

Controls on the Flux of Sediment to the Arabian Sea from the Western Himalaya since the Last Glacial Maximum

Peter D. Clift
University of Aberdeen

Liviu Giosan
Woods Hole Oceanographic Institution

Andrew Carter
Birkbeck, University of London

Ali R. Tabrez
National Institute of Oceanography, Pakistan

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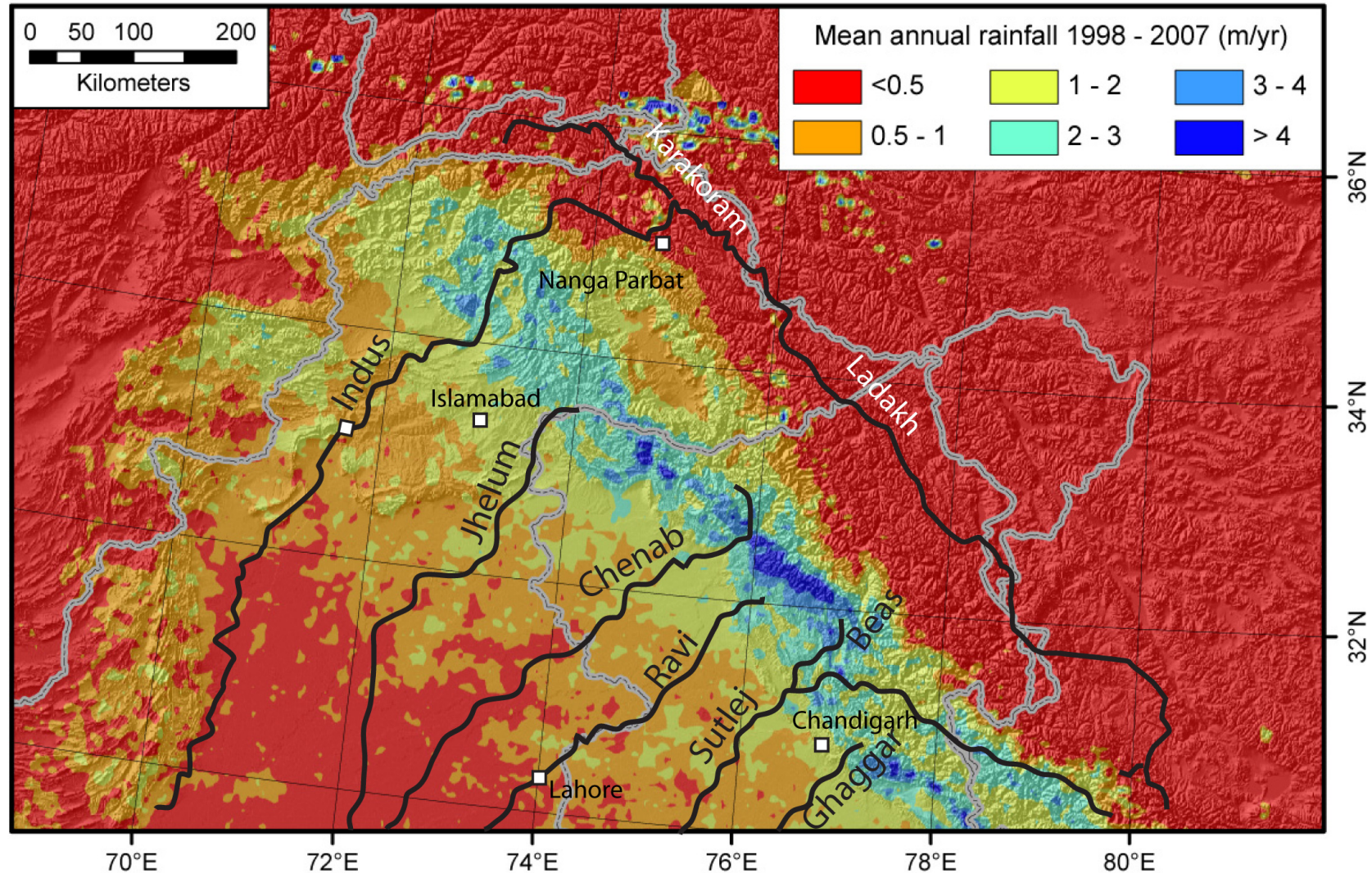


Research Objectives

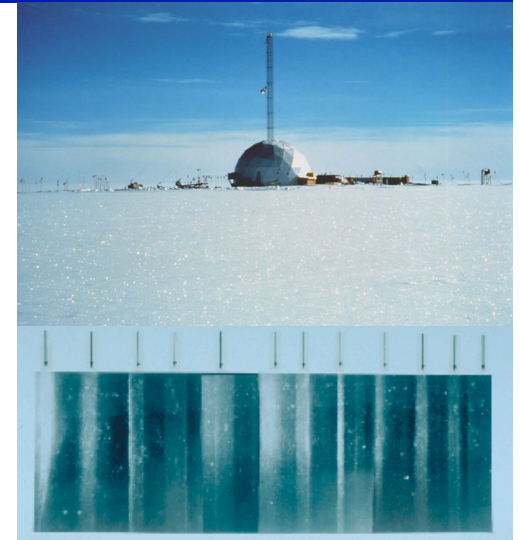
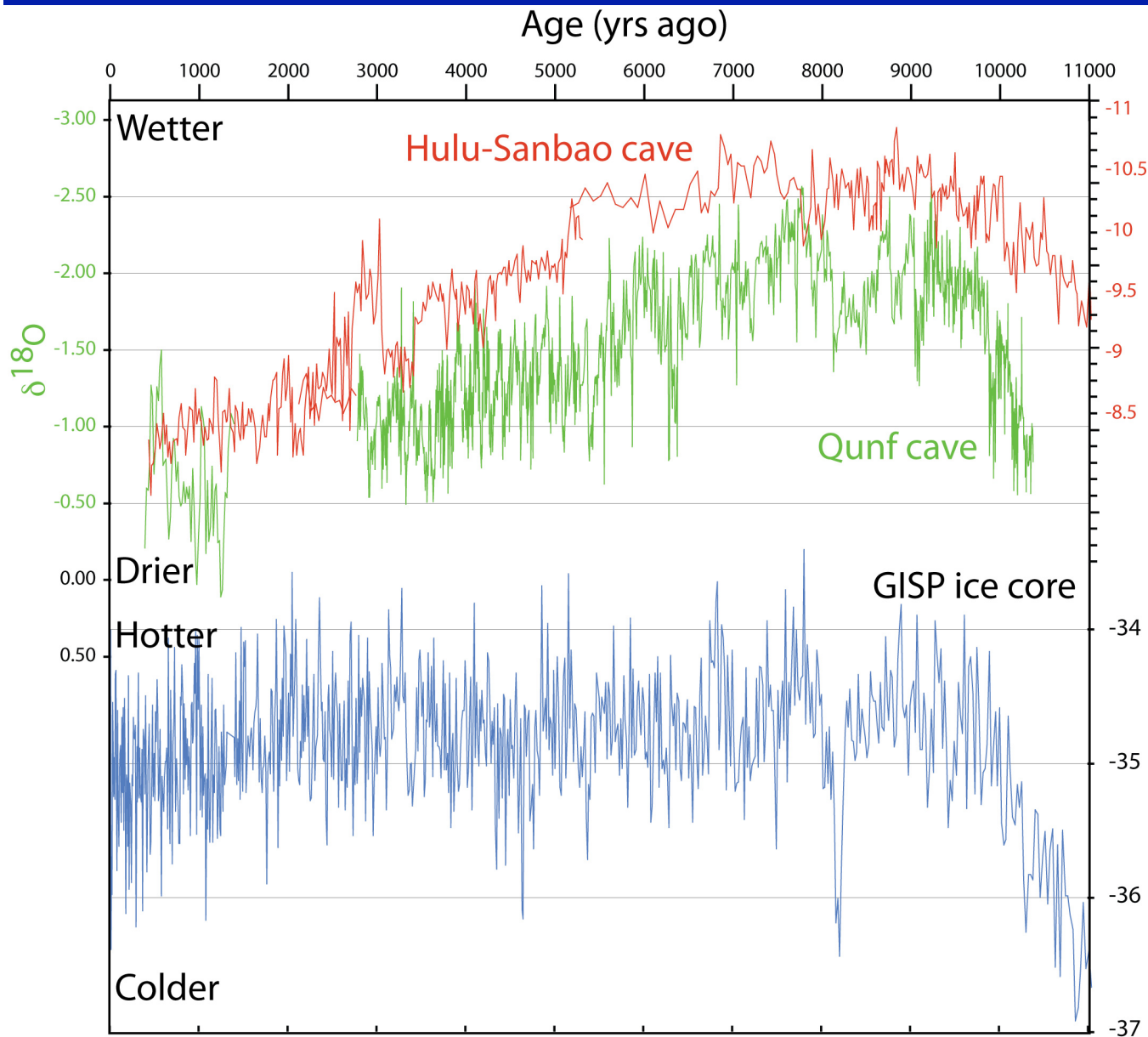
- Can we use the deep sea marine record to reconstruct past landscape and erosion onshore?
- Determine speed of sediment flux from source to sink.
- Quantify degree of sediment buffering and reworking in the flood plains.
- Estimate degree of storage on the continental shelf

To what extent can the deep-sea record be used to reconstruct erosion and landscape evolution in the mountains?

Rainfall varies along and across strike within the Indus River system: Competing effects of snow melt and monsoon rains

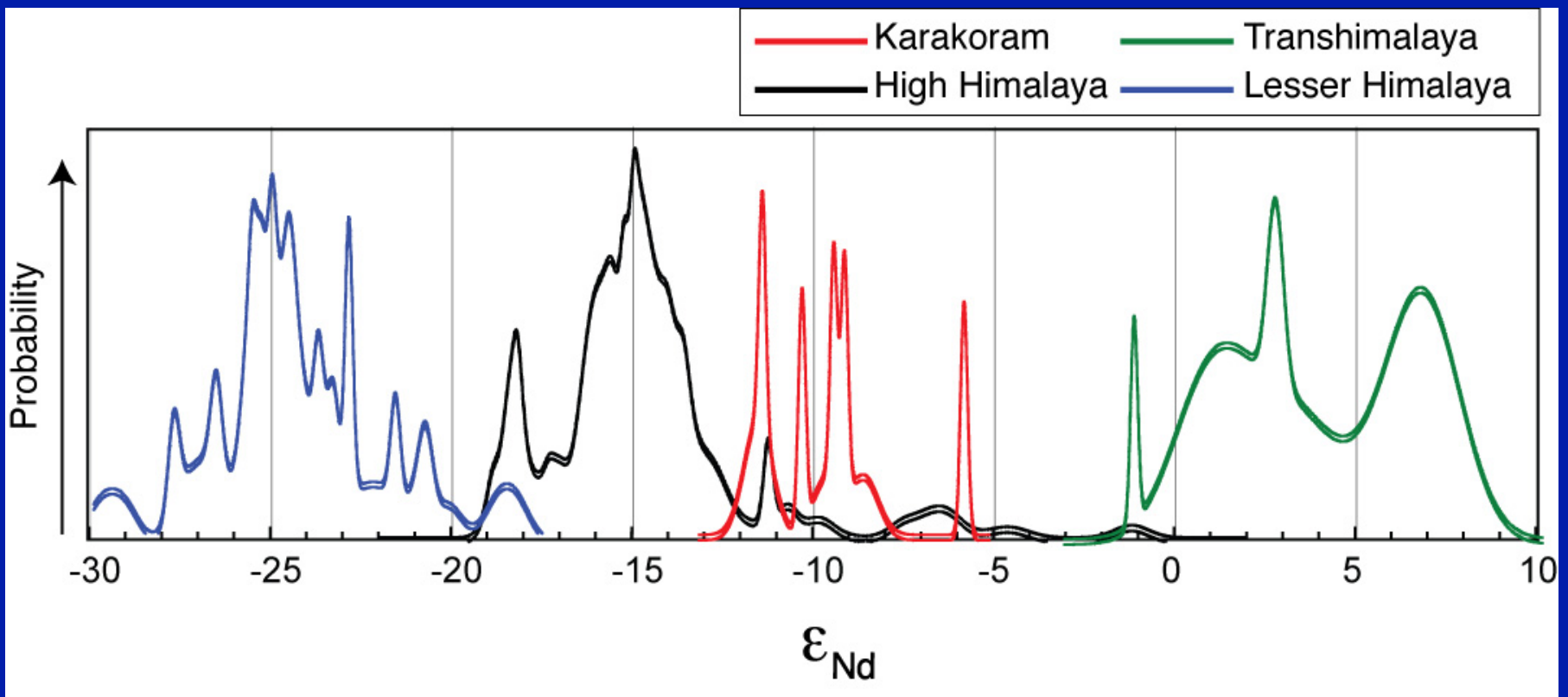


Indus system benefits from a well defined monsoon-climate history since the LGM - How fast does the landscape respond?



