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Final Report

for Research proposal:

***Late Pliocene millennial-scale fluctuations in SST and stratification  
within the North Atlantic***

## 1. Introduction

The Pliocene to early Pleistocene (5.6–1.8 Ma) represents in many ways a key interval of Cenozoic palaeoceanography, including two major changes of the Earth system: the significant glaciation of the northern hemisphere, culminating in a major expansion of Arctic ice sheets (Northern Hemisphere Glaciation, NHG) and the closure of the Panama Gateway. The impact of changes associated with the NHG on surface-water hydrology (SST and stratification) of the subpolar North Atlantic is, however, not fully understood. Given its proximity to the large dynamic ice-sheets of the northern hemisphere and the role in deep-water formation, however, the North Atlantic represents one of the climatically sensitive regions on Earth.

This study focuses on the combination of Mg/Ca and  $\delta^{18}\text{O}$  analyses on planktic foraminifera in order to understand and reconstruct climate variability during the final stage of the NHG, especially marine oxygen isotope stages (MIS) 103-95 (early Pleistocene, 2.6 to 2.4 Ma). In particular, this is relevant to better understand fluctuations in the magnitude of SST and stratification changes and their link to the intensification of NHG.

## 2. Material and methods

IODP Site 1313 constitutes a reoccupation of DSDP Site 607, originally drilled during Leg 94 [Ruddiman *et al.*, 1987]. Site 1313 gives us the opportunity to construct continuous records from the subpolar North Atlantic during the large amplitude obliquity-paced glacials of the Pliocene intensification of NHG. Site 1313 is located at the base of the upper western flank of the Mid-Atlantic Ridge at a water depth of 3426 m, (latitude 41°N, longitude 32.5°W). It therefore is under direct influence of North Atlantic Deep Water and lies on the southerly limit of the so-called 'IRD belt' [Ruddiman, 1977].

30 individuals of *Globorotalia crassaformis* were picked from the early Pleistocene samples in a 2 cm resolution (equivalent to the samples of the *G. ruber*  $\delta^{18}\text{O}$  dataset in Figs. 1-3) for MIS 103-95. They were picked in a very narrow size fraction (315-355  $\mu\text{m}$ ) to avoid ontogenetic effects. Picking was carried out at the Goethe University Frankfurt between July and November 2011 prior to the research visit in Southampton. Before measuring, all individual specimens were cracked and homogeneously mixed. Cracked samples were then separated into two halves to allow for paired stable isotope and Mg/Ca measurements on the same material.

Cleaning and measuring for Mg/Ca analyses was carried out at the National Oceanography Centre, Southampton (NOCS) during 6<sup>th</sup> and 24<sup>th</sup> November 2011. Cleaning followed the protocol of Boyle and Keigwin [1985] to remove clays and organic matter but with the reductive cleaning step omitted. The reductive step was omitted because the reducing reagent is corrosive to carbonate, possibly causing partial dissolution of the tests and therefore lower Mg/Ca values [Barker *et al.*, 2003]. After cleaning, samples were analysed using a Perkin Elmer Optima 4300DV Inductively Coupled Plasma-Optical Emission Spectrometer (ICP-OES) at NOCS.

Stable isotope were measured at the Goethe Universität Frankfurt between January and April 2012 using a Finnigan MAT 253 mass spectrometer coupled to a GasBench II for automated analyses.

