Fluvially Generated Heterolithic Stratification as a Tool for Determining Process Dominance and Location in the Fluvial-Marine Transition*

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Abstract

At the mouths of rivers, and for a considerable distance inland in low-gradient settings, fluvial and tidal processes interact to create a unique suite of deposits. Most rivers display variations in discharge, and their hydrographs can be divided simplistically into two parts: the river flood when most of the sediment discharge occurs, and the longer-duration interflood period when sediment discharge is small. Tidal currents, by contrast, act throughout the year, although their strength varies on various time scales (e.g., neap-spring cycles). Most importantly, the increase in the strength of fluvial currents during river floods decreases the tidal influence by pushing the limit of tidal intrusion (and also salt-water intrusion) seaward. In the more proximal parts of the fluvial-marine transition, depositional conditions alternate between being river-dominated during river floods and tide-dominated during interflood/low-flow periods. This is commonly reflected in an alternation between coarser sandy deposits with a unidirectional seaward paleocurrent and minimal bioturbation (river-flood deposits), and finer-grained, commonly muddy, deposits in which tidal lamination and higher levels of bioturbation are present (interflood deposits). These deposits are indicative of a fluvially dominated, tidally influenced environment. In more distal areas where tidal currents are stronger, tidal lamination and/or reversed paleocurrents begin to occur in the waning-flow portion of the flood deposits, until eventually the tidal currents become strong enough to overprint the entire river-flood bed. In such settings, river-flood deposits can be cryptic, but can be marked by the coarsest sand and thickest fluid-mud beds. Bioturbation is typically more intense, but restricted, in the interflood deposits. This pattern indicates a tidally dominated, fluvially influenced environment. Considerable local variability is expected, but general trends in the character of river-flood and interflood beds are a powerful tool for determining location in the fluvial-marine transition and the nature of coastal environments at a larger scale.

References Cited

Dalrymple, R.W., and K.S. Choi, 2007, Morphologic and Facies Trends Through the Fluvial-Marine Transition in Tide-Dominated Depositional Systems: A Systematic Framework for Environmental and Sequence-Stratigraphic Interpretation: Earth Science Reviews, v. 81, p. 135-174.

Kravtsova, V.I., V.N. Mikhailov, and V.M. Kidyaeva, 2009, Hydrological Regime, Morphological Features and Natural Territorial Complexes of the Irrawaddy River Delta (Myanmar): Water Resources, v. 36, p. 243-260.

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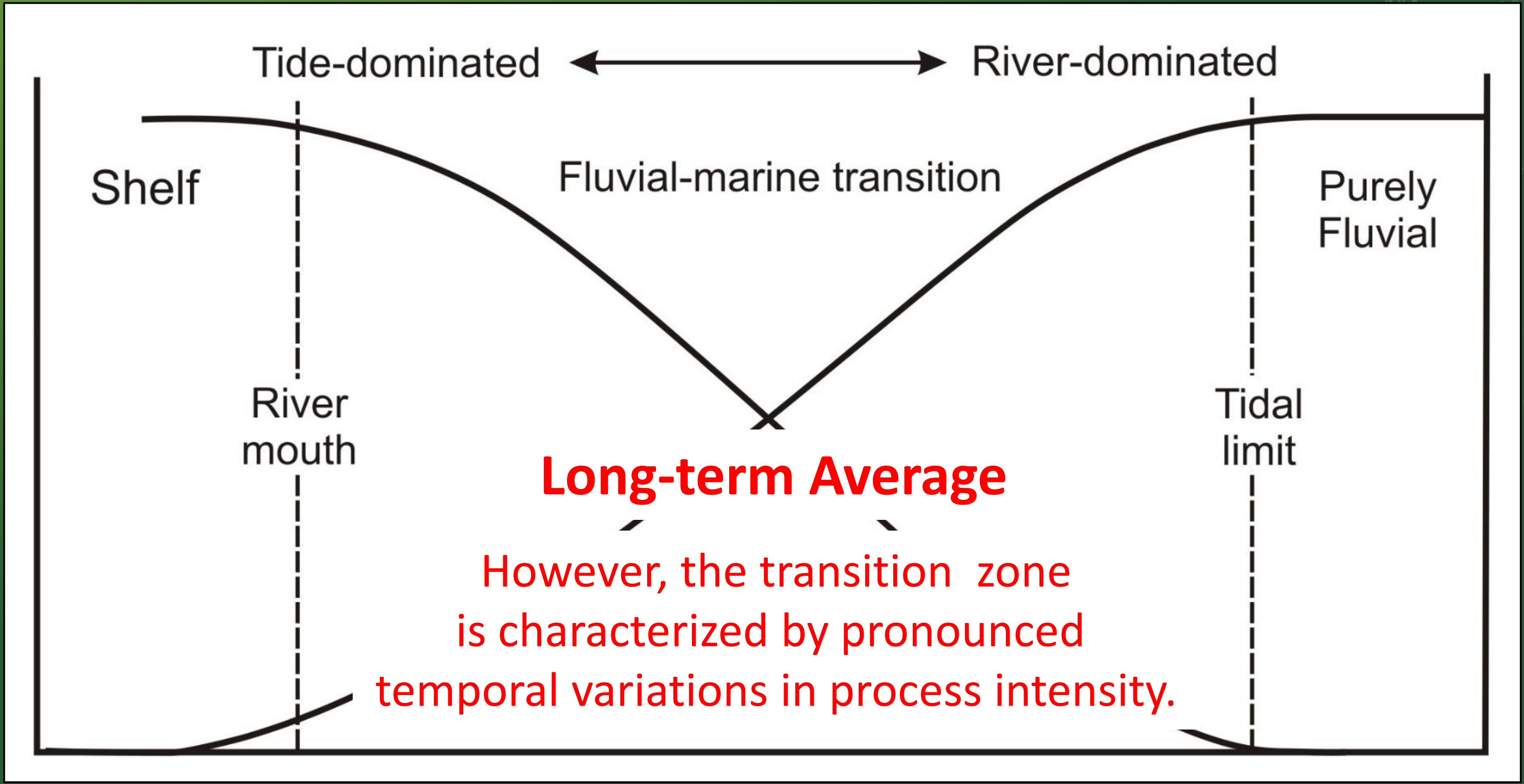
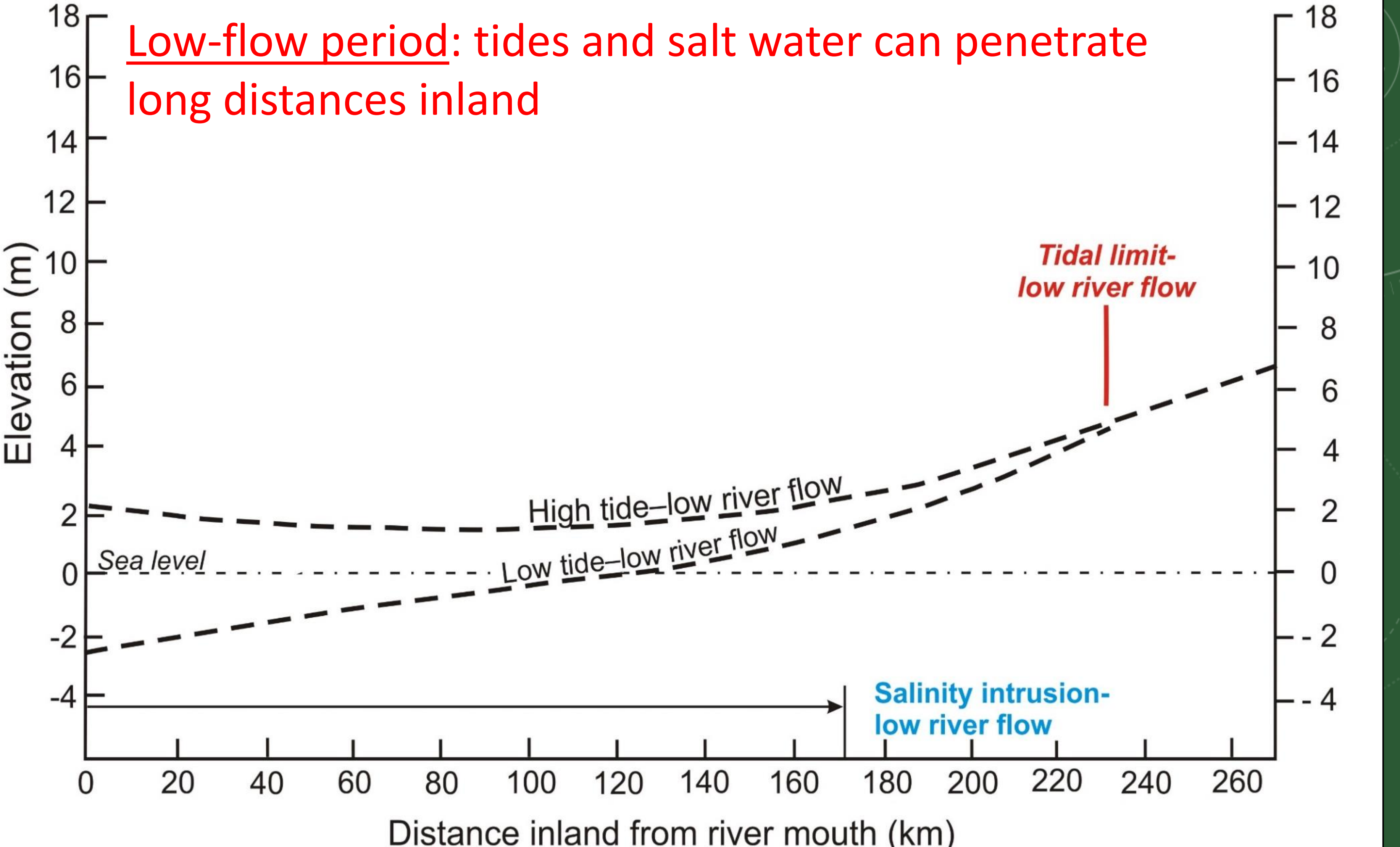
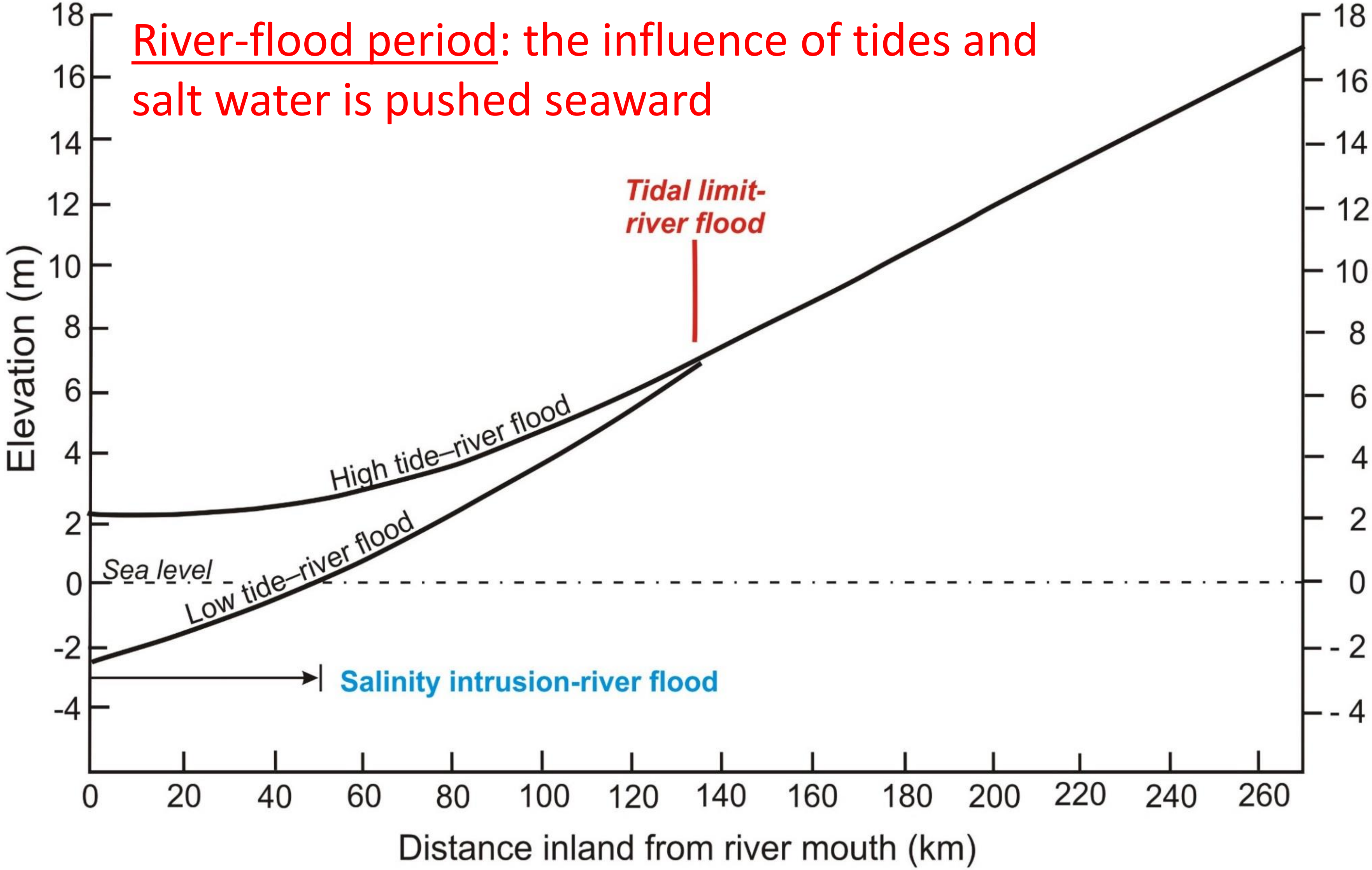
The fluvial-marine transition is the zone in which river currents and tidal currents interact (cf. Dalrymple and Choi, 2007).



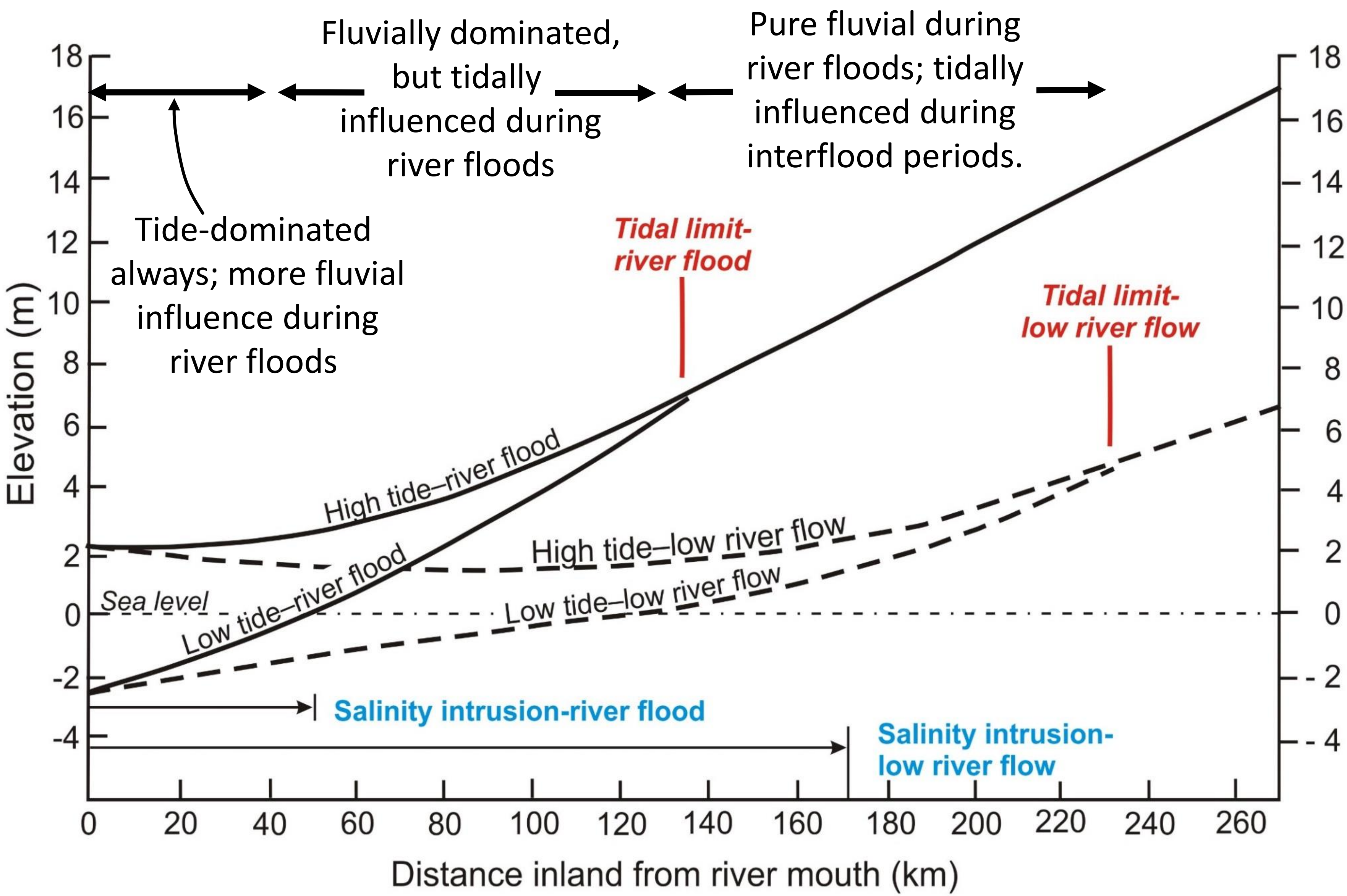
<u>Low-flow period</u>: tides and salt water can penetrate long distances inland



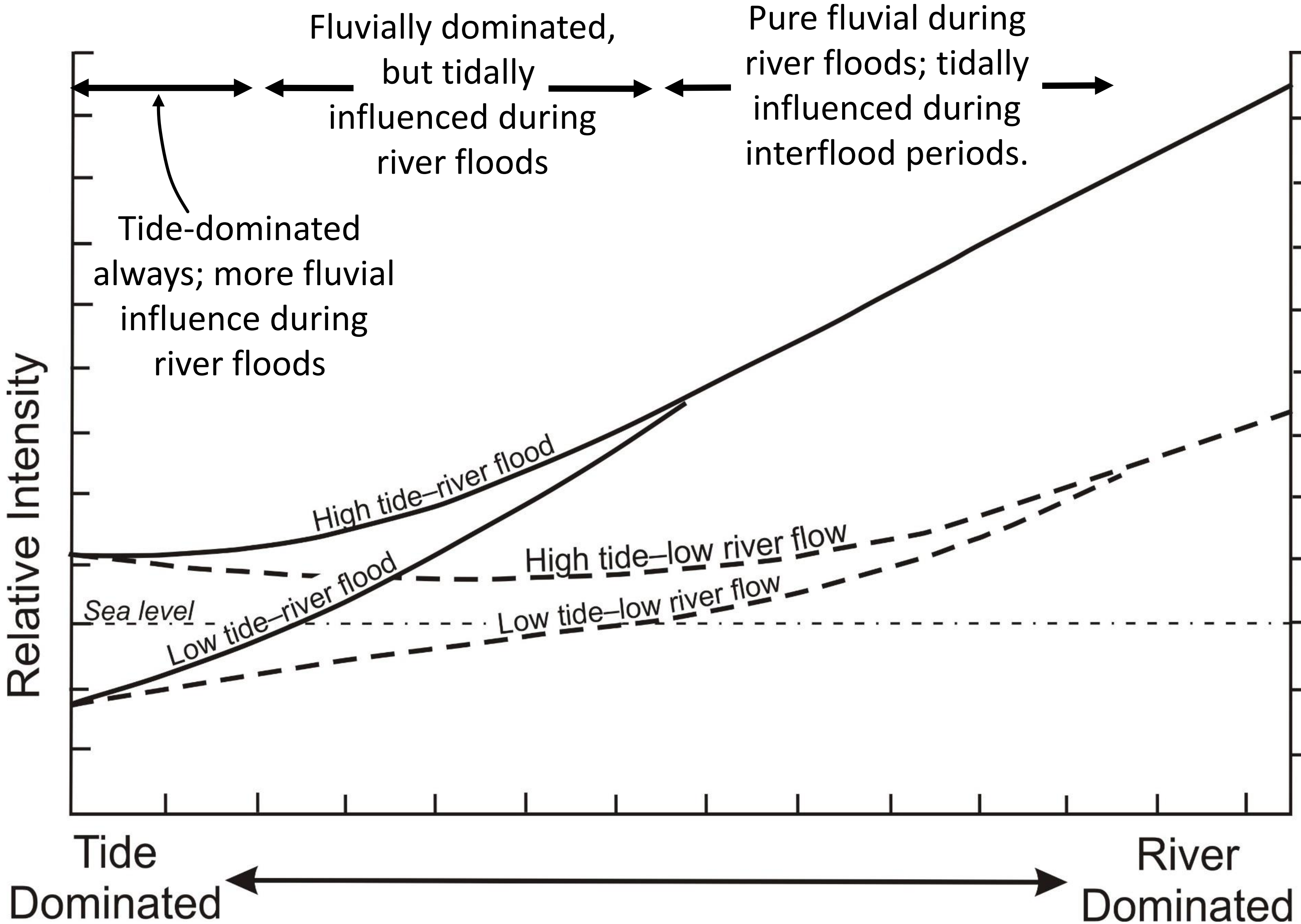
Based on the Irrawaddy River (Kravatsova et al., 2009)



