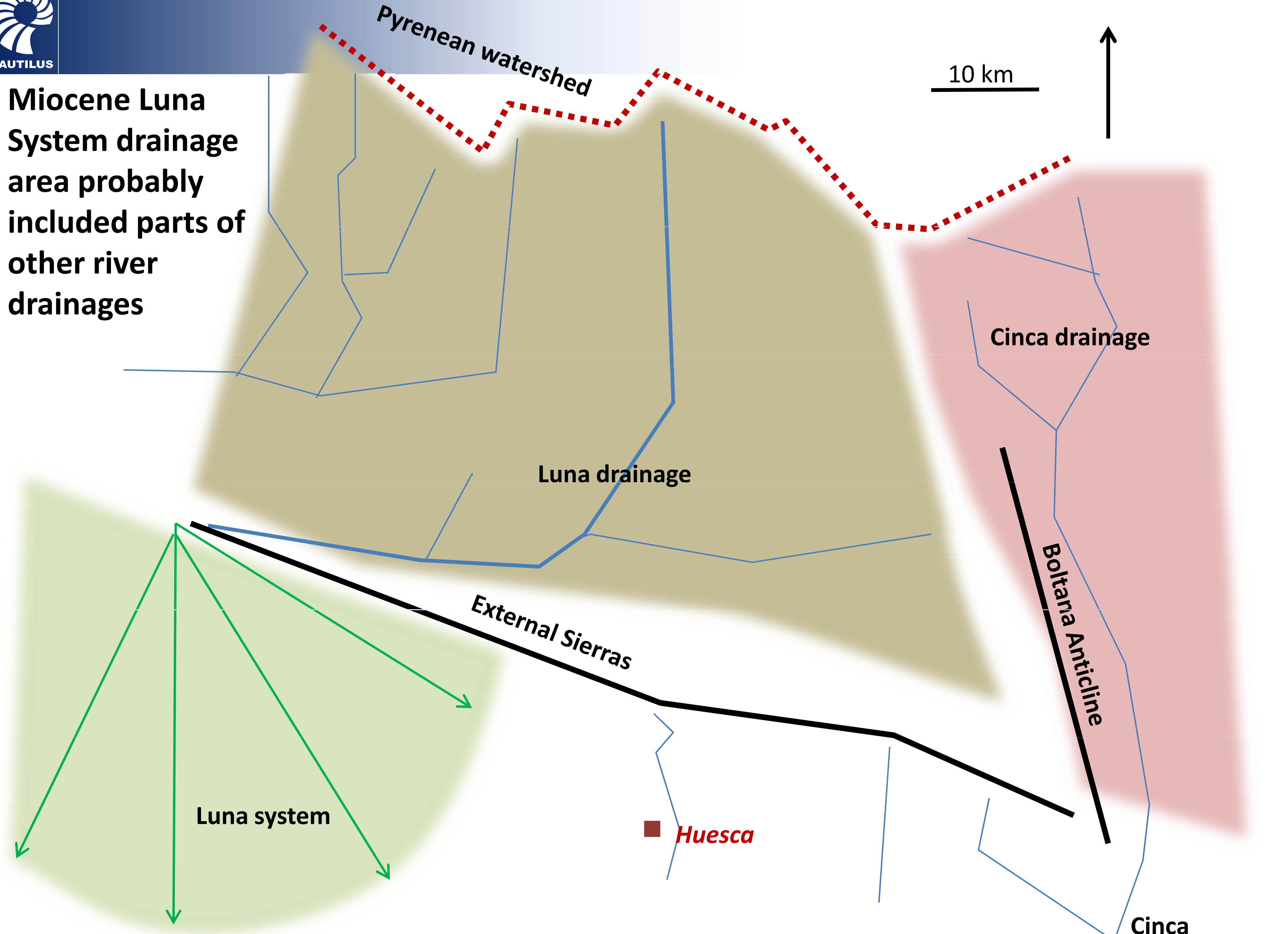
It is hence possible to determine rates of erosion from the hinterland

Modern drainage systems



Modern Gallego River is one of the major tributaries of the Ebro

Miocene Luna System drainage area probably included parts of other river drainages



Estimated drainage area of Luna DFS ~ 4,525 km²

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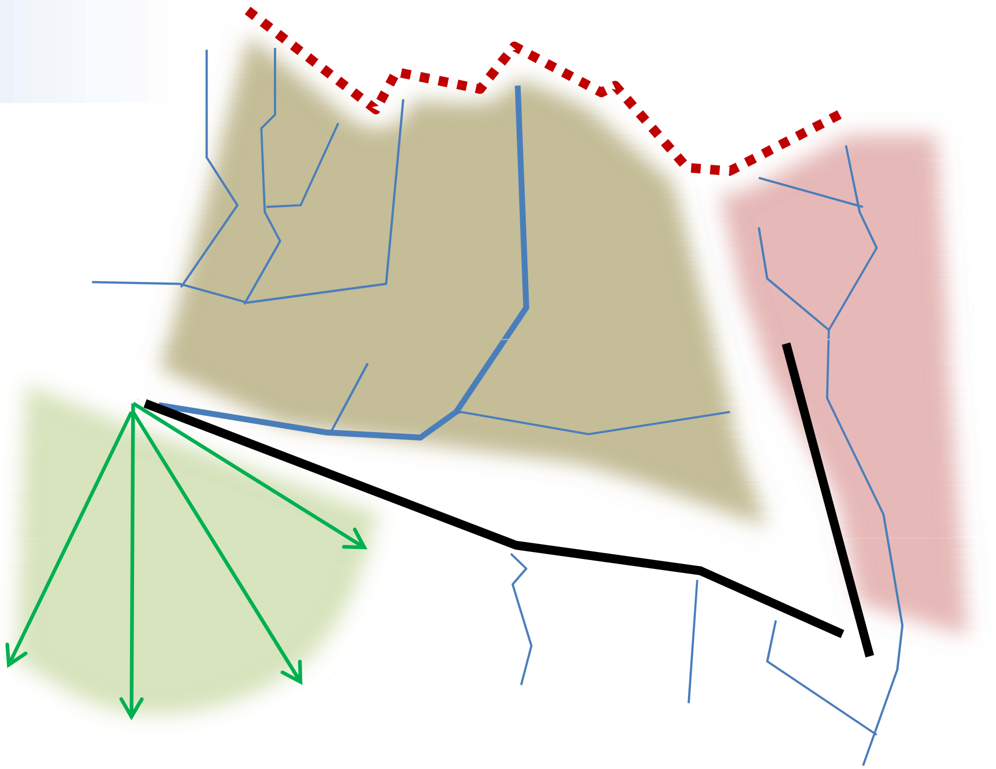
Erosion rate approx 58 mm/ky



