Controls on Sediment Flux through the Indus Submarine Canyon during the Last Glacial Cycle

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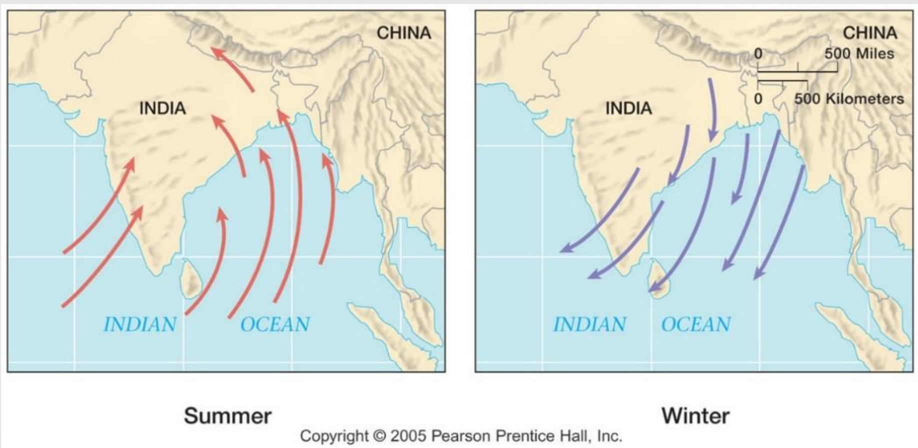
How does sediment transit through the Indus Submarine Canyon to the deep water basin?

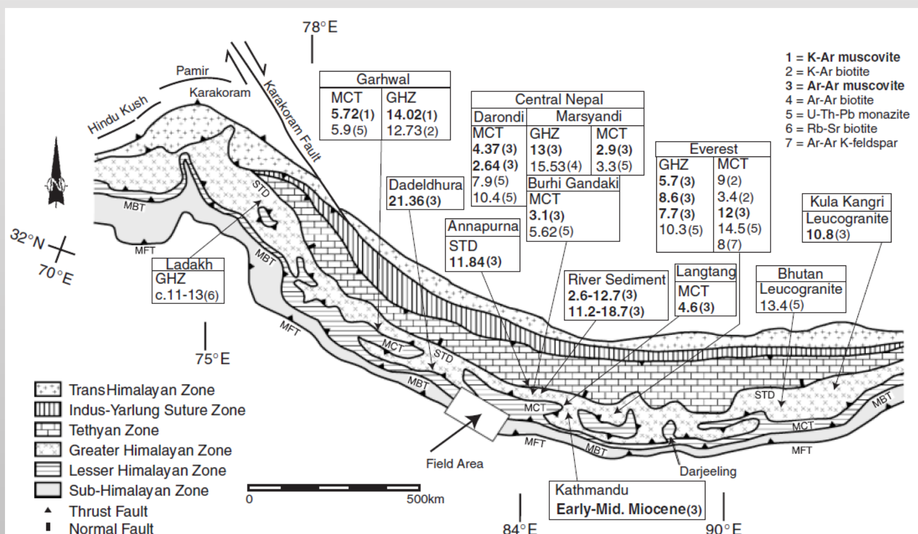
- Does sea level or climatically modulated sediment delivery dominate in controlling flux to the ocean?
- How can we use the deep-sea sediment archive to understand continental erosion and environmental evolution?

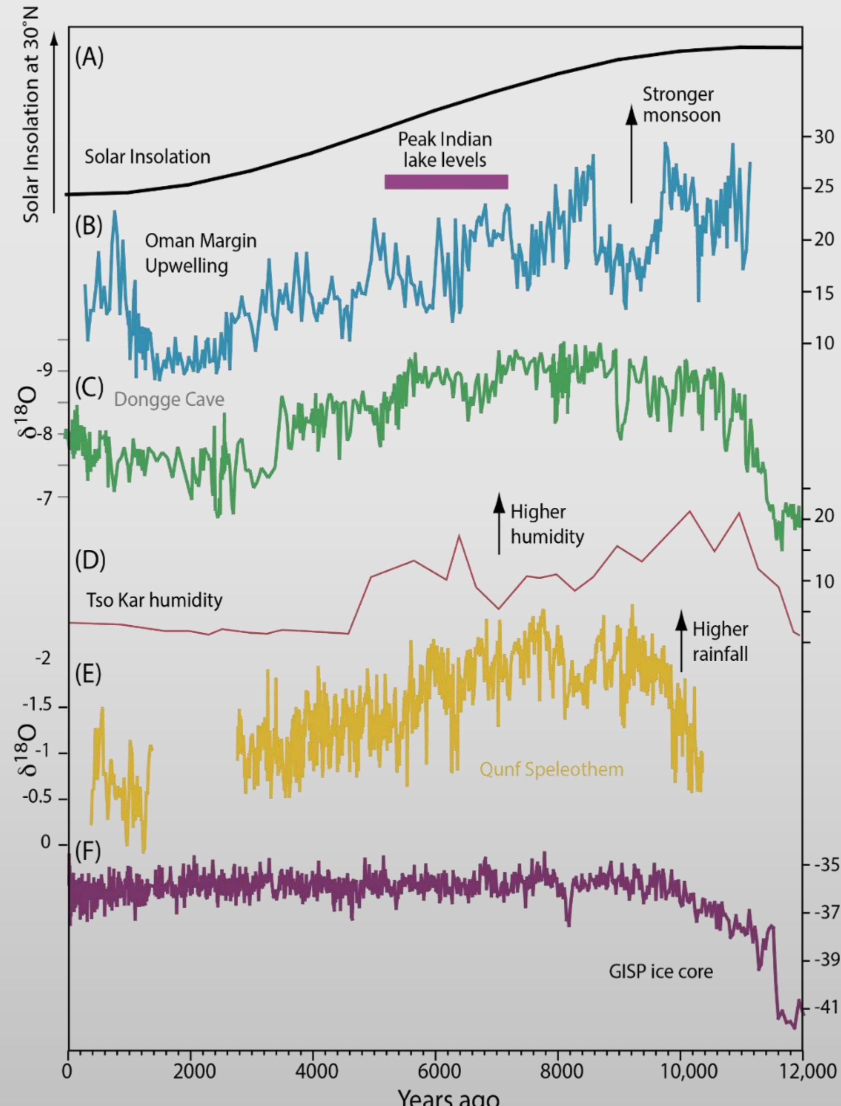
Specific Research Questions

- Is sediment delivered directly from river mouth to the canyon?
- Is reworking across shelf significant?
- Does slumping from canyon walls have a large effect?
- Does this change through time?

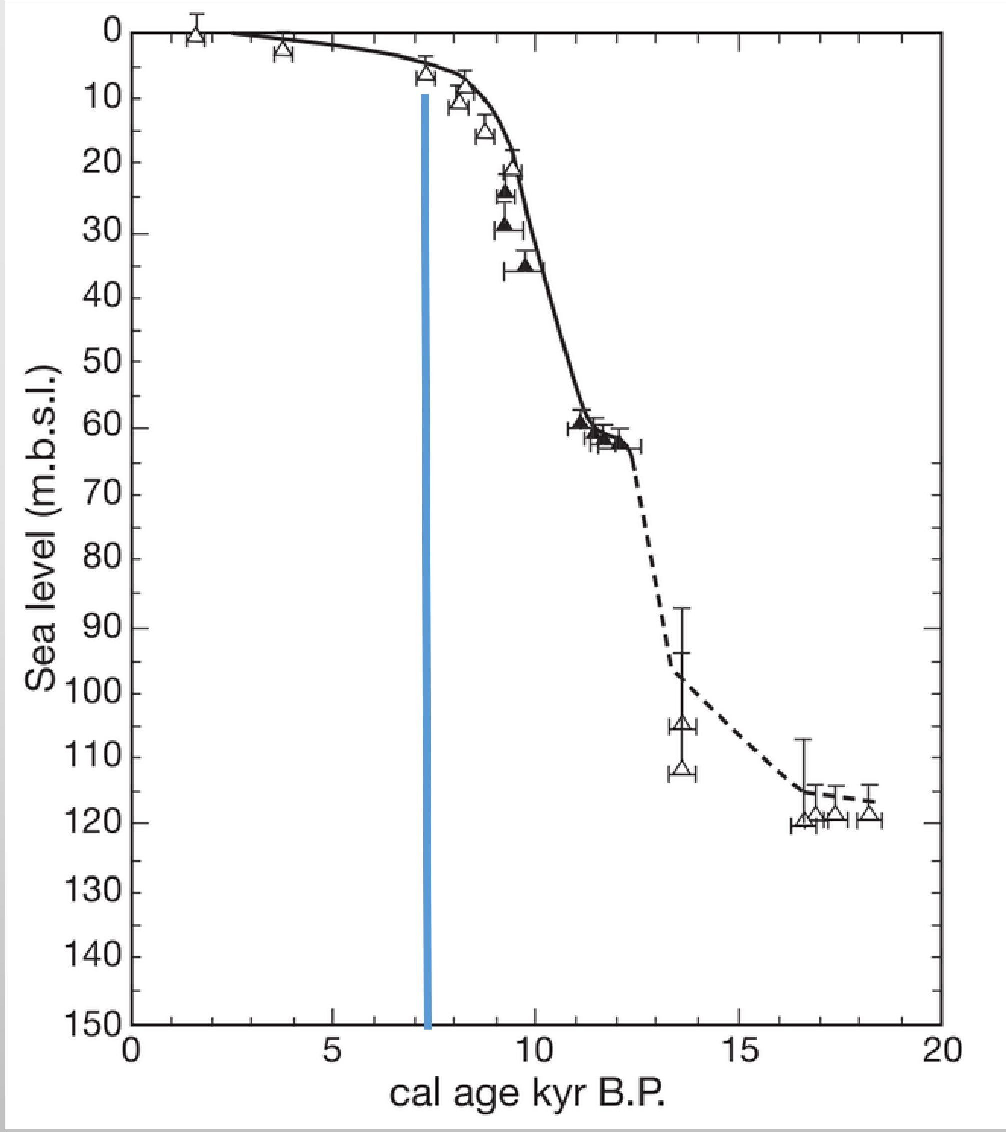
In the Quaternary, well-defined climate histories allow this relationship to be investigated