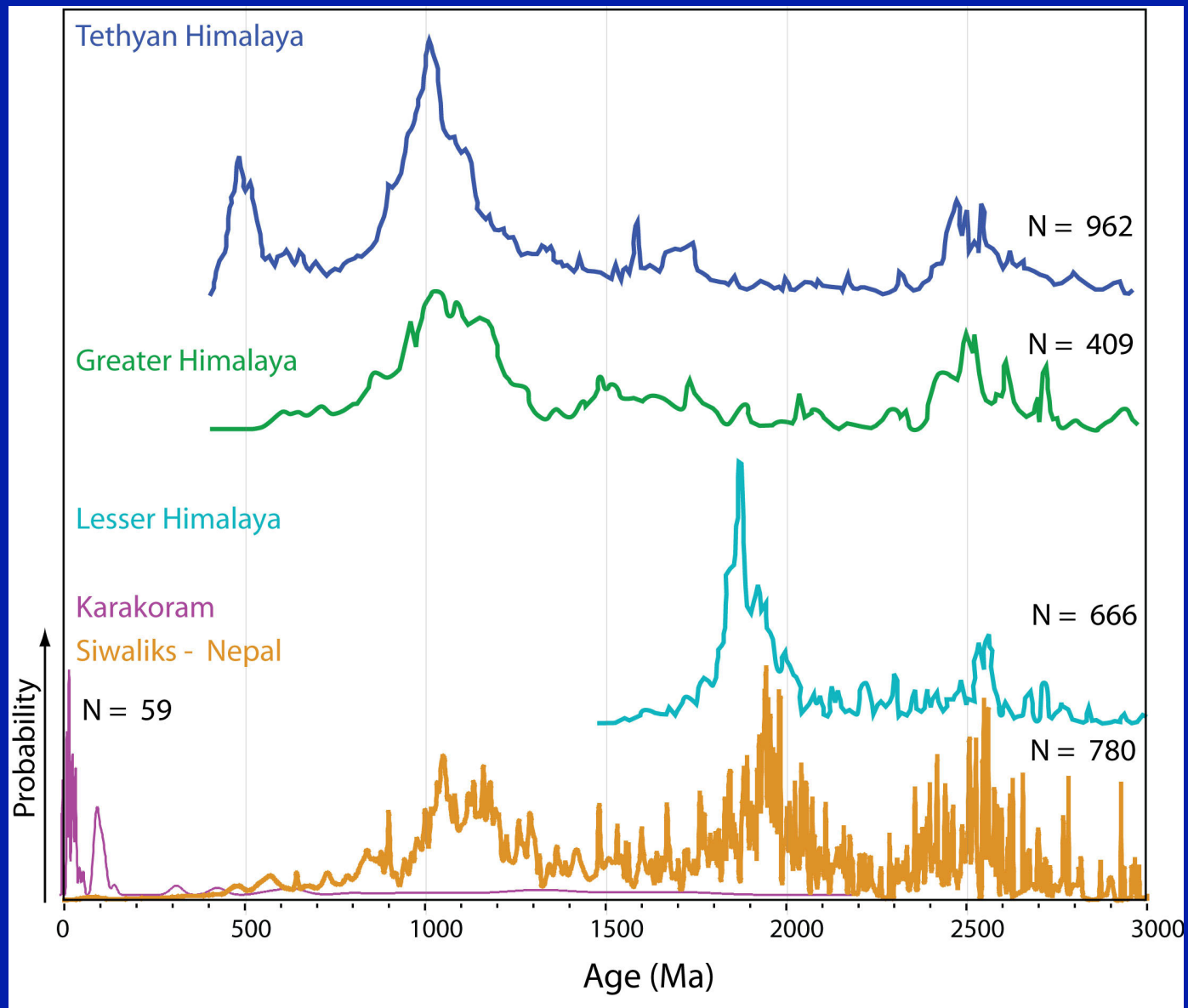
How does the source of the sediment change?

Nd isotopes in sediment make powerful source discriminants in the Western Himalaya and Karakoram



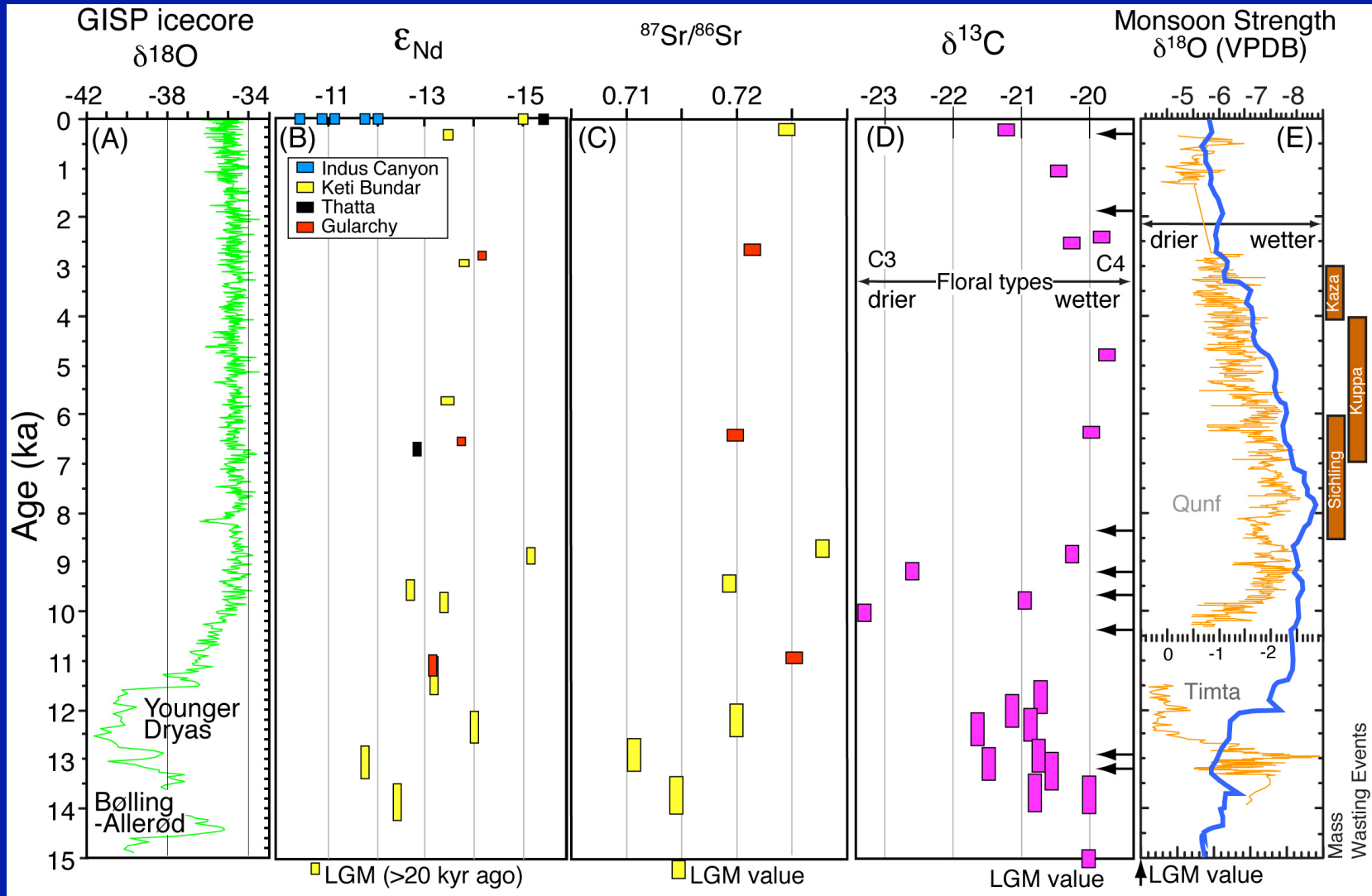
Known ranges of zircon U-Pb ages in the sources (DeCelles et al., 2004)

This is a powerful provenance tool



Evolution in Nd and Sr isotope composition since the Last Glacial Maximum

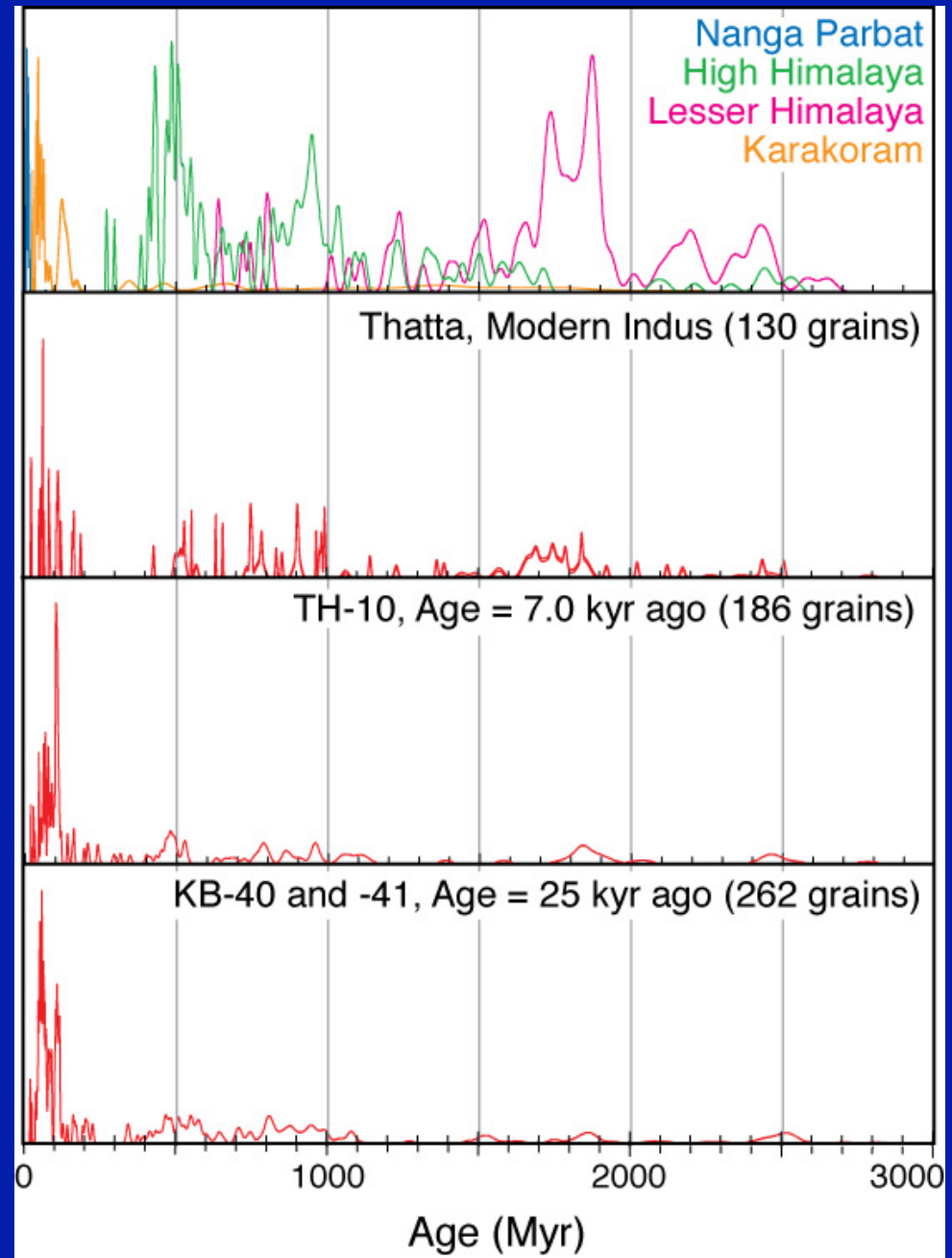
Strong change to more Himalayan erosion, less from Karakoram