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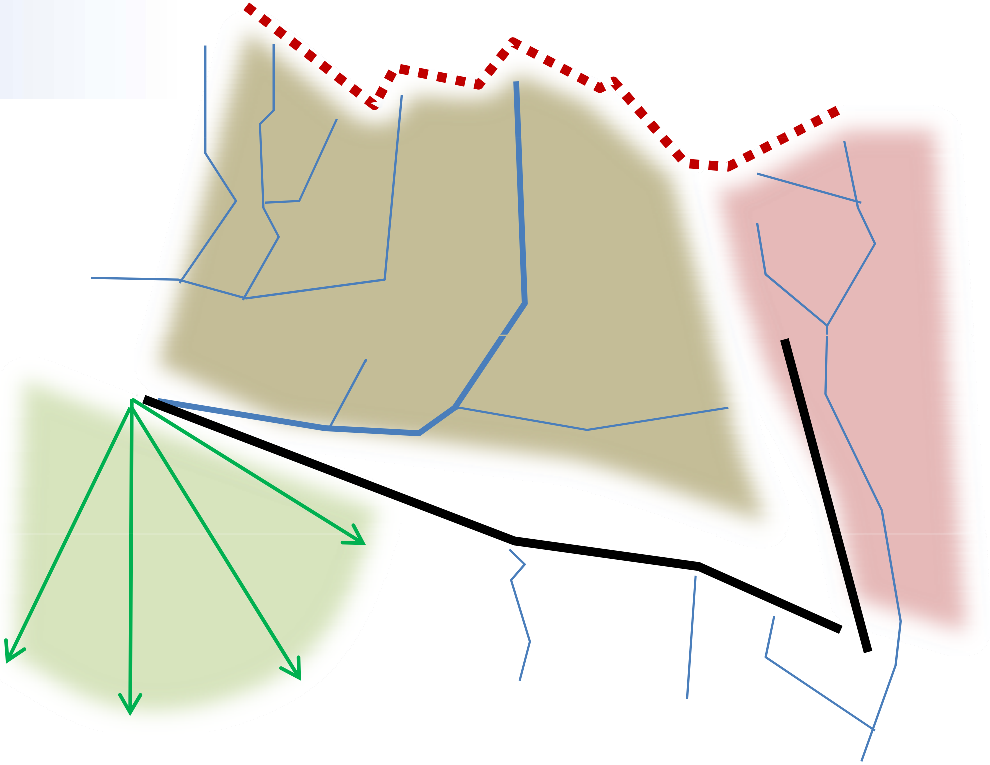

Other Estimates of Erosion rates

Erosion rate in Pyrenees calculated from thermochronology : 34-61 mm/ky (Morris *et al.* 1998)

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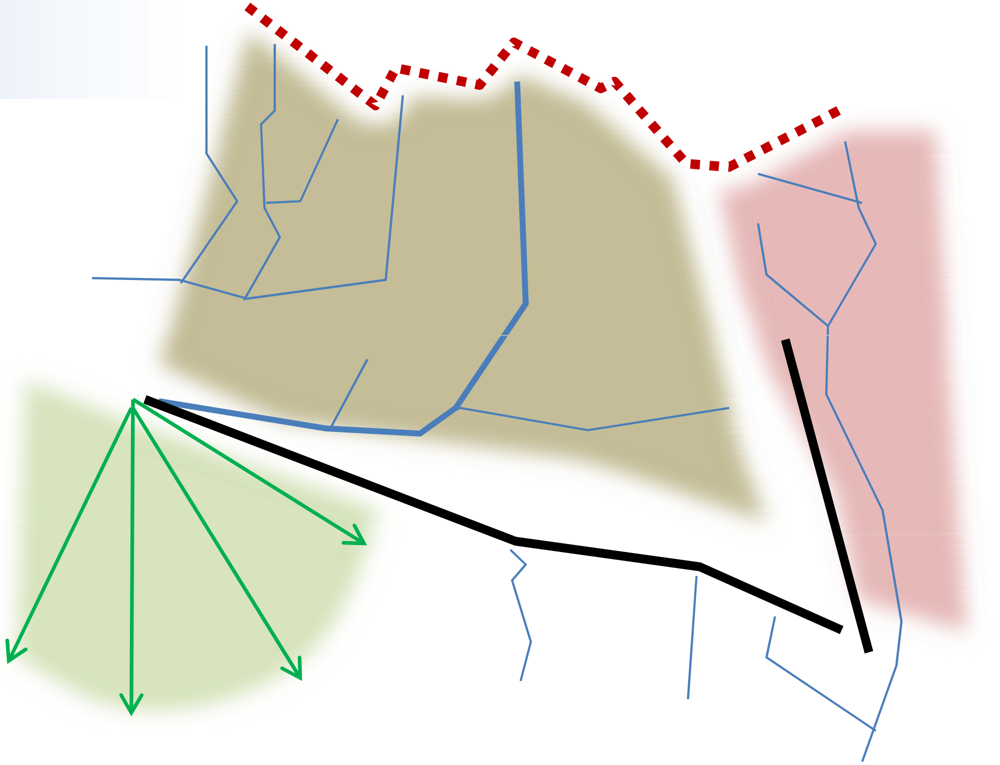