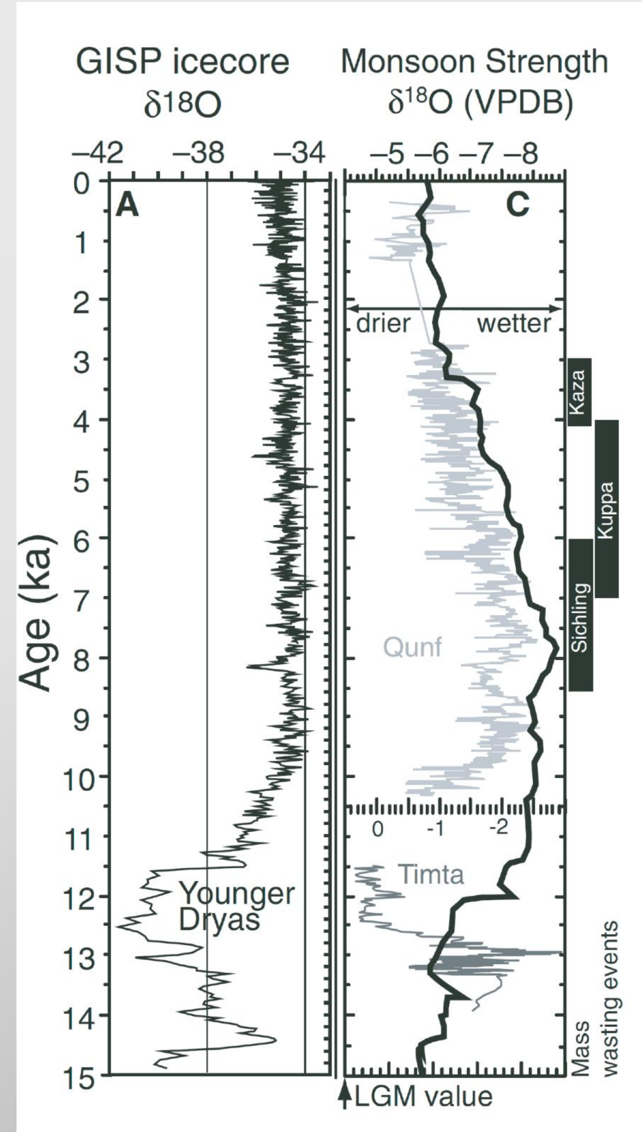
The sea level is also well known since the Last Glacial Maximum



Composite sea level curve for the last 18 ka in the Western Indian Ocean (G.F. Camoin et al., 2001)

- Stronger summer monsoon
    - Warmer temperatures
    - Enhanced moisture ➔ more precipitation ➔ more erosion and sediment discharge

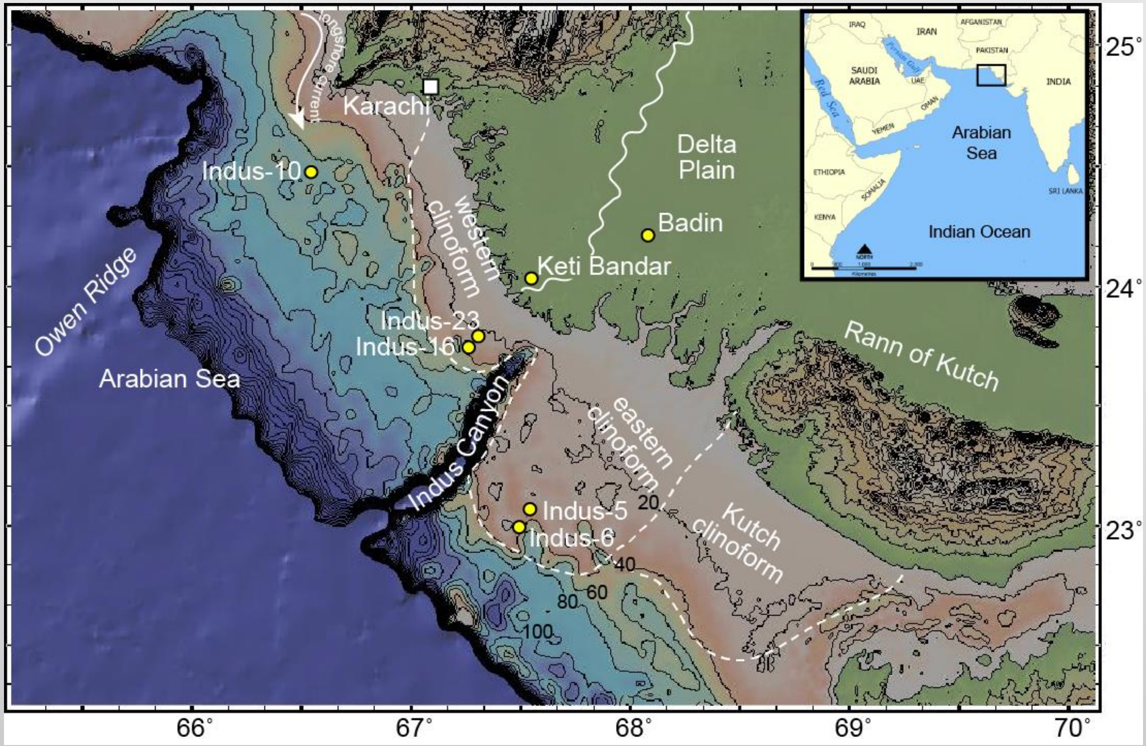
- Weaker summer monsoon
    - Colder temperatures
    - Colder, drier air ➔ less precipitation ➔ less erosion and discharge from Himalaya



Clift and Plumb (2008)

