

Sedimentary Sequences and Lake-Level Change in a Rift Lake: Observations from High-Resolution Seismic Reflection Data and Sediment Cores from South Basin, Lake Turkana, Kenya*

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Abstract

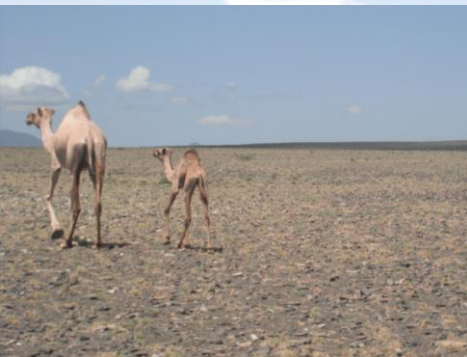
Lake Turkana is the largest lake in the world in a desert and is prone to frequent lake-level changes because of its extreme climate. A new stratigraphic framework of the Lake Turkana Rift spanning the last ~20 kyr was developed using 1300 km of high-resolution (CHIRP) and 1 in 3 airgun seismic reflection data and over 40 sediment cores collected in 2010 and 2011. Two high-amplitude reflections that extend throughout the entire basin correlate with marked decreases in total organic carbon and increases in calcium carbonate and are interpreted to have formed during major lake lowstands. These surfaces likely indicate near desiccation of this rift lake during the late Pleistocene, at ~15 and ~11 ka. In the overlying Holocene section, onlapping sequences and thick packages of flat-lying reflections indicate a major transgression during the early Holocene African humid period, when the lake level increased by ~175 m. During stillstands in the transgression, several progradational delta deposits accumulated along the eastern (flexural) margin of the South Basin at different subsurface depth and stratigraphic levels. Westward-progradational reflection packages are observed within these structures in east-west airgun profiles. Lake Turkana was hydrologically open during much of the early and mid-Holocene until ~4000 years ago, when lake level fell below the catchment spill point (~90 m above modern lake level). An unconformity ~45 m below the current lake surface in the late Holocene section suggests another drop in lake level at approximately 3 ka, after which lake level rose to its current stage. Water levels of Lake Turkana dropped approximately 15 m in the last 3 decades, indicating that dynamic hydrologic behavior has continued to the present day. Radiocarbon-dated sediment cores suggest that sedimentation rates were highest in the latter part of the African Humid period.

Reference

Owen, R.B., J.W. Barthelme, R.W. Renaut, and A. Vincens, 1982, Palaeolimnology and archeology of Holocene deposits north-east of Lake Turkana, Kenya: *Nature*, v. 298, p. 523-528.



Sedimentary sequences and lake level change in a rift lake: Observations from high-resolution seismic reflection data and sediment cores from South Basin, Lake Turkana, Kenya



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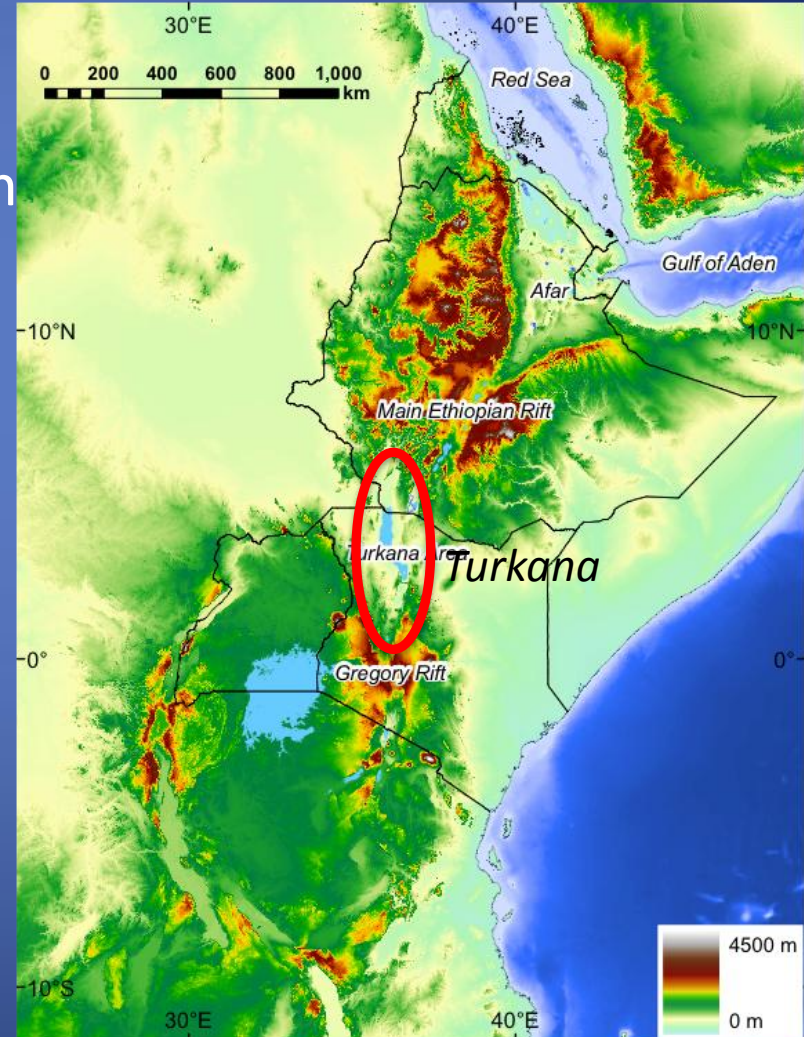
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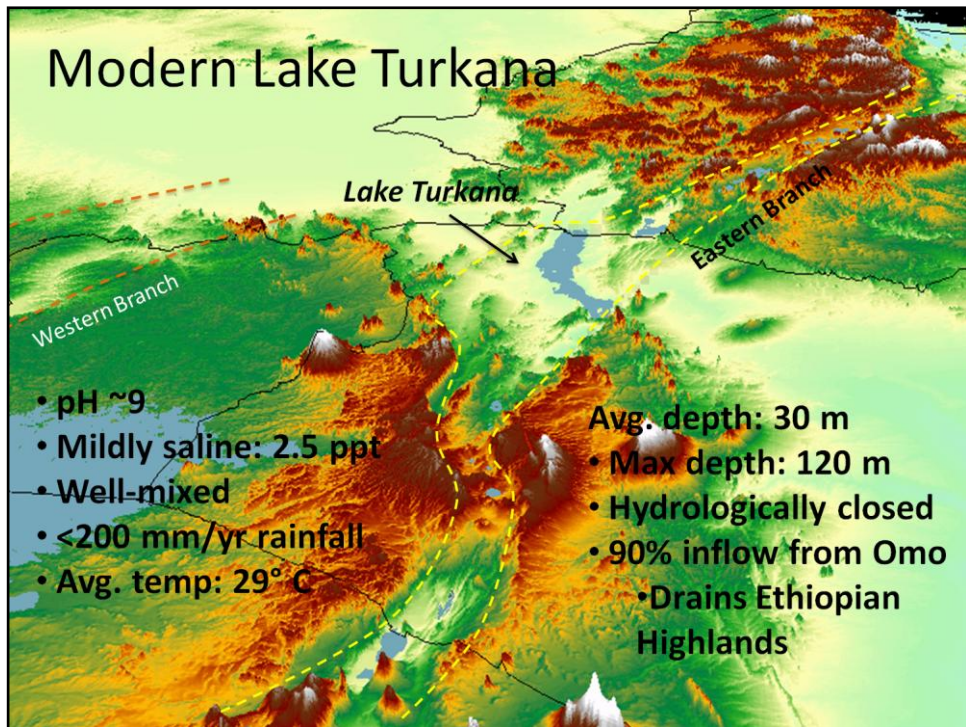
Outline

Project objective: Carbonate-clastic facies and climate variability of Lake Turkana in the Late Quaternary

- Context of Lake Turkana/Project
- Data and observations
 - High-resolution seismic reflection profiles
 - Sediment core analyses
 - Lithofacies
 - Whole core density, Magnetic susceptibility
 - Quantify organic and inorganic carbon
- Lake level history
 - Late Pleistocene – Mid Holocene
- Implications and ongoing work



Modern Lake Turkana



Presenter's notes: Largest lake in a desert, largest lake in the eastern branch of the EAR.