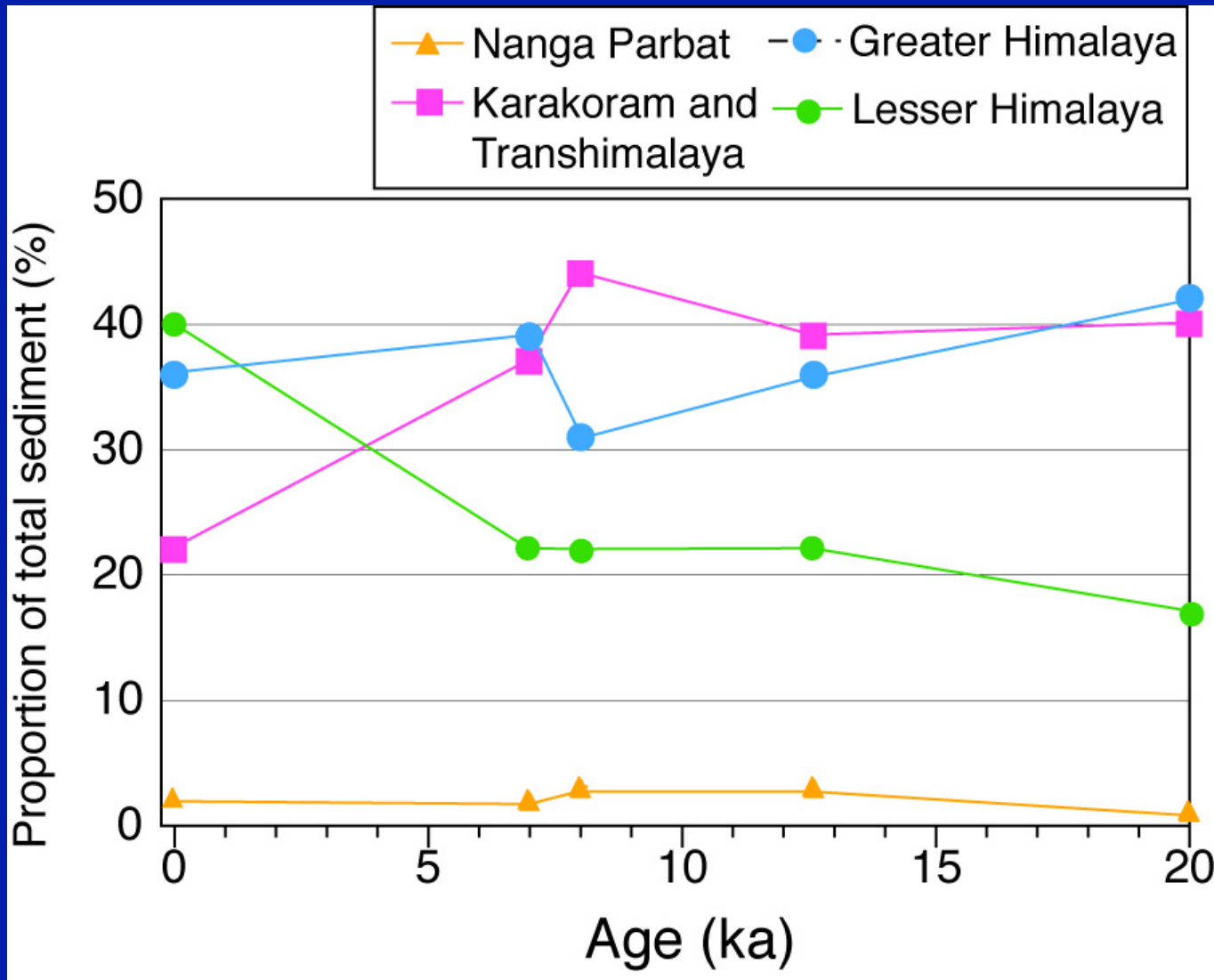
U-Pb dating of zircon

(Laser ICP-MS)

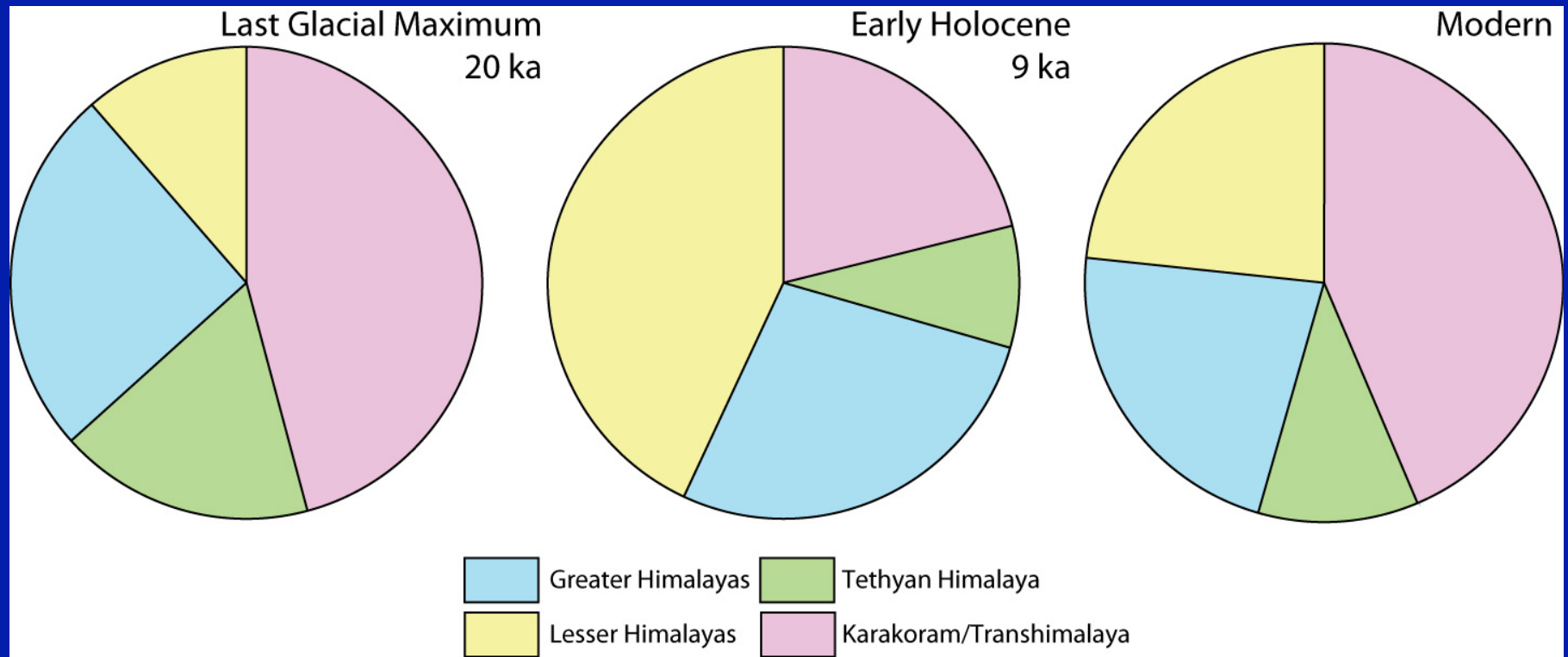
Since the LGM the proportion of Lesser Himalayan zircons (~1800 Ma) has greatly increased, while relative flux from Kohistan/Transhimalaya has decreased



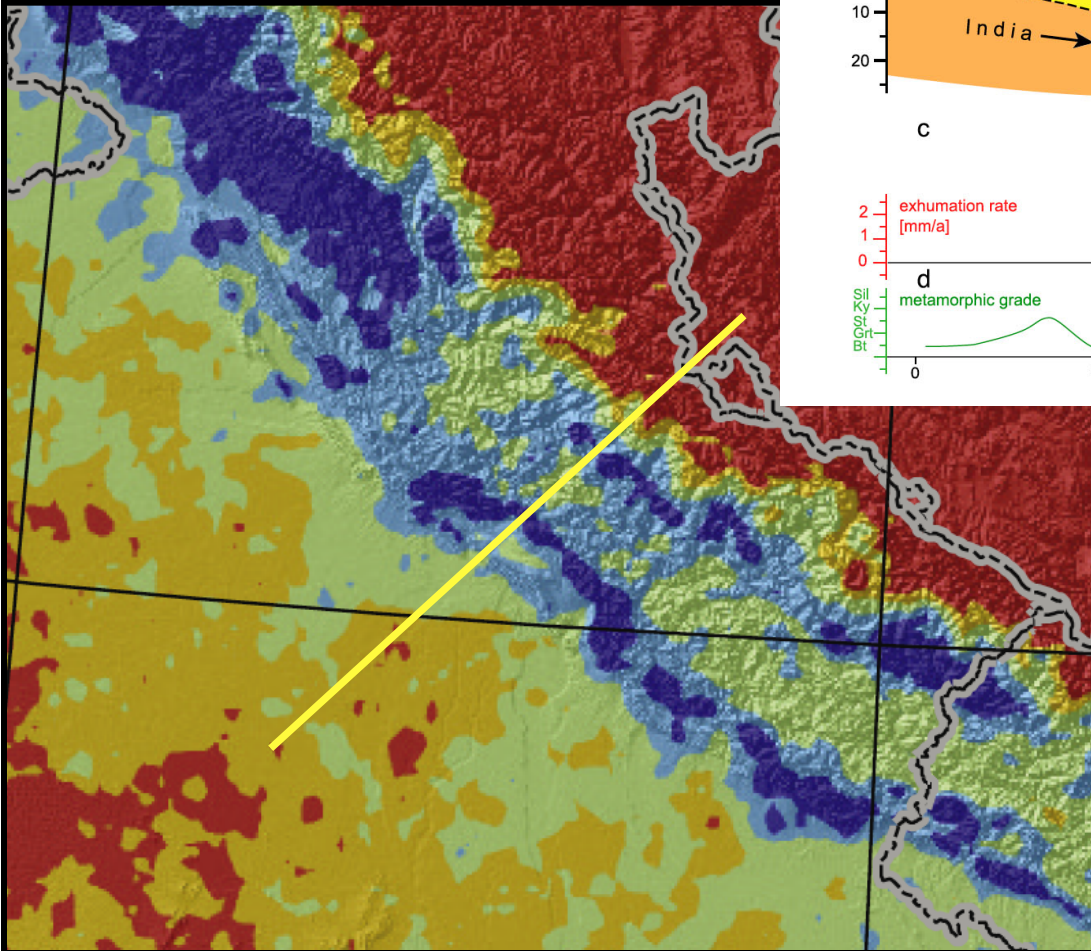
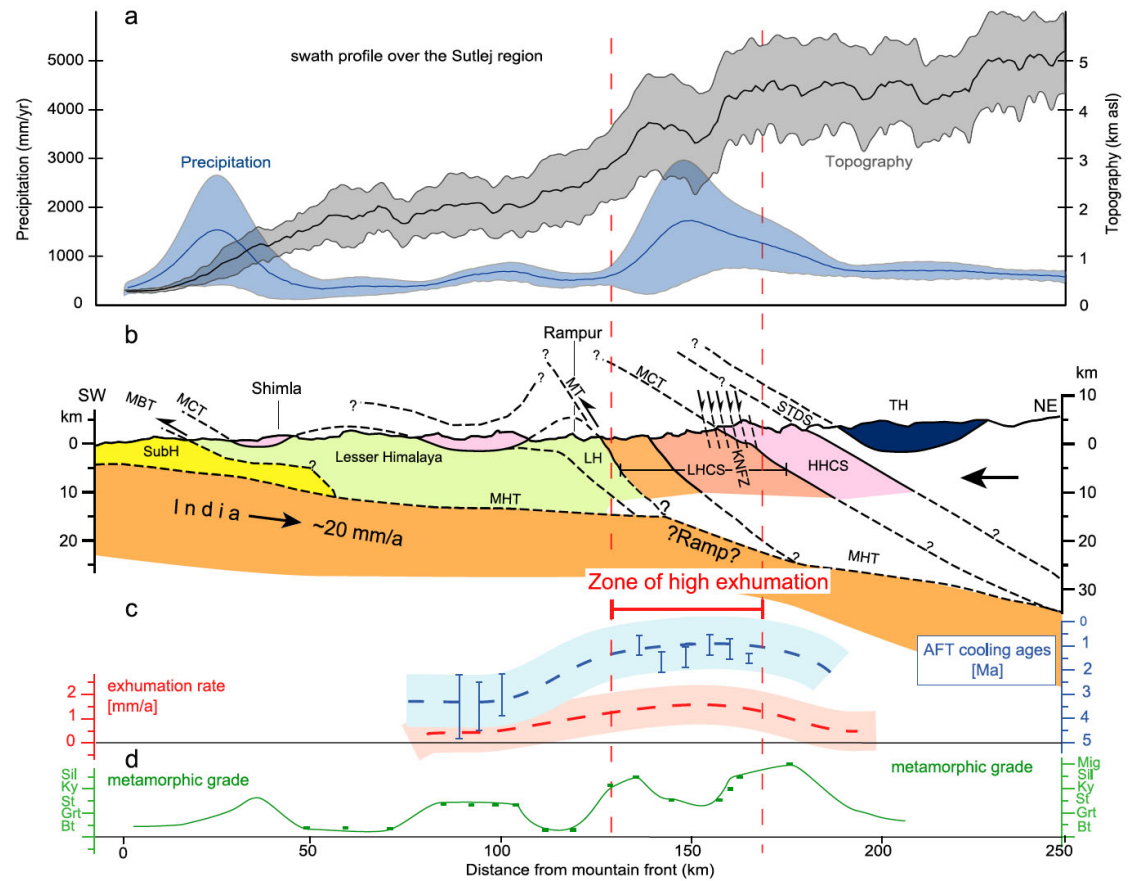
The timing of zircon population change is different from the Nd isotope shift
- suggests a lag in the zircon transport of 5-10 ka



