National Aeronautics and Space Administration

Planetary Habitability Test Beds

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Program: Topical R&TD

Project Objectives:

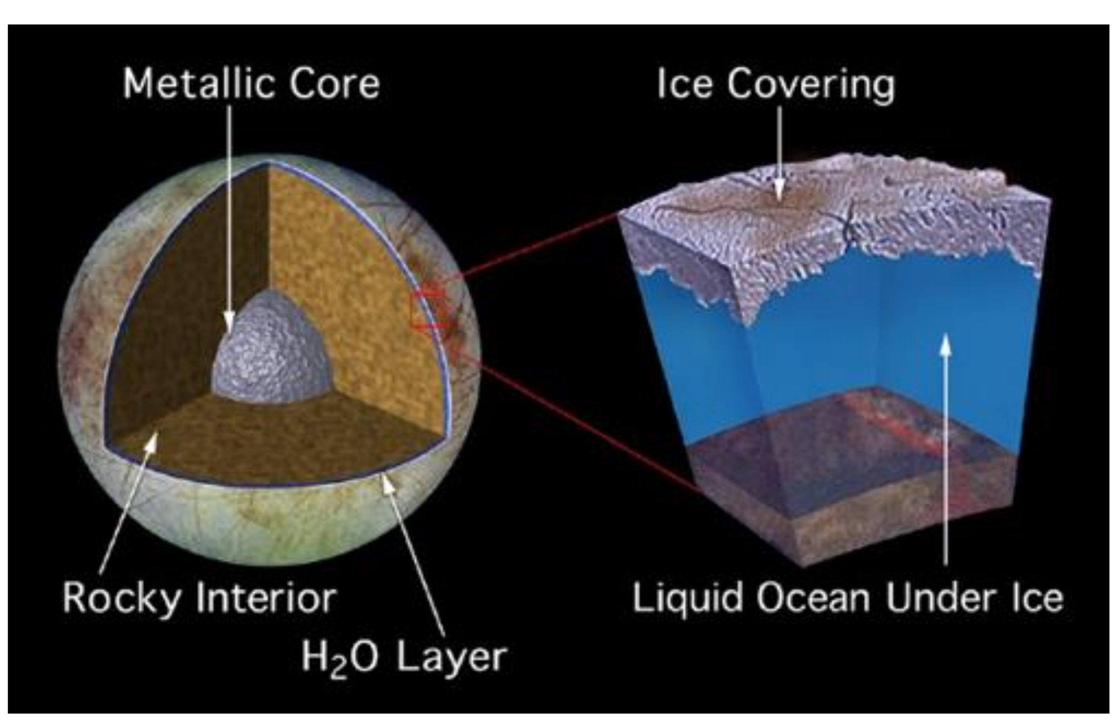
1. Create “planetary test beds” that are capable of characterizing a wide variety of relevant geological materials and settings.

2. Reproduce and analyze chemical energy gradients found at water/rock interfaces and in the subsurface on other worlds.

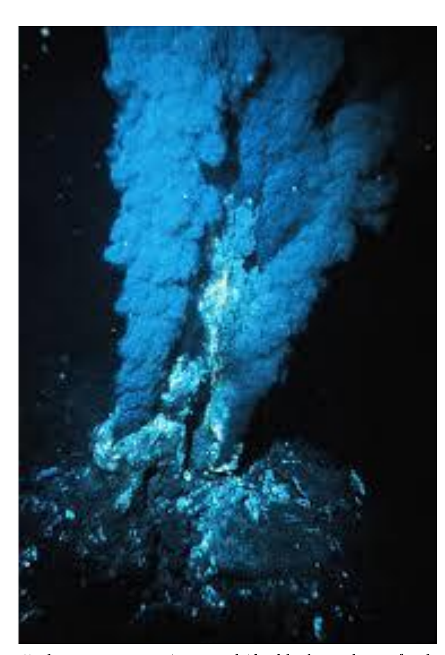
Benefits to NASA and JPL (or significance of results):

- Energetic and metabolic considerations are paramount to the Ocean Worlds strategic goals: if life exists on Europa or Enceladus, then chemosynthesis is likely a dominant process, and a primary habitable site could be hydrothermal vents.
- In seafloor systems, electrochemically active minerals could affect the redox substrates available for life, and thus would affect the dominant metabolisms that we would expect to find in these environments.
- For ocean worlds there could be many possible aerobic or anaerobic metabolisms. **Our experiments will test the energetic landscape of these systems to determine what types of life and metabolism are most likely to thrive.**

