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Stromatolites of the western Pannonian Basin reflect trace metal availability in microbial habitats during the Middle Miocene salinity crisis

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Stromatolitic carbonates are chemical sediments that formed in the presence of microbial life and occur in the sedimentary record from at least 3.4 billion years ago until today. Thus, stromatolites are unique geochemical archives to reconstruct and understand environmental conditions in which microbial life thrived and evolved through Earth's history. In this study, we further exploit the potential of stromatolites to reconstruct ancient microbial habitats and report the first geochemical data of Miocene stromatolites from the Oberpullendorf Basin (Austria) that were formed during the Badenian salinity crisis. The combined approach of C-O isotopes with trace element data, in particular REE systematics and enrichment factors of bio-essential elements, of *individual* stromatolite laminae is used to reconstruct variations of palaeo-environmental conditions on centimeter scale including element availability in microbial habitats during the Badenian salinity crisis.

Stromatolitic carbonates in the lower units show negative $\delta^{13}C_{carb}$ values and typical seawater-like shale-normalized rare earths and yttrium (REY_{SN}) patterns with positive La_{SN}, Gd_{SN} anomalies, super-chondritic Y/Ho ratios, and heavy REY_{SN} enrichments to light REY_{SN}, indicating an open marine depositional setting. Stratigraphic upwards, stromatolitic carbonates show suppressed seawater-like REY_{SN} signatures and increasing $\delta^{13}C_{carb}$ values that reflect the development of a restricted environment. Seawater-like REY_{SN} patterns and homogenously distributed negative $\delta^{13}C_{carb}$ values in the stratigraphic uppermost part resemble the transition to fully marine environmental conditions again. Enrichment factors of bio-essential elements (Fe, Mn, Co, Zn, Mo, W) reflect sufficient element availability during marine conditions but stratigraphic upwards consequetive limitation during the development of the (semi)closed lagoon.

We show that combined REY, C isotopes, and element enrichment factors bear the unique potential to reconstruct temporal changes in paleo-environments and determine the availability of bio-essential elements in microbial habitats. This approach may provide the groundwork for a better understanding of the evolution and development of microbial metabolisms under severely different atmospheric-hydrospheric conditions on planet Earth and beyond.