Shifting zircon age populations show marked differences in sediment sources since the LGM, likely driven by climatic variations



Early Holocene is characterized by intensified erosion where monsoon rains are strongest

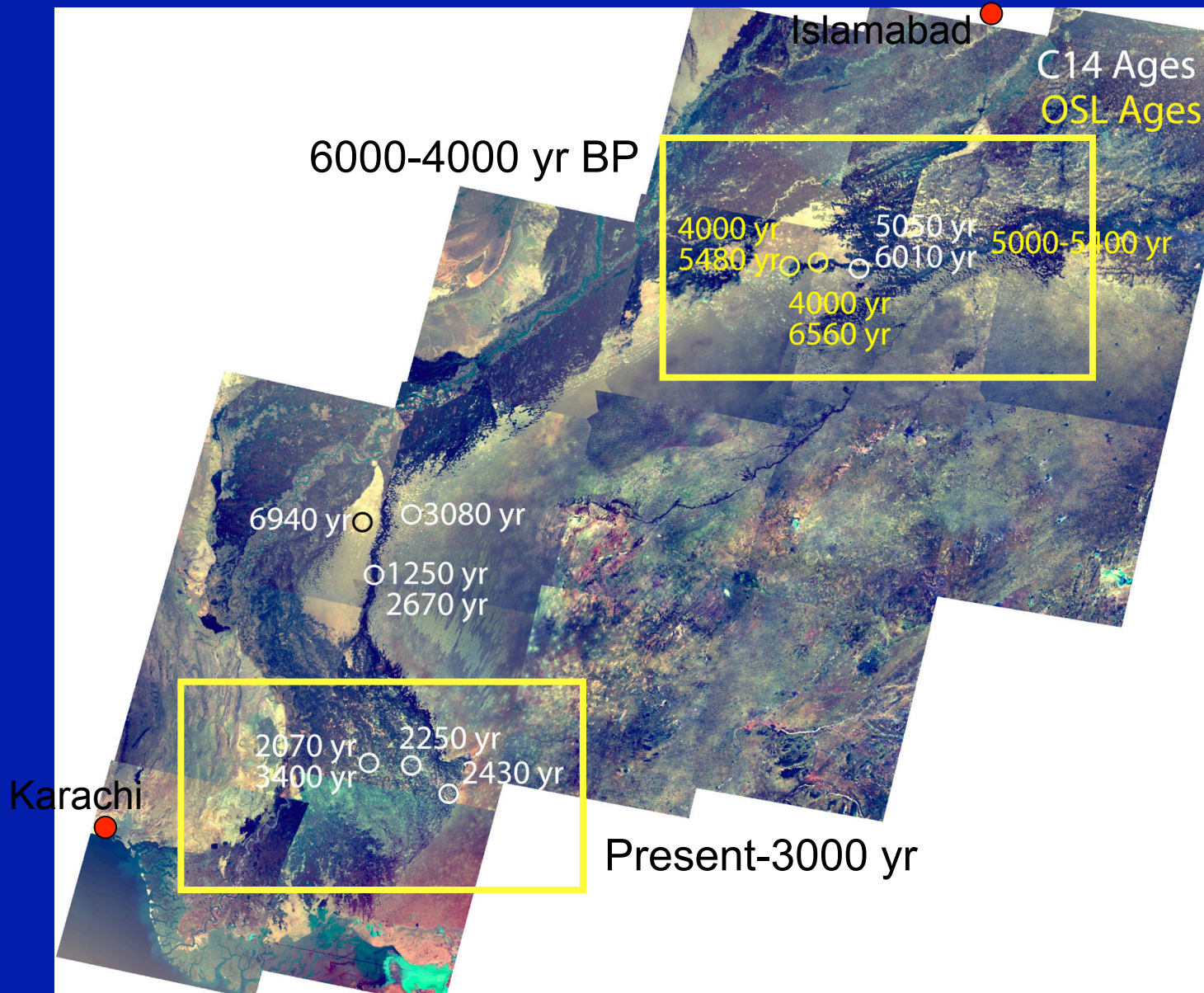


Thiede et al. (2003)

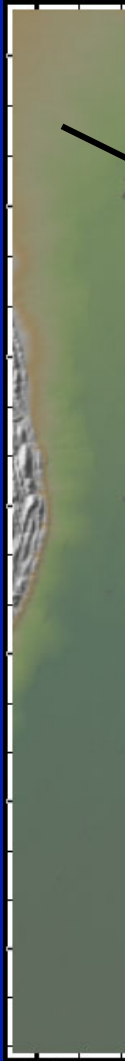
Bookhagen & Burbank (2005)

How much sediment is stored and released in the flood plains?

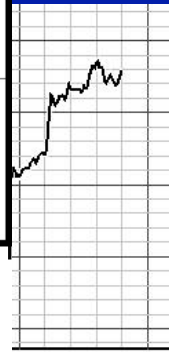
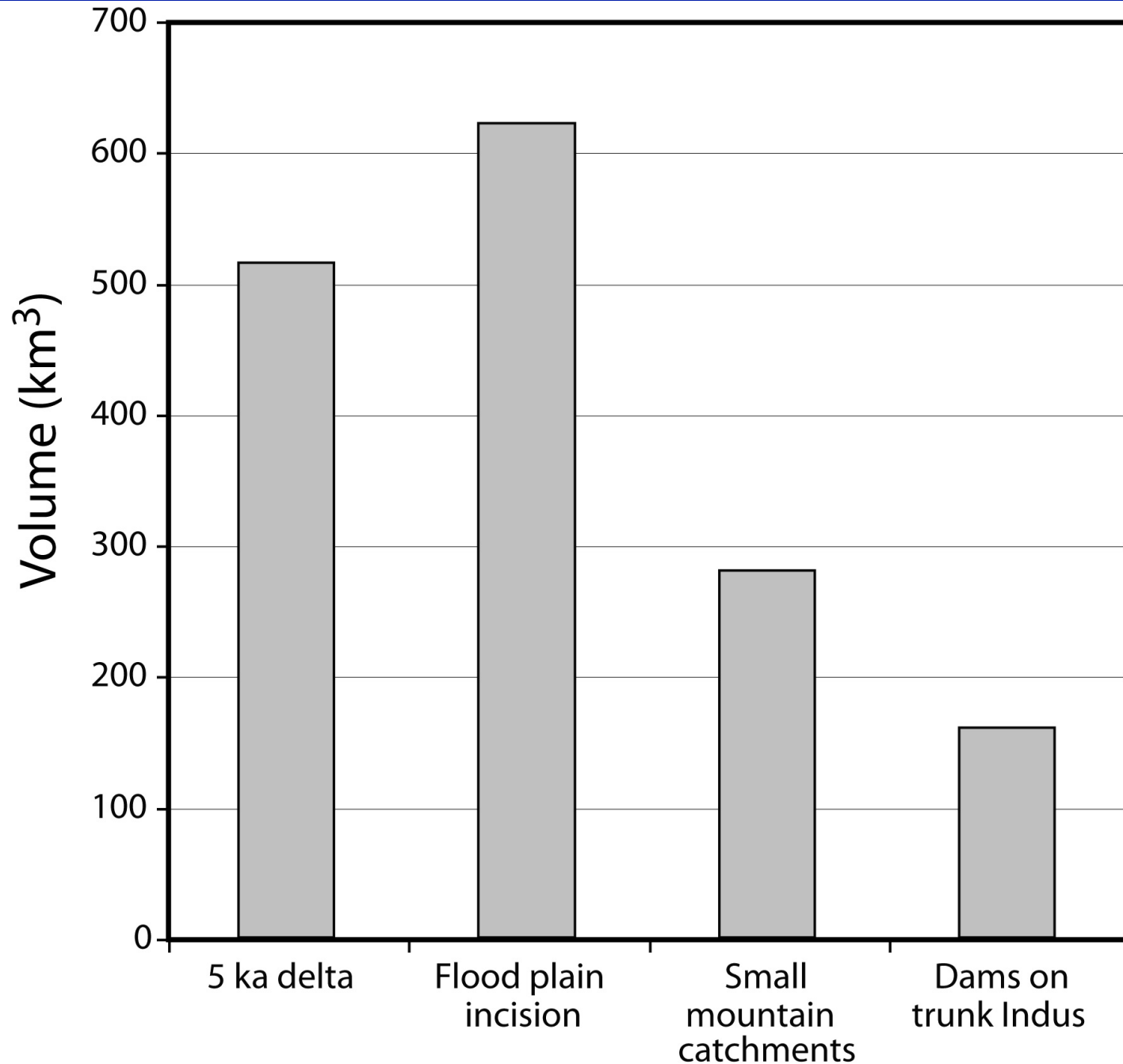
Dating reveals major changes in the patterns of sedimentation since 8 ka



Incision
Rewo



70°E30'



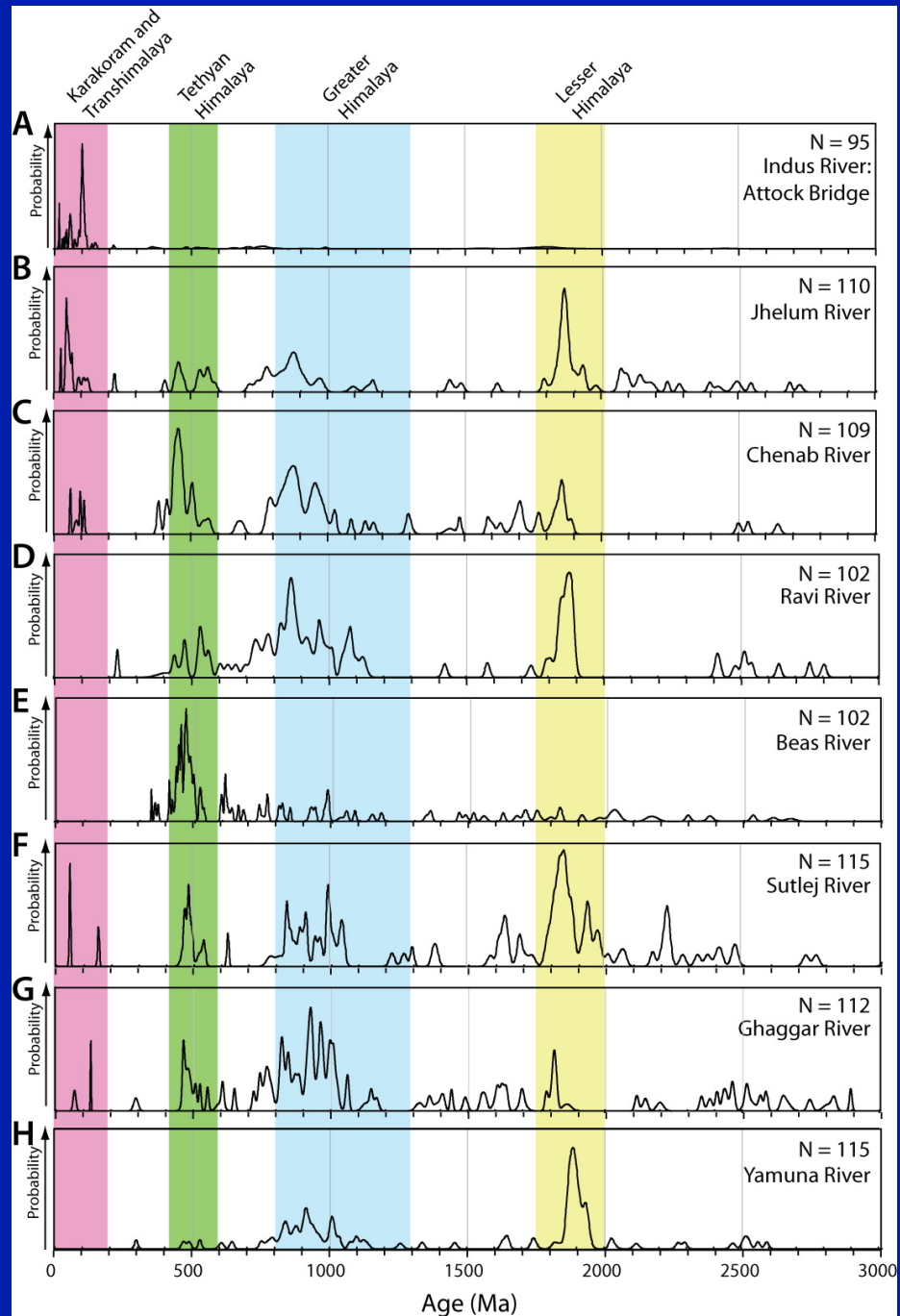
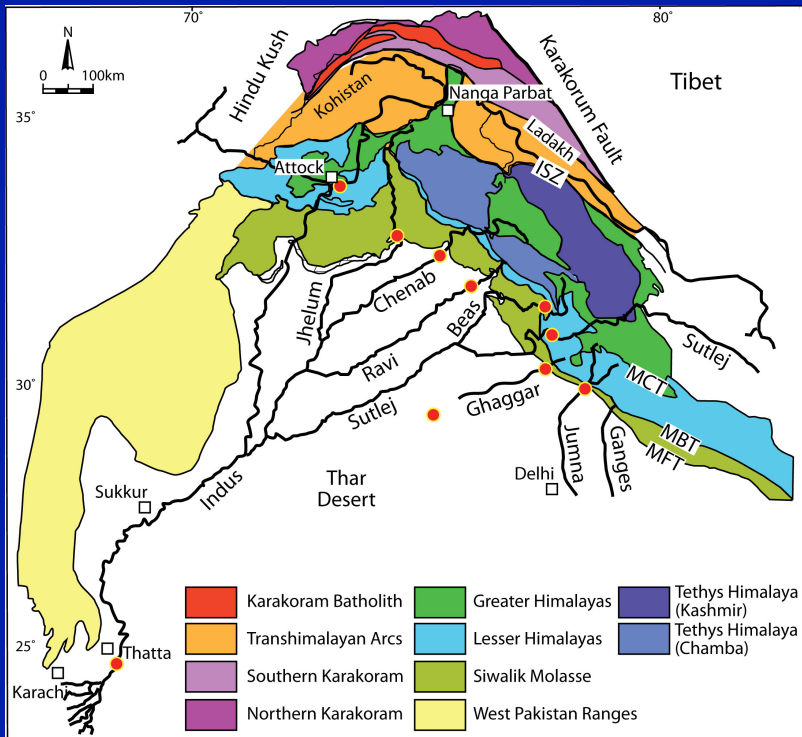
400

