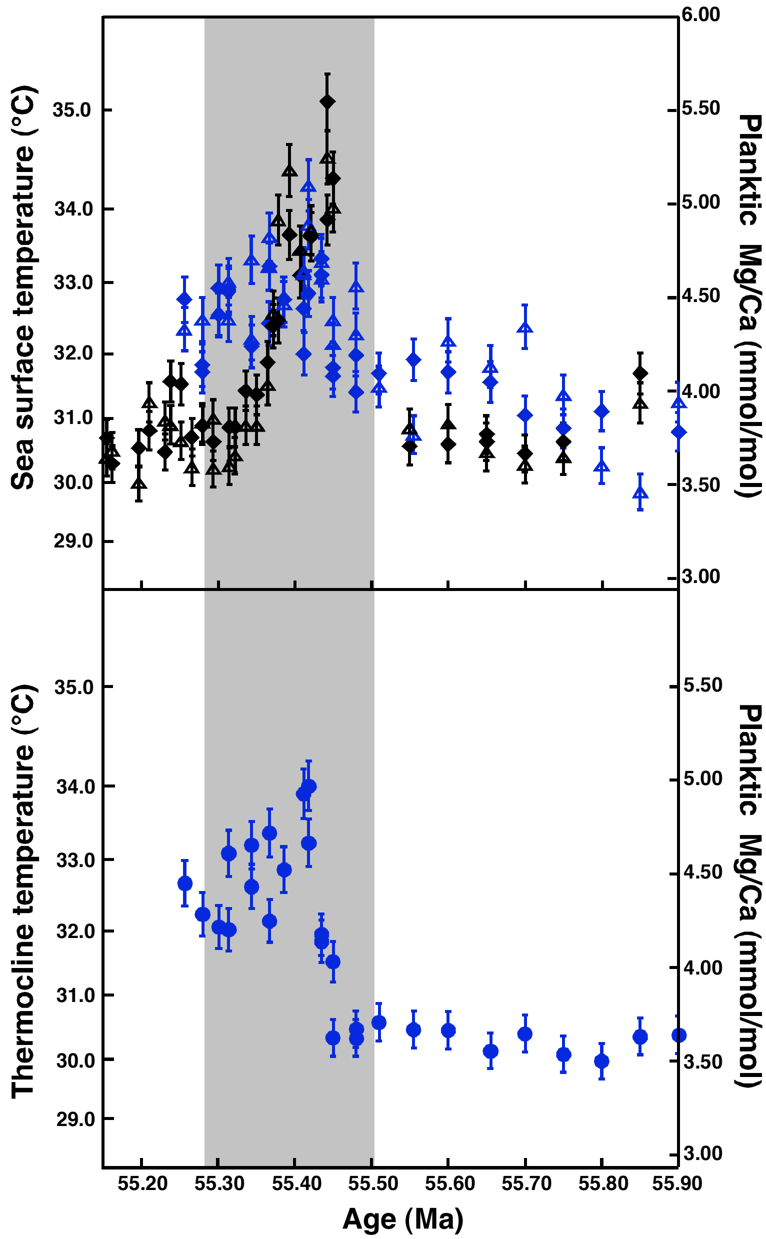
Supporting Online Materials:

