Environmental conditions for the formation of silica-witherite biomorphs and relevance for microfossil identification in Archean cherts

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Archean hydrothermal environments formed a likely site for the origin and early evolution of life. These are also the settings, however, were complex abiologic structures can form. Low-temperature serpentinization of ultramafic crust can generate alkaline, silica-saturated fluids in which carbonate-silica crystalline aggregates with life-like morphologies can self-assemble. These "biomorphs" could have adsorbed hydrocarbons from either biologic sources or Fischer-Tropsch type synthesis processes, leading to metamorphosed structures that resemble carbonaceous microfossils. It is therefore critical to study the range of geochemical conditions under which these microstructures can form, and to precisely determine their distribution in size and morphology. We conducted witherite-silica biomorph synthesis experiments in silica-saturated solutions for a range of pH values (from 9 to 11.5) and barium ion concentrations (from 0.6 to 40 mmol/L $BaCl_2$). Under these varying conditions we find a wide range of life-like structures, from fractal dendrites through framboidal structures to complex shapes with continuous curvature. The size, density and morphology of the biomorphs are strongly controlled by environmental parameters, among which pH is the most important. In order to better characterize their spatial repartition and their size distribution, biomorphs were also grown by diffusion in a silica gel. In this setup, they display a continuous gradient in size, spatial density and morphology along the direction of diffusion, related to chemical gradients within the gel. This kind of gradient is not observed in modern populations of microorganisms. Moreover, we find that biomorphs display a wider range of sizes than single strain bacteria populations. Given the diversity of biomorph morphologies, our results confirm that the morphology of an individual microstructure is a poor criterion for biogenicity. However, it also demonstrates the potential of looking at population-describing parameters in order to elaborate new biogenicity criteria.