Other Estimates of Erosion rates

Erosion rate in Pyrenees calculated from thermochronology : 34-61 mm/ky (Morris *et al.* 1998)

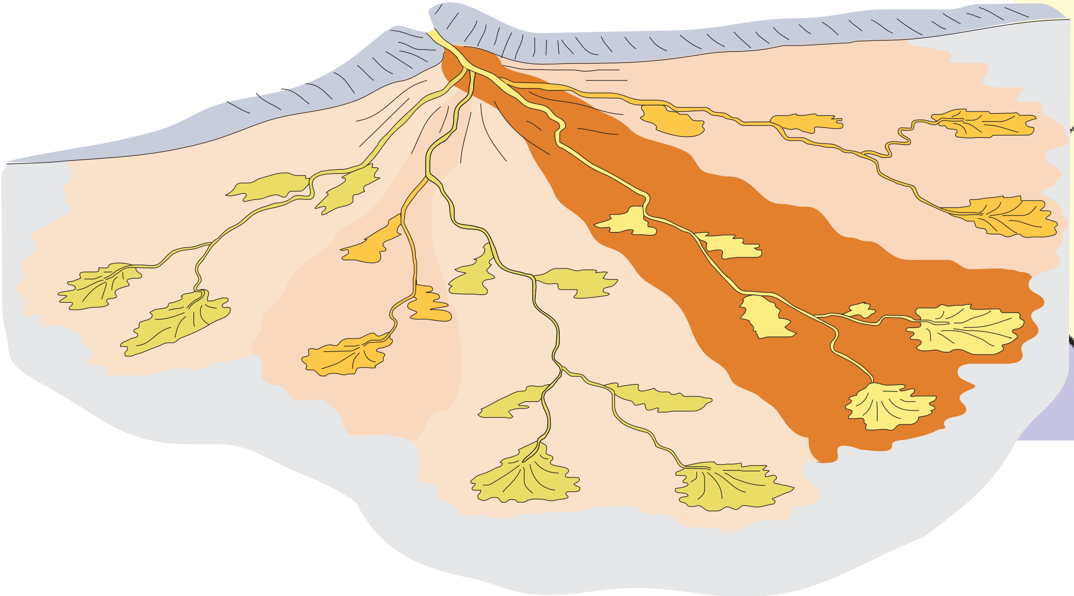
Erosion rate calculated from mass balance of whole Ebro drainage system: 45-60 mm/ky (García-Castellanos *et al.* 2003)

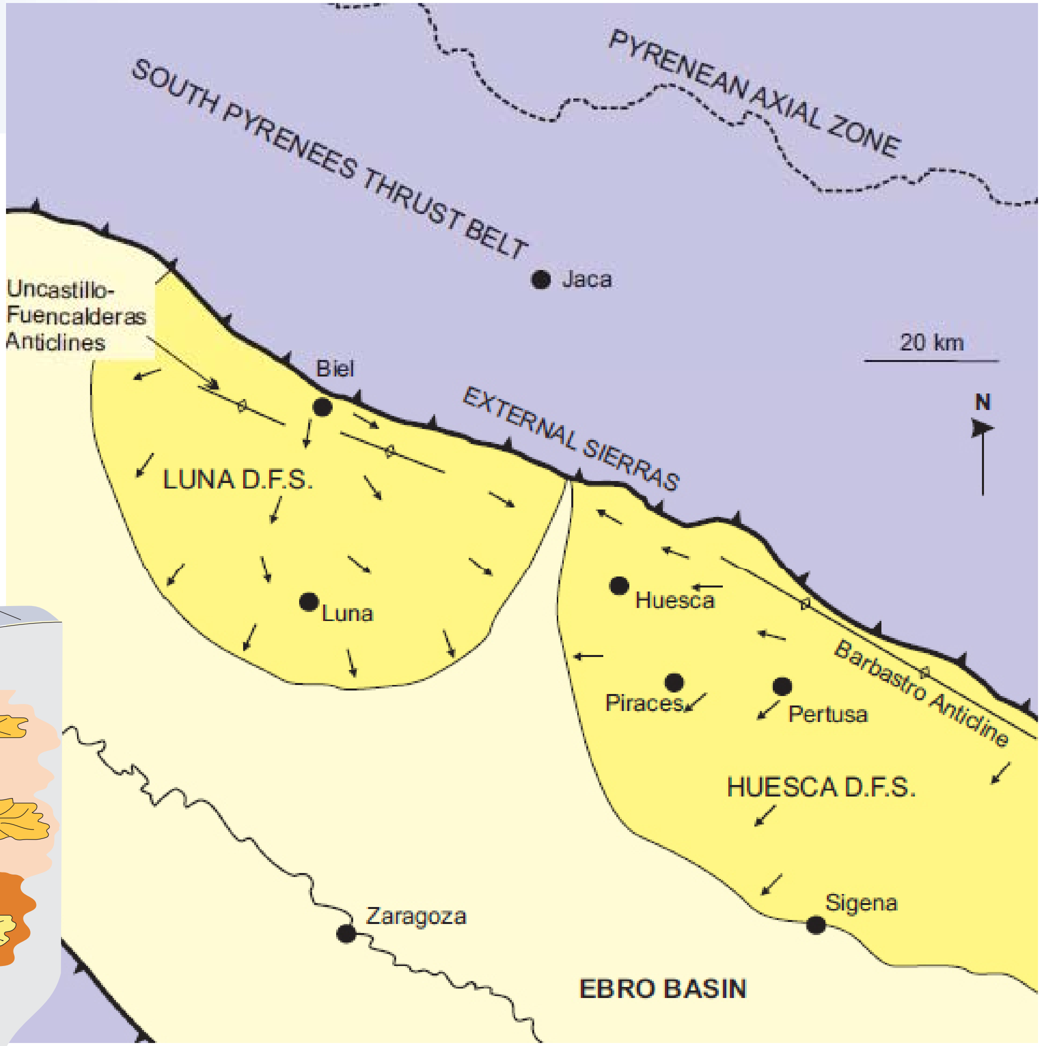
Stratigraphy is built up by river occupying part of the alluvial plain, laterally migrating, depositing, abandoning and avulsing to a new location

In time, river returns to same place.