- Turkana region:
broad zone of
extension

- Lake Turkana:
Narrow Late
Cenozoic Rift

- Recent discovery
west of lake in
Lokichar Basin

Turkana
Basin

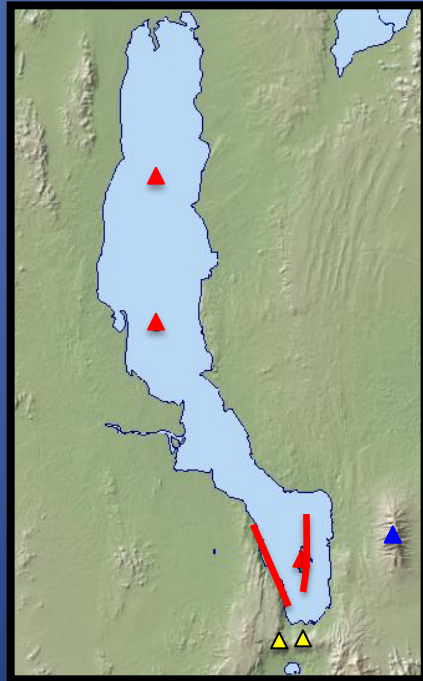
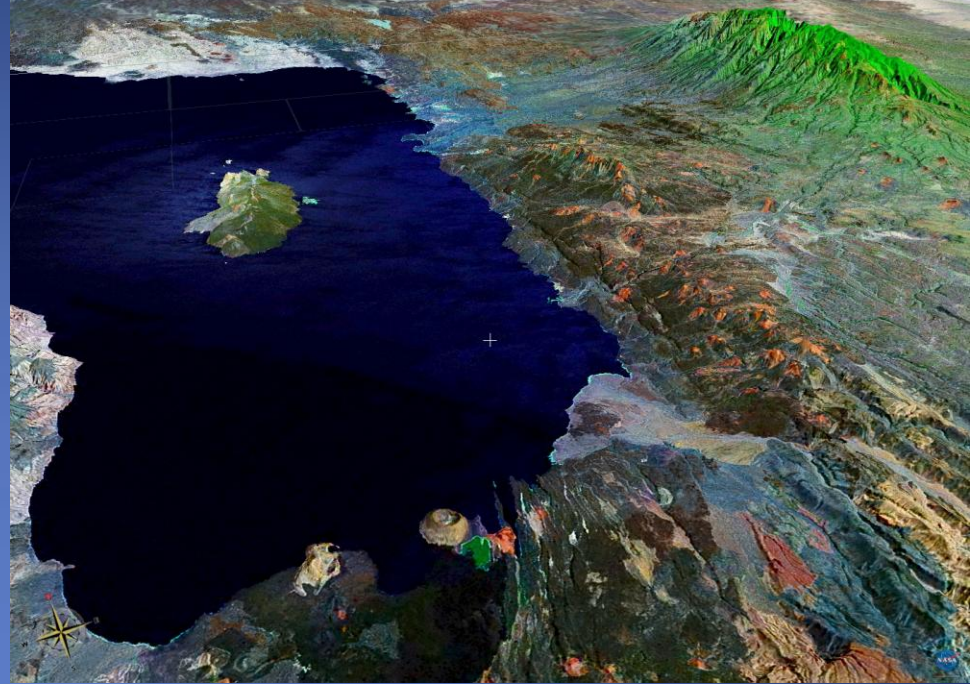
◆ Lokichar
Basin

Chalbi
Desert/
Anza Rift
Basin

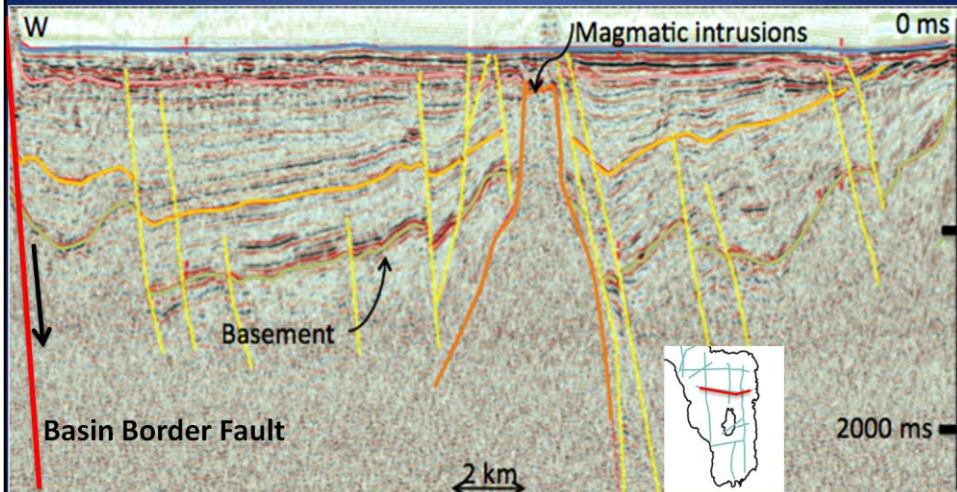


Basin Faults and Volcanic Centers

- Turkana's Axial Volcanics
 - 3 Volcanic Island
 - Southern Barrier – 1.3 – 0.1 Ma
- Pliocene Shield volcano



