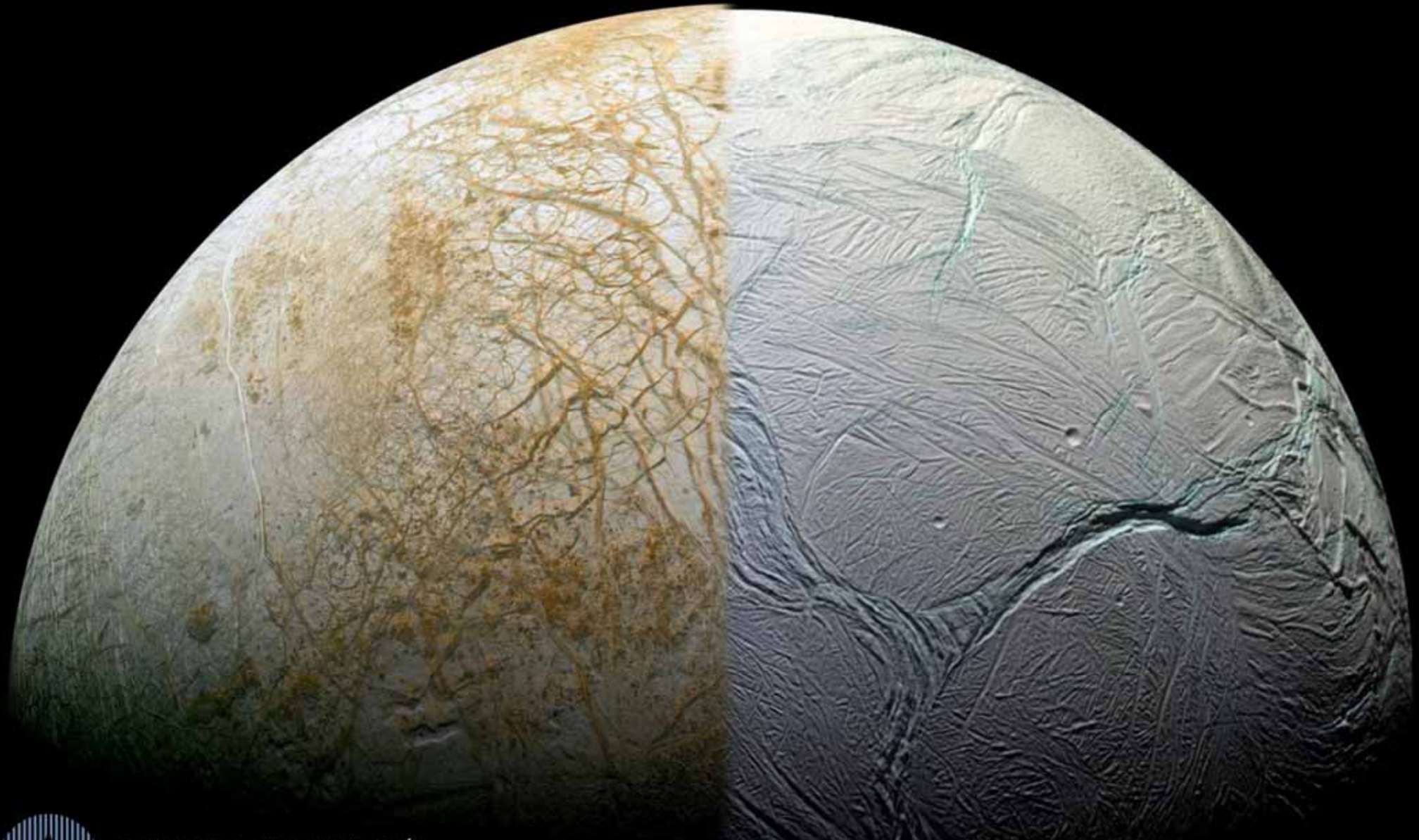


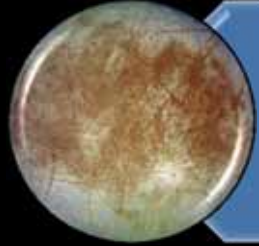
Olivine Aqueous Alteration Under Low T Conditions in the Presence of Ammonia - A Case for Ocean Moons



CENTRO DE ASTROBIOLOGÍA
ASOCIADO AL NASA ASTROBIOLOGY INSTITUTE

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CPSS - 7th June 2017

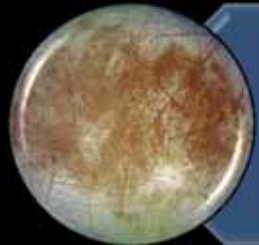
Objectives



Understand the alteration processes at work under Low T/P and their dynamics when subjected to High P/T



Understand the role and influence of Fe-Ni catalysts on aqueous alteration processes

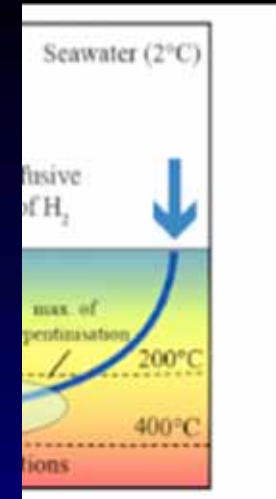
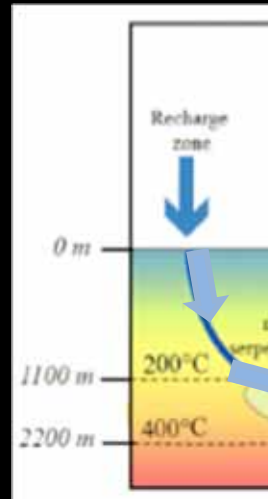


Understand the role and influence of Ammonia under the constraints studied



Combining the spacecraft-based data with our experimental results understand what processes can still occur on Ocean Worlds.