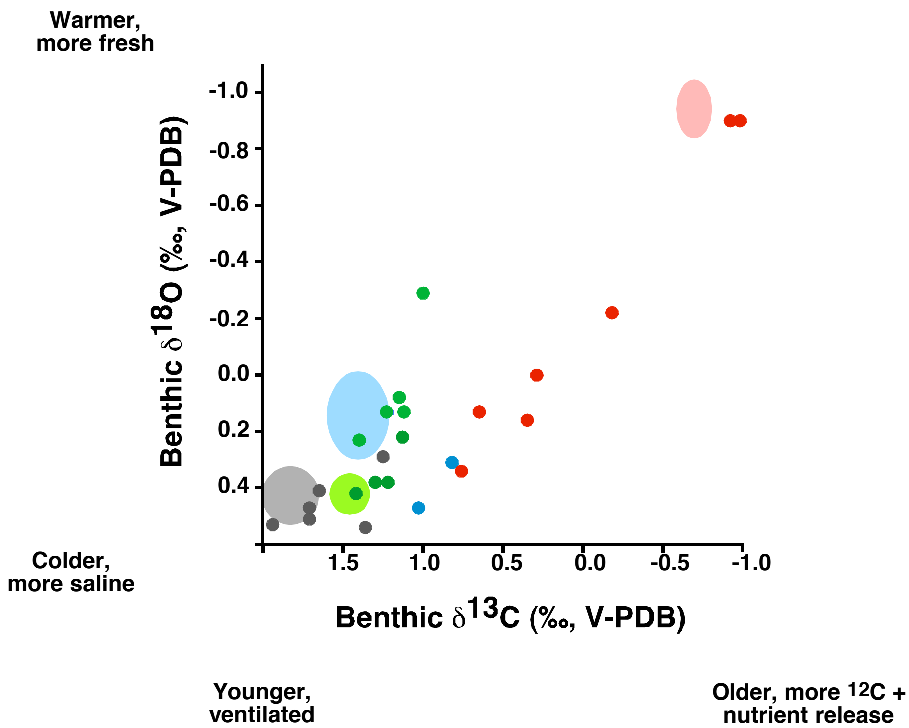
Materials and Methods

Stable isotope ratios were determined on between 1 and 15 individuals of *Nutallides truempyi* on a Micromass Multicarb Sample Preparation System attached to a PRISM gas source mass spectrometer. Measurements are reported relative to the V-PDB standard, and the analytical precision was better than 0.08‰. High-precision trace element ratios were determined on between 1 and 15 foraminifera on a Varian Vista ICP-OES (*1*). Both single foraminifera and samples comprised of multiple foraminifera were analysed across the PETM interval. Foraminiferal samples were cleaned and analysed for trace elements using a technique similar to ref. 2 and described in references therein. Long-term analytical precision of liquid standards (reported as %RSD) is ±0.4% for both Mg/Ca and Sr/Ca. Replicates of two foraminiferal standards that were processed and analysed to determine both cleaning reproducibility and sample heterogeneity yield an uncertainty of ±2.7% for Mg/Ca and ±2.5% for Sr/Ca.

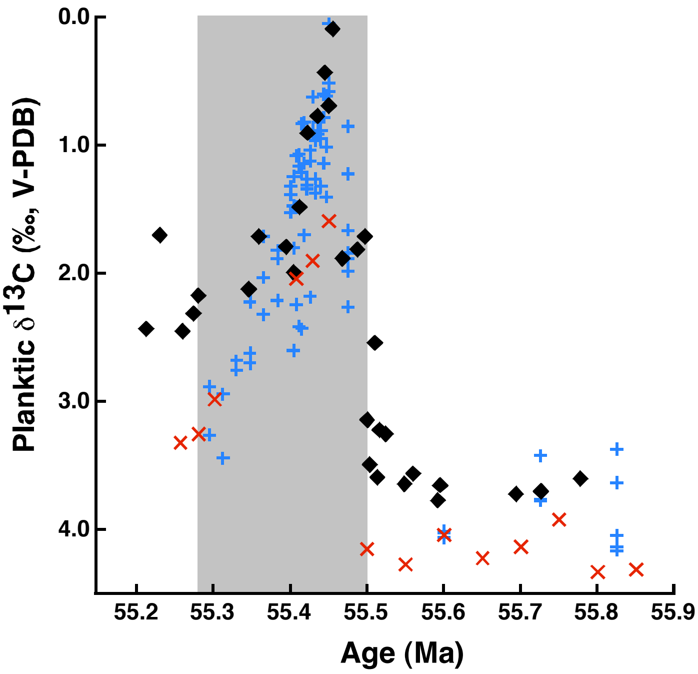
Our initial objective for reconstructing deep-sea temperatures and high-latitude sea surface temperatures was to apply the Mg/Ca paleotemperature proxy to benthic foraminifera in all samples and to planktonic foraminifera from high-latitude sites. A set of samples from each site was screened to determine whether reliable foraminiferal Mg/Ca ratios could be obtained using standard cleaning protocols and if a reductive cleaning step was necessary in sample preparation. Measured Mg/Ca ratios in foraminiferal carbonate can be biased by the presence of clays, detrital grains, adhered carbonates, secondary carbonates and overgrowths, and other contaminant phases. These can be detected using trace element/calcium ratios (including Al/Ca, Fe/Ca, Mn/Ca, Si/Ca, Sr/Ca, and Zn/Ca). Planktonic and benthic foraminiferal samples from ODP Sites 690, 738 and 1051 did not pass our screening criteria or yield reliable values, irrespective of whether a reductive cleaning step was included.

A source of uncertainty in Mg/Ca-based temperatures arises from a possible saturation state effect on Mg incorporation into benthic foraminifera tests (*12-13)*. The decrease in deep-sea carbonate saturation across the PETM may cause us to underestimate peak temperatures by 1-2°C (*14)*; calculations assume ΔT_B = 4-5°C. We assume dissolution is unlikely to pose a significant artefact in these records because benthic foraminifera in the deep ocean can calcify in waters undersaturated with respect to carbonate ion, and have tests that should be relatively homogenous in trace elements.


