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Evidence for a composite organic-inorganic fabric of belemnite rostra: implication for palaeoceanography

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Carbonate skeletons of fossil marine organisms are widely used to reconstruct palaeoenvironments. Specifically, the geochemistry of Jurassic and Cretaceous belemnite rostra is commonly applied to reconstruct palaeoseawater properties. This is due to the assumption that belemnites, as member of the mollusc group, precipitated their rostra in equilibrium with the palaeoenvironment and secondly it was assumed that rostra represent primary dense low Mg calcite structures and relatively stable against diagenetic overprinting. More recently an increasing number of published data, show significant scatter in geochemical data (e.g., d18O, d13C, element/Ca ratio) when comparing belemnite rostra from the same stratigraphic level or within a single belemnite rostrum. This scatter is not explained by differential diagenetic overprint alone but also by vertical and horizontal migration patterns, seasonality, or changes in salinity. In order to test for an ultrastructural-related explanation for the observed scatter we employed a wide range of state-of-the-art analytical tools, e.g., cathodoluminescence, fluorescence- and confocal laser fluorescence microscopy, scanning electron microscopy equipped with a backscatter detector, electron microprobe analysis, electron backscatter diffraction imaging to thin sections and ultra-thin sections of well-preserved specimens. We found petrographic evidence that the primary, i.e. biogenic, ultrastructure of rostra of Megateuthis (Middle Jurassic) and Belemnitella and Gonioteuthis (Late Cretaceous) was not a dense calcite structure, but contained primary porosity. The biogenic ultrastructure consists of a filigree framework of tetrahedrons of variable size with branches forming a honeycomb-like network. Data presented here suggest that these rostra yielded as much as 50 to 90% primary pore space. We propose that the pore space was originally filled with body fluid and/or organic compounds during the life time of these organisms in analogy with modern cephalopods. Intra-rostral porosity was occluded post mortem by earliest diagenetic isopachous calcite cements of a non-biogenic origin. These may have been precipitated due to increased alkalinity related to the decay of organic matter. If this holds true, then the resulting fabric represents a composite biogenic/abiogenic structure precipitated at different times and depths in the water column. We suggest that these findings have significance for those using belemnite rostra as archives of their palaeoenvironment, for the reconstruction of belemnite palaeoecology, and for the functional interpretation of belemnite rostra.