Latest Cretaceous foraminiferal ecology and palaeoceanographic inferences from chamber-specific LA-ICPMS analysis.

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Motivations

- Recent work (e.g. Henehan et al. 2019, Woelders et al. 2018) has demonstrated the potential for application of boron isotope and trace element proxies to late Cretaceous foraminifera.

- However, to get accurate sea surface temperature and pCO_2 estimates, we need to know which species to use, and what imprint their physiology may impart on their recorded proxy signals, as 'vital effects'.

Motivations

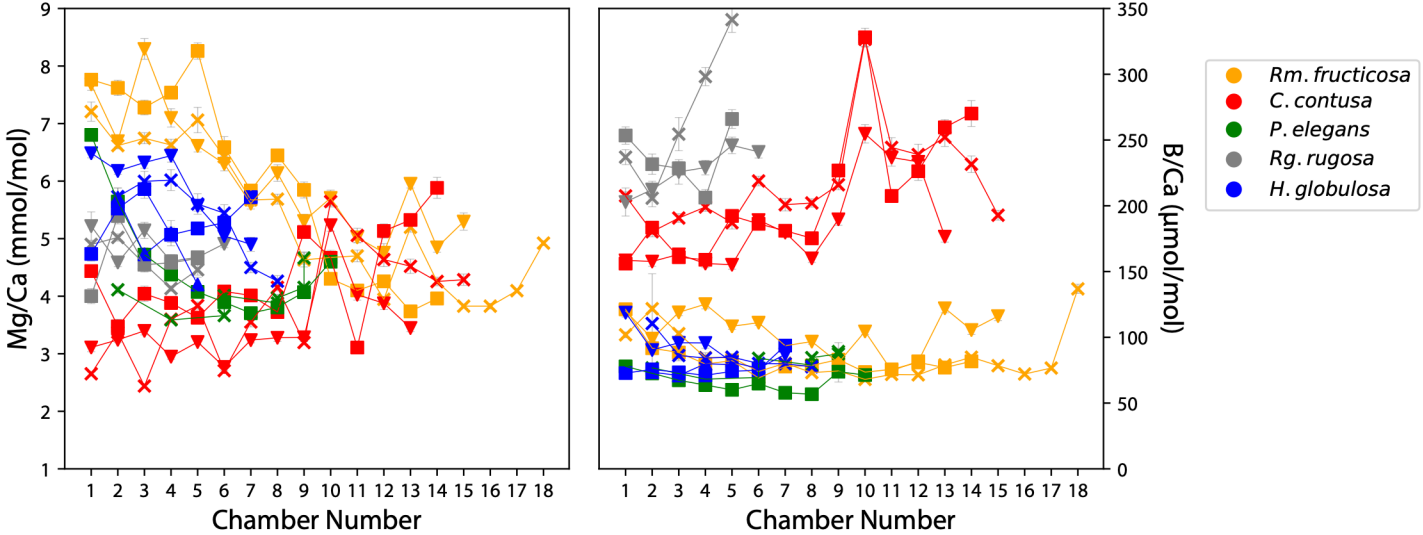
- Numerous studies have used $\delta^{18}O$ and $\delta^{13}C$ to infer depth ranking, symbiosis and calcification pathways.
- However results are often contradictory:
  - relative depth habitats vary considerably within studies (e.g. Abramovich et al. 2003)
  - Inferences for symbiosis (e.g. *R. rugosa*, Abramovich et al. 2003) are often countered by other studies (e.g. D'Hondt and Zachos 1993, Falzoni et al. 2014)

- Since calibration of foraminiferal boron isotopes is key (e.g. Henehan et al. 2016, 2020), this makes CO2 reconstruction more difficult.

Approach

- LA-ICPMS analysis, chamber-by-chamber (see Evans & Müller (2018), Müller et al. (2009) for methods)
- Allows resolution of ecophysiology similar to serial test dissection
- Mg/Ca: potentially less susceptible to ontogenetic fractionation and diagenesis than $\delta^{18}O$
- B/Ca: which in modern foraminifera is typically higher in symbiotic planktics and lower in symbiont-barren species
- Compare to solution measurements & measurements of $\delta^{11}B$.