Basin-scale Observations

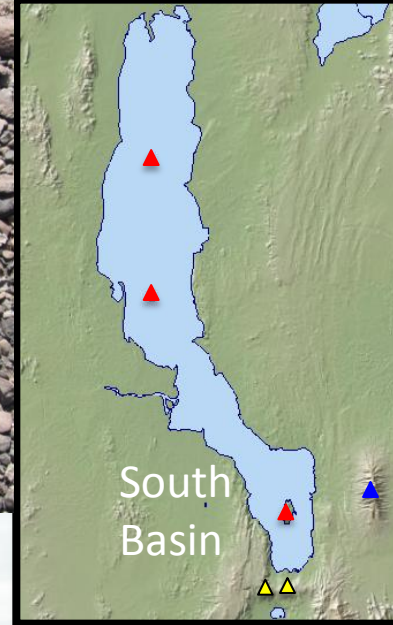


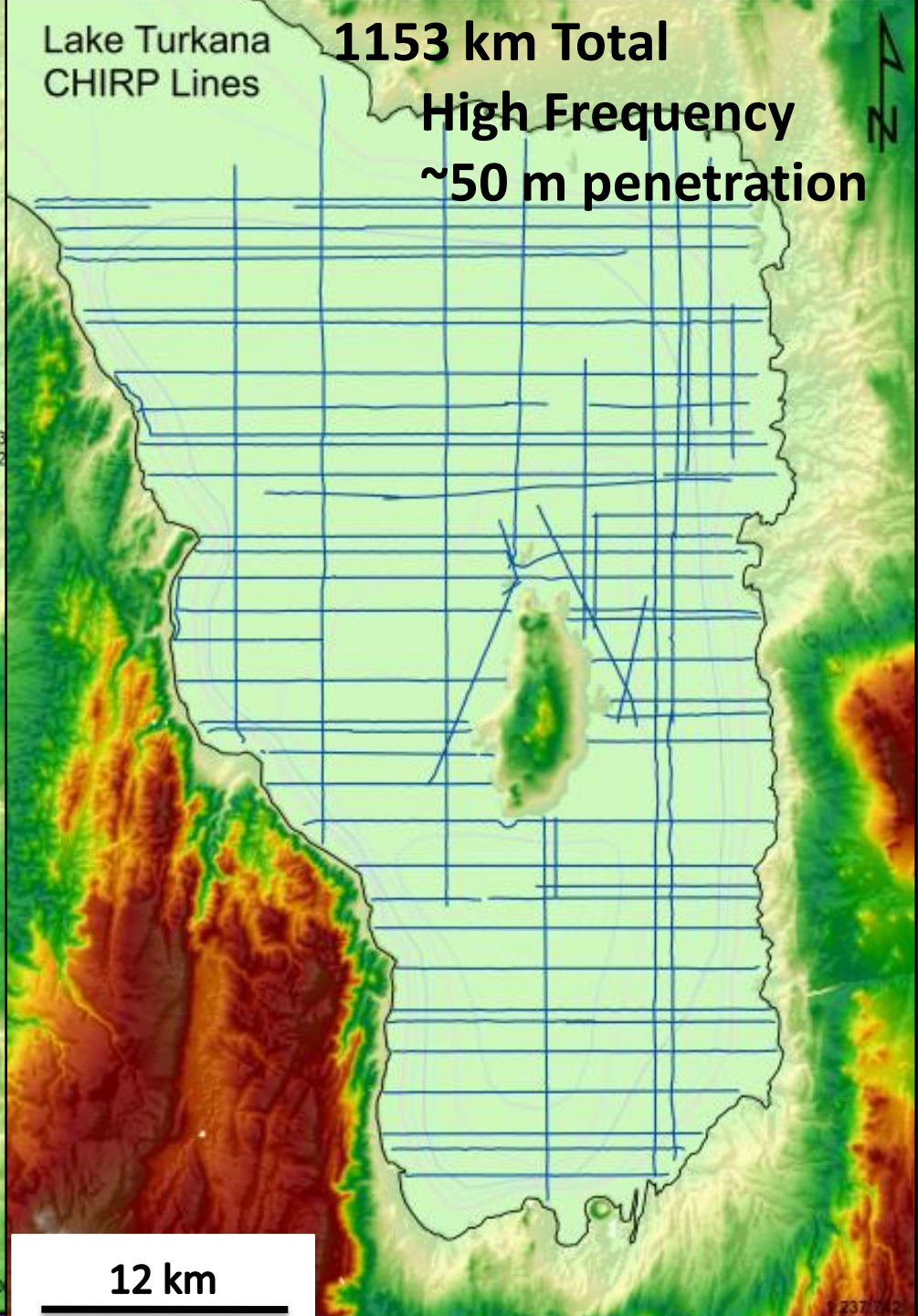
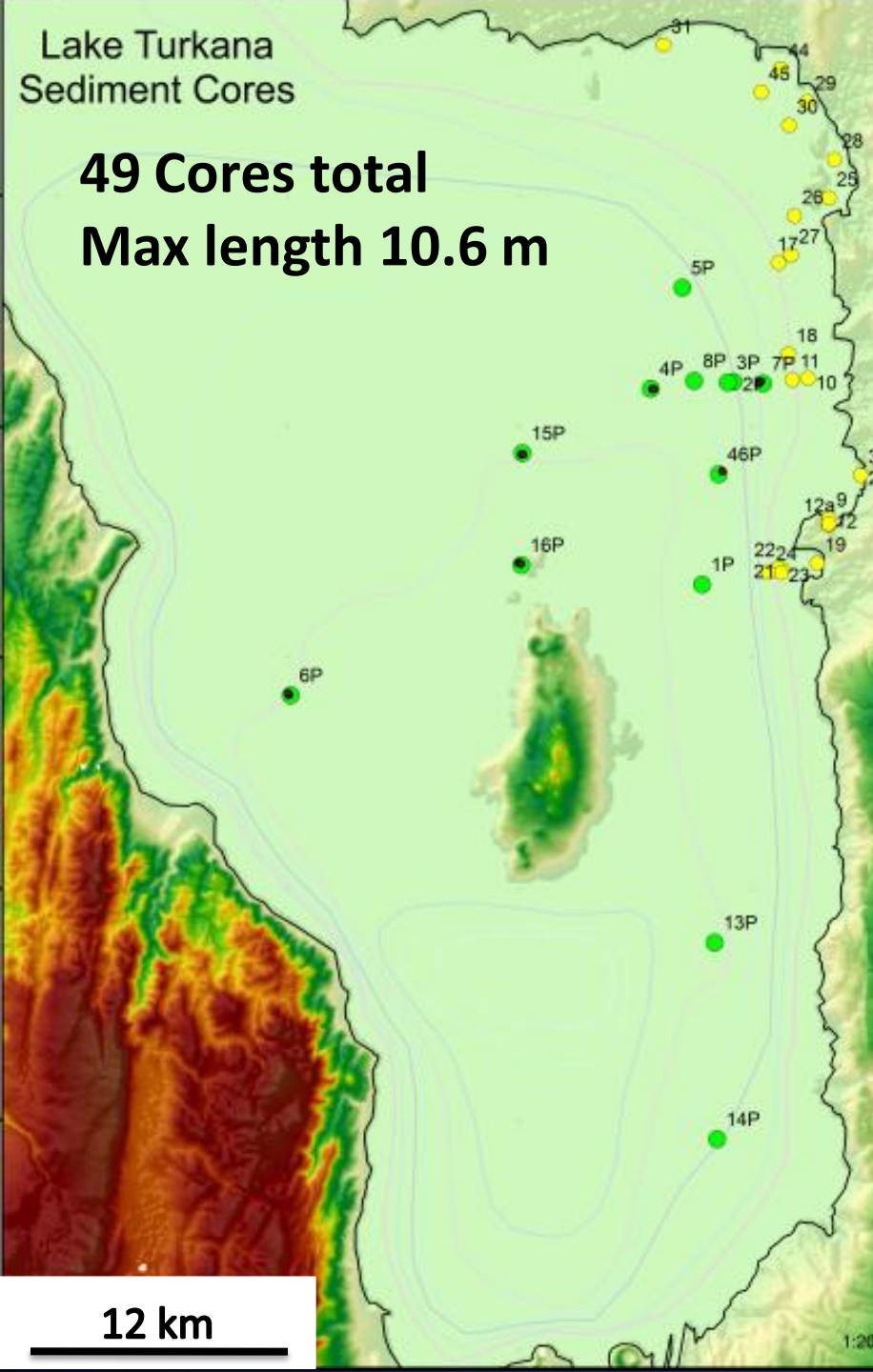
- 2 main zones of normal faulting create 2 sub-basins
- ~2km of sediment observed
- Magmatic body is extension South Island volcanic system

Presenter's notes: This is a multi-channel profile that runs across nearly the entire South Basin, just to the north of South Island. As in most rift lakes, Lake Turkana has an underlying half-graben fault system with a main border fault and a flexural margin. In the case of the South Basin of Lake Turkana, the border fault zone is on the western side of the sub-basin, while the flexural margin is to the east. The feature in the middle of this profile, where relatively flat-lying stratigraphy is truncated against a chaotic body, is interpreted to be the subsurface expression of South Island. The volcano that makes-up South Island dips into the subsurface, giving way to intrusive magmatism beneath the lake floor. This magmatism coexists with a second fault system near the center of the basin. This second fault system separates the basin into 2 parts, creating a second depocenter just east of South Island. Presenter's notes: Observe the thickening of the sediment packages to the west and the more condensed sediment packages to the east.