Sea surface temperature (°C)
35.0
34.0
33.0
32.0
31.0
30.0
29.0
Planktic Mg/Ca (mmol/mol)
6.00
5.50
5.00
4.50
4.00
3.50
3.00
Thermocline temperature (°C)
35.0
34.0
33.0
32.0
31.0
30.0
29.0
Planktic Mg/Ca (mmol/mol)
5.50
5.00
4.50
4.00
3.50
3.00
55.20
55.30
55.40
55.50
55.60
55.70
55.80
55.90
Age (Ma)



Warmer,
more fresh
Colder,
more saline
Benthic δ18O (‰, V-PDB)
-1.0
-0.8
-0.6
-0.4
-0.2
0.0
0.2
0.4
1.5
1.0
0.5
0.0
-0.5
-1.0
Benthic δ13C (‰, V-PDB)
Younger,
ventilated
Older, more 12C +
nutrient release



Planktic δ13C (‰, V-PDB)
0.0
1.0
2.0
3.0
4.0
55.2
55.3
55.4
55.5
55.6
55.7
55.8
55.9
Age (Ma)

Figure Captions

Fig. S1: High-resolution planktonic foraminiferal Mg/Ca records across the PETM and corresponding temperature scale for the tropical Pacific Ocean (*3-4*). Upper panel shows record for mixed-layer dwelling species *Morozovella velascoensis* (blue diamond: ODP Site 865; black diamond: ODP Site 1209) and *Acarinina soldadiensis* (blue triangle: ODP Site 865; black triangle: ODP Site 1209). Bottom panel shows record for thermocline-dwelling *Subbotina* spp. (ODP Site 865).

Fig. S2: Cross-plot of benthic foraminiferal $\delta^{13}C$ and $\delta^{18}O$ across the PETM, comparing values for Walvis Ridge (small circles: DSDP Site 527) to Maud Rise (shaded ellipse: ODP Site 690) during different time intervals (grey: Late Paleocene; green: Latest Paleocene; red: PETM; blue: Earliest Eocene).

Fig. S3: High-resolution planktonic foraminiferal $\delta^{13}C$ stratigraphies for sites with Mg/Ca records across the PETM (black diamond: DSDP Site 527; blue cross: ODP Site 1209; red cross: ODP Site 865). Planktonic foraminiferal $\delta^{13}C$ data are derived from *Acarinina* spp. (*3-6)*.

Table S1: Site information for Deep-Sea Drilling Project (DSDP) and Ocean Drilling Program (ODP) localities investigated in this study.

Site	Location	Lat.	Long.	Depth (m)	Paleolat.	Paleodepth (m)	Passed Mg/Ca criteria
DSDP Site 527[1]	Walvis Ridge	28°2'S	1°46'E	4428	35°S	3400	Yes
ODP Site 865[1]	Allison Guyot	18°26'S	17°33'W	1530	2°N	1300	Yes
ODP Site 1209[2]	Shatsky Rise	32°39'N	158°30'E	2387	15-20°N	2400	Yes
ODP Site 690[1]	Maud Rise	65°10'S	1°13'E	2914	65°S	1900	No
ODP Site 738	Kerguelen Plateau	62°43'S	82°47'E	2252			No
ODP Site 1051	Blake Nose	30°03'N	75°21'W	1983			No

*Described in Materials and Methods

[1]Paleolatitude and depth from ref. 5

[2]Paleolatitude and depth from ref. 7

Table S2: Change in slope of $\Delta\delta^{18}O/\Delta T$ before the PETM (between the Late Paleocene and Latest Paleocene), indicating a change in the salinity contrast between the S. Atlantic and N. Pacific.

	$\Delta\delta^{18}O/\Delta T$	ΔSalinity
S. Atlantic	0.17	Negative
N. Pacific	0.29	Positive

Table S3: Ages and depths used to construct age models for DSDP Site 527[5, 8-10] and ODP Sites 865[5, 9, 11] and 1209[4, 7, 12].

Datum	Age (Ma)	Site 527 (mbsf)	Site 865 (mbsf)	Site 1209 (mcd)
Fasculithes tympaniform LAD	55.00	189.00	100.9	209.95
CIE recovery	55.28	200.10	102.1	210.76
CIE peak	55.45	200.77	102.9	212.24
CIE base	55.50	201.08	103.0	211.26
Discoaster multiradiatus FAD	56.20	220.75	114.6	220.66

SOM References

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