3. Results

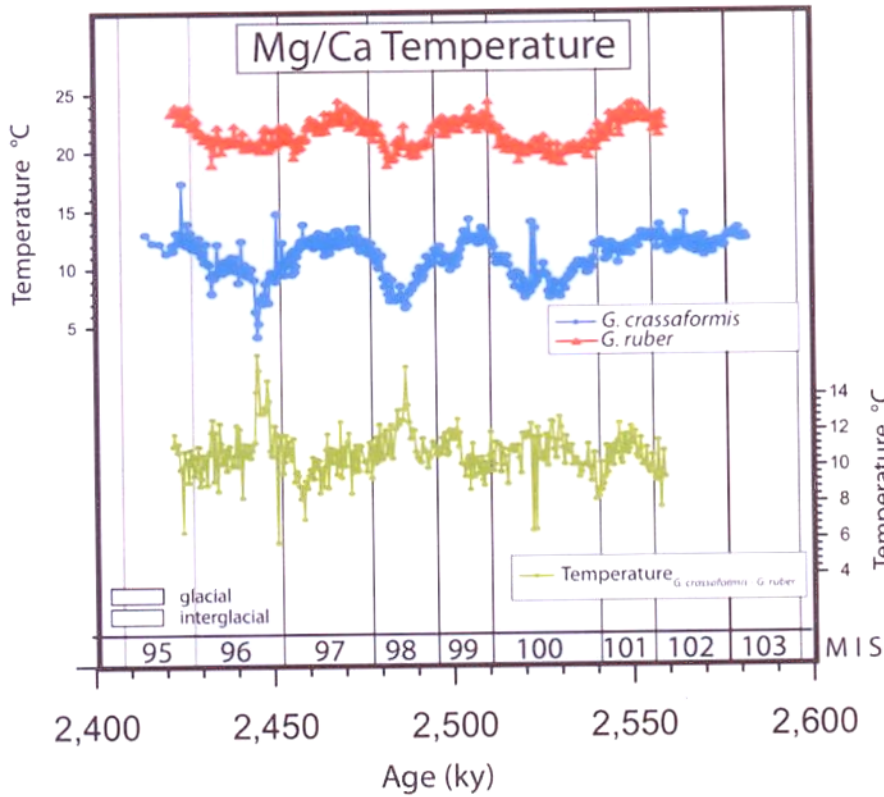


Fig. 1 *G. ruber* (measured by Friedrich et al. [subm.] and *G. crassaformis* (this study) Mg/Ca temperature estimates from Site U1313. Mg/Ca temperatures were calculated by using the species specific equation of Regenberg et al. [2009] (*G. crassaformis*) and Anand et al. [2003] (*G. ruber*).

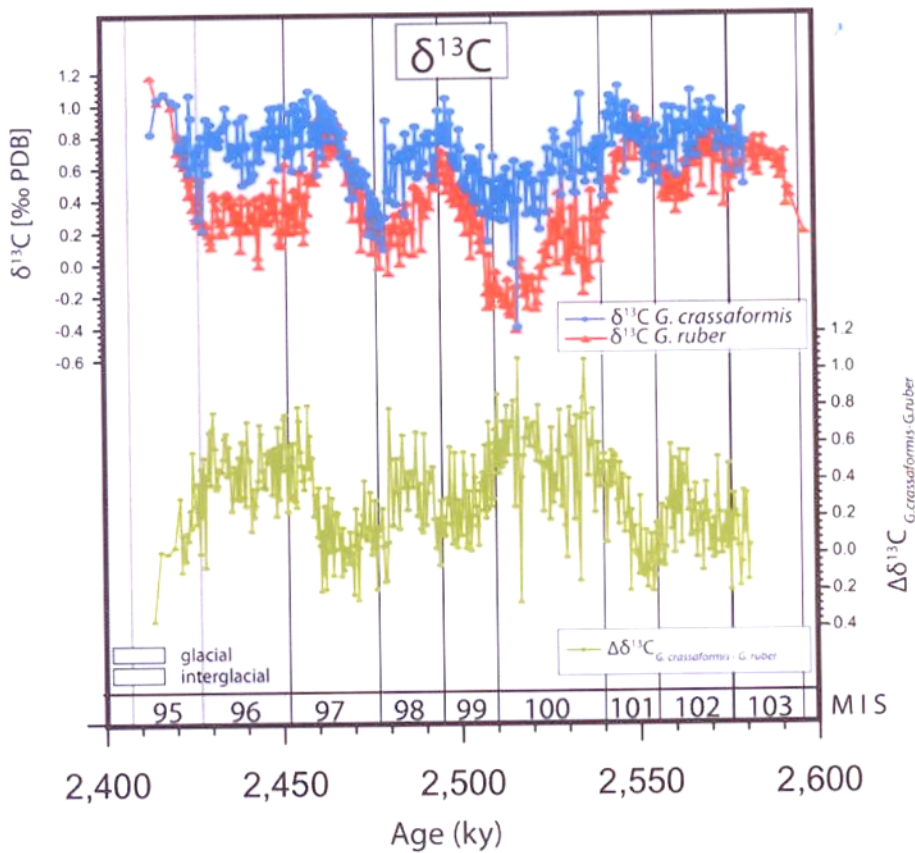
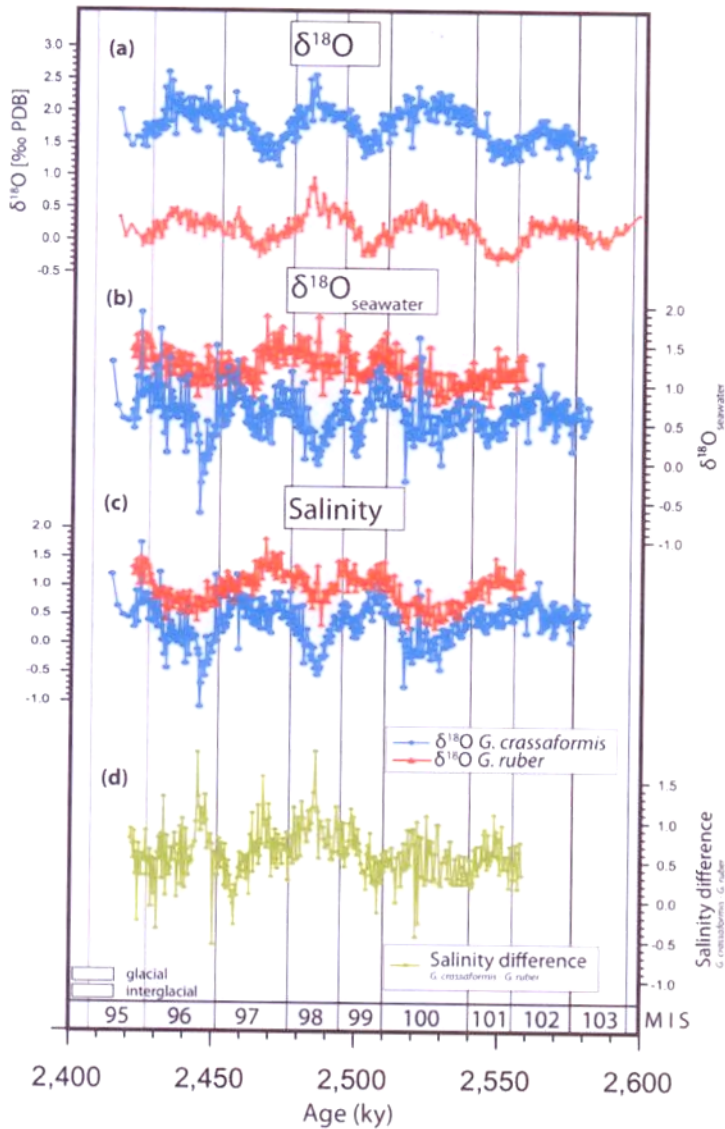


