Calcification depth of deep-dwelling planktonic foraminifera from eastern North Atlantic

Andreia Rebotim[1, 2], Antje H. L. Voelker[2, 3], Lukas Jonkers[1], Joanna J. Waniek[4], Michael Schulz[1], Michal Kucera[1]

[1] DivGM, IPMA, Av. de Brasília 6, 1449-006 Lisboa, Portugal

[2] CIIMAR, Rua dos Bragas, nº289, 4050-123 Porto, Portugal

[3] MARUM – Center for Marine Environmental Sciences, University of Bremen, Leobener Strasse, D-28359 Bremen, Germany

[4] Leibniz Institute for Baltic Sea Research, Warnemünde, Seestrasse 15, D-18119 Rostock, Germany

*E-mail: andreia.rebotim@ipma.pt

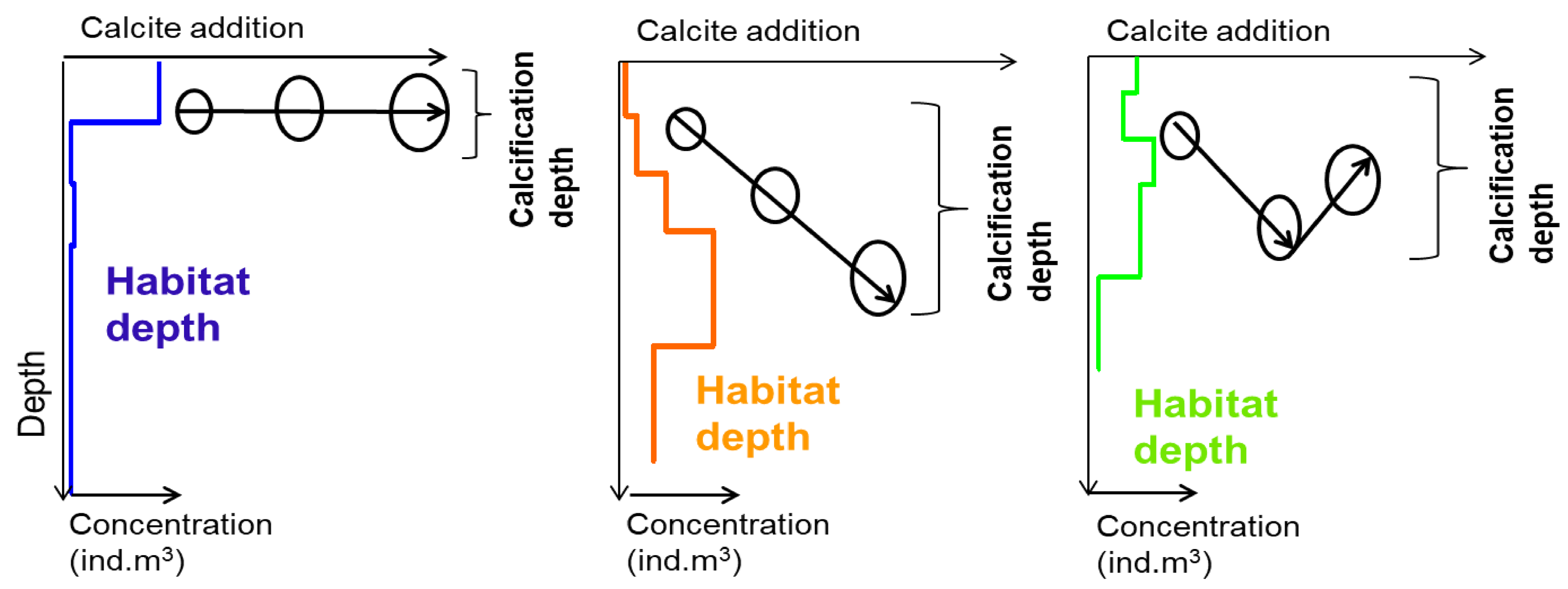
Motivation

- Stable oxygen isotopes ($\delta^{18}O$) of planktonic foraminifera are one of the most used tools to reconstruct environmental conditions of the water column.
- Different species live and calcify at different depths in the water column → $\delta^{18}O$ from different species can provide information on the vertical structure of the water column.
- In this context, deep-dwelling species calcification depth reaches below the surface mixed layer.
- To unlock the potential of deep-dwelling planktonic foraminifera as recorders of subsurface water conditions, it is necessary to understand how and under what conditions the environmental signal is incorporated into the calcite shells.

