National Aeronautics and Space Administration

FY23 Topic Areas Research and Technology Development (TRTD)

Organics and Associated Mineralogy on Ocean Worlds

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Strategic Focus Area: Ocean Worlds

Objectives: To investigate the behavior of astrobiologically-relevant organics in frozen brine systems upon exposure to ocean world surface conditions. We seek to address the fundamental questions such as (i) How do different types of organics organize in brine deposits? Do they chelate/precipitate preferentially with certain types of salt minerals? (ii) Is there an enrichment of organics at the salt/ice grain boundaries? (iii) What are the effects of ionic strength and and freezing rates on the partitioning behavior?

Background: The distribution of organics on ocean worlds is a topic of immense interest in the search for habitable environments and evidence of life in the Solar System. Space missions have revealed both the presence and impressive diversity of organic materials on Titan, Enceladus, and Ceres. These bodies also harbor subsurface oceans or liquid reservoirs that are/were highly enriched in salt minerals, whose combination with organics and water/ice present complex chemical environments that could favor conditions suitable for the emergence of life. The fundamental question of how dissolved organic species and hydrated salt minerals co-evolve upon their exposure onto ocean world surfaces, however, has not been established (Figure 1). This work helps provide an experimental framework to understand their chemical relationship. Such information will be useful in identifying potential organic-rich targets for future in situ analysis.

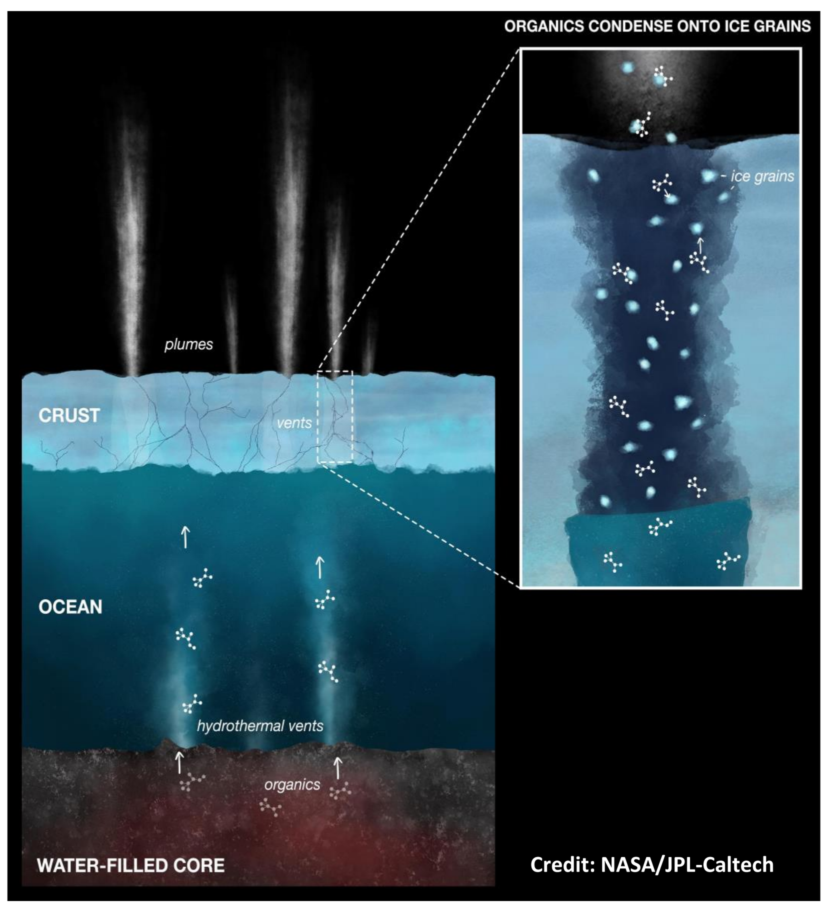

Figure 1. *Organic compounds are found in salt-rich ice grains emitted from Enceladus plumes. They are thought to originate from hydrothermal vents, followed by dissolution in briny fluid before freezing onto ice grains.*

Approach and Results: We have characterized the spatial distribution of two amino acids (glycine and aspartic acid) in a putative frozen Enceladus brine (pH ~9-10) containing sodium (0.7 M), chloride (0.4 M), and carbonate (0.15 M) ions via micro-Raman imaging. Small droplets of the samples were rapidly quenched to 110 K at estimated rate of ~40 K/s, simulating the flash-freezing condition experienced by Enceladus ice grains. Raman experiments indicate that both amino acid-bearing solutions undergo some degree of vitrification (glass formation), especially for the chloride salt and glycine (Figure 2). Upon annealing, both samples reveal preferential association of the amino acids with crystalline salt hydrates (natron $Na_2CO_3•10H_2O$ and hydrohalite $NaCl•2H_2O$) rather than with water ice (Figure 3), despite the difference in their functional side groups. Both amino acids are also found to be zoned together more often with natron than hydrohalite, a behavior that could be attributed to the higher charge density and stronger attraction of the carbonate ion as compared to the monovalent chloride. Solute-solute interaction thus appears to dominate in these frozen systems. These observations suggest that salt-rich ice particles can serve as concentrators of organic biomarkers, enhancing their prospect of detection from remote sensing or in situ analysis.