Aqueous Alteration Processes

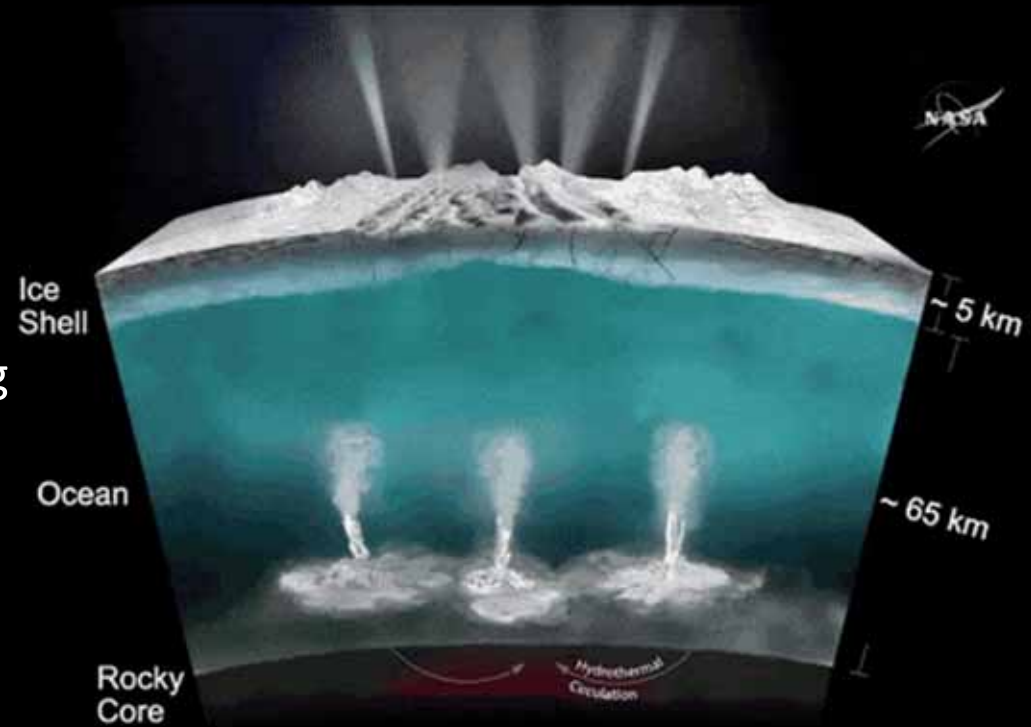


The most popular environments for these processes on Earth are hydrothermal systems such as those in Lost City, the alkaline hydrothermal field discovered in 2000, at the Mid-Atlantic Ridge.

Serpentinization, occurs in reduced and alkaline environments and may release methane.