Fluvial successions in the Ebro Basin built up by Distributive Fluvial Systems

Rivers change position on the system through time, occupying different sectors of the fan shape





Probably only one segment of the distributive pattern active at any time .

Through time rivers must return to places previously occupied

Vertical positions of sandstone bodies deposited by channel belts represent re-occupation of the same point on the DFS

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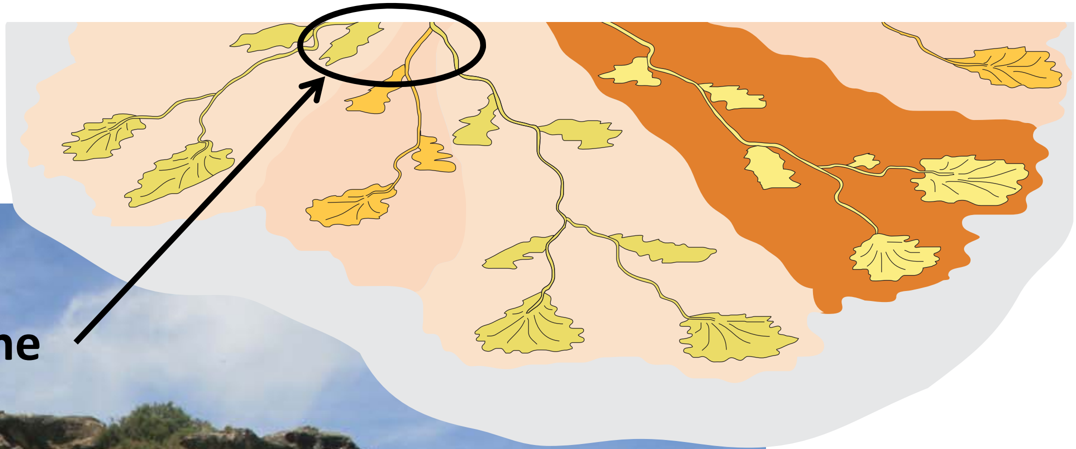
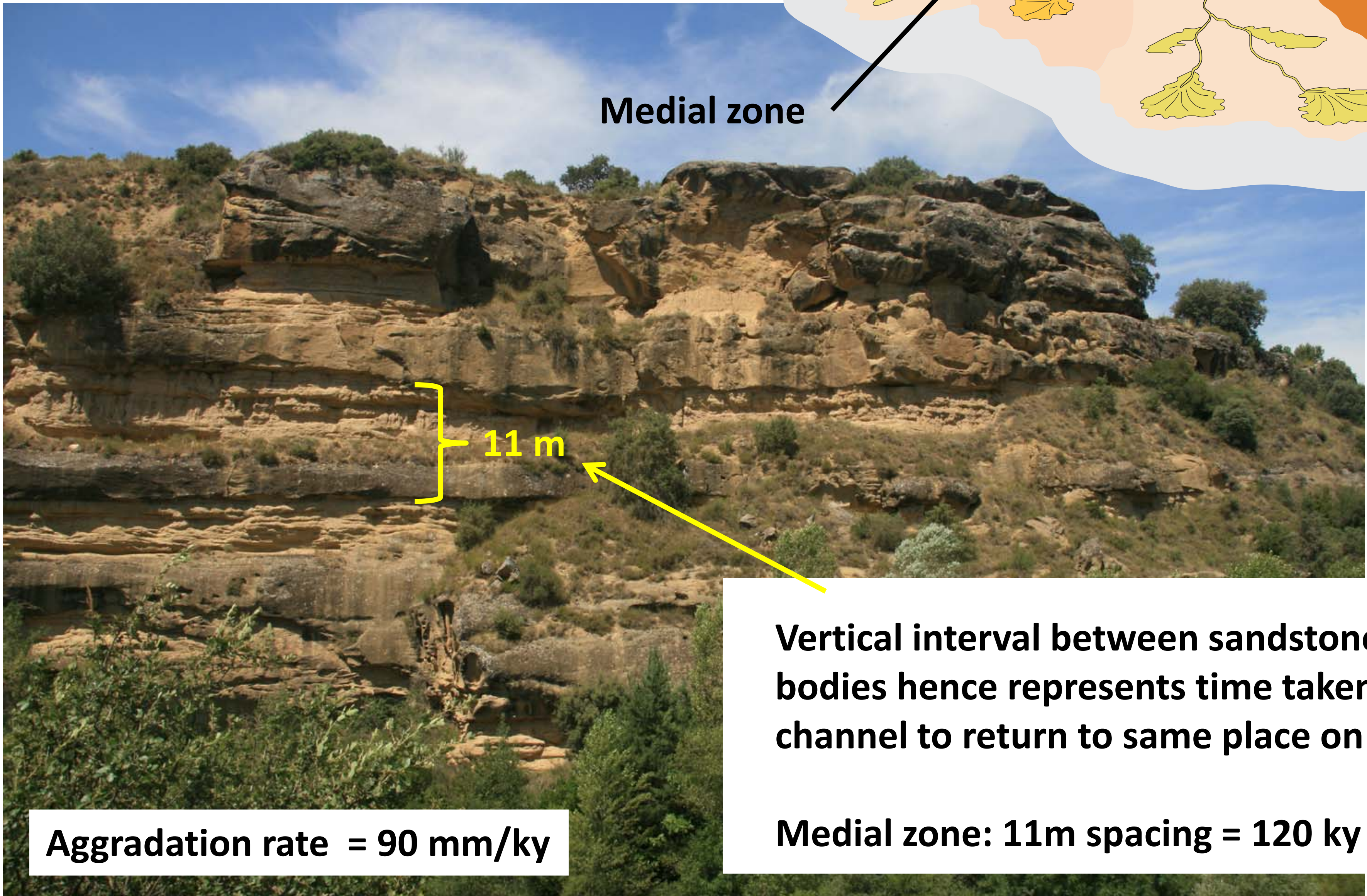