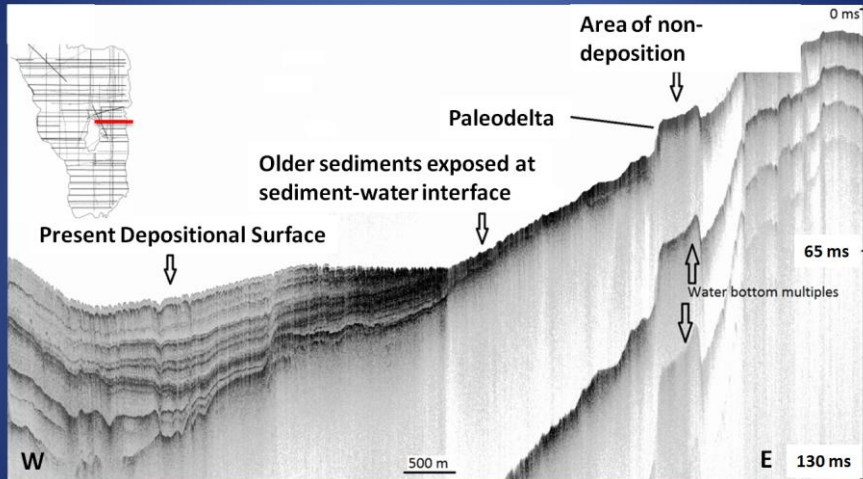
Why Turkana?

- Carbonate vs. clastic?
 - Changes through time?
- Modern sedimentary environments
 - Microbialites?
- Onshore/offshore correlation?
- Recent faulting
- Subaqueous volcanic/
hot spring activity?
- Paleoshoreline indicators
- Paleoclimate indicators





Eastern Margin (flexural)



- Coarse material nearshore
- Non-deposition close to shore
- Frequent shoreline migration
- Ramp-like margin
- Delta development
- Fine-grained sed in deep water

Presenter's notes: This is a typical line from the eastern margin of the lake. It also shows sediment thickening to the west from the shallow, ramp-like margin in the east. There is actually a zone of non-deposition along the eastern shoreline, where older sediments are exposed on the surface. Sediment accumulation is only occurring presently in water that is ~40 meters deep or more. Because of the shallow dip of this margin, the east shoreline is more prone to frequent lateral migrations. This shoreline migration and shallow dip makes the flexural margin a good place for deltas to form, as there is an example in this line. There are actually 3 sets of paleodeltas seen in the chirp data; those will be noted later.



