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Linking metabolic and mineralogical diversities layered structures microbialite-like structures in salt mudflats

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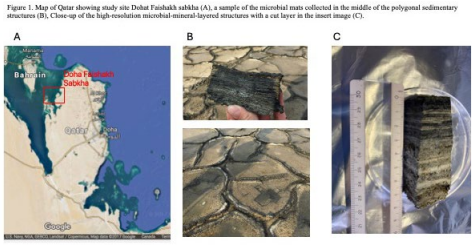


Figure 1. Map of Qatar showing study site Dohat Faishakh sabkha (A), a sample of the microbial mats collected in the middle of the polygonal sedimentary structures (B), Close-up of the high-resolution microbial-mineral-layered structures with a cut layer in the insert image (C).

Sabkhas (salt flats in Arabic) are coastal ecosystems in arid regions that offer a unique setting for studying interactions between hypersaline microbial ecosystems, mineral formation, and associated sedimentary structures. These environments are relevant for understanding modern biogeochemical processes and serve as analogs for the preservation of biosignatures on early Mars.

In this study, we investigated the microbial and mineralogical composition of the laminated surface at millimetre resolution in the intertidal zone on the northeastern coast of Qatar (Figure 1). Using high-throughput long-read 16S rRNA, X-ray diffraction (XRD), and elemental mapping via micro-XRF on thin sections, we characterized the microbial communities and minerals across 26 layers within the upper 6 cm. Despite harsh conditions, over 700 bacterial operational taxonomic units (OTUs) in 63 Phyla were revealed at the sabkha's surface. Cyanobacteria dominate (52% relative abundance) the first millimetres of mats, with several Desulfobacterota and Bacteroidota, Firmicutes, and Planctomycetota taxa, many of which are known to be halophilic and thermotolerant, being present in all samples. The mineralogical assemblage consisted of carbonates (aragonite, calcite, and dolomite), quartz, plagioclase, and evaporites (halite and bassanite). XRF mapping revealed several µm-thin layers containing potassium and magnesium, most likely phyllosilicates. Statistical analysis revealed five groups with similar microstratigraphy and microbial communities. Two layers, one at the surface and the second below the first mineralized lamina, form their groups. The third group unites the green-grey layers, probably buried microbial mats. The fourth group are the white mineralized layers, and the fifth group connects the repetitive grey-black layers, where organic matter degradation occurs. Based on principal component analysis, halite is associated with microbial diversity, likely by protecting from desiccation and solar radiation. These findings enhance our understanding of biomineralization and biosignature formation in extreme environments, supporting Sabkhas' investigation for astrobiological exploration.