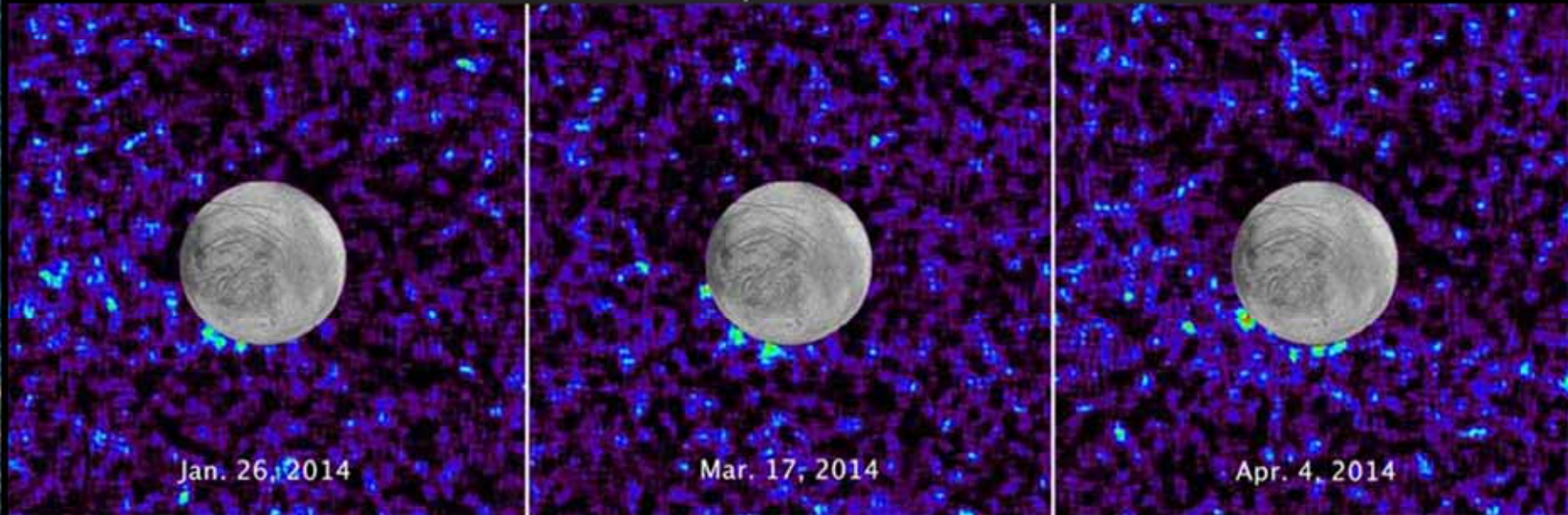
Planetary Implications

Hydrothermal processes are proposed to be one of the most important geological processes affecting the cycling of bio-essential elements not only on Earth but on other planetary bodies of the Solar System.



Artistic Representation of a cross-section of Enceladus, featuring hydrothermal plumes and the planetary plumes (NASA/JPL)

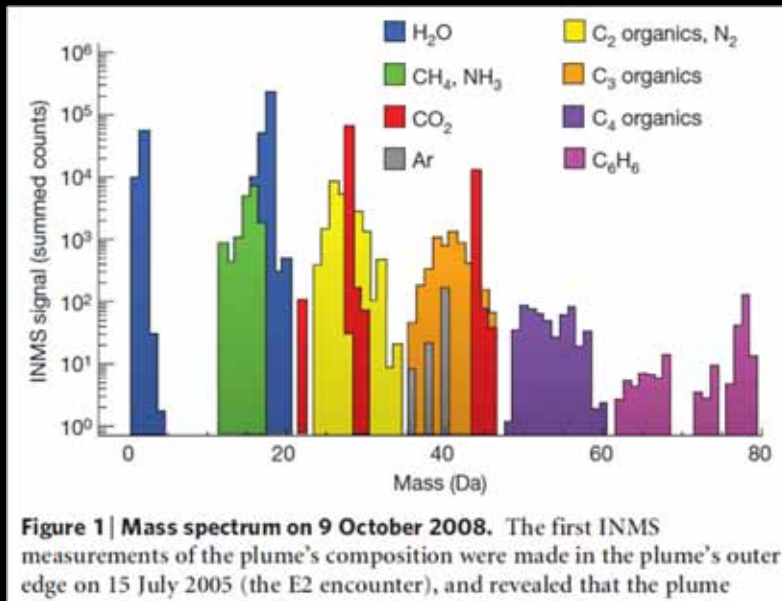
Planetary Plumes



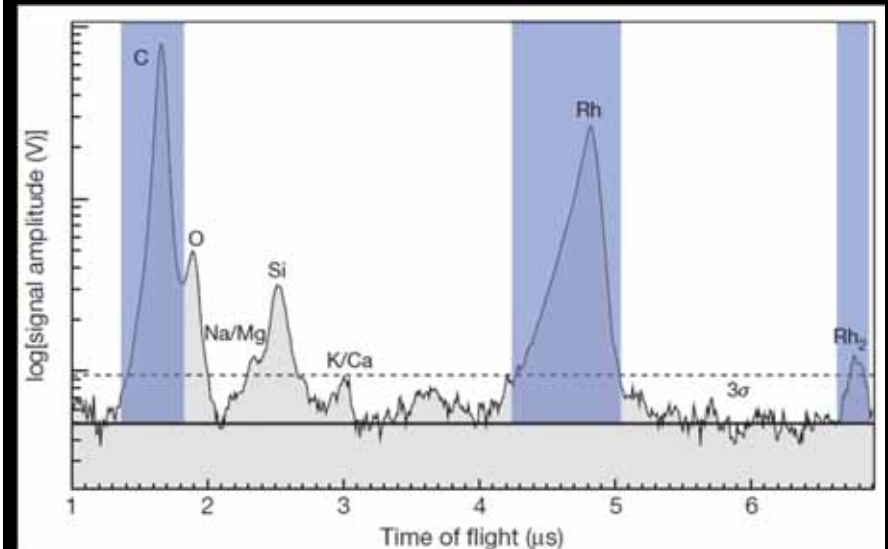
Europa's Plumes as detected by Hubble Space Telescope

Enceladus' Plumes as detected by Cassini Spacecraft

Enceladus Plumes



J.H.Waite Jr. Et al. (2009), Nature, 460, 487-49000



Hsu H. W. (2015), Nature, 519, 207-210

These alteration studies will provide experimental validation of the geochemical models that support the existence of a potential habitable liquid water ocean in direct contact with a rocky mantle and the presence of active hydrothermal processes.

Methodology

Table 1 Experimental Setup for Series 1 through 7

Run / Reactants	Hortonolite	Ni ₃ Fe	NaCO ₃ (aq)	NH ₃
Ni ₃ Fe Blank	5g	X	20ml	X
NaCO ₃ (aq) Blank	5g	20mg	X	X
Hortonolite Blank	X	20mg	20ml	X
Vial 1	5g	20mg	20ml	X
Vial 2	5g	50mg	20ml	X
Vial 3	5g	100mg	20ml	X
Vial 4	5g	20mg	20ml	0,4ml
Vial 5	5g	50mg	20ml	0,4ml
Vial 6	5g	100mg	20ml	0,4ml

Laboratory incubation experiments are conducted under Low P/T conditions and pH~8.