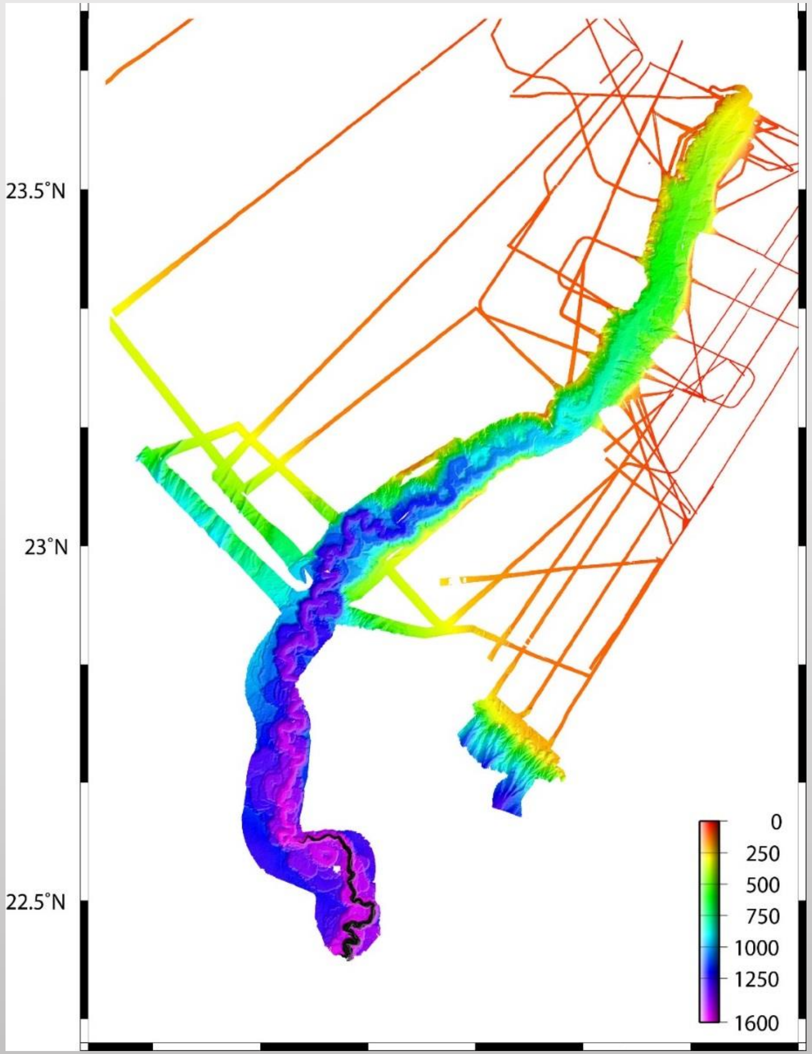
Indus Submarine Canyon

We aim to constrain the roles played by sea level variations, sediment supply, and cyclones in supplying the canyon and assess the continuity of the sandy channel fills.

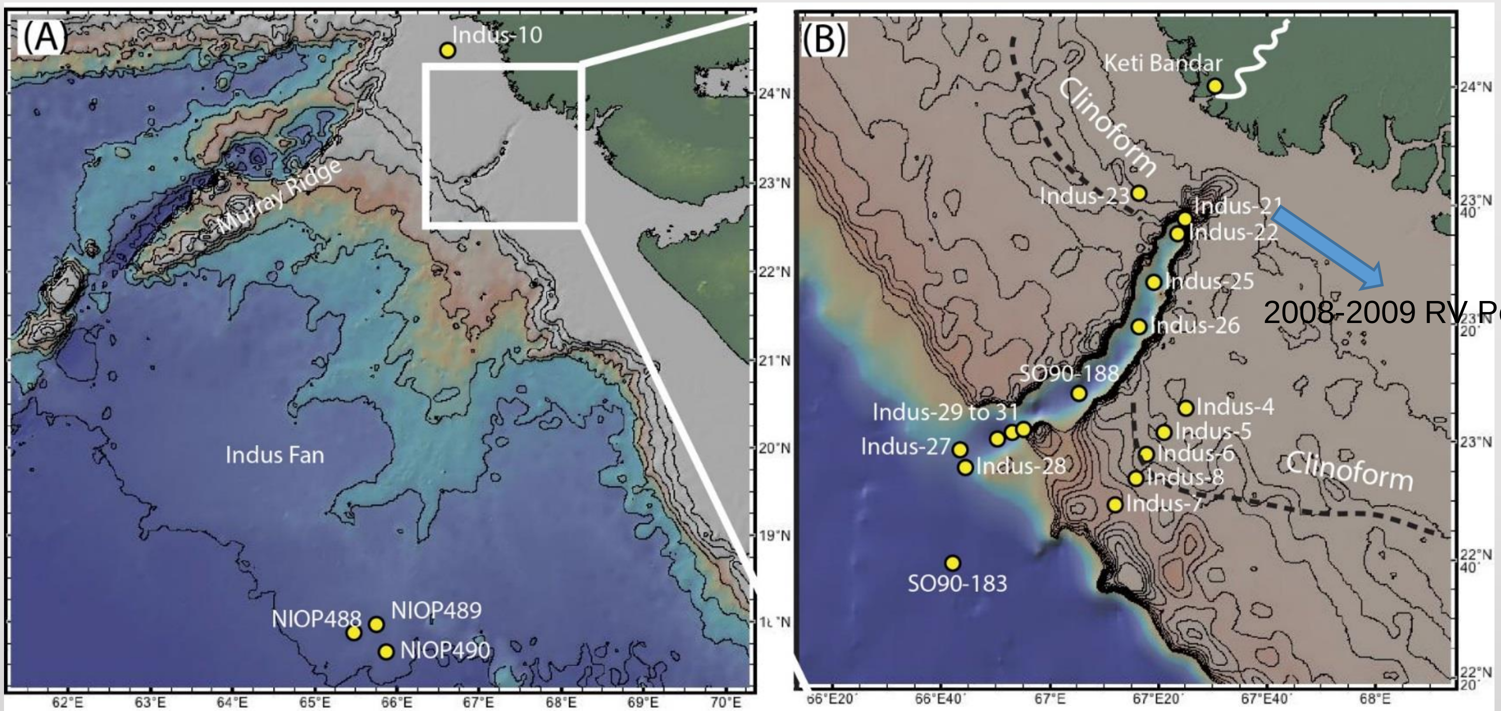


Indus Submarine Canyon

- 6.5 km away from shoreline
- 170 km long, average 8 km wide, foot 20 km wide
- Water depth: 35 m-1400 m, average 800 m
- Gradient: 1/100 to 1/50~1/200



