Integrative analysis of the mineralogical and chemical composition of modern microbialites from ten Mexican lakes: what do we learn about their formation?

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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 physical and chemical parameters prevailing in the environments where they form. Here, we measured the chemical, including major and trace elements, and mineralogical composition of microbialites from ten Mexican lakes as well as the chemical composition of the surrounding waters. Saturation states of lakes with different mineral phases were systematically determined and correlations between solution and solid chemical analyses were assessed using multivariate analyses. I will show that 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 (kerolite and/or stevensite). 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 aragonite or Mg-calcite, depending on the lake (Mg/Ca)aq. Moreover, lakes harboring hydromagnesite-containing microbialites were saturated with an amorphous magnesium carbonate phase, supporting again the involvement of precursor carbonate phases. Authigenic Mg-silicates formed by homogenous or heterogenous nucleation in lakes saturated or supersaturated with a phase reported in the literature as “amorphous sepiolite” and with a H4SiO4 concentration superior to 0.2 mM. A strong correlation between the alkalinity and the salinity of all the lakes was observed. The observed large variations of alkalinity between the lakes relate to varying
concentration stages of an initial alkaline dilute water, due to a varying hydrochemical functioning. In all cases, the size of microbialites in the lakes correlated positively with salinity, (Mg/Ca)aq and alkalinity (Figure 1). 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, while microorganisms can impact nucleation processes and textural arrangements in microbialites, we observed that the hydrogeochemical evolution of lakes exerts a primary control over the onset of microbialite formation and the evolution of their chemical and mineralogical composition.

Figure 1. Model of lake evolution over time. Microbialites start emerging at a certain stage of evaporation and/or weathering of the lake (when [Na+]aq and alkalinity become higher than certain threshold values). Then microbialite mineralogy changes according to key parameters such as the aqueous (Mg/Ca), which controls carbonate mineralogy, and aqueous [H4SiO4] controlling the precipitation of authigenic Mg-silicate.