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Structural and Compositional Diversity in Iron-Based Hydrothermal Chimney Simulants Grown with Functionalized Organics

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Background: Serpentinization at moderate temperatures produces an alkaline, reducing fluid that, upon seeping into the ocean, reacts with dissolved metal cations to form porous, tubular precipitates called hydrothermal chimneys [1]. Minerals within a chimney may couple dissipation of the electrochemical gradient between the seawater and vent fluid to organic synthesis [2]. Hydrothermal chimneys have been proposed as a possible environment for origin of life, on account of their similarity to cellular membranes in extant life, which also couple electrochemical gradients to organic synthesis [1-4]. Here, we simulate an iron-rich hydrothermal chimney and show how environmental agents affect its morphology.

Methods and Results: We simulated a hydrothermal chimney by anaerobically injecting sodium hydroxide, with or without organics, into a reservoir of aqueous ferrous and ferric chloride [5]. Tubular precipitates composed of magnetite and iron oxyhydroxides formed where the injection solution interfaced with the reservoir solution. The walls of these structures consisted of concentric layers, each with a crystalline outer surface and a smooth inner surface. Akaganéite gave way to lepidocrocite and then goethite with increasing depth into the chimney wall, perhaps owing to the chloride gradient between the reservoir and injection solutions [6]. Both pyruvate and cysteine weakened the chimney walls and imparted a rounded morphology on all surfaces throughout the chimney. Alanine also weakened the chimney walls, but it imparted a wider range of crystal morphologies, including disks and crossed spines.

Impact: Our results show that ions and organics in the growth environment may impart compositional and morphological gradients on iron-based hydrothermal chimneys. This provides a number of microenvironments throughout a single chimney, each of which may be best suited to catalyze a different reaction within a larger emerging metabolic pathway. The interaction of organics with inorganic motifs in a chimney raises the opportunity for selective concentration of organics and potentially for ligand accelerated autocatalysis, opening the possibility for large-scale organic synthesis [7].

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