Methods

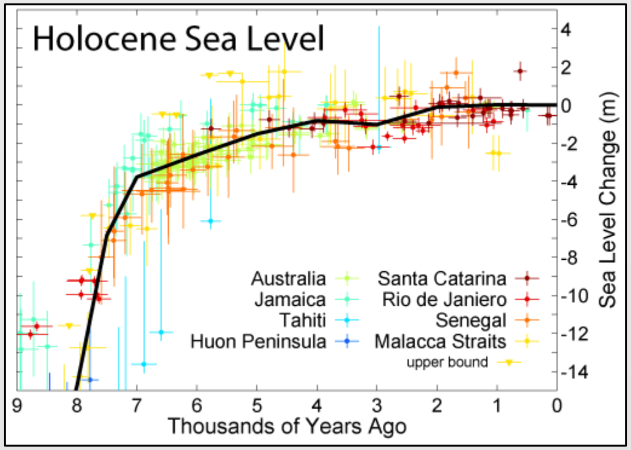


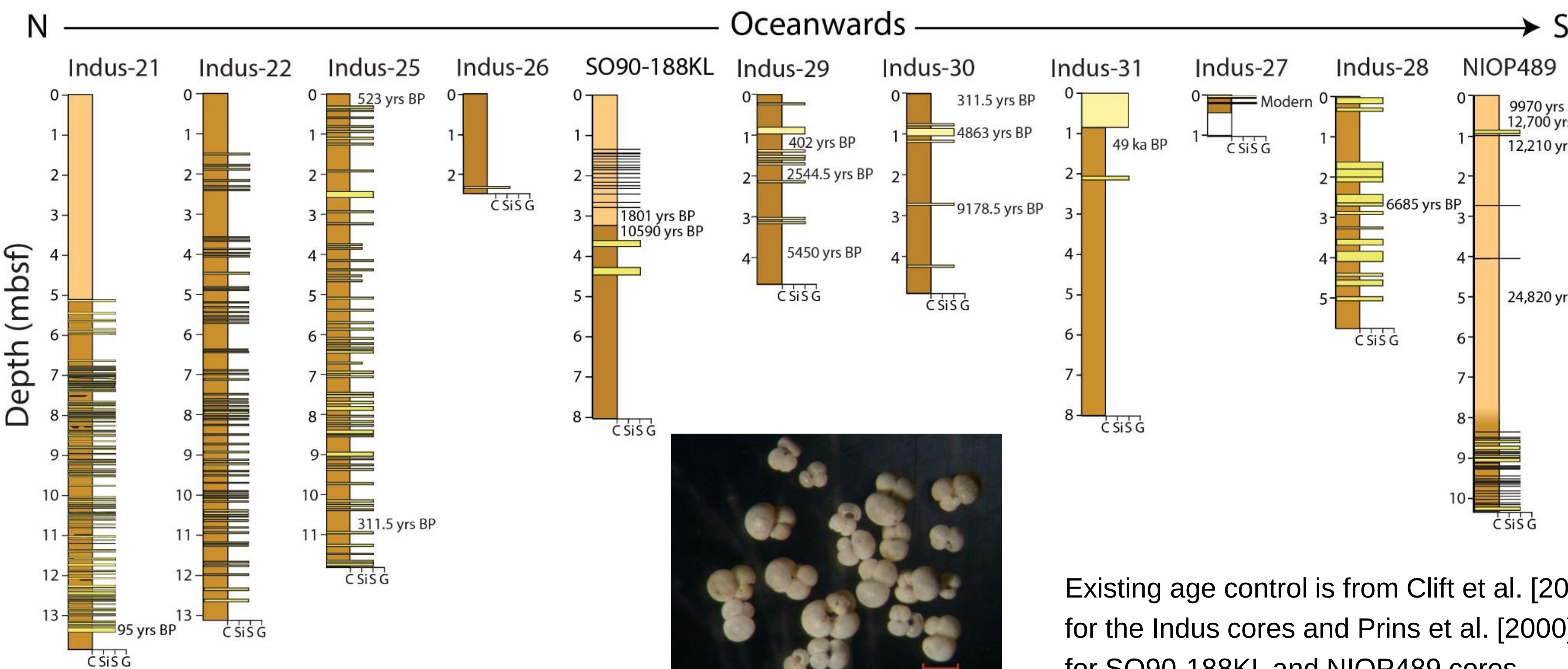
2008-2009 RV Pelagia cruise

- Age control (^{14}C dating and ^{210}Pb): the time of sediment transport and deposition
- Bulk sediment major and trace element geochemical analysis, high resolution XRF scanning: sources, continuity
- Grain size analysis, seismic data: depositional mechanisms

Transect of cores allows sediment transport to be tracked through the canyon

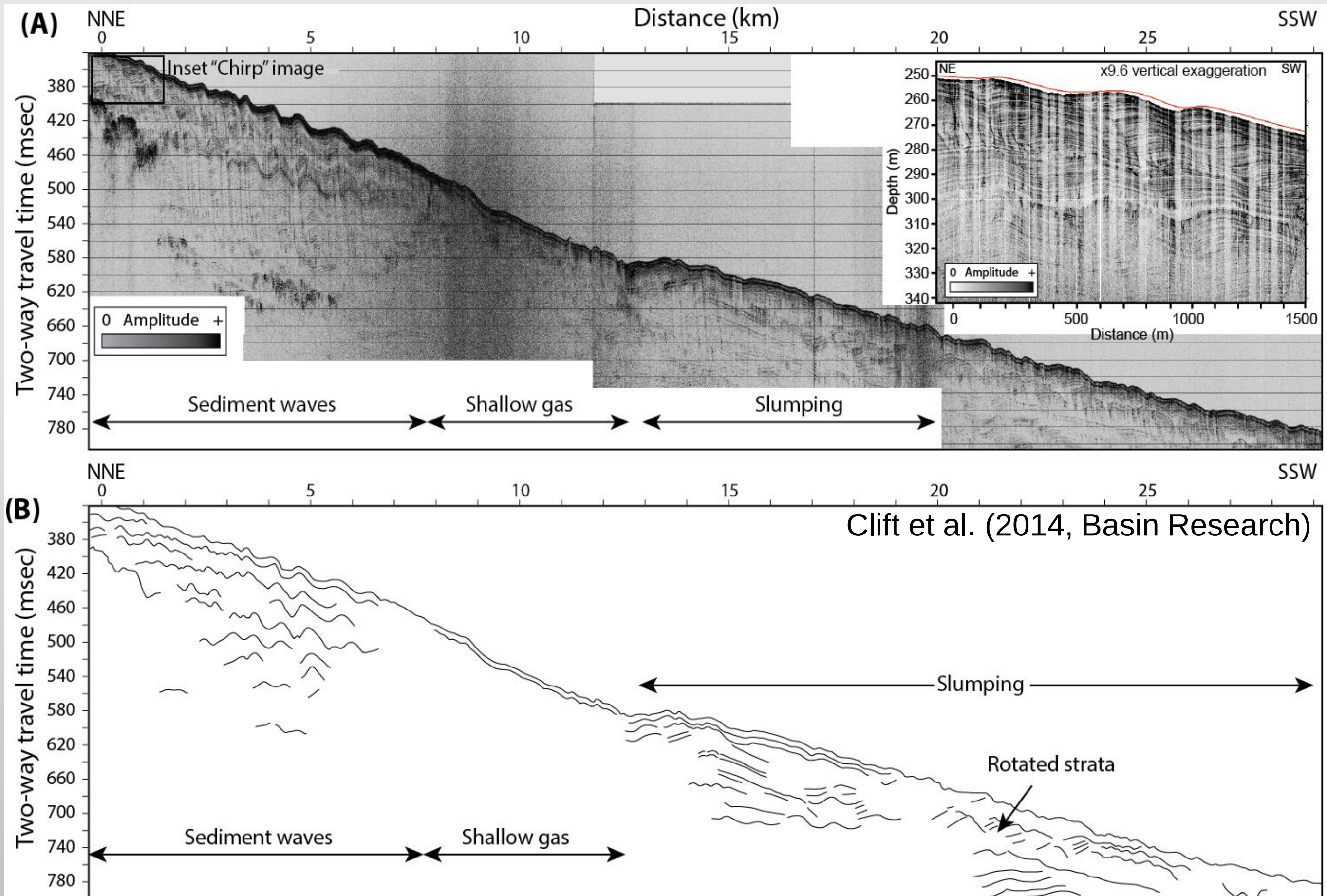
Sedimentation continues in canyon through the post-glacial sealevel rise

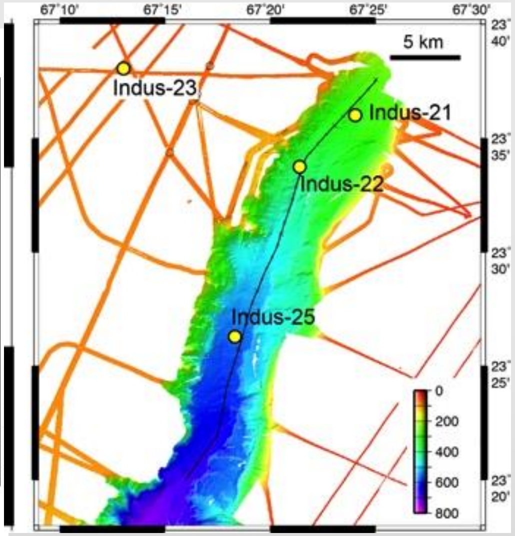




Existing age control is from Clift et al. [2014] for the Indus cores and Prins et al. [2000] for SO90-188KL and NIOP489 cores.

