3D Characterization of Stromatolites and the Emergence of Complexity

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ABSTRACT

Stromatolites offer a unique fossil record across 3.5 Ga of microbial community evolution within the context of an evolving Earth. Our interest is in developing quantitative metrics to follow the evolution of stromatolite morphological complexity. Adopting the canonical definition of complexity as the emergence of previously unseen properties in a dynamic phenomenon, we have previously proposed in these proceedings that laminations are the defining emergent property of stromatolites and we have employed a set of statistical information metrics to quantify laminae complexity in two spatial dimensions. We now demonstrate computer x-ray tomography of stromatolites and discuss the advantages of this 3D volume density distribution technique for characterizing stromatolite samples. CT imaging makes it possible to create a virtual stromatolite, enabling both research and educational efforts previously hampered by the costs of obtaining, preparing, and distributing precious Archean stromatolite fossils. We discuss recent advances in instrument miniaturization making it feasible to provide non-destructive 3D density and elemental abundance information on endolithic geobiological targets during future manned and unmanned missions to Mars.

Keywords: Stromatolites, complexity, emergent properties, quantitative metrics, computer tomography

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1. INTRODUCTION

On planet Earth life usually manifests not as isolated individual organisms, but overwhelmingly appears as complex communities. Stromatolites are laminated organo-sedimentary structures [1-4] classically thought to arise from microbial trapping and binding of sediment or precipitation of dissolved minerals [5,6]. However, some investigators have posited more descriptive definitions leaving the biogenicity of these structures as an open question [7-10]. Some abiotic precipitates appear at selected scales similar in morphology to some pre-Phanerozoic stromatolites and can be modeled using simple diffusion and accretion rules [11,12] based on random walk (Brownian motion) of particles [13]. However, conical stromatolites with very steep surface angles normal to earth defy such abiotic modeling attempts [14], and require that we invoke the high coefficients of friction normally employed to model accretion of organic molecules [15,16]. As a result, other investigators have made a persuasive case for biogenicity even in some Archean 3.45 Ga-old stromatolites [15,17]. If correct, these structures then would provide us with our most ancient record of life on Earth.

We are particularly interested in the exploration of other terrestrial planets in our solar system and in neighboring star systems. For the next three or four decades such exploration will be performed with robotic devices relying on photonic probes such as UV-Vis-NIR cameras and X-ray imaging systems. Consolidating our understanding of the morphological signatures of biology activity in the Archean fossil record of Earth would assist us in the search for