Climatic versus Eustatic Controls on Sediment Flux to the Indus Submarine Fan, Indian Ocean*

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Abstract

The Indus submarine fan is formed by the erosion of the western Himalayas and associated ranges of Southwest Asia. Sediment flux into the deep water is driven by rock uplift in the mountains but on a variety of timescales the rate of transport is modulated by both sea level (i.e., accommodation space) and climatically modulated erosion and storage of sediment onshore. New, shallow high-resolution seismic and coring data from the Pakistani shelf now shows that large amounts of sediment are stored on the shelf during sea level highstand periods and that there are significant degrees of reworking from older shelf sediments, as well as longshore drift, so that the sediment in the shelf clinoforms is not closely coupled to the composition of sediment in the river discharge at any one time. The river itself has primarily been fed since 10 ka by incision and erosion of older fluvial terraces rather than by new erosion of the bedrock. Regional-scale landsliding in the early Holocene, triggered by strong summer monsoon rain may be responsible for storage of large amounts of sediment in the big river valleys. Around 20% of flux is derived from incision of the floodplains. This introduces a lag of 10 ky in the transport of sediment from source to the coast. There is an additional lag of at least 10 ka on the shelf for the sediment to be reworked into the submarine canyon and hence into the fan. Sediment reaching the submarine fan is heavily decoupled from the erosion processes in the mountains, at least on the scale of a glacial cycle.

Selected References

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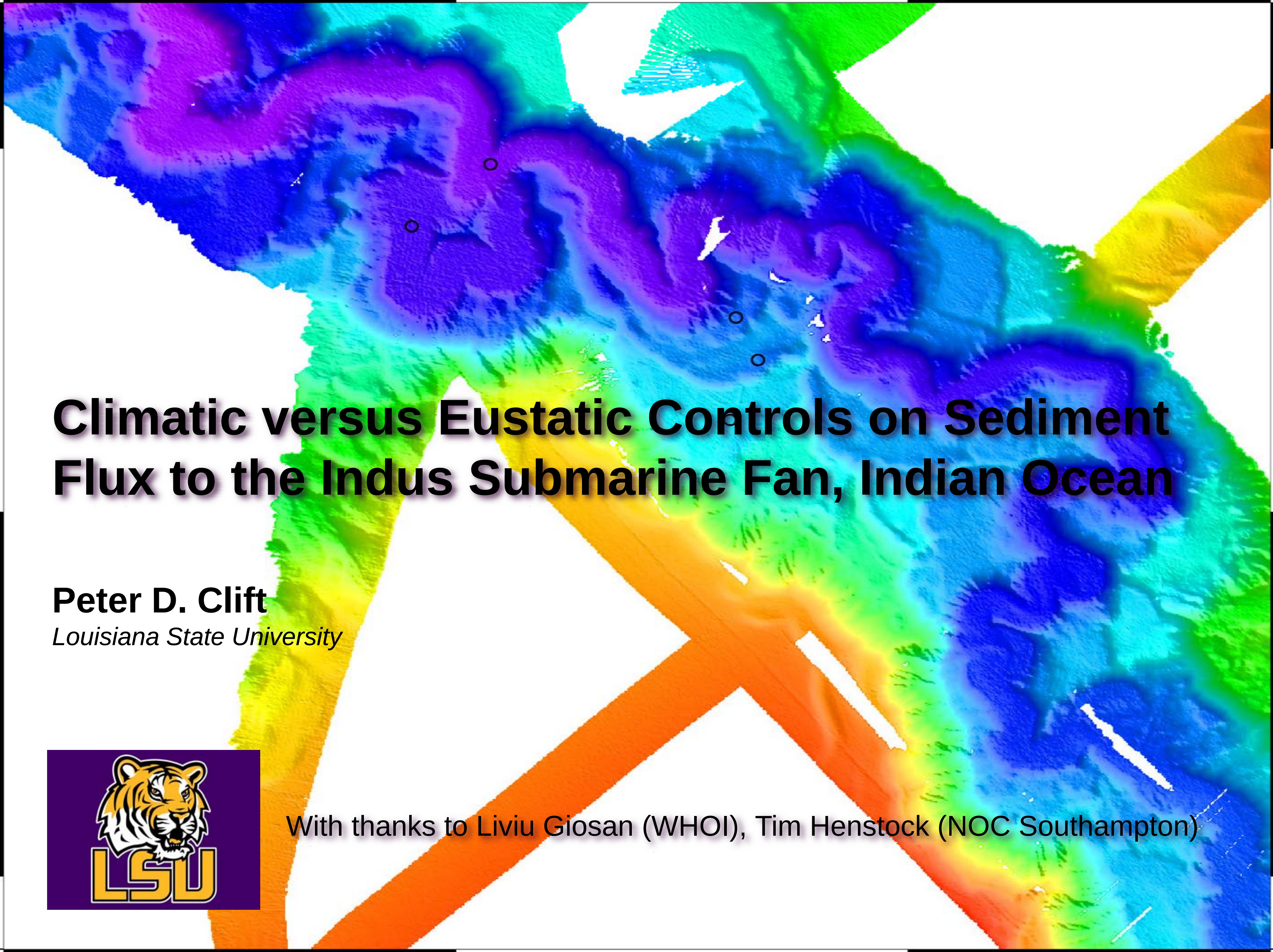

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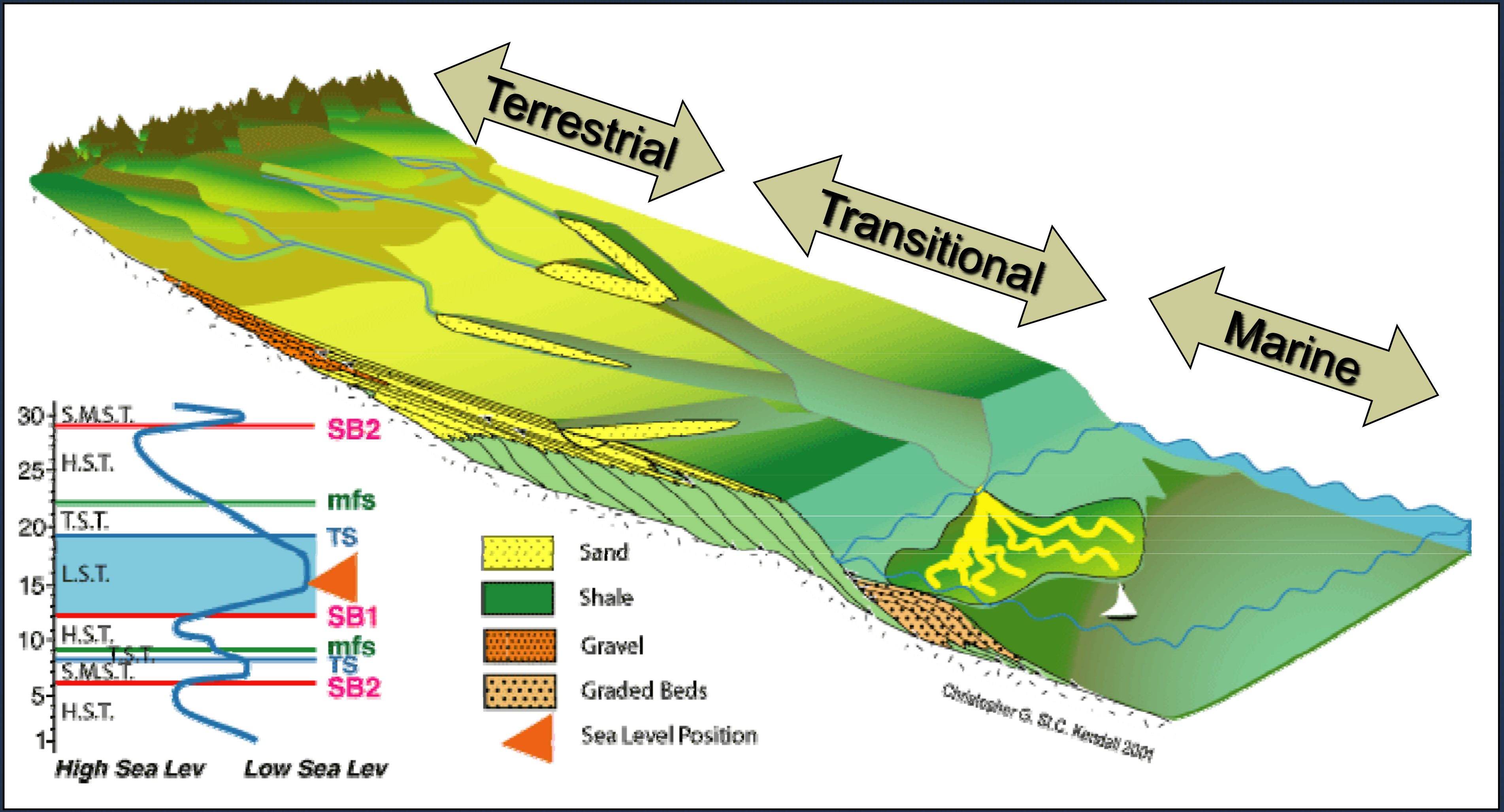
Research Objectives

- How does climate change as opposed to sealevel variation modulate the flux of sediment to the ocean?

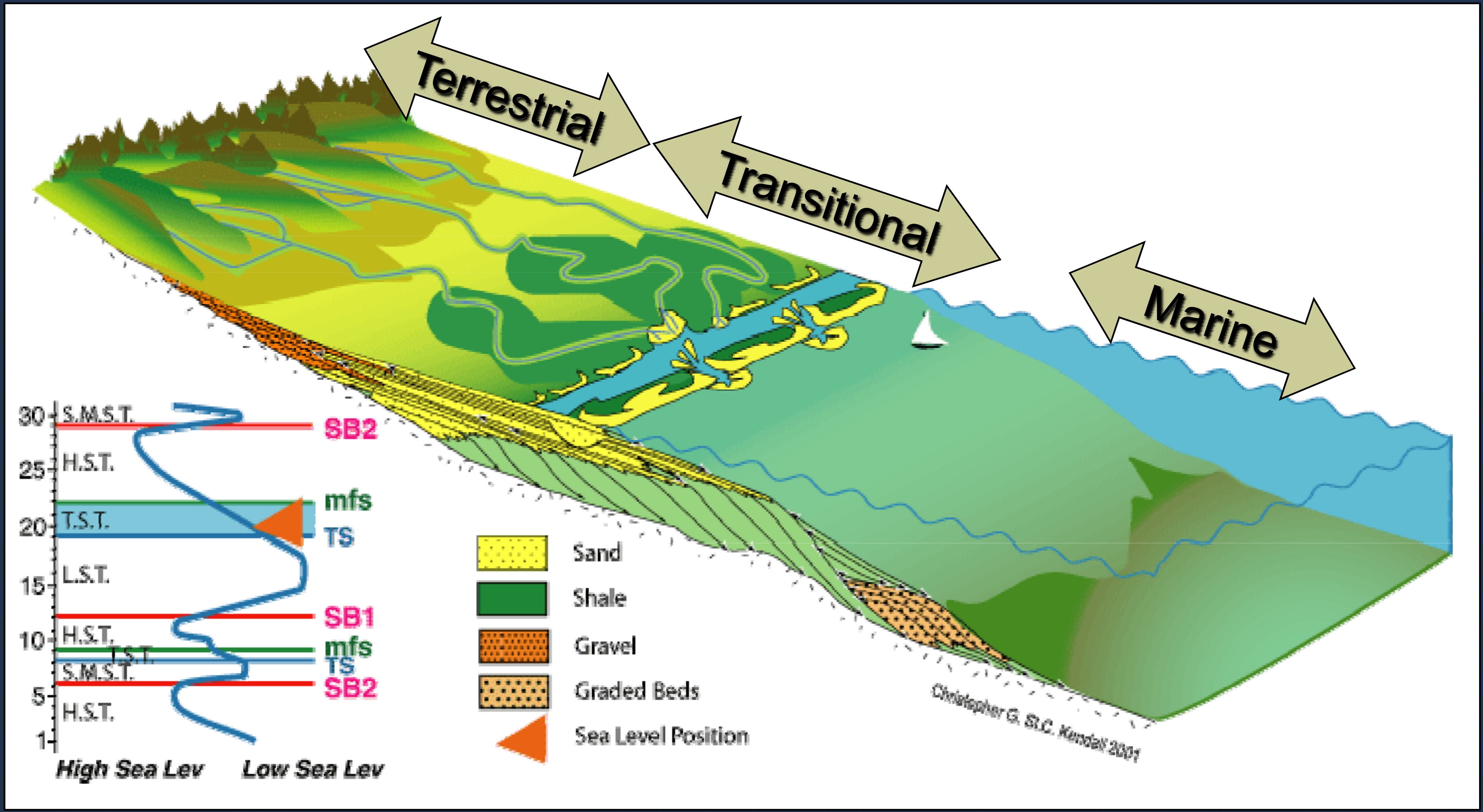
- How much does reworking and recycling contribute to the net flux at any particular time?

- Are sand bodies in submarine canyons continuous over long distances and interconnected?

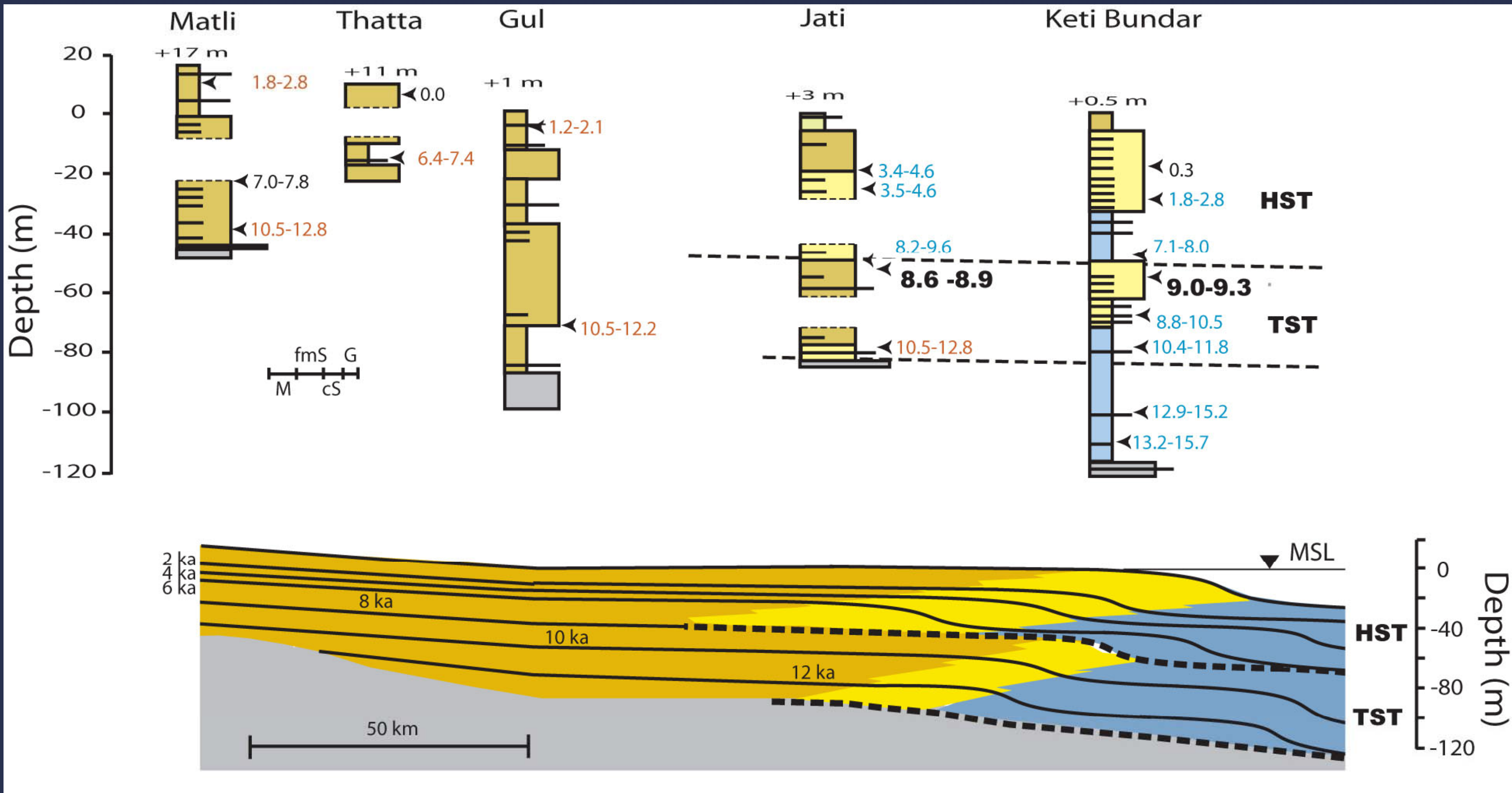
What is the expected clastic system response to sea level rise?