**Coarse sands
olivine, pyx, amph, glass**



**Carbonate muds with
sands**



Fine sands and silts



Weathered basement gneiss

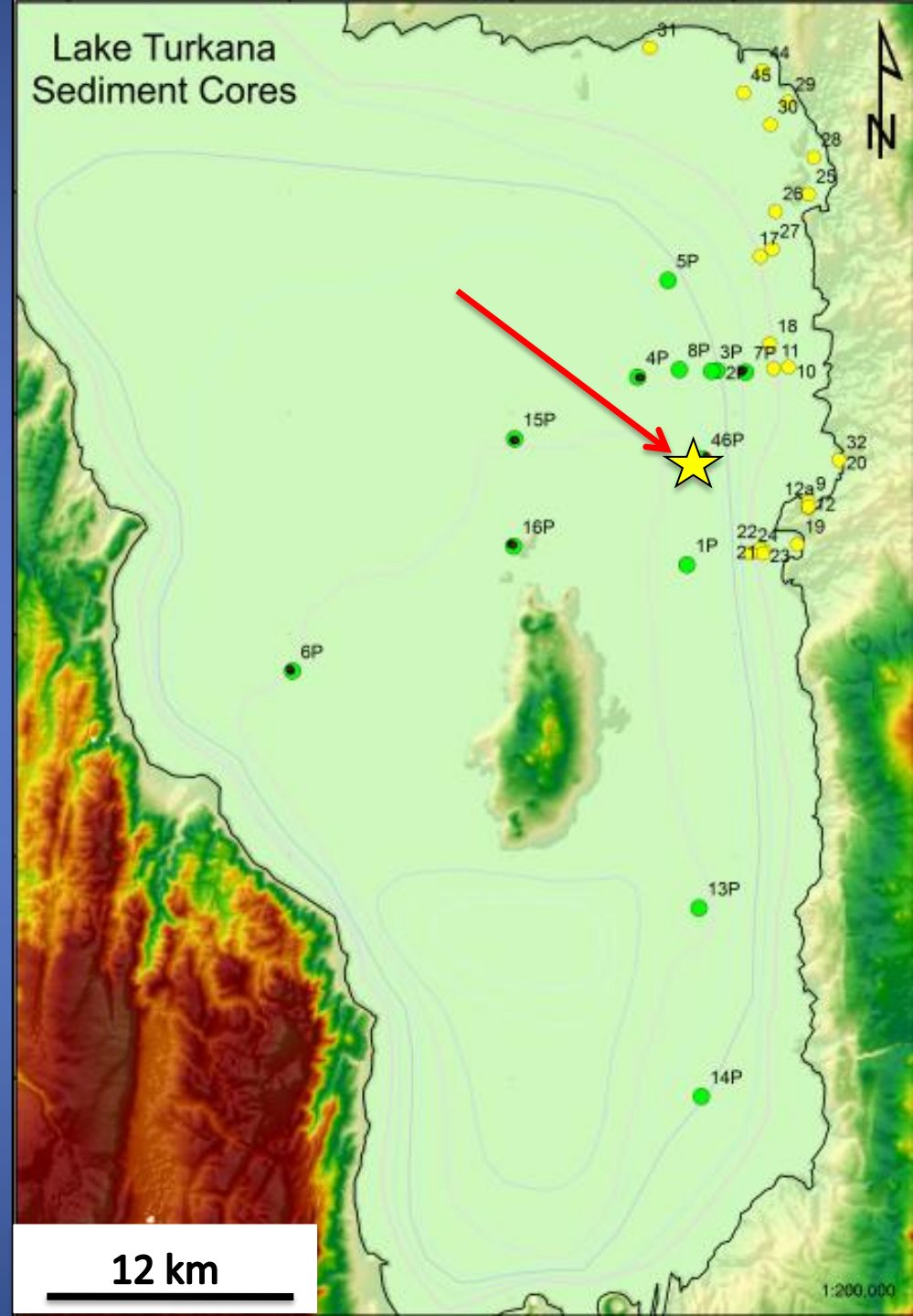


Volcanic sands

Sediment Variation Across the Basin

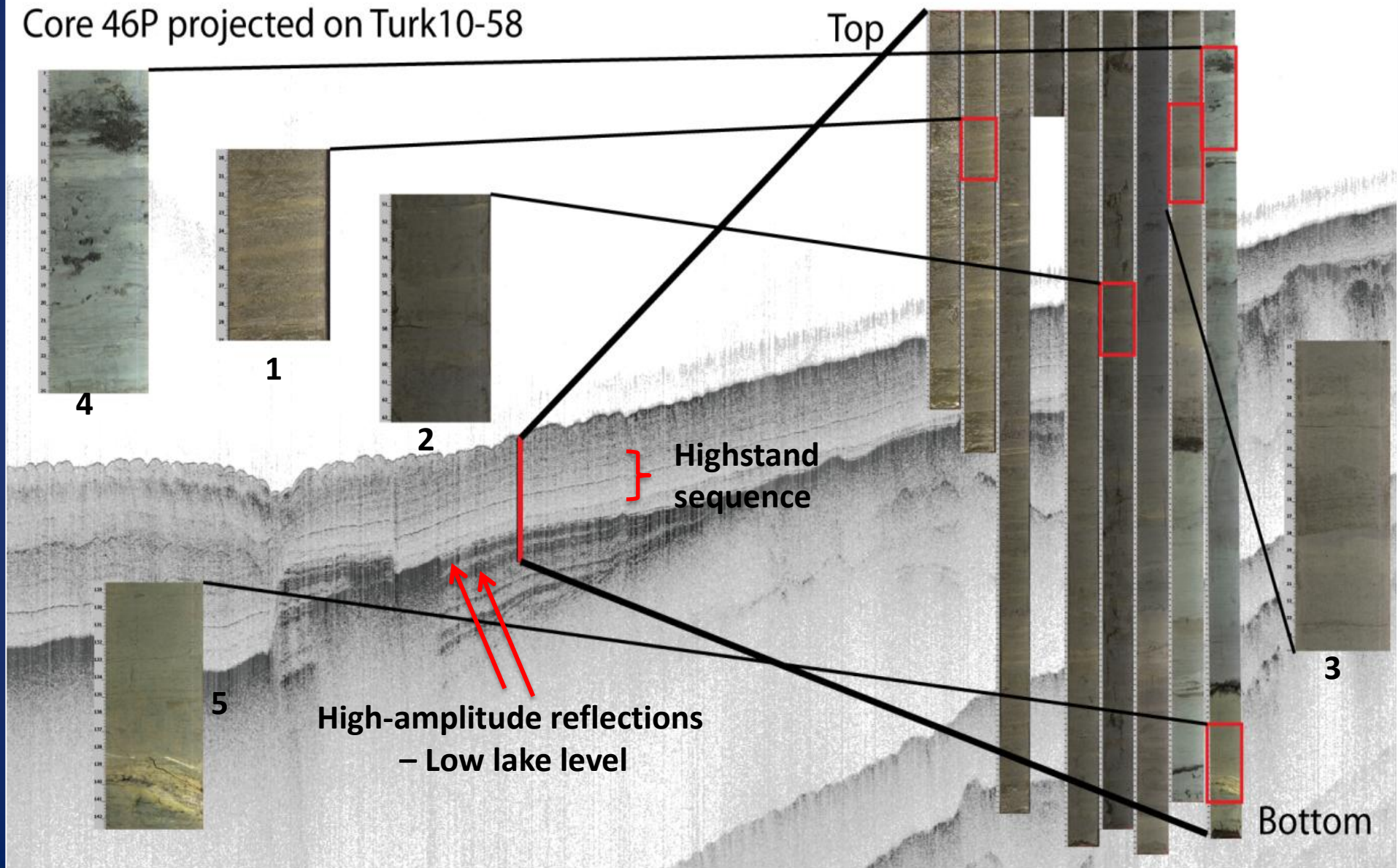
Downcore Variation

- 46P – Piston core
 - 54 m water depth
 - 10.6 m length
 - ~4.5 - 20 kyr record
 - ~ 5 km from the present shoreline



Seismic of 46P

Core 46P projected on Turk10-58



Lithofacies



Facies A – Gray, fine-grained, laminated sediments with nearly 0% TIC and >2% TOC [Highstand]



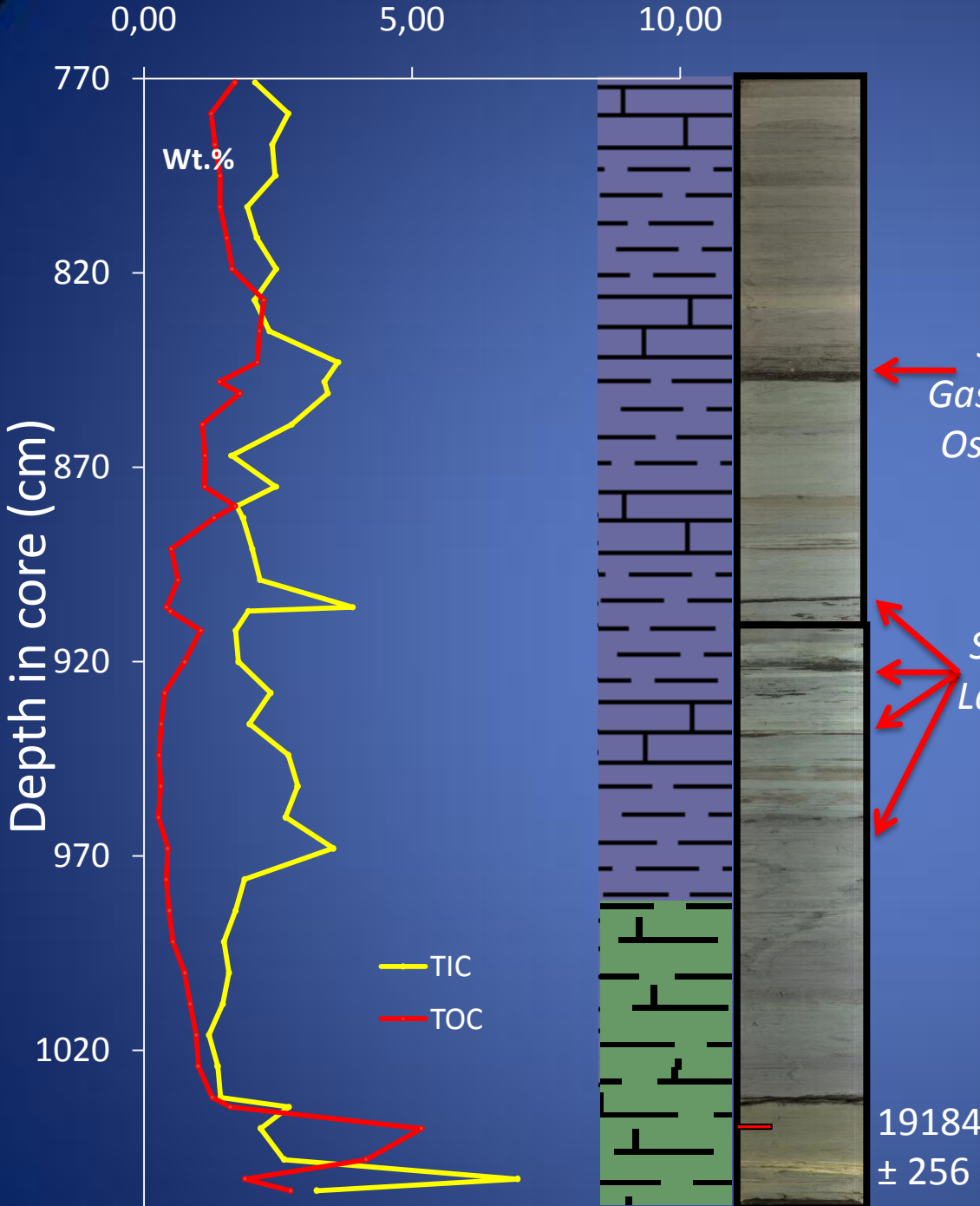
Facies B – Laminated sediment with low TIC (0.5 – 1.5%) [~modern lake]



Facies C – Massive, green carb mud with rare bedding, >1.5% TIC, and interspersed black sands [Extreme lowstand]