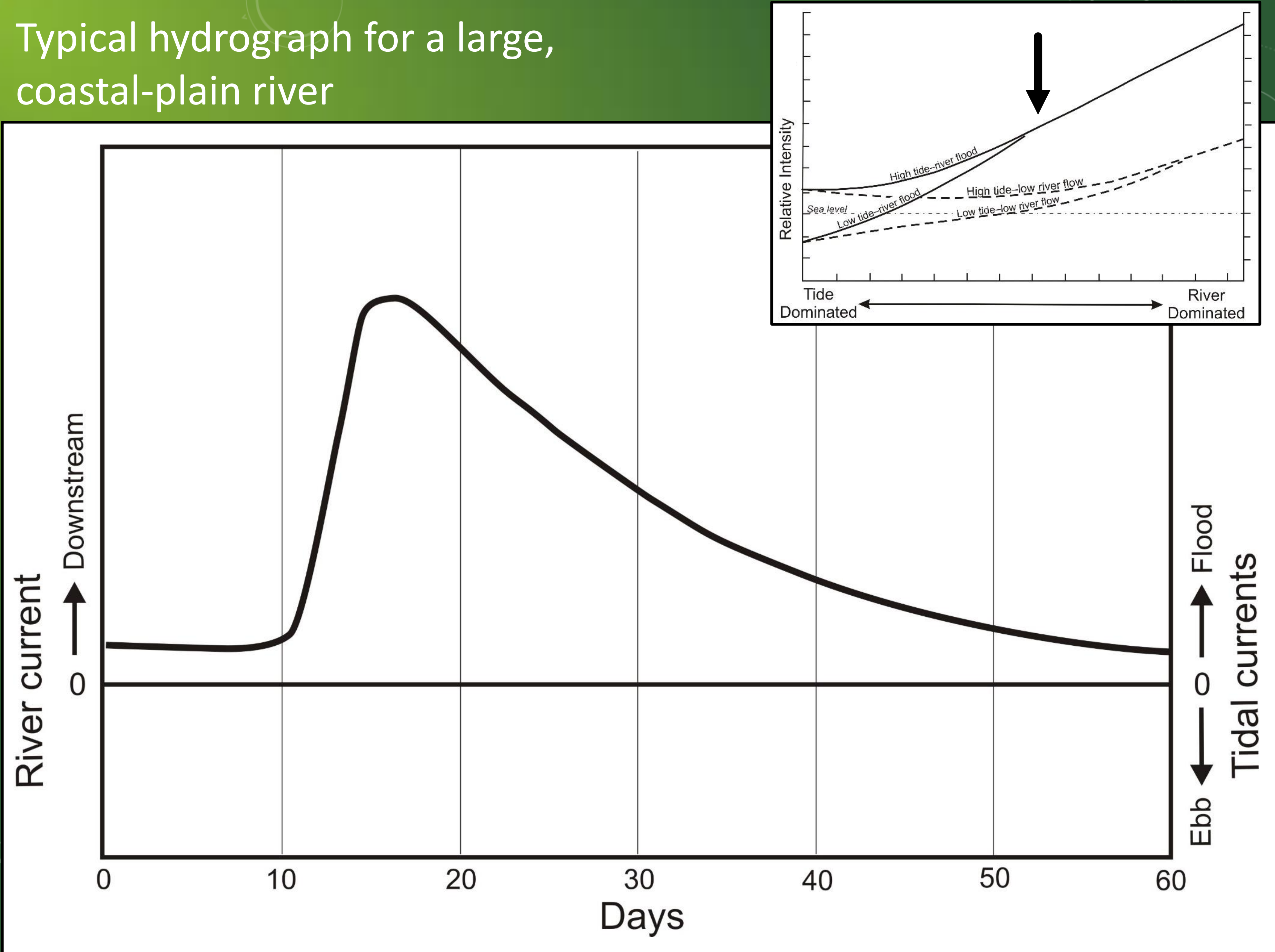
Based on the Irrawaddy River (Kravatsova et al., 2009)



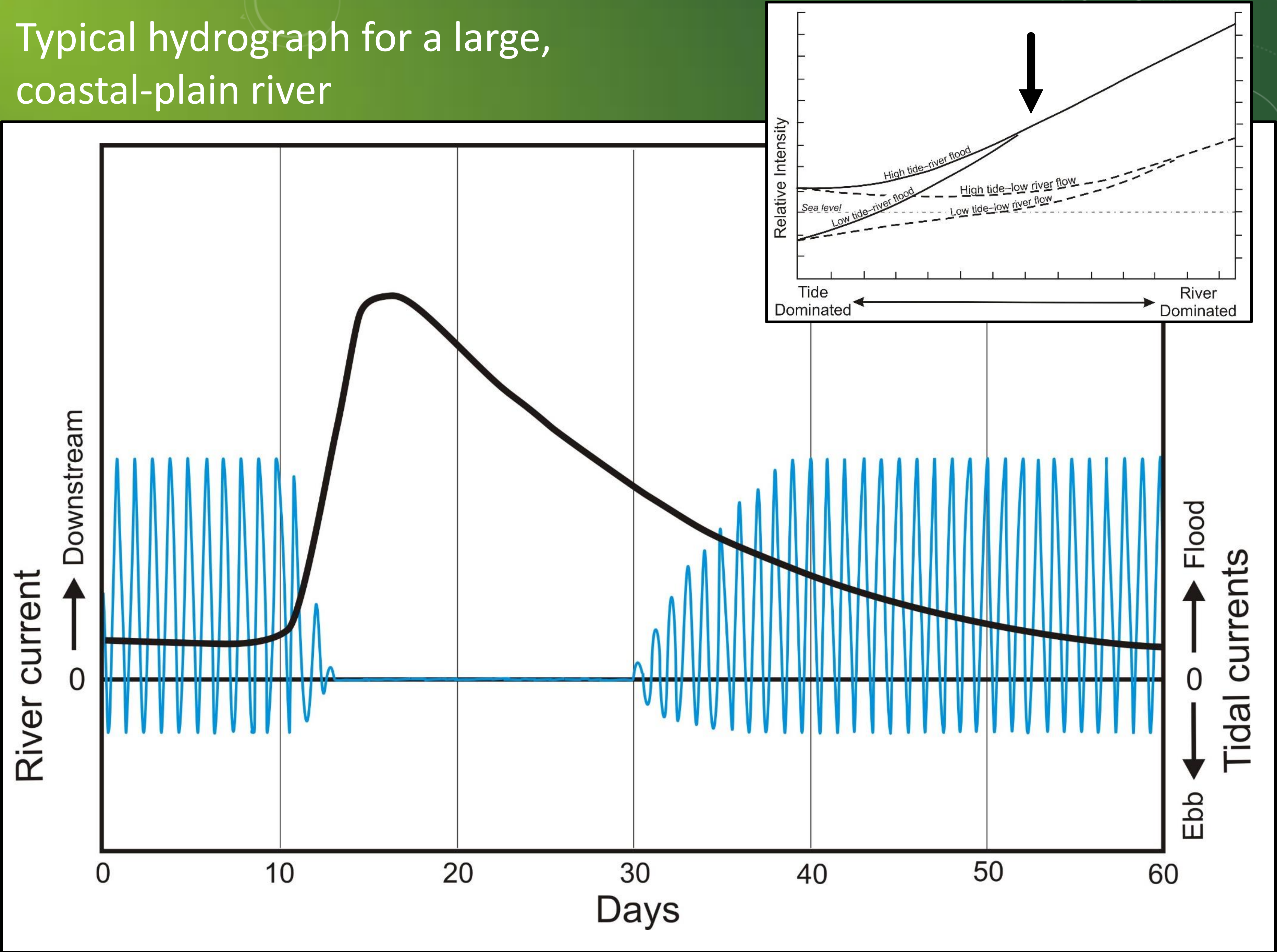
This graph can be generalized by framing it in relative terms.


Fluvially dominated, but tidally influenced during river floods
Pure fluvial during river floods; tidally influenced during interflood periods.
Tide-dominated always; more fluvial influence during river floods
Relative Intensity
High tide–river flood
High tide–low river flow
Low tide–river flood
Low tide–low river flow
Sea level
Tide Dominated
River Dominated

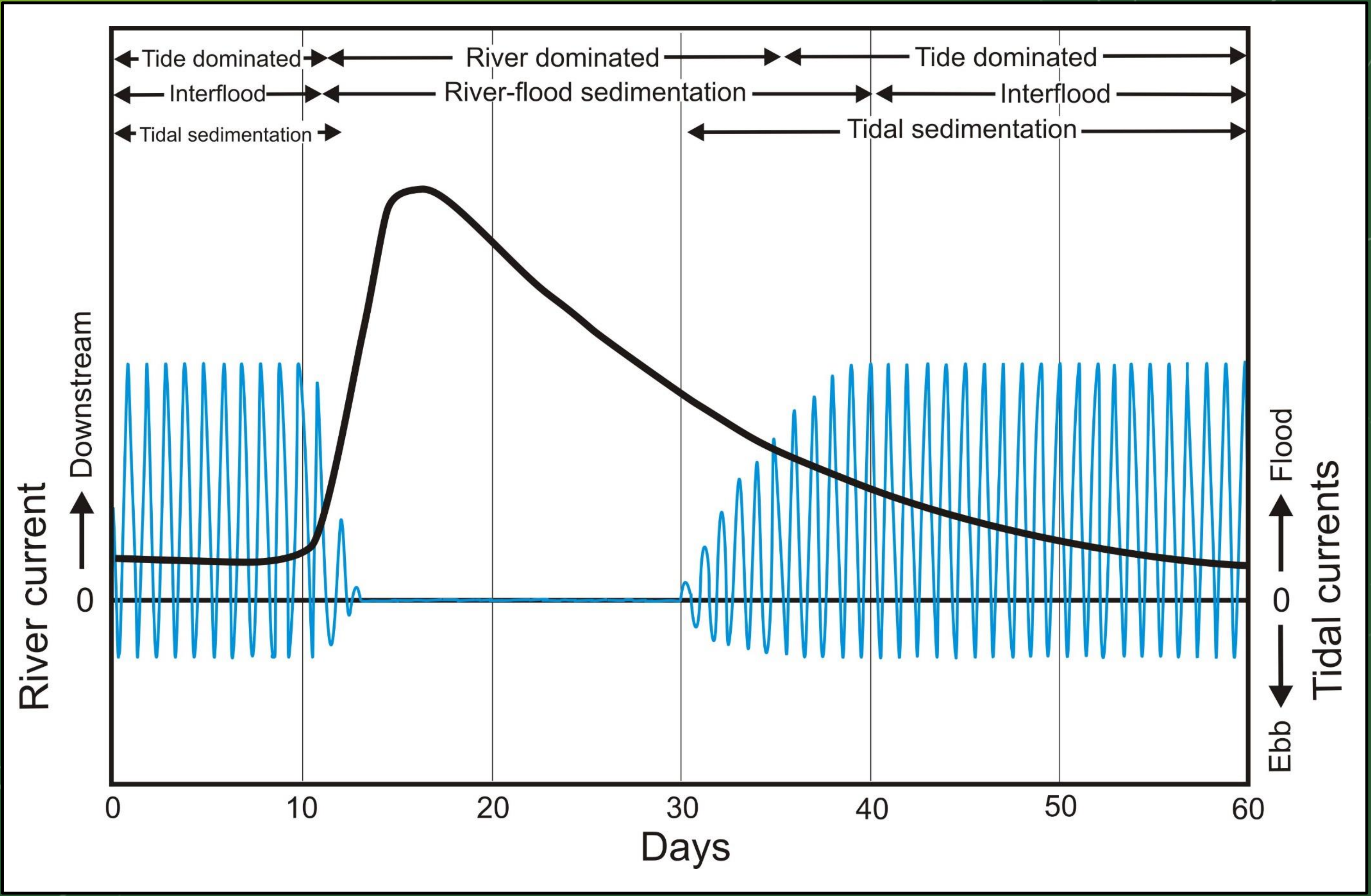
Typical hydrograph for a large, coastal-plain river



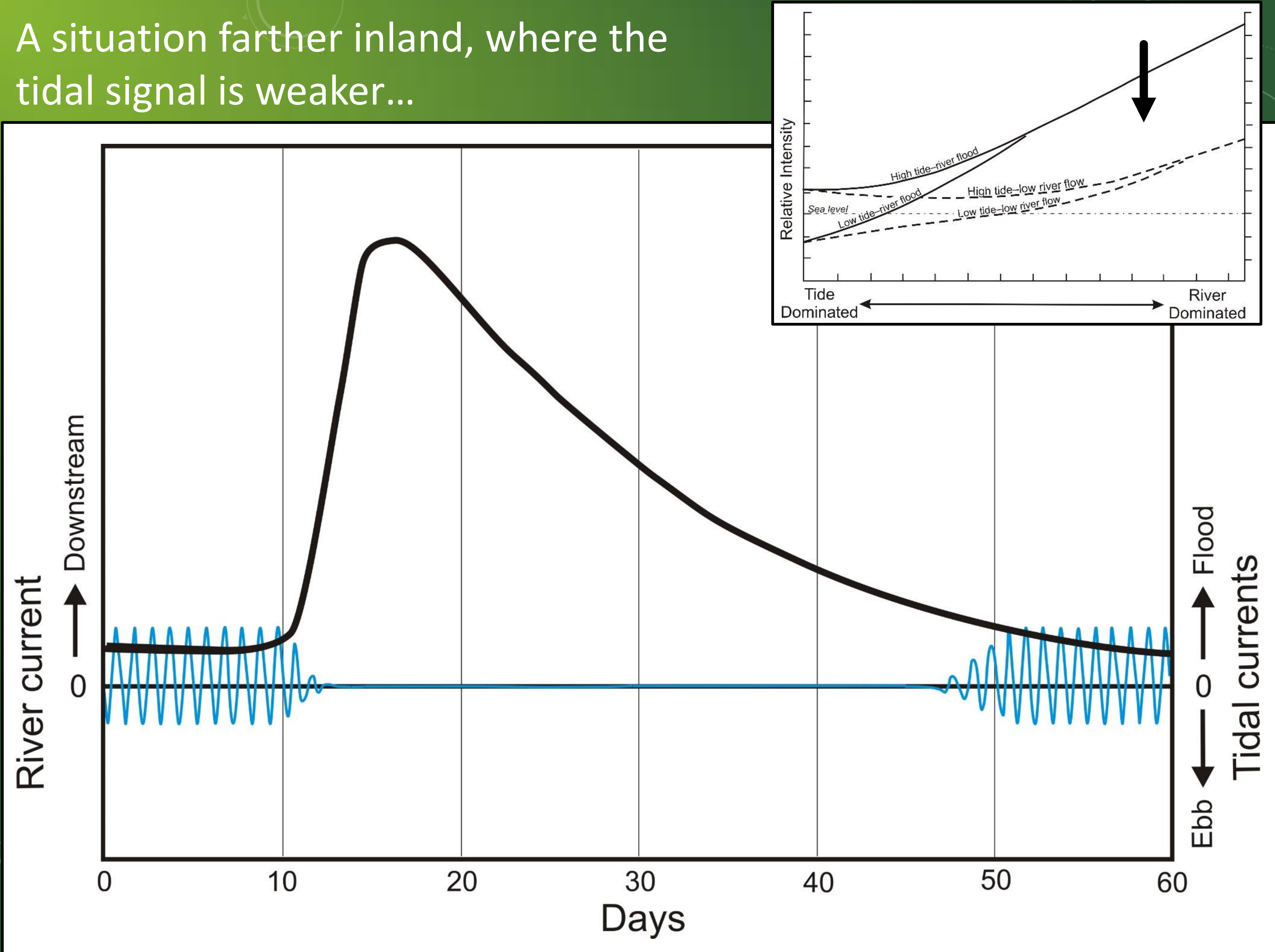
Typical hydrograph for a large, coastal-plain river



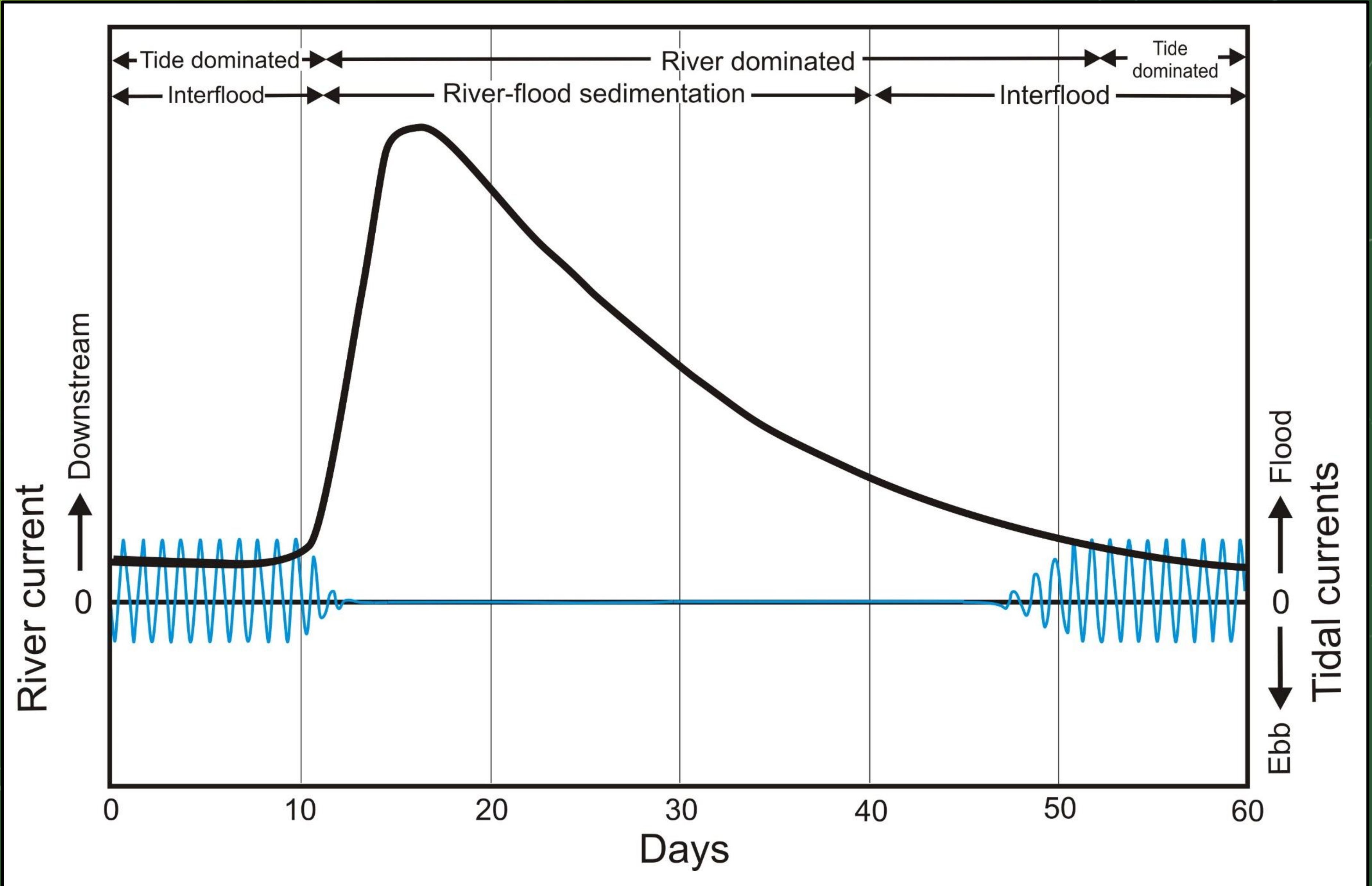
Typical hydrograph for a large, coastal-plain river