Seismic Data - Evidence for Slumping and Reworking



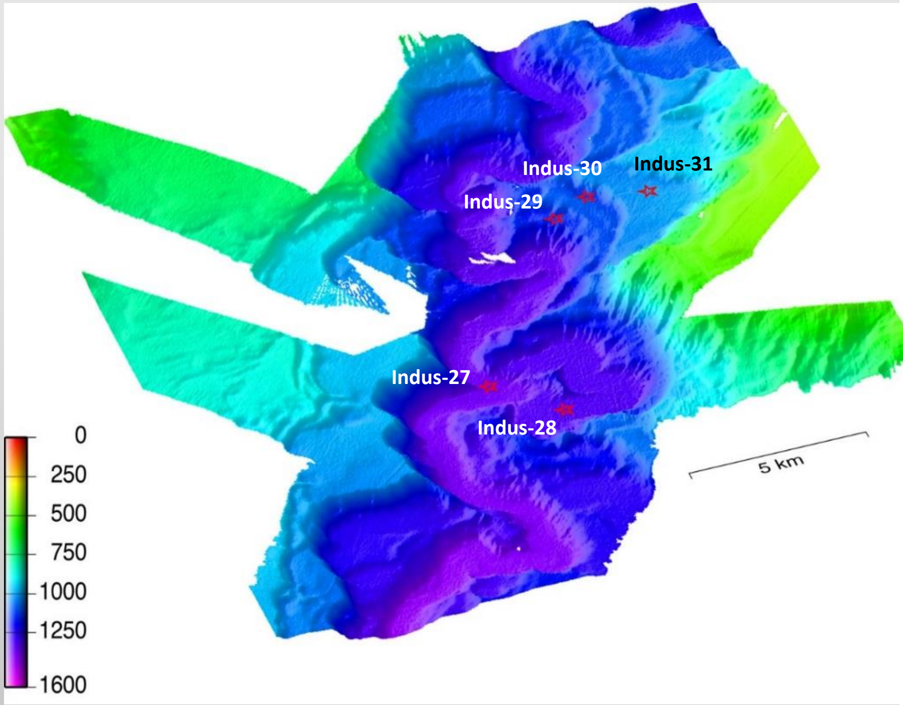


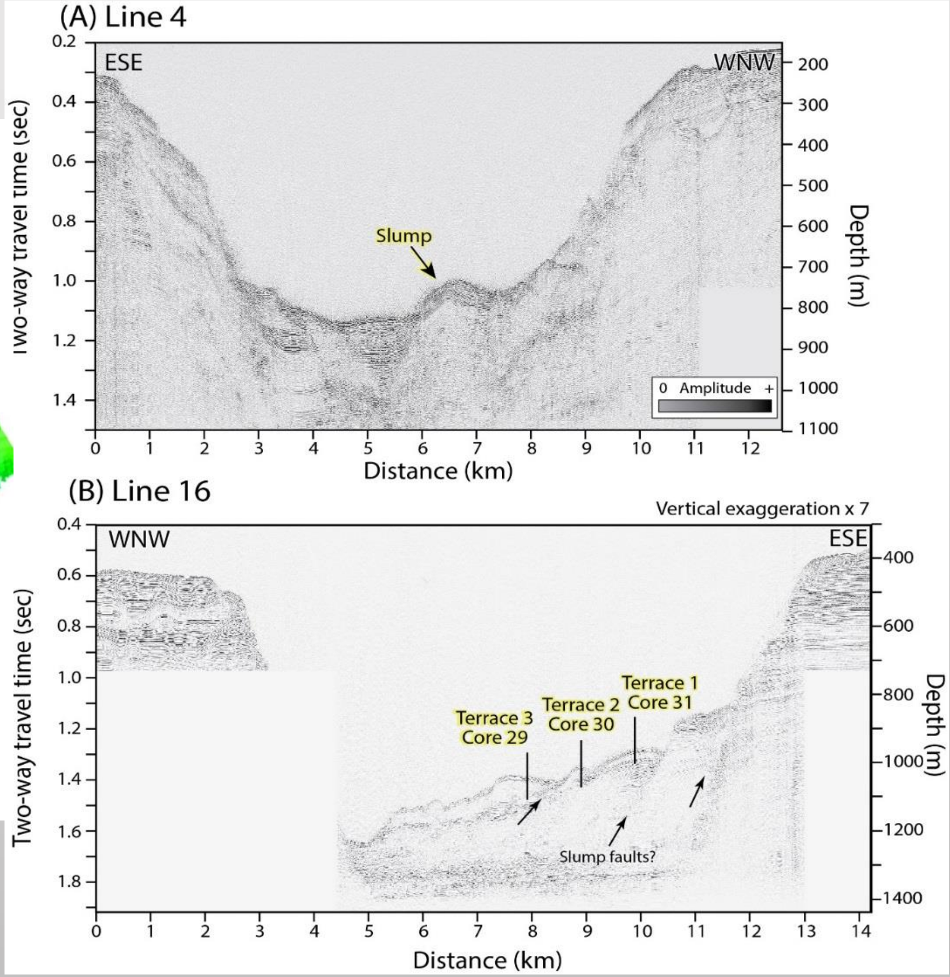
- Mud waves at canyon head: rapid sedimentation, reworking by currents;
- Rotated Strata: slumping.

Seismic Data - Evidence for Terracing

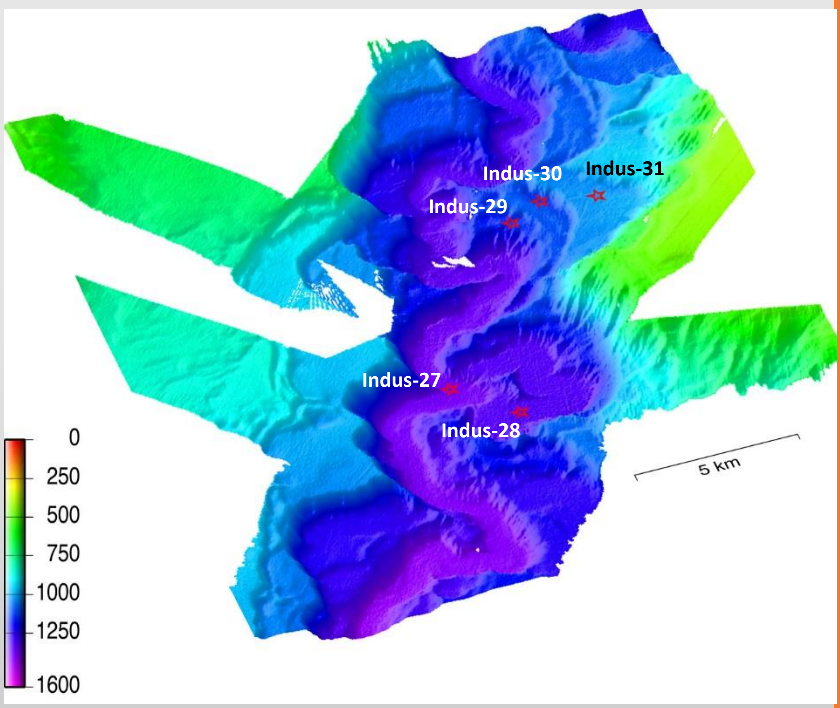
- Slumping dominates high in the canyon but terracing is more common in the mid canyon

Clift et al. (2014, Basin Research)