Representative Results: ODP Site 1049

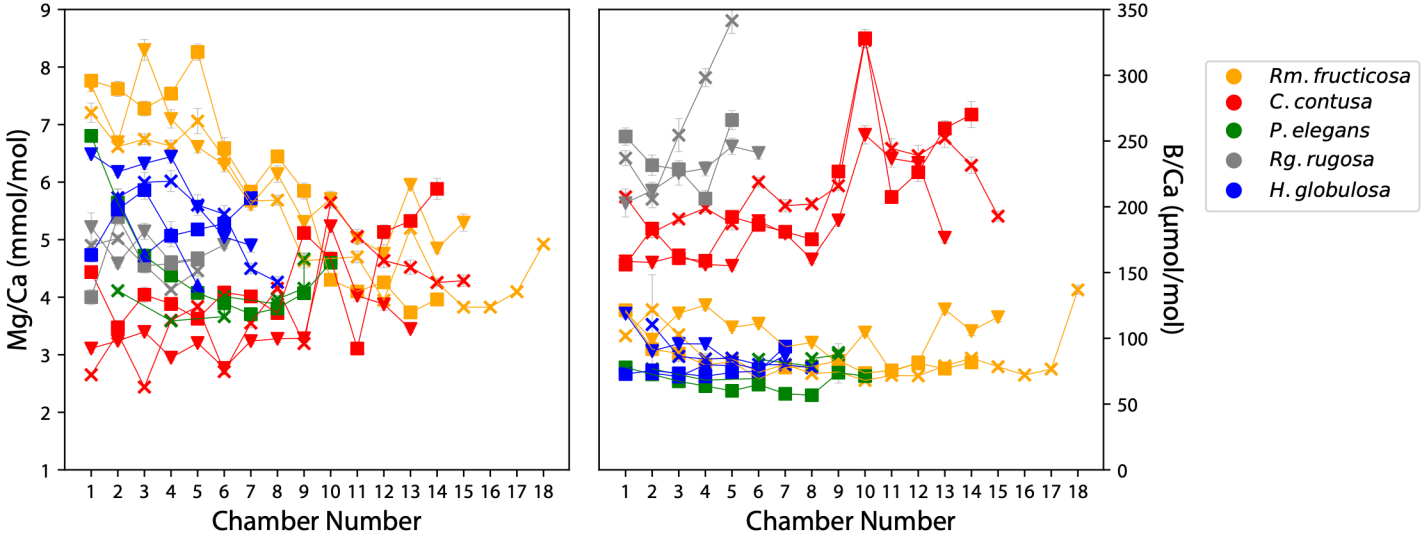


Colour denotes species, lines and markers denote different tested individuals.

Chamber No. 1 = earliest chamber analysed, Highest number = final chamber.

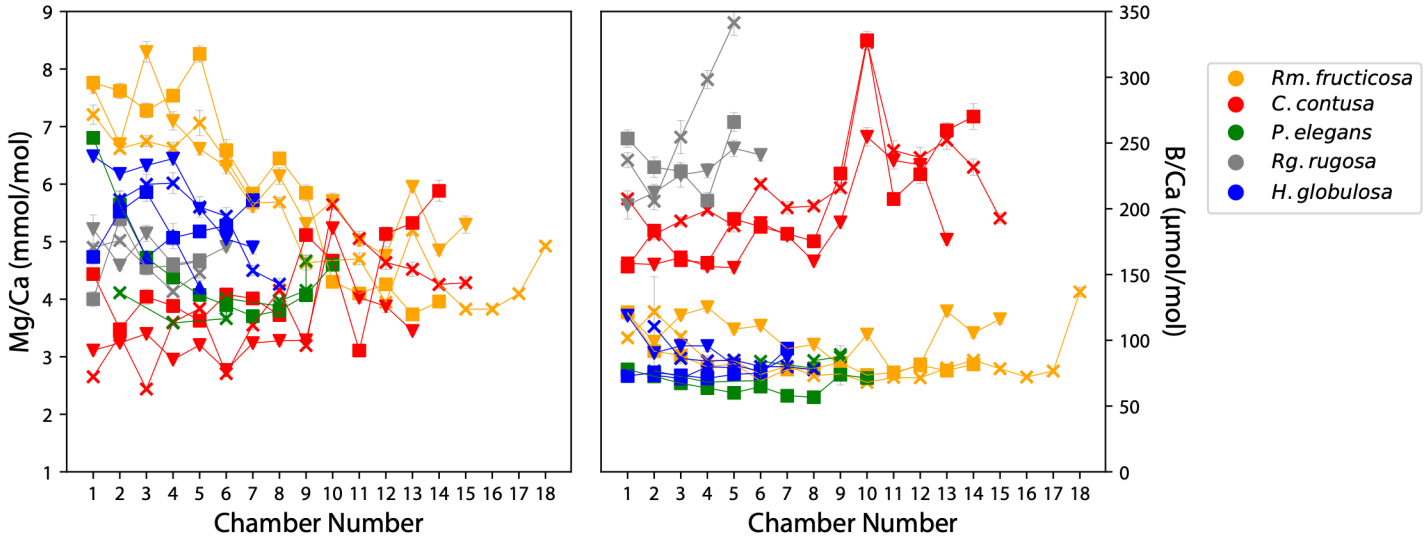
Biserial (*Pseudotextularia elegans* & *Heterohelix globulosa*), multiserial (*Racemiguembelina fructicosa*) and trochospiral (*Contusotruncana contusa* & *Rugoglobigerina rugosa*) taxa