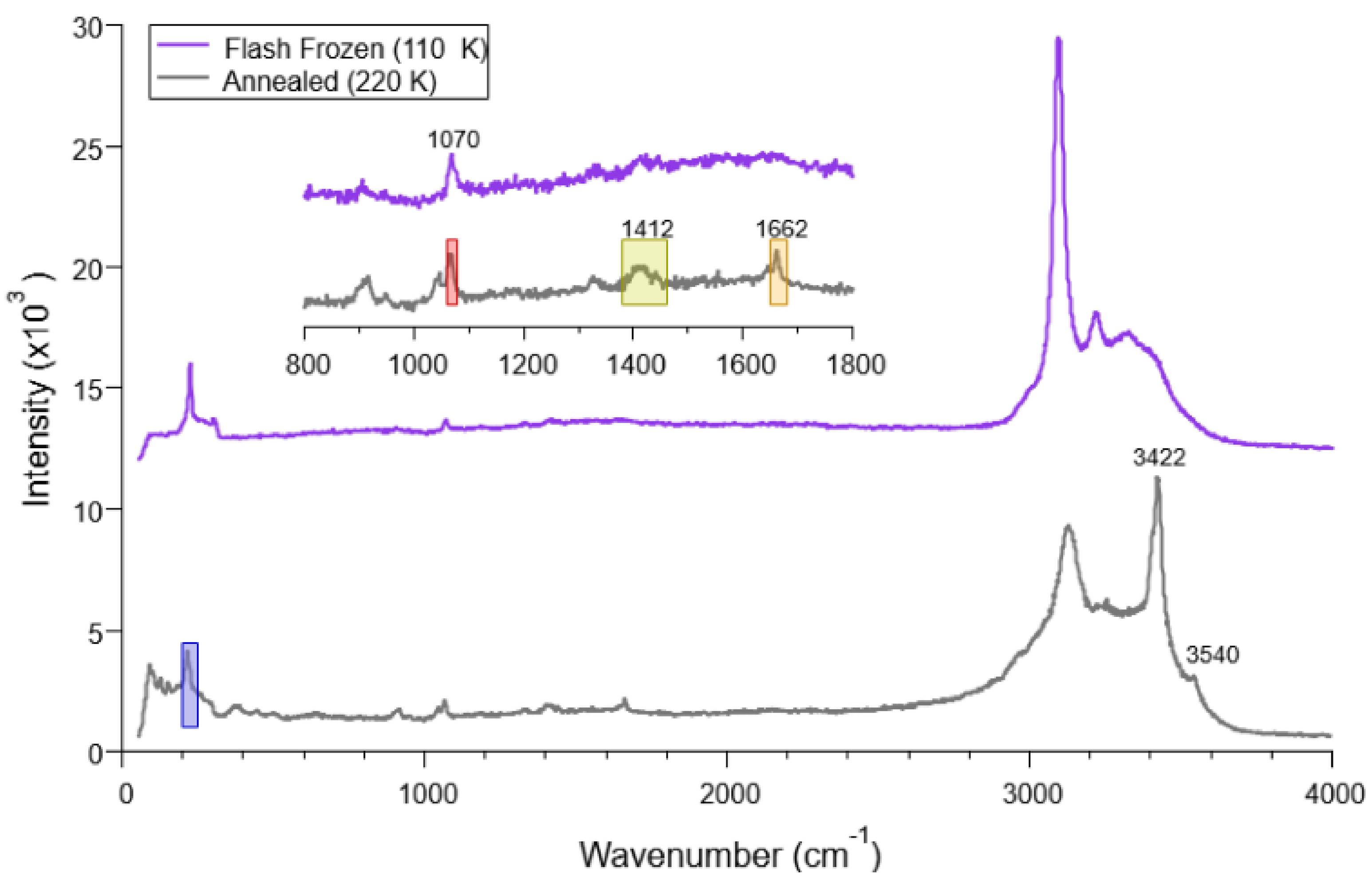

Figure 2. *Raman spectrum of an analog Enceladus brine containing glycine upon flash freezing at 110 K (top) and upon annealing at 220 K (bottom). The latter reveals several features due to glycine (yellow) and hydrohalite (orange).*

