Late Pleistocene and Holocene environmental and climatic change from Lake Tana, source of the Blue Nile

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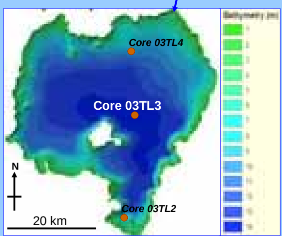


Introduction

Lake Tana, Ethiopia's largest lake, is the source of the Blue Nile, one of Africa's most important rivers. Although shorter than the White Nile, it accounts for 56% of lower Nile flow, and together with the Atbara river (Ethiopia), for 90% of flow and 96% of transported sediment. The ancient Egyptian civilisations of the lower Nile were founded on the rich alluvial soils of its floodplain, and were dependent on the annual replenishment during peak discharge caused by summer (monsoonal) rainfall in the Ethiopian highlands. The river remains critically important to the economies of Ethiopia, Sudan and Egypt.

Despite the Blue Nile's significance, little is known about the Late Quaternary history of its headwaters, in contrast to the abundant information about the history of Lake Victoria, the source of the White Nile. The level of Lake Victoria fell at about 18.0 - 17.0 cal ka BP, and dried completely between 15.9 and 14.2 cal ka BP. The White Nile resumed flowing at 14.5 cal ka BP, when Lake Victoria refilled to the level of its outflow into the river.

Objectives & Research Questions

High-resolution seismic survey to detect desiccation surfaces.

Diatom analysis of central and littoral sediment cores, supported by geochemical and mineral magnetic analyses to reconstruct environmental and climatic change over the last 17,000 years.

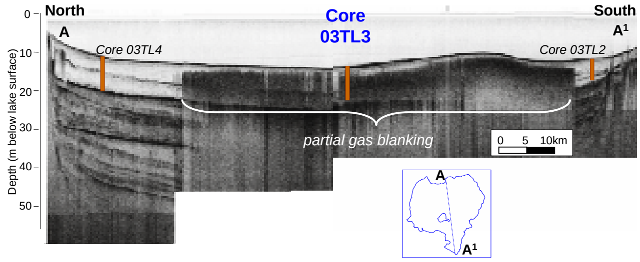
Was Lake Tana dry at the same time Lake Victoria, at 16.0 - 14.0 cal ka BP?

Is there any evidence for other major drought events recorded elsewhere in the region? e.g. Younger Dryas, 8.0 ka, or 4.2 ka when the Egyptian Old Kingdom collapsed.

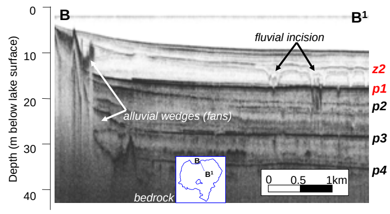
Characteristics of Lake Tana

Large area (3156 km^2), but **very shallow** (mean depth 9 m, max 14 m), therefore sensitive to evaporation. Four inflows contribute 95 % of inflow, from 16,500 km^2 drainage basin, only outflow is Blue Nile. Freshwater (220 µS cm^{-1}) and oligotrophic.

Seismic overview

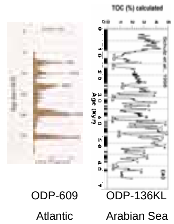


North shore: seismic detail

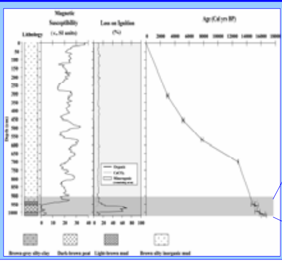


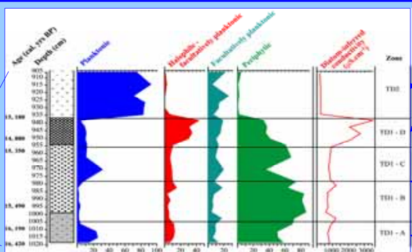
Deep sedimentary sequence with a series of strong reflecting horizons

Tana desiccation related to Heinrich events?



Core 03TL3 base: Late Pleistocene desiccation


Core 03TL3: lithology and age depth model.
Further penetration was prevented by seismic reflector *p1*.



Core 03TL3 base: diatom lifeform summary and inferred-conductivity.

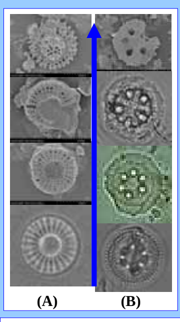
TD2 – Inorganic sediments, freshwater planktonic diatoms (*Aulacoseira* sp.): **overflow to the Blue Nile resumed at 14.7 cal ka BP**. Salinity (~190 µS cm^{-1}) close to modern values.