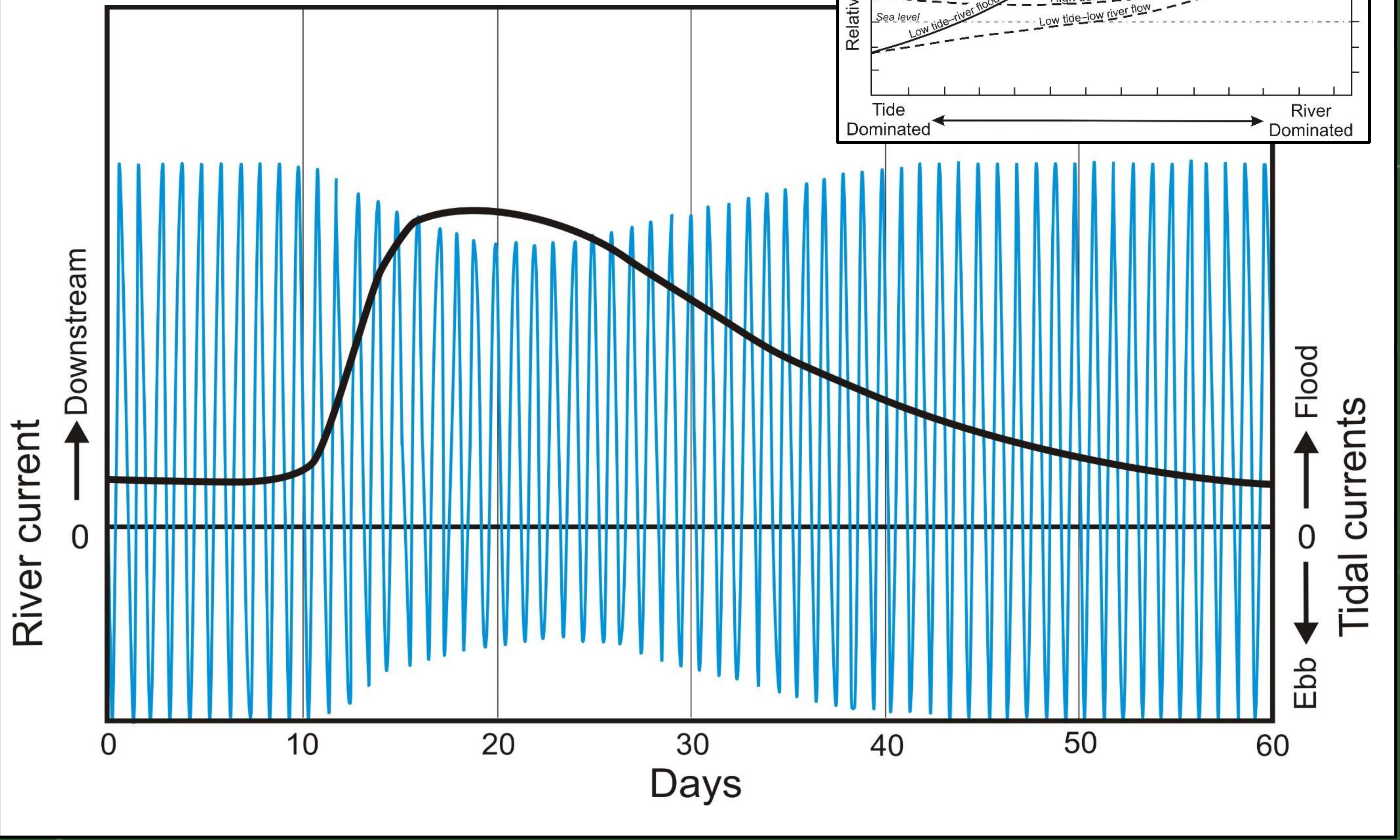
A situation farther inland, where the tidal signal is weaker…

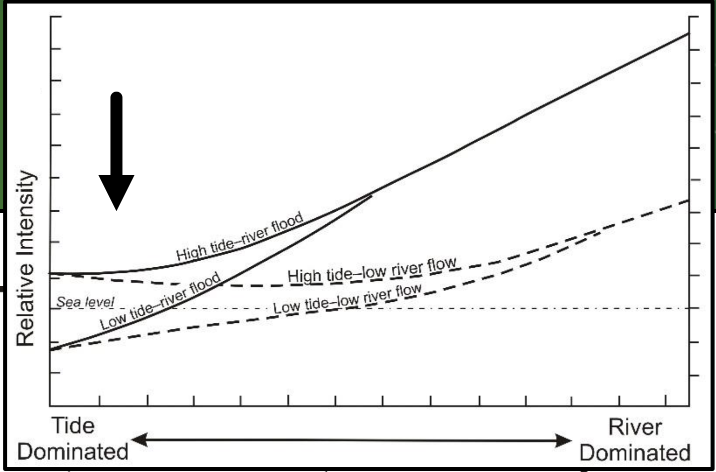


A situation farther inland, where the tidal signal is weaker…

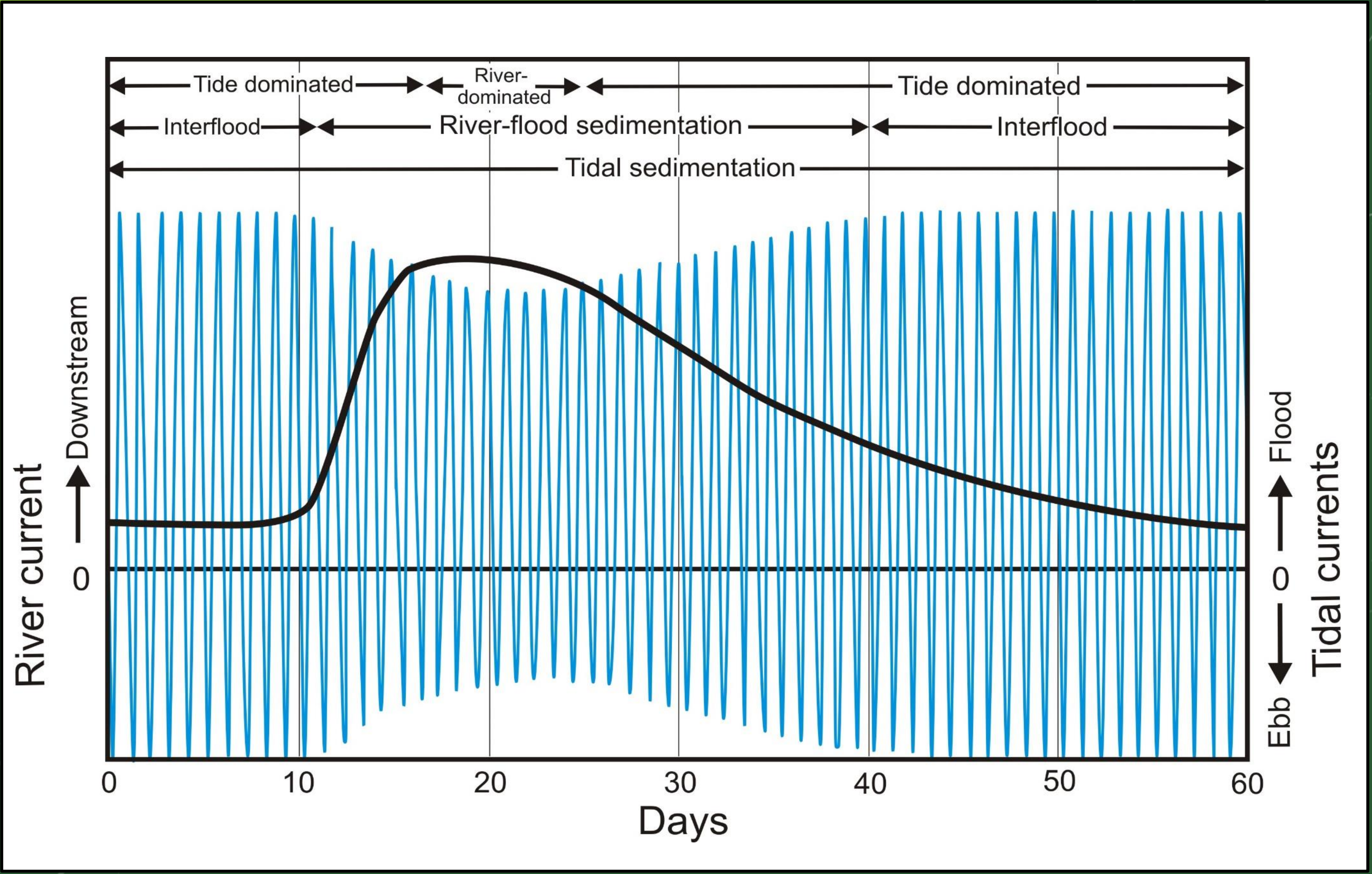


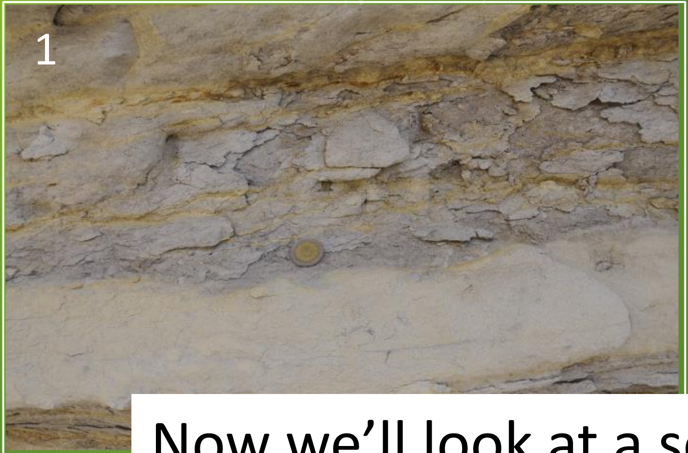
A situation farther seaward, where the tidal signal is much stronger…

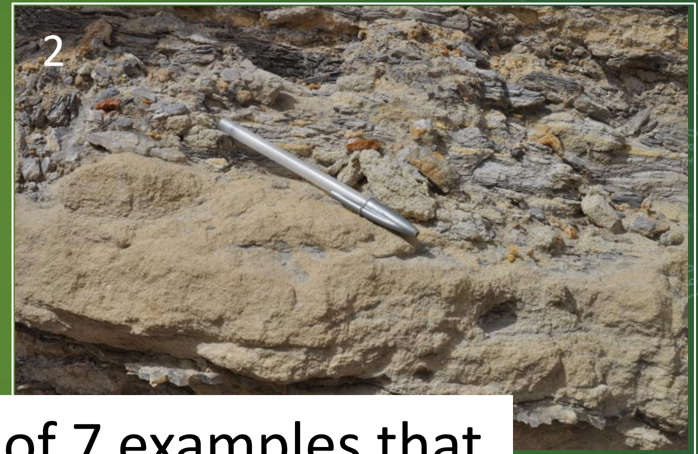




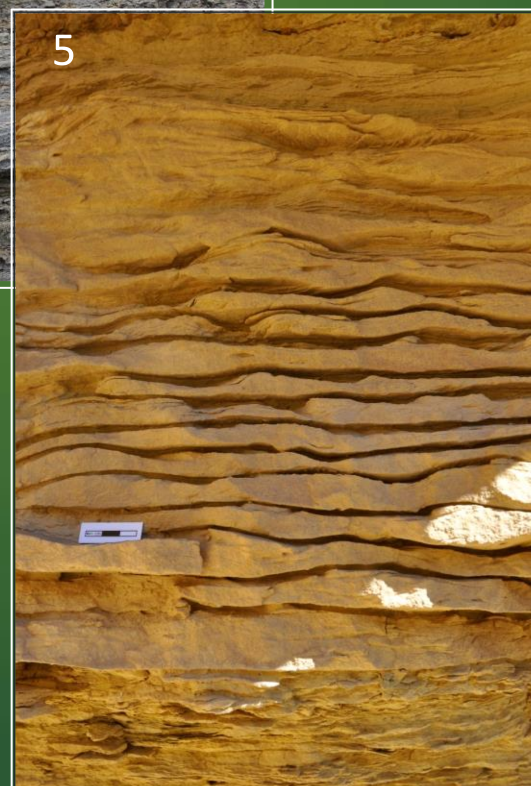
A situation farther inland, where the tidal signal is much stronger…

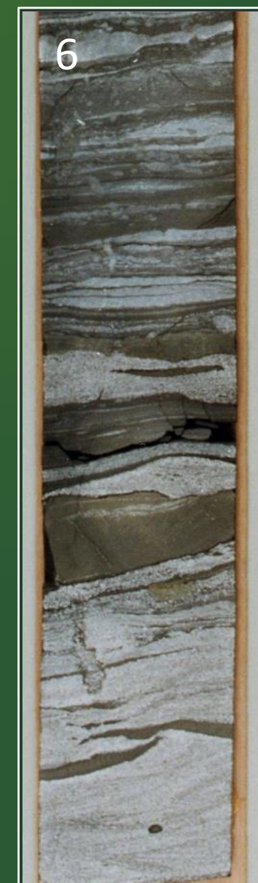


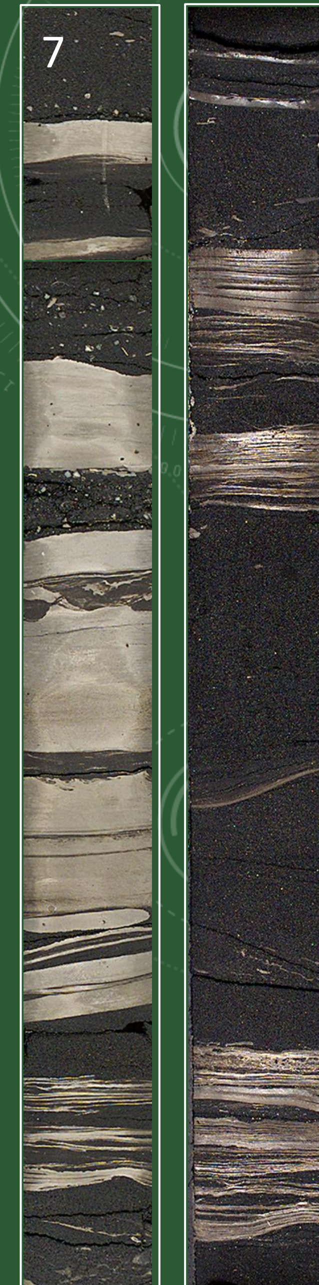




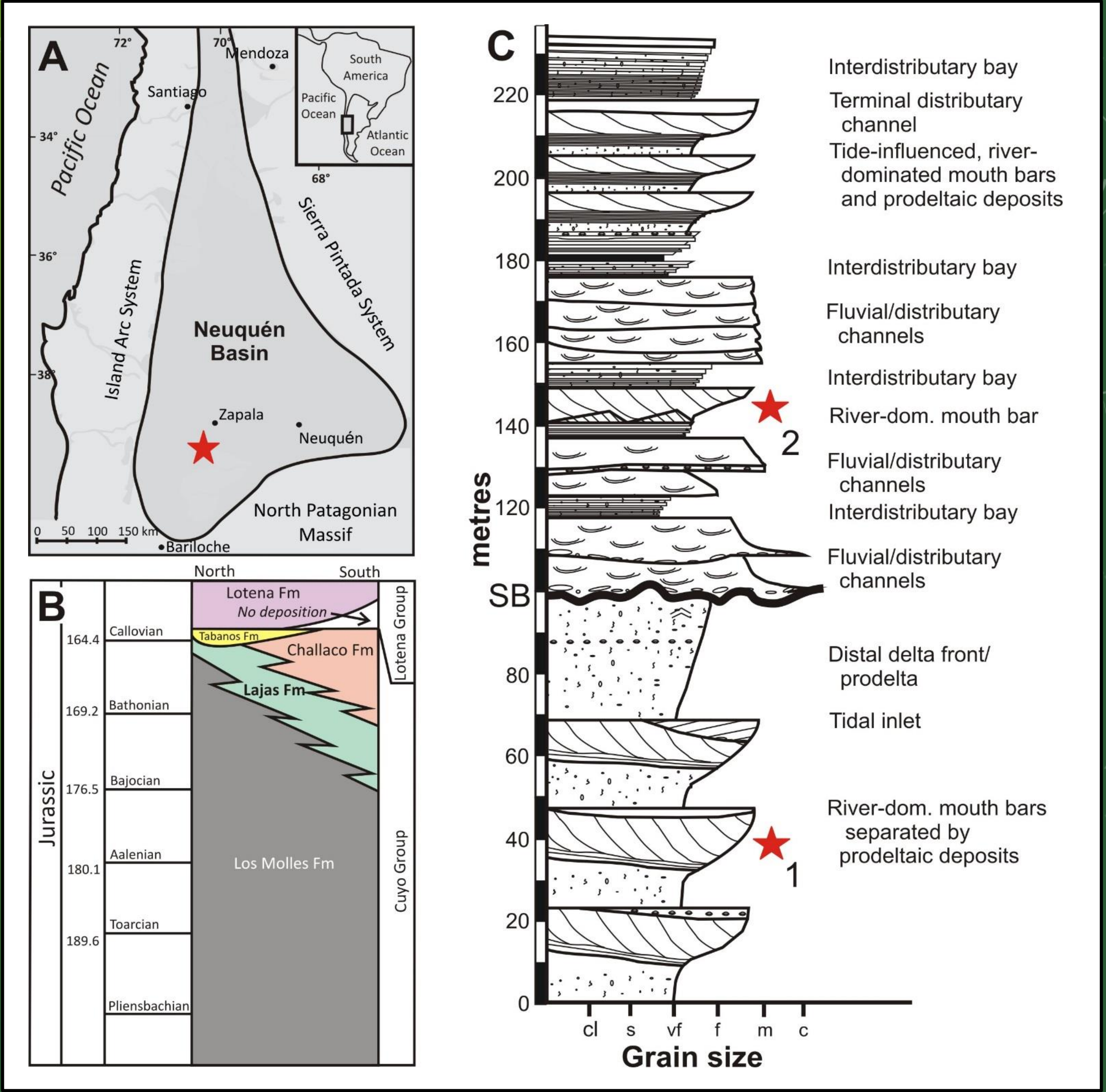
Now we'll look at a set of 7 examples that Illustrate the concepts just described.

