Chemical Gardens: The Effects of Organic Compounds on Inorganic Precipitates

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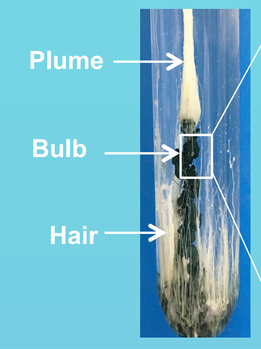
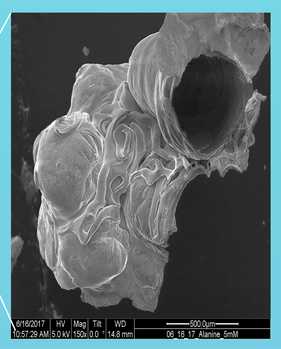
Introduction

- Geological “hydrothermal chimneys” found deep in the Earth’s oceans are mineral rich, energetic environments. Chemical gardens are inorganic, self-organizing precipitates that form when metal salts are added to a solution of another precipitating ion. Chemical gardens recreate similar geological structures in Earths oceans and putative systems elsewhere in our solar system (such as on Saturn’s moon, Enceladus or Jupiter’s moon, Europa).
- Chemical Gardens grow by a process of osmotic pressure buildup which leads to membrane rupture. This process repeats forming a precipitate structure that continues to grow until all reactants are exhausted. [1]
- Introducing Organics to Inorganic chemical garden precipitation systems to determine if/how the organics can affect self-assembling morphologies or crystal growth.

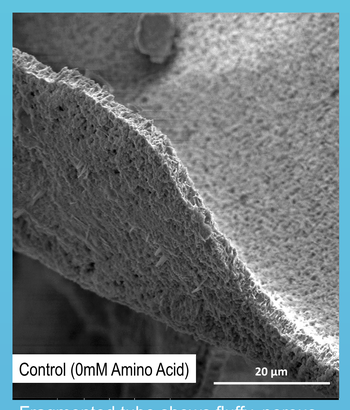




5mM Alanine- Bulbs appear to grow on top of each other. Broken, larger tubes allowed visual observation from multiple angles. Membranes as thin as 0.5 microns observed- thinner than most chemical garden inorganic membranes reported in literature.

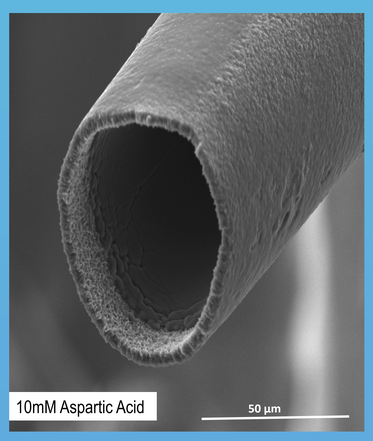
Effect of Amino Acid

Gradient across membrane shows a smooth exterior coupled with a highly porous internal surface.

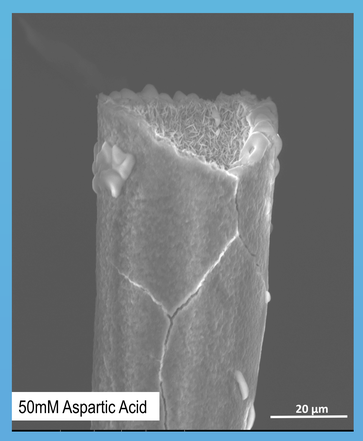


Fragmented tube shows fluffy, porous membranes (inside and outside). Uniform thickness of membranes (2.5microns)

