The Coupled Evolution of Temperature and Carbonate Chemistry during the Paleocene–Eocene; New Orbital-Resolution Trace Metal Records from the Low-Latitude Indian Ocean (ID: 2019002320)

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1. Introduction

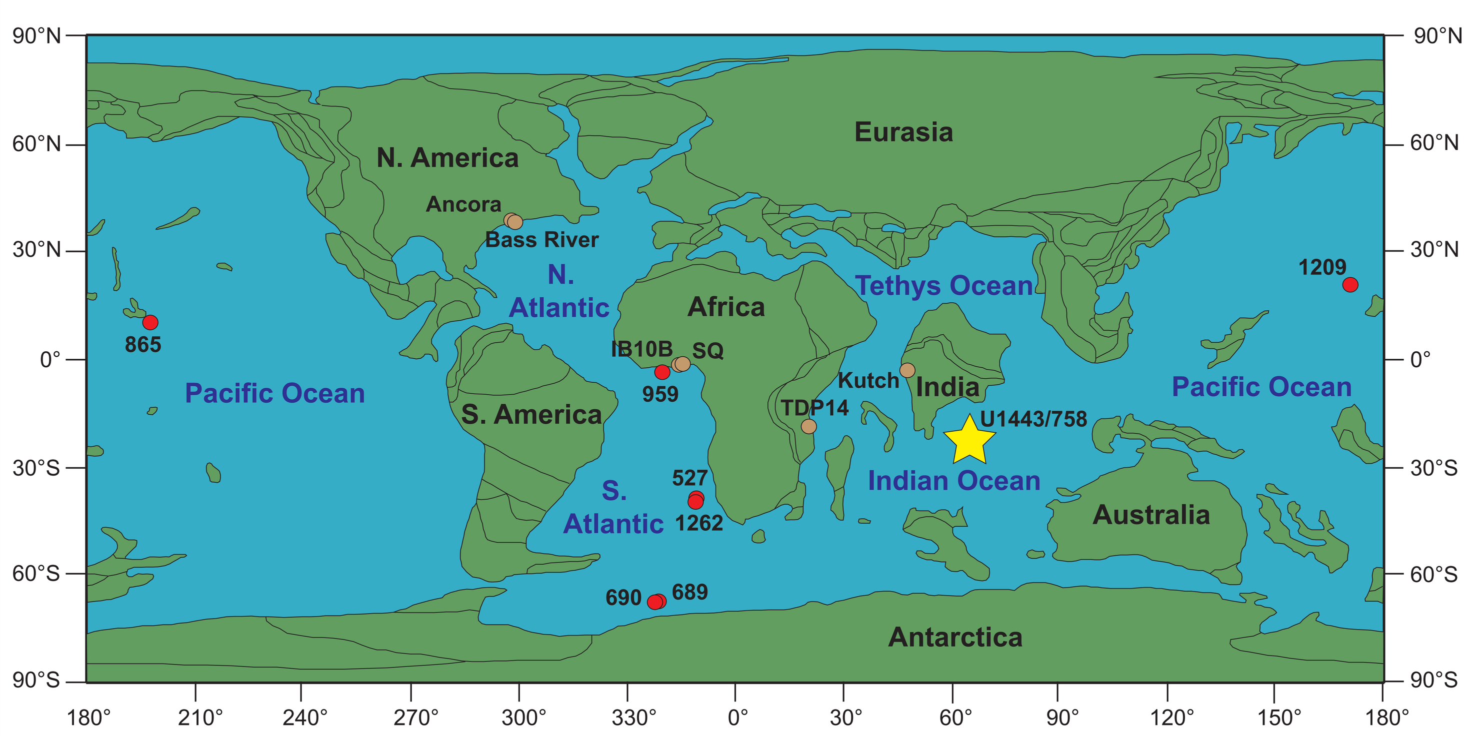
- The long-term evolution of low-latitude surface ocean temperature and carbonate chemistry during the Paleocene to early Eocene is poorly constrained, especially at orbital resolution

