Breaking news on biomineralization in foraminifera

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Foraminifera are single-celled eukaryotic organisms with temporary reticulose projections of the cell membrane called pseudopods. Several thousand extant foraminiferal species occupy almost every planktic and benthic marine habitat. Most foraminifera construct a test from organic and inorganic components. Inorganic foraminiferal tests occur in the fossil record since the early Cambrian and tens of thousands of species have been described from Phanerozoic sediments. These microscopic shells represent the ultimate recorders of environmental and stratigraphic information and have become irreplaceable in many branches of geo- and life sciences. Their vast abundance and high rates of evolution make them ideal index species for stratigraphy correlation; shifts in test morphology over time allow phylogenetic reconstructions and the testing of hypothesis in evolutionary and molecular biology; intraspecific plasticity of test characters such as pore patterns are largely driven by discrete environmental parameters and allow the assessment of environmental conditions in the past and present; assemblage composition and species distribution document biogeographic dynamics and paleoenvironmental change; the elemental and isotopic composition of the test chronicles conditions of the surrounding water and allows the reconstruction of critical parameters in paleoceanography and paleoclimatology. Due to their ubiquitous abundance in marine sediments and manifold applications, foraminifera are arguably amongst the longest and best studied protist groups in micropaleontology.

The construction of their tests is one of the most intriguing abilities of these single-celled organisms. Several basic modes of foraminiferal test construction are distinguished: 1) Organic tests are made of tectin; 2) agglutinated tests are built from sedimentary particles collected by the foraminifer and embedded into an organic or cemented matrix; 3) biomineralized tests are primarily made of carbonate and – very rarely – of silica. Carbonate tests differ in their mineralogy (calcite/aragonite), biomineralization pathways and the formation of the crystals, and the arrangement of the crystals in the test wall (microgranular, miliolid, hyaline).

The origin of biomineralization is still enigmatic. Molecular data indicate that the origin of foraminifera dates back to the late Precambrian. Single-chambered agglutinated shells first occur with the Cambrian explosion at c. 543 Ma. Microgranular tests from the late Devonian represent the first evidence of biomineralization in foraminifera. Subsequently, miliolid tests appear in the early Carboniferous and hyaline shells appear in the early Triassic. While the fossil record seems to support notions of a stepwise process of increasing complexity in biomineralization, molecular data paint a more complicated picture, indicating that different modes of shell construction developed independently within different groups of agglutinating foraminifera. This complex picture stimultated a renewed interest in foraminiferal test construction. Over the past two decades significant progress has been made in our understanding of how foraminifera construct their test, how inter- and intraspecific plasticity is driven and how chemical signals are incorporated during test formation. With the advent of new high-resolution imaging techniques, successful laboratory cultures, and molecular biology, concepts of biomineralization in foraminifera have been significantly refined. In this paper, I will discuss the status quo of research on foraminiferal calcification and present new results on test ultra-microstructure in selected hyaline and miliolid groups.