Subsurface Sulfur Systems: Production and Preservation of Distinctive Biogenic Signatures in Sulfur, Iron, Manganese, and Carbonate Cave Systems

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A unique class of caves produced by the dissolution of bedrock by sulfuric acid are atypical on Earth in terms of origin, geochemistry, and ecosystem properties. However, such chemistry could have been present in the apparent acid sulfur conditions recently inferred for an earlier Mars. On Earth, these sulfuric acid caves exhibit conspicuous and distinctive sulfur minerals, characteristic cavity topologies, and notable biological diversity and biomass abundance resulting directly from the conditions that produce the caves. Even long-inactive systems of great antiquity harbor these indicators as traces of their sulfuric acid origins. The microbial and macroscopic ecosystems within such caves are clearly geologically mediated and maintained.

When young and active, these caves produce an abundance of isotopic, geochemical, and morphological biosignatures. In ancient examples, these signals are preserved although in many instances they are replaced by other lithologies, e.g. calcite after gypsum. Long after the active sulfur phase of speleogenesis has ceased, a secondary set of active microbial communities based on oxidation of iron and manganese can be the inheritors of the original sulfur-based microbial communities. The overprint of these secondary communities in combination with the traces of the original sulfur-based ecosystem provide a complex but interpretable history over millions of years even in the aqueous weathering environment on Earth. We anticipate that any analogous subsurface traces of sulfur, iron, and manganese microbial communities on Mars could have been preserved far longer in a potentially less aggressive weathering environment of the Martian subsurface.