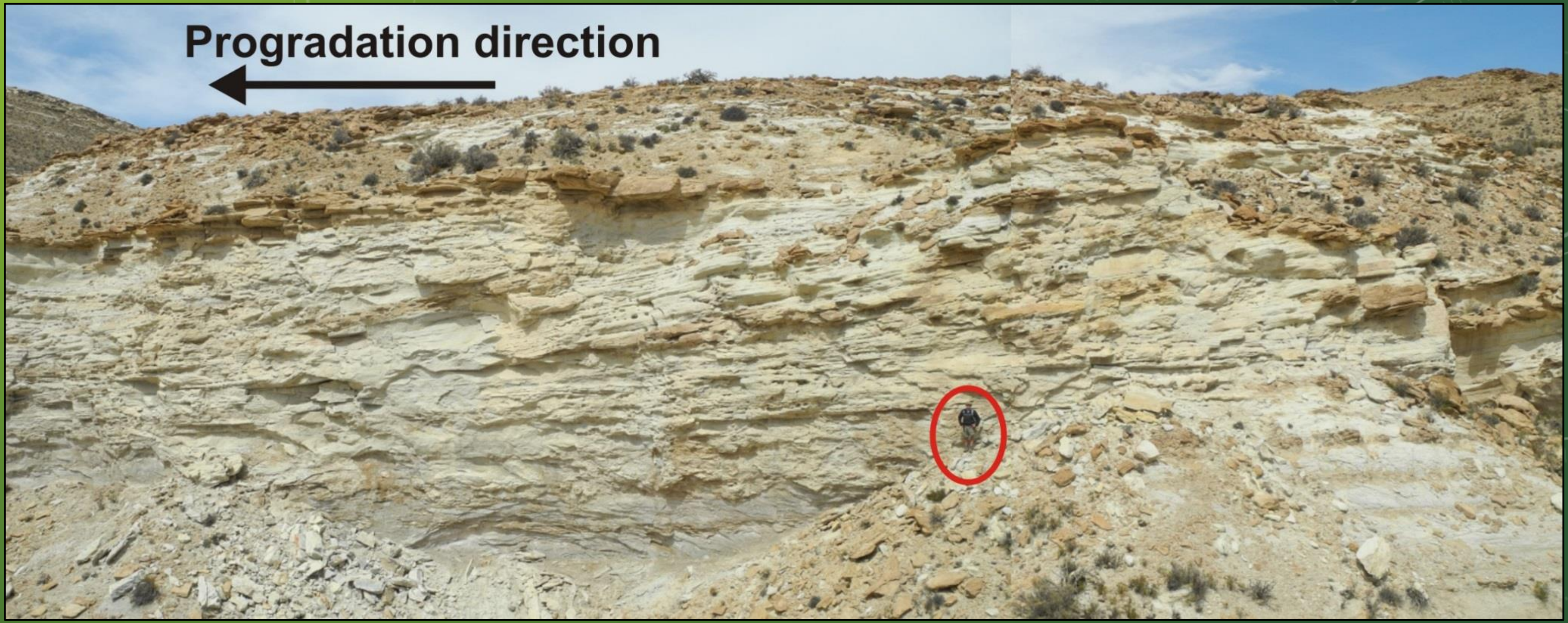




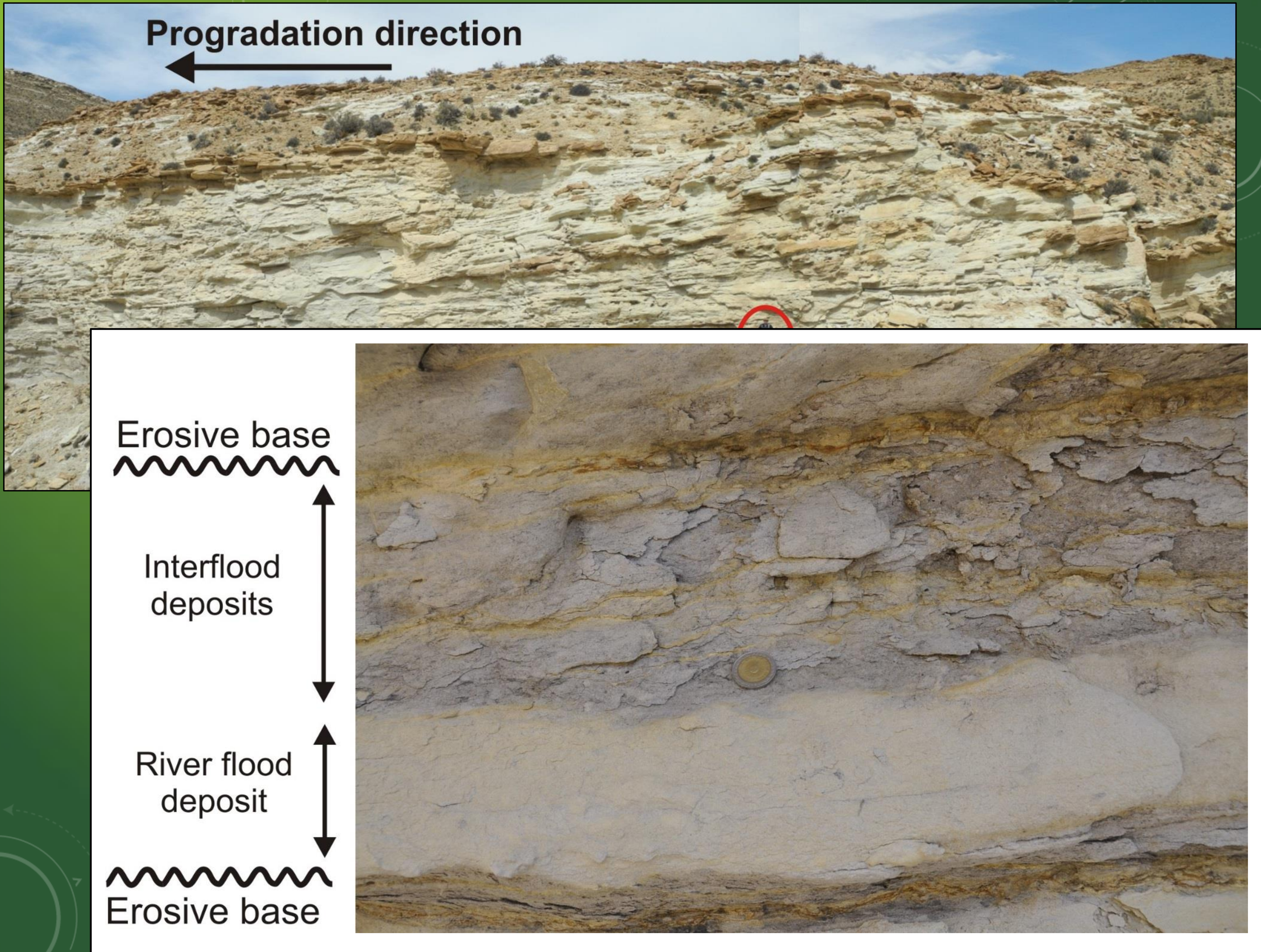


Examples 1 and 2:
Lajas Formation (Jurassic), Argentina

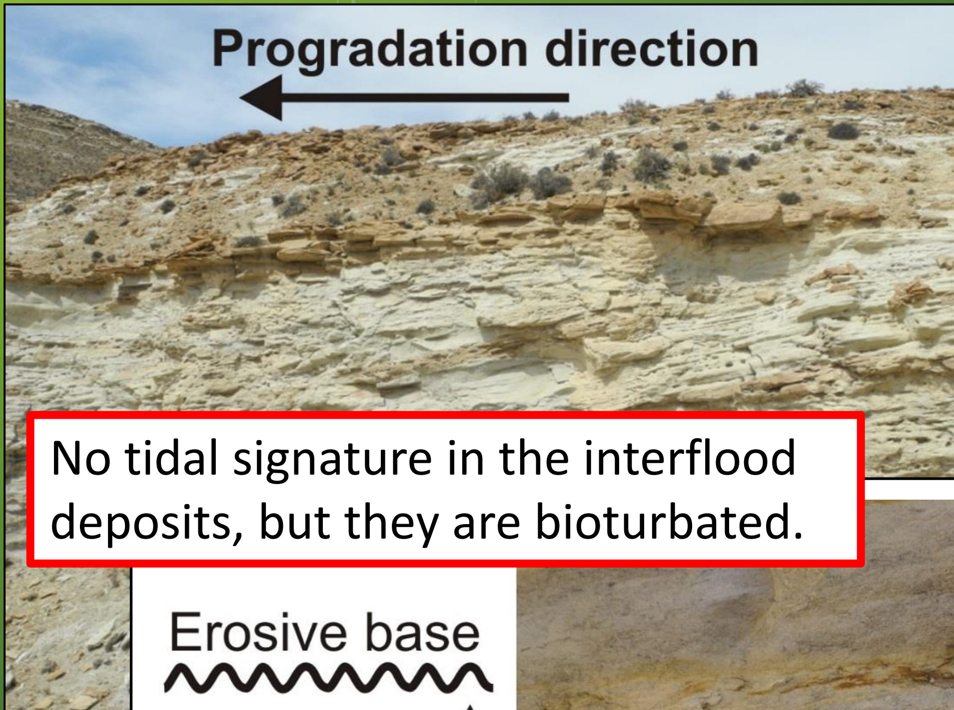




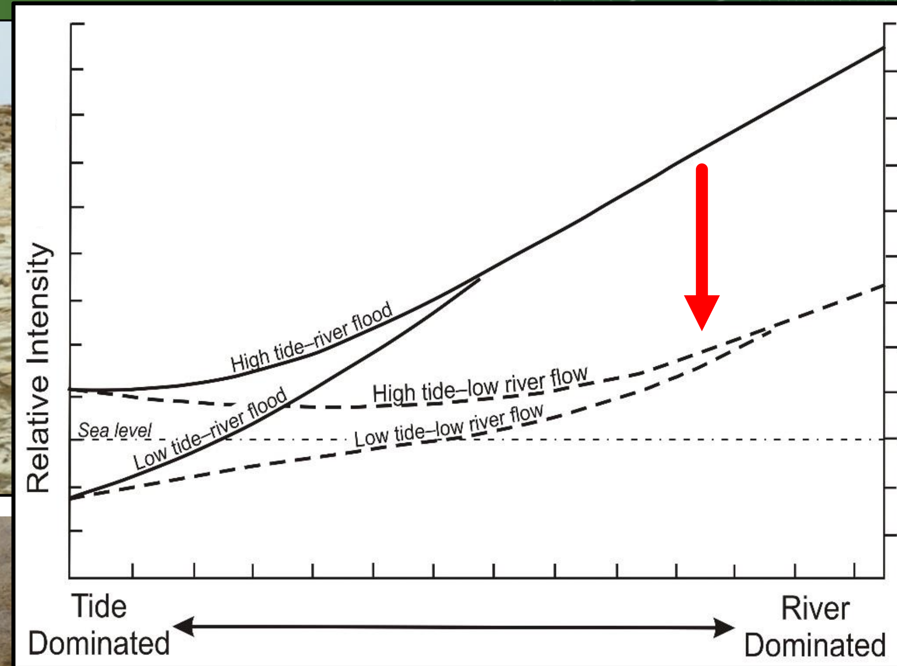
Distributary mouth-bar deposit

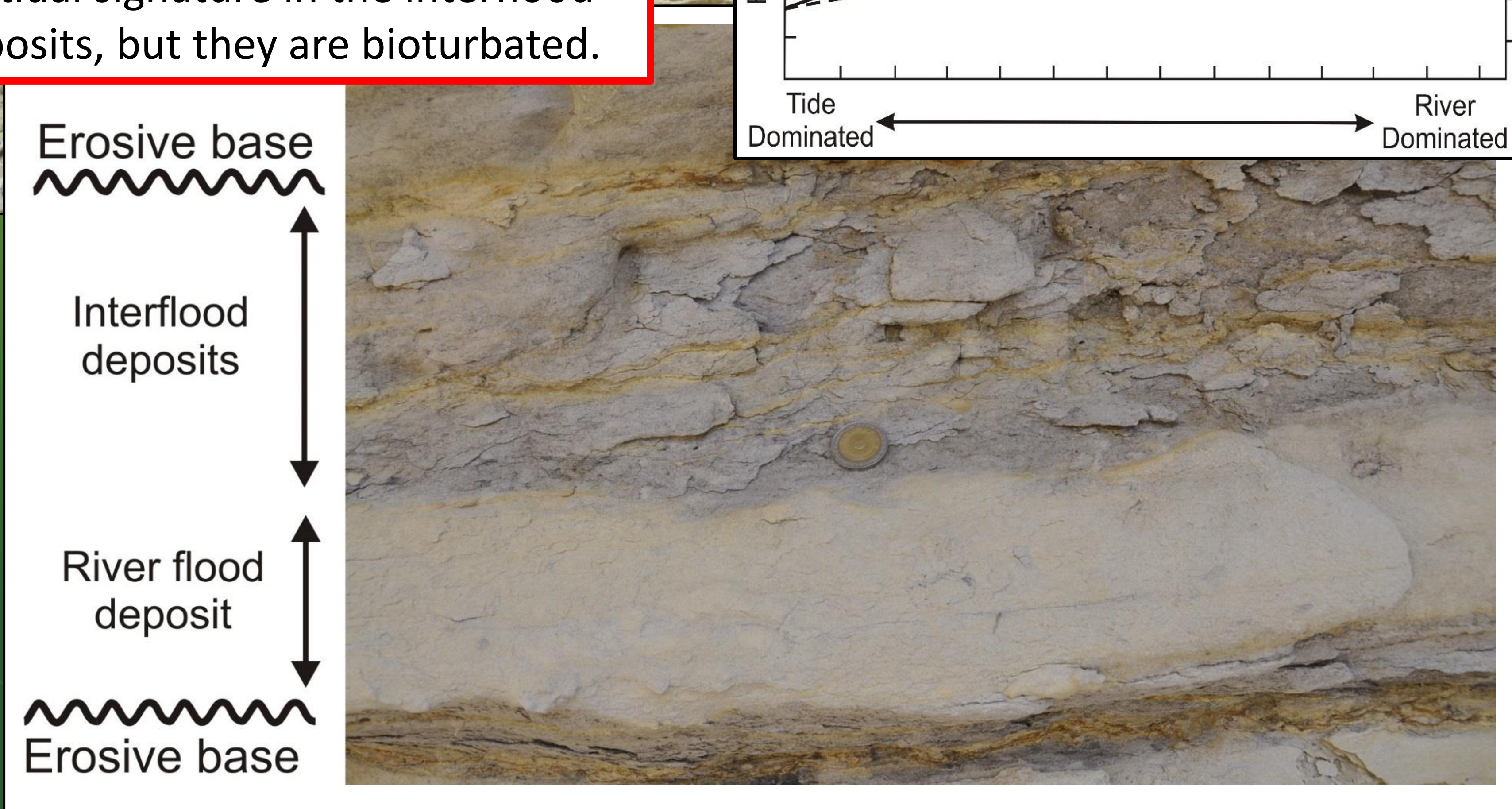


Progradation direction
Erosive base
Interflood deposits
River flood deposit
Erosive base

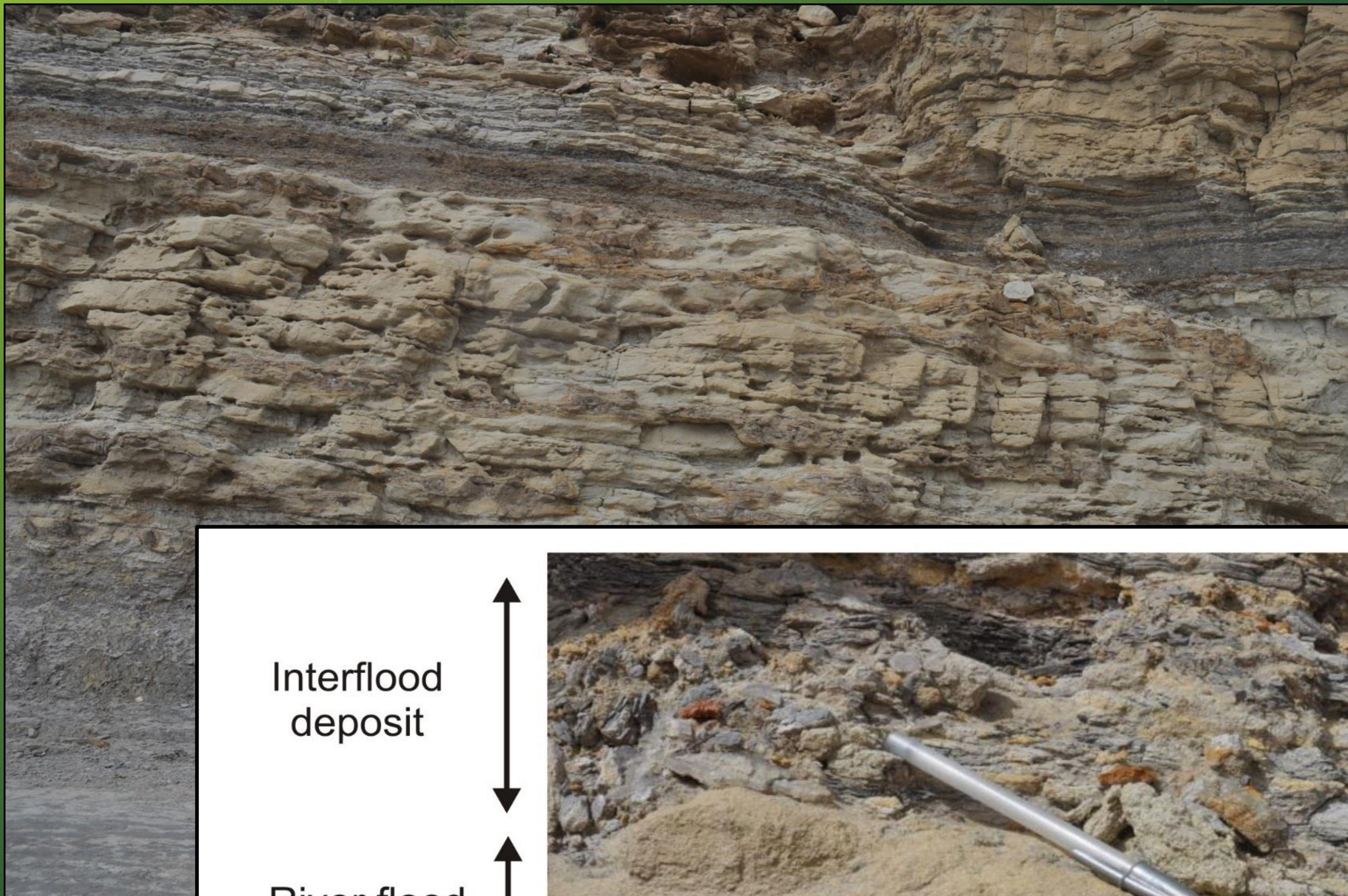


No tidal signature in the interflood deposits, but they are bioturbated.