How is habitat depth connected with calcification depth? Does calcification depth coincide with maximum abundance depth?

Here we report $\delta^{18}O$ measurements on four deep-dwelling *Globorotalids* species collected with stratified plankton tows in the Eastern North Atlantic.

Calcification depth vs habitat depth



Species live and calcify at the same depth

Vertical ontotogenic migration occurs on a monotonously descending trajectory and continuous calcification

Calcification occurs at all depths independently of its living depth

How $\delta^{18}O$ changes with depth for each species?

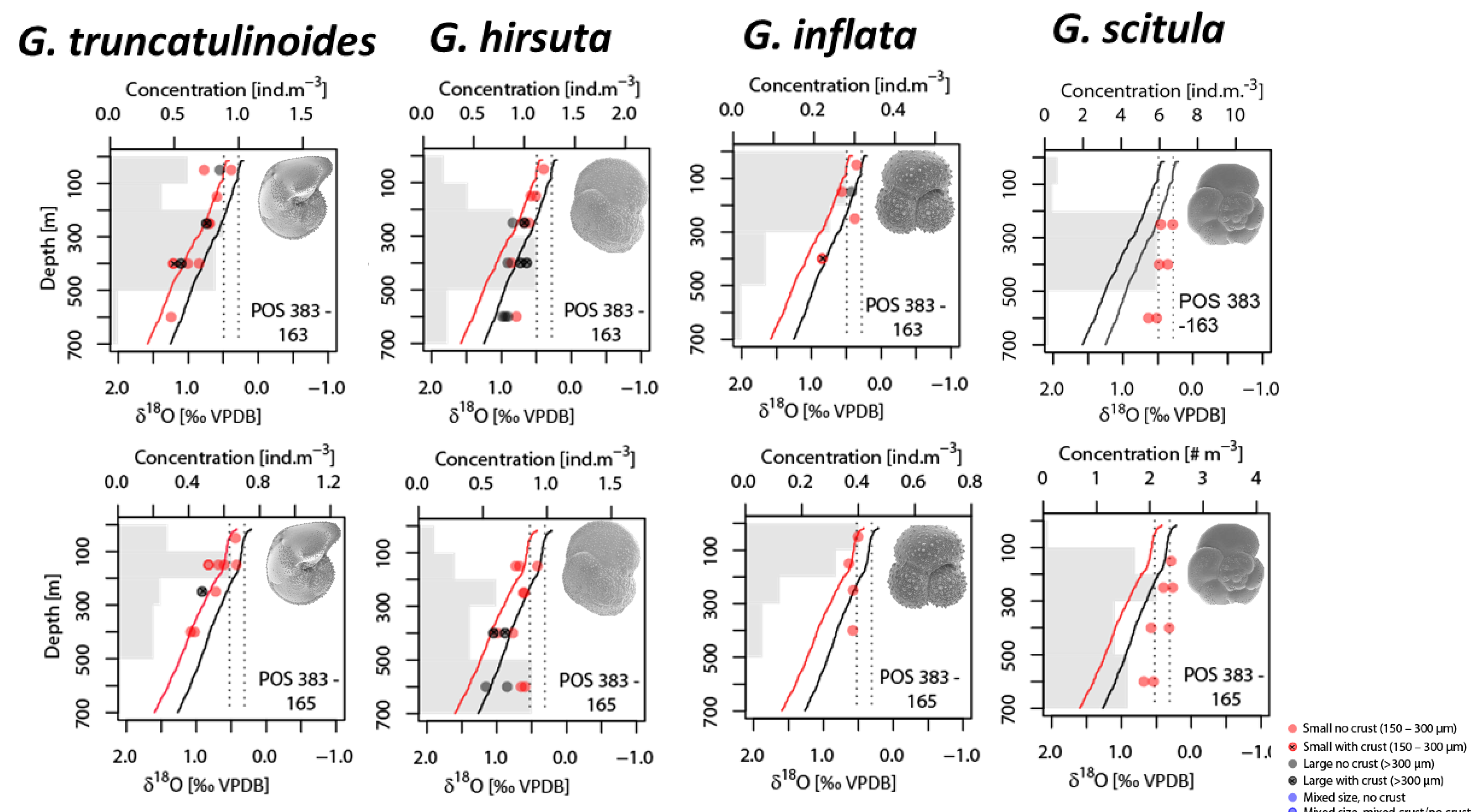


Fig. 3 Vertical profiles of $\delta^{18}O$ and concentration (grey bars, ind/m³). Red line shows $\delta^{18}O_{eq}$ for calcite based on the Shackleton (1974) equation, black line shows the same using the Kim and O'Neil (1997) equation. Dashed lines indicate the mean $\delta^{18}O_{eq}$ values of the upper 100 m.

