National Aeronautics and Space Administration

FY23 Strategic University Research Partnership (SURP)

Laboratory Characterization of Carbon in Salts: A Study of Ceres Analogs

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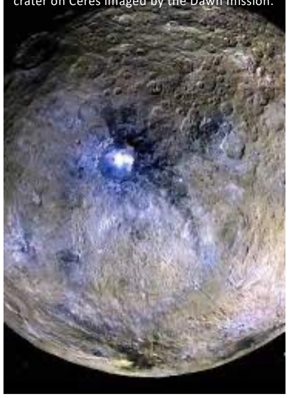
Student Investigators: Lucas Reynoso (Years 1-3), Makeyla Joplin (Year 1)

Objectives: The goal of this work is to provide an experimental framework to understand preservation of carbon in both organic and inorganic forms in sodium chloride and sodium carbonate salts. The focus is on carbonaceous bodies, and dwarf planet Ceres in particular, but the projected results apply to many large volatile-rich bodies. The key questions addressed for the past year of activity are:

How do brines and organics freeze together? Is there a kind of carbonaceous matter that would preserve its chemical and physical characteristics wthin salt particles?

What is its elemental, isotopic and structural makeup?

Figure 1. Field of evaporites in 92-km Occator crater on Ceres imaged by the Dawn mission.



Background: Ceres is a differentiated small body with an icy crust over a rocky mantle and perhaps a shallow liquid-brine layer above the mantle remaining today. It is characterized by recent cryovolcanic activity, abundant organic matter, and pervasive display of salts. The recent emplacement of salt-rich subsurface material on Ceres' surface is interpreted as evidence for briny liquids at depth. These organics likely harbor biocritical elements (including nitrogen, phosphorus, and sulfur) that could be trapped as 'elemental fossils' within the mineral salts evolved from the brine solutions and are potential tracers of geologic processes.

We want to probe if carbon (in any form) can be encapsulated and preserved in the sodium chloride and sodium carbonate salts found on the surface of Ceres, and are likely a result of hydrothermal alteration in its interior.

Significance/Benefits to JPL and NASA:

Extraterrestrial salts are rarely found within meteorites, because the salts are so easy to degrade, while the meteorites are sitting on the Earth's surface.

Hence, this proposed work is novel in that it will develop experimental protocols that can be extended to the study of salt crystals in situ and returned to Earth by future missions.

Approach and Results: Student Lucas Reynoso conducted several experiments to grow NaCl crystals under equilibrium conditions in a supersaturated solution of glycine. Reflected light optical microscope images with a Nikon Eclipse LV100ND revealed two prominent features within the glycine-bearing crystals (Figure 2): (a) blebs of dark material (ranging from 5 to 25 µm) scattered heterogeneously in the NaCl matrix and (b) a dark hue over the entire crystal.

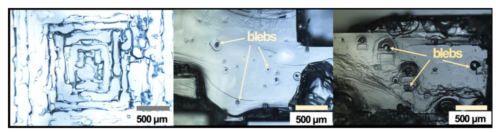


Figure 2. Different types of NaCl (halite) crystals analyzed in this study, here observed with optical microscopy. (Left) Pure sodium chloride crystal; (center) crystal grown from a solution with 0.07 M glycine; (right) crystal grown from a solution with 0.13 M glycine. Arrows points at regions enriched in glycine.

Fourier-transform infrared spectroscopy (FTIR) on the glycine-bearing crystals confirm that the glycine was intact within the NaCl crystals (Figure 3).

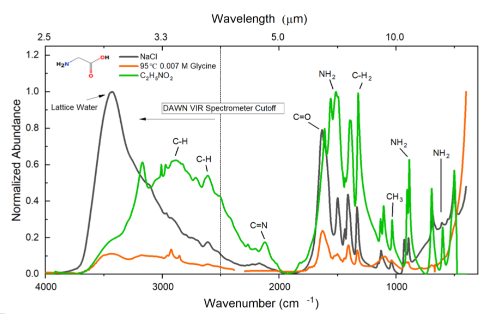


Figure 3. FTIR spectrum for pure glycine, pure NaCl, and a 0.007 M Glycine sample

Gas chromatography and Brunauer-Emmett-Teller (porosity) measurements were also carried out on the NaCl crystals with variable amounts of glycine.

This work shows that glycine survives fragmentation or decomposition during its incorporation into NaCl crystals and can be detected as individual molecules with a current detection limit of 8 ppm. Additionally, inclusions of glycine can decrease the crystal porosity, especially if the crystallites form under non-equilibrium conditions.

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Publications:

[A] Froh, V., Bose, M., Suttle, M. D., Nava, J., Folco, L., Williams, L. B., & Castillo-Rogez, J. (2023) Water-rich Ctype asteroids as early solar system carbonate factories. Icarus, 391, 115300. https://doi.org/10.1016/j.icarus.2022.115300

[B] Reynoso, L. R., Robinson, K. J., Root, R. A., Williams, L. B., Castillo-Rogez, J. C., Bose, M. (2023) Positive glycine incorporation in Ceres analogue minerals, Lunar and Planetary Science Conference 54, 1321. https://www.hou.usra.edu/meetings/lpsc2023/pdf/1321.pdf

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