Quantitative methods for evaluating the biogenicity of fossil stromatolites

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Conical stromatolites arranged in egg carton-like arrays were reported recently from 3.45 Ga-old strata in Western Australia (Hofmann et al. 1999). These stromatolites are arguably the best evidence for the nature of early life on Earth. Understanding their morphogenesis may therefore serve as a prelude to exploration of the ancient terrains of Mars because distinctive sedimentary structures of this type are an obvious target for astrobiological missions. The case for an abiotic origin for some Precambrian stromatolites was advanced by Grotzinger and Rothman (1996), who used 2D power spectral analysis to quantify their 3D shape. They believed that the stromatolitic growth process could be modeled in 2+1 dimensions by the KPZ interface equation of condensed matter physics (Kardar et al. 1986). Results to date have shown that the KPZ equation, and others like it, are incapable of producing simulated structures that resemble the Archean coniform stromatolites from Western Australia. On the other hand, an equation that is important in the physics of metal atom sputtering (Smilaeur et al. 1999) simulates conical structures effectively. The reason is that the process being modeled (electron beam epitaxy) has an uphill component caused by an edge effect at the atomic scale. Thus, models constructed using this equation (SRK) incorporate an upslope diffusion term that is not present in KPZ-based models. As upslope diffusion is a process that is readily attributable to life but not to other non-vital agents at anything larger than atomic scale, this parameter may provide a definitive test for biogenicity.