Can zircon be used to reconstruct
changes in drainage patterns?

Need to fingerprint possible contributions

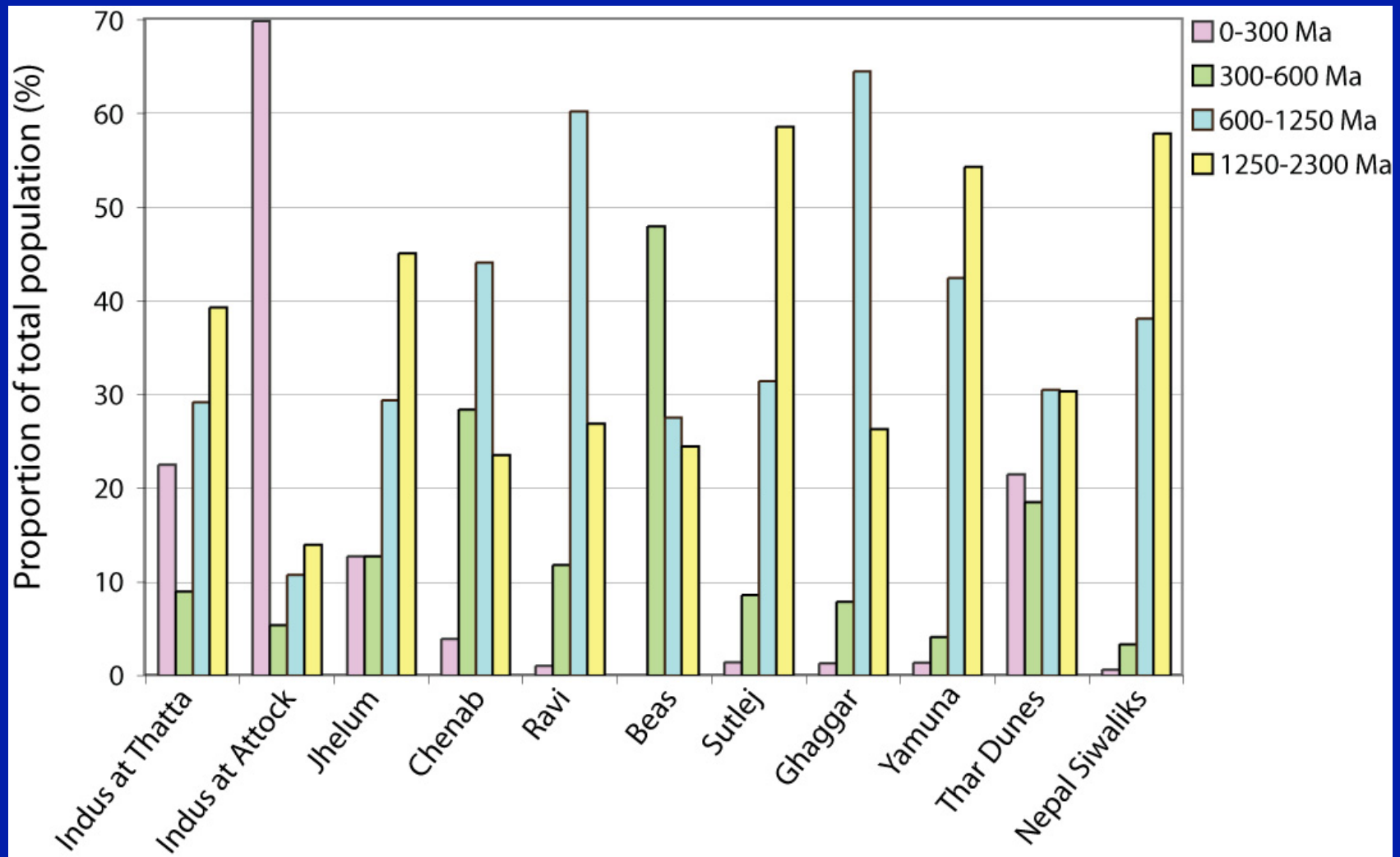
Measured zircon age populations for modern Indus zircons.

Each river has its own unique signature



Simplified age spectra for the different parts of the modern Indus

Note young grains are unique to Indus, Jhelum and Thar Desert



So what do we predict the net flux to the delta to be like, assuming water discharge is proportional to sediment load?

The sediment at the delta seems to have far too much material from sources typical of the Sutlej and not enough from the Chenab or trunk Indus compared to modern discharge

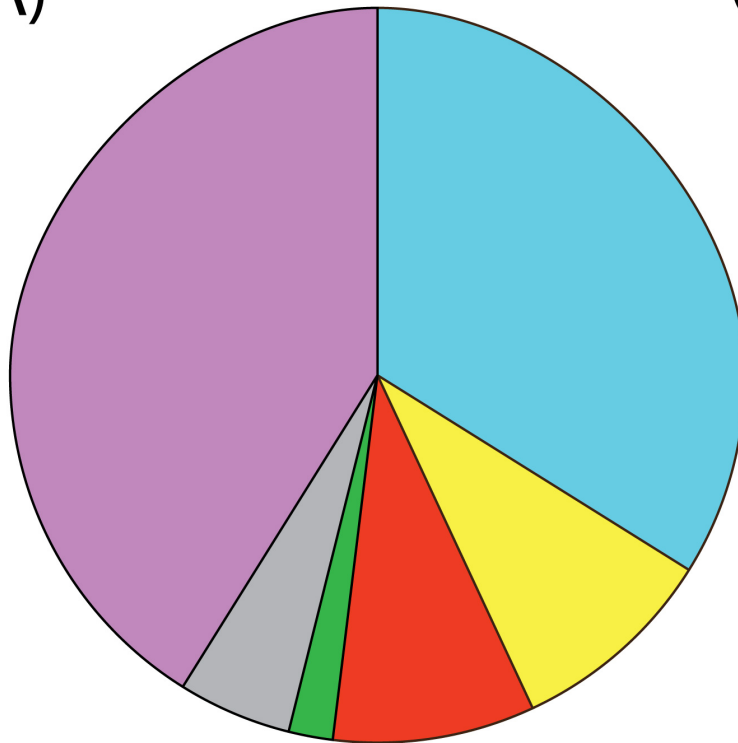
Age groups	% contribution from each river							
	Indus	Jhelum	Chenab	Ravi	Beas	Sutlej	Ghaggar	Yamuna
Water discharge (% of total in the modern Indus)	56	14	16	4	4	6	na	na
0-300 Ma	67.9	13.1	4.1	1.1	0.0	3.0	3.3	0.9
300-750 Ma	10.7	15.2	31.6	20.7	61.2	10.1	17.6	5.7
750-1250 Ma	7.1	28.3	43.9	52.2	18.8	27.3	58.2	40.6
1500-2300 Ma	14.3	43.4	20.4	26.1	20.0	59.6	20.9	52.8
% of total sediment flux in modern Indus at Thatta	34	9	9	2	5	41	na	na
Epsilon Nd	-10.8	-15.4	-15.0	-15.1	-19.0	-19.0		

We suggest that this mis-match reflects long transit times for zircons in the river, i.e., delta reflects past sediment flux

Measurements of the zircon age spectrum near delta suggest a very different mixture than that indicated by water discharge.

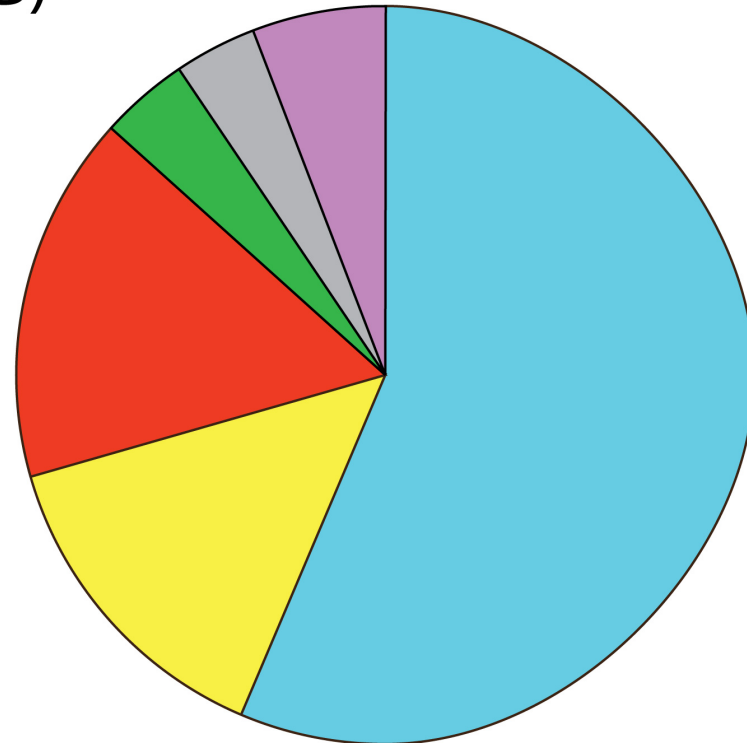
The delta sands were not generated by system like the modern river.