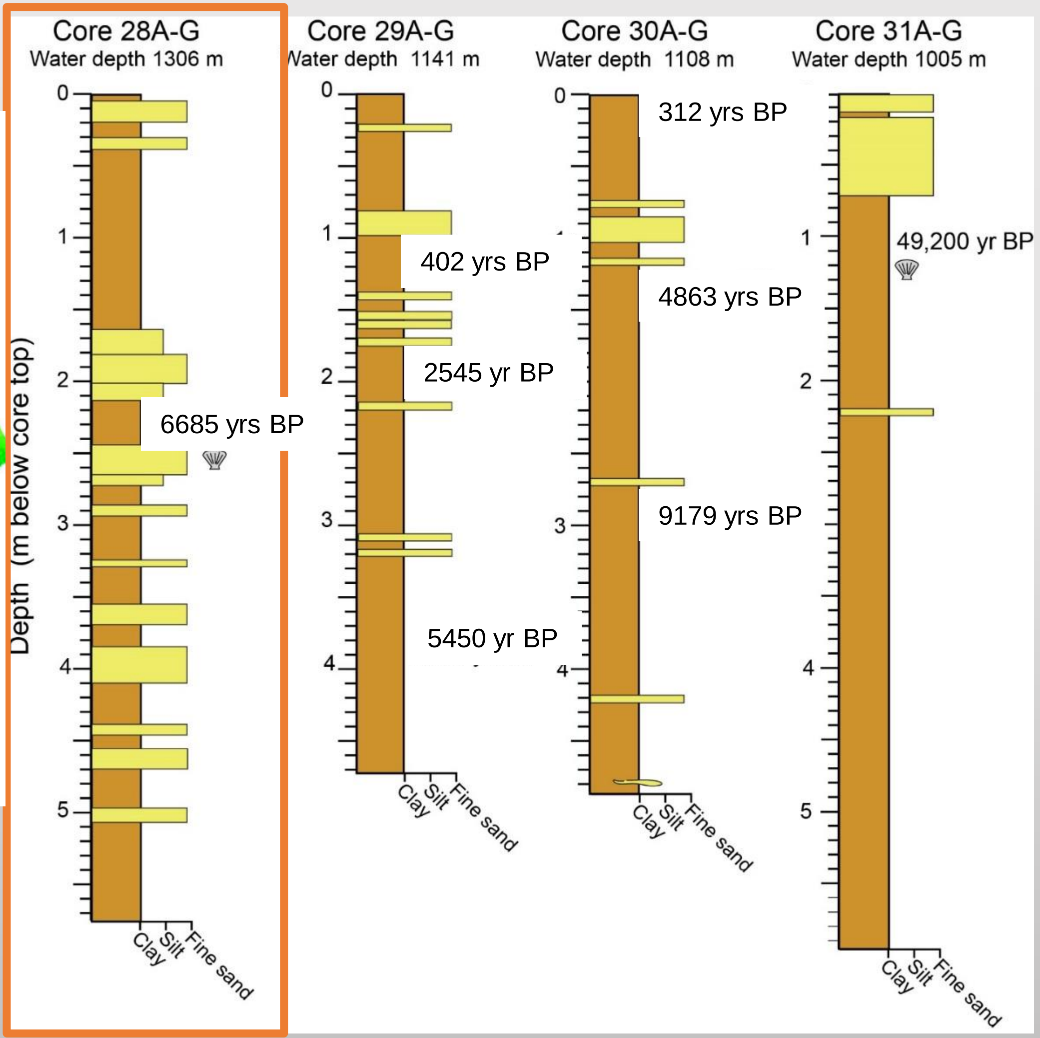




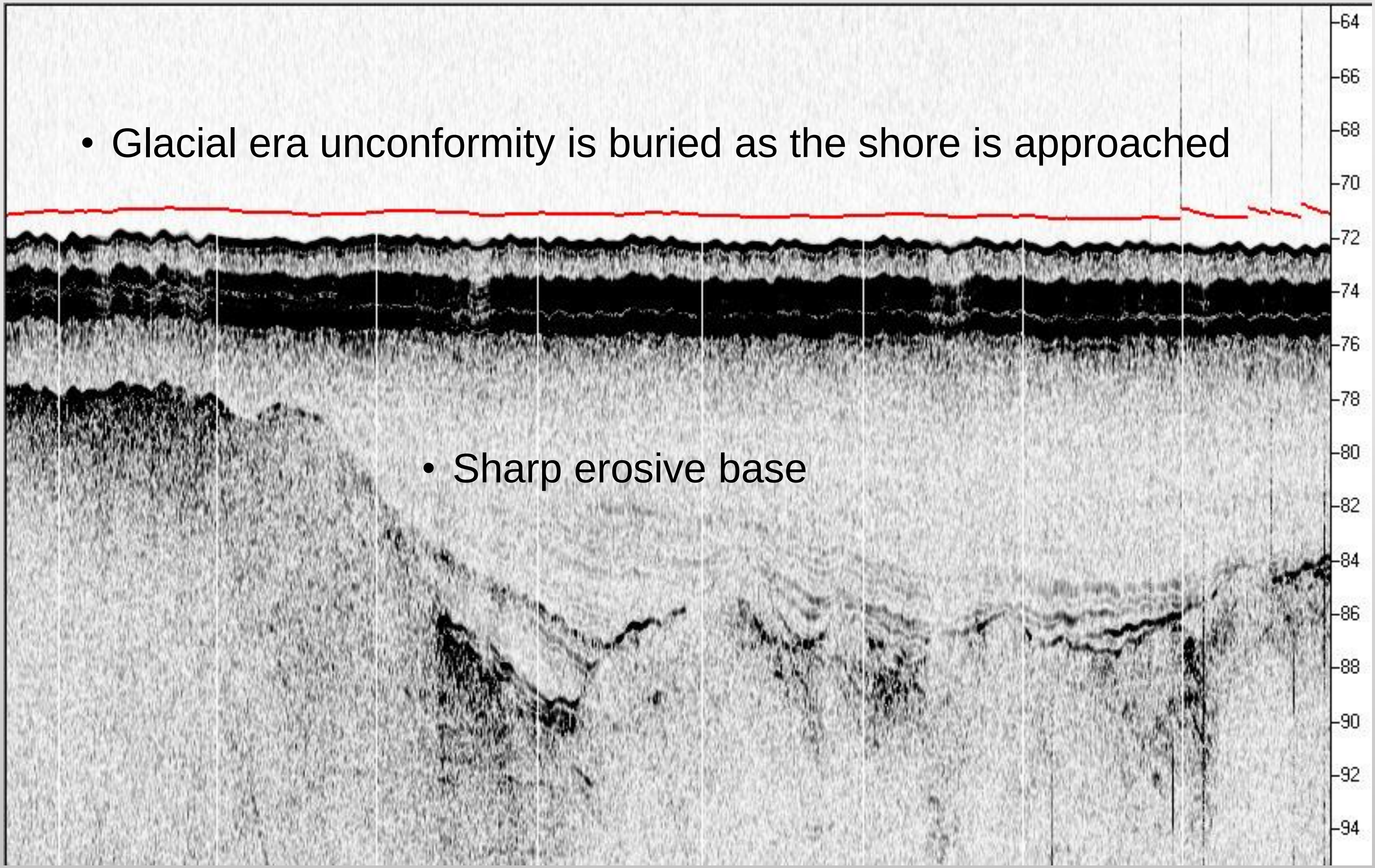
Sedimentation on two of the terraces has been ongoing through the Holocene



Sedimentation in the Ox-bow finished after ~6.5 ka but not too recently



Seismic Data – Glacial era unconformity

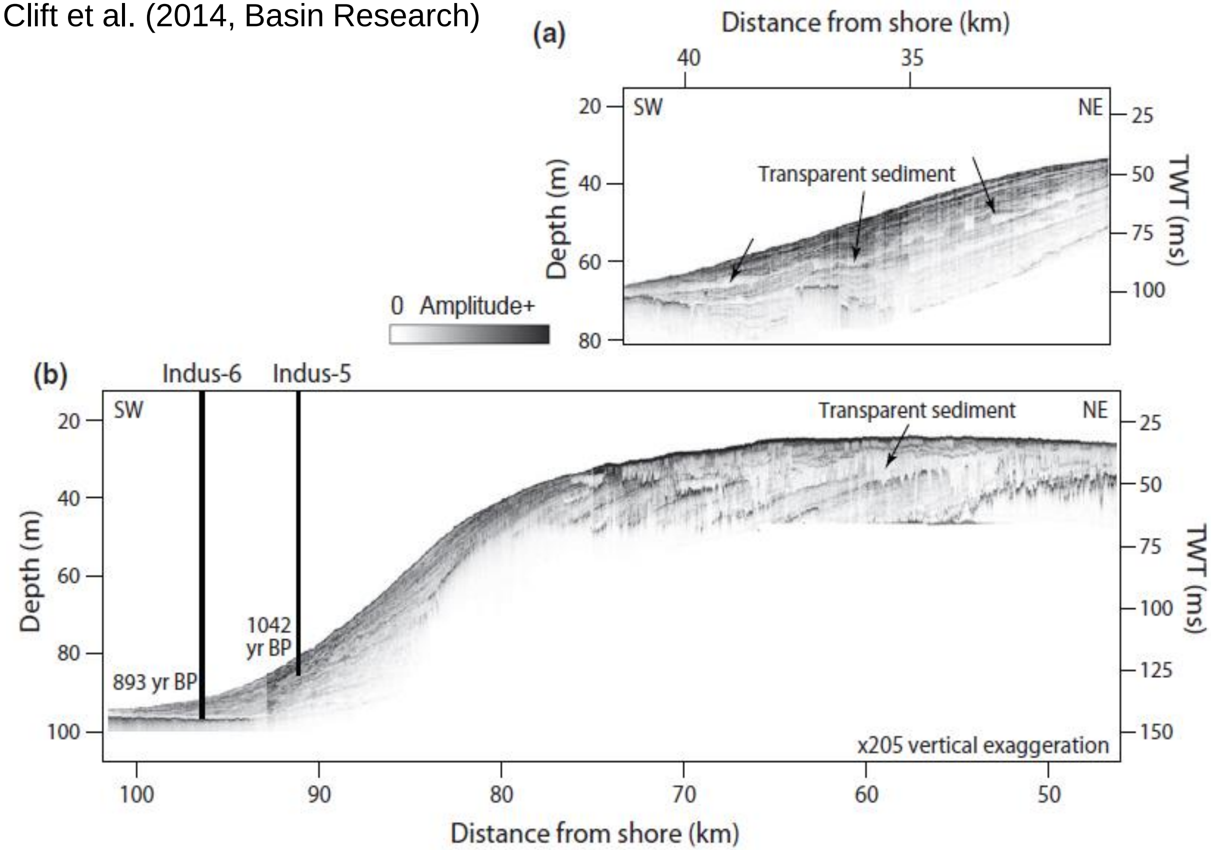


- Glacial era unconformity is buried as the shore is approached
- Sharp erosive base

Clift et al. (2014, Basin Research)

