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Early diagenetic controls on the preservation of organic compounds and intact cells in alkaline lake sediments

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Distinct organic biosignatures may survive low-temperature and low-pressure diagenetic processes on geological timescales even when identifying cell morphology in fossils has been lost. Dynamic interactions between organic matter and aluminosilicate clay surfaces are increasingly appreciated as a significant driver in organic preservation and microbial fossilization. In hyperalkaline and hypersaline environments, cation bridging can dominate clay-mineral interactions over ligand exchange and promote preservation. Because we do not know the extent to which these interactions impact biological degradation or are sensitive to pressure and temperature, we do not have a clear idea of which environments are most likely to preserve biomarkers or cell morphology. Here we interrogate the impacts of sulfide, salinity, alkalinity, and mineral associations on the preservation of organic-rich sediments from Mono Lake, CA, and of cells in artificial sediments via targeted incubation experiments and hydrous pyrolysis experiments. Preliminary results in Mono Lake sediment incubations suggest greater respiration of $\delta^{13}C$-depleted organic matter in the treatments that reduce salinity level than in those that target pH alone or sulfide. SEM/EDX analyses reveal spatial association between organic matter and authigenic Mg-smectite clays such as stevensite, hinting at a potential physical control for sequestration. Microbial community shifts tracked through 16S DNA sequencing and FISH microscopy experiments with targeted gene probes help distinguish the physical and biological mechanisms of preservation in the varying geochemical conditions. To observe the long-term preservation potential of cell morphology and biomarkers, we perform hydrous pyrolysis experiments with natural Mono Lake sediments and with single-strain cyanobacterial biomass or isolated organic compounds incubated with artificial soda lake water and Mg/Fe-bearing aluminosilicate clays. Samples are sealed into 1.5cm-long gold capsules then heated within cold-seal pressure vessels to 250-300°C and 250 bars for up to three days. Raman spectroscopy and the evolution of N:C by EA-IRMS are used to evaluate decomposition of organic matter content. SEM/EDX analysis on chemically-dried samples enables visualization of cell morphology and the placement of organic materials with elemental mapping. Our findings may help elucidate geochemical conditions that foster preservation in Earth's history or on other planets, and the extent to which those biosignatures survive early diagenesis.