Clastic System Response to Sea Level Rise – Shoreline retreat



Onshore drilling in 2003-2004 allowed a sequence stratigraphic model for the Holocene delta to be generated

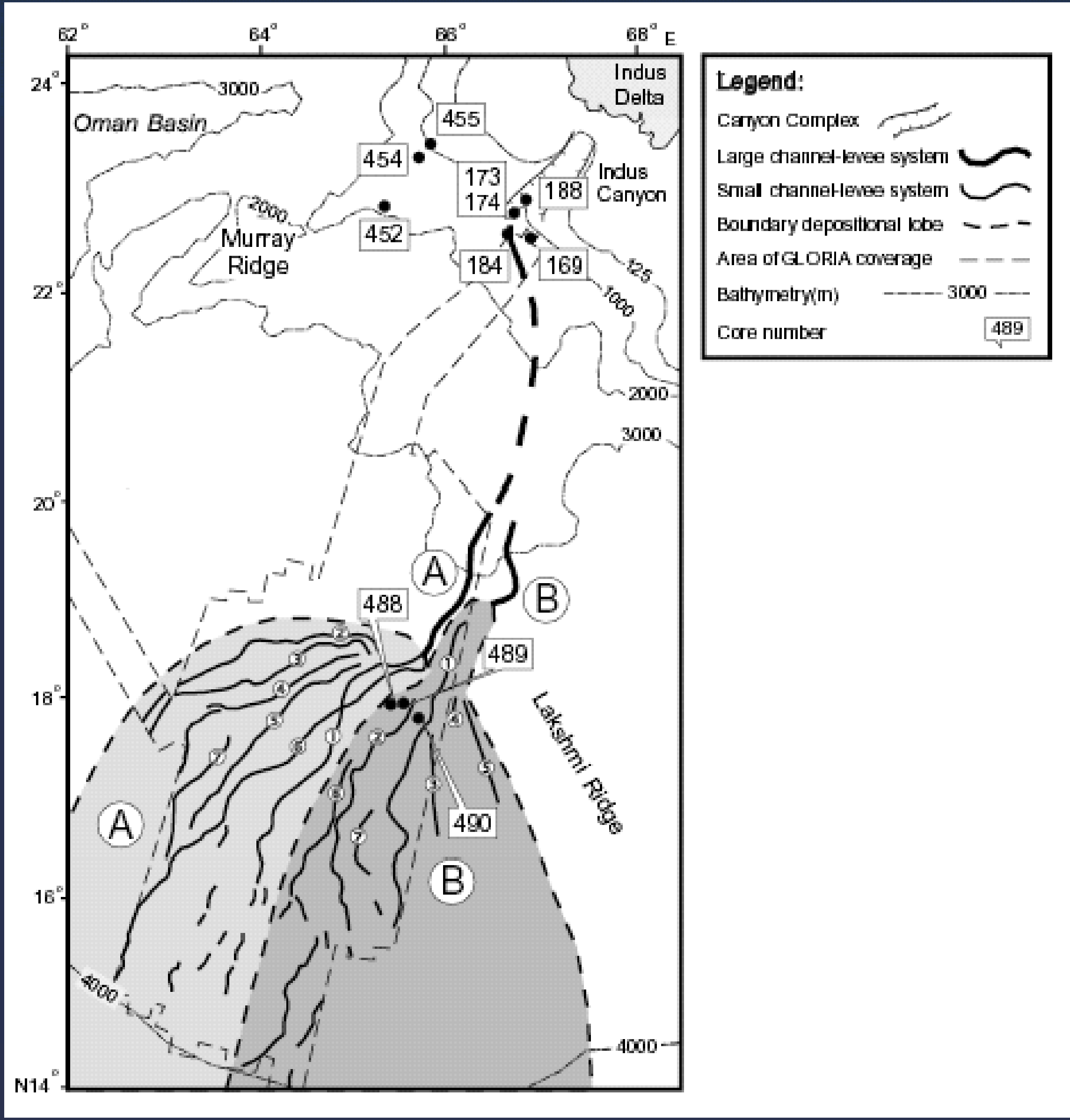


Clift & Giosan (in press)

Progradation but flooding at 8.2 ka

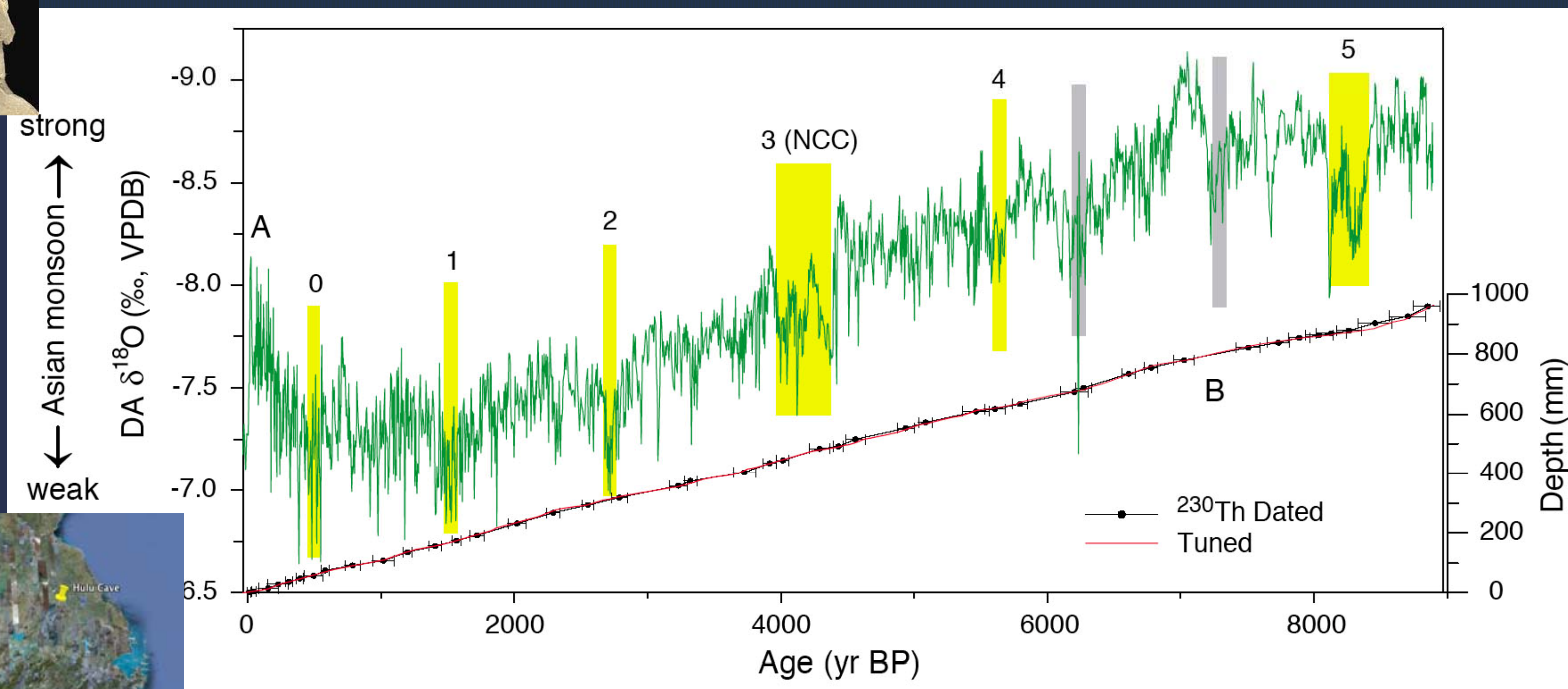
Holocene sealevel rise cut off fan sedimentation

Youngest fan channel-levee system - MIS2 (24 to 11 ka)

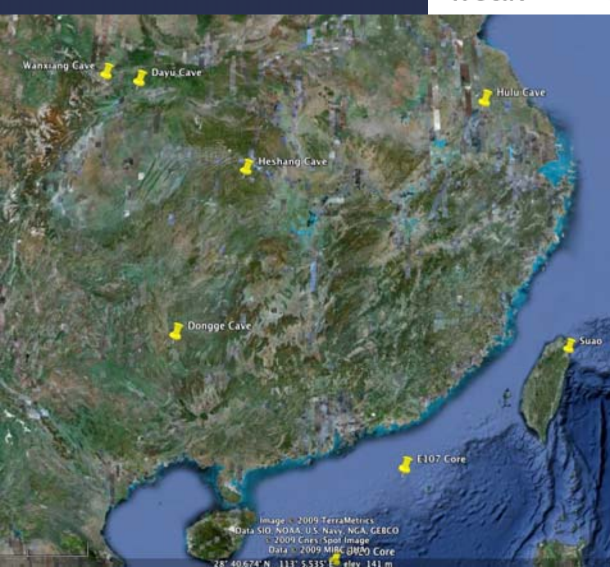


Prins et al. (2000)

I focus on the past glacial cycle because sealevel has been reconstructed and climate variability is constrained



Wang et al. (2005)

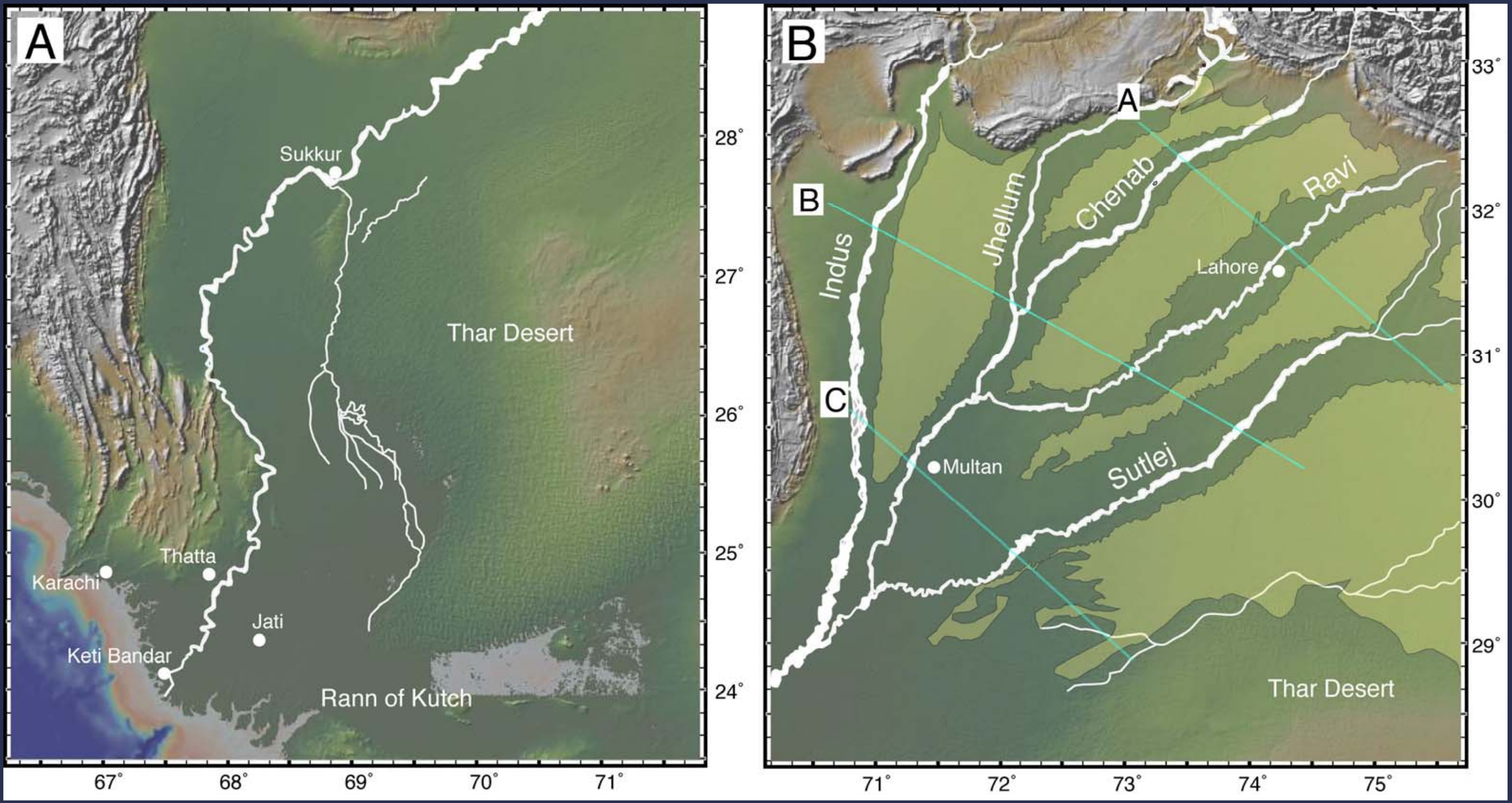


Dongge Cave, SW China

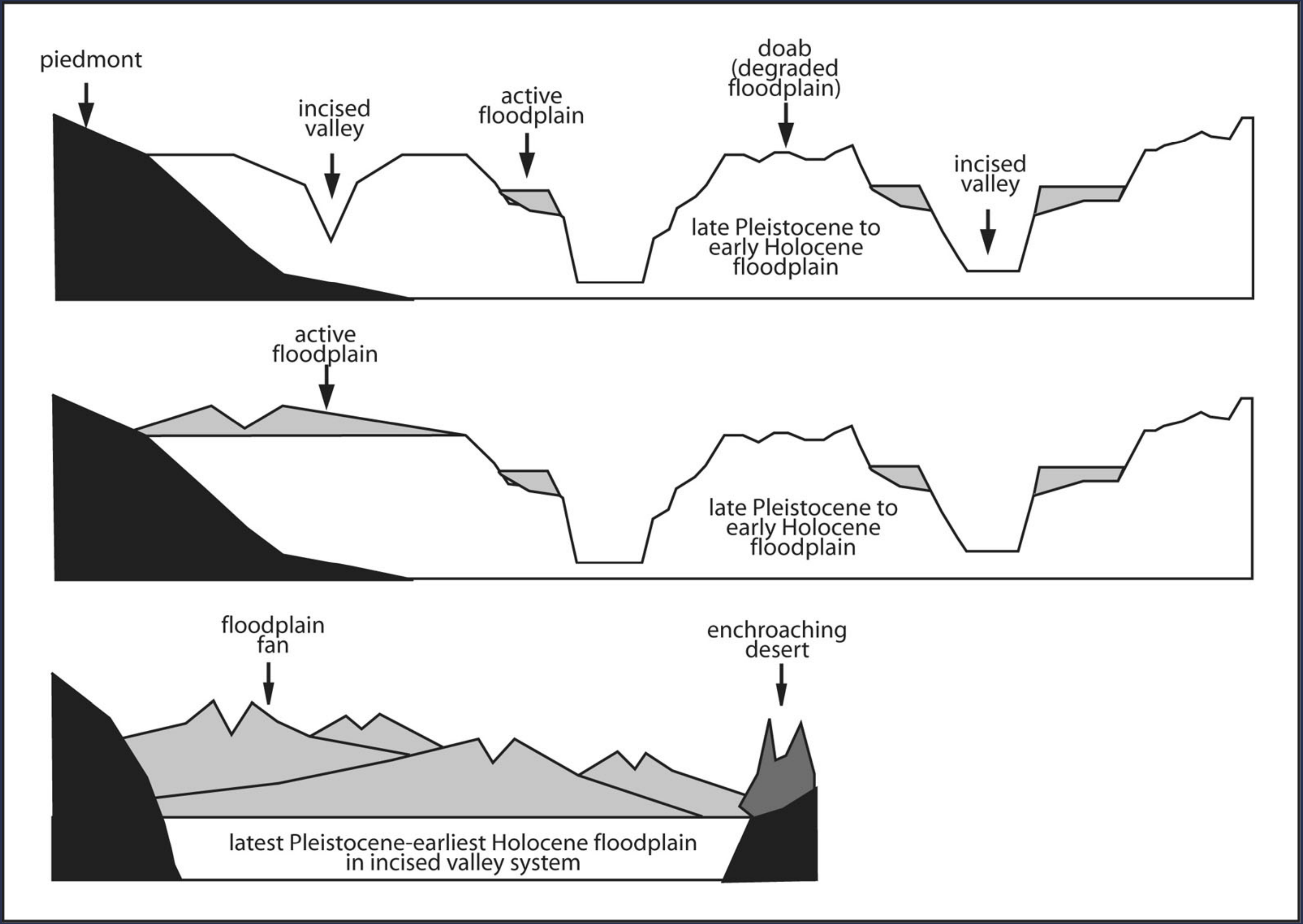
How is sediment flux to the ocean buffered in the mountains and flood plains?

