Significant ice sheets during the cold mid-Paleocene?

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The mid-Paleocene (60-58 Ma) had atmospheric pCO_2 concentrations about as low as present-day. Deep-sea temperatures and global sea level were relatively low. For as yet unknown reasons, Paleocene cold gradually changed into the warmth of the Early Eocene Climatic Optimum, with high pCO_2 and global temperatures. It was suggested that the mid-Paleocene was cold enough to sustain ice sheets on Antarctica, but neither physical evidence nor $\delta^{18}O$ tracers could confirm this suspicion. Questions that remain are: Were there ice sheets during the cold mid-Paleocene? If there were no large ice sheets, why did cold climates of the mid-Paleocene not result in the formation of large ice sheets? And why then was global sea level so low?

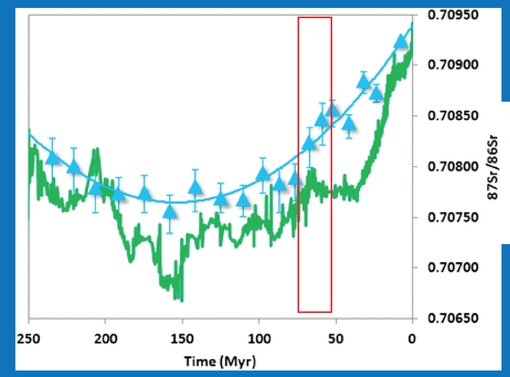
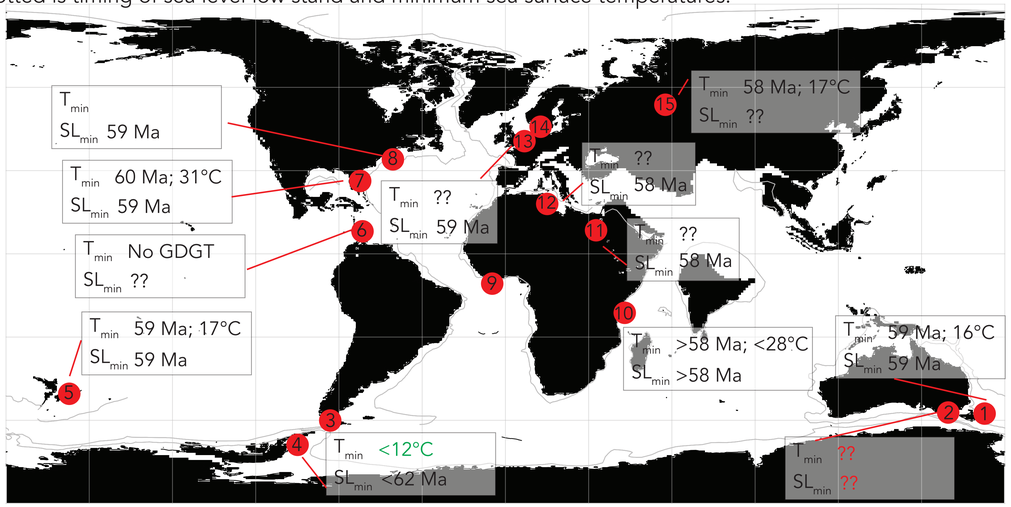


Figure 2. Sr isotopes (green) and reconstructed subduction slab length (blue) for the past 250 Myr. In red is the time interval of interest. Obtained from ref k.

Figure 1. Mid-Paleocene (59 Ma) paleogeographic reconstruction (using G-Plates and Torsvik et al., 2012). Plotted is timing of sea level low stand and minimum sea surface temperatures.



Legend

1. ODP Site 1172, Tasmania[a, b]
2. Otway Basin, Australia[c]
3. Isla Riesco, Chile[c]
4. Seymour Island[d, e]
5. Mid-Waipara, Nw Zealand[b]
6. ODP Site 1001Carribbean[f]
7. ODP Site 1052 and hinterland[g, h]
8. New Jersey Shelf, USA[i, j, k]
9. ODP Site 959, Ivory Coast[l]
10. TDP 19; Tanzania Shelf[f, m]
11. Gebel Aweina, Egypt[n]
12. El Kef, Tunisia[o]
13. Belgium[p]
14. Viborg-1, Denmark[q]
15. Siberia[r]

Relatively low sea level

The low sea level during the mid-Paleocene is remarkable given ocean spreading rates are relatively high, as seen in subduction slab lengths and Sr isotope ratios (Fig. 2). The absence of major positive excursions in benthic foraminiferal $\delta^{18}O$ (Fig. 3) precludes the possibility of storage of water as ice sheets on the continents. As alternative, Paleocene sea levels minght have been low due to excessive water drawdown by accellerated subduction of old lithospheres during this time. In this scenario, water is stored for longer time in the thick subducted slab, to be returned via volcanic activity (Fig. 4).

