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Gypsum as a Repository of Extinct and Extant Biosignatures at Salar de Pajonales, Northern Chile

MS. CINTHYA TEBES-CAYO[1], CECILIA DEMERGASSO[1], ÓSCAR CABESTRERO[1], GUILLERMO CHONG[2], DANIEL CARRIZO[3], LAURA SÁNCHEZ[3], VICTOR PARRO[4], KIM WARREN-RHODES[5], NATHALIE CABROL[5], ALEX ECHEVERRÍA-VEGA[6], EDUARDO CASTRO-NALLAR[7], ANDREW MENZIES[8] AND M. ESTHER SANZ-MONTERO[9]

[1]Centro de Biotecnología, Universidad Católica del Norte
[2]Facultad de Geología, Universidad Católica del Norte
[3]Centro de Astrobiología (CAB), CSIC-INTA, Madrid, España.
[4]Centro de Astrobiología (CAB), CSIC-INTA, Madrid, España
[5]SETI Institute, Carl Sagan Center
[6]Centro de Investigación de Estudios Avanzados del Maule (CIEAM), Vicerrectoría de Investigación y Postgrado, Universidad Católica del Maule
[7]Instituto de Ciencias Biológicas, Universidad de Talca
[8]Bruker Nano GmbH
[9]Universidad Complutense de Madrid

High-altitude Andean salt flats constitute natural laboratories for investigating microbe–mineral interactions under extreme physicochemical gradients.

Terraces near Flamencos Lagoon in the southeastern Salar de Pajonales (Chile), located at 3,517 m above sea level in the arid Altiplano, host relic gypsum stromatolites and crusts formed under extreme desiccation, intense solar radiation, with episodic hydration events. These gypsum-rich environments provide a natural analog for Martian evaporitic settings, where habitability and biosignature preservation may coexist.

By combining meteorological, geochemical, isotopic, and microbiological data from 19 gypsum-dominated microhabitats, we identified strong environmental controls on mineral formation and microbial community structure. Climate data confirmed prolonged aridity punctuated by potential short-lived wetting events, which provided conditions favorable for microbial reactivation and long-term biosignature retention within gypsum.

Fossil stromatolites exhibited laminated fabrics, micritic filaments, and Fe–Si-rich laminae, together with diatom frustules, indicating long-term biosignature entrapment. Microbial diversity varied with mineralogy and moisture availability: stromatolites hosted specialized cyanobacteria and archaea, whereas crusts and sediments contained more diverse photoautotrophic and heterotrophic assemblages.

Lipid biomarkers and $\delta^{13}C$ signatures indicated active carbon fixation via the Calvin cycle, dominated by cyanobacteria, photoautotrophs, and archaea in gypsum stromatolites and crusts. Fluorescence signals of *chlorophyll a* and carotenoids confirmed photosynthetic activity in near-surface layers. In contrast, signatures of the reverse tricarboxylic acid cycle were less common in gypsum samples and were mostly restricted to unconsolidated sediments near the lagoon.

Overall, the gypsum evaporitic systems of the Salar de Pajonales preserve both molecular and morphological biosignatures while sustaining microbial life under extreme conditions. The spatial separation between fossil and extant signatures underscores gypsum's exceptional capacity to entomb and protect biological evidence, reinforcing its importance as a prime target for astrobiological exploration on Mars.