FY24 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 simulated ocean world surface conditions. In particular, we seek to address fundamental questions such as (i) How are different types of organics partitioned in frozen brine deposits? Do they associate 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 concentrations 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 beyond Earth. Past space missions have revealed both the presence as well as the impressive diversity of organic materials on Titan, Enceladus, and Ceres. Organics have also been long speculated for Europa, with their identification being one of the primary objectives of the JUICE and Clipper missions. All of these bodies are thought to harbor subsurface oceans/liquid reservoirs that are/were highly enriched in salt minerals, whose complex interactions with organics and water/ice could present enticing conditions for entrapment of organics. The fundamental issue of how dissolved organics and salt minerals co-evolve upon exposure to ocean world surfaces (e.g. Figure 1) has not been explored prior to this project. Here we seek to reveal the fundamental detail of this process, with an aim towards providing useful constraints for identifying potential organic-rich targets in future in situ analysis.

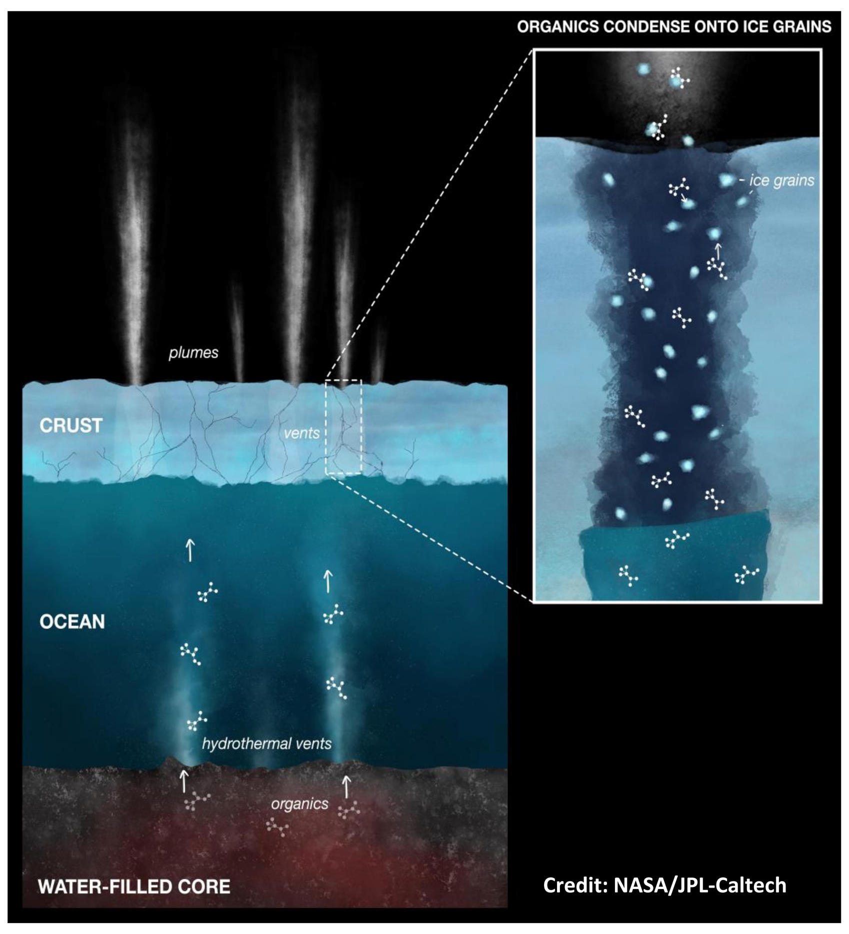

Figure 1. *Organic compounds were found in salt-rich ice grains emitted from Enceladus plumes. They are thought to originate from hydrothermal vents, followed by dissolution in briny fluid before freezing onto ice grains.*

Approach and Results: We have conducted laboratory studies on a diverse suite of analog organic-brine systems, covering a range of putative ocean compositions and organic species under different freezing conditions for various bodies (see Table). For each system, small droplets (~5 µL) of the brine samples were exposed to the desired freezing conditions using a liquid nitrogen-cooled Linkam optical cryostage. The frozen products were then investigated using a high-resolution confocal dispersive Raman microscope (532 nm laser source), where spectra were obtained over defined areas on the surface to construct the spatial distribution maps by integrating the area under the characteristic peaks of each individual components in the sample (salts, organics, ice).

