Clumped isotope paleotemperature analysis of Turonian and Campanian foraminifera from southeast coastal Tanzania

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Introduction

Foraminifera are abundant microfossils whose calcium carbonate ($CaCO_3$) shells reflect the chemistry of their environment from the time they were alive, making foraminifera carriers of valuable proxies for paleoclimate and paleoceanographic conditions. The burgeoning method of carbonate clumped isotope (Δ_{47}) analyses measures the abundance of the heavy isotopologues of carbon and oxygen (e.g., $^{13}C^{18}O^{16}O$) in carbonate minerals. The method has gained popularity in paleoclimate research as its results are independent of the unknown stable isotope compositions of oxygen ($\delta^{18}O$) and carbon ($\delta^{13}C$) in seawater at the time of mineral precipitation. In this project, we used well-preserved benthic and planktic foraminifera from Tanzania Drilling Project (TDP) sites 23 and 36, which are middle Campanian (~75-77 Ma) and lower-middle Turonian (92-93 Ma), respectively. We analyzed these samples for Δ_{47}, $\delta^{18}O$, and $\delta^{13}C$ values to obtain paleotemperature estimates To compare to previously obtained $\delta^{18}O$ values.

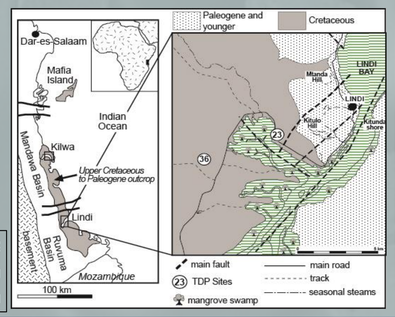

Figure 1. Location of TDP sites 23 and 36 in the Lindi Formation in southeast Tanzania

Methods and Materials

- Used a sodium polytungstate (SPT) flotation method for larger samples (>5 g) to better separate foraminifera tests from sediment grains.
- Picked benthic and planktic foraminifera from >250 µm and >125 µm sieve fractions
  - In earlier samples, tests were picked by avoiding those with apparent signs of infilling with secondary calcite.
  - In later samples, infilled tests were separated by floating them in water, relying on positive buoyancy to float the hollow tests.
- Completed SEM imaging and EDF light microscopic images on dissected specimens to examine their preservation and identify evidence of infilling in foraminiferal chambers.
- Samples (>2 mg) were analyzed for Δ_{47}, $\delta^{18}O$, and $\delta^{13}C$ values on a Nu Perspective dual inlet mass spectrometer
- Δ_{47} paleotemperatures were derived from the Anderson et al., 2021 calibration equation:

$$\Delta_{47(1-CDES90℃)} = 0.0391 \pm 0.0004 \times \frac{10^6}{T} + 0.154 \pm 0.004$$

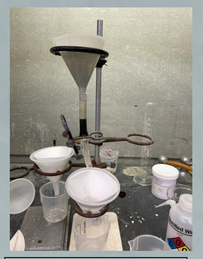

Figure 2. SPT flotation apparatus

Figure 3. Nikon SMZ-U Stereomicroscope and >250 µm and >125 µm sieves used to identify foraminifera

Results

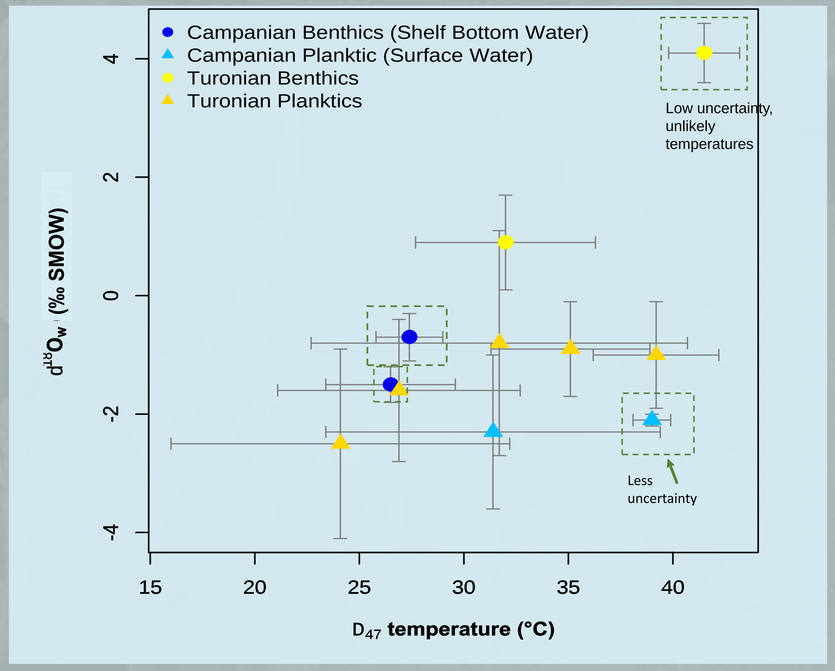

Figure 4. Crossplot of preliminary paleotemperature data derived from Δ_{47} values against $\delta^{18}O_w$ values. Points in blue correspond to Campanian values while yellow is Turonian. Circles represent benthic species while triangle represent planktic species values. Points encased in green, dashed boxes indicate values in which we have higher confidence.