Seismic Data – Glacial era unconformity

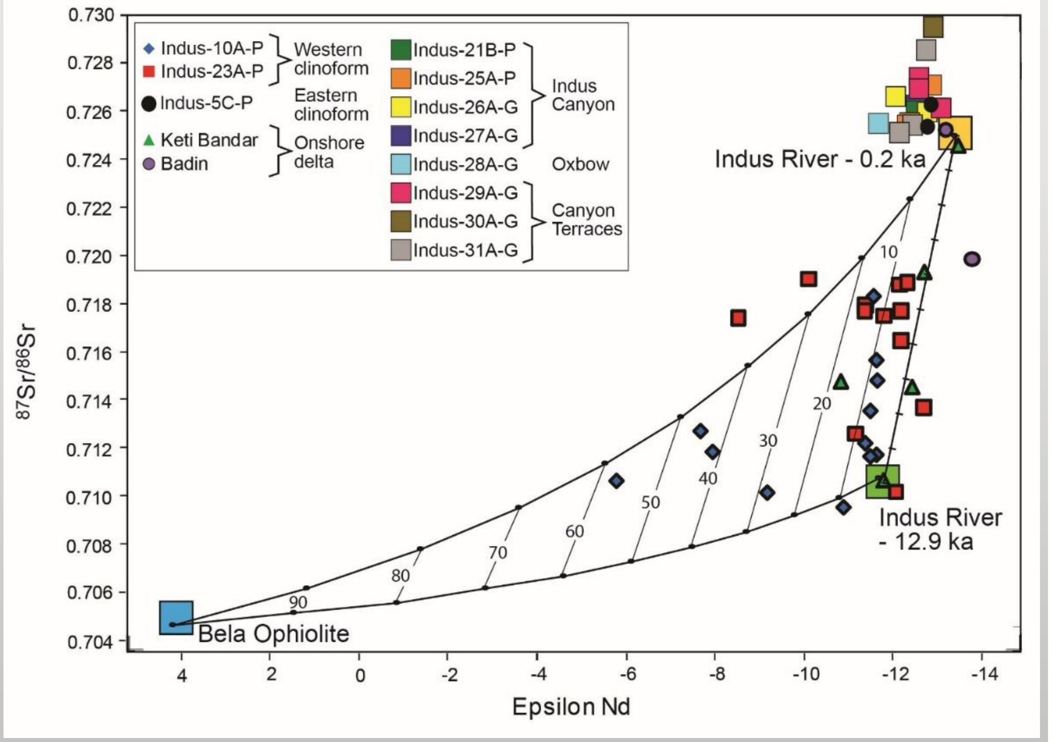
Clift et al. (2014, Basin Research)

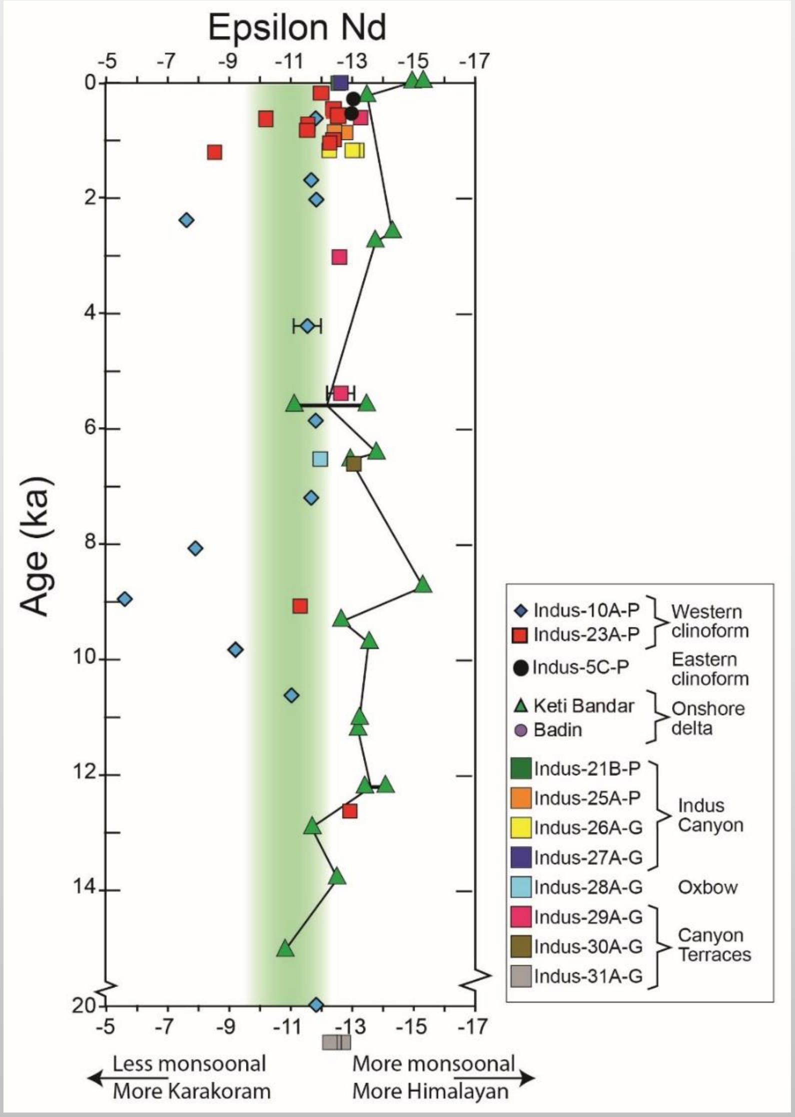


- Eastern clinoform represents a much larger sedimentary mass than the western clinoform, since the LGM.
- Seaward-dipping foresets, with higher dips in the larger, more mature eastern clinoform (3.7 m elevation/km compared to 0.8 m/km).
- Recently active.

Provenance by Sr and Nd isotopes

Indus is known to change composition with time.





Conclusions

- Recent sedimentation at the head of the canyon has been extremely rapid but lacks sand.
- Sedimentation is continued in submarine canyon including on lower terraces through the last glacial cycle.
- Slumping dominates high in the canyon whereas terracing is more common in the mid canyon.
- there is a close correspondence between periods of high clastic flux and the sediment being more weathered
- Sediment in the canyon and on the eastern clinoform are both derived from the modern Indus River whereas the sediment mixes on the western clinoform with long-shore material and reworked older deposits.
- Sediment supply driven by the strong monsoon appears to have overwhelmed the sea level effect in supplying sediment into the canyon.

Acknowledgements

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Guy Rothwell at BOSCORF at NOC Southampton (UK) for access to core material.

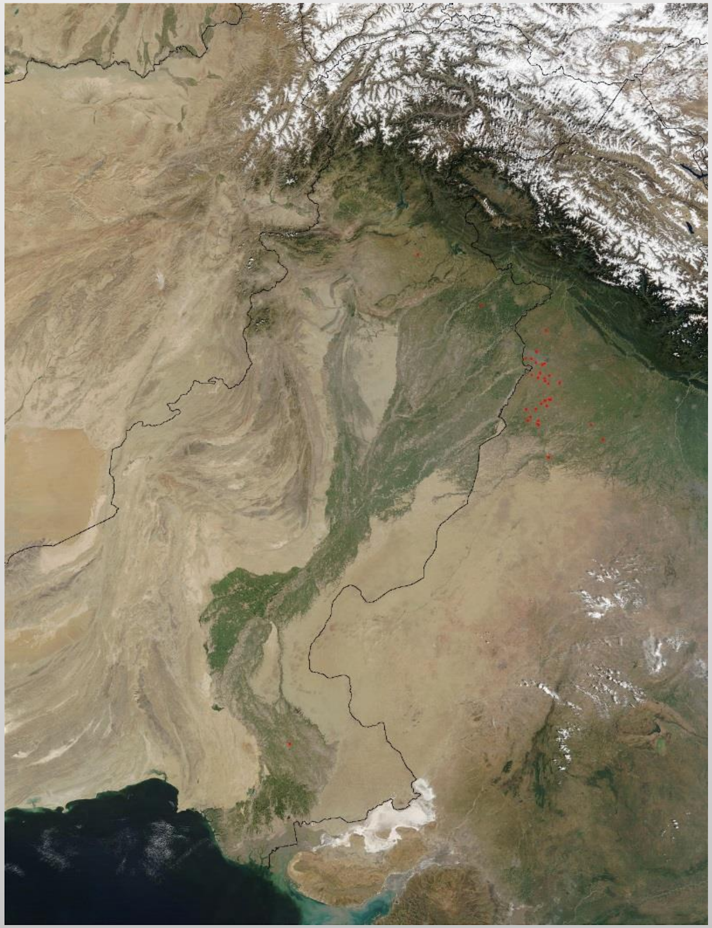
Thank you

Research Objectives

- Submarine fans (economic, sediment archives), largest sediment bodies on Earth
- Are canyon sand bodies continuous and large, or are they small and segmented? Possible petroleum reservoir analog for fan systems?
- What is the relationship between climate, tectonics, erosion, and weathering?
- Earlier models for sediment transport through such canyons indicated a dominant role for sea level in controlling this flux (Vail et al., 1977)

How does Sediment Transit through the Submarine Canyon to the deep-water basin?