Images courtesy of Marcello Gugliota



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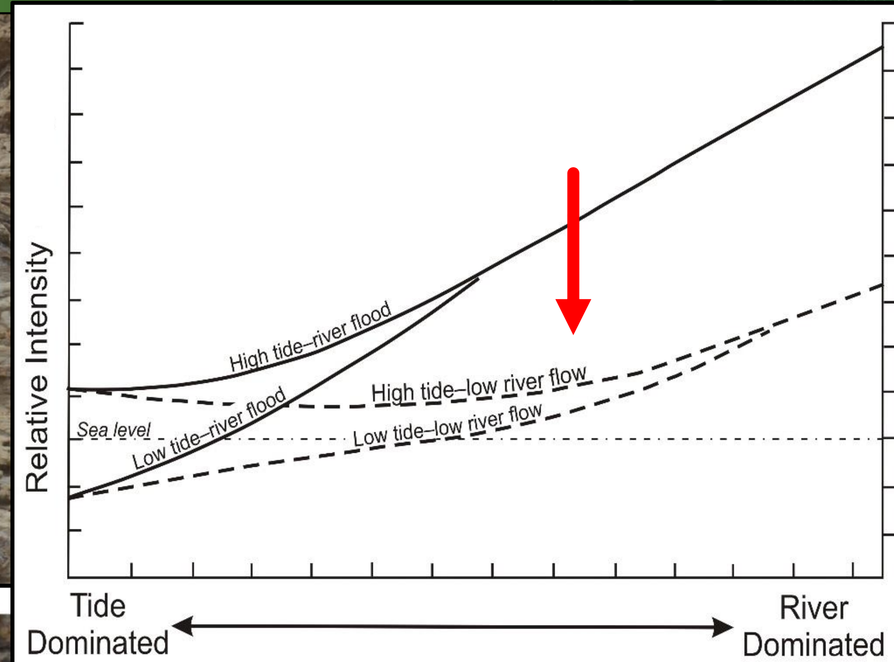
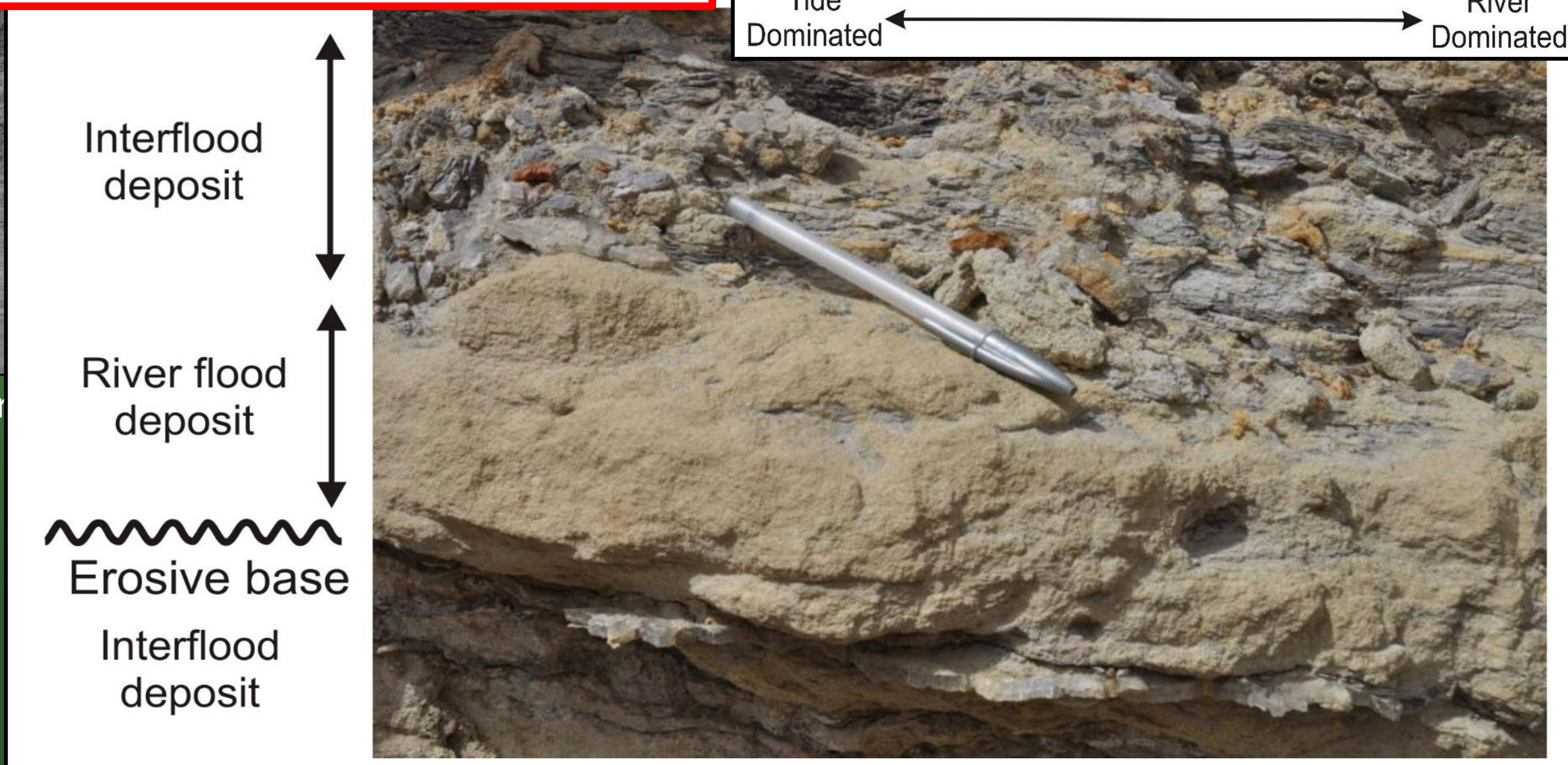
Interflood deposit
River flood deposit
Erosive base
Interflood deposit

Tidal lamination and bipolar ripple cross-lamination is present in the interflood deposits.





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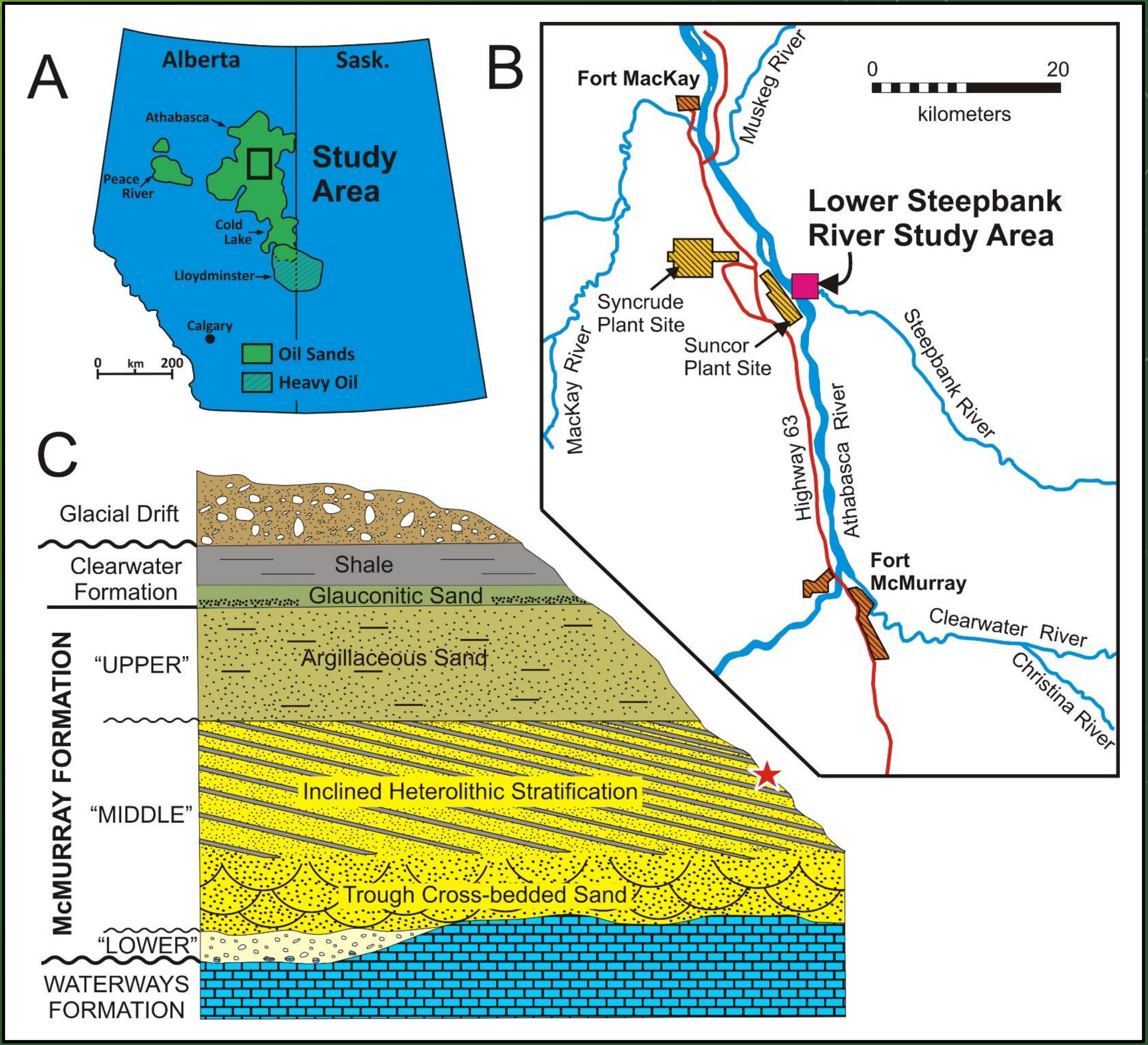
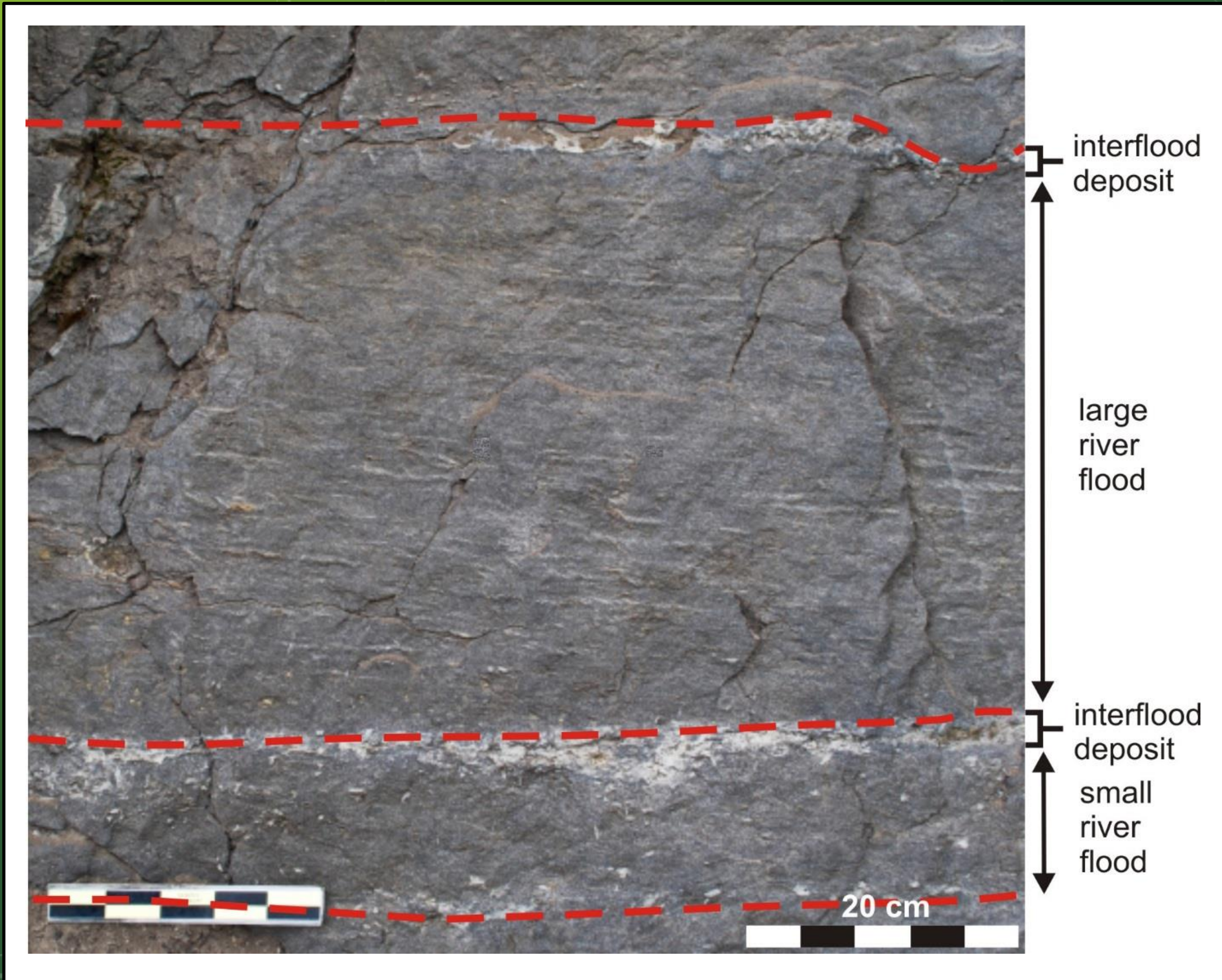
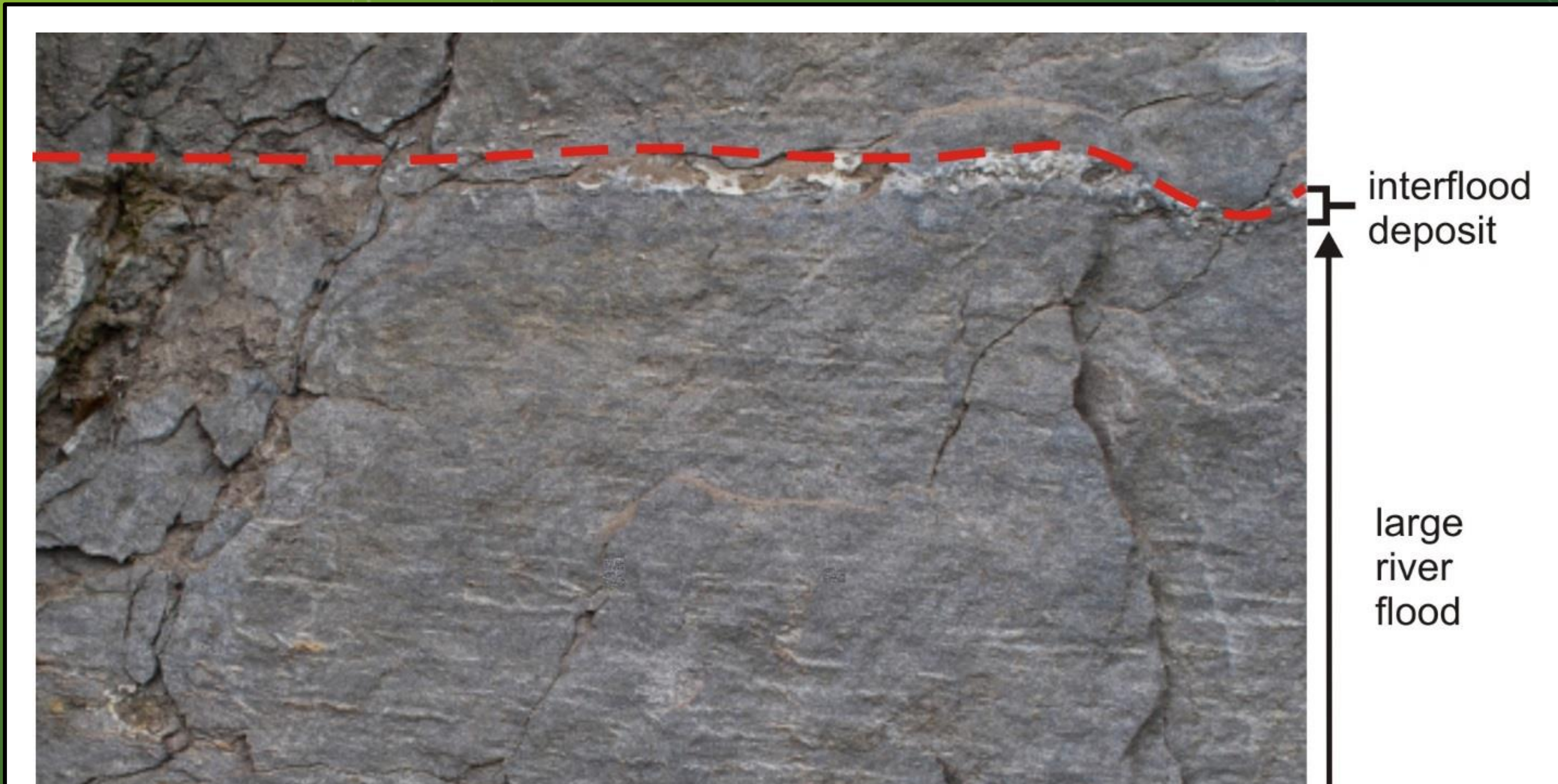
<u>Example 3</u>: McMurray Formation (Cretaceous), Alberta, Canada