- Here we present new orbital-resolution foraminiferal Mg/Ca and B/Ca records spanning the late Paleocene to early Eocene (~58–53 Ma) from a splice between ODP Site 758 and IODP Site U1443 (Ninetyeast Ridge, Indian Ocean)

- We generated trace metal data from surface and deep dwelling foraminifera, to reconstruct changes in temperature and carbonate chemistry across a water column depth transect

- Our records allow us to identify both long-term and orbital-scale changes in temperature and carbonate chemistry

2. Location map



The new trace metal data generated during this project are from IODP Site U1443 and ODP Site 758, located ~100 metres apart at a shallow palaeo-depth of ~1500 metres on the crest of the Ninetyeast Ridge (Indian Ocean). Locations of other sites from which previously published data were used to generate the data compilations presented below are shown.

Reconstruction from: http://www.odsn.de/odsn/services/paleomap/paleomap.html

3. Methods

- The mixed layer species *Morozovella velascoensis*/*M. subbotinae*, thermocline-dwelling species *Subbotina velascoensis*/*S. hornibrooki*, and benthic species *Oridorsalis umbonatus*/*Nuttallides truempyi* were analysed

- The age model was generated using carbon isotope stratigraphy combined with calcareous nannofossil and planktic foraminifera biostratigraphy

- Foraminifera were cleaned using both oxidative and reductive procedures, then analysed on an ICP-MS at the University of California Santa Cruz

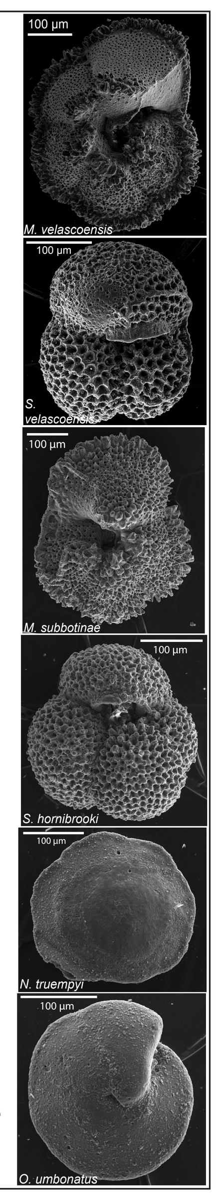
- Raw planktic Mg/Ca values were pH-corrected using the linear correction of Evans *et al.* (2016), then temperatures were calculated using the multi-species temperature calibration of Anand *et al.* (2003), modelling the evolution of seawater Mg/Ca after proxy data in Evans *et al.* (2018)

- Mixed layer seawater $\delta^{18}O$ ($\delta^{18}O_{sw}$) was calculated following Bemis *et al.* (1998), using Mg/Ca-derived temperatures and $\delta^{18}O$ values from *Morozovella* samples

- Benthic Mg/Ca data were converted to temperature using the species-specific temperature calibration of Lear *et al.* (2015) for *O. umbonatus*

