Towards a mechanistic understanding of element incorporation in foraminiferal calcite: consequences for a Na-based salinity proxy

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Seawater salinity and temperature gradients drive ocean thermohaline circulation and thereby play an essential role in regulating Earth's climate. Salinity reconstructions largely rely on nested proxy approaches, which inherently result in relatively large uncertainties. Sodium incorporation in foraminiferal calcite might provide a more direct reconstruction tool for salinity. However, element/Ca ratios in foraminiferal calcite generally show relatively large variability between species, between specimens and even across chamber walls. The origin and extent of intra- and inter- specimen variability in element/Ca ratios needs to be understood and quantified to improve the robustness of the reconstructions.

We cultured two benthic foraminiferal species, *Ammonia tepida* and *Amphistegina lessonii* over a salinity range of 25 to 45, analyzed average Na/Ca-values and investigated the elemental distribution across chamber walls using Electron Probe Micro Analysis and Nanoscale Secondary Ion Mass Spectrometry. Maps obtained with these micro-analytical techniques indicate that Na and other incorporated elements (Mg, K, S, and P) occur in distinct bands, around the primary organic sheet. Width and intensity of these bands differ between elements and between the species investigated. We evaluated the intensity of the high-Na, -Mg, -K, bands as a function of salinity. These results provide the basis of a new mechanistic calcification model, which explains observed banding of these elements as a function of 1) seawater chemistry and 2) biological control during calcification by the foraminifer. Model results explain why foraminiferal Na/Ca is primarily controlled by seawater salinity and provide a better understanding of El/Ca variability between and within species.