



Trends in element incorporation in hyaline and porcelaneous foraminifera as a function of $p\text{CO}_2$

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Abstract. In this study we analyzed the impact of seawater carbonate chemistry on the incorporation of elements in both hyaline and porcelaneous larger benthic foraminifera. We observed a higher incorporation of Zn and Ba when $p\text{CO}_2$ increases from 350 to 1200 ppm. Modeling the activity of free ions as a function of $p\text{CO}_2$ shows that speciation of some elements (like Zn and Ba) is mainly influenced by the formation of carbonate complexes in seawater. Hence, differences in foraminiferal uptake of these might be related primarily by the speciation of these elements in seawater. We investigated differences in trends in element incorporation between hyaline (perforate) and porcelaneous (imperforate) foraminifera in order to unravel processes involved in element uptake and subsequent foraminiferal calcification. In hyaline foraminifera we observed a correlation of element incorporation of different elements between species, reflected by a general higher incorporation of elements in species with higher Mg content. Between porcelaneous species, inter-element differences are much smaller. Besides these contrasting trends in element incorporation, however, similar trends are observed in element incorporation as a function of seawater carbonate chemistry in both hyaline and porcelaneous species. This suggests similar mechanisms responsible for the transportation of ions to the site of calcification for these groups of foraminifera, although the contribution of these processes might differ across species.

1 Introduction

Calcareous foraminifera, cosmopolitan unicellular protists, are widely used to reconstruct past environmental conditions, since the chemical composition of the carbonate shells reflect a wide variety of environmental parameters. For instance, the Mg / Ca of foraminiferal shells is primarily determined by seawater temperature (Nürnberg et al., 1996; Allen and Sanders, 1994) and seawater Mg / Ca (Segev and Erez, 2006; Evans et al., 2015) and has been widely applied as a paleothermometer (Elderfield and Ganssen, 2000; Lear et al., 2000). The use of foraminifera as proxies for the inorganic carbon system in the past (seawater pH, alkalinity, saturation state, etc.) has more recently been added to the foraminiferal proxy toolbox. For example, the concentrations of trace elements in foraminiferal shells, including U (Keul et al., 2013; Russell et al., 2004), Zn (Marchitto et al., 2000; van Dijk et al., 2017) and B (Yu and Elderfield, 2007), correlate with seawater carbonate ion concentration ($[\text{CO}_3^{2-}]$), while the boron isotopic composition of foraminiferal calcite is used as a proxy for pH (Sanyal et al., 1996). However, insight into vital effects (Erez, 2003) and inter-specific differences in trace element incorporation (Bentov and Erez, 2006; Toyofuku et al., 2011; Wit et al., 2012) is needed to increase robustness of these proxies.

On the broadest taxonomic scale, foraminifera produce tests using either one of two fundamentally different mechanisms. These calcification strategies reflect the evolutionary separation of foraminiferal groups dating back to the Cambrian diversification, from where the imperforate porcelaneous species and perforate hyaline foraminifera developed