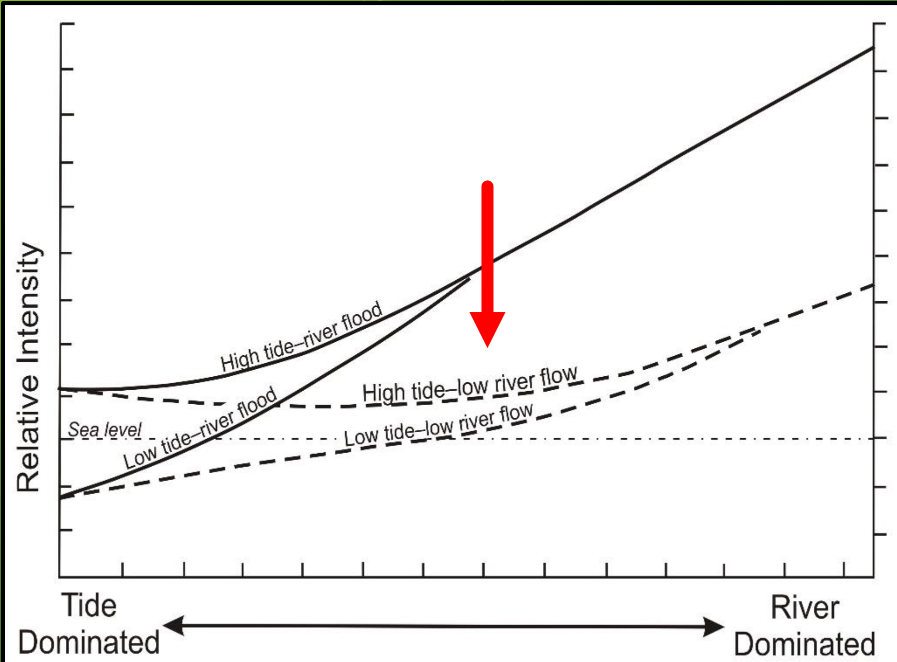
Large-scale point-bar deposit

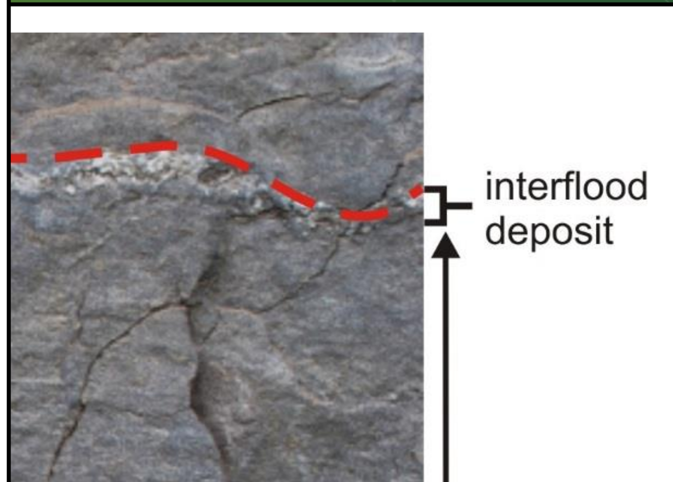


Large-scale point-bar deposit

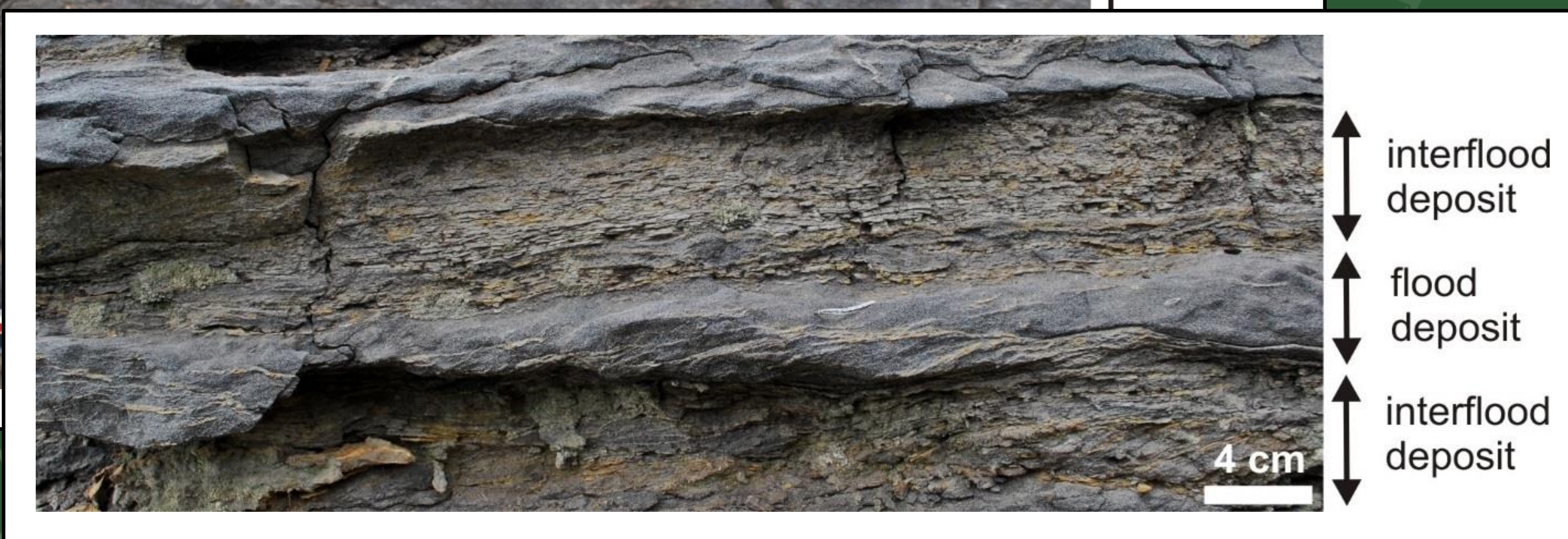


Large-scale point-bar deposit

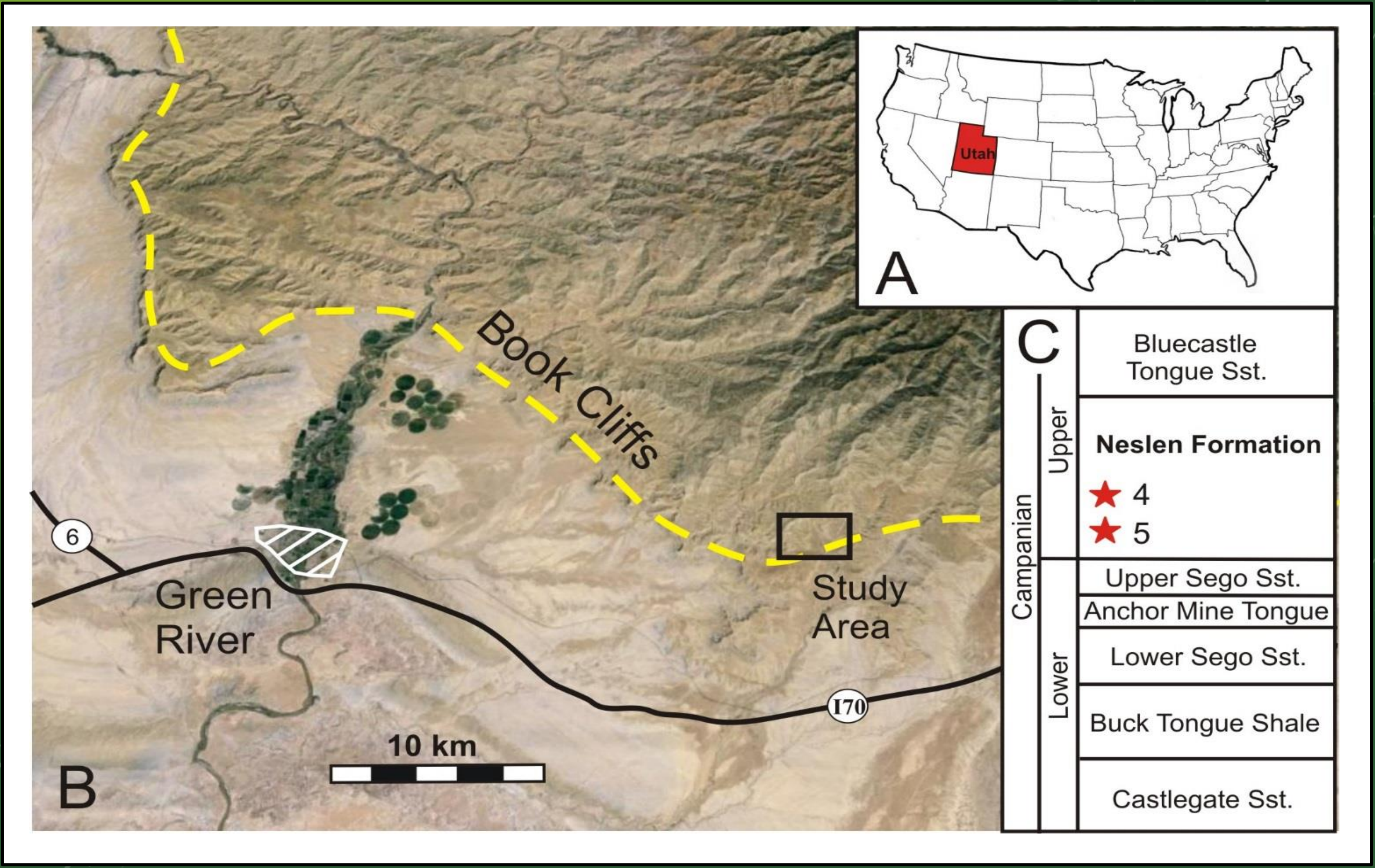


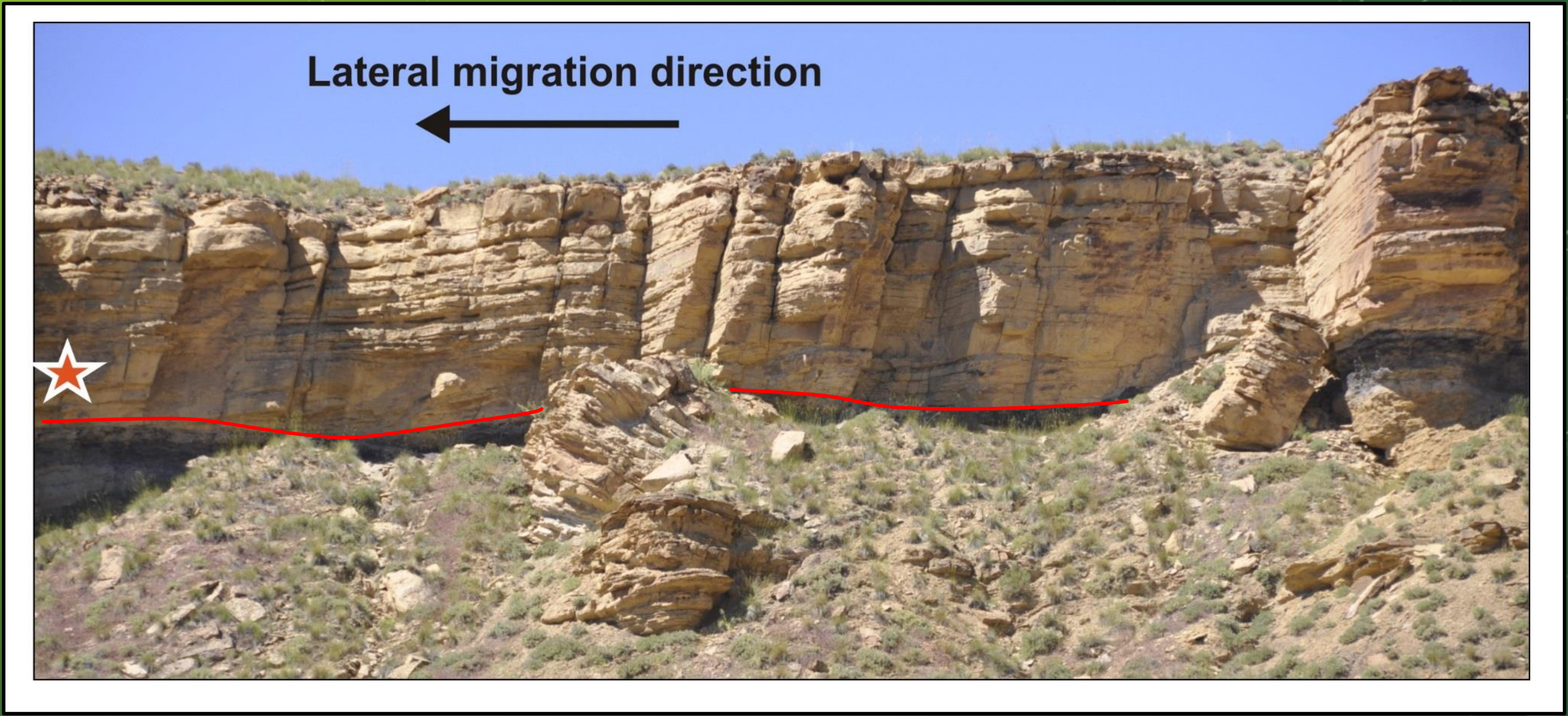


Distinct tidal lamination is present in the interflood deposits, and possible tidal modulation is evident in the some river-flood deposits.