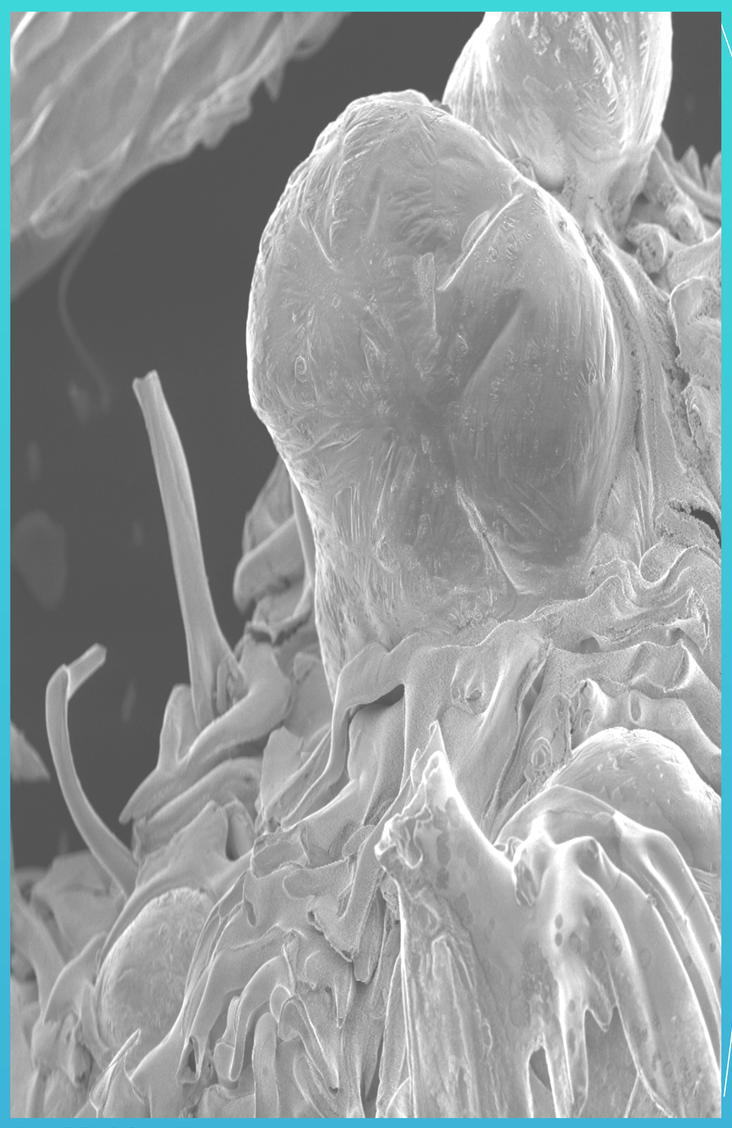
Effect of Concentration



Internal gradient along membrane shows a smooth interior that gets more porous towards the end. External surface is quite smooth. Membrane thickness around 5microns.



Higher concentration of Aspartic Acid showed even thinner membranes, approximately 3microns thick.

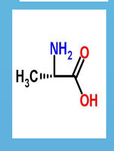


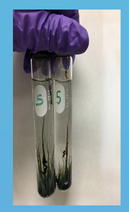
5mM Alanine

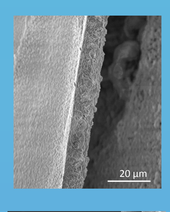
Bulbs and plumes identified post-reaction. Plumes were stunted and grew in aggregates on top of one another. SEM images like these have important implications for life detection. While the morphology and organization appear biological, even though precipitate is purely chemical. This underscores the importance of not using morphology alone as a biosignature.

