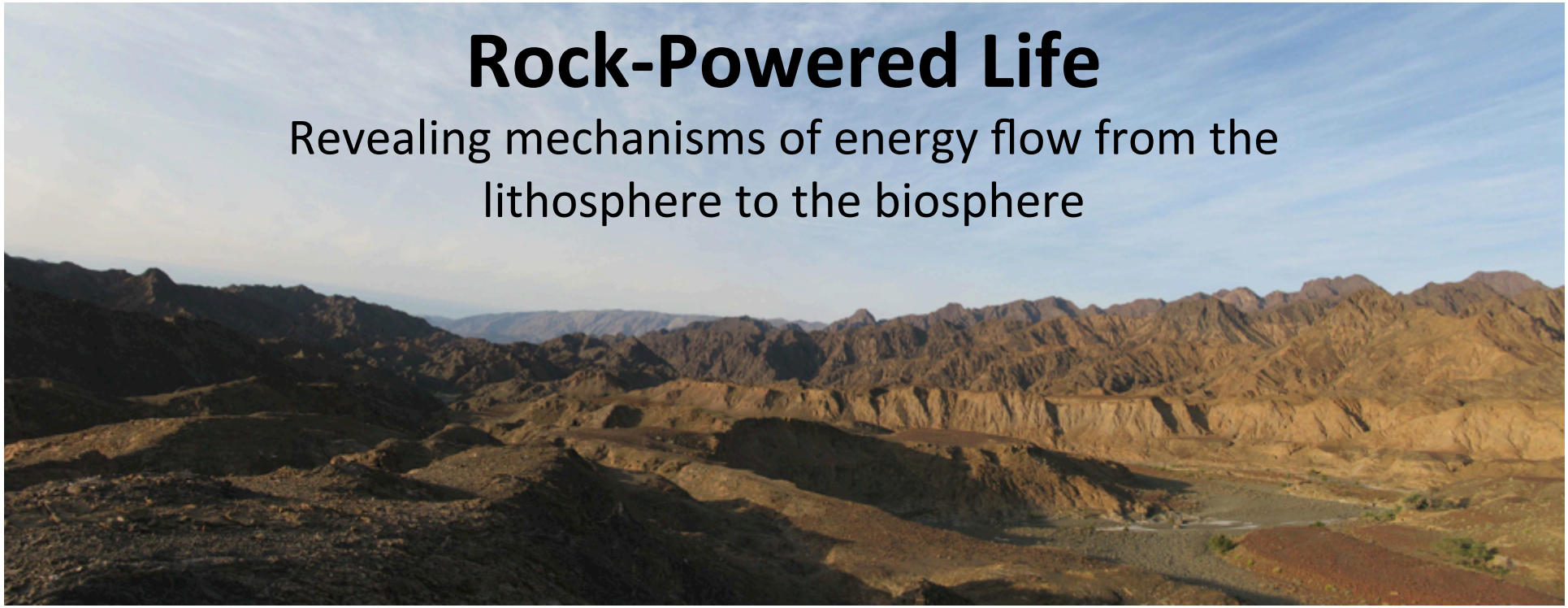
Rock-Powered Life

Revealing mechanisms of energy flow from the lithosphere to the biosphere



University of Colorado **Boulder**

NASA

MONTANA STATE UNIVERSITY

COLORADO SCHOOL OF MINES 1874

ASU ARIZONA STATE UNIVERSITY

MICHIGAN STATE UNIVERSITY

THE UNIVERSITY OF UTAH

MIT Massachusetts Institute of Technology

UNIVERSITY OF RHODE ISLAND HOPE 1892

How do the mechanisms of low temperature water/ rock reactions control the distribution, activity, and biochemistry of life in rock-hosted systems?