Testing electrochemical energy available for metabolism in Ocean World vent systems

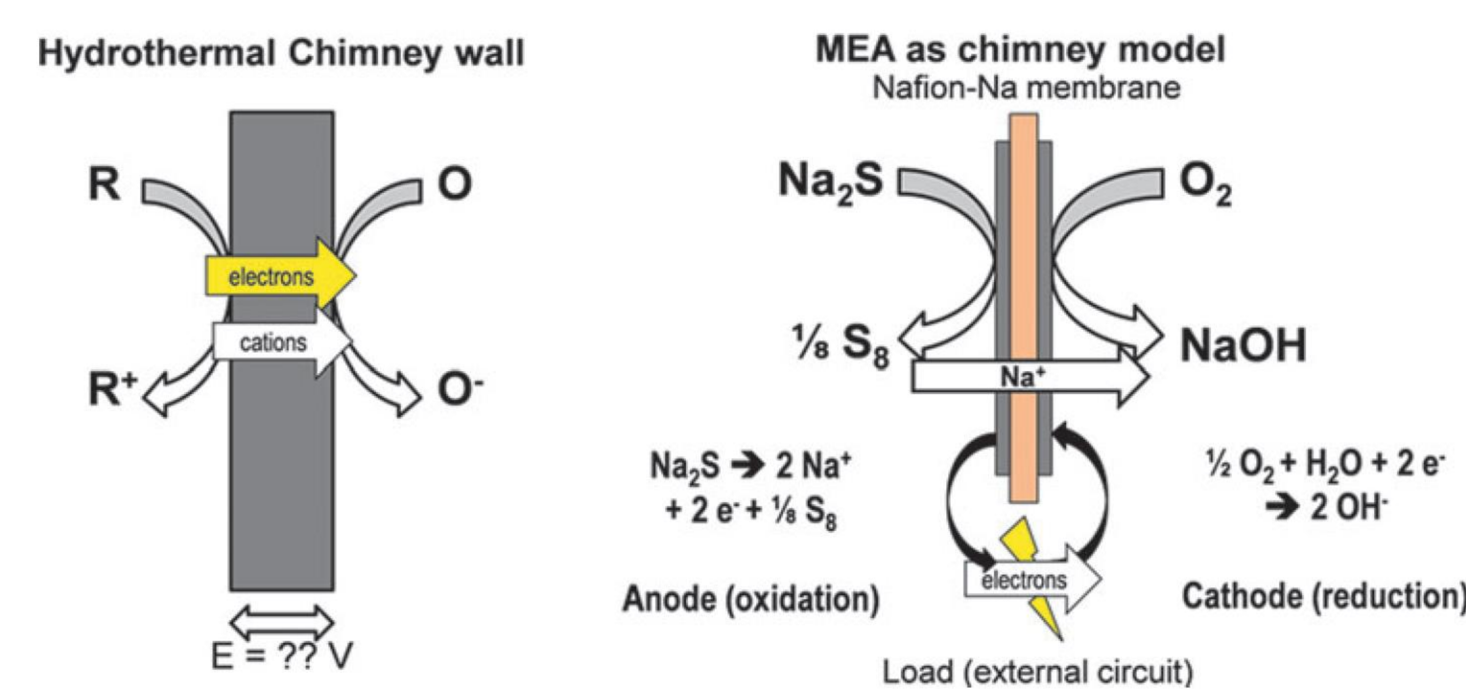


Water-rock interfaces on ocean worlds could give rise to seafloor vent systems. The chemistry & energy of a vent system would be a function of the rock type, the temperature of reactions, and the ocean composition / oxidation state.



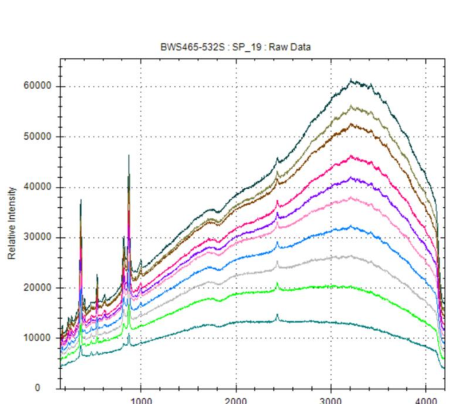
https://galapagosconservation.org.uk/the-black-smokers-of-galapagos/

Many terrestrial vents host electrochemically active minerals that can affect energy for life. Though different types of vents may be found on ocean worlds, similar electro-active minerals might still affect energy & habitability.