TD1 - D – Calcareous lake sediment, saline euryplanktonic diatoms (*Cyclotella meneghiniana, Thalassiosira faurii, Nitzschia obtusa, Anomoneis sphaerophora*): **lake level increased after 15.2 cal ka BP**. Evaporation from large, shallow, closed lake increased water salinity (~3500 µS cm^{-1}).

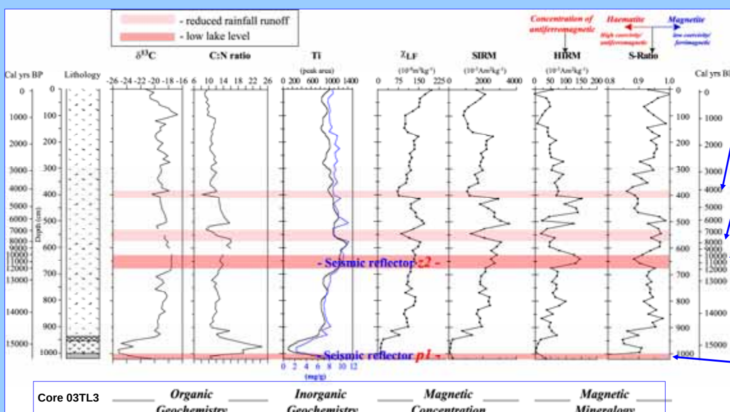
TD1 - C, TD1 - B – *Cyperus* peat and periphytic diatoms (*Cymbella muelleri, C. silesiaca, Nitzschia amphibia*): **freshwater papyrus swamp in basin centre, 15.7-15.2 cal ka BP, 24m below present lake surface**. Seasonal inflow, but less than evapotranspiration.

TD1 - A – Silt-clay unit: alluvium above **desiccation surface *(seismic reflector p1)***, with some reworked diatoms.

Core 03TL3: Holocene drought events?



Valve dissolution & breakage up-core 03TL3
(A) *Stephanodiscus minutulus*
(B) *Cyclotella ocellata*



~4.2 ka BP – Overall decrease in allochthonous inputs, and haematite >> magnetite, indicates reduction in catchment rainfall. Drought event, but superimposed on a period of increasing aridity.

~8.0 ka BP – Significant decrease in allochthonous inputs indicates an equivalent reduction in rainfall runoff in the catchment and hence drought.

11.8-10.5 ka BP – Seismic reflector ***z2***. Slow accumulation, no overall change in composition of allochthonous in-wash, but high concentration of haematite (HIRM peak) and haematite >> magnetite (low S-ratio) = post-depositional formation of haematite through oxidation and/or in-wash from anaerobic soils during dry/low lake level, and/or aeolian input; therefore prolonged aridity. Diatoms not preserved.

~16.5 ka BP – Alluvium on top of ***p1***. Haematite >> magnetite (very low S-ratio) = high aeolian input (Saharan origin) and/or formation through oxidation during intense aridity. Low allochthonous inputs reflecting low rainfall runoff, erosion and transport of sediment.

Conclusions

1. **Stratigraphic analyses of short (~10m) cores (03TL4/3/2) show that *p1* represents a desiccation surface that formed ~16.5 cal ka BP.** Lake Tana dried out and flow to the Blue Nile ceased.

2. **A papyrus swamp occupied the lake centre from 15.7-15.2 cal ka BP.**

3. **As the lake refilled, river inflows cut channels in the dry lake margins redepositing sediments towards the lake centre.** Evaporation from the closed basin initially led to an increase in water salinity.

4. **Lake Tana overflowed into the Blue Nile ~14.7 cal ka BP.**

5. **Desiccation surface *p1* coincides in time with drying up of Lake Victoria, source of the White Nile, and with North Atlantic Heinrich event H1.**

6. **Diatom valve breakage and substantial dissolution through the Holocene record.**

7. **Mineral magnetic data indicate that reflector *z2* may represent lake drying or a low lake stand from 11.8-10.5 cal ka BP.** The early part of this event overlaps with the latter stages of the Younger Dryas.

8. **Tentative interpretation that allochthonous inputs were reduced in response to low rainfall ~8.0 and ~4.2 cal ka BP.**

We aim to obtain a long (>60m) core from Lake Tana, to test the hypothesis that strong reflectors p2 – p4 represent earlier desiccation surfaces that may be related to previous Heinrich events.

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