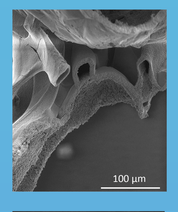
Organic Compounds

Alanine

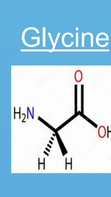


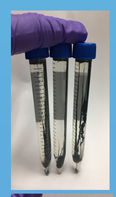


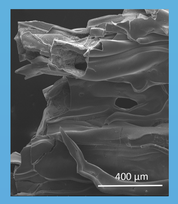


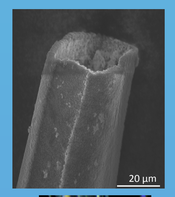


Glycine

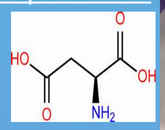


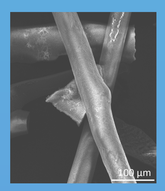


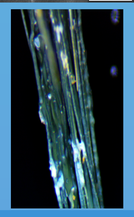




Aspartic Acid

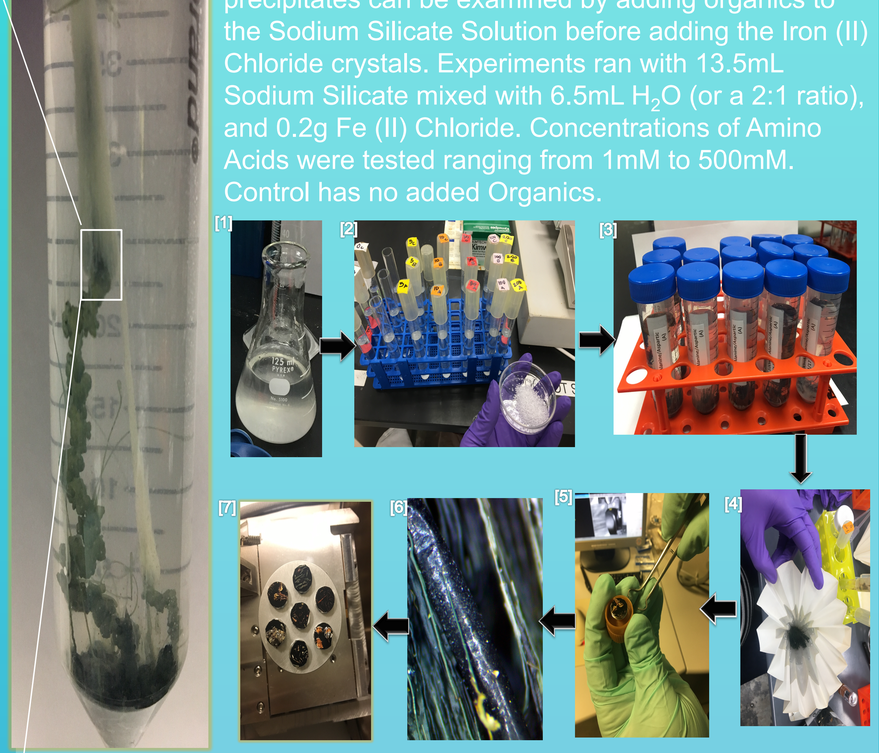






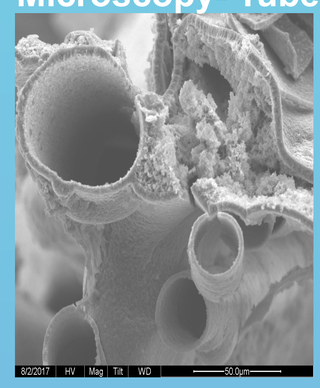
Methods

Chemical Gardens are formed by adding Iron (II) Chloride Crystals to Sodium Silicate Solution. The effects of organic compounds on these inorganic precipitates can be examined by adding organics to the Sodium Silicate Solution before adding the Iron (II) Chloride crystals. Experiments ran with 13.5mL Sodium Silicate mixed with 6.5mL H_2O (or a 2:1 ratio), and 0.2g Fe (II) Chloride. Concentrations of Amino Acids were tested ranging from 1mM to 500mM. Control has no added Organics.

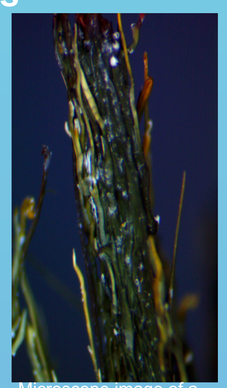


[1] Combine Sodium silicate solution and H_2O.Gently mix. [2] Add Amino Acid to solution. Gently invert falcon tube repeatedly to fully dissolve added Amino Acid. [3] Add 0.2g Iron (II) Chloride Crystals. Gently tap the top of the falcon tube until crystals fall to the bottom of the test tube. Allow Chemical Gardens to sit for 10minutes while reaction proceeds and precipitate forms. [4] Pour chemical garden onto filter paper and allow to dry. [5] Carefully transfer in tact portions of chemical gardens to mounting stubs. [6] & [7] Examine under microscope and Scanning Electron Microscope

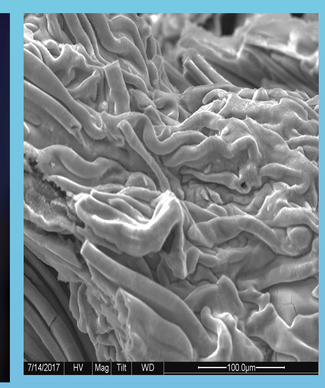
Microscopy- Tubes



Cross section of Chemical Garden base using Scanning Electron Microscope (SEM). The diameter of tubes ranging from 25microns to 60microns. Membranes are 2microns thick.



Microscope image of a tube. With visual inspection, it appears to be one single tube. Under microscope, and aggregate of tubes is visible.



SEM image of tubes in a chemical garden. Tube growth in aggregates.

Results / Future work:

- Organics can interact with minerals and affect their growth. The type and concentration of organics effect chemical garden morphology on all three scales tested: Visual, microscope, and Scanning Electron Microscope.
- Though similarities abound, every chemical garden is unique.
- These results show that inorganic precipitation systems analogous to geological environments can produce self-assembling membranes that might have relevance to prebiotic processes at hydrothermal vents on early Earth and other worlds. Future work will include extensively testing the impact of previously untested organics, with a specific focus on Amino Acids.

References: [1] Barge et al. (2012) Barge et al. (2012) *Langmuir* 28 (8), 3714-3721, Acknowledgements: This material is based upon work supported by the National Science Foundation through the Robert Noyce Teacher Scholarship Program under Grant # 1418852-. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation. The research was also made possible by the California State University STEM Teacher and Researcher Program, in partnership with Chevron (www.chevron.com), the National Marine Sanctuary Foundation (www.marinesanctuary.org), and NASA Jet Propulsion Laboratory.