Ocean World	Organic Species (0.1 Molar)	Brine System (Molar Concentration)	Approx. pH	Experimental Conditions
Enceladus	Glycine	Na-Cl-CO_3 (0.68 : 0.4 : 0.14)	10	Flash freezing - 80 K
	Aspartic acid		9	
Ceres	Glycine	Na-NH_4-Cl-CO_3 (3.1 : 0.6 : 3.1 : 0.3)	9	Flash freezing – 160 K Slow freezing – 160 K
	Aspartic acid		8.8	
	Hexylamine		8.3	
Europa	Glycine	Na-Mg-Cl-SO_4 (0.1 : 0.1 : 0.1 : 0.1)	7.9	Flash freezing – 100 K Slow freezing – 100 K

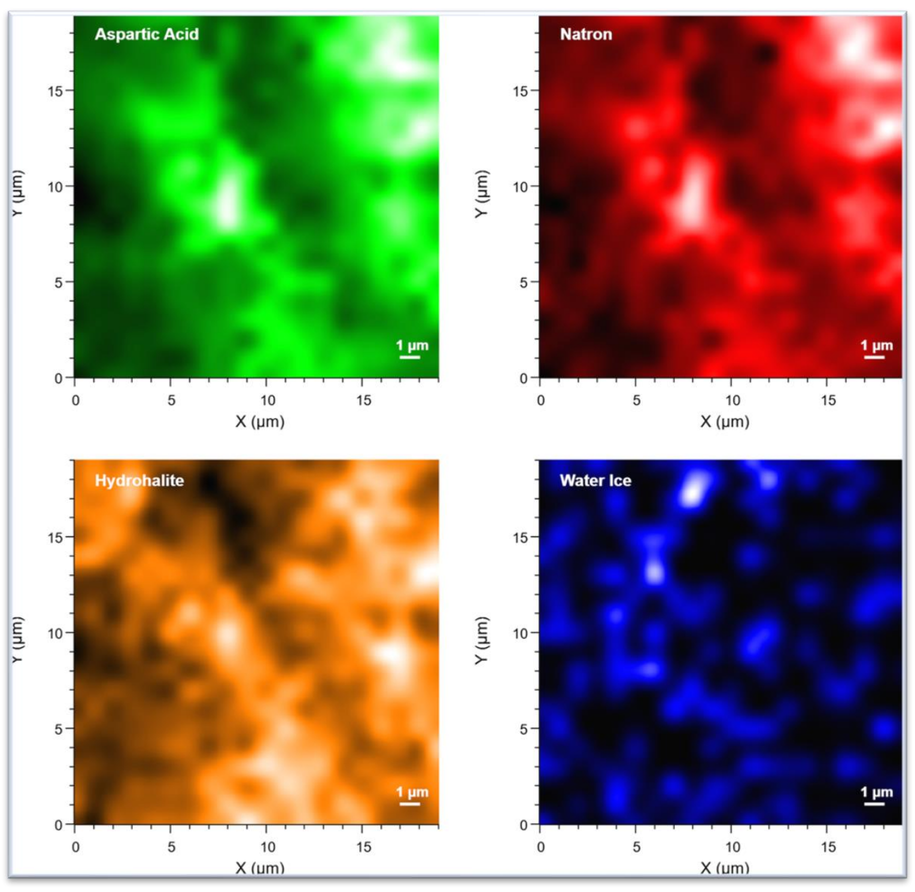

Figure 3. *Raman maps showing spatial distribution of each component within the aspartic acid-bearing Enceladus brine [1].*

