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Regional to micron-scale controls on preservation of biosignatures in Phanerozoic hot spring microbial sinter

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More than 130 years of study of siliceous hot-spring deposits (sinter) since Weed's insightful observations on “algous vegetation” at Yellowstone National Park have illuminated a variety of deposit geometries, sedimentary facies, and macro- and micro-fabrics in global sinters, many of which are microbial in origin and considered textural biosignatures. A large number of microbial fabrics are entombed in sinter, with their characteristics and distributions controlled by spring temperature and pH, as well as environmental setting. Sinters are relevant to studies of early life on Earth and the search for past life on Mars.

Microbial fabric preservation is affected by sinter diagenesis, which is, in turn, influenced by water table fluctuations, regional volcano-tectonic evolution, and burial/exhumation history. Thus, putative microbial fabrics, and their associated organic/inorganic geochemical fingerprints that may help differentiate biotic vs. abiotic origins, can be highly variable in their preservation states within the deep time geological record, with deposits ranging in quality from lagerstätte to strongly diminished, with respect to retaining original paleoenvironmental information. Nonetheless, our studies indicate that stromatolitic textures generally are the most robust of biosignatures, except for the most extreme cases of diagenetic overprinting. Early silicification is paramount to locking in biological traces in sinter. In addition, laser micro-Raman and lipid biomarker analyses show promise as high-quality, mineralogical and geochemical biosignatures in ancient hydrothermal settings, although with some important caveats. This nested, integrative approach, from micrometer to regional scales of observation, has proven to be helpful in narrowing the search for the highest quality microbial signatures in hydrothermal silica, identifying stromatolite mimics and tracking the fate of carbonaceous material in sinters through time.

Finally, on Earth all old, and some young, sinters have diagenetically transformed from amorphous opal to micro- or mesocrystalline quartz. In contrast, the inferred sinters at Columbia Hills in Gusev Crater on Mars remain opaline, indicating little to no subsequent diagenesis. Hence, because of its unique history, Mars may be the best place in the Solar System to preserve the oldest biosignatures in hydrothermal silica, if ever they were present. Focused investigations of Earth-analog paleoenvironmental-diagenetic models help pinpoint where to search for them.