- Inferred calcification depths differ from the observed dominant living depths for all species
- *G. truncatulinoides* maximum abundances in the upper 200 m but calcification occurs in equilibrium until 500 m.
- Highest abundances for *G. hirsuta* below 300 m, yet it calcifies throughout the top 500 m.
- *G. inflata* has higher abundances near the surface, but continues to calcify down to 300 m.
- *G. scitula* is most abundant between 200-300 m, but its isotopic signal derive from shallower depth.

References: Rebotim, A., Voelker, A. H. L., Jonkers, L., Waniek, J. J., Schulz, M., and Kucera, M.: Calcification depth of deep-dwelling planktonic foraminifera from the eastern North Atlantic constrained by stable oxygen isotope ratios of shells from stratified plankton tows, JM, 38, 113–131, 2019. Kim, S.-T. and O'Neil, J. R.: Equilibrium and nonequilibrium oxygen isotope effects in synthetic carbonates, Geochim. Cosmochim. Acta, 61(16), 3461–3475, 1997. Rebotim, A., Voelker, A. H. L., Jonkers, L., Waniek, J. J., Meggers, H., Schiebel, R., Fraile, I., Schulz, M. and Kucera, M.: Factors controlling the depth habitat of planktonic foraminifera in the subtropical eastern North Atlantic, Biog., 14(4), 827, 2017. Shackleton, N. J.: Attainment of isotopic equilibrium between ocean water and the benthonic foraminifera genus Uvigerina: Isotopic changes in the ocean during the last glacial, Colloq. Int. du C.N.R.S., 219, 203–210, 1974. Voelker, A. H. L., Colman, A., Olack, G., Waniek, J. J. and Hodell, D.: Oxygen and hydrogen isotope signatures of Northeast Atlantic water masses, Deep. Res. Part II, 1–18, 2015.

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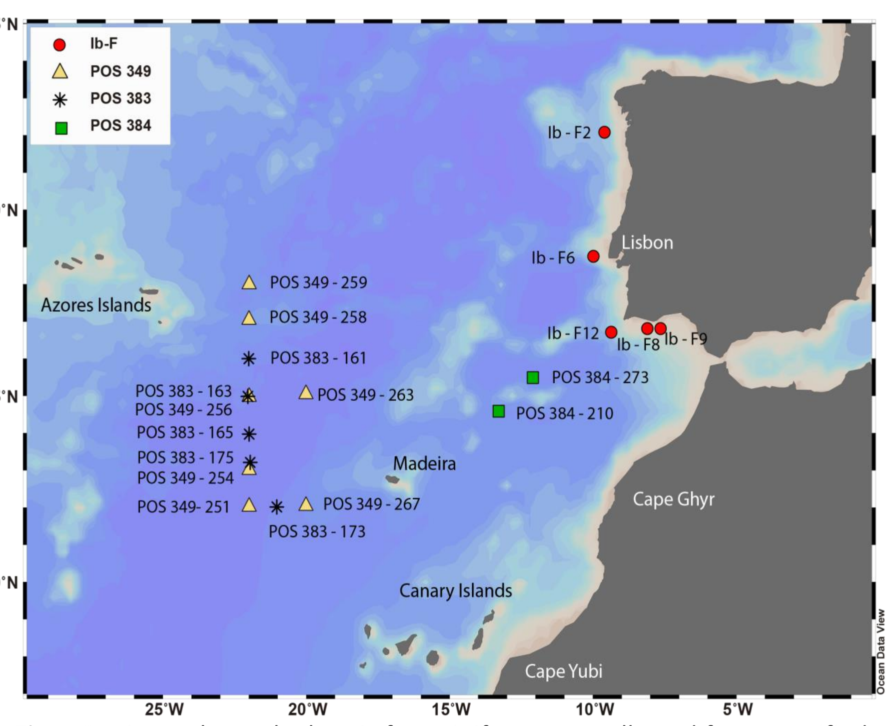


Fig 1. Stations where planktonic foraminifera were collected from stratified plankton hauls. Station symbols are coded by cruises.

