Fractal morphology and non-classical twinning of calcite in the hydrogel matrices regulating foraminiferal chamber growth

W. W. Schmahl¹, J. Lastam¹², X. Yin¹, E. Griesshaber¹, A. Checa³, I. Sánchez-Almazo⁴, M. Kucera⁵, J. Erez⁶, M. Hess⁷, P. Walther⁸

¹Department of Earth and Environmental Sciences, LMU Munich, Germany, ²Forschungszentrum Jülich, Institut für Energie und Klimaforschung, Jülich, Germany, ³Departamento de Estratigrafía y Paleontología, Universidad de Granada, Spain, ⁴Centro de Instrumentación Científica, Universidad de Granada, Spain, ⁵MARUM and Fachbereich Geowissenschaften, Universität Bremen, Germany, ⁶Institute of Earth Sciences, The Hebrew University, Jerusalem, Israel, ⁷Biozentrum LMU München, Martinsried, Germany, ⁸Central Facility for Electron Microscopy, University of Ulm, Germany

wolfgang.w.schmahl@lrz.uni-muenchen.de

Keywords: Biomineralization, Twinning, EBSD

Foraminifera are single-celled organisms that belong to the globally most important marine producers of biogenic CaCO₃ as most foraminifera protect their cytoplasm with a chambered shell of calcite¹. With SEM imaging an electron backscatter diffraction (EBSD) we²,³,⁴ found that the biocalcite formed by the diverse forms of foraminiferal species is as biodiverse as it displays unique mesocrystal architectures which are distinctly different from calcite formed by other marine organisms. Shell formation starts with mineralization of a rhizopodial network, the primary organic sheet (POS). For rotaliid foraminifera the crystals on the proximal side of the POS have blocky shapes in the 1 μm size range. On the distal side of the POS crystals with dendritic-fractal morphologies interdigitate and reach sizes of some tens of micrometers. These dendritic-fractal crystals are bundles of crystallographically well-co-oriented nanofibrils which merge into blade-shaped plates further away from the POS, i.e. towards the outer surface of the shell chambers. The morphological nanofibril axis is the crystallographic c-axis, both are perpendicular to shell vault. The nanofibrillar calcite is polysynthetically twinned according to the 60°/[100] (= m/{001}) twin law. In addition, systematically and frequently reoccurring misorientations of 78°7[6-6 1] are present, which represent a non-classical form of twinning. We demonstrate for the twinned, fractal-dendritic, crystals formation at high supersaturation and growth through crystal competition. We show also that c-axis-alignment is already induced by biopolymers of the POS and is not simply a consequence of growth competition. We discuss determinants that lead to rotaliid calcite formation.

Figure 1. Cone shaped micro-scale calcite crystal units of the shell of Pulleniatina obliquiloculata. Left: Fibrous internal sheaf-like nanostructure near the POS revealed by selective etching. Right: EBSD patterns (inverse pole figure color scheme showing that the sheafs are twinned crystal units. This is a figure caption (Heading 6 style, Times New Roman 9 pt).