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Constraining foraminifer calcification models using cryo-electron microscopy and energy-dispersive X-ray spectroscopy

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Foraminifera produce a substantial portion of all organically-mediated $CaCO_3$ precipitated in the ocean and are key geochemical 'proxy' archives, underpinning a large amount of our understanding of past climate change. However, our mechanistic understanding of how foraminifera build their shells, and therefore how resilient this aspect of $CaCO_3$ production is likely to be to environmental change, remains limited, principally because of the difficulty in noninvasively observing the processes controlling the dynamics of ion transport to the site of calcification. We address this via cryogenic sample preparation, thus preserving the shell, cell, vacuoles, and vesicles intact, and enabling the spatial relationships between these to be understood in detail. Specifically, we couple high pressure freezing, ensuring sample vitrification, with cryo-ultramicrotomy in order to produce a sample surface optimised for (chemical) imaging. We examine samples prepared in this way with both a retractable backscatter and energy-dispersive X-ray detector, the former of which is optimised for low-kV imaging of beam sensitive biological material or metastable solid phases. Using this information, we present preliminary results in which we use this methodology to determine the degree to which seawater is transported through the cell in benthic species with strongly contrasting shell chemical compositions.