Is its capture and release significant in controlling flux to the delta?

Flood plain incision and reworking onshore is likely a major source of sediment after 10 ka - monsoon control



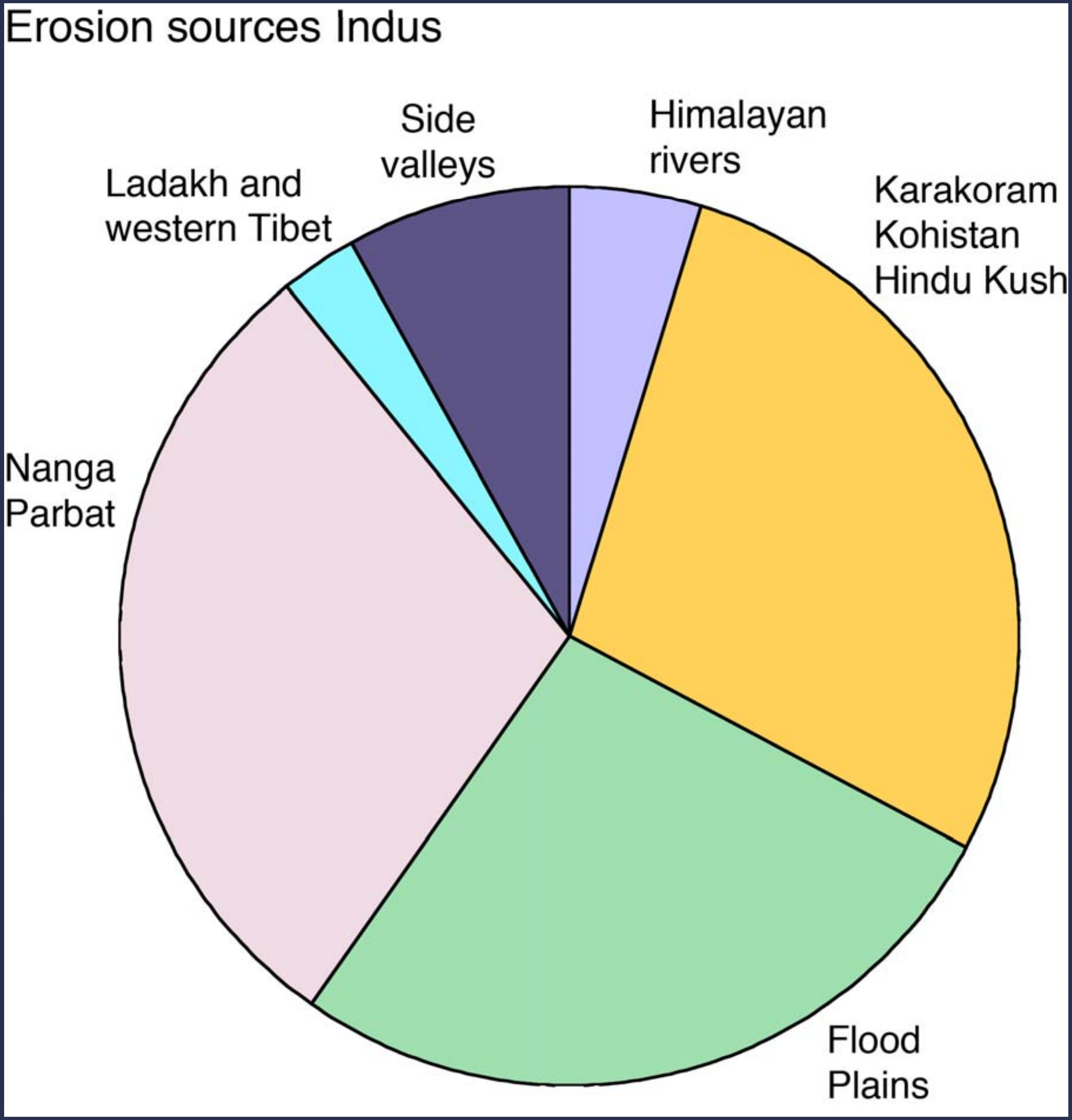
Incision in the northern flood plain is matched by deposition in the south



Sediment storage in the mountains is also important

Double terraces on the trunk Indus in western Tibet

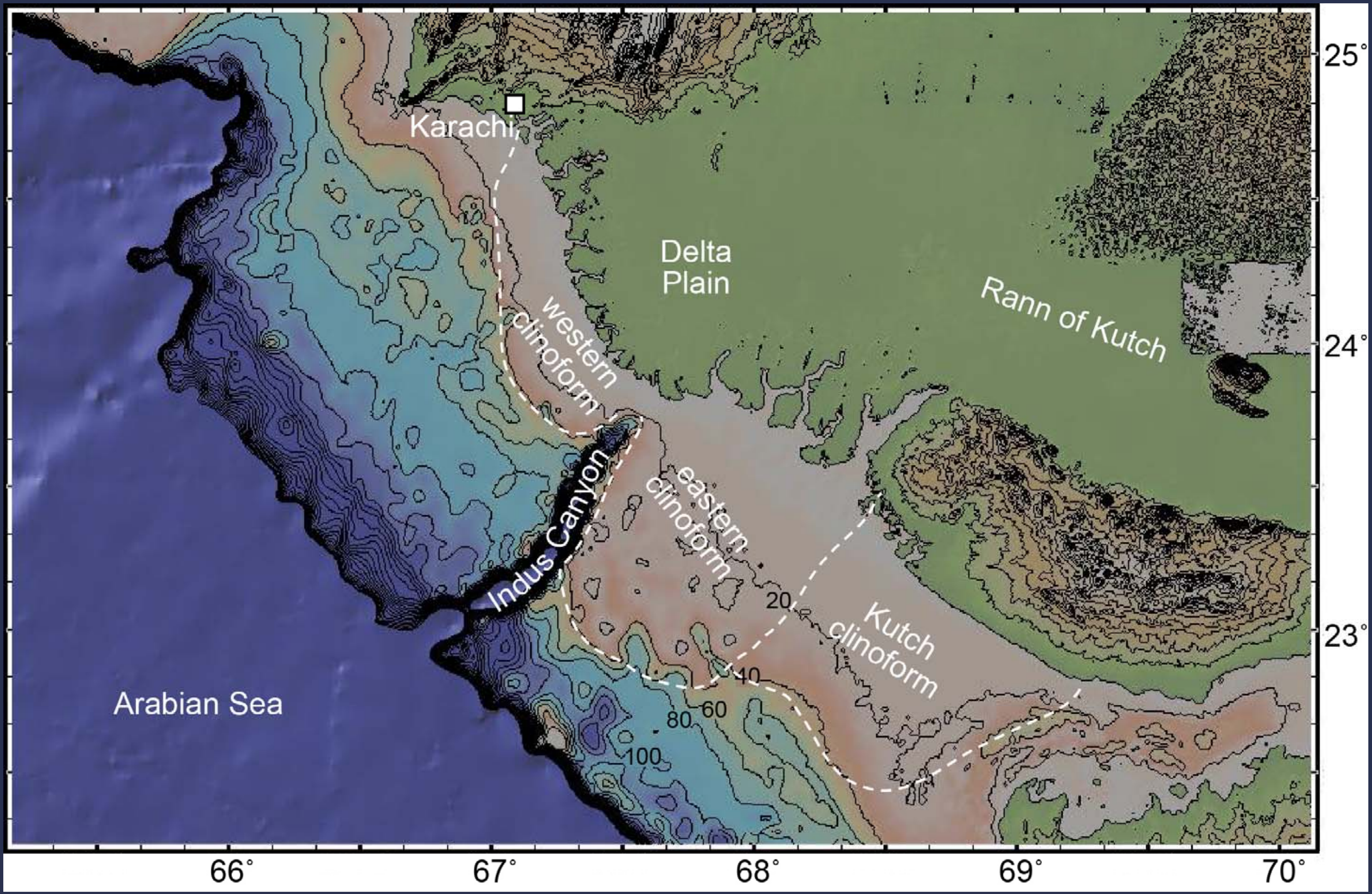
Total eroded terrace volume is 1750-4100 km^3



Average uncertainty is ±40%

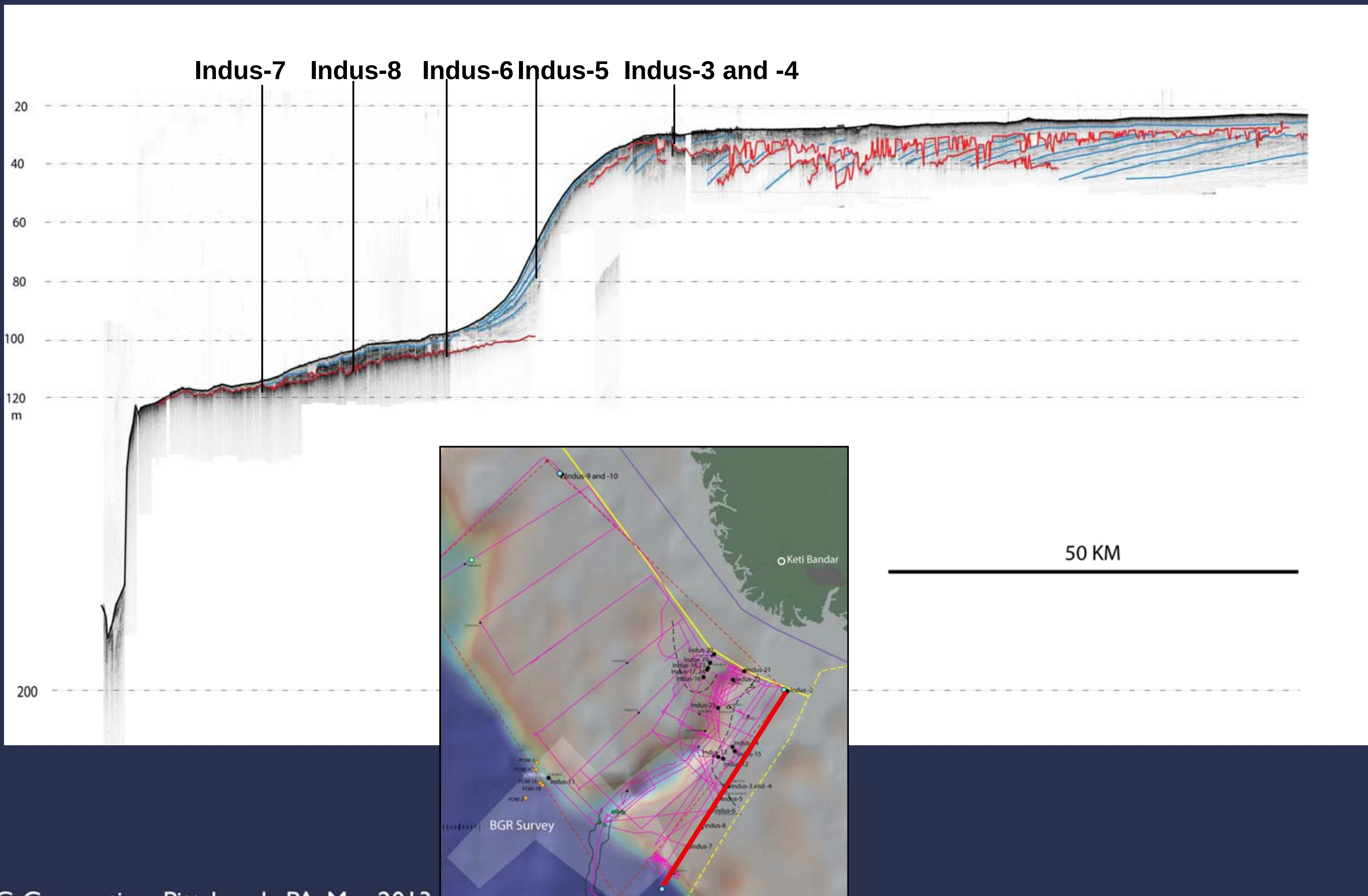
Reaching the ocean is only part of the journey to the fan

Three major clinoforms have been identified



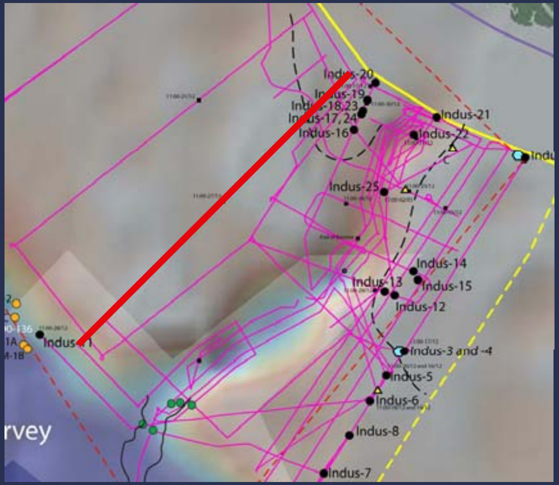
Clinoform on east side of the Indus Canyon