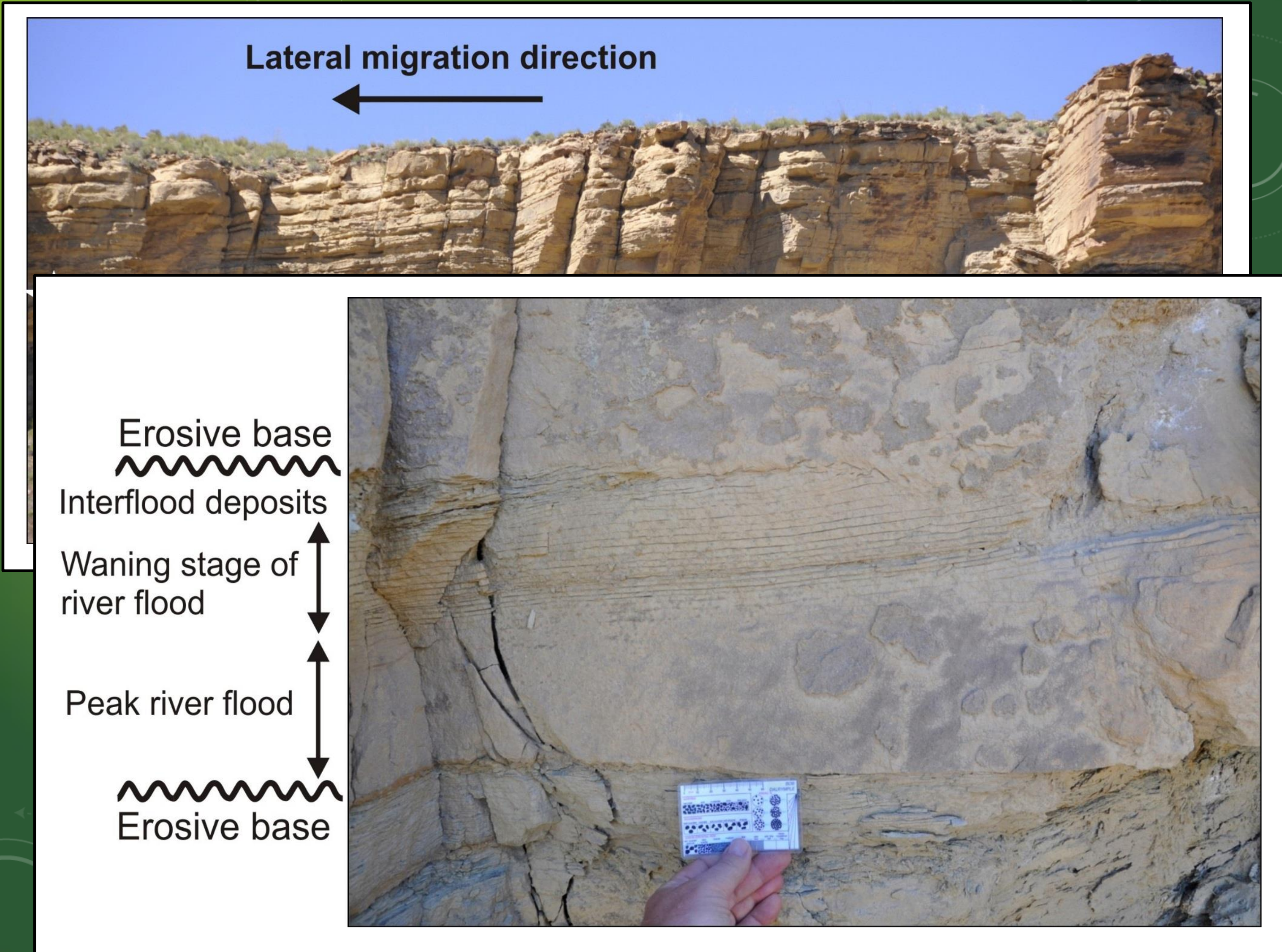


Examples 4 and 5: Neslen Formation (Cretaceous), Utah



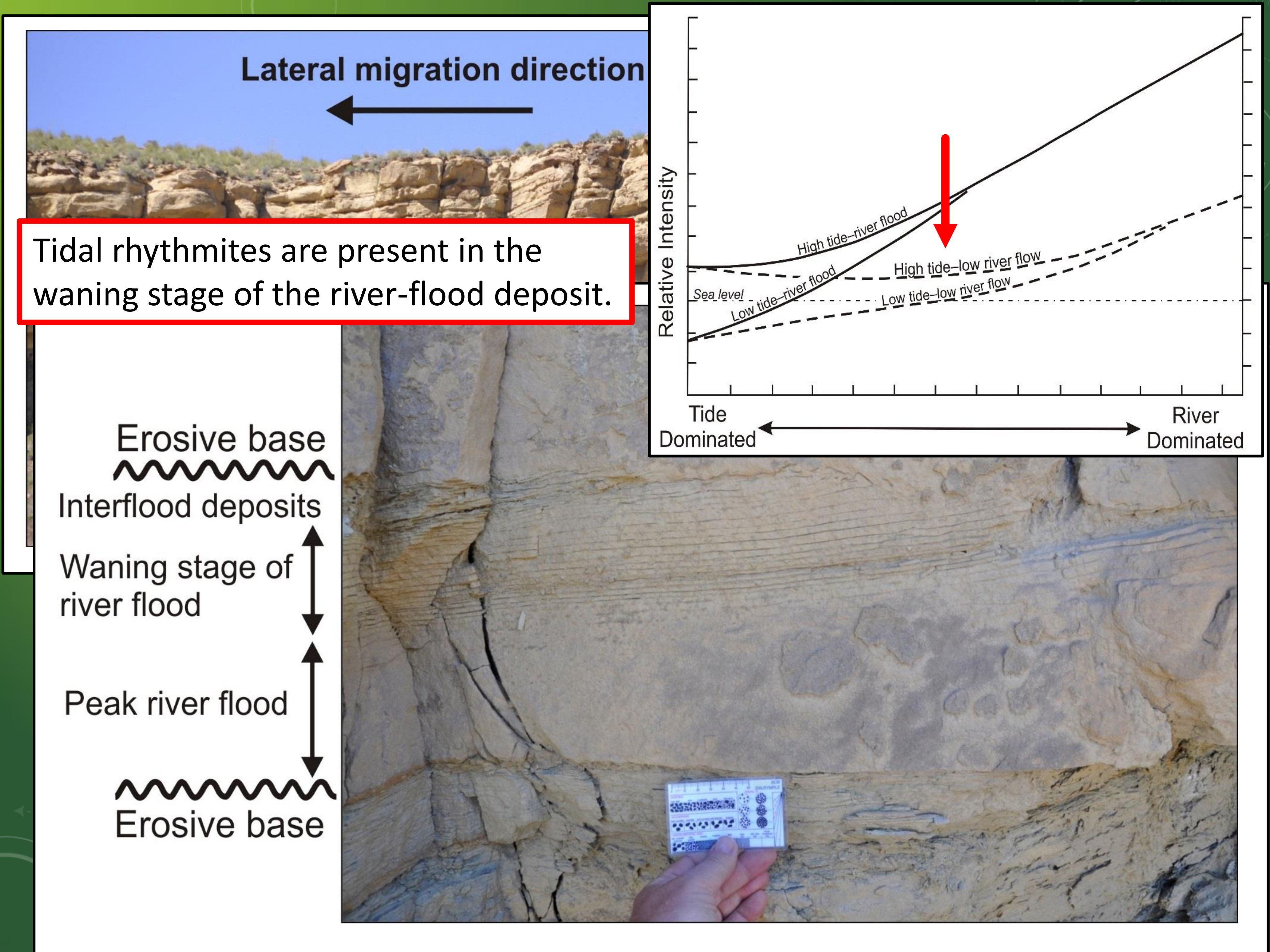


Point-bar deposit

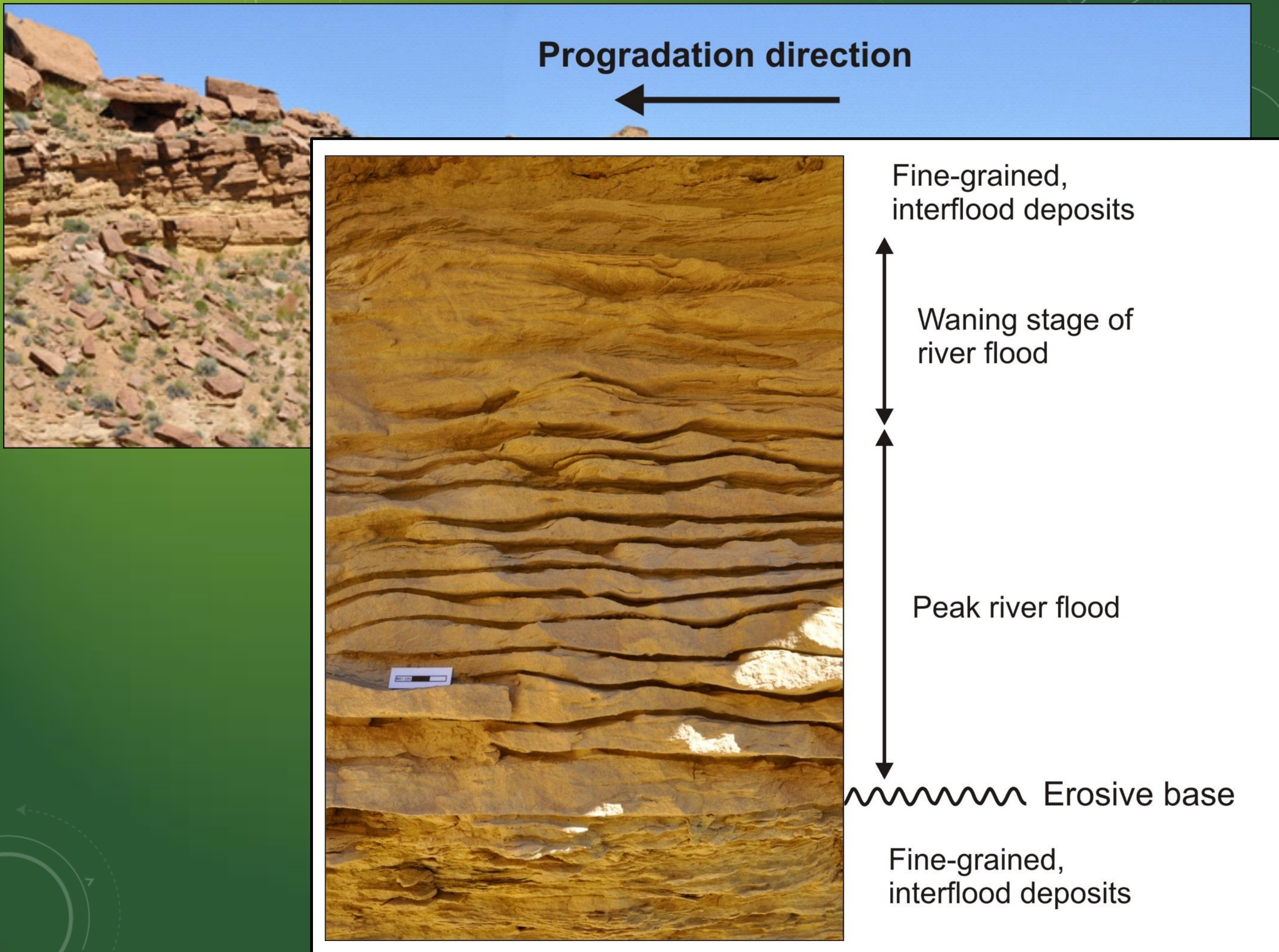


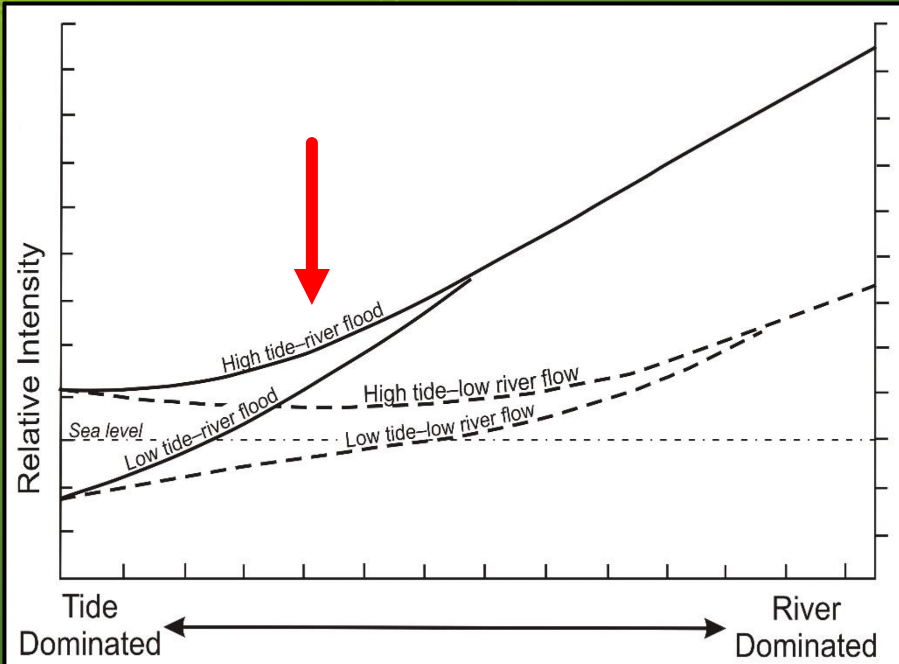
Lateral migration direction
Erosive base
Interflood deposits
Waning stage of river flood
Peak river flood
Erosive base

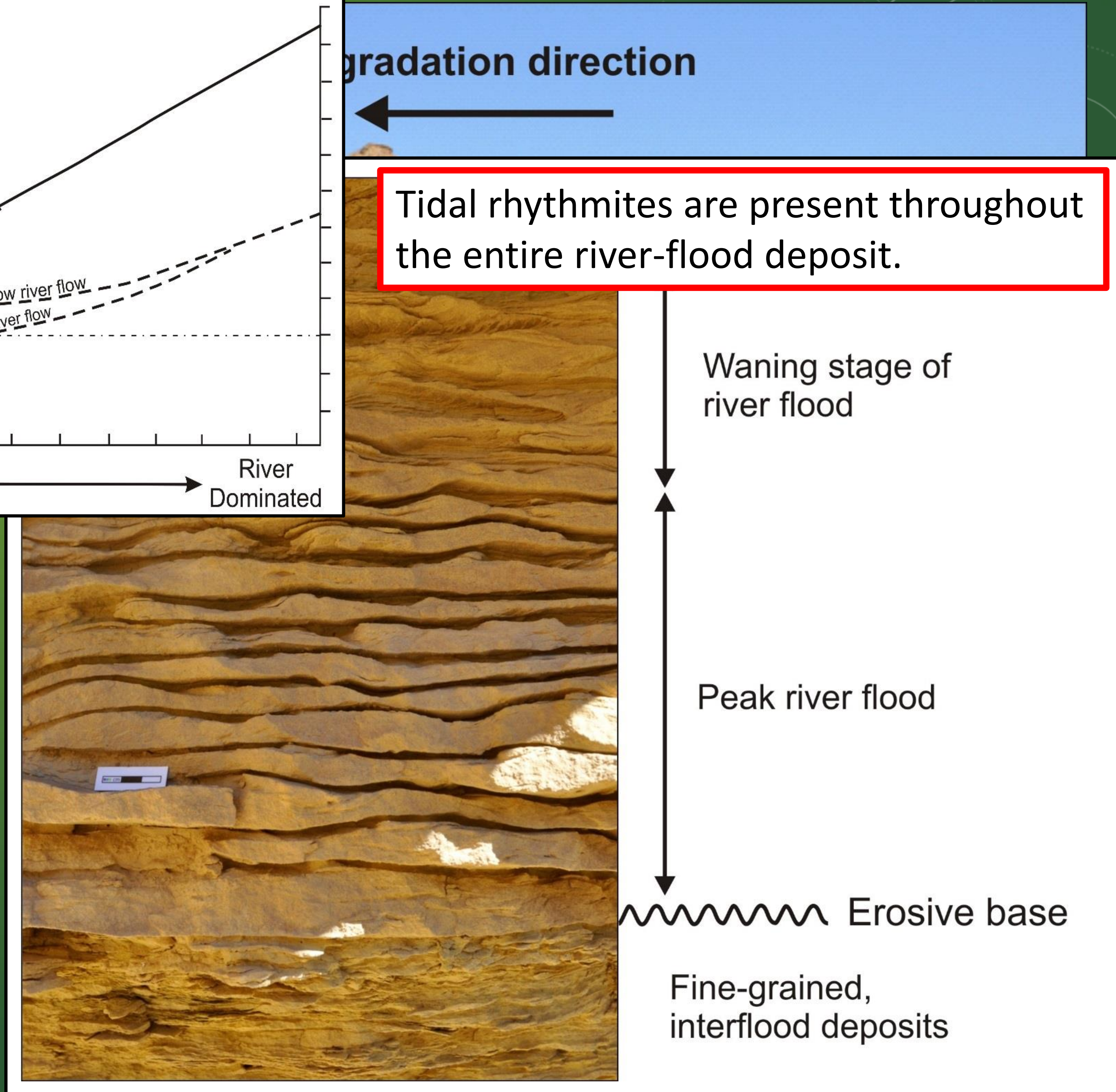
Tidal rhythmites are present in the waning stage of the river-flood deposit.



Distributary mouth-bar deposit or crevasse delta

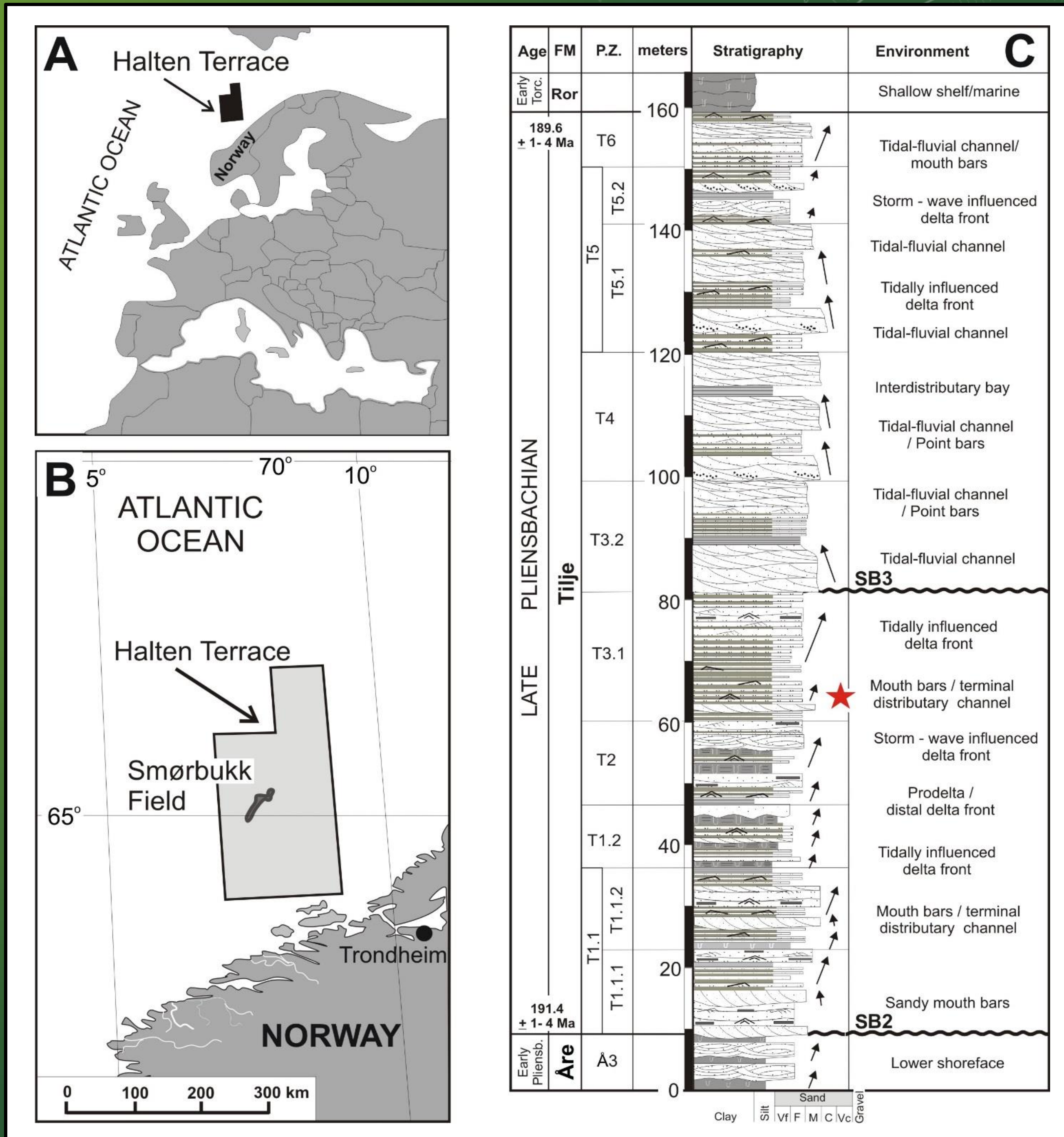

Progradation direction
Fine-grained,
interflood deposits
Waning stage of
river flood
Peak river flood
Erosive base
Fine-grained,
interflood deposits

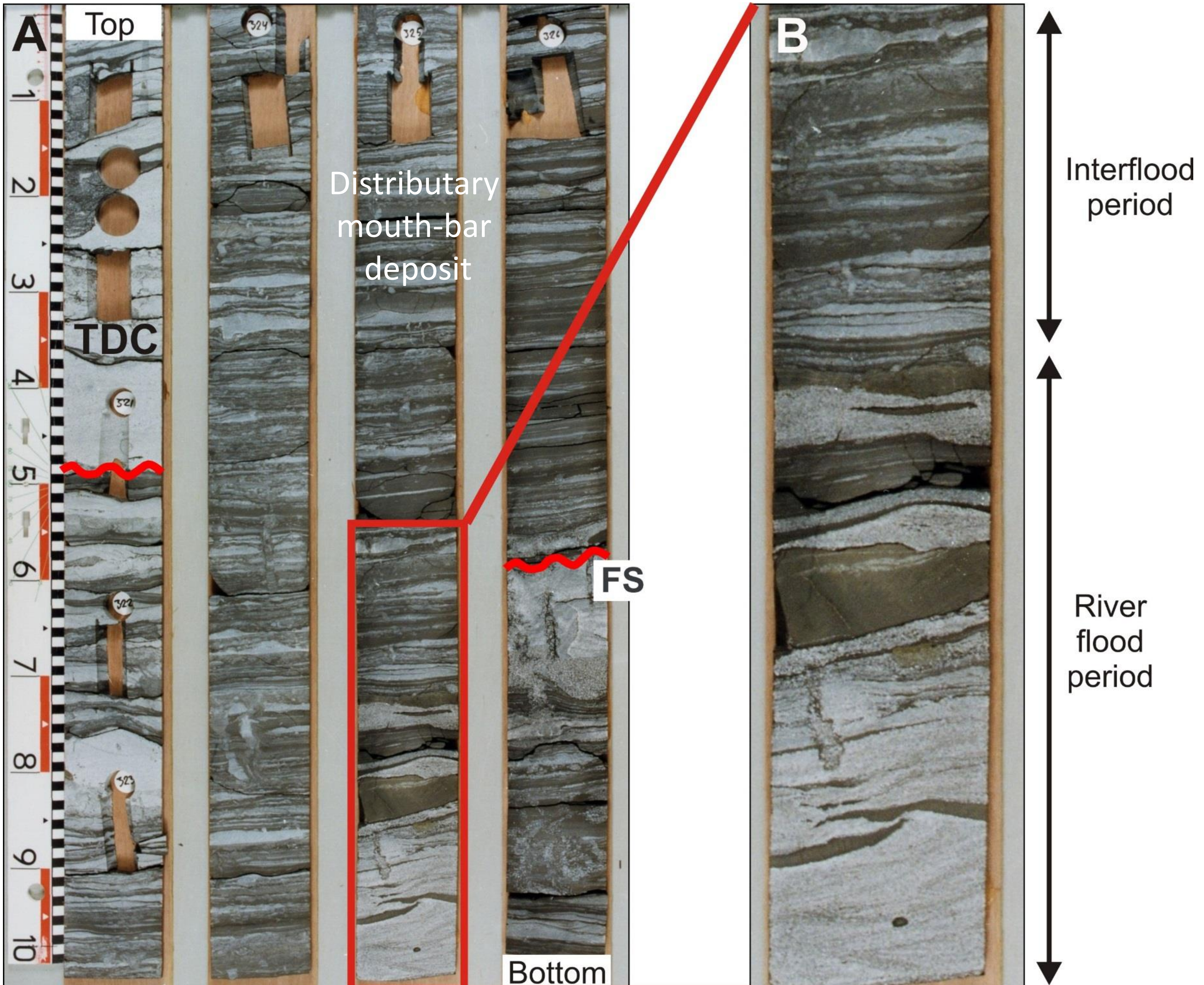




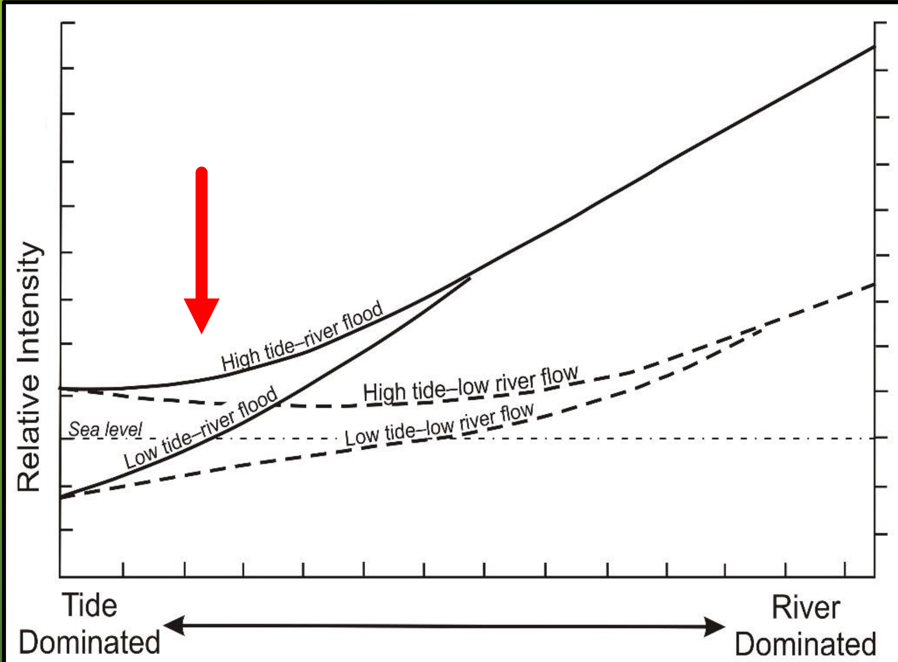
Tidal rhythmites are present throughout the entire river-flood deposit.