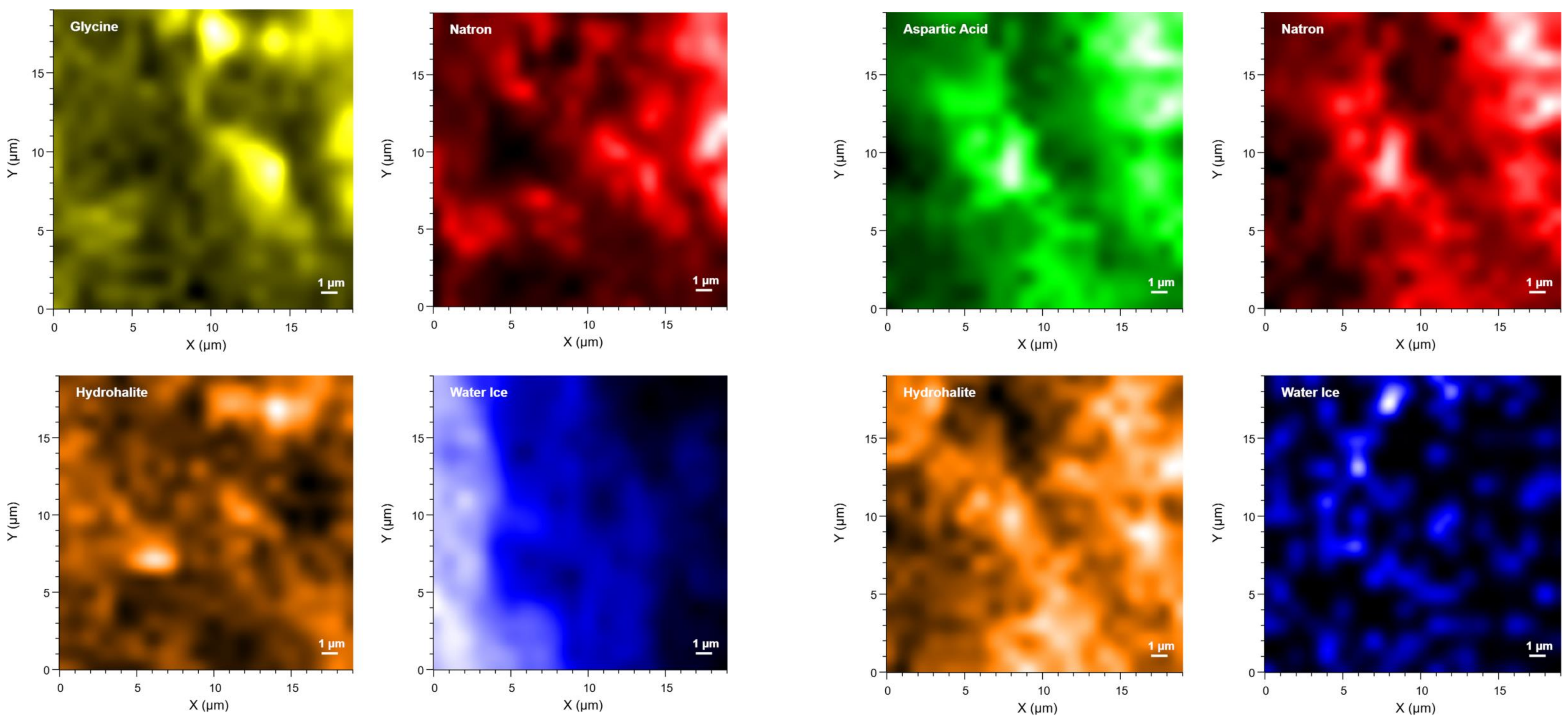

Figure 3. *Raman maps obtained at 220 K showing the distribution of each component in the glycine- (left) and aspartic acid-bearing (right) brines.*

Significance/Benefits to JPL and NASA: The results provide insights into where potential biosignatures might accumulate and be preserved on ocean world surfaces. This could help constrain the best places to look for organic-rich deposits, as well as informing spectral models and refining detection strategies.

Publications:

Vu, T. H., Hodyss, R., Johnson, P. V., Cable, M. L. (2023). "Spatial Distribution of Glycine and Aspartic Acid in Rapidly Frozen Brines Relevant to Enceladus." *Planet. Sci. J.* 4(8): 156. DOI: 10.3847/PSJ/aced90

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