Racemiguembelina fructicosa



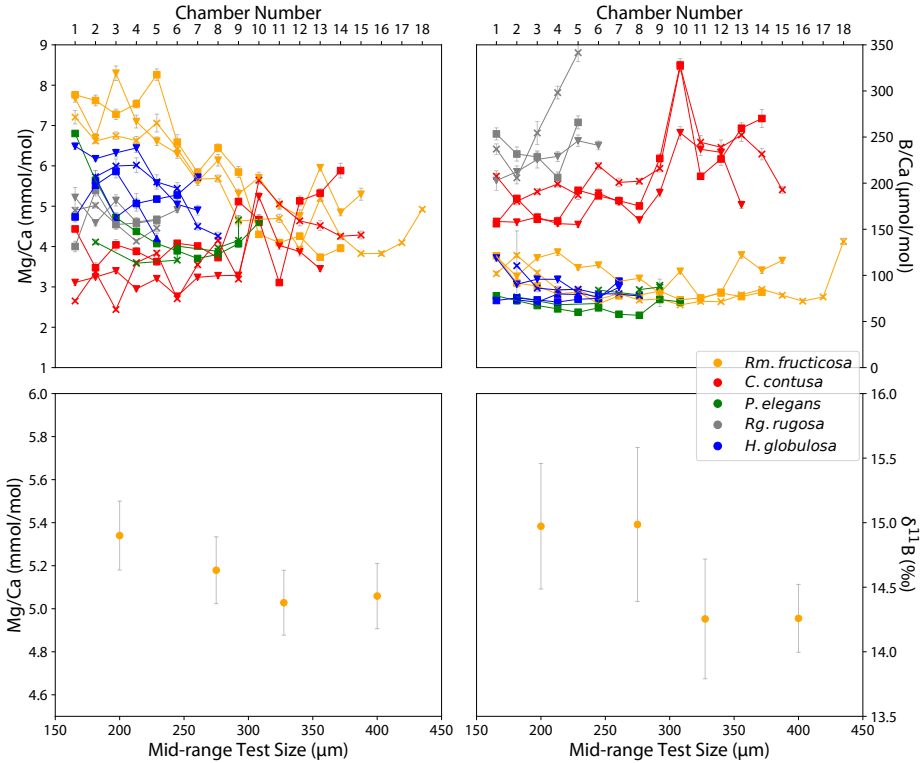
- Clear depth migration in *R. fructicosa* with depth
- However magnitude of change and extreme temperatures from early chambers suggest a non-thermal influence on Mg/Ca

Racemiguembelina fructicosa



- This species often thought to be shallowest dwelling and most clearly photosymbiotic (e.g. Houston et al. 1999, Isaza-Londoño et al. 2006).. Hence natural target for B isotope-pCO_2 reconstruction?