The mineral-driven redox reactions of a hydrothermal vent can be modeled as a fuel cell: the cathode and anode contain conductive / catalytic minerals, driving abiotic or biotic redox reactions that that are electrically linked, affecting potential metabolisms in these systems. (Barge et al. 2018, Astrobiology, DOI: 10.1089/ast.2017.1707)

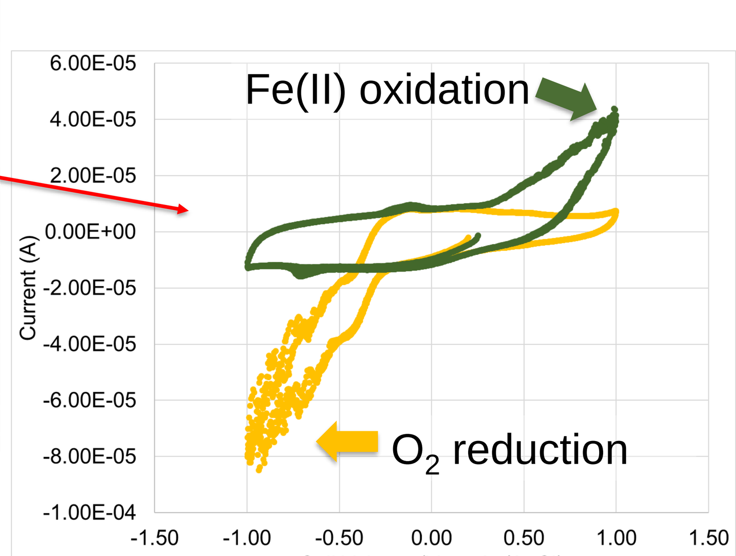
Geo-electrodes from ocean world mineral analogues



Preliminary Raman scattering analysis of the San Carlos Olivine with notable peaks at 584nm, 605nm, 823nm, and 855nm agrees with Guyot et al. 1986 and Foster et al. 2013.

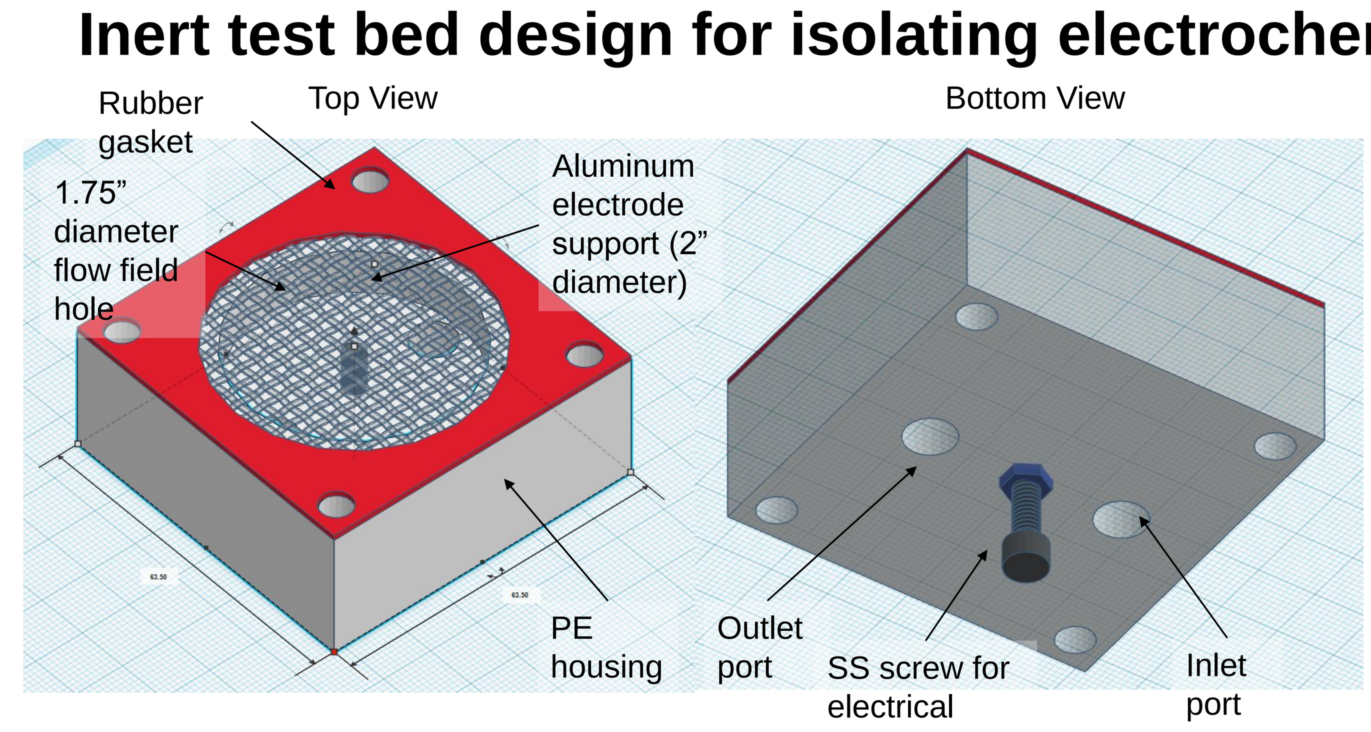
- To represent the chondritic interiors of ocean worlds, we use samples of olivine, fayalite, and added Fe/Ni to represent various reactive chondrite materials. Electrodes are made by painting these samples onto an electrode and incorporated into the test bed reactor.

