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Comparison of crystallographic orientations between living (*Emiliania huxleyi* and *Gephyrocapsa oceanica*) and fossil (*Watznaueria barnesiae*) coccoliths using electron microscopes

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Abstract

Crystallographic orientations of coccoliths produced by the extant species *Emiliania huxleyi* and *Gephyrocapsa oceanica*, and of a fossil cocccolith, *Watzunaueria barnesiae*, all of which are mainly composed of calcite crystals with horizontally oriented *c* axes (termed R-units), were investigated using two electron diffraction techniques. According to electron backscattered diffraction (EBSD) analyses, the *c*-axis inclinations of all R-units were oriented about 10–30° from the sample substrate, which is approximately parallel to the organic base plate of the coccolith. However, the directions are toward the coccolith exterior in living coccoliths but toward the interior in fossil coccoliths. The crystallographic orientations of calcite crystals characterized by sub-vertically oriented *c* axes (termed V-units) were determined only for *W. barnesiae* and were similar to those of V-units in another living cococlith, *Pleurochrysis carterae*. Highly regulated crystallographic orientation and consistent chirality were evidenced for all the coccoliths with only a few degrees of variations by Kikuchi patterns analyses from TEM. To determine the indices of the crystallographic plane and edge direction that constitute distal and proximal shield elements, SEM stereo-photogrammetry in combination with EBSD analyses was applied. In the living coccoliths both shields contain the *c*-axis and the surface is estimated to be $\{2\bar{1}\,\bar{1}0\}$ with [481] the longer peripheral edge. On the other hand, the two shield surfaces of *W. barnesiae* are evaluated $\{10\bar{1}4\}$ and the distal shield surface is surrounded by clear [481] edges. This indicates that the crystallography and morphology of R-units were not fixed for the past 230 million years. Based on these results, the calcite nucleation mechanisms are discussed with respect to the atomic arrangements on the organic template through all the coccoliths.

Keywords: Biomineralization, coccolith, EBSD, SEM, stereo-photogrammetry, Kikuchi pattern, TEM, calcite