(A)



Best-fit Zircon Budget

(B)

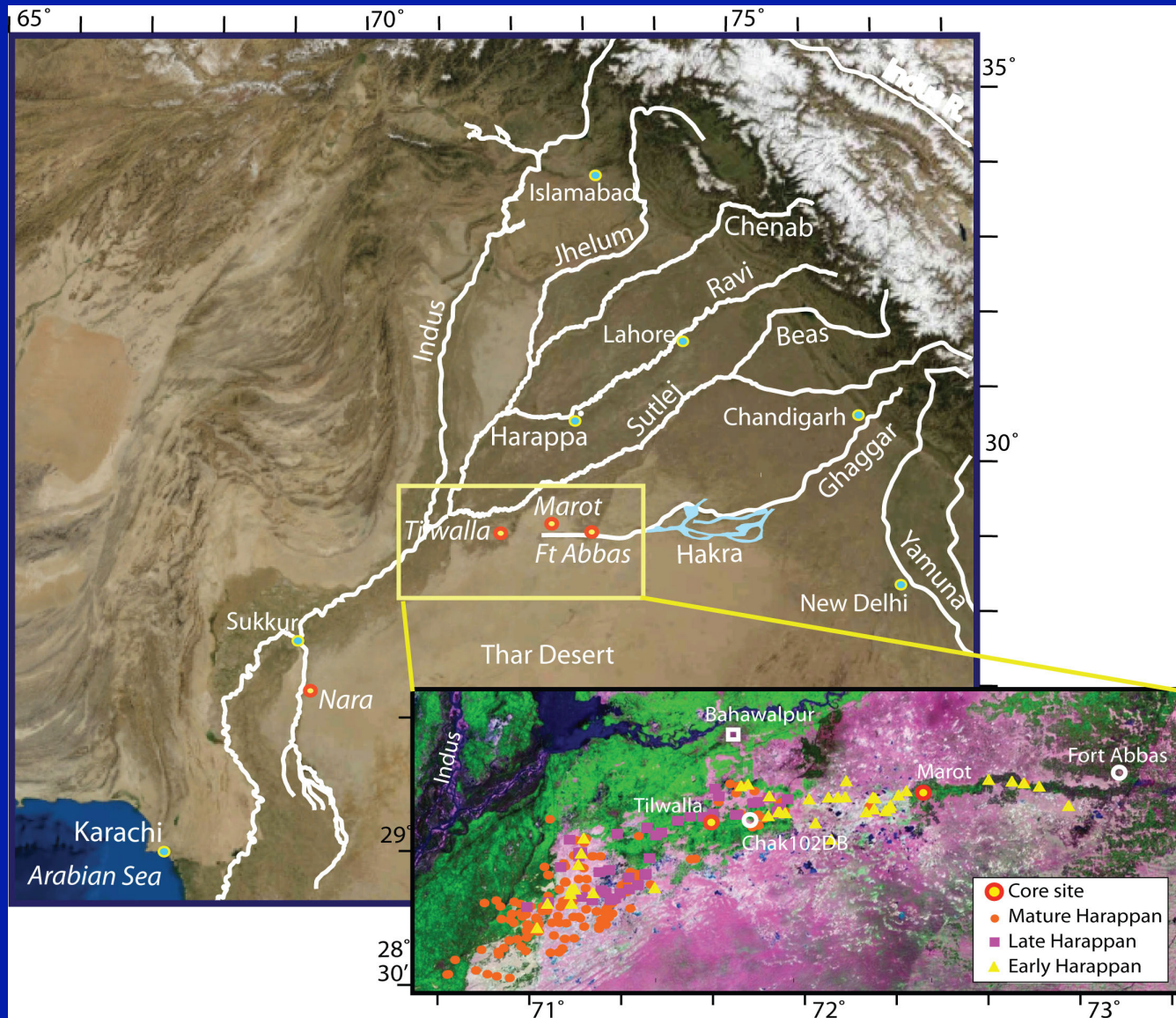


Water Discharge Budget

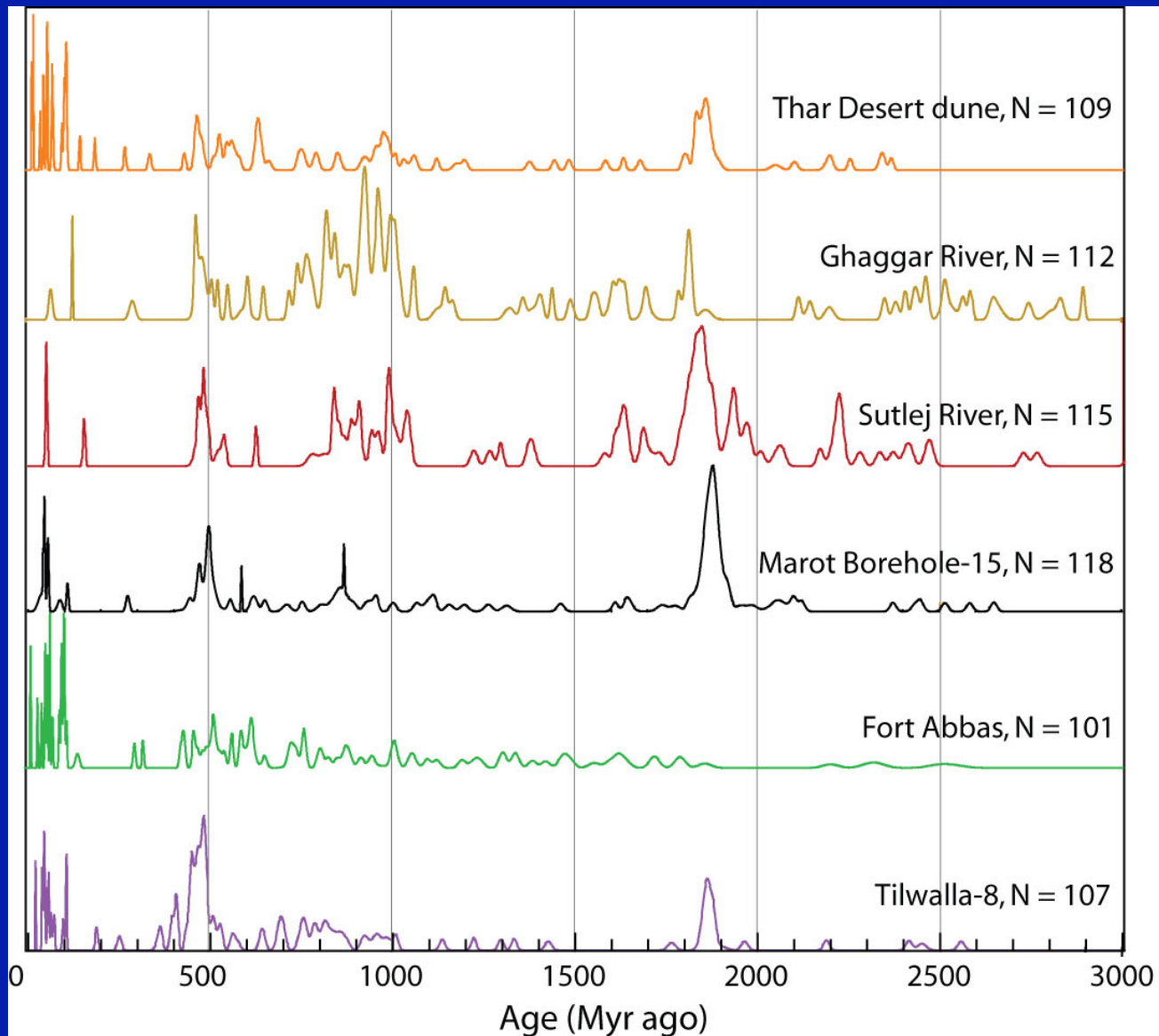


Can we use the thermochronologic data to reconstruct old drainage patterns?

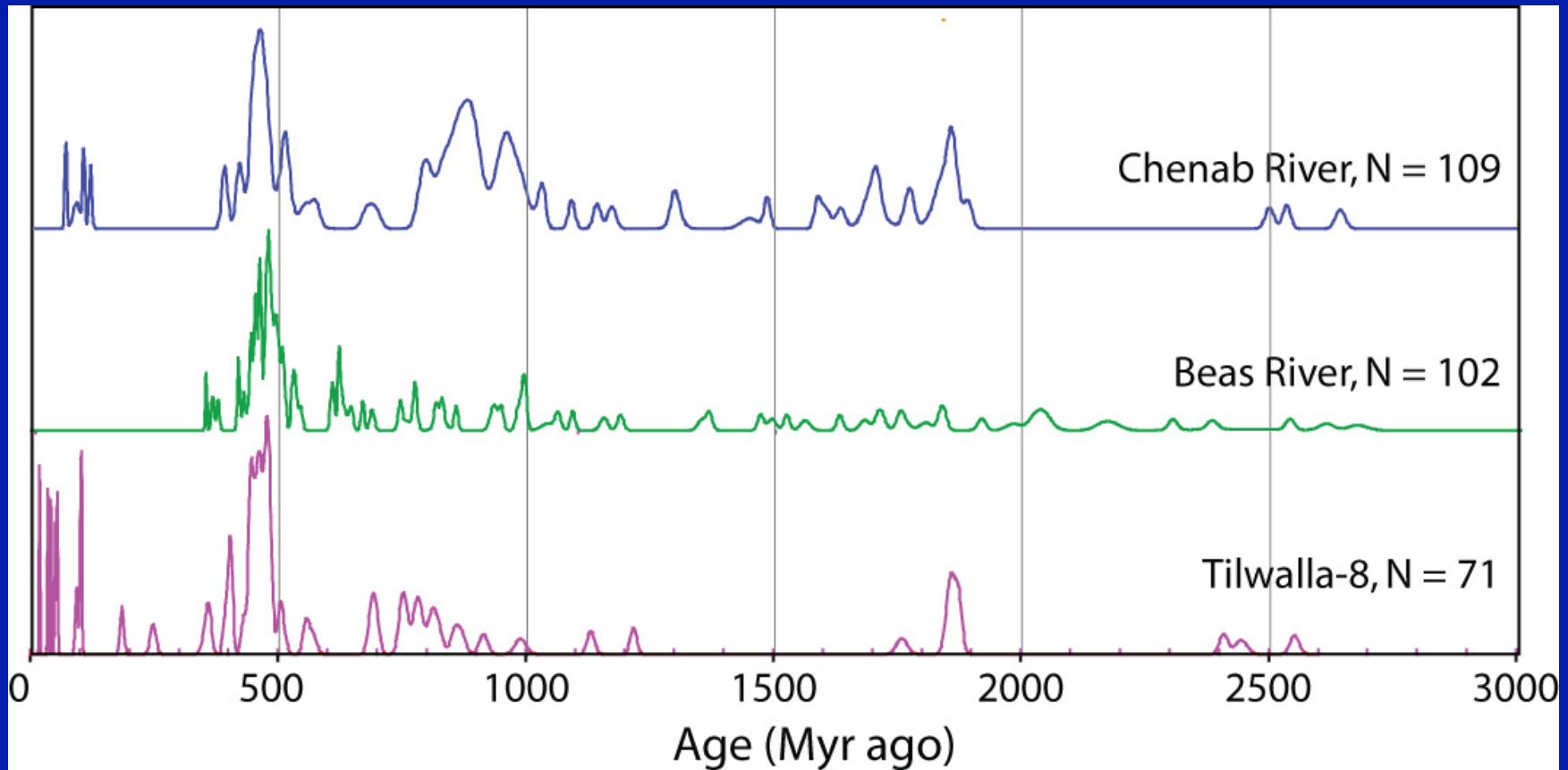
Sampling of sand focused in the region of the archaeological sites of the Indus Valley Civilization



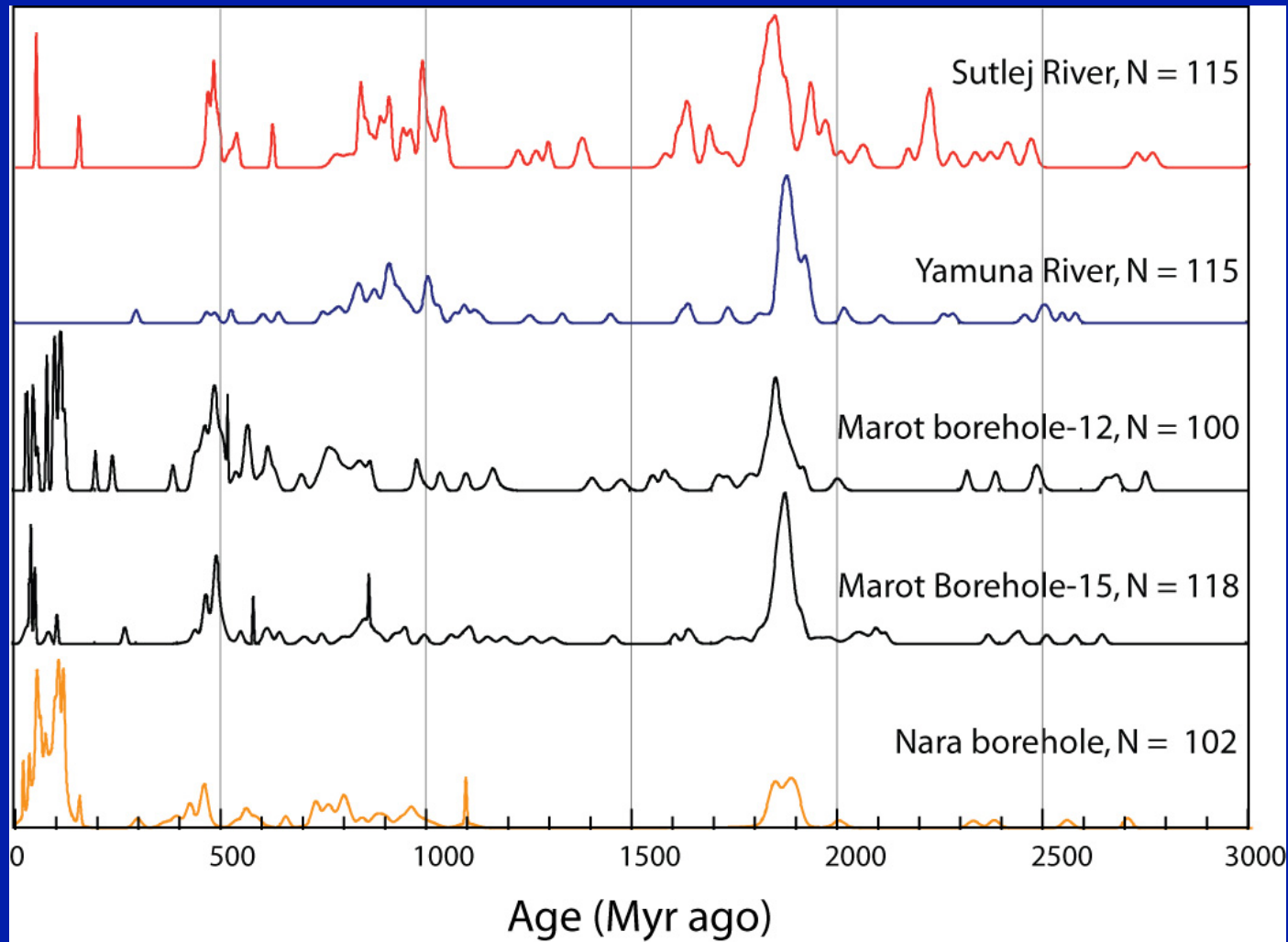
How do the Holocene sands compare to their nearest modern stream? - Lots of differences



