The Trouble with Tubules: Iron-Mineral Chemical Gardens Mimic Numerous Purported Fossil Microbial Filaments

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Abstract

Microscopic filaments and tubes composed of nano- or microcrystalline iron (oxyhydr)oxides and iron (alumino)silicates (and less commonly of similar magnesium or manganese minerals) occur as dense assemblages in diverse rocks of all ages, including submarine hydrothermal chert beds and veins; fractures, veins, vesicles and amygdales in numerous marine and terrestrial basalts; mineralised cavities in limestones; and the porous oxidation zones of metal ore bodies. These microstructures are widely interpreted as fossil bacteria or fungi, and include Earth's oldest purported fossils as well as putative remains of the ancient deep biosphere. However, we have found experimentally that a non-biological, environmentally feasible process of chemical gardening can produce filamentous microstructures strongly resembling such purported fossils in both composition and morphology.
We report the experimental production of microscopic iron-mineral biomorphs that replicate key morphological features previously taken to imply a biotic origin for compositionally similar filaments in the rock record. These structures resulted from the well-known phenomenon of chemical gardening, whereby the dissolution of a "seed" metal salt into an alkaline carbonate or silicate solution produces a pocket of acidic fluid enclosed by a membrane of colloidal metal carbonate or silicate; the chemistry is different from that of the "silica-carbonate biomorphs" previously shown to replicate some morphological features of ancient candidate microfossils.

In this study, biomorphs of iron-silicate lined with iron (oxyhydr)oxide were produced in $<$ 48 hours from polycrystalline ferrous mineral grains placed into aqueous solutions of sodium silicate or sodium carbonate at standard temperature and pressure. Elaborate tubes grew within 2–5 minutes of immersion and darkened over 24–48 hours as iron minerals formed internally. Tube diameter was controlled primarily by seed grain size; grains sieved to < 63 μm produced tubes consistently 1–5 μm in external diameter. These biomorphs showed several features previously suggested to eliminate non-biological explanations for compositionally similar filaments occurring in rocks, including both straight and curved trajectories, both filled and unfilled (hollow) interiors, circular cross-sections, multiple attachment to an individual knob, frequent true branching, rare anastomosis, nestedness, and discrete swellings. These results do not exhaust the morphological diversity of chemical gardens, which can also produce pseudoseptate filaments and spherical bulbous terminations resembling fungal sporangia.

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Simple morphological criteria, with the possible exception of true internal septation, appear unable to distinguish the remains of mineralised filamentous microorganisms from chemical gardens in a straightforward way. Thus, we conclude that iron mineral filaments are not reliable biosignatures in and of themselves and would make a questionable sampling target for evidence of an ancient biosphere on early Mars, where chemical gardens may well have formed in the presence of alkaline, silica-rich groundwater. However, further characterisation of the chemistry and morphology of chemical gardens may eventually allow us to recognise them in the rock record and distinguish them from microfossils.