Ten distinct series were prepared and incubated in 27 ml vials, gassed with N₂ and sterilized in an autoclave.



Serie 1 (125 days)

Methodology



Lunar olivine (Apollo 15)

Olivine is ubiquitous throughout the solar system and one of the first condensates of the solar nebula.

(Weinbruch S. et al. (1998) *Meteor & Plan Sci*, 35, 161-171)

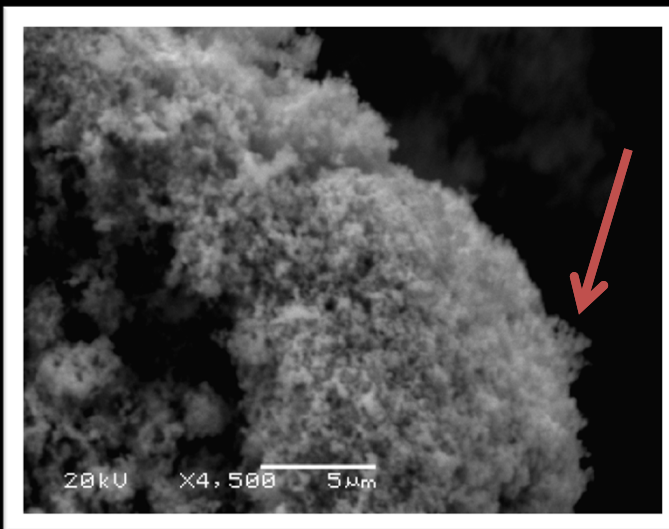
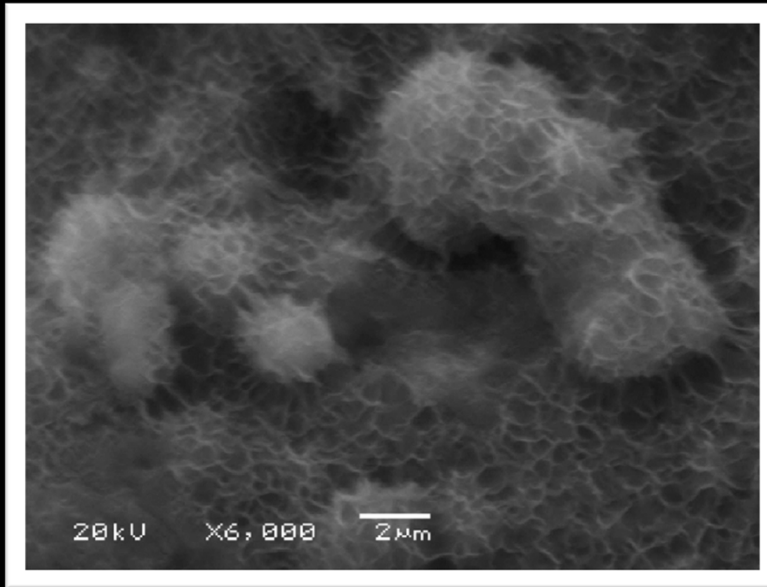


Image obtained with JEOL 6400 with coupled EDS

Synthesized awaruite via hydrazine hydrate reduction in an ethanol solution.

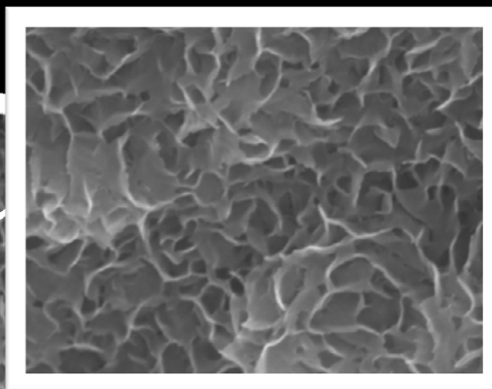
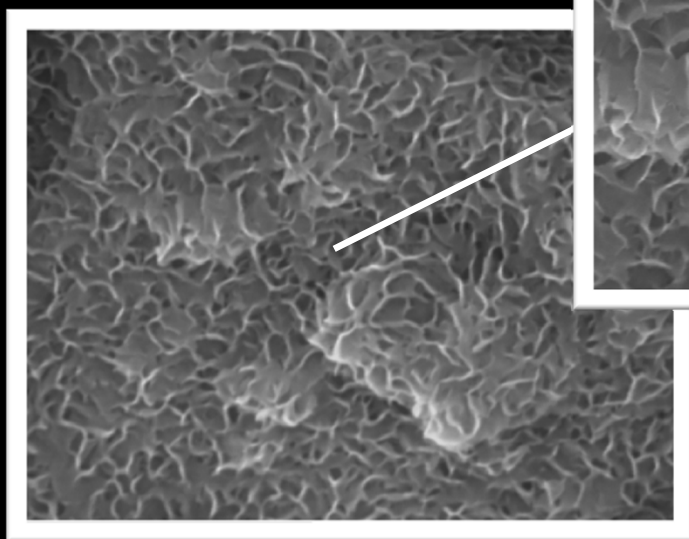
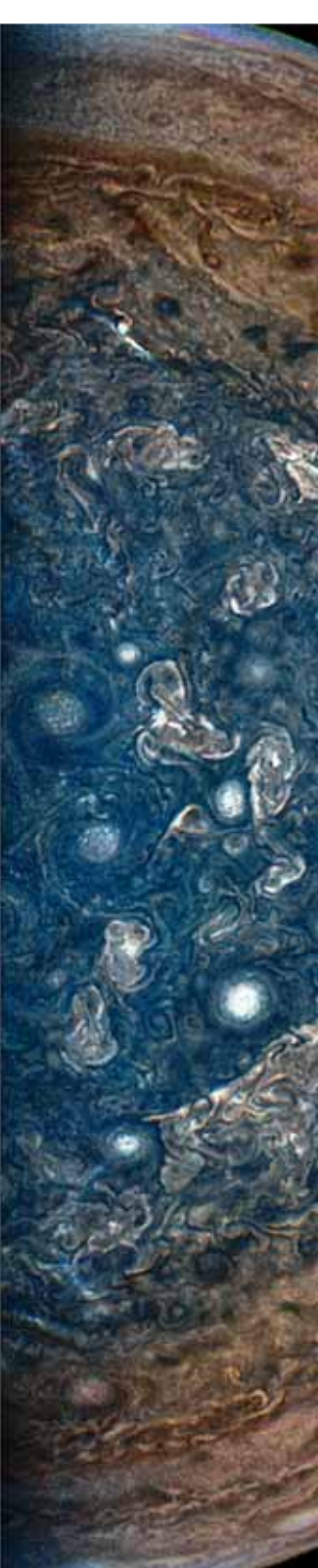
(Abellán G. et al. (2014) *J Sol Gel Sci Technol*, 70, 292-299)