Racemiguembelina fructicosa



- But solution MC-ICPMS shows $\delta^{11}B$ decreases with size, counter to modern symbiont-bearers
- Also low in B/Ca
- And awkward to crush all chambers to remove clays!

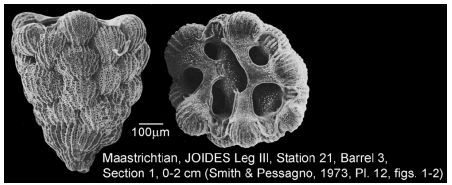
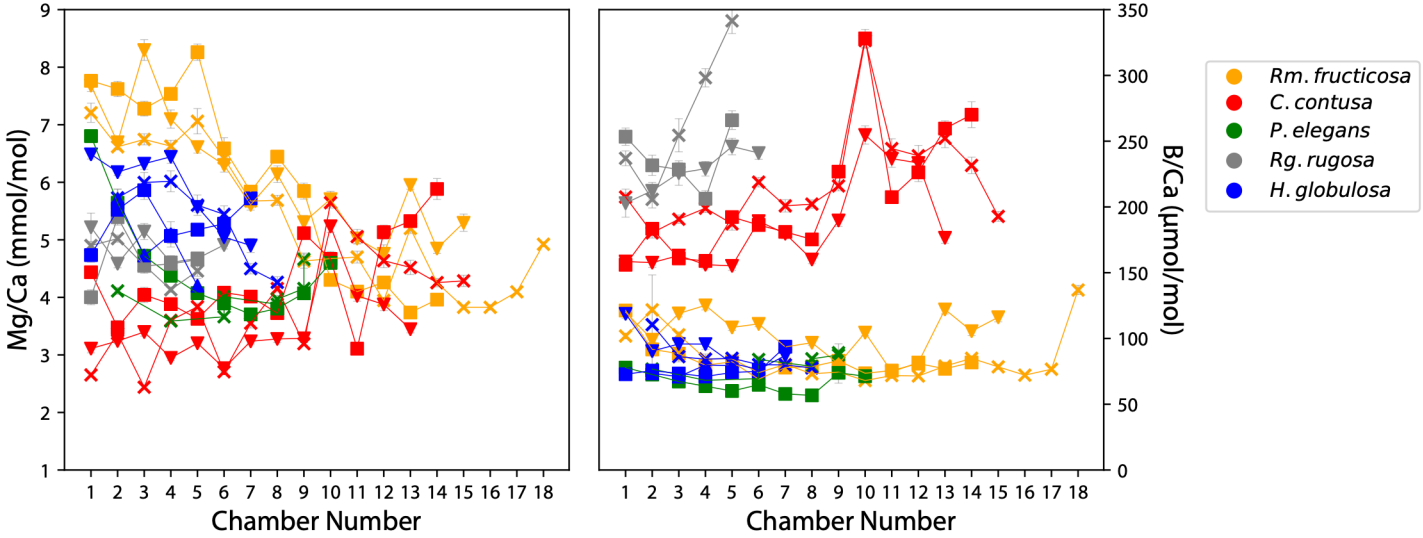


Fig. from microtax.org

B/Ca: Serials vs. Trochospirals



- Despite supposed lack of symbionts (e.g. Isaza-Londoño et al. 2006), *Rugoglobigerina rugosa* and *Contusotruncana contusa* are relatively enriched in Boron.

Takeaways: *R. fructicosa*

- Despite published evidence from carbon isotopes for symbiosis in the photic zone, Mg/Ca (and $\delta^{11}B$) suggests progressive migration to cooler, deeper waters with ontogeny (even as $\delta^{13}C$ is known to increase; Houston et al. 1999).

- In agreement with dissection-derived $\delta^{18}O$ (Houston et al. 1999)

- However, extremely high Mg/Ca in early chambers may indicate ontogenetic changes in biomineralization pathways of multiserial foraminifera that influence Mg incorporation.

Takeaways: Trochospirals

- Very high B/Ca (even in an ocean of lower [B]; Lemarchand et al. 2002) may hint at more fundamental differences in biomineralization between major clades of Cretaceous foraminifera.

- Also suggests B/Ca is not necessarily a good indicator of photosymbiont association in Cretaceous planktic foraminifera.

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