Glacial Climate in the Tropics:

Ca Isotopes as a Recorder for Past Sea Surface Temperatures

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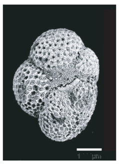
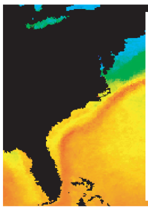
Introduction



We present palaeo-sea surface temperature (SST) changes from the Equatorial Atlantic based on δ^{44}Ca of the planktonic foraminifera ***Globigerinoides sacculifer***. The frequently discussed question of the amount of tropical temperature change in the upper water column at the Holocene-Last Glacial Maximum (LGM) boundary gave a strong impetus for the current work.

Significance



Sea surface temperature is among the most important variable for Earth's climate system. It influences

- sea-air gas exchange
- global heat transfer
- evaporation-precipitaion patterns
- primary biological production
- continental ice masses
- deep sea circulation

Calcium isotope basics

Thermal Ionisation Mass Spectrometry (TIMS)

^{43}Ca-^{48}Ca double spike technique

δ-notation: $\delta^{44}Ca = \left[\frac{^{44}Ca/^{40}Ca_{\ sample}}{^{44}Ca/^{40}Ca_{\ normal}} - 1\right] * 1000$

Standardisation: Δ(SRM 915a-Seawater) = -1.88 ± 0.04

Δ(SRM 915a-CaF_2) = -1.44 ± 0.04

Magnitude of Cooling in the Tropics

Termination I (Holocene-LGM)

SST_{CLIMAP}	1-2°C	global	faunal assemblages	CLIMAP Members 1981
SST	3°C	tropical oceans	δ18O, alkenone	see W.Broecker 1996
SST_{GCM}	3.3°C	tropical Atlantic	GCM	Ganopolski 1998
SST	4°-5°C	SW of Barbados	Sr/Ca (corals)	Guilderson et al. 1994
Temperature	4°-6°C	global, Brazil	snowline, noble gas	Stute et al. 1995, Rind et al. 1985

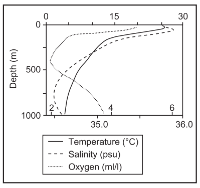
Eastern Equatorial Atlantic (GeoB1112)

$SST_{\delta 44Ca}$	**2.5-4.0°C**	our study
$SST_{Mg/Ca}$	**3°C**	Nürnberg et al. 2000

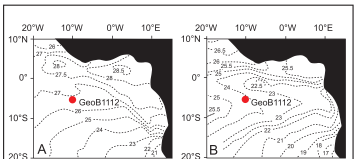
Equatorial Pacific

$SST_{Mg/Ca}$	3°C	Lea et al. 2000
$SST_{Mg/Ca}$	3.5-4°C	Visser et al. 2003

Oceanographic background of core GeoB1112

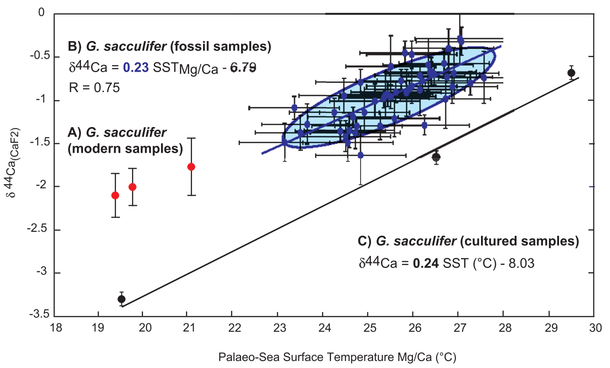


Core GeoB1112 is located in the low productive South Equatorial Current and was recovered from the Guinea Basin from 3125m water depth (5°46.7'S, 10°45.0'W). Average sedimentation rate is 3.0 cm/kyr.



Surface water temperatures in the equatorial Atlantic for February (A) and July (B). Note that the eastern equatorial region is relatively warm in February, that is, temperatures follow seasons of the southern hemisphere.

δ^{44}Ca-Thermometry based on *G. sacculifer*



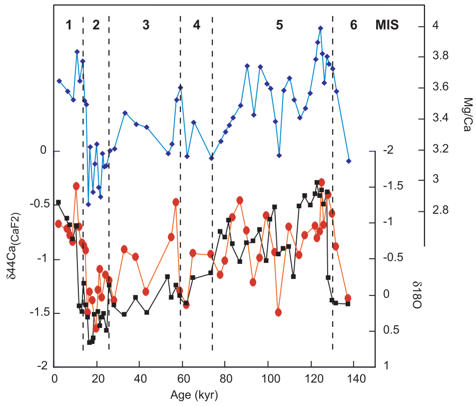
A) Preliminary δ^{44}Ca ratios of modern *G. sacculifer* B) The SST(Mg/Ca)-cross-calibrated thermometer based on fossil *G. sacculifer* support the refined calibration (A) in slope and absolute temperatures. C) The δ^{44}Ca ratios of *G. sacculifer* cultured under controlled temperature conditions (Nägler et al. 2000). The temperature gradients are identical. However, there is an apparent offset of approximately 3.5°C in absolute temperature. (A) and (B) tend to predict lower sea surface temperatures than (C). The most probable reason is that cultured samples are biased.

Conclusion

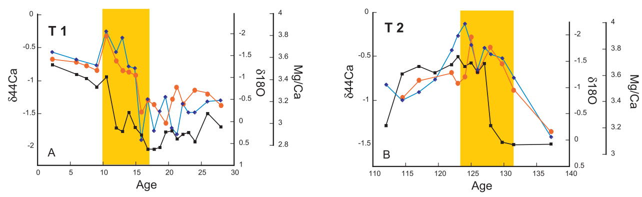
- δ^{44}Ca in *G. sacculifer* is a promising **sea surface temperature-proxy**
- A possible **key** to estimate more **climate relevant variables**
- Overall **glacial-interglacial amplitude** of δ^{44}Ca is 0.6-0.8 permil
- **Intermediate temperature changes** at Terminations I and II (2.5 to 4°C)
- SST-records (δ^{44}Ca, Mg/Ca) lead the δ^{18}O signal:

Warming predates melting

Down-core variations on fossil *G. sacculifer* (GeoB1112): A multi-proxy comparison in the tropical East Atlantic



The δ^{44}Ca (red) and corresponding Mg/Ca ratios (blue, Nürnberg et al. 2000) of *G. sacculifer* from sediment core GeoB1112 versus time. Both records show glacial/interglacial fluctuations predicting higher SSTs during interglacial and lower SSTs during glacial periods. The oxygen isotope record also derived from *G. sacculifer* is added for a multi-proxy comparison. It is obvious that the δ^{44}Ca and Mg/Ca records are leading the δ^{18}O signal. This means that warming occurs prior to ice melting by several thousend years. Dashed lines mark the transition between marine isotope stages.



G. sacculifer Ca isotope (orange), Mg/Ca (blue) and oxygen isotope (black) records for GeoB1112 plotted versus time for MIS 1 and 2 (A) and MIS 5e and 6 (B). For both terminations, in equatorial Atlantic the sea surface temperature warming occurs several thousand years before the decrease in ice volume reflected by the oxygen isotope record. Pronounced temperature increase to interglacials (f.e. MIS 5e) seems to be characterised by a double peak.

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