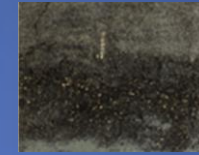


Facies D – Homogeneous sediment



- 19 – 13 kyr ago
- Regression -> low

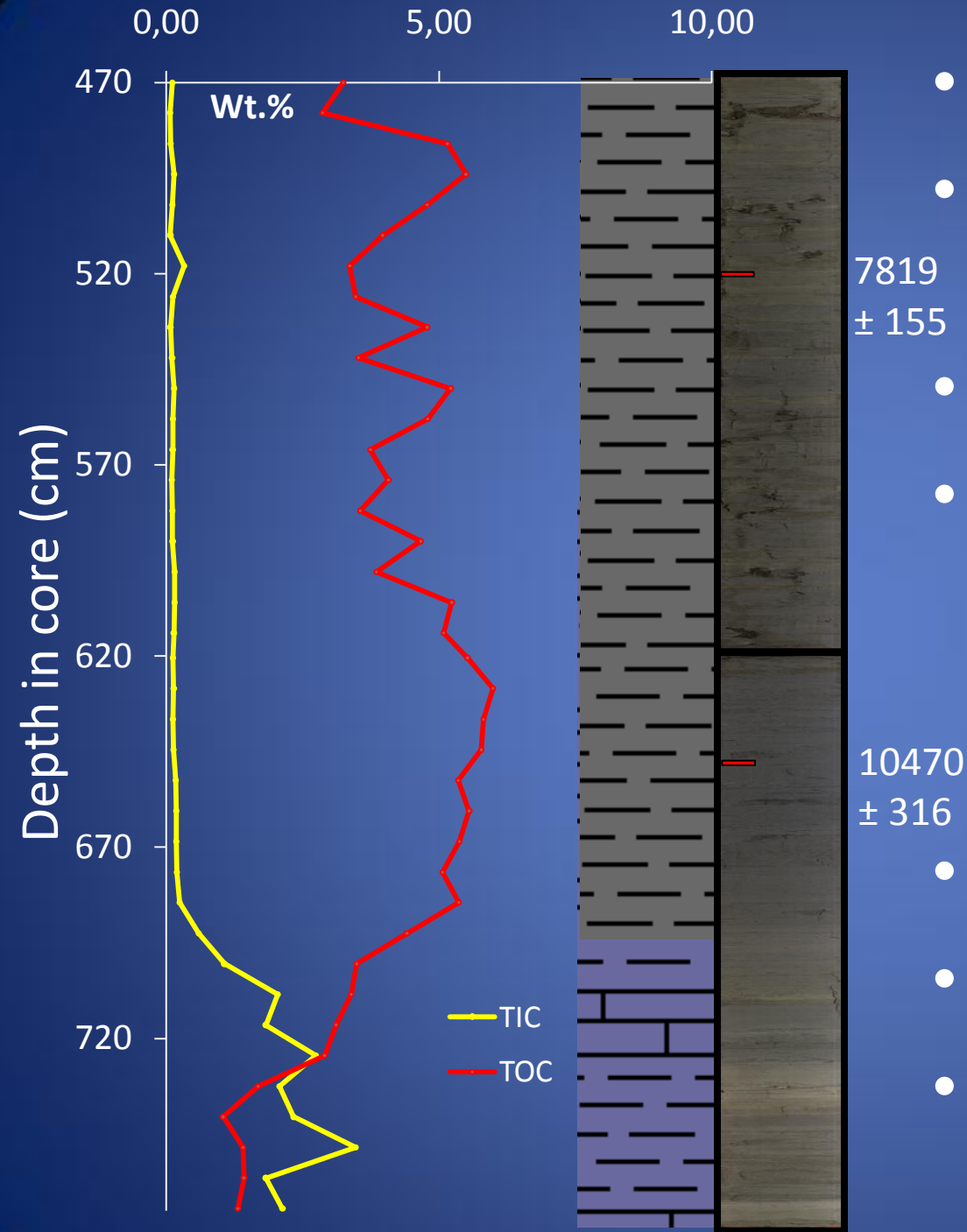
Sand,
Gastropods
Ostracods



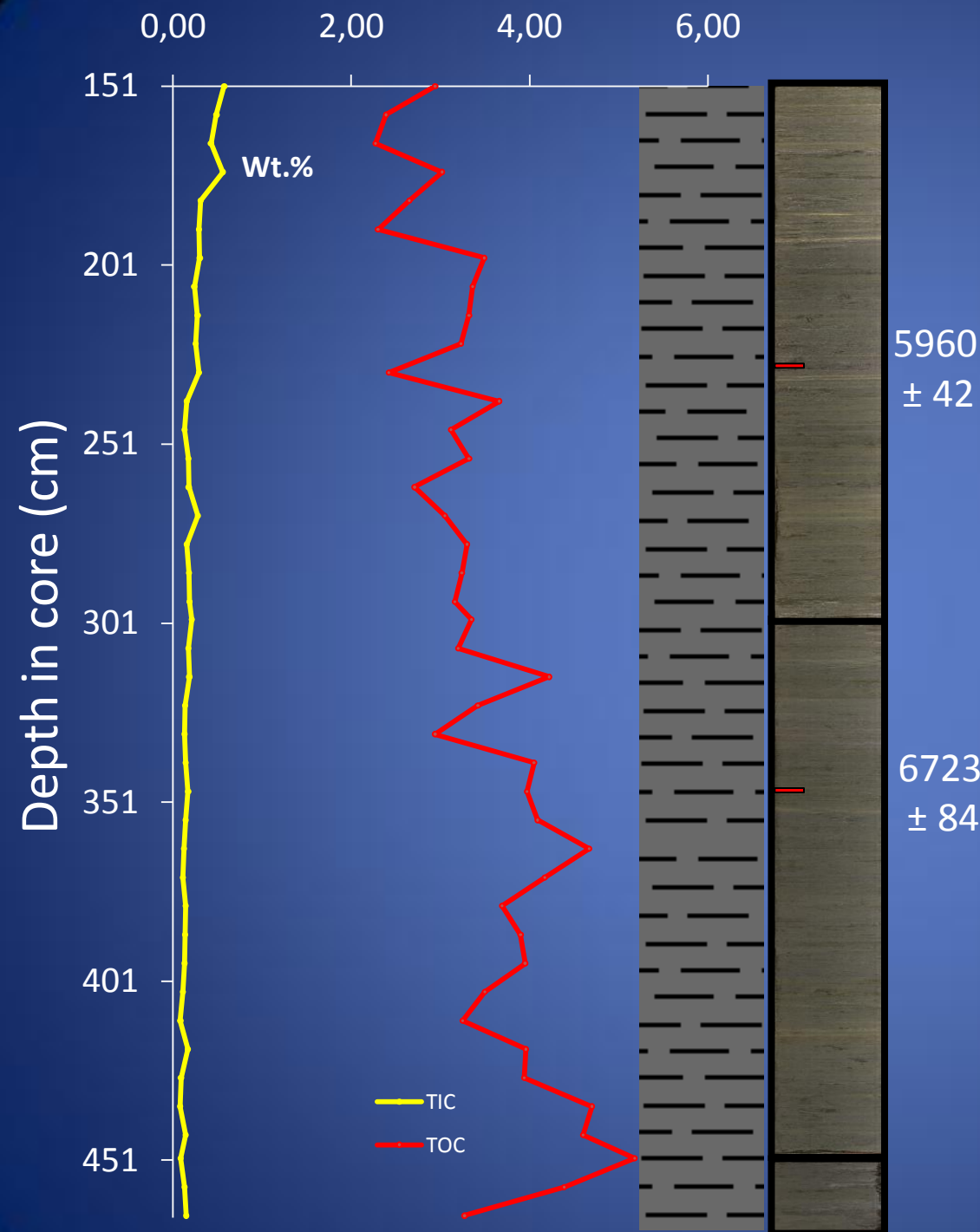
- Shoreline migration

- Frequent sand beds
- Ostracod beds
- Density increase
- Lower %water