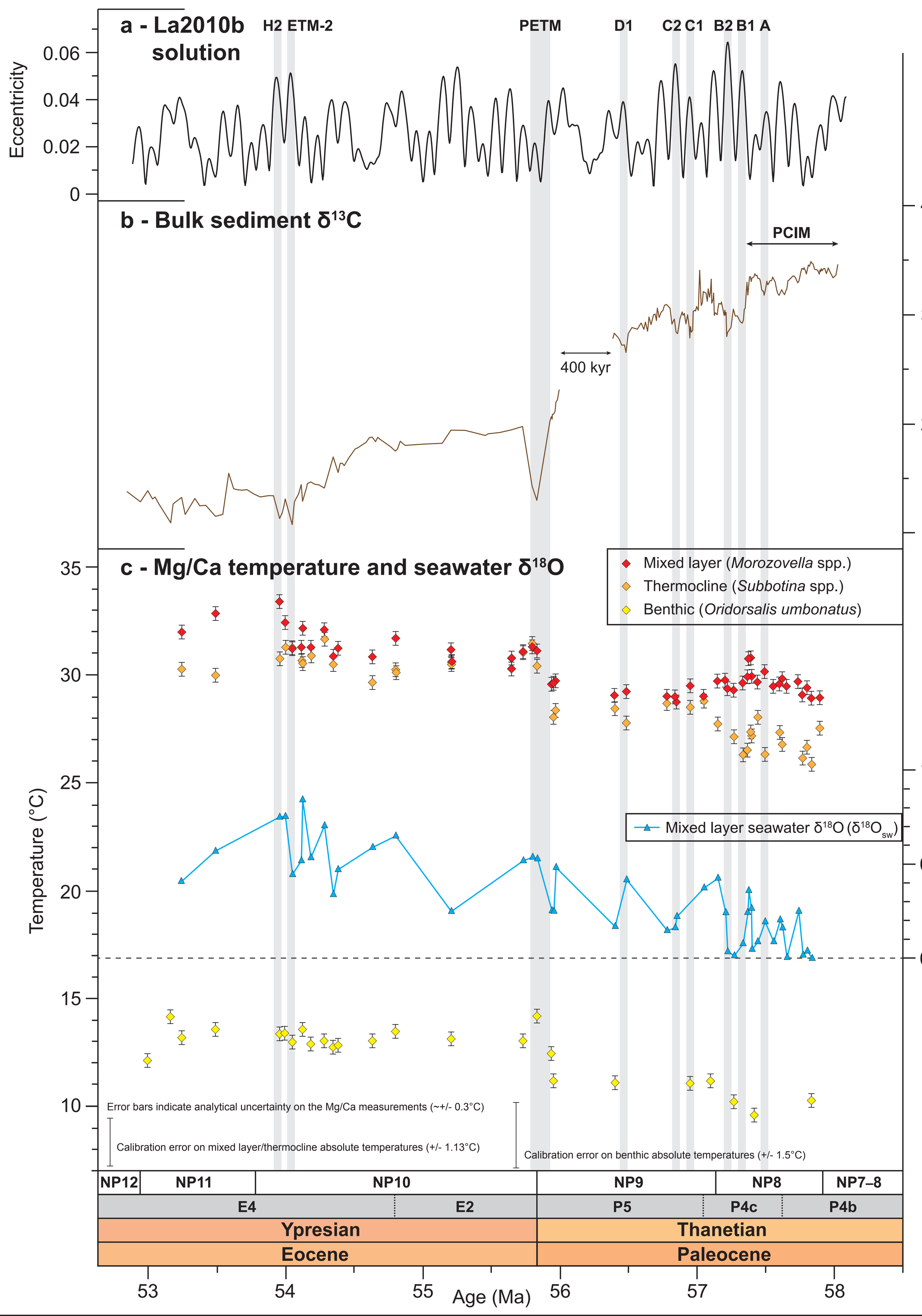
- Relative changes in carbonate chemistry ($[B(OH)_4^-]$/DIC) were calculated from the planktic B/Ca data after Haynes *et al.* (2017)

- Relative changes in carbonate saturation state ($\Delta[CO_3^{2-}]$) were calculated from the *N. truempyi* B/Ca data after Brown *et al.* (2011)

