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Untangling the primary biotic and abiotic controls on oxygen, inorganic and organic carbon isotope signals in modern microbialites

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Microbialites are complex organo-sedimentary structures involving different degrees of biomineralization and interaction of biotic and abiotic factors. They formed throughout most of Earth history, over a wide range of geological contexts and environmental conditions. The carbon and oxygen isotope records of microbialite carbonates (often their main constituents) have thus been widely used for reconstructing paleoenvironments and biomineralization processes. However, such geochemical records – in both ancient and modern settings – do not always enable to properly distinguish among the multiplicity of factors that influence microbialites formation. We analyzed the carbon and oxygen isotope compositions from bulk and micro-drilled carbonates as well as bulk organic carbon isotope compositions in microbialites from four Mexican volcanic crater lakes. This survey of four lakes allows comparing microbialite formation processes and their geochemical record within distinct physico-chemical contexts. Combining the geochemical analyses with petrographic, mineralogical, and microbiological data, we show that the potential for isotopic biosignature preservation primarily depends on physico-chemical conditions, notably on alkalinity levels. Our results allow proposing a new interpretation framework for the microbialite carbonate C isotopes, as recording the balance between the microbialite net primary productivity and the amount of precipitation that relates to physico-chemical forcing, on top of reflecting the signature of the fluid from which microbialites precipitate. The signals of microbialite oxygen isotope compositions highlight a lack of understanding in the oxygen isotope records of relatively rare carbonate phases (e.g., hydromagnesite). We show that these signals are primarily influenced by the basins' hydrology, though biological effects may also play a (minor) role. Therefore, both carbon and oxygen isotopic signals may record a combination of different local/global and biotic/abiotic factors, making microbialites intricate archives of their growth environment, which should thus be interpreted with cautions and in the light of their surrounding sediments.