Results

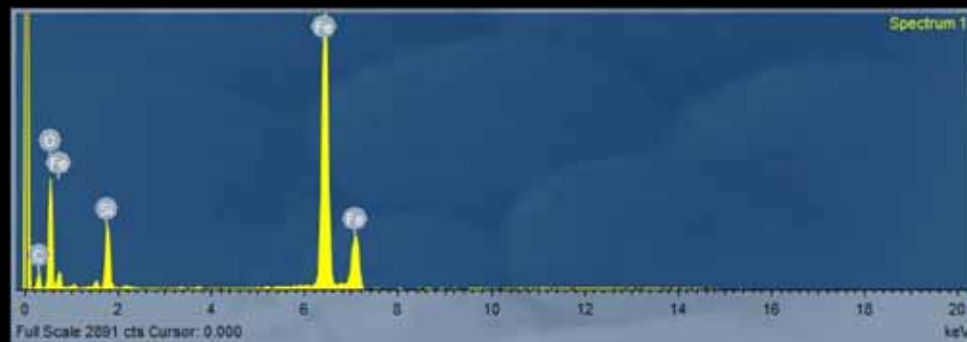


SEM photograph as an example of the structures found
(Vial 4 Serie 2 – 215 days)

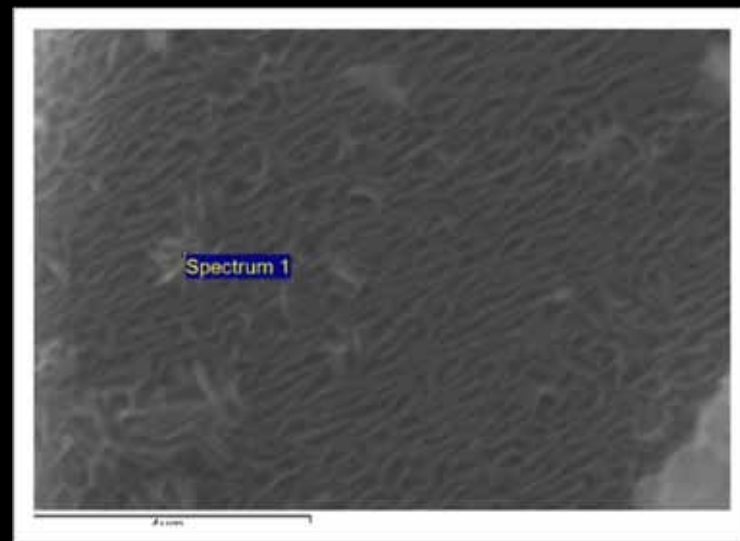
Through structural and compositional studies, resorting to XRD, IR and SEM-EDS of the series incubated for 51, 125, 215 and 344 days, we can observe the formation of honeycomb-like structures.