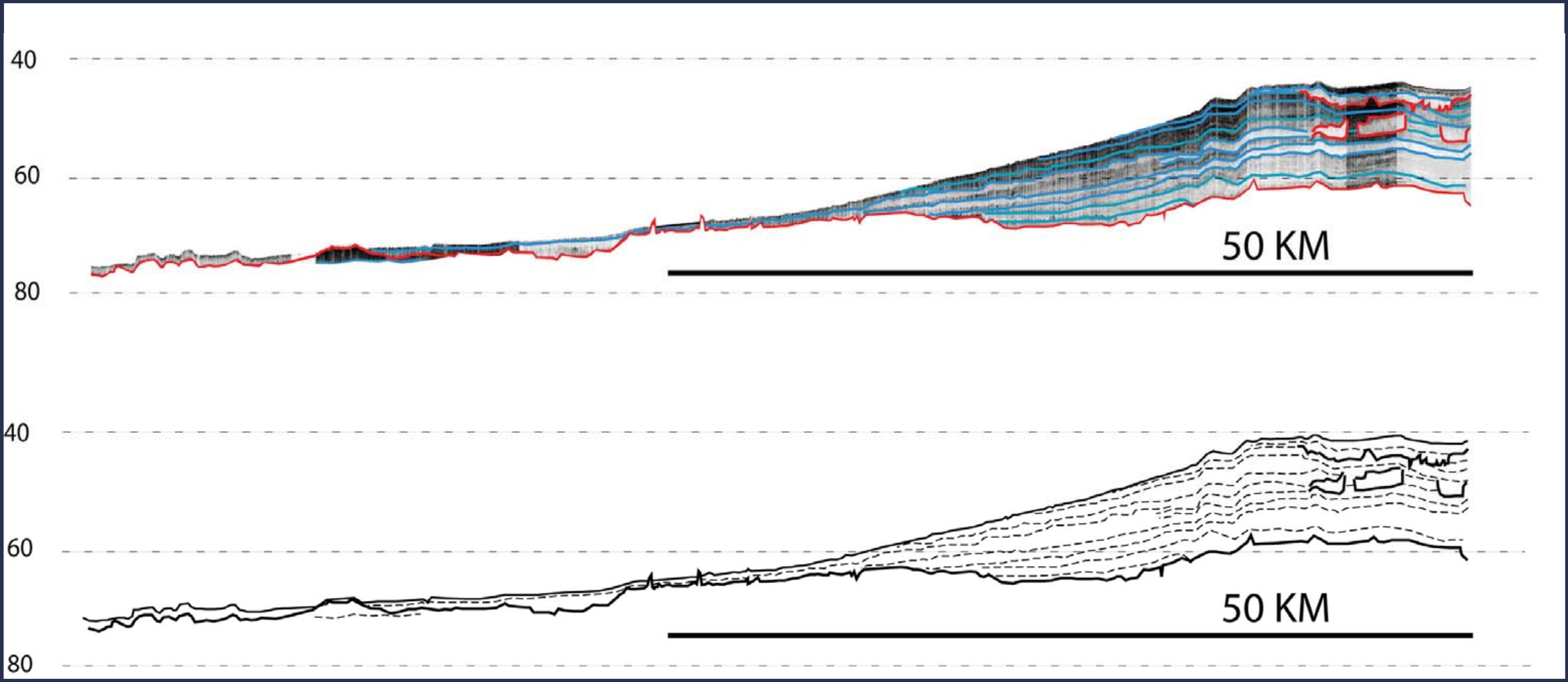
A very large and active clinoform



Clinoform on west side of the Indus Canyon

Smaller but actively building clinoform





Depo-centers in the Indus Offshore

Sindh alluvial plain 1450 km^3

Delta plain 1410 km^3

Western clinoform 1260 km^3

Eastern clinoform 630 km^3

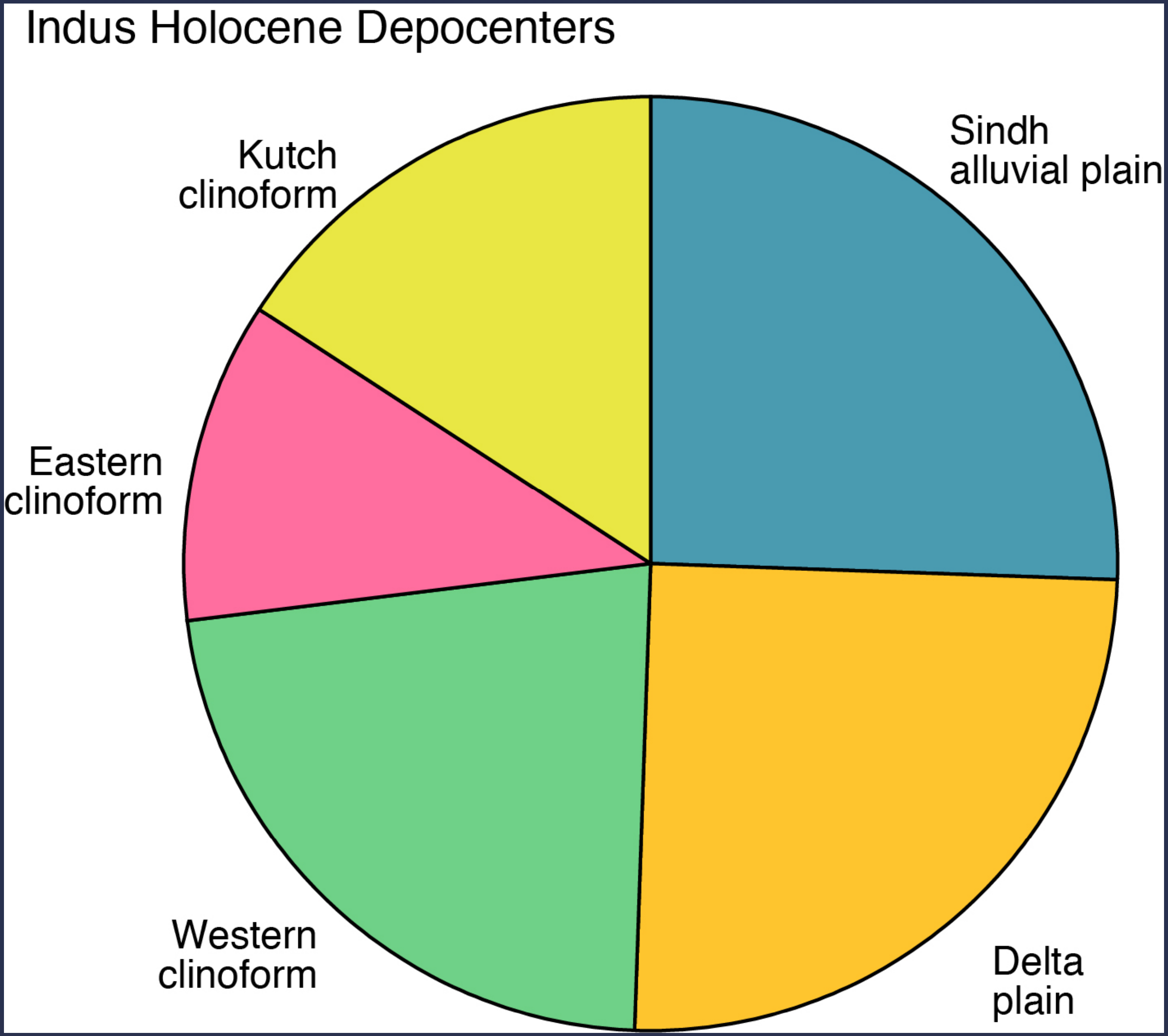
Kutch clinoform 900 km^3

Total = 5650 km^3

Eroded volume from terraces = 1752-4104 km^3

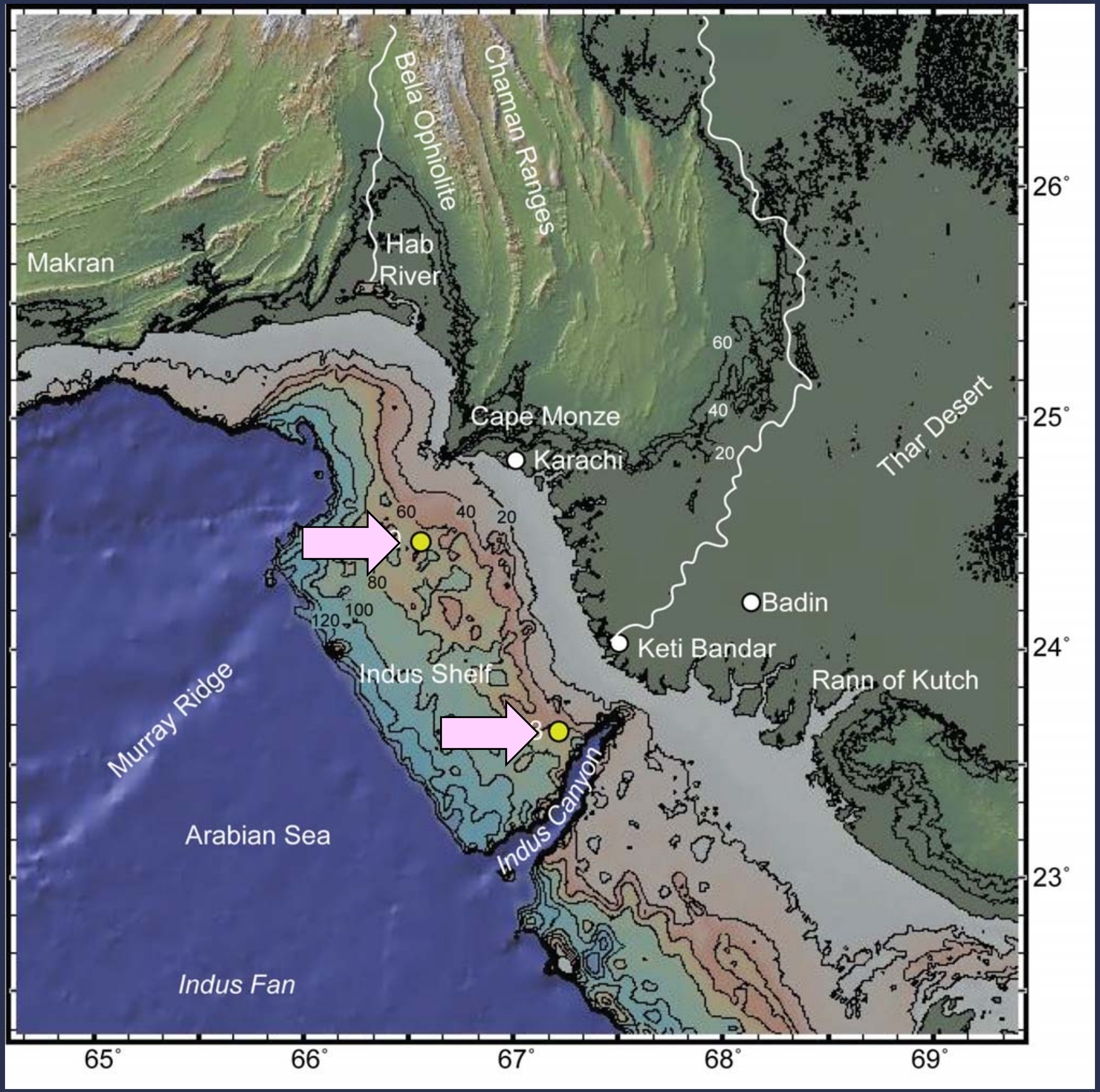
Average 56% reworked

Sediment deposition is partitioned, ~50% onshore, 50% offshore



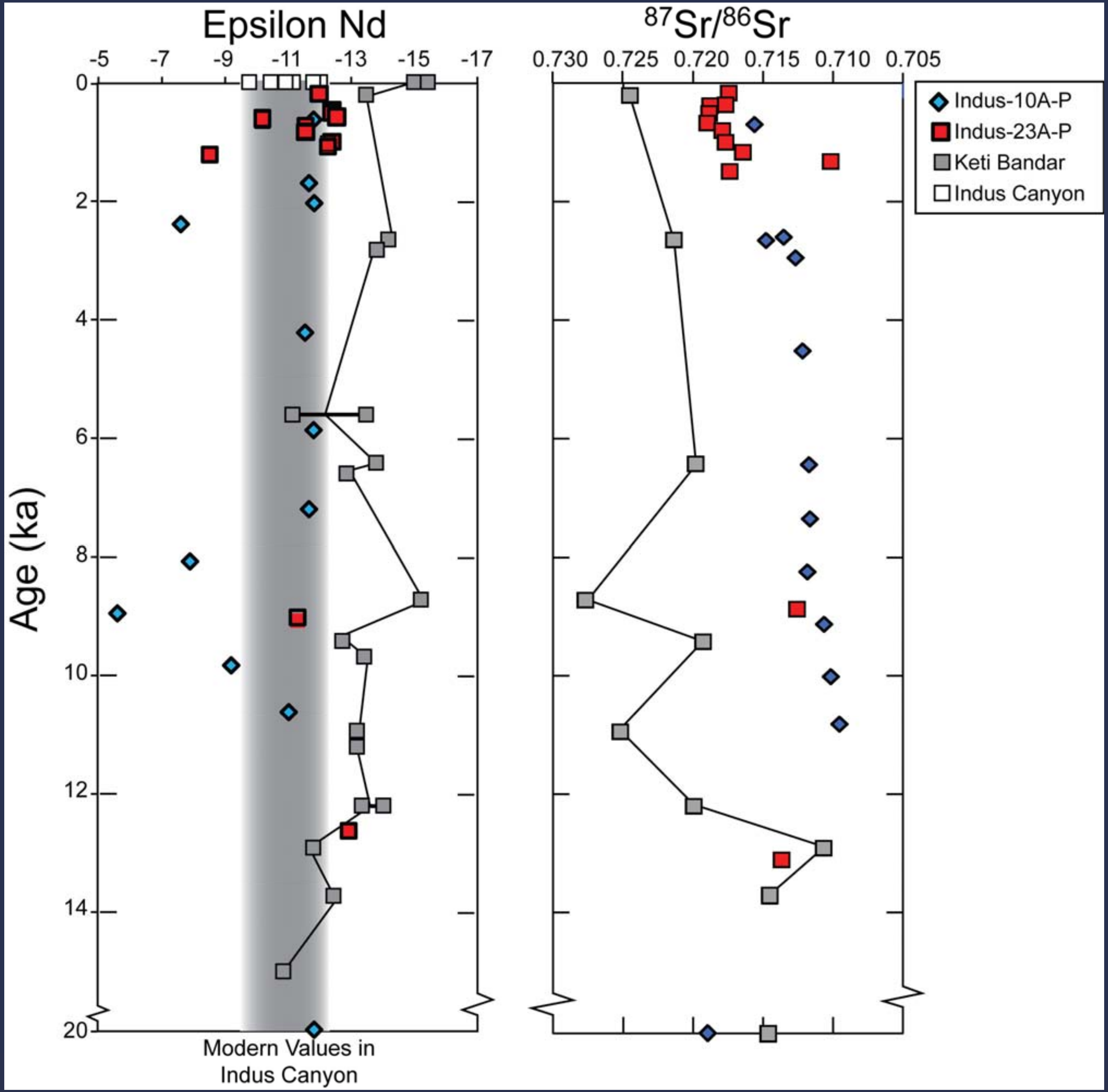
Clift & Giosan (in press)

Coring on the Indus Shelf now allows degree of reworking to be constrained in the western shelf and clinoform

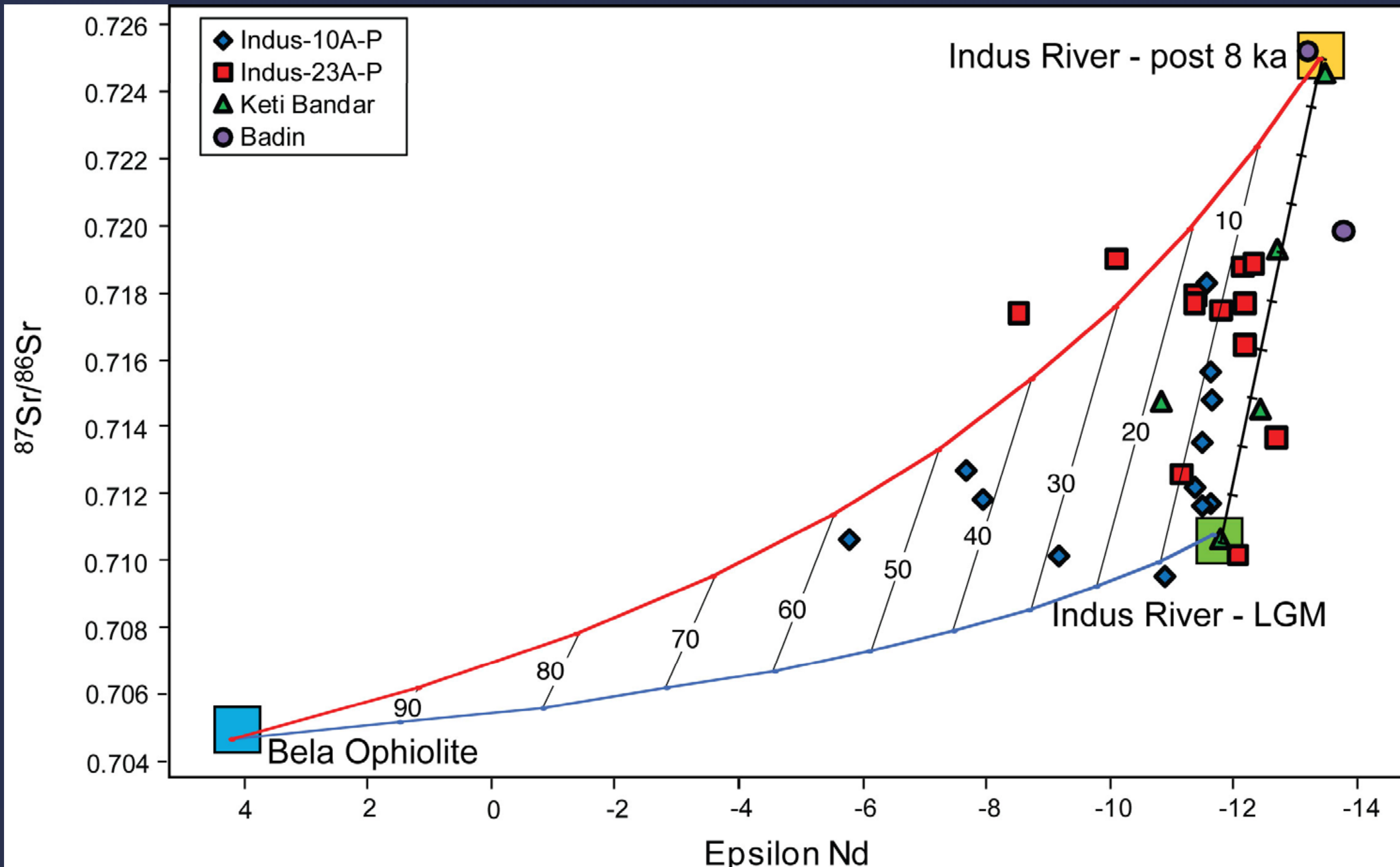


Nd isotopes show that the shelf and clinoform are resolvably different from the river mouth, especially in the Early Holocene