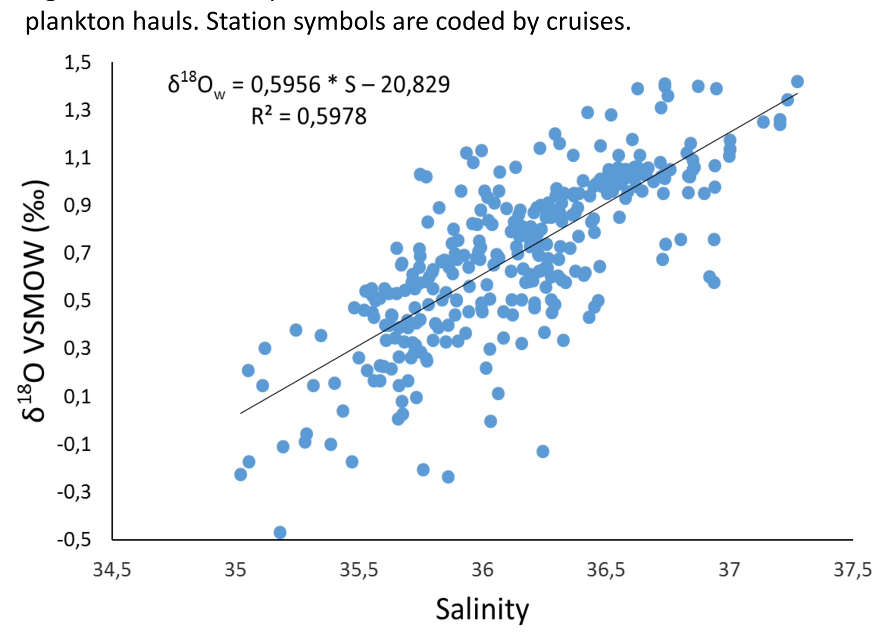
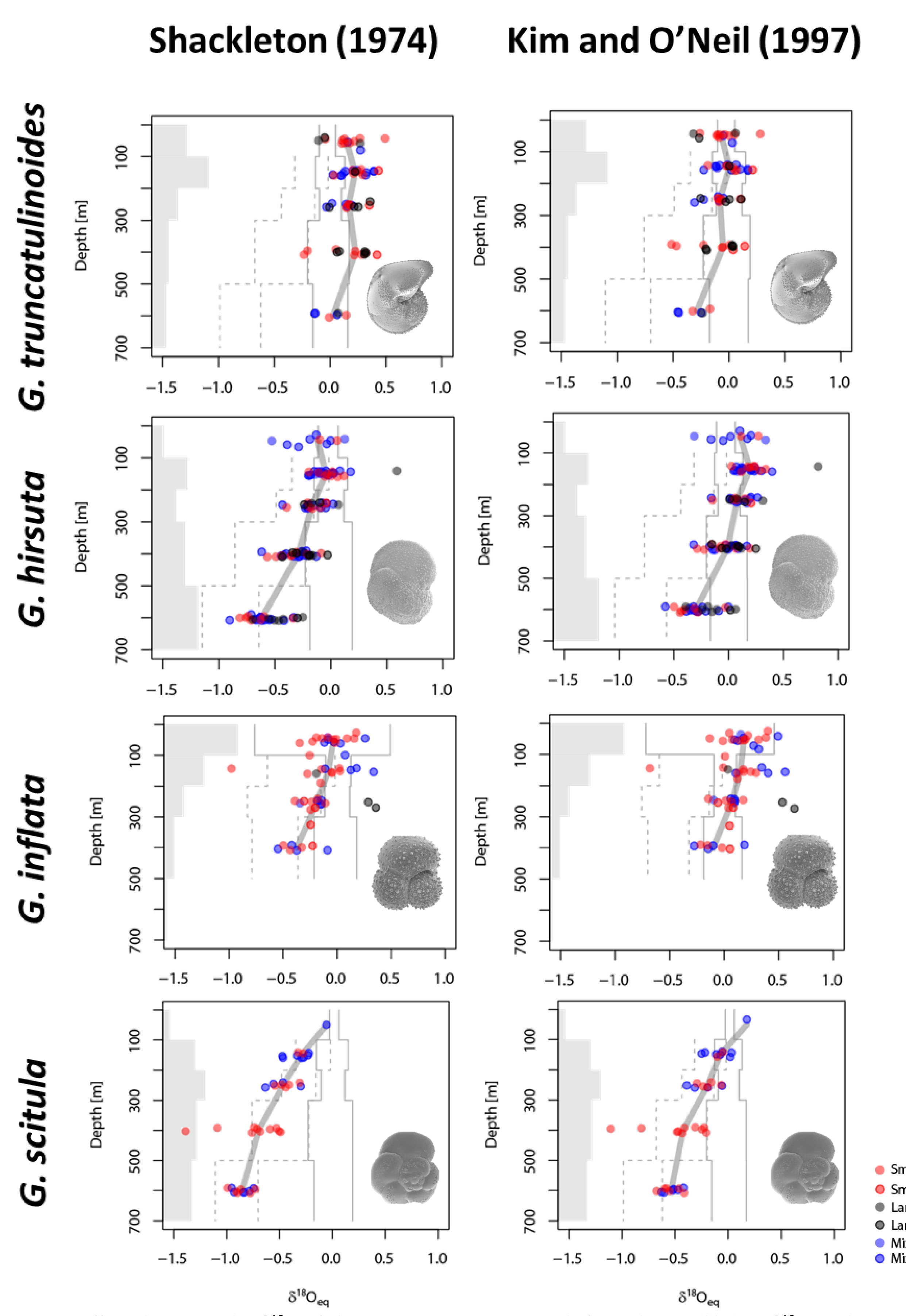