Rock-Powered Life NAI Team Investigators

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Matt Schrenk

Masako Tominaga

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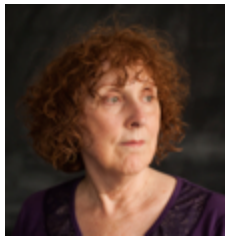
Sanjoy Som

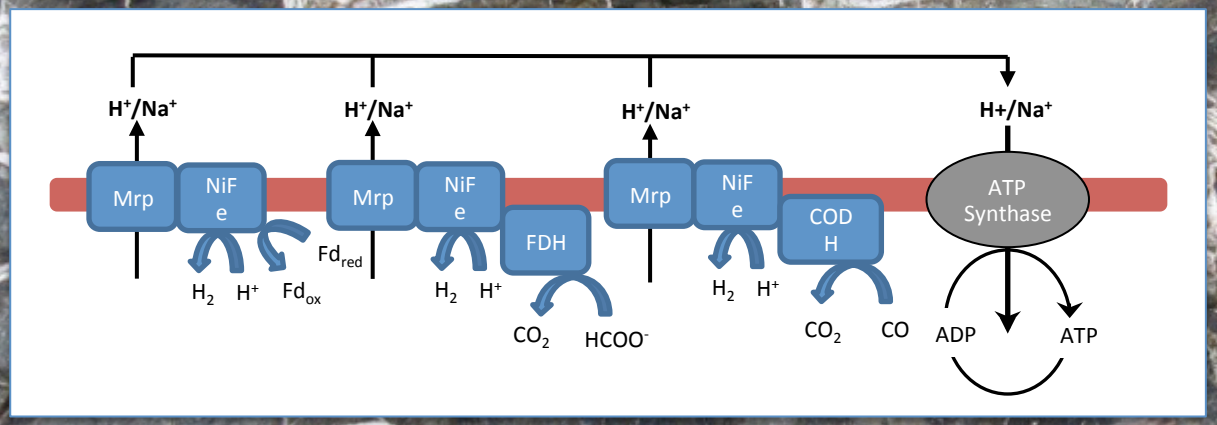

Carol Cleland

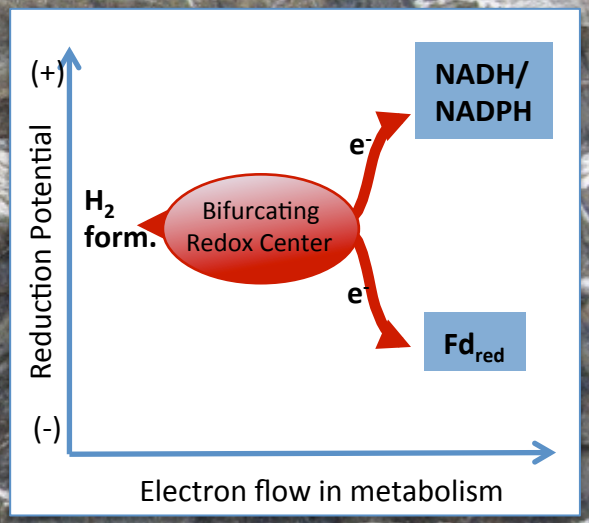
Peter Kelemen

Brian Hynek