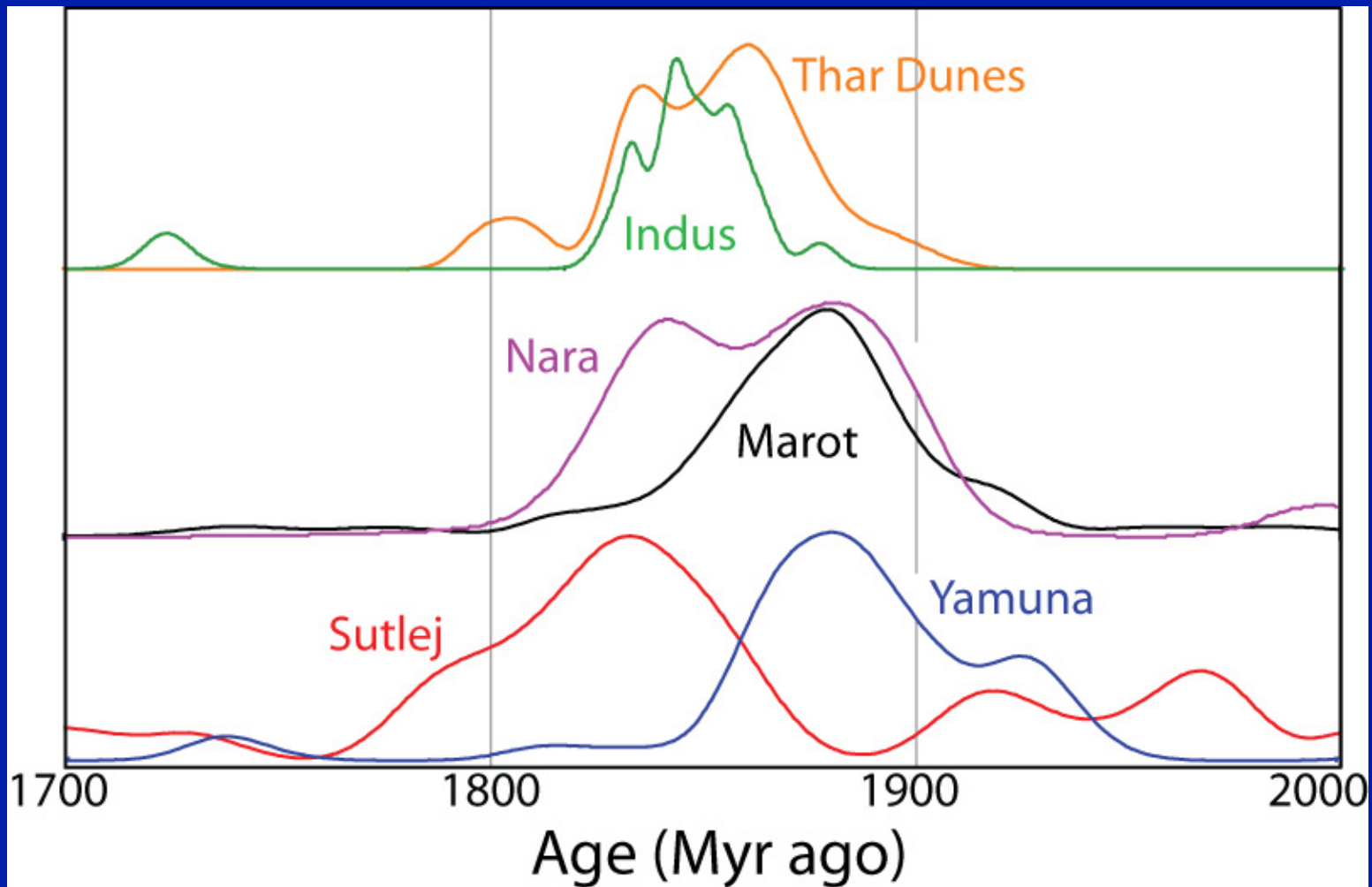
The sands at Tilwalla have a strong 400-500 Ma population similar to the Beas, now a Sutlej tributary



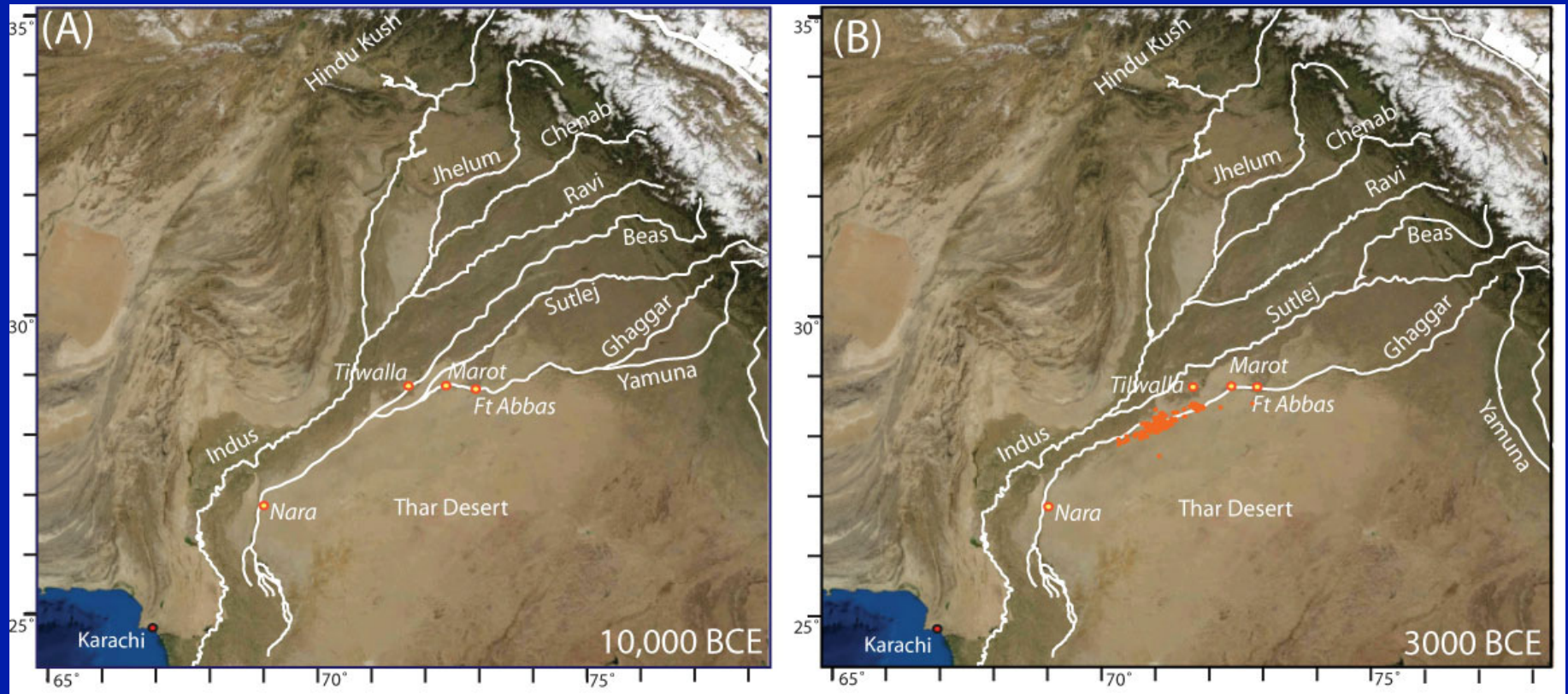
The Marot borehole shows strong similarities with the Sutlej and the Yamuna



Marot sands show best match with the Yamuna not the Sutlej, but are likely >10 ka



Possible drainage evolution model

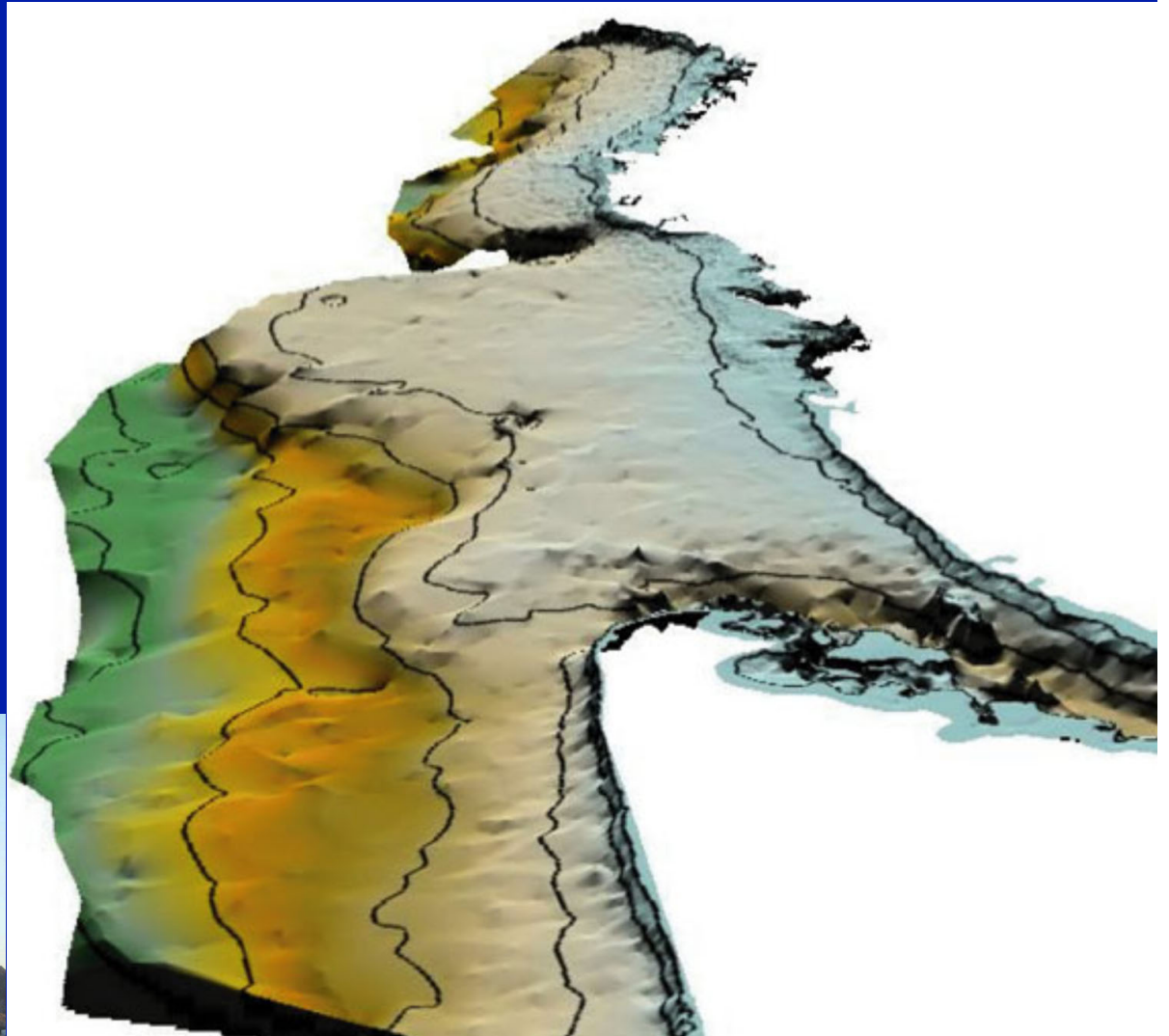


How much sediment is stored in the delta
on its way to the deep sea?

To what extent is
sediment stored on the
shelf?