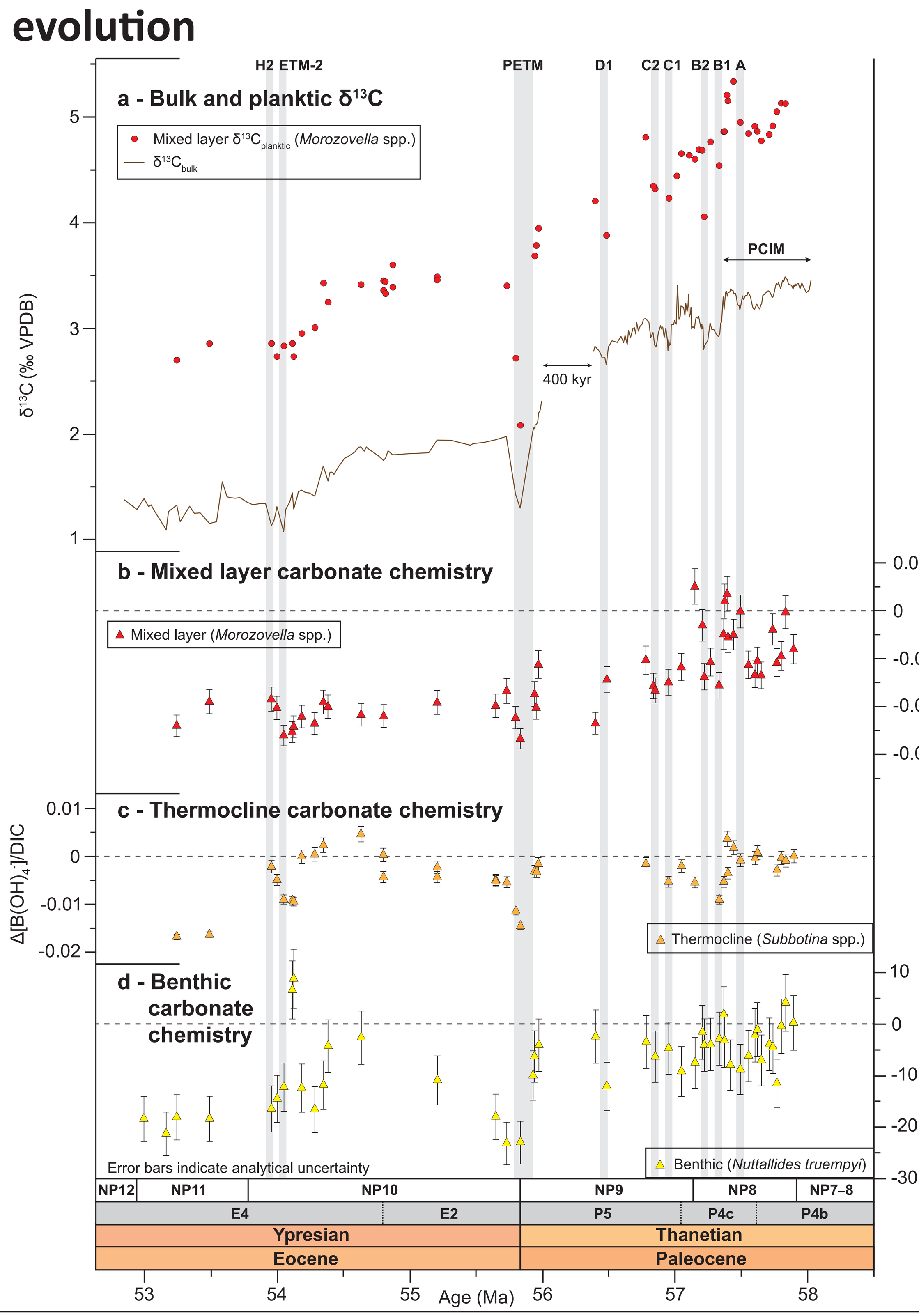


4. Results

