Can the pattern of foraminiferal intratest trace element variations be explained by Ca dilution during biomineralization?

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Recently Hathorne et al. (2009) documented large intratest trace element (TE) variations in planktonic foraminifera from a single sediment trap sample that could not be explained by variations in water column properties. The laser ablation ICP-MS depth profiles of trace elements through the test walls revealed strong positive correlations between Li, Mg, Mn and Ba resulting from the mixing of a lower TE outer calcite with a higher TE inner calcite. In contrast Sr/Ca ratios remained relatively constant throughout the test wall. These intratest TE variations likely result from biomineralization processes and therefore should be explained by any valid biomineralization model. However, changes in calcite precipitation rate, crystal structure, or the chemical composition of the internal calcification reservoir could not, by themselves, fully account for the pattern of cation intratest variability. Here I expand on this work and investigate if a model of coral biomineralization by Sinclair and Risk (2006) can be adapted to explain the pattern of intratest TE variability in foraminifera.

It is clear that the low Mg calcite secreting foraminifera must reduce the Mg/Ca ratio of the calcifying solution by at least a factor of 10 (e.g. Hathorne et al., 2009) and it has been suggested this is achieved by active removal of Mg from the calcification reservoir, although the actual mechanisms remain debatable (e.g. Bentov and Erez, 2006). However, a recent study of the calcification of a low Mg calcite species in the laboratory found a large shortcoming in the amount of Ca potentially provided by seawater transported to the site of calcification in vacuoles compared to a conservative estimate of the amount required to form the new calcite wall (de Nooijer et al., 2009a). This suggests active Ca transport to the site of calcification is required to provide sufficient Ca. If Ca specific, this Ca addition would effectively dilute the TE content (including Mg) of the calcification reservoir to varying degrees and potentially cause the positive TE correlations seen across the test wall. Sinclair and Risk (2006) used this dilution model to successfully explain some TE correlations in coral skeletons.

This model can be effectively adapted to foraminifera as it accounts for recent observations of foraminiferal calcification including the transport of seawater by liquid endocytosis to the calcification site and an elevated pH at the site of calcification (Bentov et al., 2009; de Nooijer et al., 2009a, 2009b). This model therefore provides a powerful tool with which to integrate constraints from experimental observation with those from micro-analytical measurements to improve the accuracy, precision and scale of the palaeoceanographic application of foraminiferal geochemistry.

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