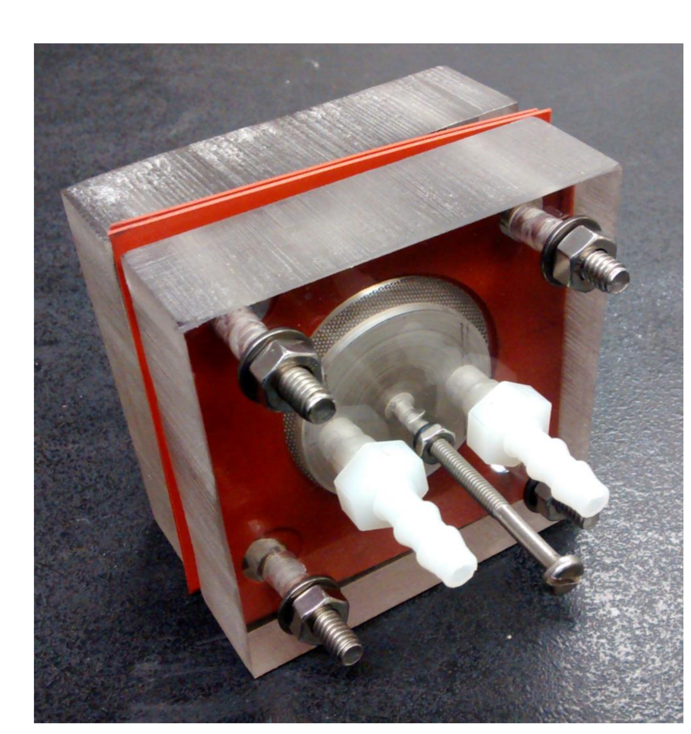
Electrode ink made from minerals is sprayed onto Nafion to make multiple MEA's for use in the inert test bed reactor.



- Two redox half-reactions – iron oxidation and oxygen reduction – are occurring separately but are electrochemically linked together by the conductive minerals.

Inert test bed design for isolating electrochemical activity





Inert hardware:

- The previous version of the test bed used standard graphite plates which turned out to be too redox active. New hardware (above, right) has been shown to be inert when tested for Na_2S/O_2 operation; it still senses voltage.
- This hardware can be used for a variety of hydrothermal vent systems in the future

Aerobic sulfide oxidation: $H_2S + O_2 \rightarrow SO_4^{2-} + H^+$ (or other S species)
Aerobic iron oxidation: $Fe^{2+} + O_2 + H_2O \rightarrow Fe(OH)_3 + H^+$
Anaerobic sulfate reduction: $SO_4^{2-} + Fe^{2+} \rightarrow H_2S + Fe(OH)_3$

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