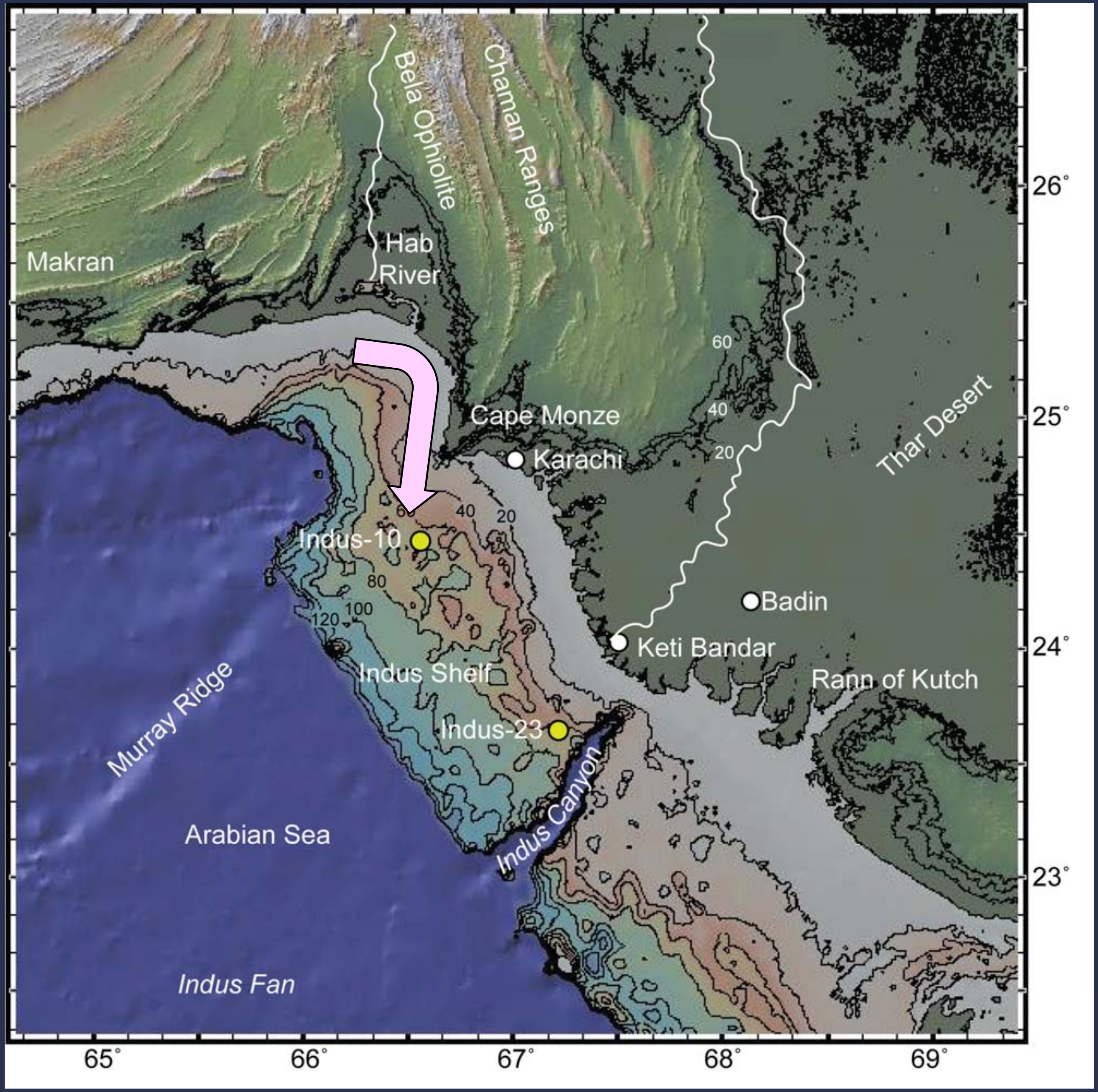
Likely coast-parallel transport when sealevel was lower coupled with reworking of older shelf deposits



The most primitive sediments are receiving more sediment along the coast from Bela Ophiolite, especially at the western shelf edge

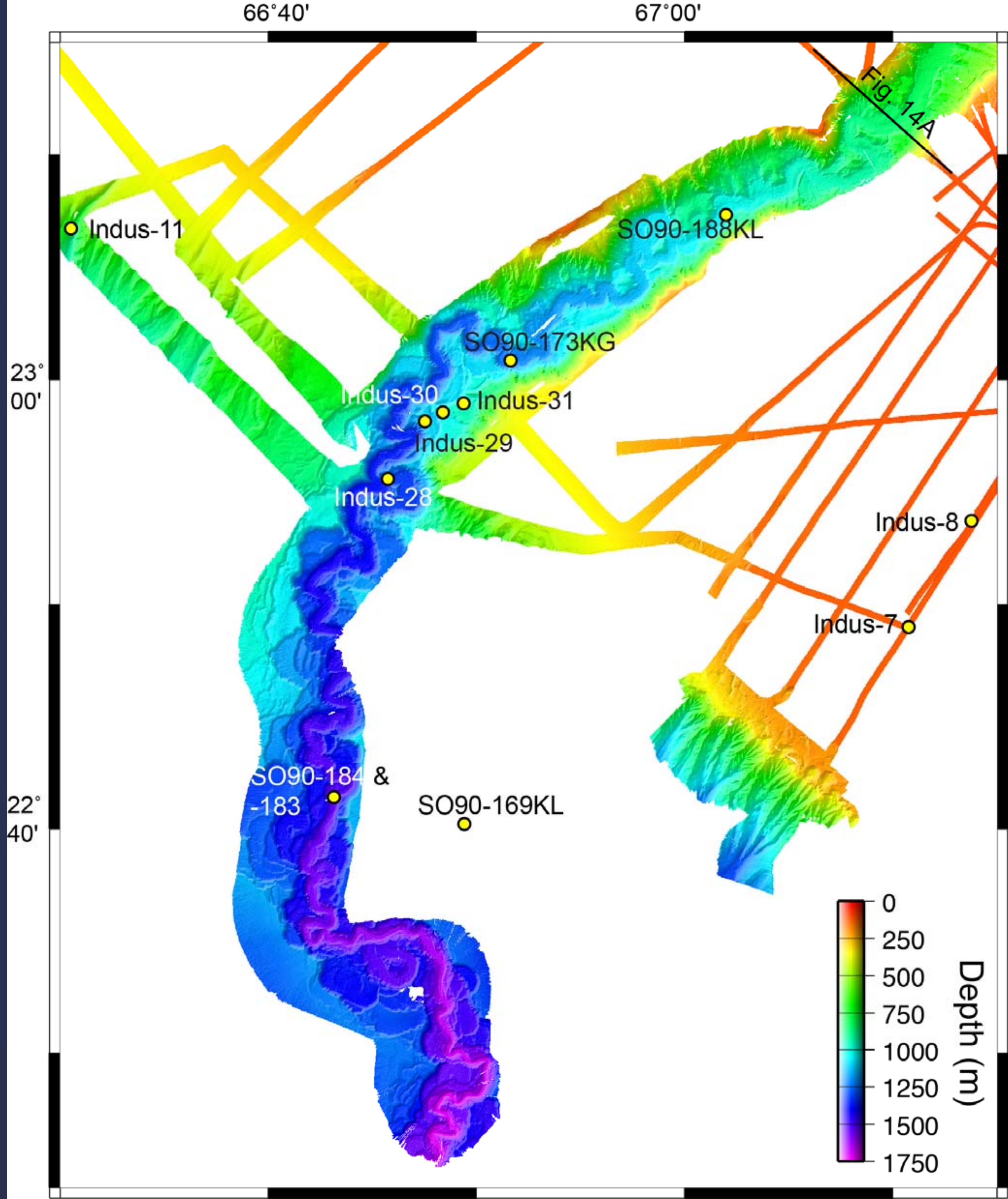


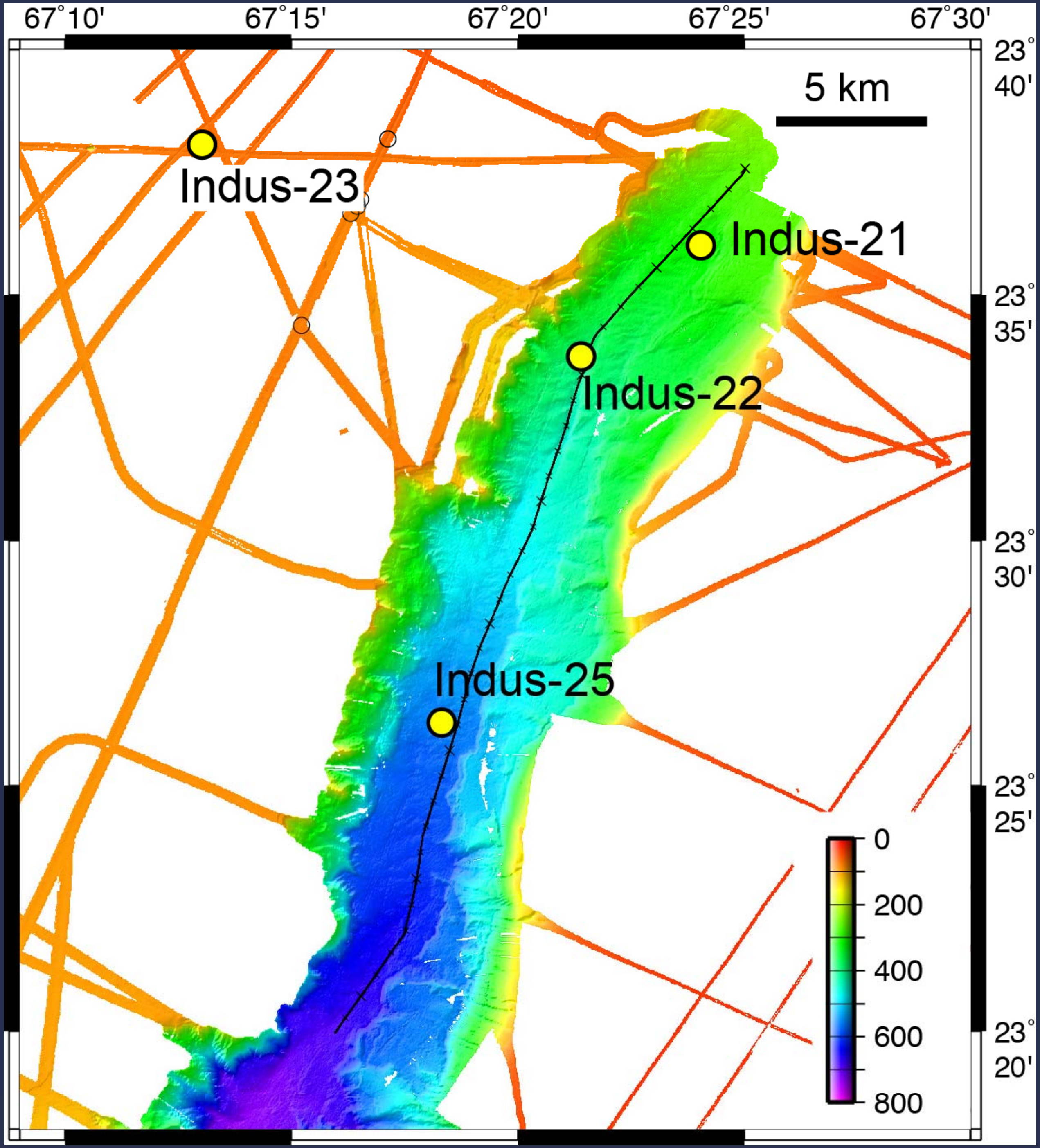
During the Early Holocene longshore currents brought sediment from the Makran coast – Bela Ophiolite



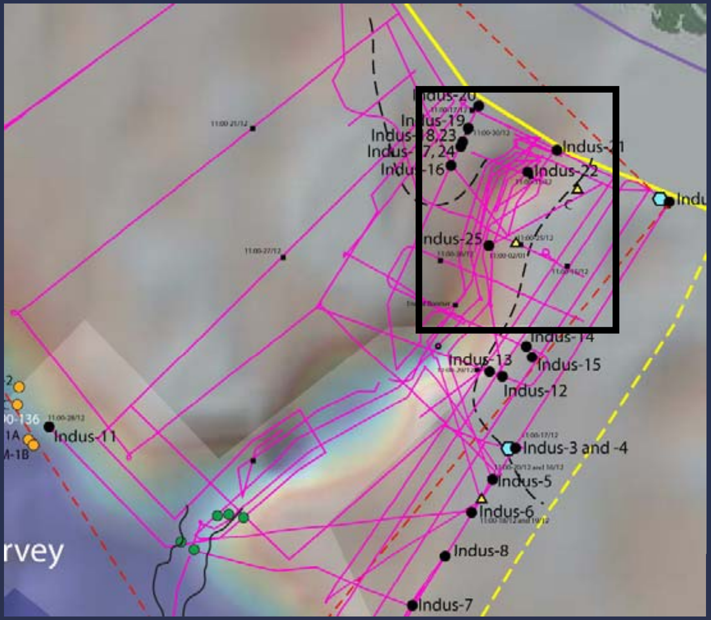
Transport through the canyon

The Indus is now covered by a large number of cores within and adjacent to the canyon