Large clinoforms suggest
that it could be great

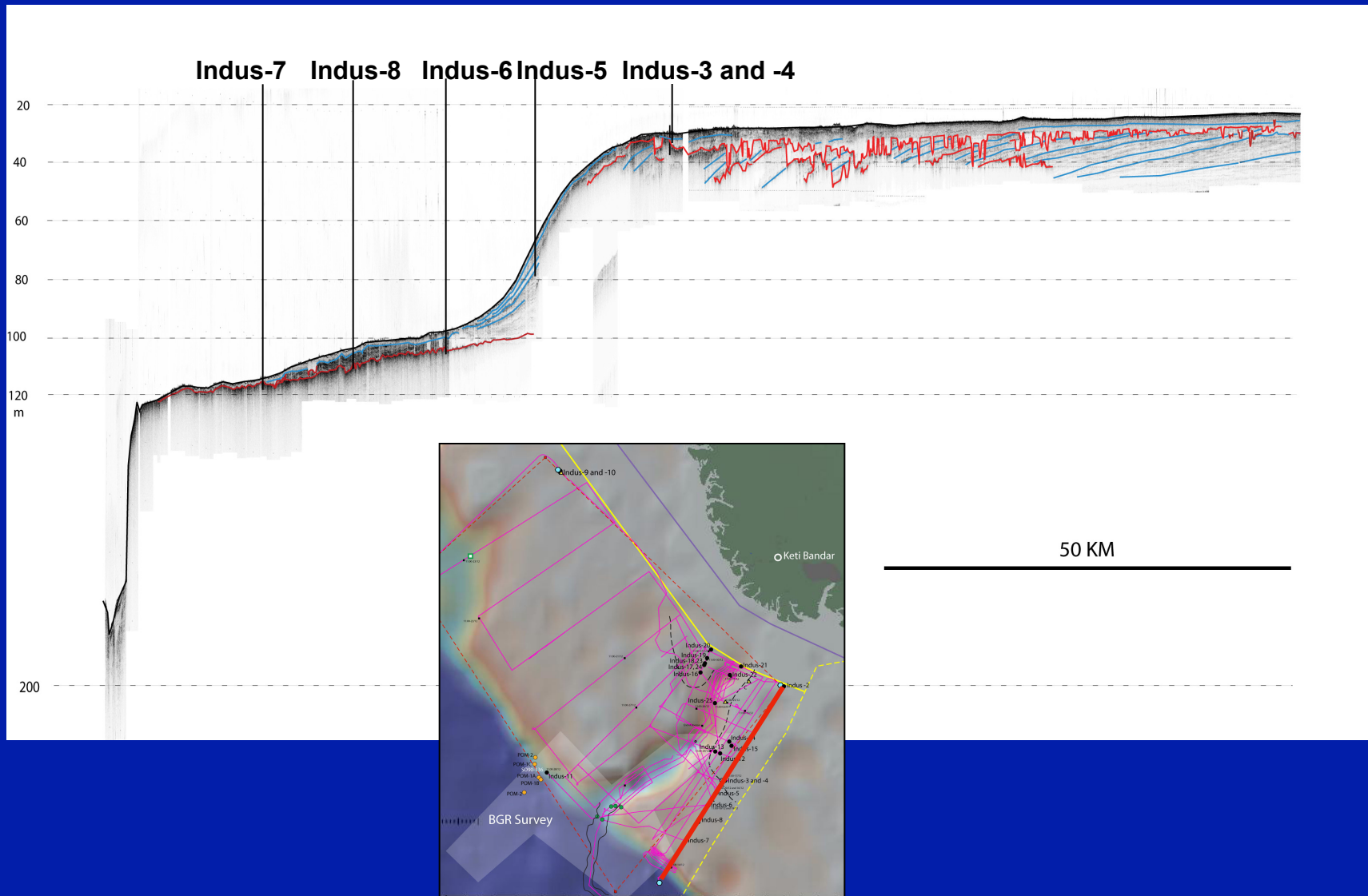
Investigated by a cruise
in 2008-2009



Giosan et al. (2006)

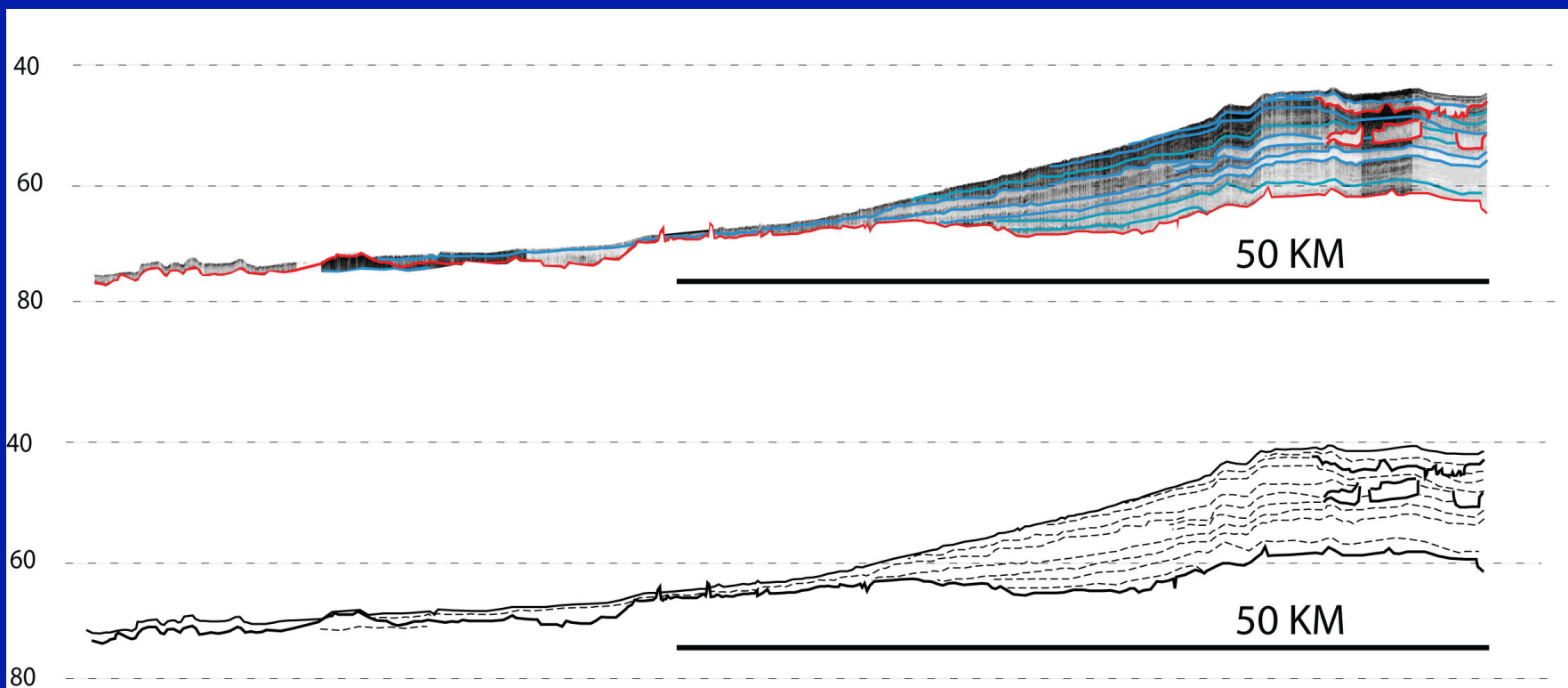
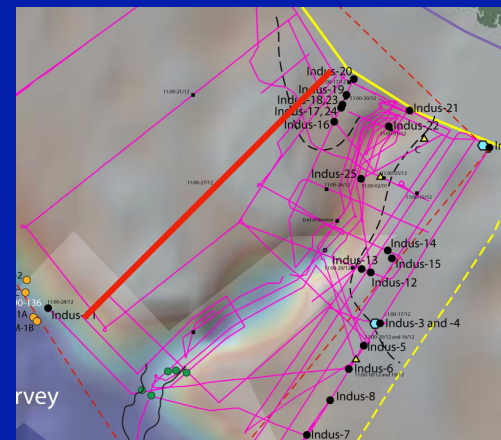
Clinoform on east side of the Indus Canyon

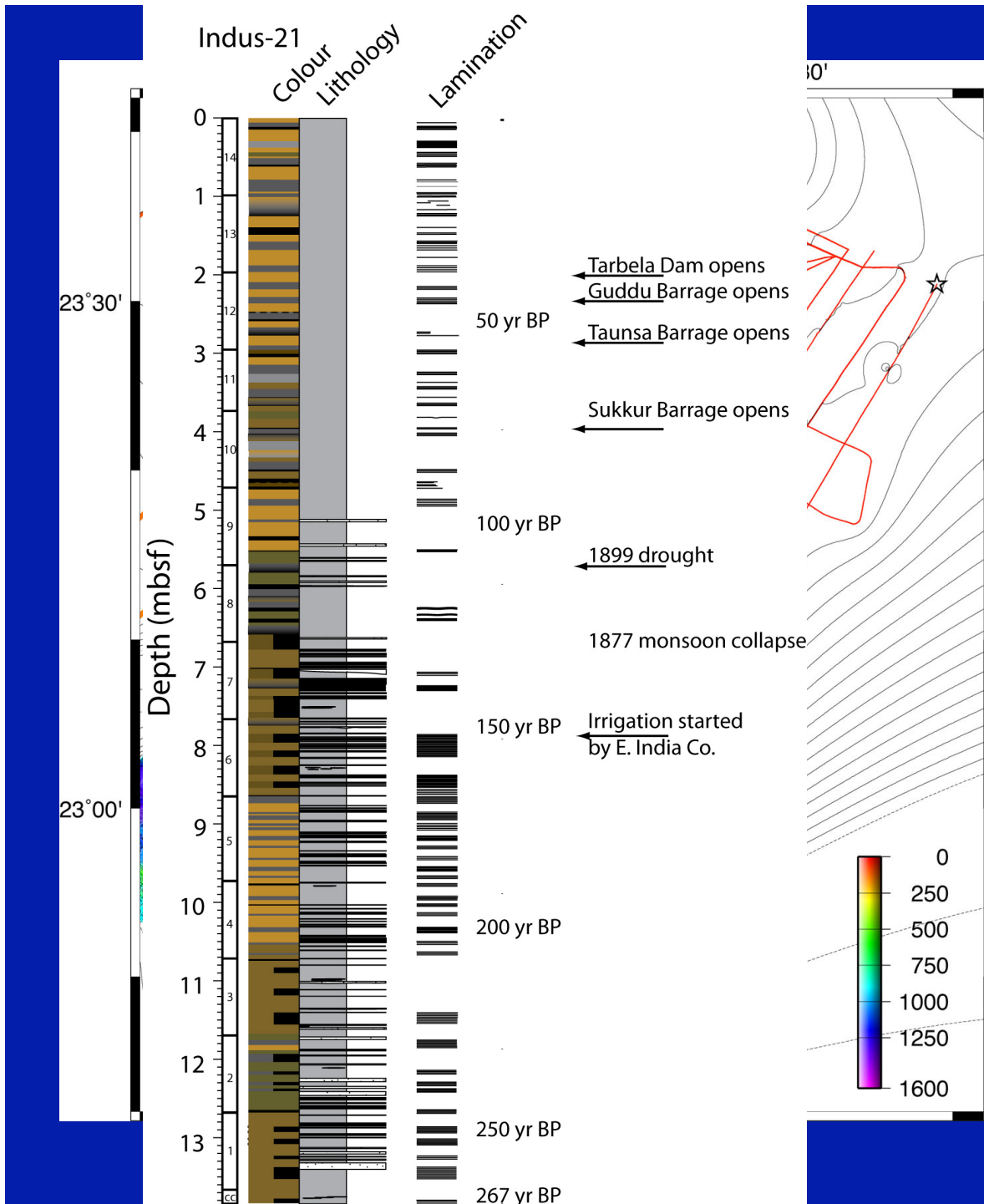
Mostly relict and eroded rather than active



Clinoform on west side of the Indus Canyon

Newly building and active, but modest volumes





New coring suggests that much of the Indus sediment load is reaching the upper canyon but not yet the abyssal plain



Conclusions

- Erosion in the Indus basin appears to react quickly to changes in climate.
- Strong monsoon causes faster erosion of Lesser Himalaya - Not glacial sediment
- Nd isotopes, dominated by clays, show rapid response. Zircons lag by 5-10 ka.
- Reworking of flood plains since Mid Holocene can account for ~80% of the recent sediment flux.
- Modest storage on the shelf in clinoforms but recent rapid sedimentation in canyon.
- Lag between erosion in Himalaya and sedimentation in the Indus submarine fan ~10 ka.

Read more about this and related science in the new Geological Society Special Publication

Monsoon Evolution and Tectonic–Climate Linkage in Asia

Edited by
P. D. Clift, R. Tada and H. Zheng



Geological Society
Special Publication 342