Fig. 2 *G. crassaformis* and *G. ruber* δ<sup>13</sup>C values from Site U1313. In green: difference between δ<sup>13</sup>C of *G. crassaformis* and *G. ruber*.





**Fig. 3** High-resolution records from Site U1313 for MIS 103 to 95 (2.6 to 2.4 Ma). The age model is based on benthic isotope stratigraphy [Bolton *et al.*, 2010] tuned to the LR04 isotope stack [Lisiecki and Raymo, 2005]. All *G. ruber* measurements are from Friedrich *et al.* [subm.]. (a) *G. crassaformis* (blue) and *G. ruber*  $\delta^{18}\text{O}$  (red) from Site U1313. (b)  $\delta^{18}\text{O}_{\text{seawater}}$  calculated with  $\delta^{18}\text{O}$  of *G. crassaformis* and *G. ruber*, respectively, by using the equation of [Bemis *et al.*, 1998]:  $T(^{\circ}\text{C}) = 16.5 - 4.81(\delta^{18}\text{O} - \delta^{18}\text{O}_{\text{seawater}})$ . Paired Mg/Ca measurements make it possible to estimate the temperature at which the foraminiferal test was precipitated by using the same phase as for  $\delta^{18}\text{O}$ . (c) Salinity signal ( $\delta^{18}\text{O}_{\text{ivc-seawater}}$ ) calculated by subtracting the normalized LR04 benthic stack (representing the ice volume signal) from the  $\delta^{18}\text{O}_{\text{seawater}}$  record. (d) Salinity signal of *G. crassaformis* subtracted from the salinity signal of *G. ruber*. This represents the difference in salinity between surface and intermediate water masses.

### Preliminary conclusions

- ▶ relatively stable conditions in surface water temperatures while intermediate waters show strong temperature fluctuations on a glacial-interglacial time scale (Fig. 1)
- ▶ salinity and temperature difference between surface and intermediate water is greater in glacials than interglacials (Fig. 1, Fig. 2)
- ▶ this reflects changing intermediate water masses between glacials and interglacials: during interglacials deeper waters are influenced by enhanced North Atlantic Deep Water (NADW) formation in high latitudes, whereas during glacials NADW influence at Site 1313 is reduced and a different intermediate water mass influences this site (Glacial North Atlantic Intermediate Water, GNAIW)

**4. Accounting of Expenditures** (see attachement for more details)

**4.1. Research visit to National Oceanography Centre Southampton (Great Britain)**

(cleaning of Mg/Ca samples; Mg/Ca analyses)

06th Nov 2011 – 24th Nov 2011

Travel expenses

246.79€

Hotel for 18 nights

756.45€

Lunch at National Oceanography Centre

177.29€

**4.2. Isotopic measurements (Goethe Universität Frankfurt) and Mg/Ca measurements (National Oceanography Centre, Southampton)**

January – April 2012

Isotopic measurements

419 samples á 5€: 2095€.

Please note that we measured more than the originally planned 230 samples. This had been agreed to in advance by the ESSAC chair, provided that the additional costs were funded otherwise. We thus spent considerably more money than was granted. The additional costs for both the isotopic measurements and Mg/Ca measurements that exceeded the permitted money of 1950€ were fully paid for by money granted to the proponents supervisor, O. Friedrich.

## 5. Acknowledgements

I thank the ESSAC committee for providing the financial support that enabled my visit to the National Oceanography Centre, Southampton.

I thank Paul Wilson and Matthew Cooper from the NOCS who facilitated my research visit and for their kind assistance in the laboratory.

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