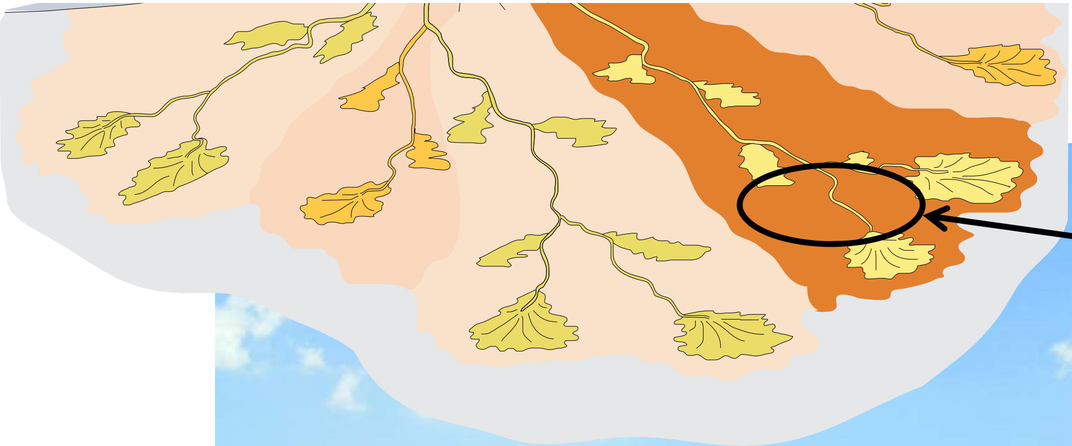


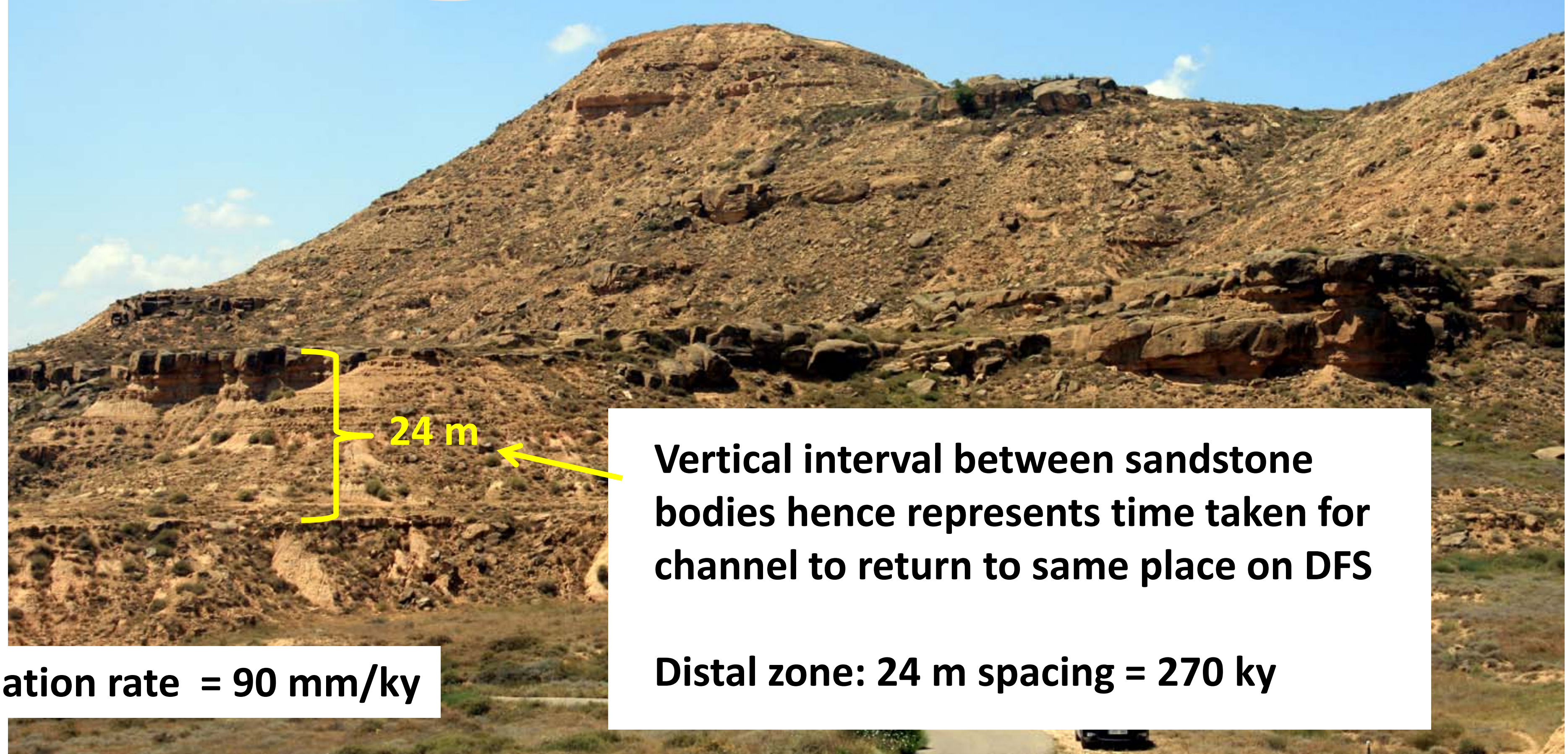
Vertical interval between sandstone bodies hence represents time taken for channel to return to same place on DFS

Medial zone: 11m spacing = 120 ky

Aggradation rate = 90 mm/ky

Vertical positions of sandstone bodies deposited by channel belts represent re-occupation of the same point on the DFS



