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Testing the preservation of organic compounds in hydrothermal silica-rich environments under early Earth conditions

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Microbial life may have originated on Earth about 4 billion years ago in terrestrial hydrothermal settings that were strongly reducing and rich in silica. Such siliceous environments (e.g. hot springs) have persisted throughout Earth's history and today commonly host diverse communities of Archaea and Bacteria. However, archaeal lipid remnants have mainly been reported from modern and subrecent siliceous sinter settings, suggesting a possible bias against long-term preservation in such environments. Here, we used laboratory experiments to assess the preservation potential of prokaryotic lipids, especially those from Archaea. Our experiments simulate early diagenesis in the presence and absence of silica. Therefore, we performed closed-system experiments in gold capsules, exposing the organic compounds to elevated pressure (300 bar) and temperature (250 °C) over an extended time period (14 days). As model compounds, we used (i) archaeol, (ii) isoprenoid glycerol dialkyl glycerol tetraethers (isoGDGTs), and (iii) an extract from a microbial mat containing both archaeal and bacterial hydrocarbon biomarkers. We found that the presence of silica enhanced the degradation of compounds with extended isoprenoid chains, most likely caused by oxidative attack of hydroxyl radicals generated from silica–fluid interactions. The results indicate that both the silica matrix and the molecular structure of the organic compounds strongly influence the preservation of the tested compounds in hydrothermal silica-rich environments (e.g. hot springs). Expanding these experiments to a broader range of organic compounds will improve our understanding of the preservation of the biosignatures as well as processes that shaped microbial communities in hydrothermal silica-rich environments.