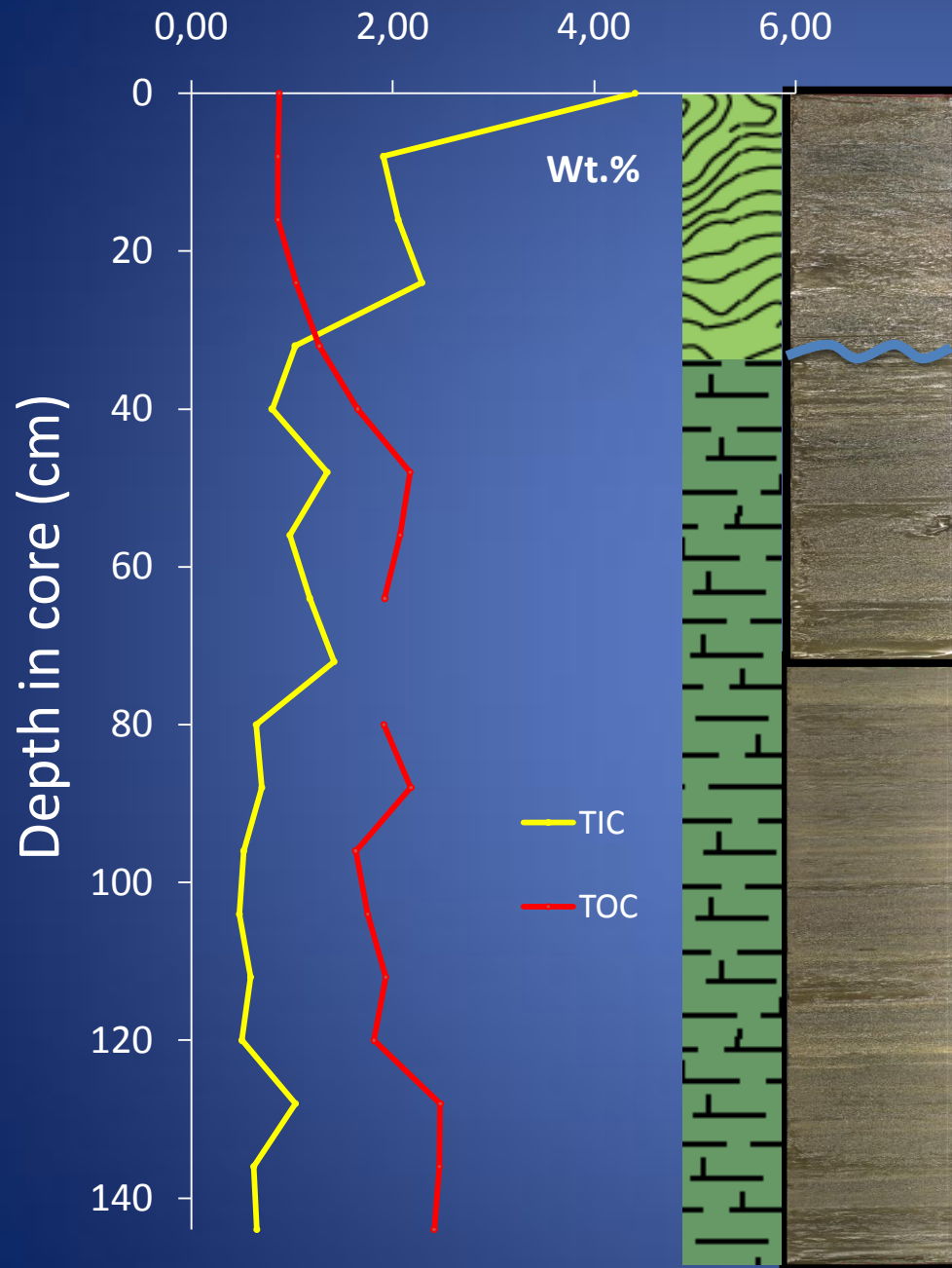
- Short-lived freshening at ~14kyr??



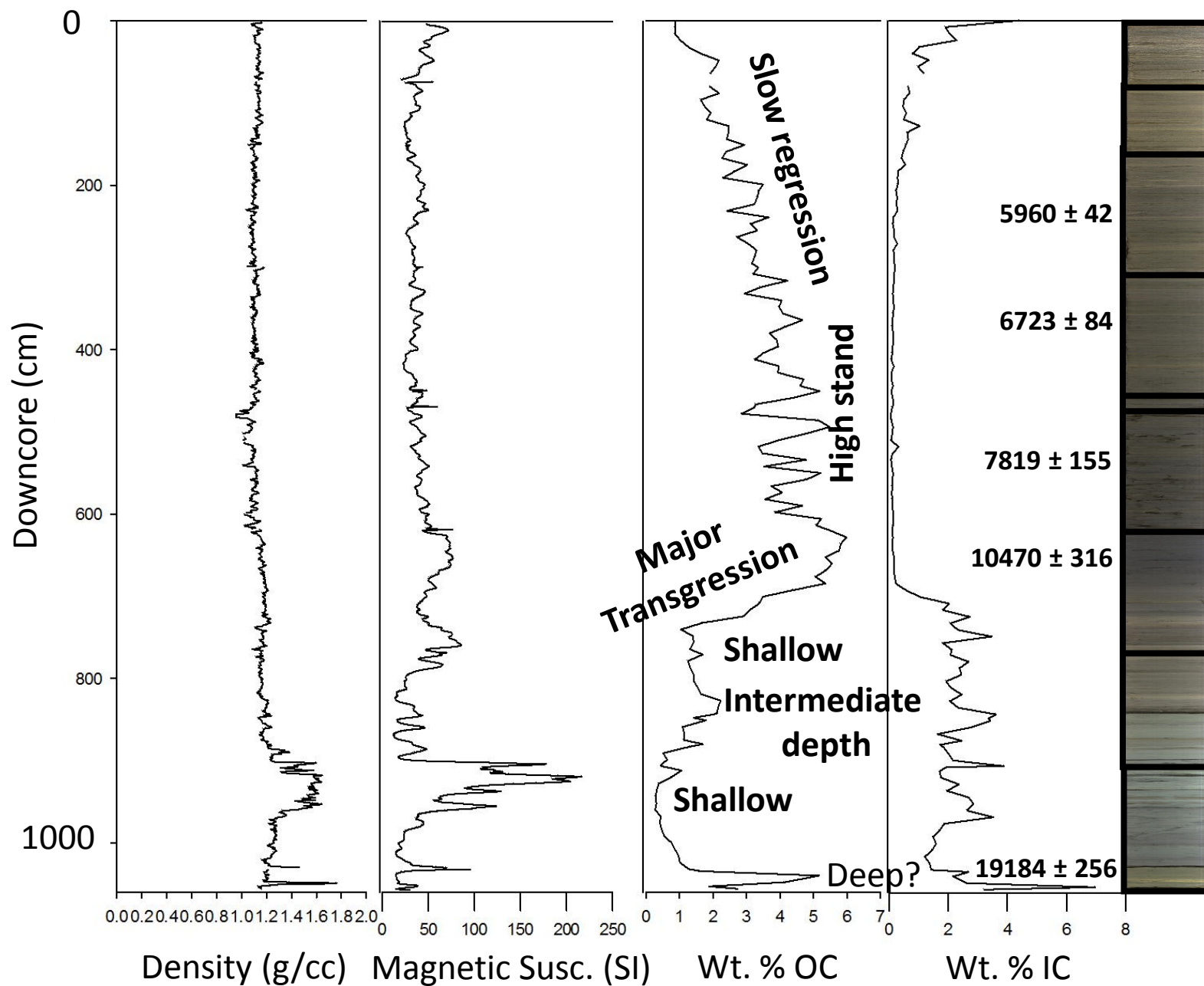
- ~13 – 7 ka
- Transgression to high stand by 10 ka
- Stable high lake level
- Microbialites deposited on NE shoreline (Owen et al., 1982)
- Nearly 0% TIC
- No sand layers
- Dark(er) organic mud



