POTENTIAL BIOAVAILABILITY OF CRYSTALLIZATION WATER IN SULFATE MINERALS UNDER WATER-RESTRICTED CONDITIONS – A CASE STUDY OF GYPSUM INTERDUNES IN THE TULAROSA BASIN, NEW MEXICO

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Abstract: The formation of gypsum sand dunes in the Tularosa Basin, New Mexico, was closely related to a "water-loss" history of paleo salt lakes, thereby representing the end-member of a certain type of modern brine environments. As these gypsum sand dunes only persist in dry and water-restricted conditions, they are considered generally harsh and extreme environments for life. Different from silicates (of which most terrestrial sand dunes are composed), however, gypsum is a hydrate mineral, which contains ~ 21% of water in its crystal structure. This simple but intriguing fact has urged us to examine the habitability of gypsum-dominated environments (which are largely arid to hyper-arid and results of continuous water loss) from a different angle. Here we report the findings of our field work based on the gypsum sand dunes and interdune basins in the Tularosa Basin, NM. In this work, we have conducted systematic measurement and sampling at five sites, followed by geochemical, mineralogical, and microbiological analyses of the collected samples. The focal point of this work is to understand "if microbial life may capitalize on the structural water in gypsum under water-restricted conditions". The results of this work may provide new insight into our current understanding the life limits on Earth and into the search of life in extraterrestrial environments.

The samples of the five sites showed high variations in microbial abundances and community structures, which are also dependent on the sample depth within each site (Fig. 1a). The niches with the highest bio-abundance are exclusively confined within the surface layers of gypsum sediments. These niches also contain relatively high abundances of sulfate-reducing communities based on *dsrA* quantification (Fig. 1b) and measurements of S isotopic fractions in the enriched samples. Additionally, the samples with significantly higher bio-abundances have less weight loss when heated from 65-200ºC in the thermal gravity analysis (i.e., indicative of the water content in the sediment mineral structures) (Fig. 1c), and are enriched in both

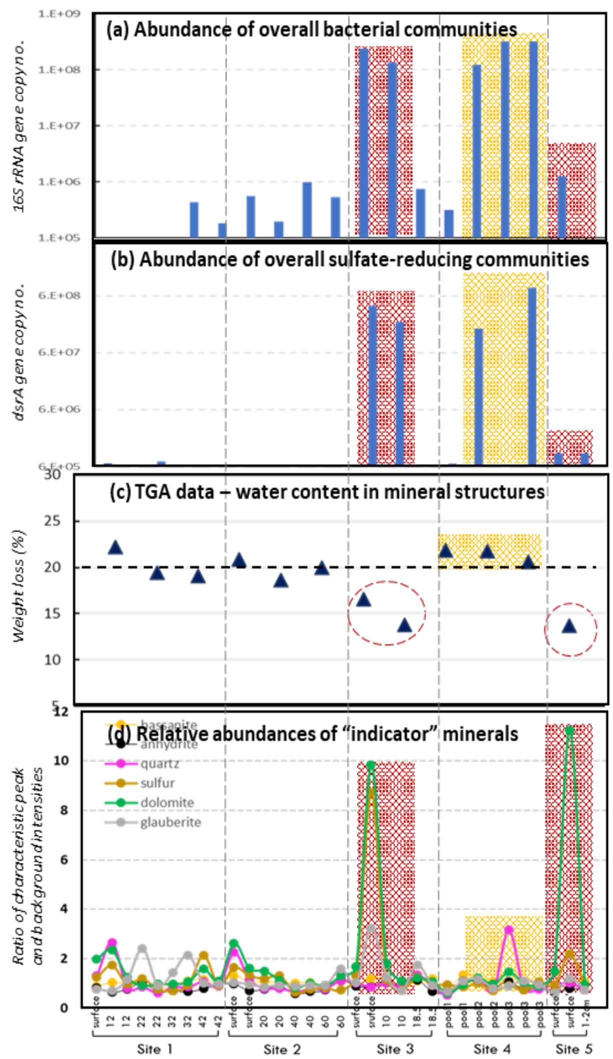

Figure 1. Integrated microbiological and mineralogical data of the interdune basin samples from five sites within the White Sands National Monument, the Tularosa Basin, New Mexico.

dolomite and native sulfur (Fig. 1d) (except those in the vicinity of ephemeral ponds, site 4, which were formed during the unusually wet season of 2019). Collectively, evidence pointing to different survival and growth mechanisms of associated bacterial com-munities was identified in the constantly dry interdune sediments (sites 3 and 5) versus the ephemeral pond sediment (site 4) (both composed of > 95% of gypsum), indirectly supporting the hypothesized role of sulfate hydrate minerals being an alternative water source in water-restricted geochemical settings. Based on the results of this study, a specific pathway was proposed leading to the possible release of gypsum structural water (Fig. 2).

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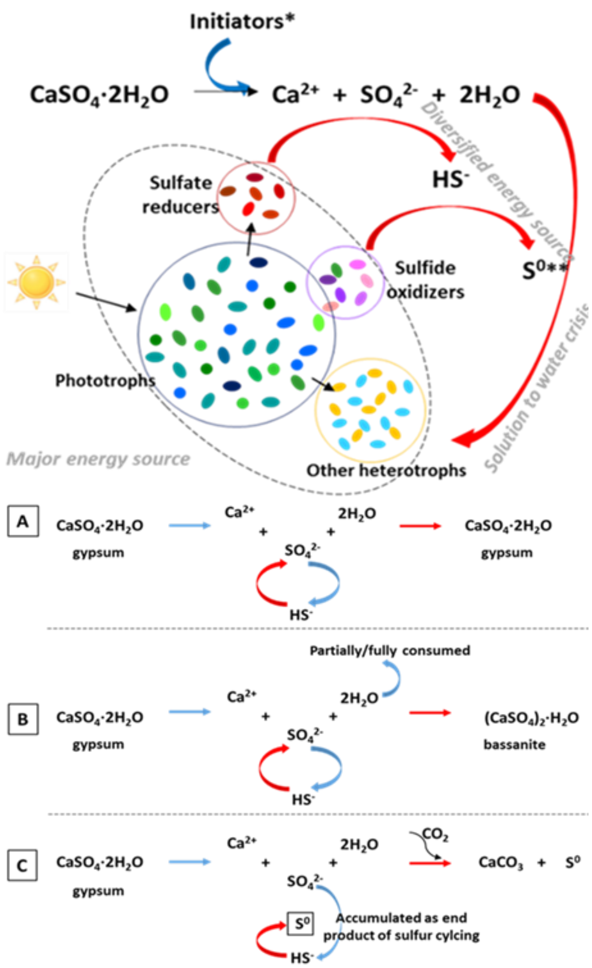

Figure 2. Proposed mechanisms for creating habitable niches in the gypsum interdunes within the Tularosa Basin, New Mexico. Coupling of microbial sulfate reduction with photosynthesis (as all high-bio niches are located within the surface layers of the sediments and contain significant fractions of photosynthetic bacteria) may have resolved the biological needs of carbon, energy, and hydration. Based on the detection and semi-quantification of calcite, dolomite and native sulfur, this previous work also proposed a specific pathway (boxed) leading to the release of gypsum structural water.