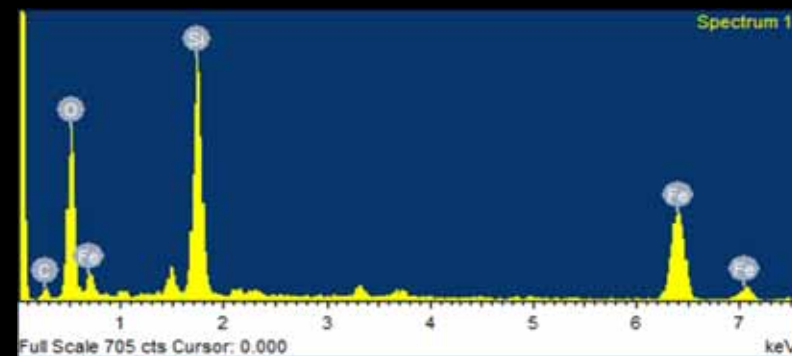
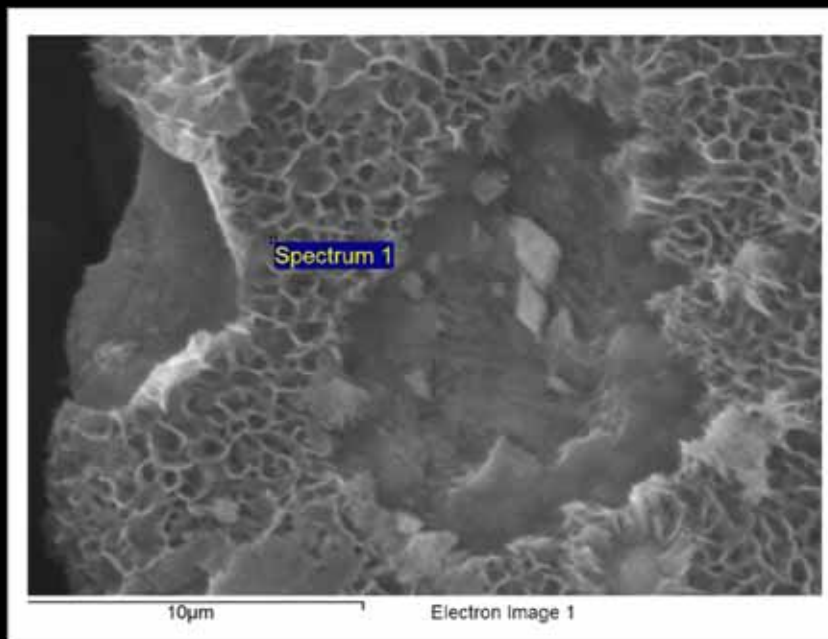
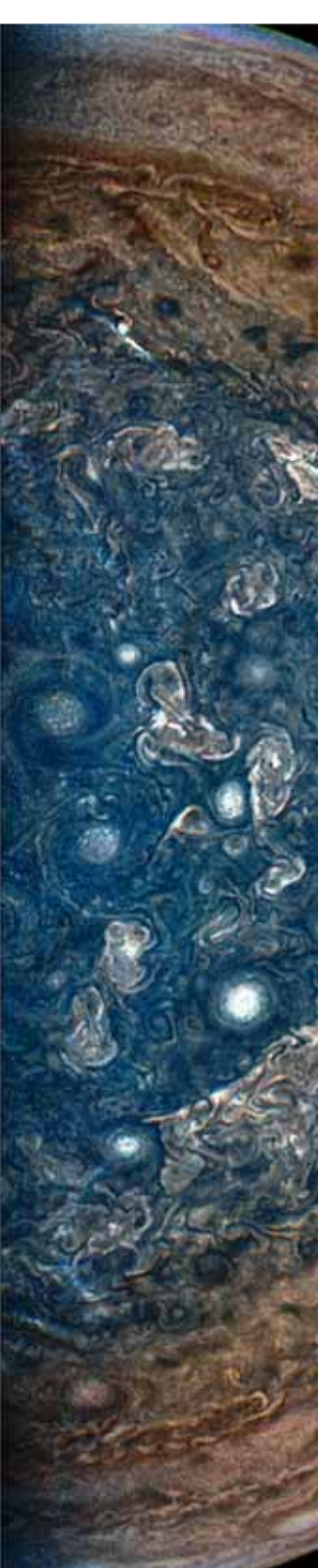


Fe- Talc “honeycomb” structures
(Vial 4 Serie 1 – 125 days)

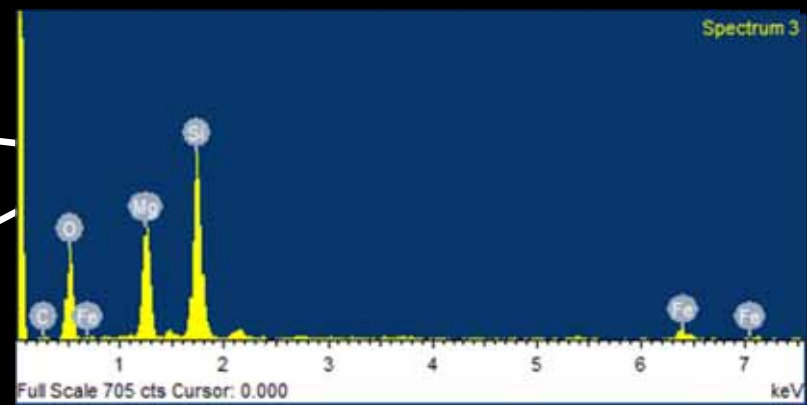
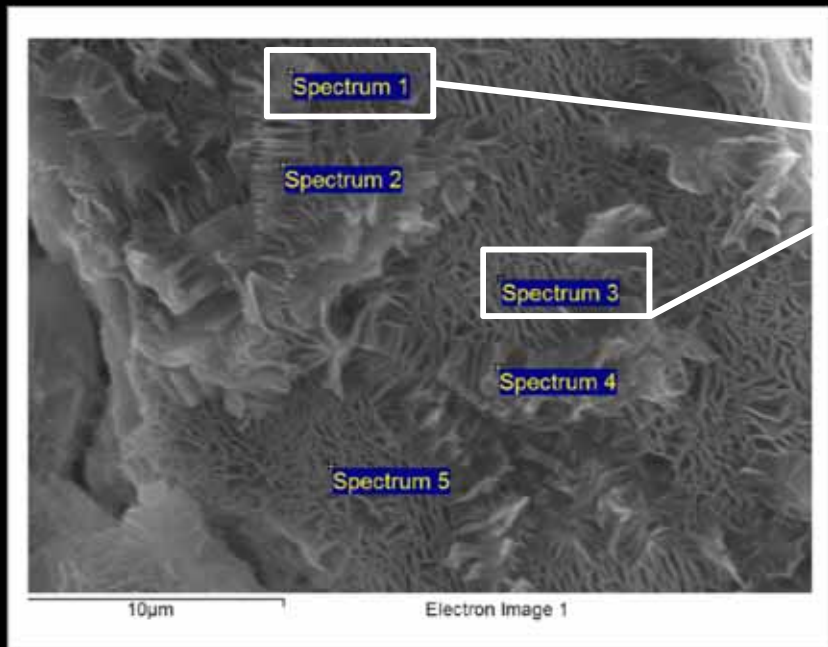


