

Proton pumping explains low-Mg foraminiferal calcite?

DANIEL DO NASCIMENTO SILVA¹, OSCAR BRANSON²,
LENNART J DE NOOIJER³ AND GERT-JAN REICHART⁴

¹Royal Netherlands Institute for Sea Research

²University of Cambridge

³NIOZ Royal Netherlands Institute for Sea Research

⁴Royal Netherlands Institute for Sea Research (NIOZ)

The Mg/Ca of foraminifera is one of the best established proxies for past ocean temperature. However, the Mg/Ca of many foraminifera tests is both orders of magnitude lower, and around twice as sensitive to temperature than expected from a calcite precipitated from seawater. These discrepancies require the use of empirical calibration factors when converting Mg/Ca to temperature, which introduce substantial uncertainties into palaeo-temperature reconstructions. The cause for these differences are unknown, but are thought to arise from some aspect of foraminiferal biomineralisation processes.

It has long been established that foraminiferal calcification causes a reduction in the pH of their local micro-environment during calcification. We explore the sensitivity of boundary-layer pH, and therefore proton (H^+) export rate, to the temperature of the environment. We find a linear increase in proton pumping rate with temperature. We then develop a model of ion transport processes in foraminiferal biomineralisation to explore the impact of this trend on foraminiferal Mg/Ca and our understanding of biomineralisation mechanisms.

Our model includes a proton-calcium (H^+/Ca^{2+}) antiporter that increases its activity with temperature and is slightly 'leaky' to Mg, alongside a degree of exchange between seawater and the site of calcification. In this configuration, our model is able to quantitatively explain both the low Mg/Ca in foraminifera, and its enhanced sensitivity to temperature compared to inorganic precipitates, offering a mechanistic explanation for the operation of the Mg/Ca palaeothermometer.