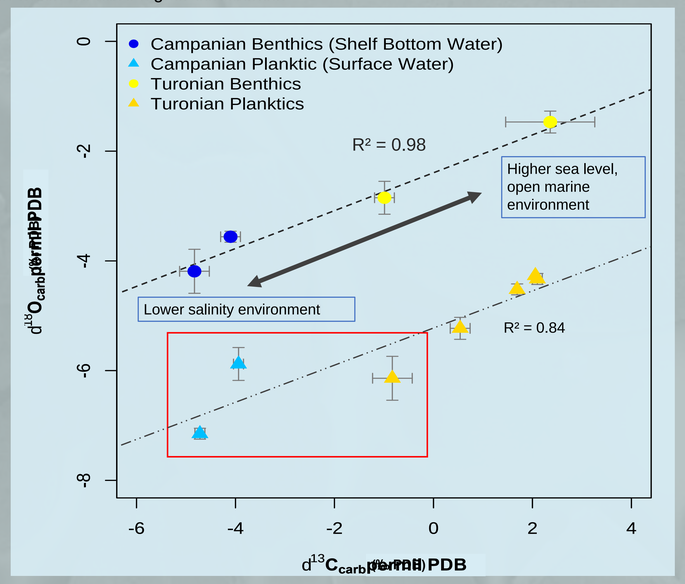

Figure 5. Crossplot of $\delta^{18}O_{carb}$ and $\delta^{13}C_{carb}$ values. There is a significant correlation between $\delta^{18}O_{carb}$ and $\delta^{13}C_{carb}$ values among benthic (R^2 of 0.98) and planktic (R^2 = 0.84) specimens (bottom dashed black lines). Campanian values may be more negative than Turonian values because of lower sea level and greater influence of freshwater deltaic system. The red box highlights samples with low $\delta^{18}O_{carb}$ values (>-6‰ PDB) likely altered from diagenetic calcite infilling.

SEM Imaging

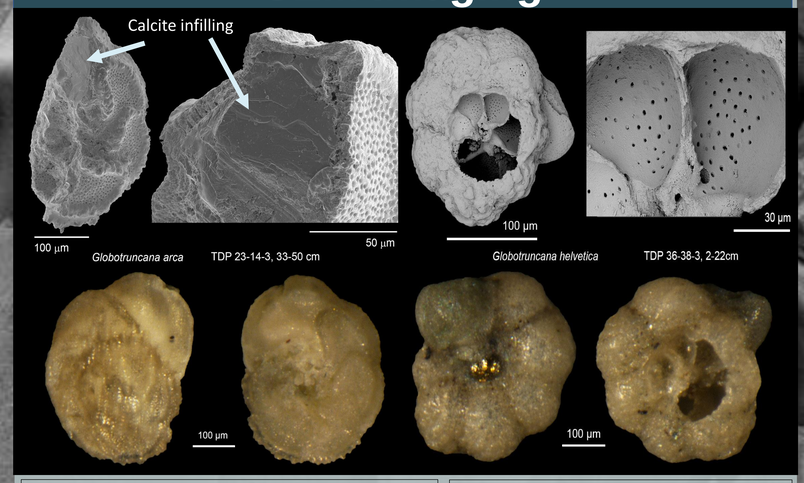

Figure 6. SEM (top) and EDF light microscopic (bottom) images of *Globotruncana arca* with secondary calcite infilling from Campanian TDP Site 23.

Figure 7. SEM (top) and EDF light microscopic (bottom) images of hollow *Globotruncana helvetica* from Turonian TDP Site 36

Conclusions

- Turonian benthic samples yielded warmer average Δ_{47} paleotemperatures (32°C) than those from the Campanian (26-27°C).
- Turonian planktic samples yielded average Δ_{47} paleotemperatures of 31.5°C compared to Campanian planktics (34.5°C).
- These paleotemperatures, though higher than expected, present predicted differences between compared groups and fell near previous temperature estimates, demonstrating Δ_{47} analysis functions as an effective paleothermometer using foraminifera in geologic time intervals of greenhouse paleoclimate, such as the Late Cretaceous.
- Some TDP36 samples present some suspicious temperature estimates. We analyzed these samples before incorporating the water flotation method, so these tests may have been infilled.

Future Research

- Add replicates to samples previously analyzed in this project and complete water floats to investigate if suspicious paleotemperature values are due to infilling
- Compare infilled and hollow test values to quantitatively investigate how diagenesis impacts geochemical analyses.
- Analyze samples from higher latitudes to expand the record of paleotemperatures (the project focus of YES! Interns Nalia Molina and Meron Abraham).

Acknowledgements and References

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