Parallel “honeycomb” structures
formed on the reaction surface (Vial 1
Serie 8 – 51 days)

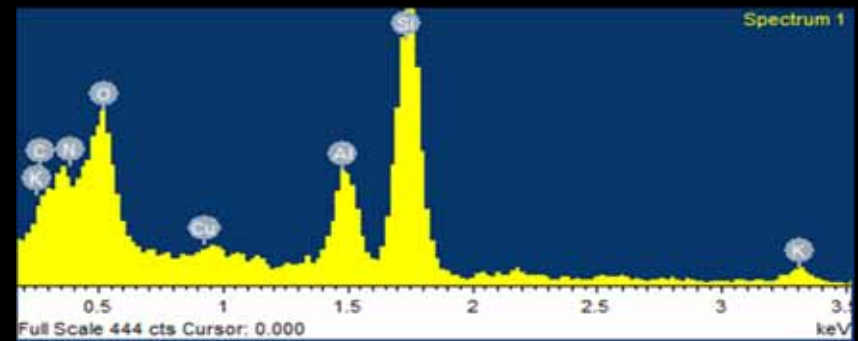
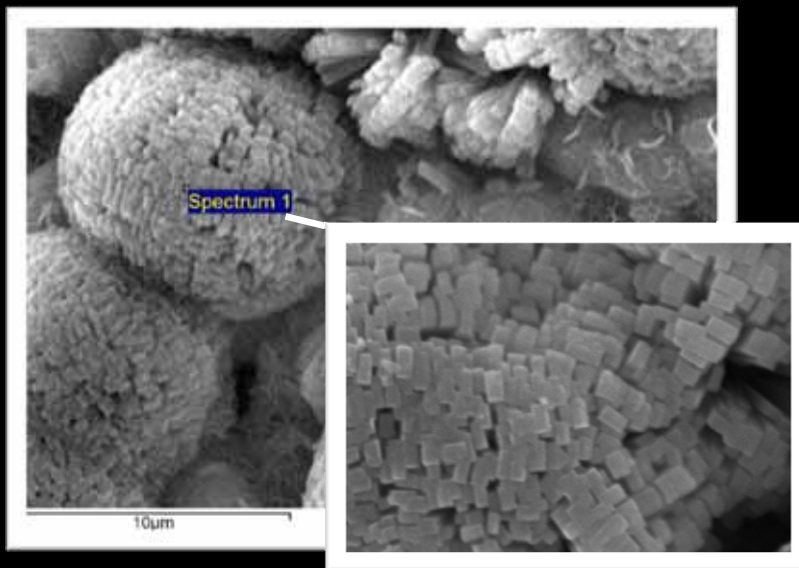
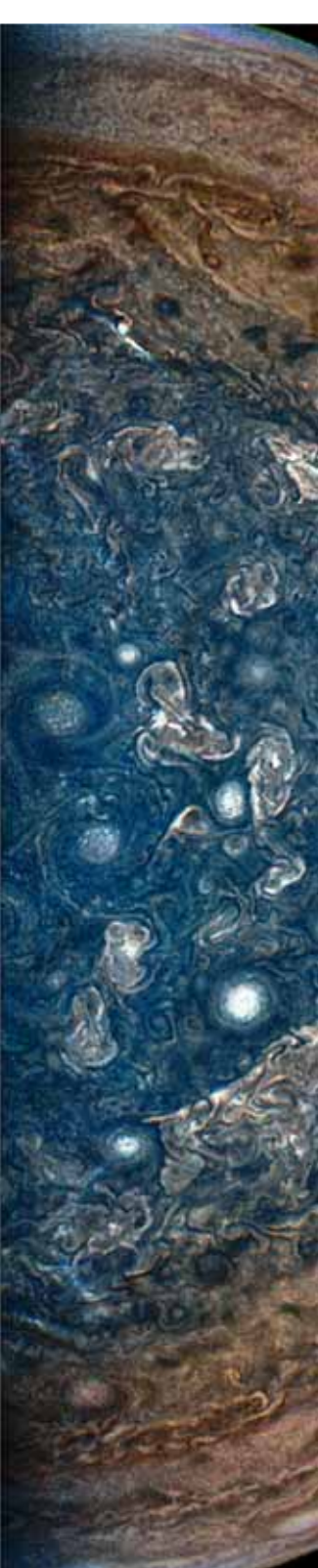