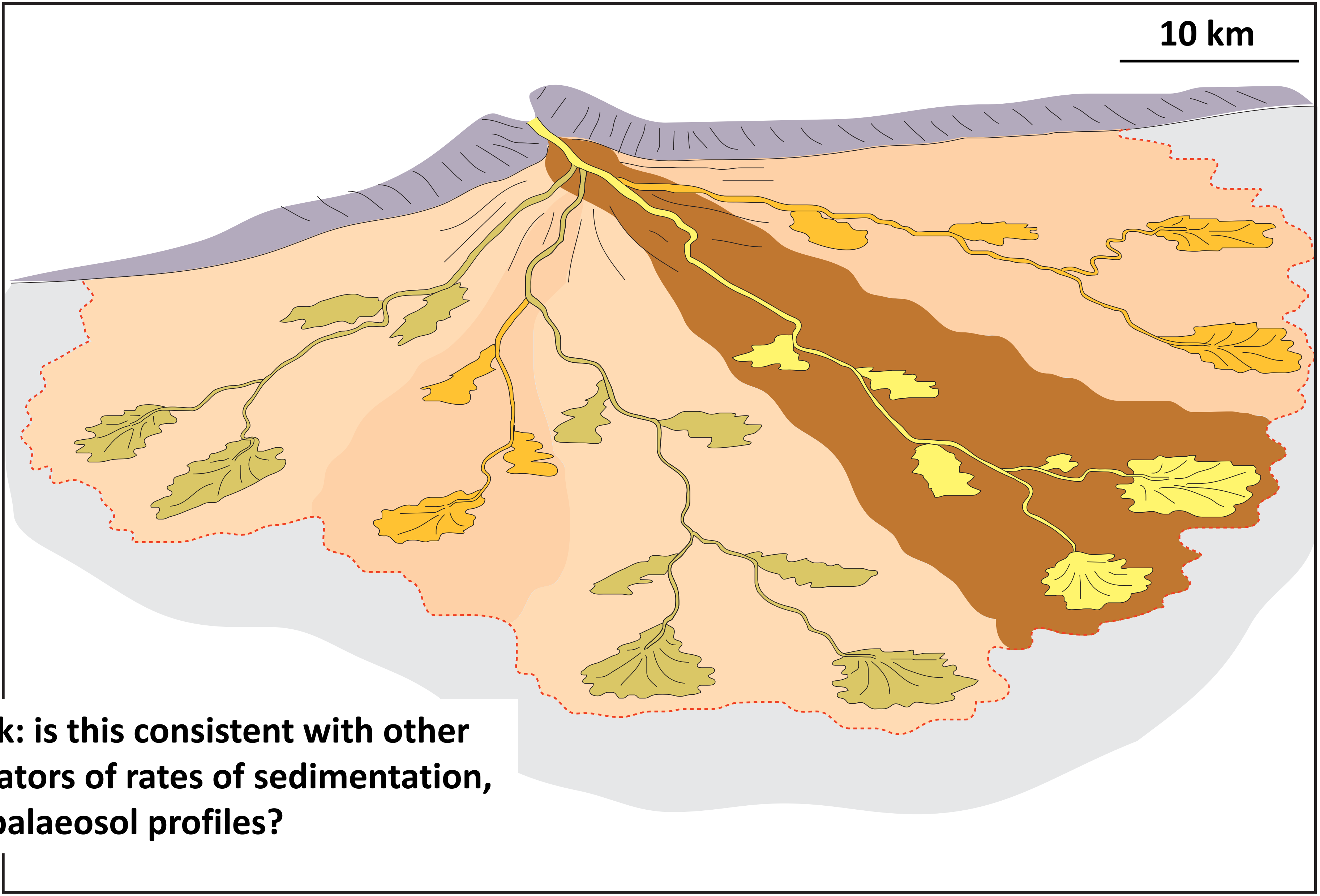


Vertical interval between sandstone bodies hence represents time taken for channel to return to same place on DFS

Distal zone: 24 m spacing = 270 ky

Aggradation rate = 90 mm/ky

Time taken for river channel to return to same position on alluvial plain is approximately 100 - 200 ky



Check: is this consistent with other indicators of rates of sedimentation, e.g. palaeosol profiles?

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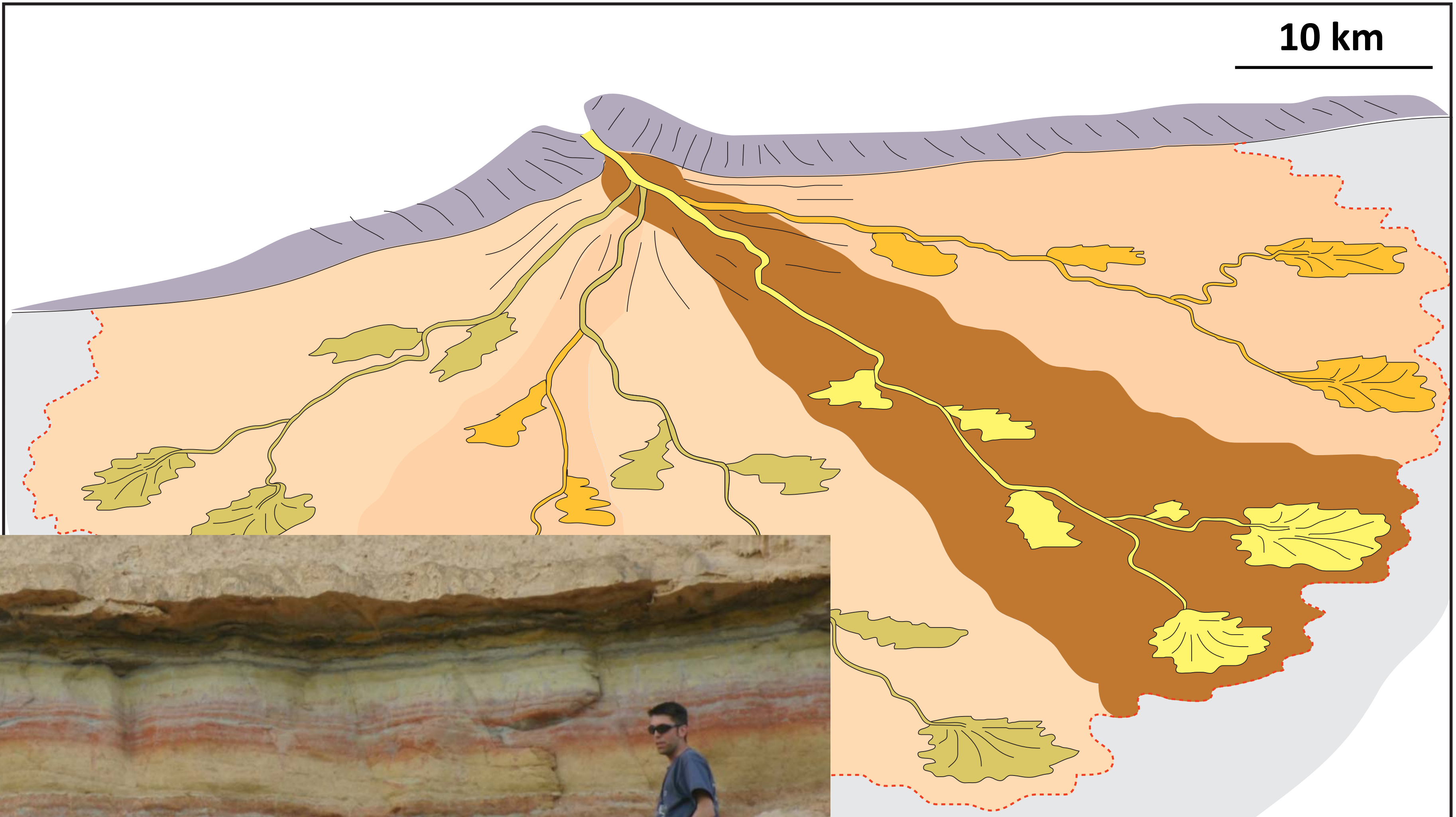


