Order and disorder of the microstructures of the *Cidaris rugosa* sea urchin stereom

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The sponge-like biomineralised calcite materials found in echinoderm skeletons are of interest in terms of both structure formation and biological function. Despite their crystalline atomic structure, they exhibit curved interfaces that have been related to known triply-periodic minimal surfaces. Here, we investigate the endoskeleton of the sea urchin *Cidaris rugosa* that has long been known to form a microstructure related to the Primitive surface (ref. 1). Using X-ray tomography, we find that the endoskeleton is organised as a composite material consisting of domains of bicontinuous microstructures with different structural properties (ref. 2). We describe, for the first time, the co-occurrence of ordered Primitive and Diamond structures and of a disordered structure within a single skeletal plate. A representative Diamond volume is shown in Figure 1. We show that these structures can be distinguished by structural properties including solid volume fraction, trabeculae width, and to a lesser extent, interface area and mean curvature. In doing so, we present a robust method that extracts interface areas and curvature integrals from voxelized datasets using the Steiner polynomial for parallel body volumes. We discuss these very large scale bicontinuous structures in the context of their function, formation, and evolution.

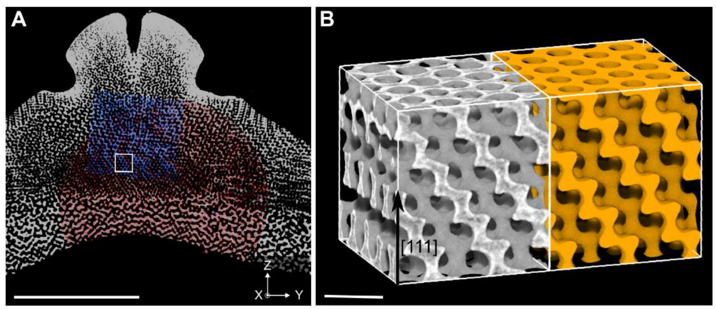

Figure 1 A representative subvolume of the stereom that closely resembles a single Diamond surface. (A) Cross-section through the interambulacral plate showing the location of the representative subvolume. Scale bar = 1 mm. (B) The subvolume of the sea urchin stereom (in grey; isotropic voxel size of 732 nm) and a simulated nodal approximation of a single Diamond surface with a solid volume fraction $\phi = 0.3$ (in yellow).

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