Constraining foraminiferal $CaCO_3$ formation mechanisms from aggregate geochemical data.

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Numerous studies investigate the geochemistry of foraminiferal $CaCO_3$ produced under different chemical and physical conditions, seeking to both establish functional ‘proxy’ relationships between environment and geochemistry, and understand biomineralisation mechanisms. Experimental and analytical constraints mean that the majority of these studies are restricted to varying subsets of environmental parameters, and are only able to consider a subset of the numerous trace element and isotopic signatures contained within the mineral. As a result, most studies are necessarily restricted to partially-complete geochemical datasets, which can complicate the robust identification of proxy relationships and biomineralisation processes. This is particularly problematic for studies of biomineralisaiton, where a proposed model cannot be adequately tested unless multiple diverse aspects of foraminiferal geochemistry are considered – a biomineralisaiton model must be able to explain *all* aspects of geochemistry to be considered ‘correct’.

Over the last few decades, a wealth of geochemical data from cultured foraminifera has accumulated in the literature, spanning numerous species, growth conditions, and measured geochemical parameters. We have compiled this data in a consistent and comparable format, providing a comprehensive overview of foraminiferal geochemistry, its species-specificity, and its sensitivity to diverse physical and chemical parameters. We explore the consistency of geochemical patterns across different species and culture experiments, and use cutting-edge machine learning and sparse matrix completion methods to build up a complete, internally-consistent database relating foraminiferal geochemistry to growth conditions. We use this unified geochemical dataset to conduct a quantitative appraisal of foraminiferal biomineralisation mechanisms and their variation between species, by testing the ability of existing models (seawater vacuolisation, Rayleigh fractionation, trans-membrane-transport, and amorphous precursor phases) to explain geochemical patterns in the data.