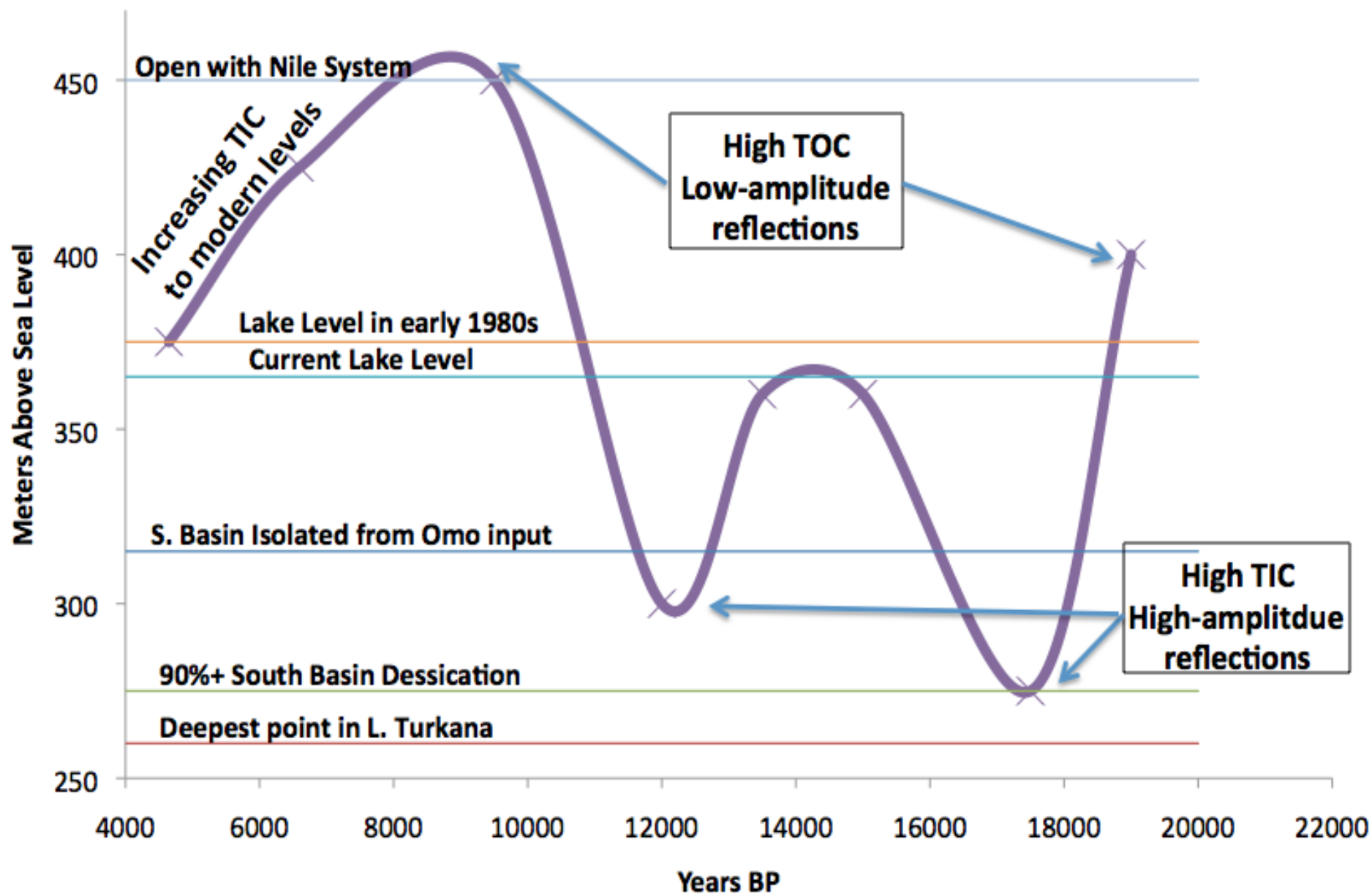
- 7 – 5.5 ka
- Highstand until ~8ka
- Slow lake level drop through the mid-Holocene
- TOC decrease and TIC increase 4-5 ka
- Rare fine sands
- Closer to modern lake



- 5.5 – 4.5 ka
- TIC increases into the late Holocene
- TOC preservation decreases
- Perhaps open or intermittently closed until ~4 ka => Closed system



Lake Turkana Lake Level



Conclusions and ongoing work

Extreme fluctuations in lake level over the last 20 kyr

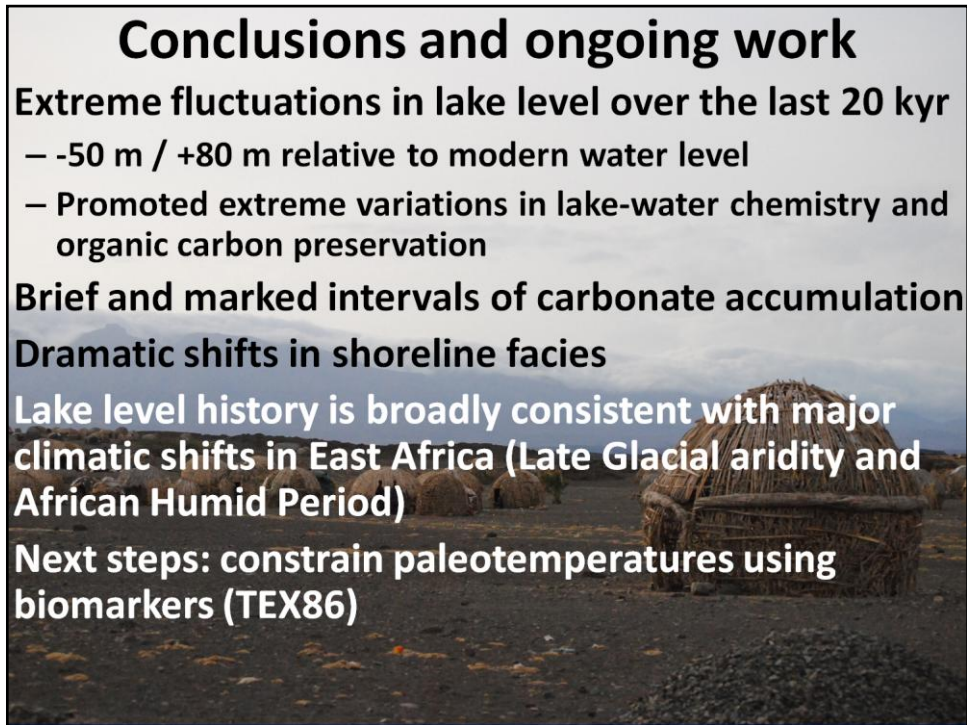
- -50 m / +80 m relative to modern water level
- Promoted extreme variations in lake-water chemistry and organic carbon preservation

Brief and marked intervals of carbonate accumulation

Dramatic shifts in shoreline facies

Lake level history is broadly consistent with major climatic shifts in East Africa (Late Glacial aridity and African Humid Period)

Next steps: constrain paleotemperatures using biomarkers (TEX86)



Thanks!