Fig 2. Regional linear regression of salinity versus $\delta^{18}O_w$ for the eastern North Atlantic Ocean.

Methods

- Samples collection occurred during four oceanographic campaigns between 2007 and 2012 (Fig. 1), with a Hydrobios Midi/Maxi multiple closing net hauled vertically. After collection, content from each net was transferred to a flask, preserved and refrigerated.
- Cytoplasm-bearing shells of planktonic foraminifera were picked from two size fractions (150 – 300 µm – small and >300 µm – large).
- Stable oxygen isotope measurements were performed using a Finnigan MAT 251 isotope ratio mass spectrometer coupled to a Kiel I or Kiel III automated carbonate device.
- Seawater $\delta^{18}O$ was established using a regional $\delta^{18}O_w$ – salinity relationship based on previous measurements in the study area (25°N to 45°N and 5°W to 35°W) (Voelker et al., 2015), covering the top 700 m of the water column (Fig.2).

Which paleotemperature equation fits to each species?



G. truncatulinoides $\delta^{18}O$ values are better estimated by Shackleton $\delta^{18}O_{eq}$

$\delta^{18}O$ values of *G. hirsuta* are more approximated to Shackleton $\delta^{18}O_{eq}$

$\delta^{18}O$ values of *G. inflata* are more approximated to Shackleton estimation

G. scitula's $\delta^{18}O$ values are better predicted by Kim and O'Neil equation

Small no crust (150 – 300 µm)
Small with crust (150 – 300 µm)
Large no crust (>300 µm)
Large with crust (>300 µm)
Mixed size, no crust
Mixed size, mixed crust/no crust

Fig. 4 Offsets between the $\delta^{18}O$ of the species at a given depth from the equilibrium $\delta^{18}O$ at that depth calculated using each paleotemperature equation. Solid lines represent the range of $\delta^{18}O_{eq}$ at each depth across all stations. Thick grey line - median profile of $\delta^{18}O$ offsets Relative shell concentrations across all stations where the respective species are indicated with the grey bar plots.

Conclusions

- **All the species $\delta^{18}O$ values are more approximated to Shackleton prediction except for *G. scitula* value's which are more consistent with Kim and O'Neil equation.**
- ***G. truncatulinoides* $\delta^{18}O$ pattern does not appear to be associated with ontogenetic migration which implies that its sedimentary signal is dominated by the depth and season where they are more abundant.**
- **In contrary, *G. hirsuta* $\delta^{18}O$ values are consistent with ontogenetic migration.**
- **Despite the higher abundances of *G. scitula* being found at the subsurface, its oxygen isotopic signal reflects the surface layer**
- **Some discrepancies between habitat and calcification depth in some of the species highlight the need to understand the causes and effects of these differences → the knowledge of both is needed to interpret the geochemical signals from the sediments.**

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