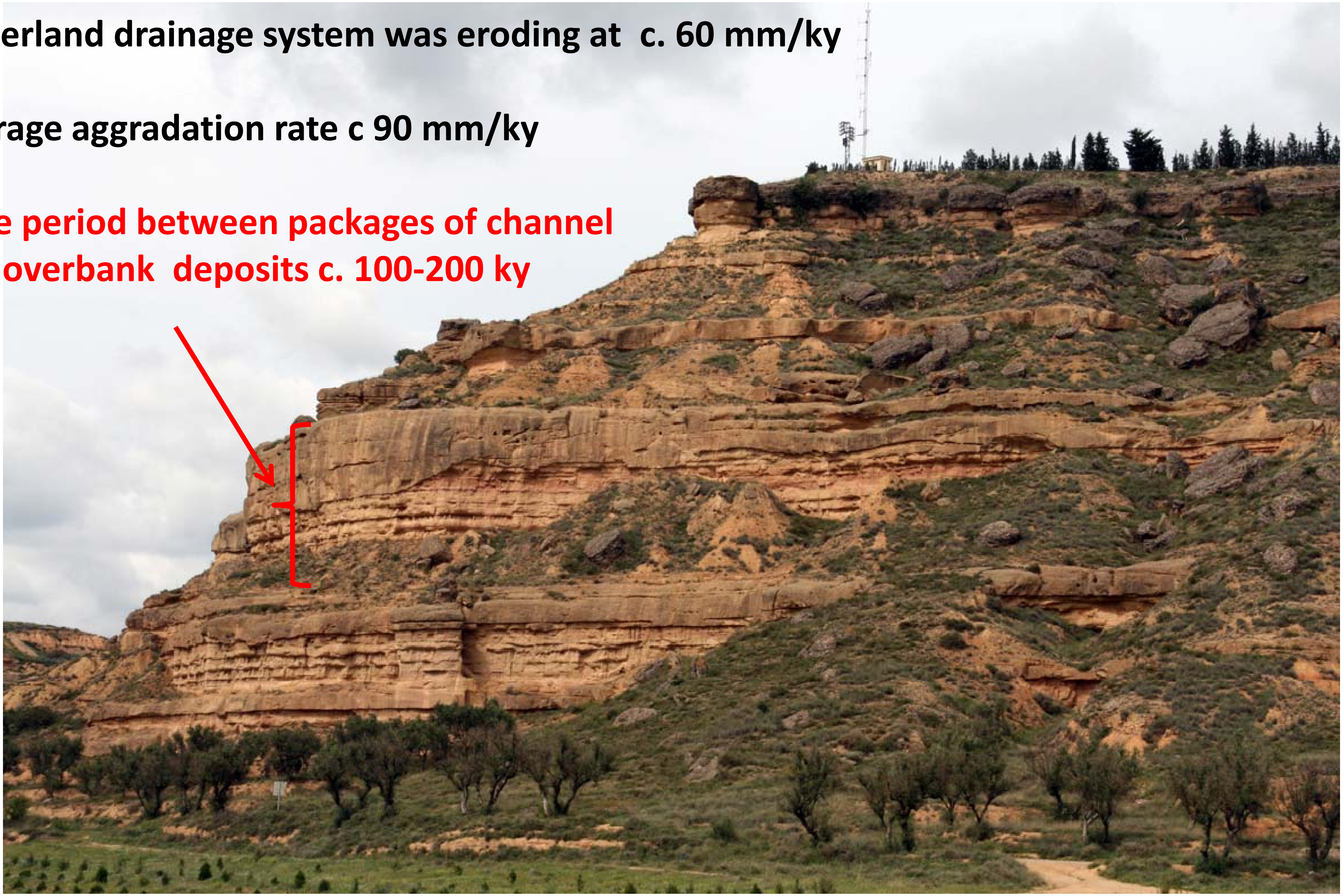
Alfisol profiles between channel sandstones take 10s ky to form (Hamer *et al.* 2007)