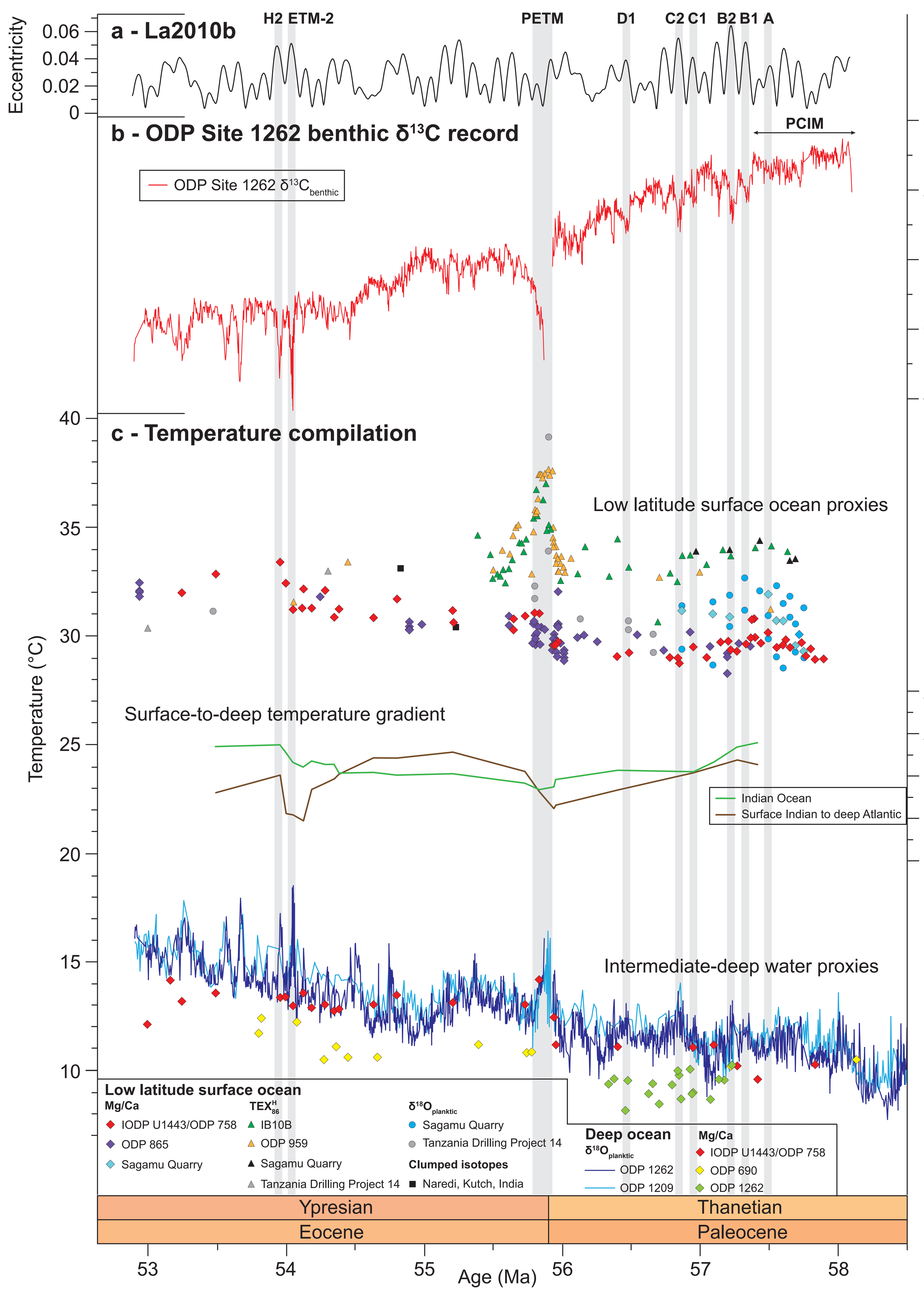
4a. Long-term Indian Ocean temperature evolution