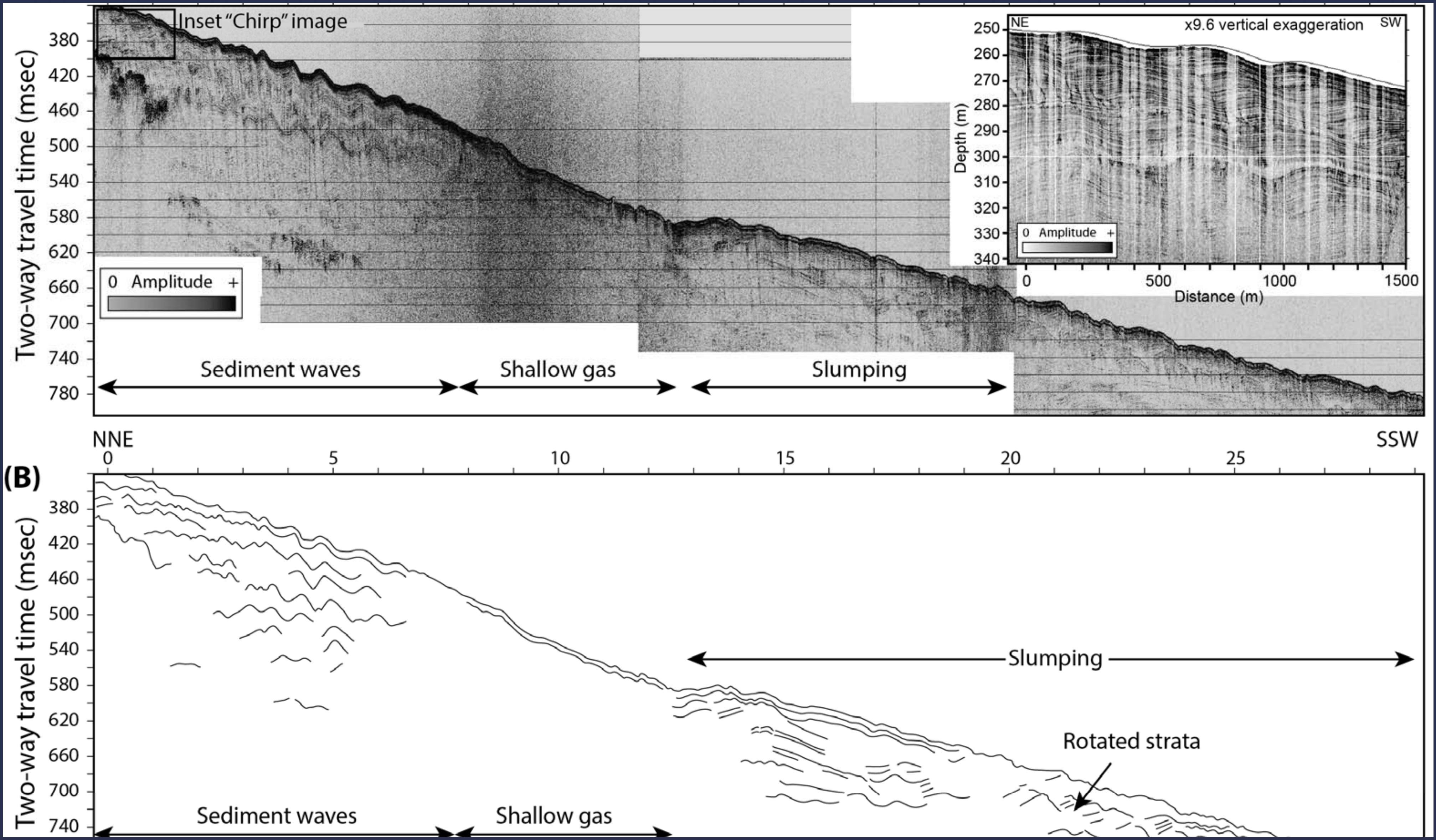




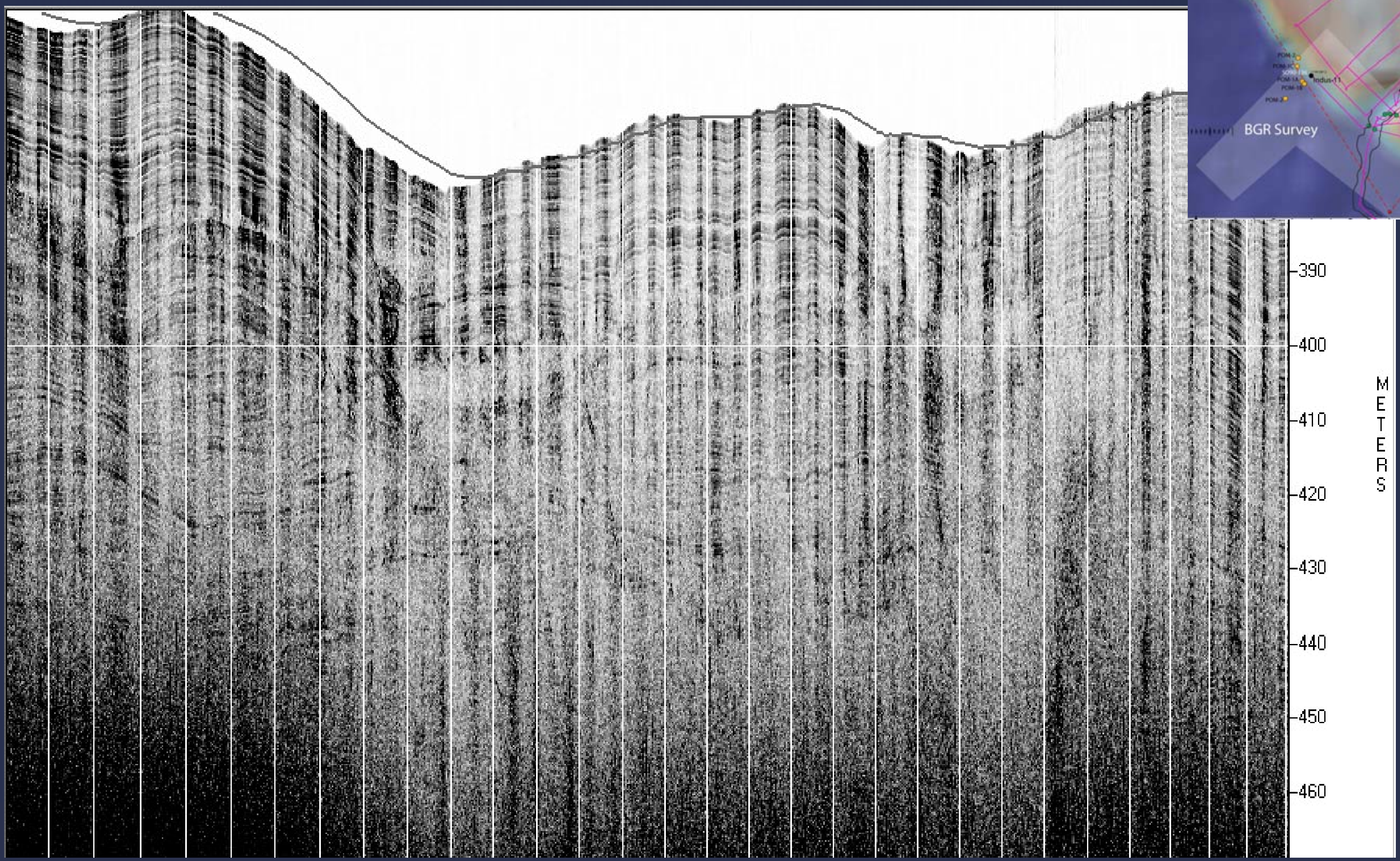
Along-canyon seismic profiles now allow transport at top of canyon to be studied

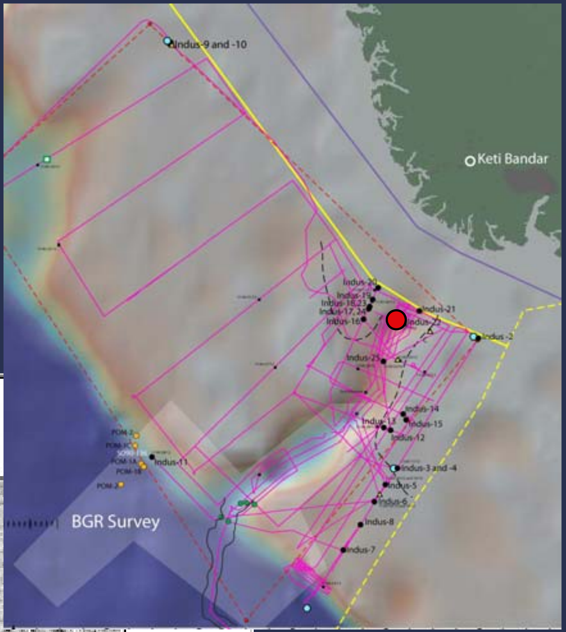


Along canyon seismic show transition from rapid accumulating mud waves to slumping and mass wasting

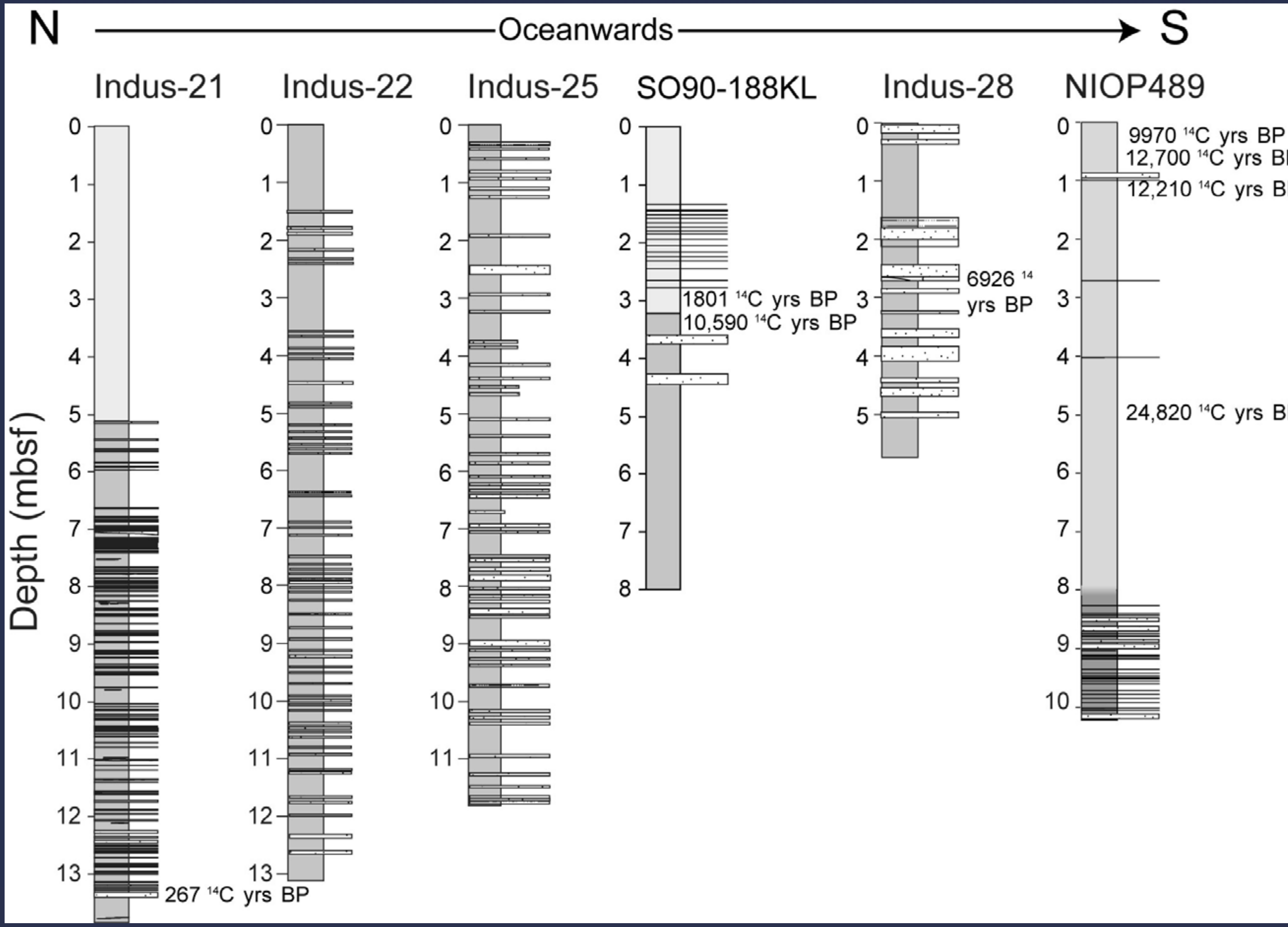


Mud waves in the head of the canyon

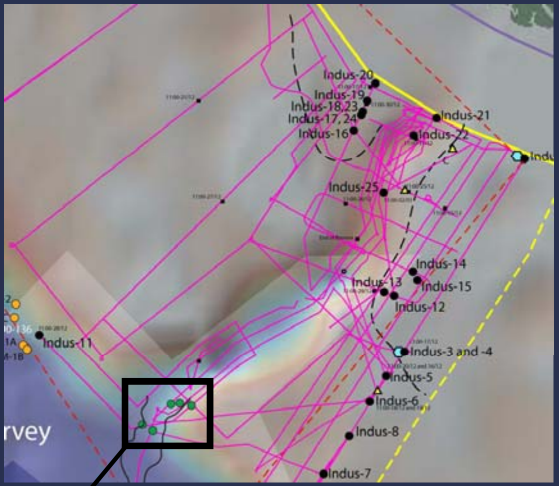


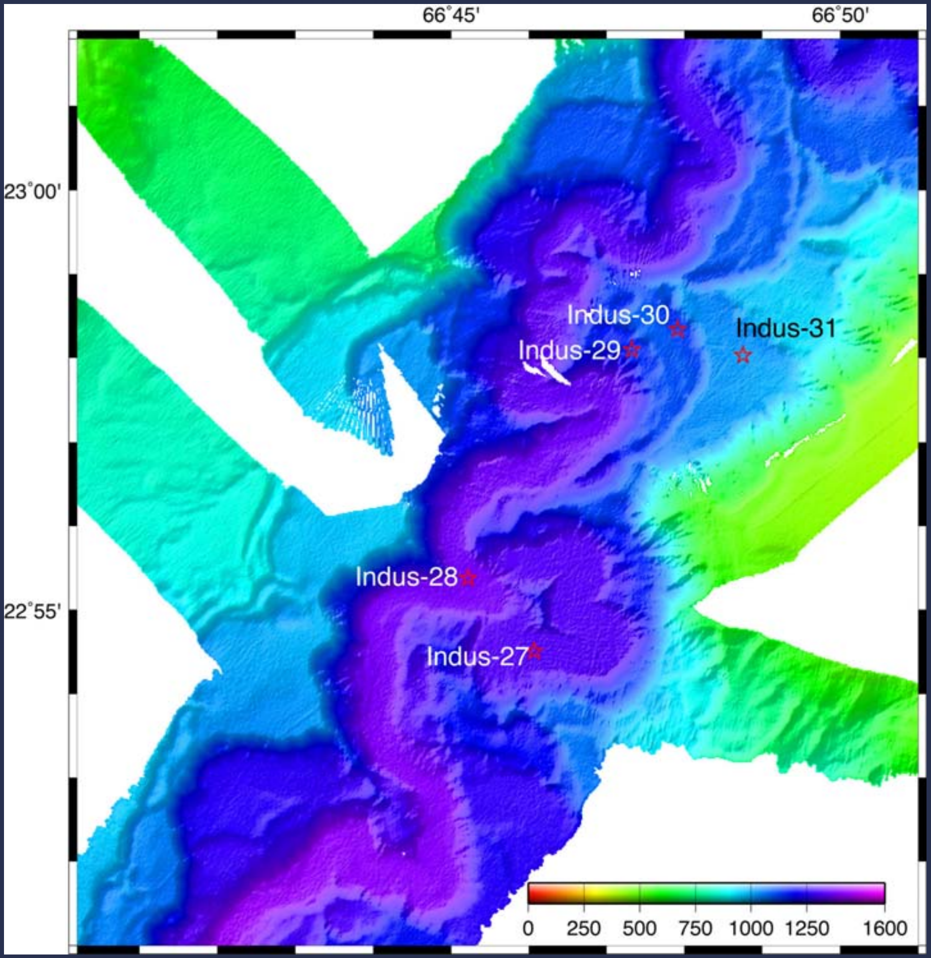


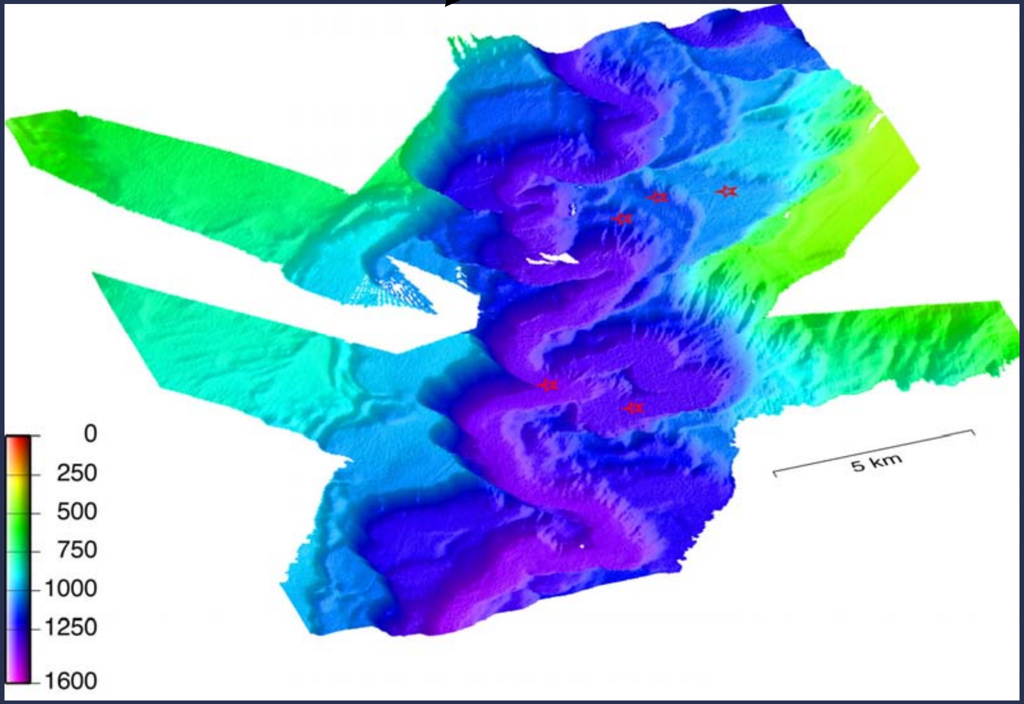
Transect of cores suggests discontinuous sediment transport



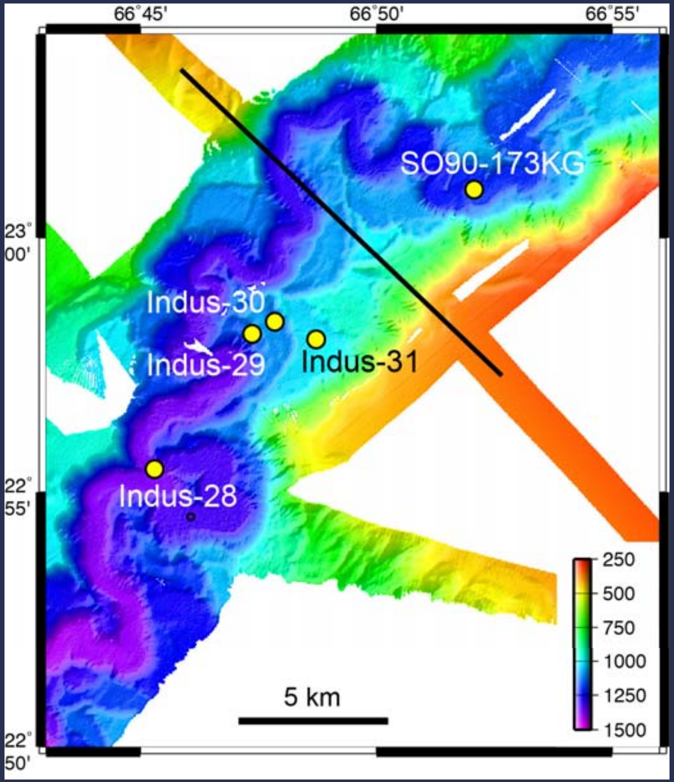
Bathymetric mapping in canyon allowed core sites in canyon axis, in an oxbow and on three terraces