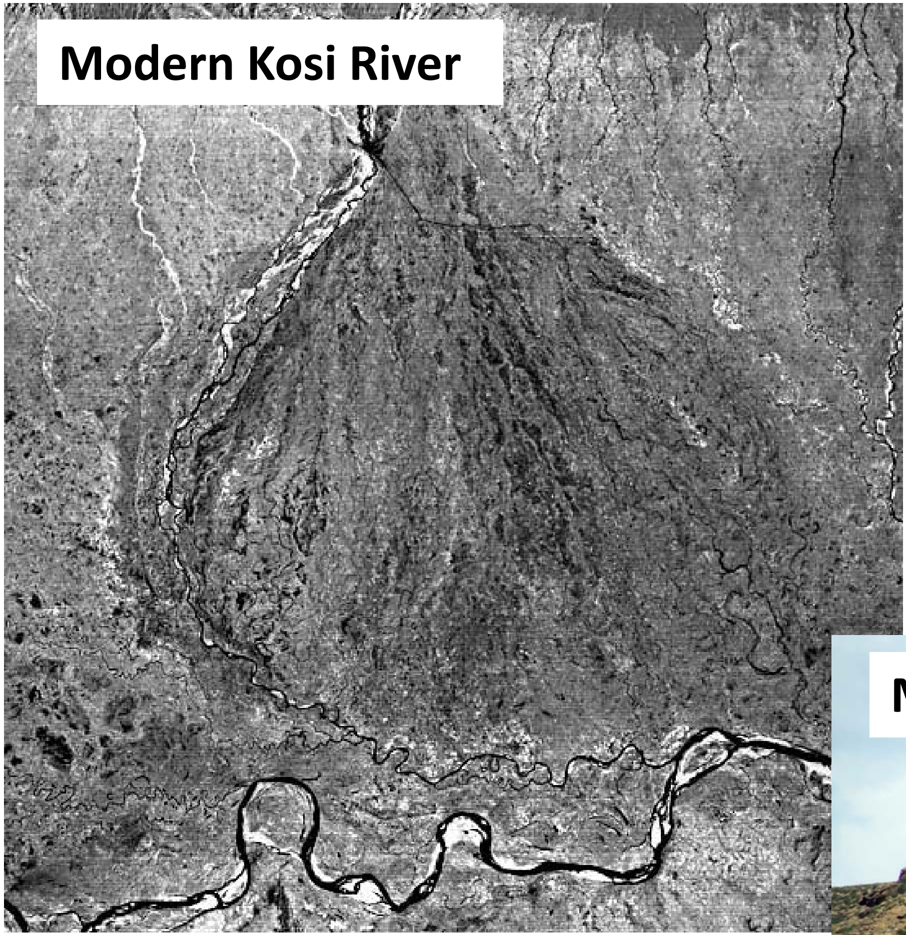
Succession was deposited by a river with a sediment load of c. 13 kg/s

Hinterland drainage system was eroding at c. 60 mm/ky

Average aggradation rate c 90 mm/ky

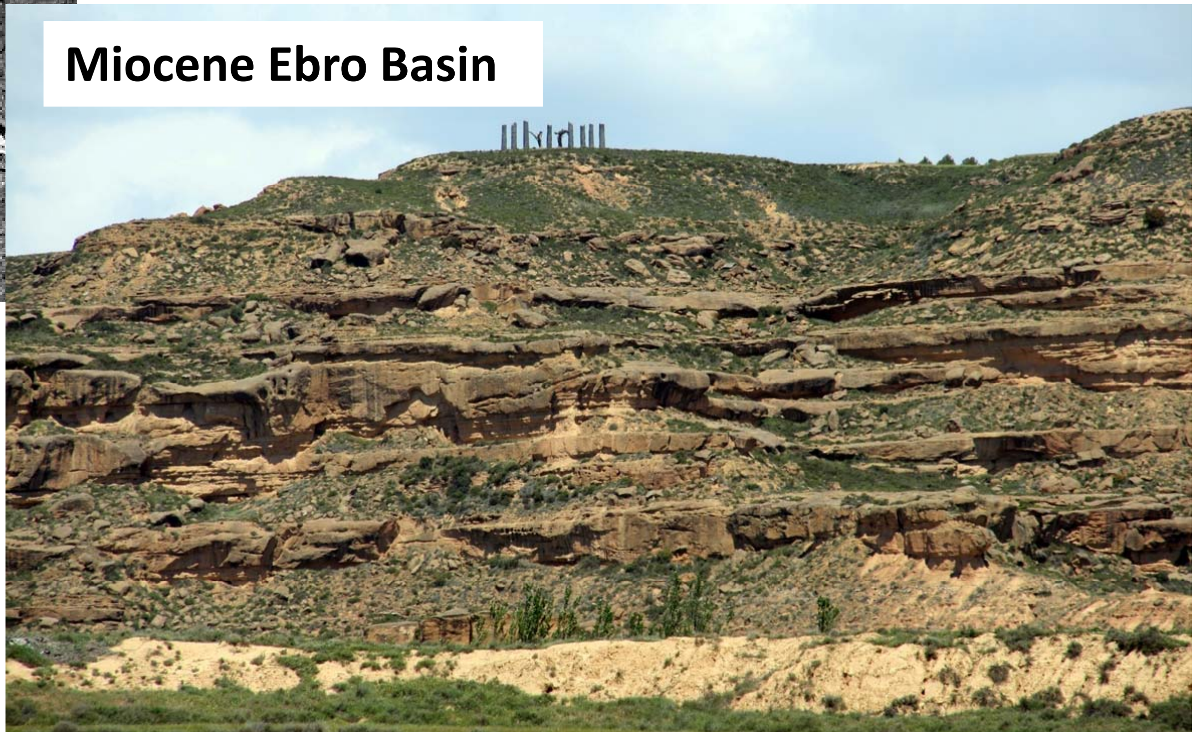
Time period between packages of channel and overbank deposits c. 100-200 ky





Rate of avulsion processes in the present day Kosi River results in channels migrating across DFS in 100s years.

Rate of avulsion processes in the Miocene Ebro Basin resulted in channels migrating across DFS in 100,000s years.



Variables:

- Accommodation/aggradation
- Climate/discharge
- Sediment supply