Crystallographic architecture of sea urchin biocalcite

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Echinacea (regular sea urchins) form their skeletal hard parts from magnesian calcite, which occludes dilute organic matrix, making it resistant against cleavage fracture. The single-crystal-like calcite organization of their teeth [1] and spines [2] have attracted much attention in the past. The renowned macroscopic five-fold symmetry of both the body and the feeding apparatus of the Echinacea is thus intriguing with respect to the crystallographic architecture of the calcite. To complement our earlier investigations [1, 2] we conducted single-crystal X-ray diffraction and detailed electron backscatter microdiffraction experiments on spines and cross sections of the body tests of the species *Paracentrotus lividus* and *Cidaris cidaris.*

The spine of *P. lividus* (Fig. 1, right) shows a single-crystal like orientational pattern of the biocalcite although it consist of 18 segments separated by gaps (which are bridged by calcite). There is a coherence of {10.0} plane normal and the radial axis of every third segment. In the center of the spine is a porous meshwork of biocalcite and hollow space. This material type is called stereom. The bulk of the spine of *C. cidaris* (Fig. 1, left) consists of stereom material with single-crystal like lattice orientation. The outside of the single-crystalline *C. cidaris* is lined with 18 protruding buttresses of polycrystalline material. The material of the tests is stereom, where the characteristic wave-length of the sequence of calcite walls and hollow space varies from the inside to the outside of the test between 50 and 5 micrometers in layers of constant wave-length. The biocalcite of the stereom shows indeed single-crystal like coorientation over distances in the order of 1 mm, with sharp small-angle boundaries between such blocks. The misorientation at these boundaries occasionally reaches 20°. The lattice orientation follows the curvature of the tests. For *P. lividus* the calcite c-axes are radially oriented; for *C. cidaris* the c-axes are tangential to the surface of the tests. In contrast to the stereom in the bulk of the test plates, the tubercles (knobs on which the single-crystal-like spines are anchored) form partial spherulites.

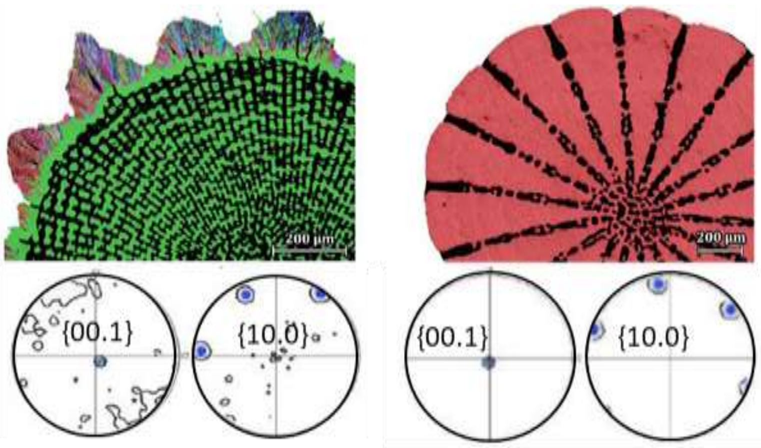

Fig. 1 EBSD maps and pole-density figures for the spines of *Cidaris cidaris* (left) and *Paracentrotus lividus* (right). Uniform color represents uniform crystal lattice orientation.

[1] Goetz A, Griesshaber E, Abel R, Fehr Th, Ruthensteiner B, Schmahl WW. Tailored order: The mesocrystalline nature of sea urchin teeth. Acta Biomaterialia, 10, 3885-3898 (2014)

[2] Kelm K, Goetz A, Sehrbrock A, Irsen S, Hoffmann R, Schmahl WW, Griesshaber E. Mosaic Structure in the Spines of *Holopneustes porossisimus*. Zeitschrift für Kristallographie-Crystalline Materials, 227, 758-765 (2012)