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Protein Catalyzed Biomineralization of Magnetite as the Key to Magnetofossil Identification

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The search for life on Mars has opened many unanswered questions, especially with recent discoveries about Mars' ancient environment. The hope of finding biomarkers, microfossils, or other signs of ancient life has captivated the attention of astrobiologists to the general public. Magnetotactic bacteria (MTB), discovered living on Earth in the 1970s, are considered possible proxies of ancient life because they synthesize intracellular magnetite with distinct characteristics through biologically controlled mineralization. These microbes lyse, or break open, when they die and release magnetite crystals into the environment, along with their proteins, creating magnetofossils, which have been recovered from soils, freshwater, and deep-sea sediments. Magnetite nanoparticles have even been recovered from carbonate globules in Martian samples, such as the 1996 ALH84001 meteorite, but their origin is still a topic of much debate. MTB provide a window to Earth's present and past chemical and biological systems, and possibly other planetary conditions. Biogenic magnetite has high chemical purity in comparison to abiogenic magnetite, as well as specific physical configurations (e.g., unique bullet, prismatic, or octahedral shape). MTB synthesizes magnetite in conditions similar to a younger Martian environment, as there is an overlap in time when ancient Mars would have had a magnetic field and aquatic surface. While the chemistries of these waters may have resembled acid mine drainage, MTB are incredibly resilient and are found in extreme environments, from Antarctic lakes to arsenic-rich hot springs. Analysis of the individual proteins MTB utilize in the biomineralization process and understanding not only how each protein functions, but how it is preserved, creates the potential for these proteins to act as biomarkers for MTB, aiding in identification of biomagnetite vs abiotic magnetite on Earth, and perhaps even Mars.