Large eddy simulations reveal skeletal adaptations of archaeocyaths

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Abstract

As an extinct group of hypercalcified sponges, archaeocyaths are the first undoubted metazoan builders of abundant reefs and mounds in the Cambrian. Although the morphology of archaeocyaths has been well described in previous studies, the biomechanical significance of the archaeocyathan skeletal morphology remains incompletely explored. In the past decade, computational fluid dynamics (CFD) has been increasingly adopted for reconstructing the function and ecology of ancient and enigmatic fossils by numerical simulations of fluid flows. However, most of the earlier in silico experiments performed on extinct organisms are based on the Reynolds-averaged Navier Stokes (RANS) equations. In order to conduct reliable fluid dynamic simulations, we constructed simplified three-dimensional digital models of regular archaeocyaths by using SolidWorks based on typical specimens. With COMSOL Multiphysics, we performed a time-dependent analysis using the large eddy simulation (LES) turbulence model. As a comparison, the RANS model has also been applied to the same fluid dynamic settings. These CFD analyses reproduce the hydrodynamic conditions on the sea floor where archaeocyaths live. Both RANS and LES experiments reveal a rich, multifaceted role of the skeletal motifs of archaeocyaths on the flow physics within and beyond its central cavity. Compared to RANS model, the LES experiments resolved the eddy trail with more details exhibiting the classic pattern of swirling vortices. Overall, our computational results confirm the archaeocyathan models show passive entrainment of flow, on which modern sponges depend for suspension feeding. The flow direction through the models is consistent with predictions of the spongiomorph-affinity interpretation of archaeocyaths.

Keywords: archaeocyaths, hypercalcified sponges, paleoecology, biomechanics, computational fluid dynamics

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