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The mineralogical and chemical composition of microbialites as environmental proxies: lessons learned from the integrative analysis of modern microbialites from ten Mexican lakes

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Interpreting the environmental conditions under which ancient microbialites formed relies upon comparisons with modern analogues. This is why we need a detailed reference framework relating the chemical and mineralogical compositions of modern microbialites to the physico-chemical parameters prevailing in the environments where they form.

Here, we measured the chemical and mineralogical composition of microbialites from ten Mexican lakes as well as the chemical composition of the surrounding waters. Correlations between solution and solid chemical analyses were assessed using multivariate analyses. A large diversity of microbialites was observed in terms of mineralogical composition, with occurrence of diverse carbonate phases such as (Mg-)calcite, monohydrocalcite, aragonite, hydromagnesite, and dolomite as well as authigenic poorly crystalline Mg-silicate phases. Interestingly, all lakes harboring microbialites were saturated or supersaturated with monohydrocalcite, suggesting that such a saturation state might be required for the onset of microbialite formation and that precursor soluble phases such as amorphous calcium carbonate and monohydrocalcite play a pivotal role in these lakes. Subsequently, monohydrocalcite transforms partly or completely to Mg-calcite or aragonite, depending on the lake $(Mg/Ca)_{aq}$. Moreover, lakes harboring hydromagnesite-containing microbialites were saturated or supersaturated with an amorphous Mg-carbonate phase, supporting again the involvement of precursor carbonate phases. Authigenic Mg-silicates formed by heterogenous or homogenous nucleation in lakes saturated or supersaturated with a phase reported in the literature as "amorphous sepiolite" and with a H_4SiO_4 concentration >0.2 mM. The size of microbialites in the lakes correlated positively with salinity, $(Mg/Ca)_{aq}$ and alkalinity. Last, some microbialites poorly affected by detrital contamination showed (REE+Y) patterns with features commonly reported for marine microbialites, questioning the possibility to infer the marine versus lacustrine origin of a microbialite only based on (REE+Y).

Overall, we observed that the hydrogeochemical evolution of lakes exerts a primary control over the onset of microbialite formation and the evolution of their mineralogical composition, suggesting that this latter could be used as a paleoenvironmental proxy. To this end, the diversity of transformations occurring with diagenesis and/or metamorphism of the phases composing modern microbialites will need to be assessed.