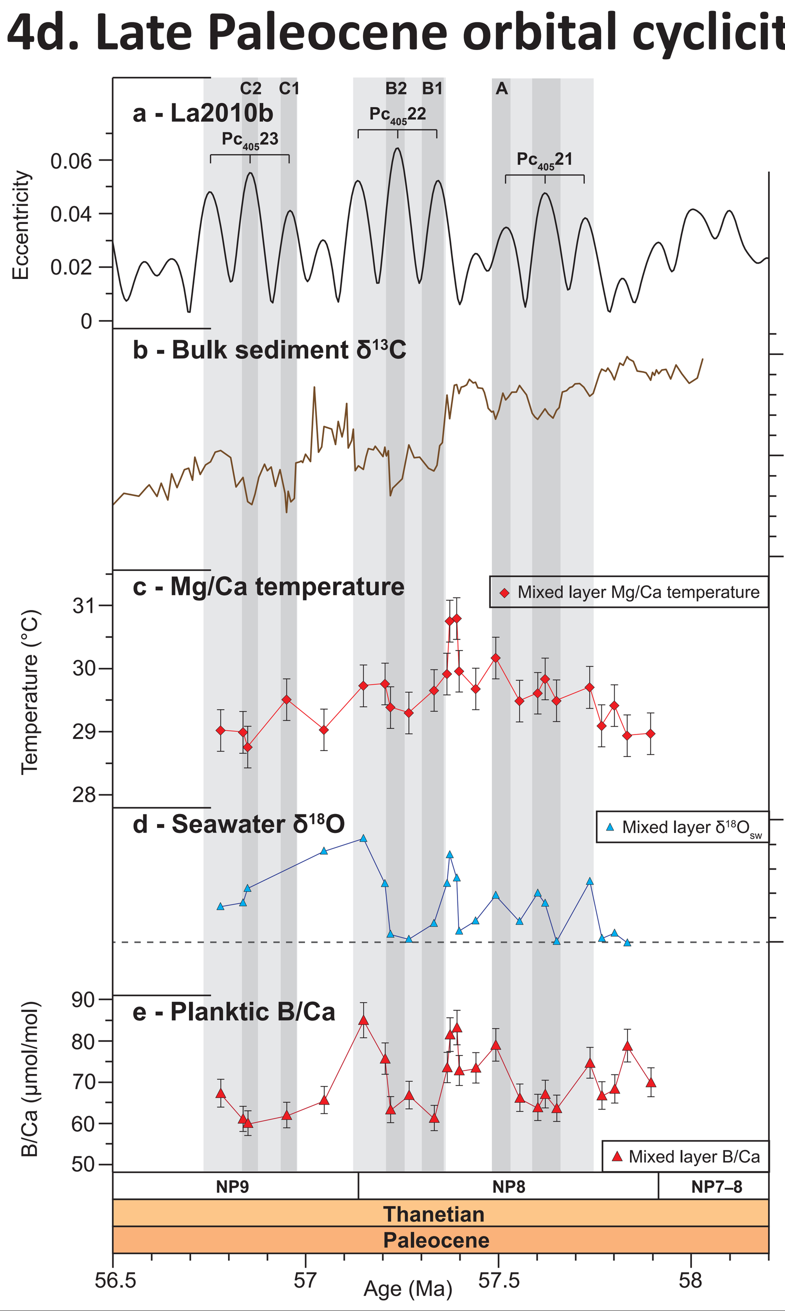
4b. Long-term Indian Ocean carbonate chemistry evolution