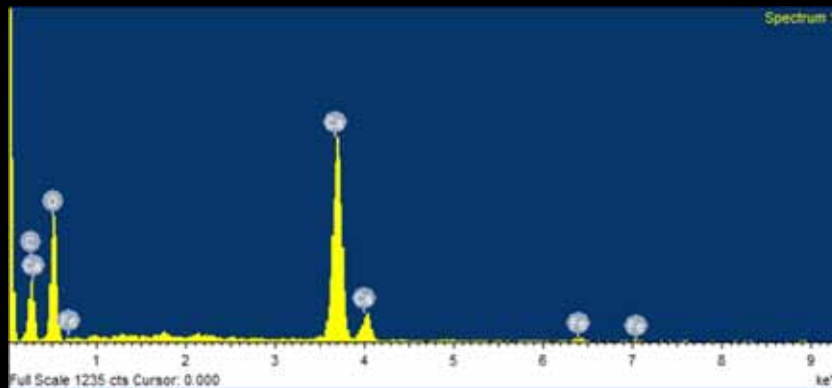
Reaction Surface of hortonolite grains (Vial 6 Serie 2 – 215 days)



Reaction Surface of hortonolite grains (Vial 6 Serie 7 – 344 days (Top Layer))



Zeolites formed on the surface of sheet-like precipitates (final pH 11,5)



Calcite low T polymorph, aragonite (Awaruite Blank Vial Serie 2 – 215 days)

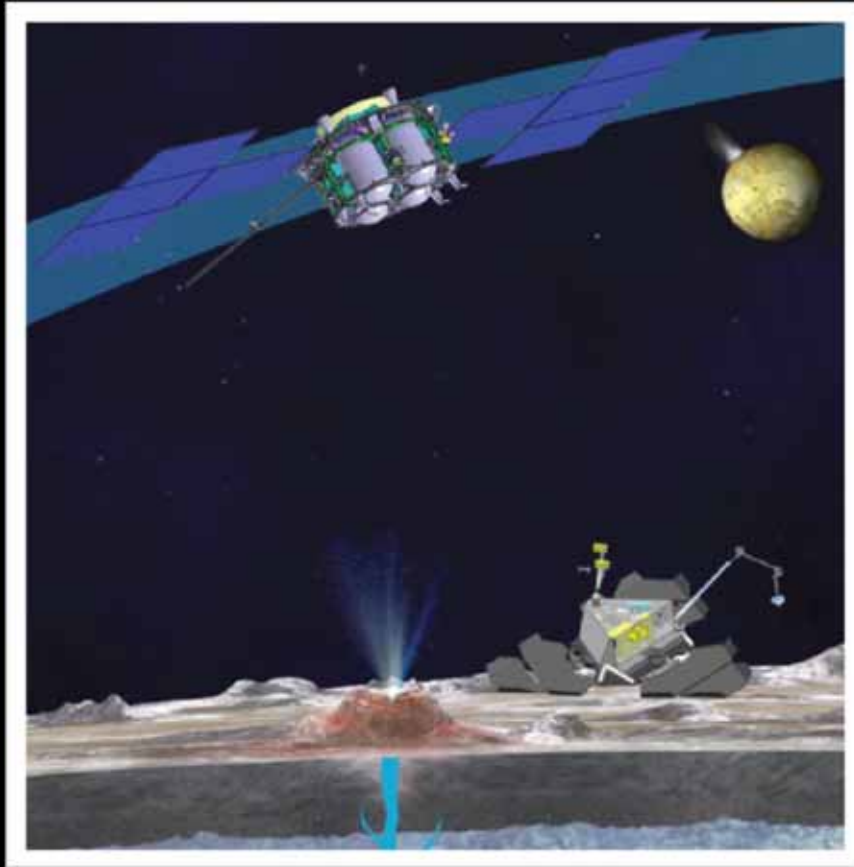




Results

- The growth and complexation of these honeycomb-like structures accompanies the addition of higher quantities of awaruite catalyst.
- It's observed substantial visual differences between the honeycomb-like structures grown with and without ammonia present.
- The combination of ammonia and awaruite catalyst increases further the growth rate and variability of the observed structures.

Conclusions



Representation of Joint Europa Mission (JEM)

These experiments are key to understand the aqueous alteration processes that occurred/still occurring on ocean worlds.

We can use the information collected by Cassini Mission on Enceladus' plumes and future missions exploring Europa to better know identify these aqueous alteration processes.



Acknowledgments

This work has been funded by the MINECO project ESP2014-55811-C2-1-P



NASA's Juno spacecraft soared directly over Jupiter's south pole when JunoCam acquired this image during Perijove 6 in May, 2017. Credit: NASA/SwRI/MSSS/Gerald Eichstädt / Seán Doran.