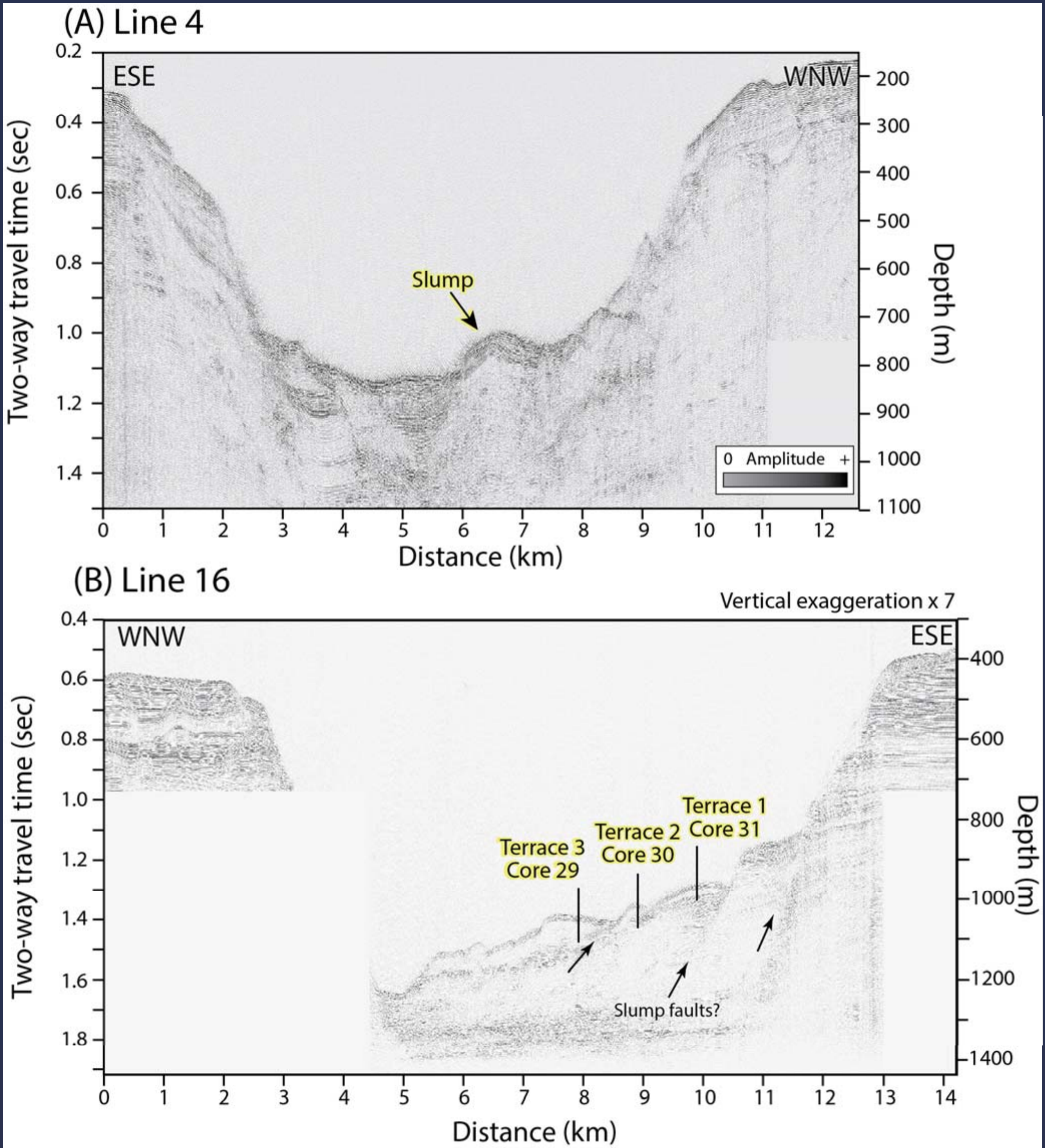






Slumping dominates high in the canyon but terracing is more common in the mid canyon





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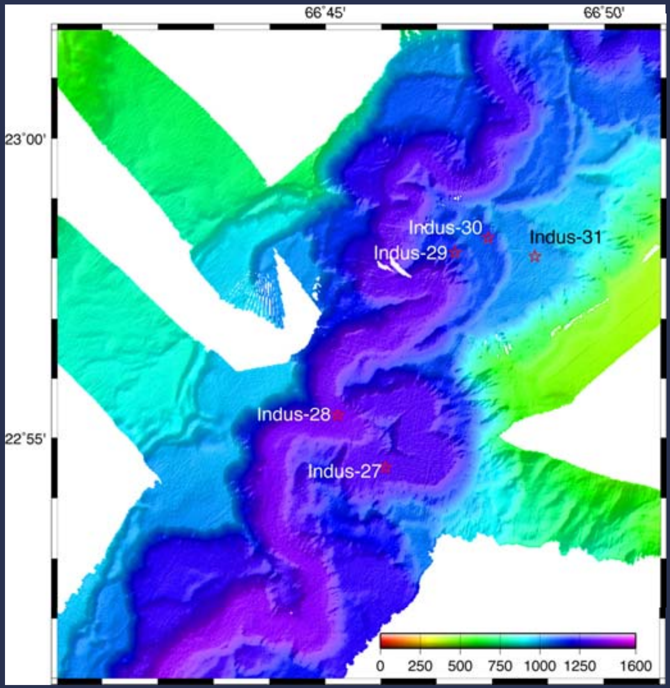
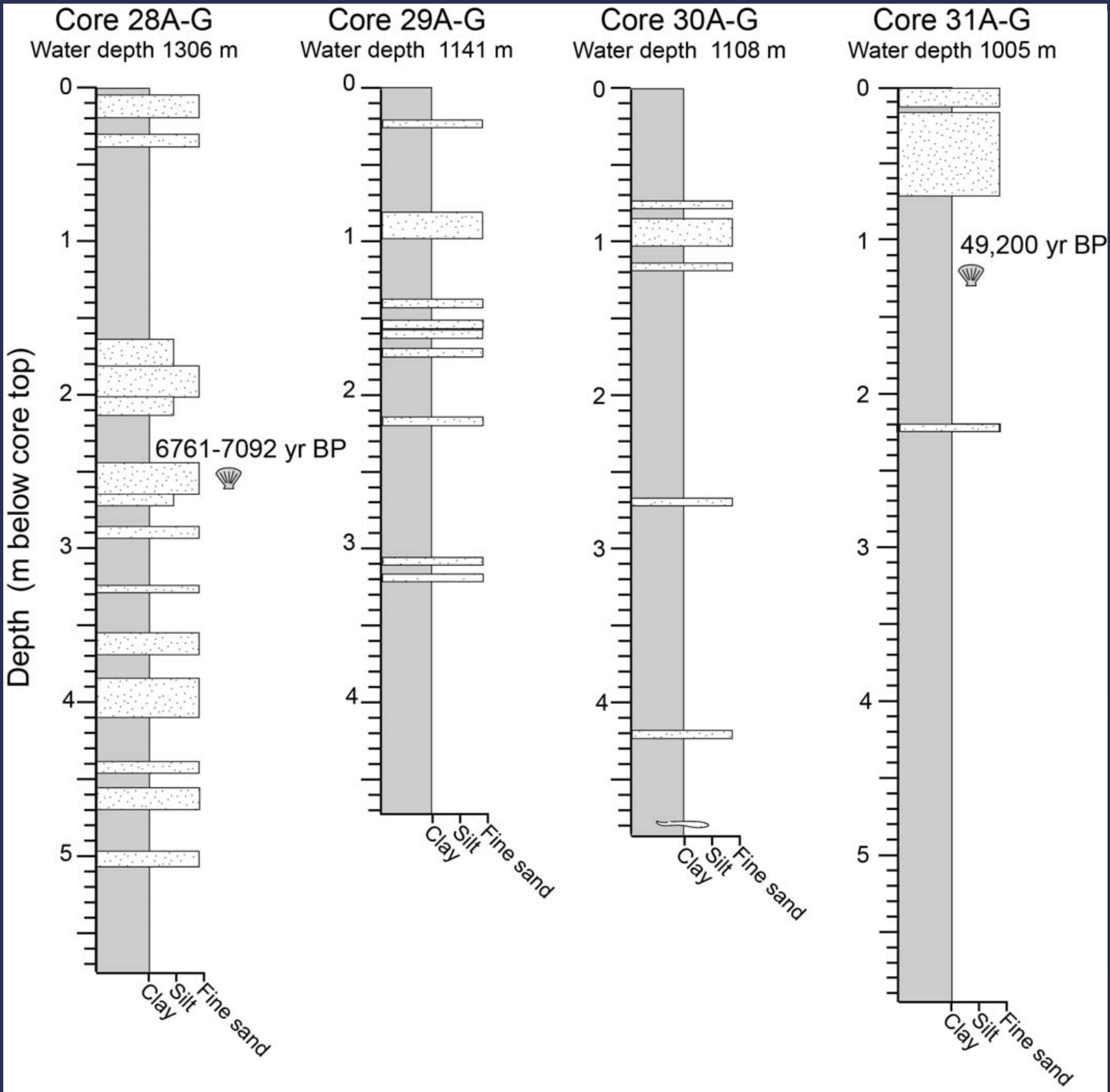
Age of terrace formation is now starting to be revealed





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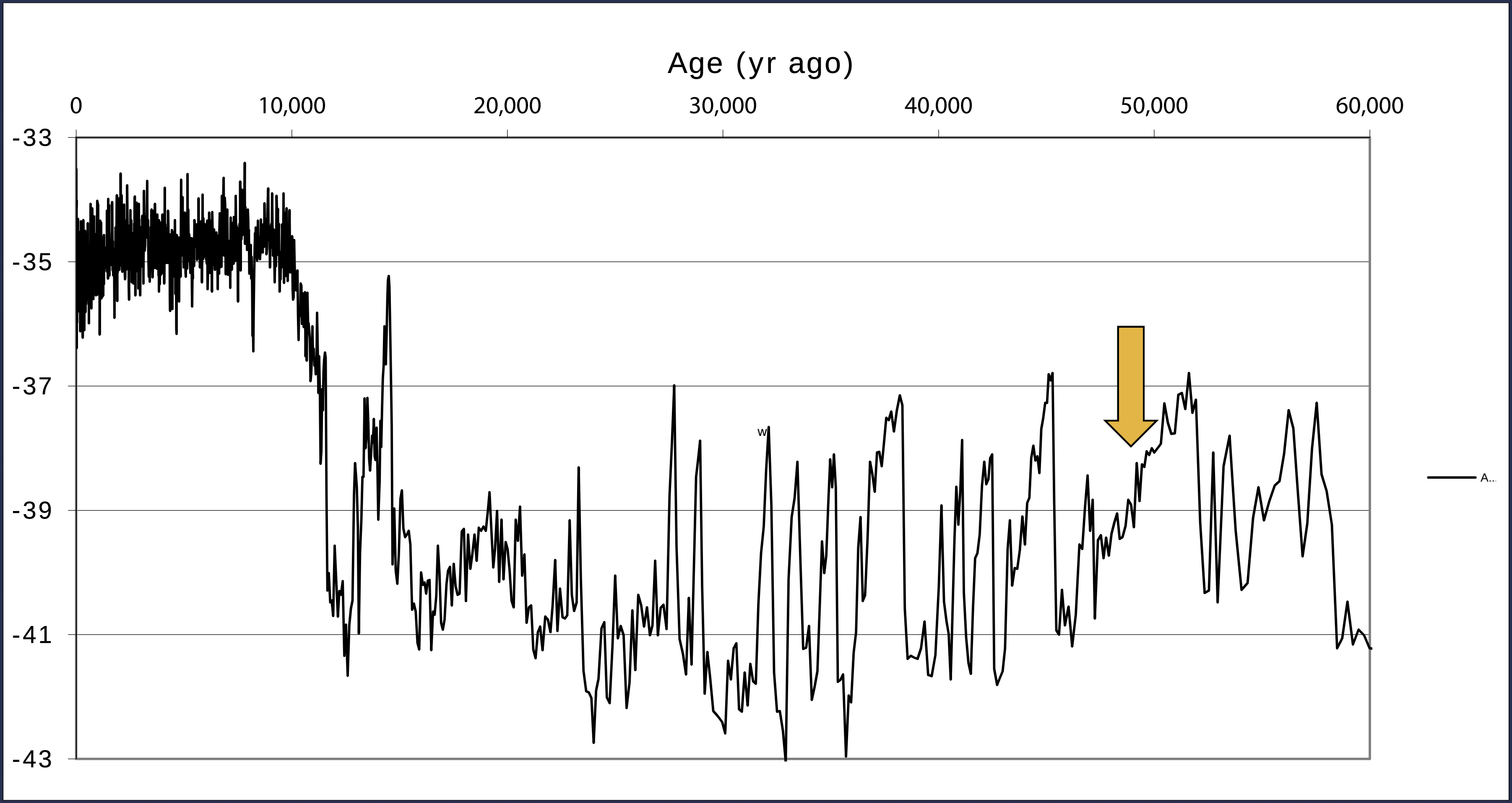
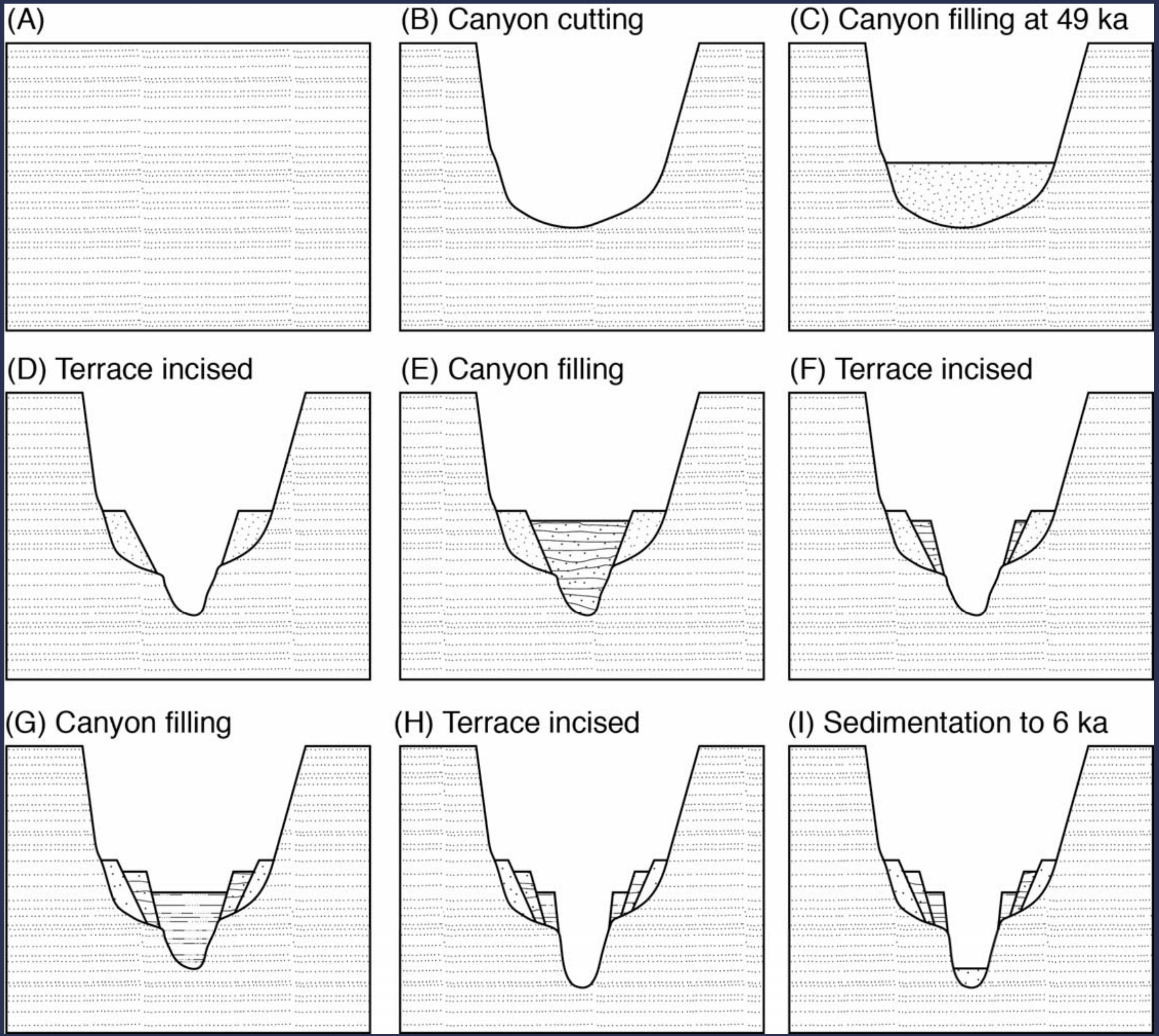
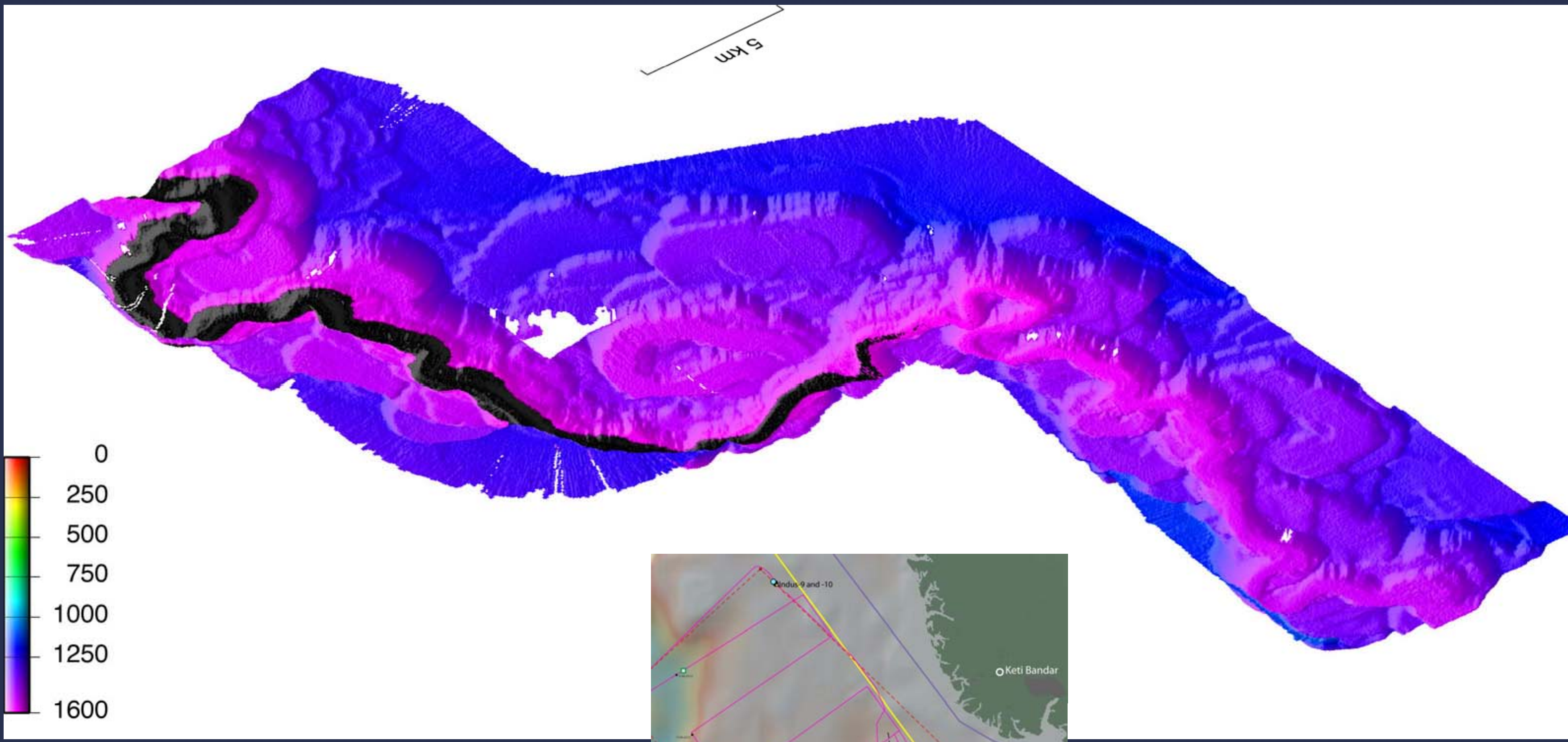
Terrace filling shortly after interglacial peak and during rapid fall in global sealevel