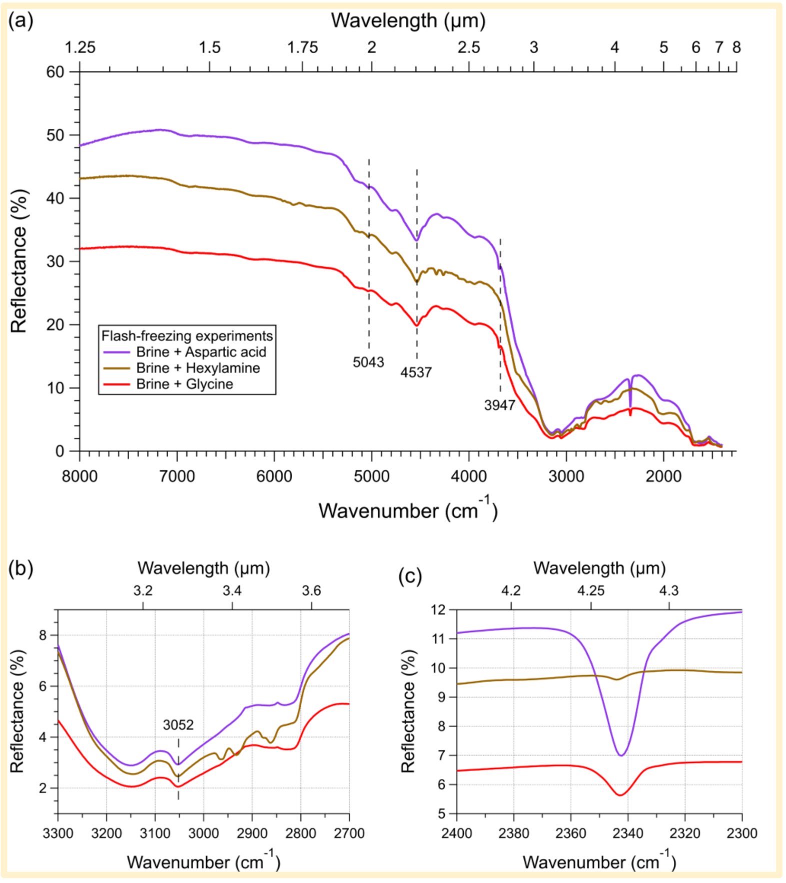

Figure 4. *IR spectra of the flash-frozen Ceres brines. Dashed lines indicate organic and salt peaks [2].*

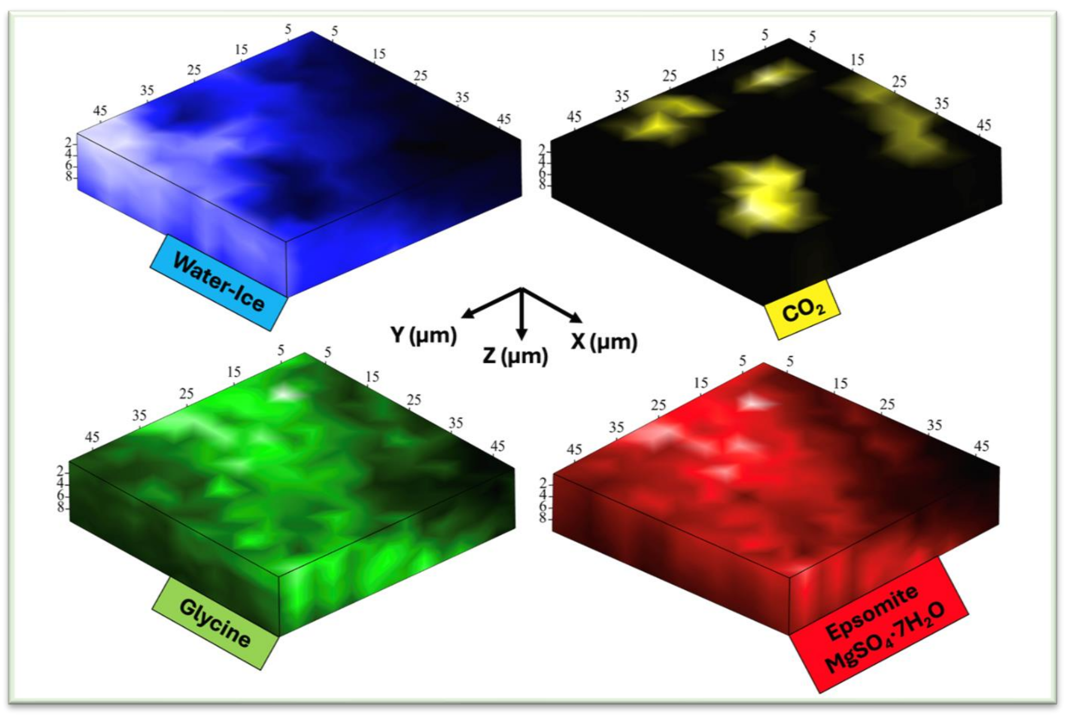

Figure 2. *Raman maps showing the distribution of observed products in the slow-frozen Europa brine. In each of the maps, pixel brightness increases with relative abundance (i.e. white pixels correspond to highest concentration) [3].*

Organics consistently display preferential association with salt minerals

Significance/Benefits to JPL and NASA: The results provide insights into where potential biosignatures might accumulate or be entrained 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. Such information could be pertinent to Clipper (MISE instrument) and potential future missions (e.g. Orbilander, Ceres lander).

Publications:

[1] 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

[2] Vu, T. H., Reynoso, L. R.; Johnson, P. V., Hodyss, R. (2024) "Amino Acid-Mediated Formation of CO_2 in Flash-Frozen Ceres Brines." *ACS Earth Space Chem.* 8(6), 1214

[3] Reynoso, L. R., Vu, T. H.; R. Hodyss, Johnson, P. V. (2024) "Glycine Partitioning in Frozen Putative Europan Brines." *Planet. Sci. J.*, under review.

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