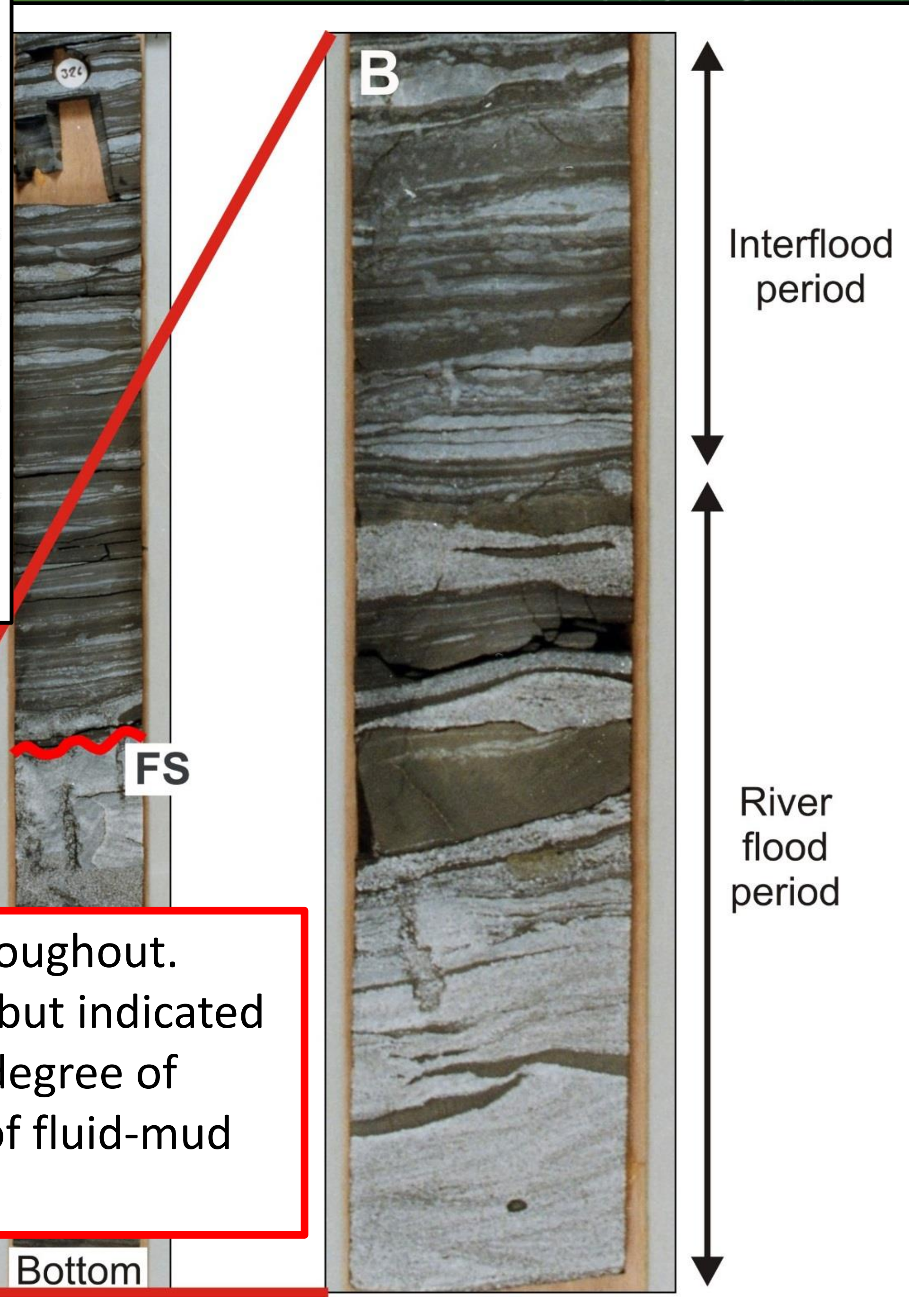
Example 6:
Tilje Formation (Jurassic), offshore Norway





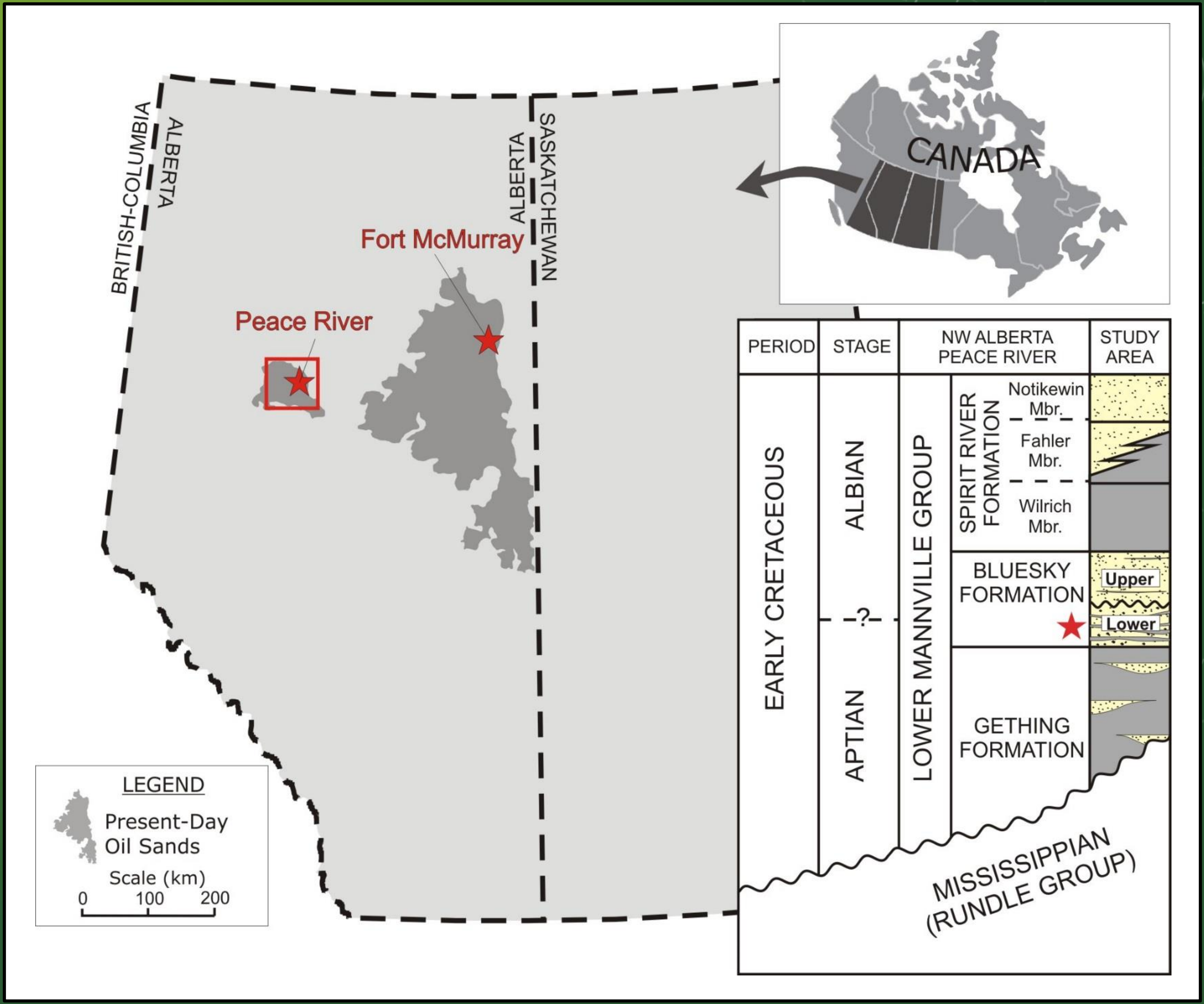
A
Top
TDC
Distributary mouth-bar deposit
FS
Bottom
B
Interflood period
River flood period

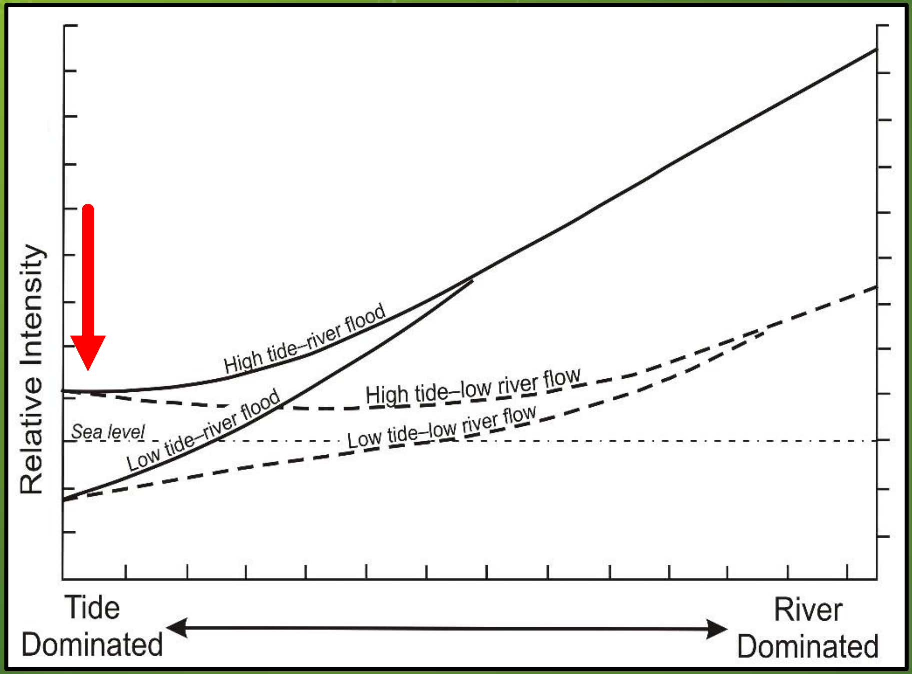


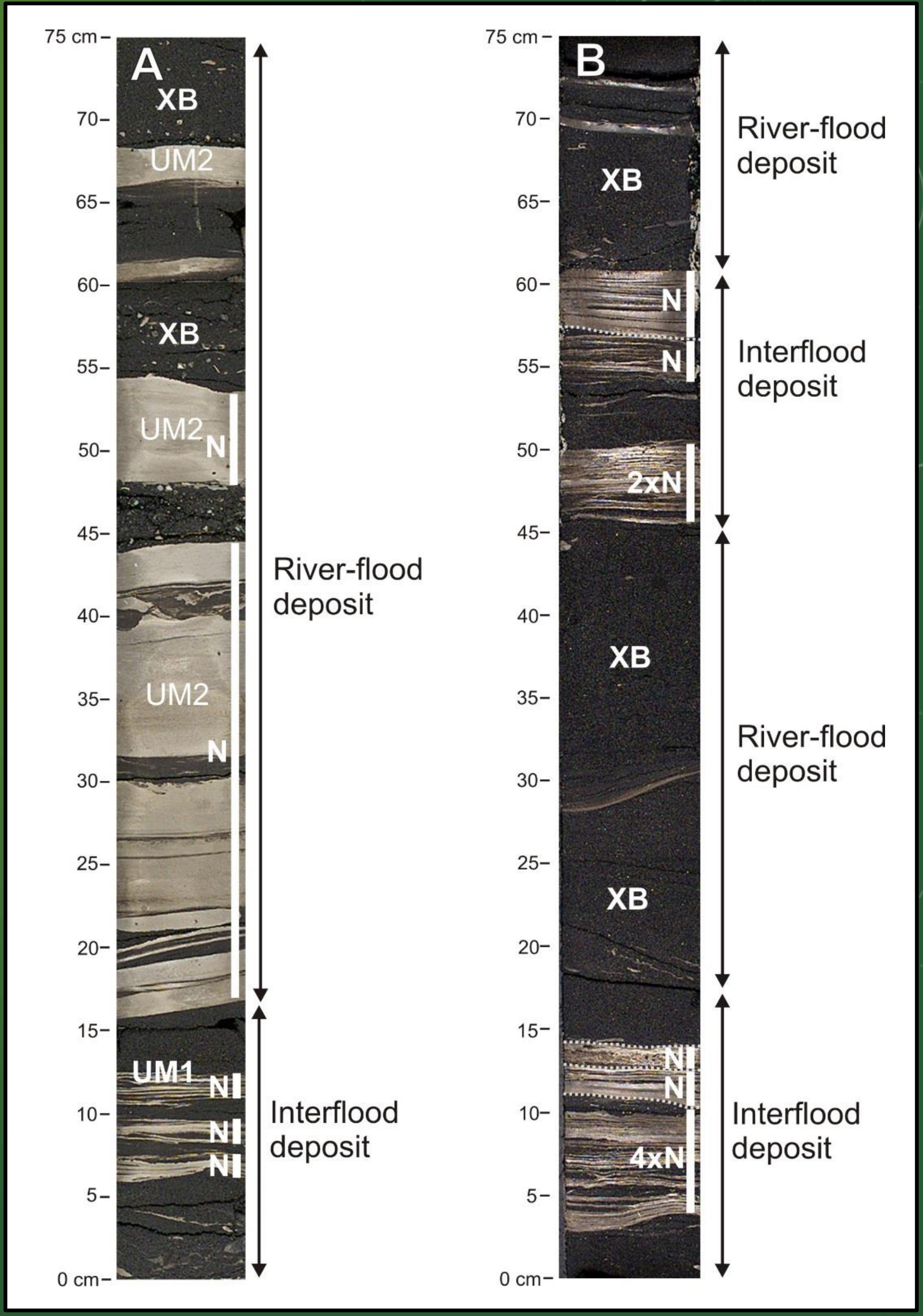


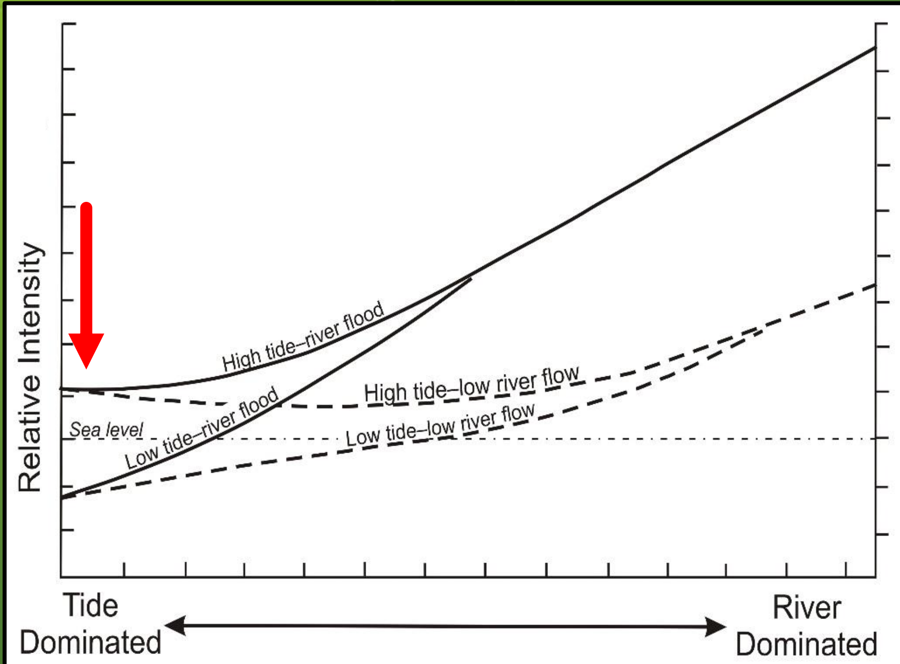
Tidal lamination present throughout. River-flood deposits subtle, but indicated by coarser sand size, lower degree of bioturbation and presence of fluid-mud deposits.

Example 7: Bluesky Formation (Cretaceous), Alberta, Canada

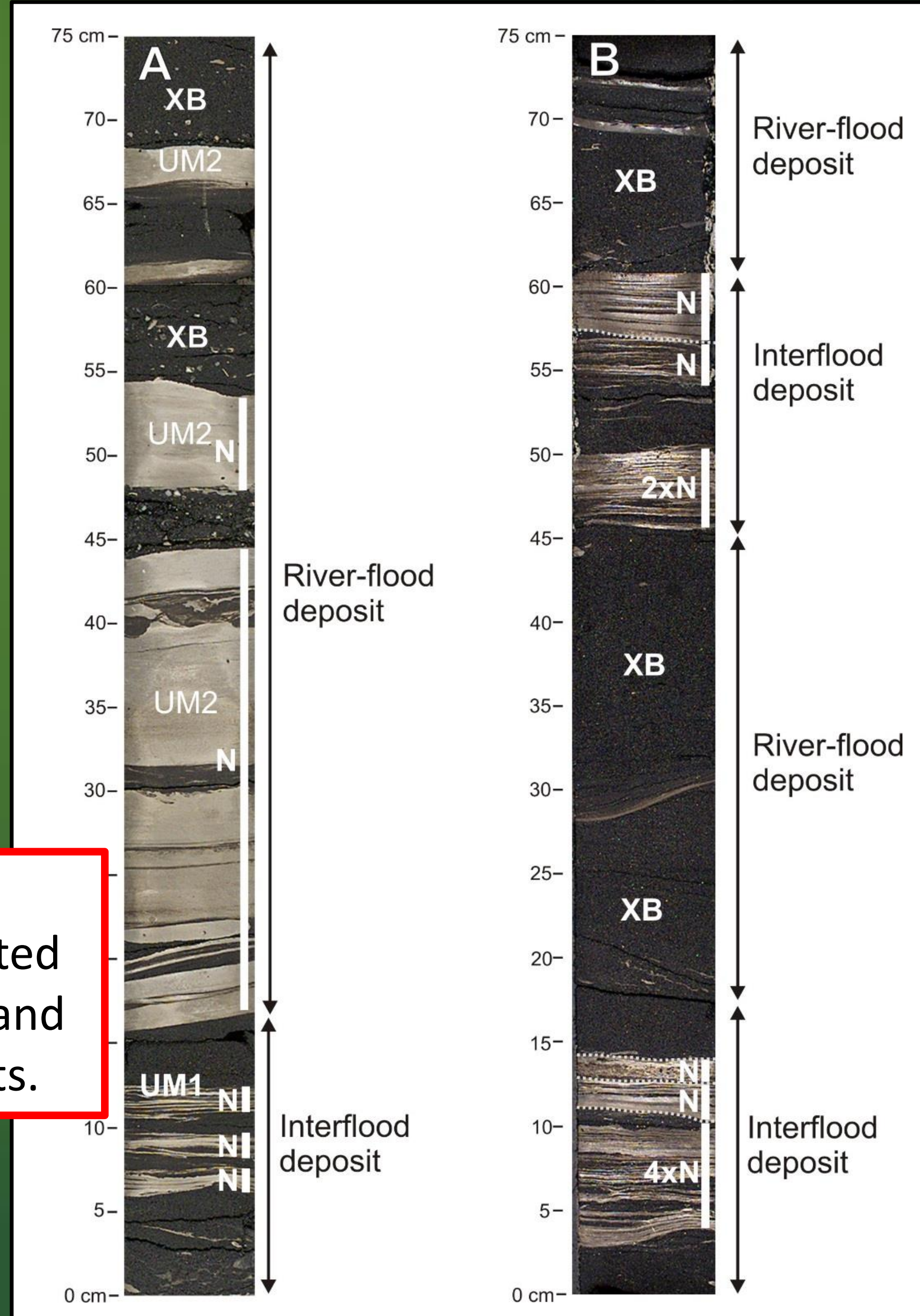



Relative Intensity
High tide–river flood
High tide–low river flow
Low tide–river flood
Low tide–low river flow
Sea level
Tide Dominated
River Dominated


A
B
75 cm
0 cm
XB
UM2
UM1
N
2xN
4xN
River-flood deposit
Interflood deposit



Tidal lamination present throughout. River-flood deposits cryptic, but suggested by coarser sand size, larger cross beds, and greater abundance of fluid-mud deposits.



SUMMARY AND CONCLUSIONS (1)

- Heterolithic strata (HS) are abundant in the tidal-fluvial transition because of the temporal variation in flow strength.
- There are two end-member types, river- and tide-generated, but mixed-energy HS predominates through much of the transition zone.
- The fundamental control on the nature of these deposits is the river-flood/interflood cycle of river-discharge variation.
- In fluvially dominated areas, tidal processes are recorded only during the interflood period.
- As the tidal signal becomes stronger, tidal lamination can be developed during the waning stage of the river flood, and extends lower into the river-flood deposit as tidal influence increases.
- In tidally dominated areas the river-flood signal becomes cryptic.

SUMMARY AND CONCLUSIONS (2)

- Such bed-level determinations of relative process intensity must be averaged over an entire unit to assess the overall process dominance at that site.
- Such evaluations at the mouth of a system allows one to assess the relative importance of river and tidal processes at the level of the entire depositional system.
- Longitudinal variations in the relative intensity of river and tidal processes can be used to determine the relative position of a given deposit within the fluvial-marine transition.
- Comparison of the physical and ichnological indicators of position within the transition has the potential to provide information on the discharge characteristics of the river.

THANKS FOR YOUR ATTENTION