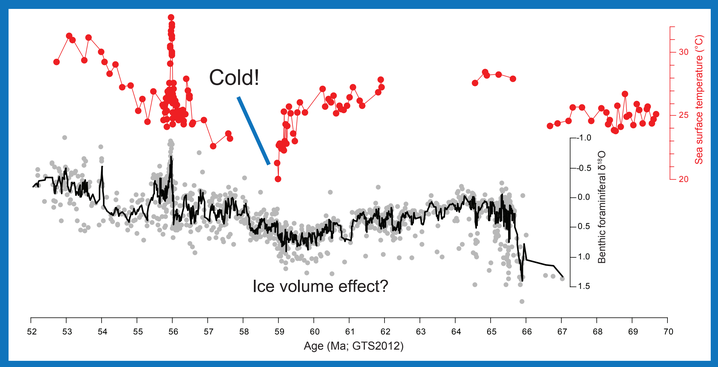
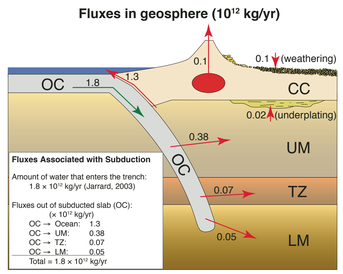


Figure 5. Global long-term water cycle, from Bodnar et al., 2013). Particularly old, thick and cold lithosphere is capable of storing large volumes of water and extracting it from surface reservoirs. The fast subduction of Carboniferous oceanic crust under Asia during the Paleocene might have subtracted large quantities of water causing blobal sea level to be low during the mid-Paleocene. This idea is now further explored.



Take Home Message

- Mid-Paleocene was relatively cold; meridional temperature gradients steep
- Sea level extremely low globally; only outer shelf sedimentation
- No physical evidence for glaciations
- Possible water loss through accellerated subduction of old oceanic crust?

Meridional SST gradients

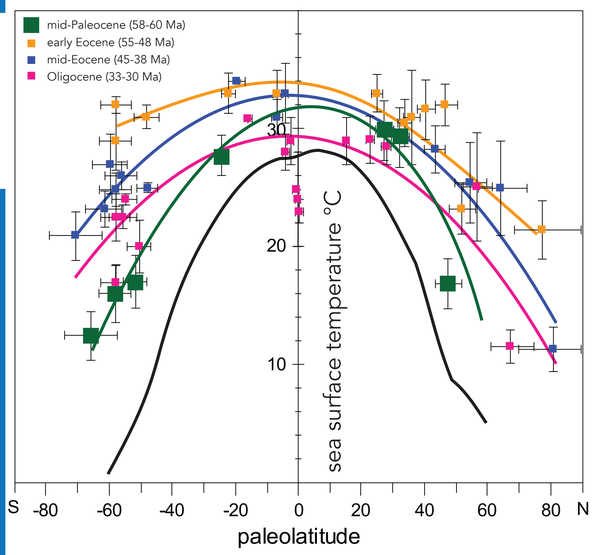


Figure 4. Meridional SST gradients based on TEX_{86} analyses for early Eocene (orange), middle Eocene (blue) Oligocene (magenta) and mid-Paleocene (green). Paleolatitudes based on v. Hinsbergen et al., 2015. Data recalibrated from Liu et al., 2009, Bijl et al., 2009, Houben, 2012 and unpublished records.

References

a Bijl et al., 2009; 2013
b Hollis et al., 2014
c Bijl, Frieling, data in progress
d Bowman et al., 2015
e Kemp et al., 2014
f Bijl, unpublished
g Cramwinckel, MSc thesis UU
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