Indus River: A Few Facts

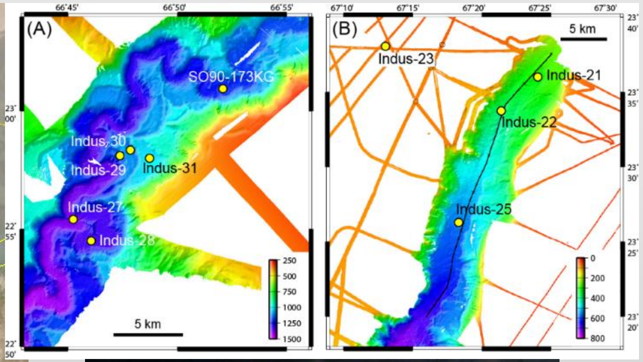


- Water discharge: 20th largest
- Sediment discharge: 5th largest (natural conditions)
- 5th largest delta
- 2nd largest fan
- Highest offshore wave energy

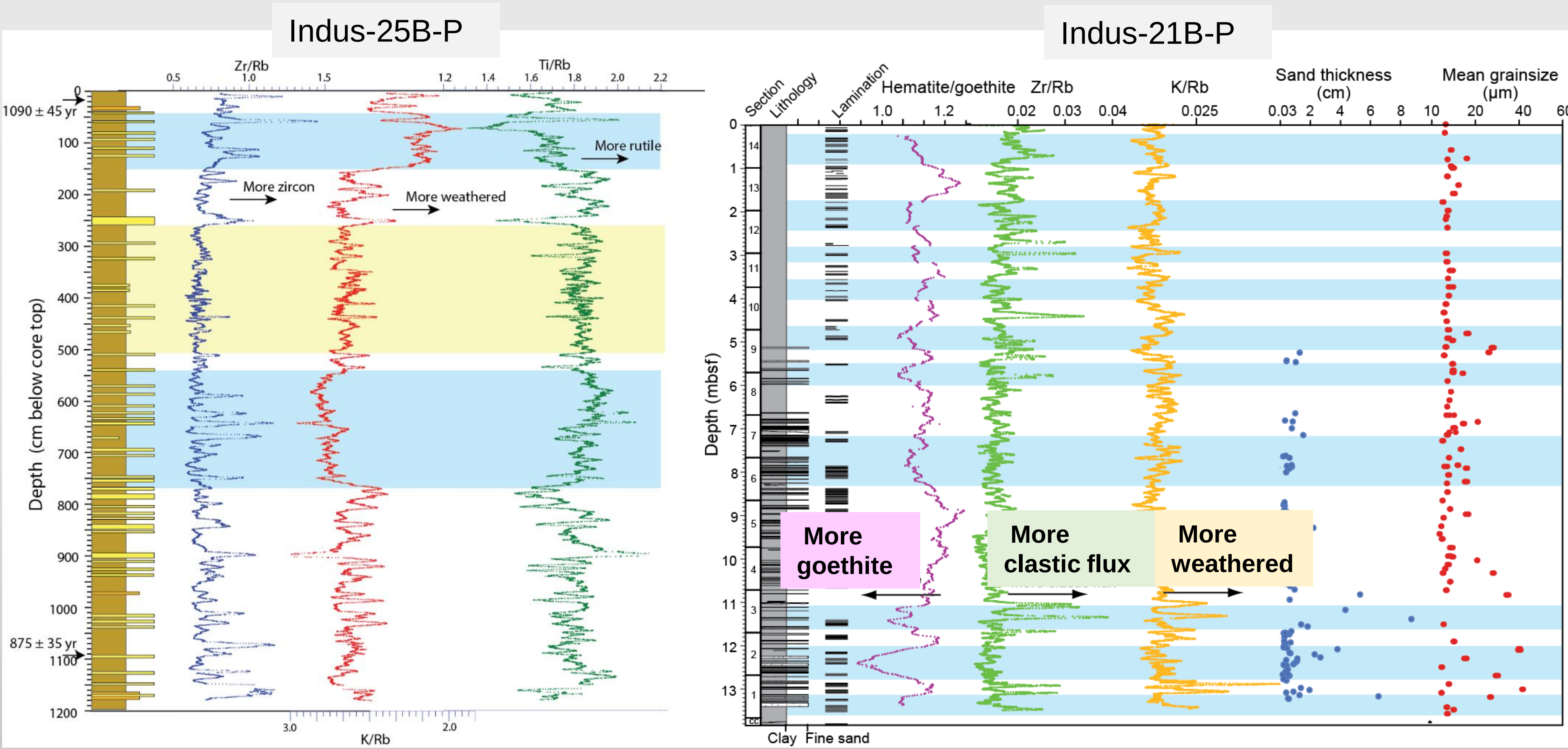
If we are to understand the deep-sea fan record, we must constrain what triggers sediment flux from the river mouth to the submarine canyon

Age Control

- ^{14}C dating: nine samples (Globigerinoides spp.) from four cores (Indus-25, 27, 29, 30)
- ^{210}Pb: twenty samples from two cores (Indus-22, 25)



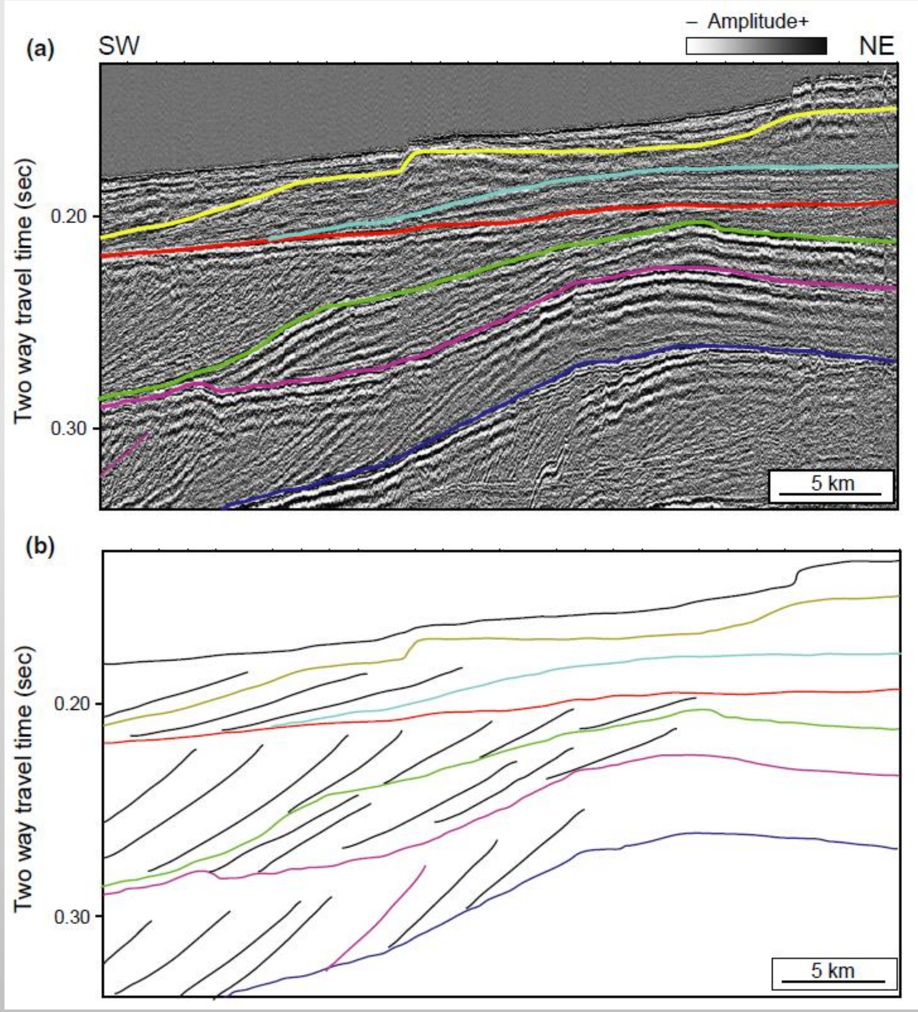
Geochemistry and Mineralogy at high resolution from scanning



Short timescale changes in alteration must reflect reworking not primary weathering

Seismic Data – Edge of Continental Shelf

The sequence is distinguished by a number of stacked shelf-edge deltas with clear seaward migrating clinoform foresets that we link to periods of forced regression.



Clift et al. (2014, Basin Research)