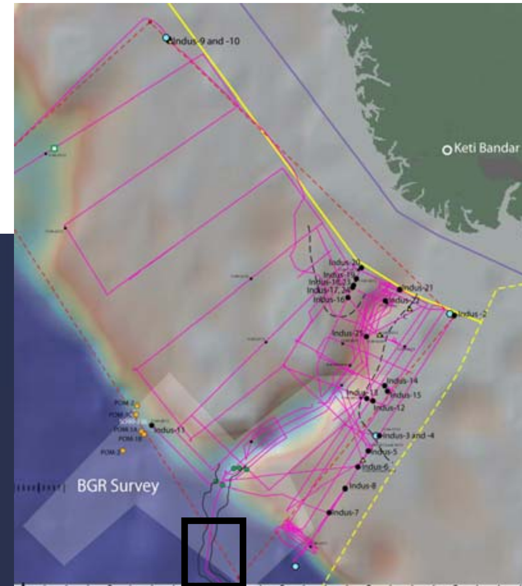


Terracing is s cyclical process reflecting progressive and repeated filling and cutting of canyon fill - at least in the mid canyon

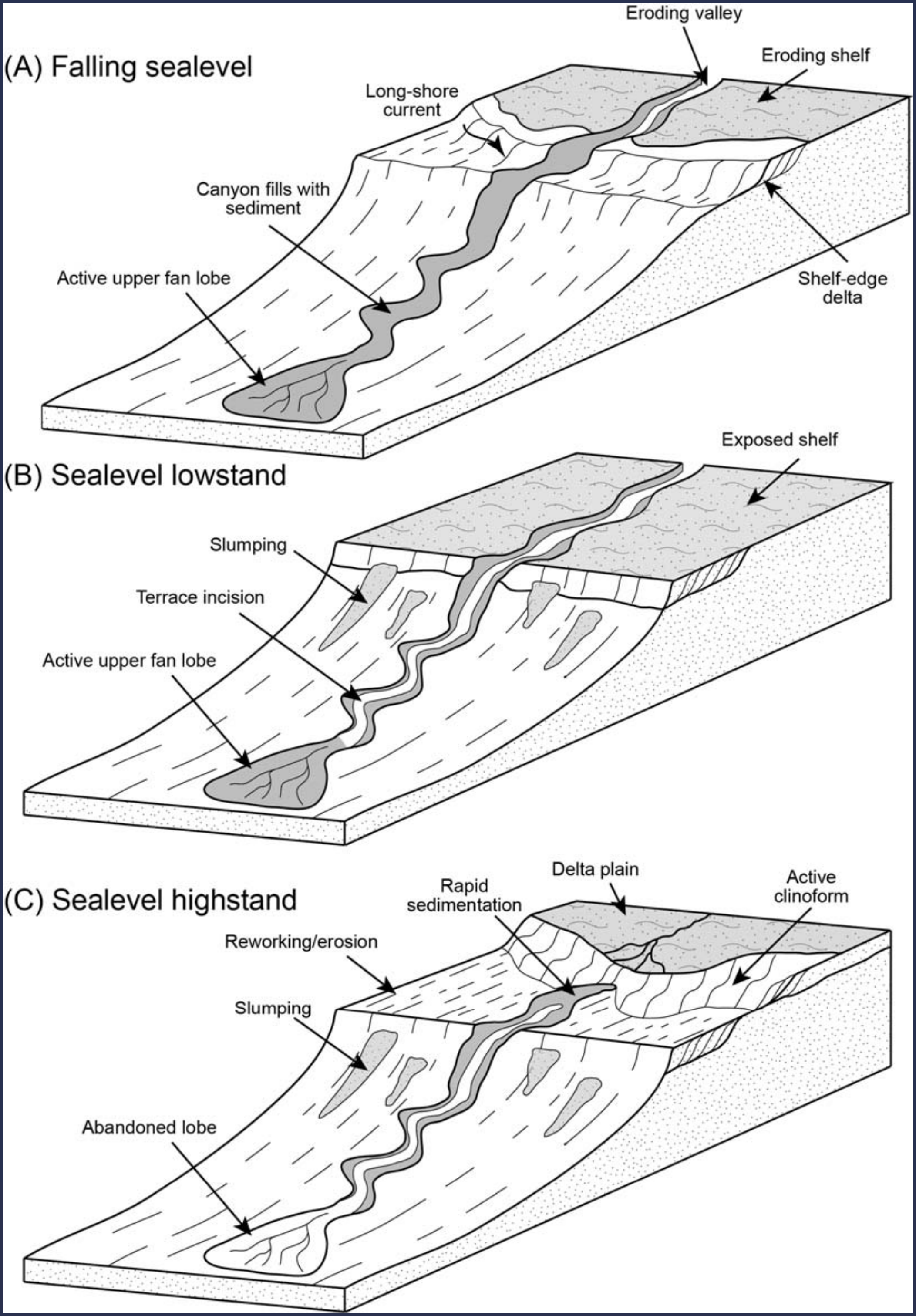


Terracing and ox bows are seen to extend into deep water, but these are likely related only to meander loop migration





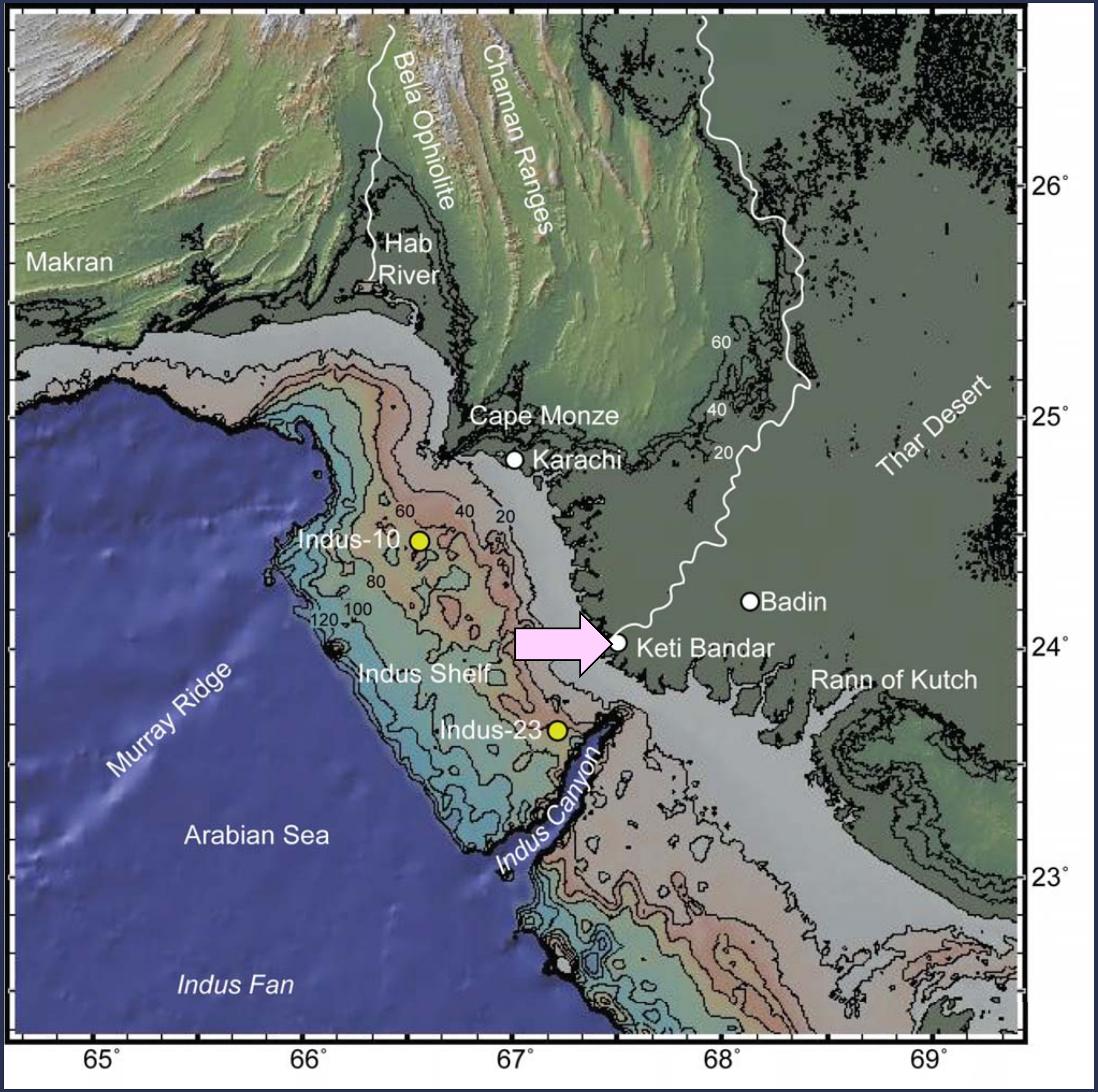
Response of delta to the combined effects of sealevel variation and changing sediment supply modulated by monsoon



Conclusions

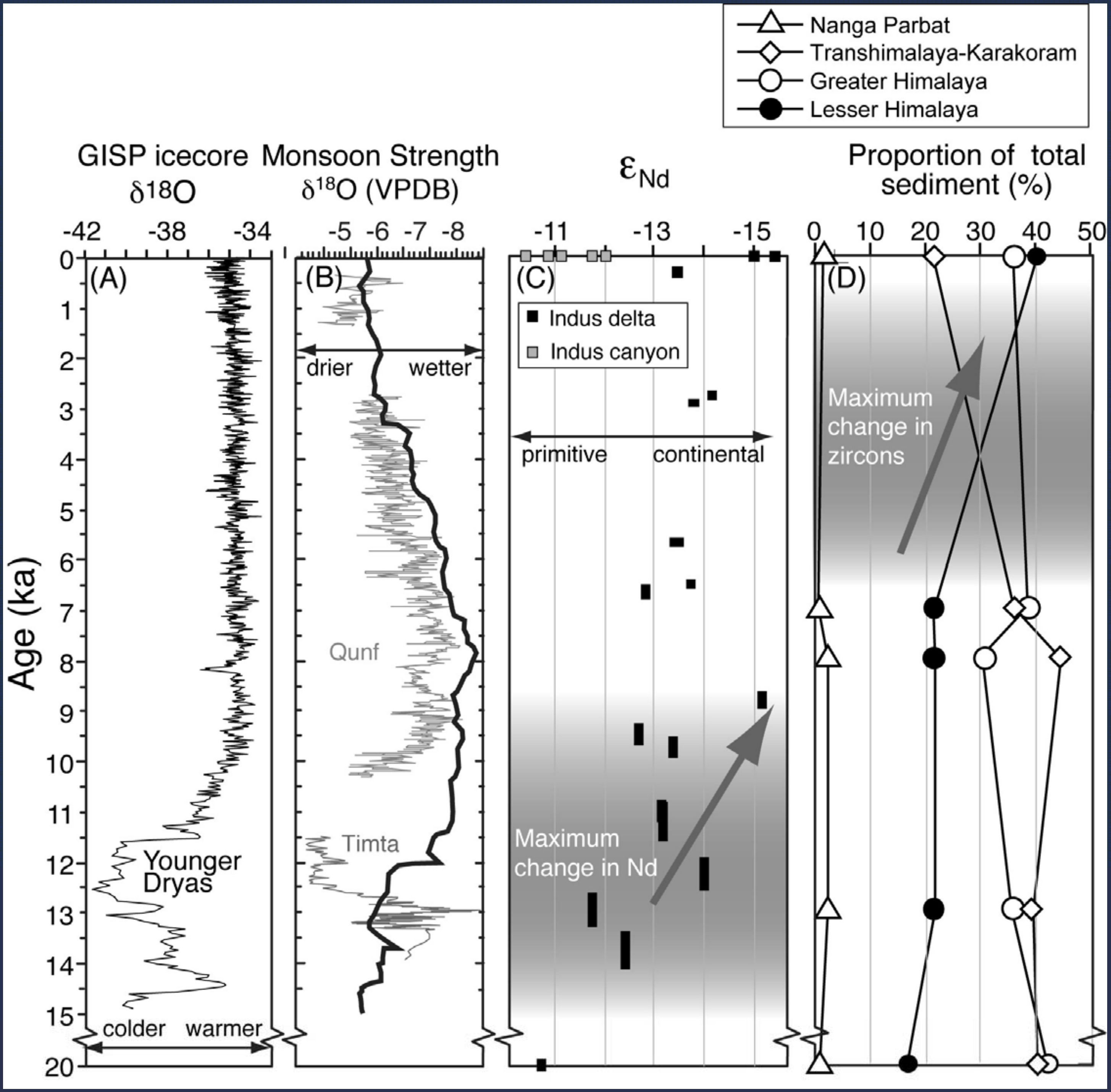
- Flux to the Indus delta since 10 ka comprises ~55% reworking from terraces driven by strong monsoon
- Sediment mixes on the shelf with long-shore material and reworked older deposits
- Sediment transport source to sink is at least 10 ka.
- Sands in canyon are likely not very continuous.
- Slumping down and across canyon is important.
- Canyon filling may be linked to climatic cycles as much as sealevel.

Drilling at the Indus delta provided a record of evolving sediment chemistry and provenance since 14 ka



The timing of zircon population change is different from the Nd isotope shift
- suggests a lag in the zircon transport of 5-10 ka

Lag in transport of dense mineral phases – bedload versus suspended load



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