Geochemical plausibility of silica self-assembly and its relation to life detection studies and prebiotic chemistry

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Silica self-assembly -the inorganic, silica-induced process in which nanocrystalline particles self-assemble spontaneously into composite materials with non-crystallographic symmetry- is best represented by silica-carbonate biomorphs and metal-silica(te) membranes, known also as silica gardens. It has been demonstrated that: a) silica biomorphs can mimic the morphology and the chemical signature of putative microfossils found in cherts, b) Metal-silica(te) membranes can catalyze the formation of life-relevant organic molecules (i.e., nucleobases and aminoacids) in the presence of formamide, and c) silica-induced carbonate precipitation can mimic the texture of biominerals. Up to now, all these self-assembled inorganic-inorganic nano-composites have been prepared in the laboratory with model solutions of sodium silicate and salts.

We collected alkaline (pH 11.9), silica-rich (4236 ppm) spring water from the Ney, California, and show that the precipitation of: a) nanocrystalline biomorphs of barium carbonate and silica, b) Me-silica membranes produced with Fe(II)/(III)-, Co-, Cu- and Zn-salts, and c) calcium carbonate mesocrystals, is geochemically plausible in natural environments of high pH and high silica concentration. We use XRD, FESEM-EDS, micro-Raman, IR and GC-MS for the characterization of the structures and present their growth features as a function of temperature, pH, silica concentration and atmospheric composition. Particularly we focus on the Fe-silica membranes and investigate their catalytic potential in relation to their chemical composition, oxidation state and nanostructure with means of HRTEM/HAADF/STEM/EELS.

The geochemical prerequisites for silica self-assembly (pH>10 and high silica concentration) are relatively rare in modern Earth but are thought to be widespread in the Hadean-Early Archean, for instance, in serpentinization environments. Therefore, our finding that mineral self-assembly is geochemically plausible has direct implication in primitive life detection in Earth and Earth-like planets, as well as, in the role of silica self-organization in prebiotic chemical reactions.