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Biogeochemical controls on modern microbialite mineralogy in the hydrothermally active Lake Specchio di Venere, Italy

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Microbialites are regulating Earth's climate over geological time scales by influencing the global carbon cycle, yet the biogeochemical processes governing their formation and mineralogical composition remain incompletely understood. In this study, we investigate actively growing microbialites from Lake Specchio di Venere located on the Pantelleria volcanic island, Italy. This endorheic alkaline and saline lake is characterized by intense hydrothermal activity, with CO_2 emission from the lake floor and by a (~50°C) hot spring feeding the surface of the lake. By combining mineralogical, geochemical, and carbon isotope data, we aim to investigate the relationships between the lake water, the hydrothermal vent, and the hot spring, and to assess their collective effect on microbialite mineralogy.

The geochemical results reveal distinct aqueous compositions between the hot spring and the lake. The hot spring is supersaturated with respect to amorphous silica and undersaturated with respect to Mg-clays and calcite, whereas the lake water shows the opposite behaviour. This aqueous difference is accompanied by contrasting mineralogy. The microbialites from the hot spring mouth are dominated by authigenic minerals, including aragonite, Mg-calcite, and amorphous silica, with minor Mg-clays. In contrast, the microbialites formed within the lake are dominated by aragonite, hydromagnesite, and Mg-clays, with the minor presence of amorphous silica. The precipitation of the authigenic phases appears to be influenced by CO_2 outgassing from the hot spring, with a hot spring pCO_2 of 0.9 atm decreasing to 0.001 atm in the lake water, resulting in pH elevation from ~6.2 to ~9.0, modulating the free carbonate and major ion availability in solution for mineral nucleation. The $\delta^{13}C$ of the dissolved inorganic carbon (DIC) increases from − 2.9 ‰ in the hot spring mouth to + 4‰ in the lake water, indicating intense CO_2 degassing, evaporative concentration, and/or microbial activity along the flow path. The − 4 ‰ $\delta^{13}C$ of the gas from the hydrothermal vent and the + 4 ‰ $\delta^{13}C$ of coexisting DIC, showing a $\Delta^{13}C_{DIC\text{-}gas}$ = 8 ‰, is consistent with equilibrium isotopic fractionation, confirming the massive magmatic CO_2 contribution to lake DIC, which in turn feeds carbonate formation in Lake Specchio di Venere.