A Pyramid of Life Detection for Ancient Life, Based on Deep-Time Earth Experience

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Introduction: Neveu et al.'s (2018) "Ladder of Life Detection" model for the search for life in the Solar System lists "biofabrics" at the base of the ladder and labels them, together with "potential metabolic byproducts" and "potential biomolecule components", as "Suspicious Biomaterials" based on adopting the "null hypothesis" for life (i.e. a feature is not life unless *proven* to be so). This approach stems from high-profile disputes of *some* proposed microfossils (Earth: Schopf, 1993 v. Brasier et al., 2002; Mars: McKay et al., 1996 v. Blake et al., 2009), the abiogenic origin of *some* stromatolite-like structures (e.g., Grotzinger and Rothman, 1996; McLoughlin et al., 2012) and putative ichnofossils (McLoughlin et al., 2008), and contamination of biomolecules (Brocks et al., 1999 v. Rasmussen et al., 2005). However, by labelling all biomaterials as "suspicious", and assigning them to the lower rung in search strategies for life in the Solar System, are we "throwing the baby out with the bathwater"? Rather, we regard these past mistakes as stepping stones to more sophisticated science that is now highly capable of determining the biogenicity of biomaterials.

Here, we present an alternative Pyramid of Life Detection, based on >60 years' combined experience in mapping and researching ancient rocks on Earth, with all the necessary cautions indicated by recent scientific advances.

Results: Early Precambrian rocks containing preserved evidence for on Earth are overwhelmingly in siliceous and/or carbonate sedimentary rocks from shallow water settings: non-silicified and deepwater clastic sedimentary rocks have not been found to contain reliable biosignatures, or even significant organic matter concentrations. Community-accepted ancient biosignatures include stromatolites (3.5 Ga Dresser Formation (DF), 3.4 Ga Strelley Pool Formation (SPF), 2.72 Ga Tumbiana Formation), microfossils (SPF, 3.0 Ga Farrell Quartzite, 2.4 Ga Turee Creek Group), biofilms (3.33 Ga Josefdal Chert) and organic matter signatures (DF, SPF). All early life discoveries are based on field observations of stromatolites and black chert: this forms the peak of our Pyramid of Life Detection, and provides a contextual basis for further laboratory analyses.

In order to be considered as a potential biosignature: Stromatolites must show clear biological growth features that contrast (texturally and compositionally) and interfere with adjacent, contemporaneous, demonstrably abiogenic geological features; Microfossils must be composed of Organic Matter (OM) with fractionated $\delta^{13}C$ values, have demonstrable 3-D morphology, be composed of a community with distinct morphotypes, and have shapes demonstrably independent of host crystal growth; OM must be located in contextually suitable rocks away from an obvious source of abiological OM formation, and have characteristics unique to biology. A range of further analytical tests will heighten the probability of biogenicity for each of these components.

Implications: We must be justifiably cautious re: claims of life on early Earth or Mars. But the null hypothesis for life sets the bar unrealistically high; for example, no early Precambrian stromatolites would be classed as biogenic under such criteria, which is nonsensical. Trilobite or dinosaur fossils can be proven to have been alive based on morphology because no abiological process can explain how such features could form. The same applies to microbial life signatures in Deep Time, with due diligence and the latest analytical techniques applied to all such investigations. There are a range of features that cannot simply be dismissed by the catch phrase of some reviewers: "It could be something else". In sound geobiological practice applied the world over, morphology is often a key flag that leads researchers into further, relevant detail through the use of multiple analytical approaches and scale-integrated, contextual investigations (e.g., Farmer, 1999). Instead of relegating morphological biosignatures to the bottom of a Ladder of Life Detection, we employ morphological biosignatures at the top of a descending pyramid of robust tests for biogenecity.

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