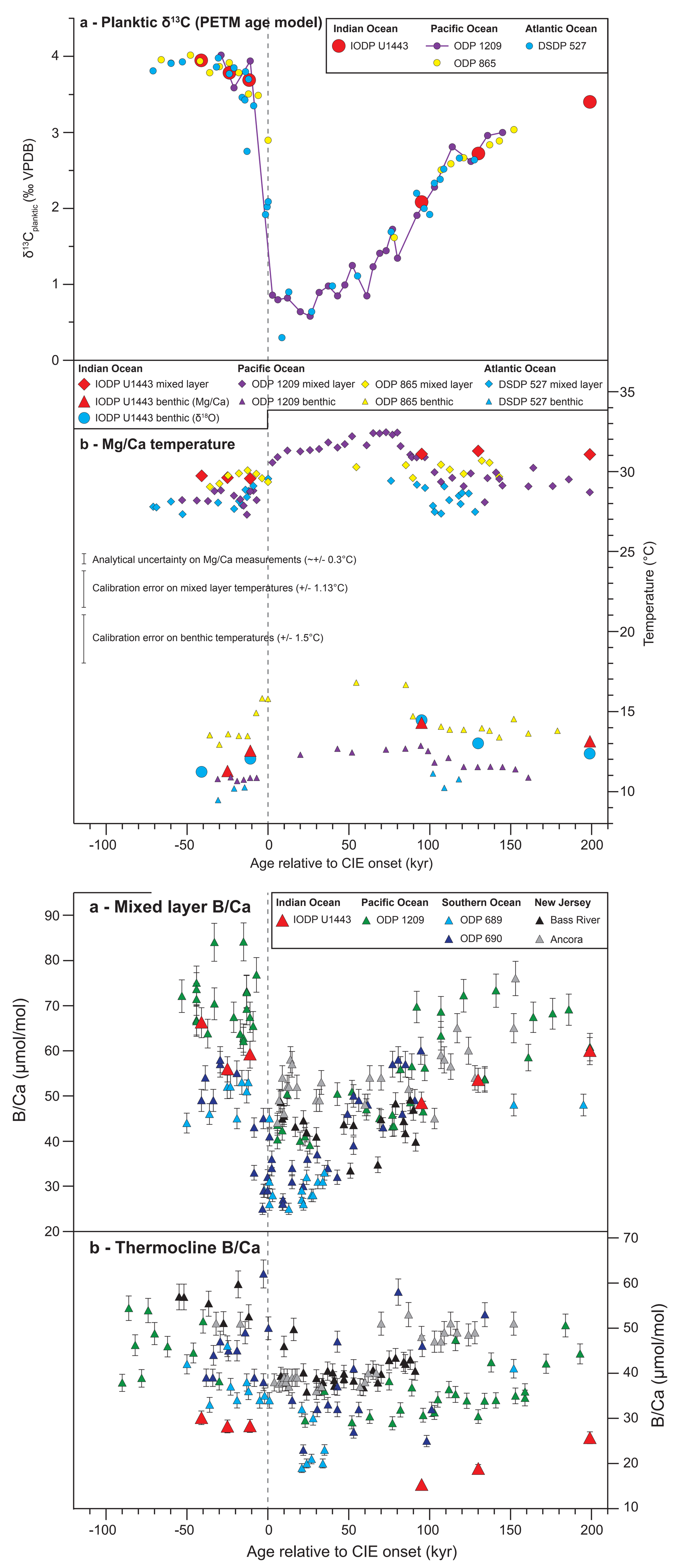
4c. Temperature compilation



4d. Late Paleocene orbital cyclicity



4e. PETM



5. Discussion and conclusions

- Synchronous long-term warming within both the low and high latitudes during the late Paleocene to early Eocene suggests that global climate was forced by greenhouse gases during this time

- A surface-to-deep temperature gradient decrease is evident during hyperthermals such as the PETM and ETM-2, with a gradual long-term gradient decrease between the surface Indian and deep Atlantic

- A deepening of the thermocline took place within the low latitude Indian Ocean during the late Paleocene, potentially in response to downwelling of increasingly saline surface waters

- Long-term late Paleocene–early Eocene decreases in mixed layer $\Delta[B(OH)_4^-]$/DIC and deep water $\Delta[CO_3^{2-}]$ suggest a long-term decrease in surface ocean pH and/or increase in DIC, along with a decrease in carbonate saturation state at ~1500 m depth

- There is evidence of 405-kyr cyclicity within late Paleocene B/Ca and $\delta^{18}O_{sw}$ data, however orbital-scale changes within the Mg/Ca data fall largely within analytical uncertainty

- A portion of the PETM recovery has been captured in the new record from IODP Site U1443, confirming similar recovery temperatures in the northern Indian Ocean to other low latitude sites

- Lower absolute mixed layer and thermocline B/Ca values in the Indian Ocean compared to the central Pacific may indicate a source from the Southern Ocean, due to upwelling in the northern Indian Ocean