

Unraveling the mechanisms of fungal metal(loid) biomineralization

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The impact of microorganisms, specifically their functional activities, on geological processes on the Earth's surface is undeniably significant. Minerals formed by biological processes provide critical life functions for many organisms, preserve clues to the history of our planet, greatly influence the distribution, form, and bioavailability of essential elements, and have myriad applications such as promoting contaminant remediation and synthesis of bio-inspired minerals. Carbonate and phosphate biominerals have long been studied, as they are commonly formed by recognizable and charismatic eukaryotes. Environmentally abundant and metabolically active micro-eukaryotes, such as fungi, also promote geochemical transformation reactions that lead to the precipitation of a diversity of organic and inorganic biominerals. Many of these solid phases may also be critically questioned as to whether or not they can be called minerals, as they are often nano-sized, poorly ordered, or entirely X-ray amorphous particles. Research to uncover the processes and pathways by which fungi promote metal(loid) phase transformations that induce biomineralization are imperative for better understanding and controlling the contributions of these organisms on ecosystem and planetary health.

Our work examines diverse filamentous fungi and the biological pathways by which they promote the biomineralization of metals and metalloids, such as manganese (Mn) and selenium (Se). Multi-pronged approaches to co-examine the geochemistry, mineralogy, and genetic expression across time and space are utilized to better understand the biological mechanisms, the intracellular and extracellular geochemical reactions, and the formation and subsequent transformation of the mineral products. For example, gene expression analysis of fungi exposed to selenite (Se(IV)) reveal a suite of actively expressed genes that promote selenite reduction to solid-phase Se(0) nanoparticles. Interestingly, these gene functions also yield other Se products that are not biominerals, such as volatile and organo-Se compounds. Microscopic analyses of extracellular Se(0) nanoparticles suggest they are surrounded an organic matrix, which likely stabilizes them against geochemical transformation. These observations invoke further questions surrounding the interactions of these biominerals with these other byproducts and organic compounds that influence the fate and reactivity of these minerals in the natural environment.