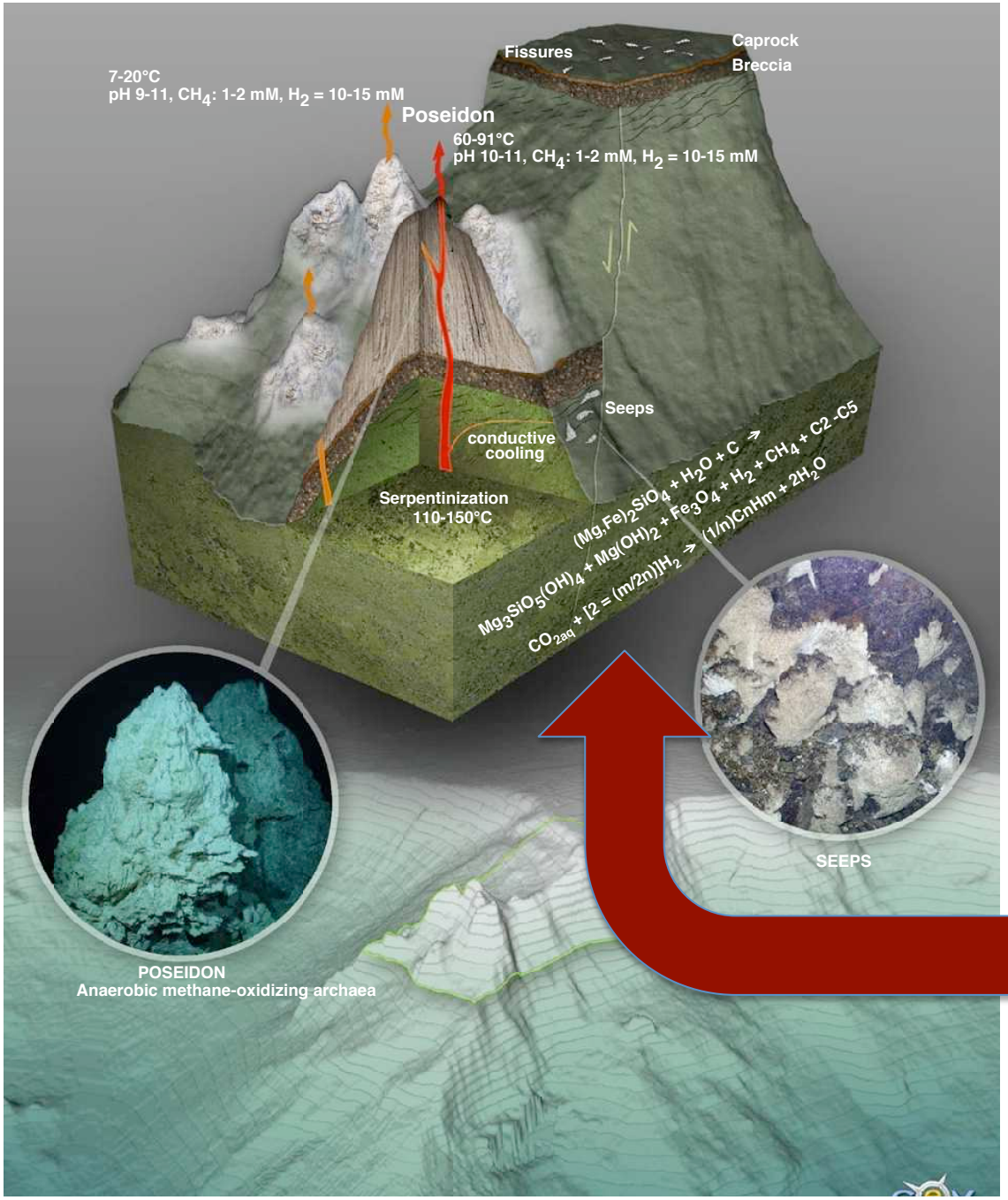
Mike Kubo

Water/Rock Interaction



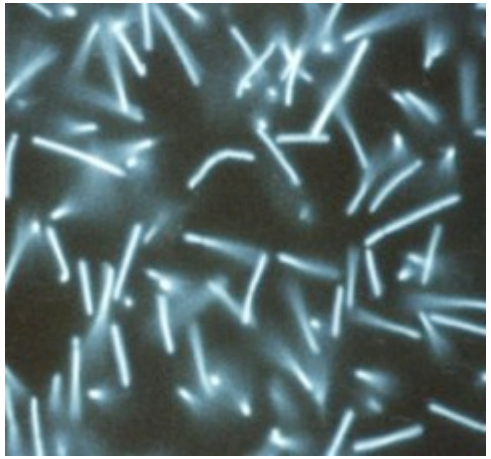


H_2-based ecosystems on Mars, Europa and beyond from reaction of water with mafic & ultramafic rocks?



Martin, Baross, Kelley and Russell, Nature Reviews, 2008

Coupled Geological and Biological H_2-production and consumption



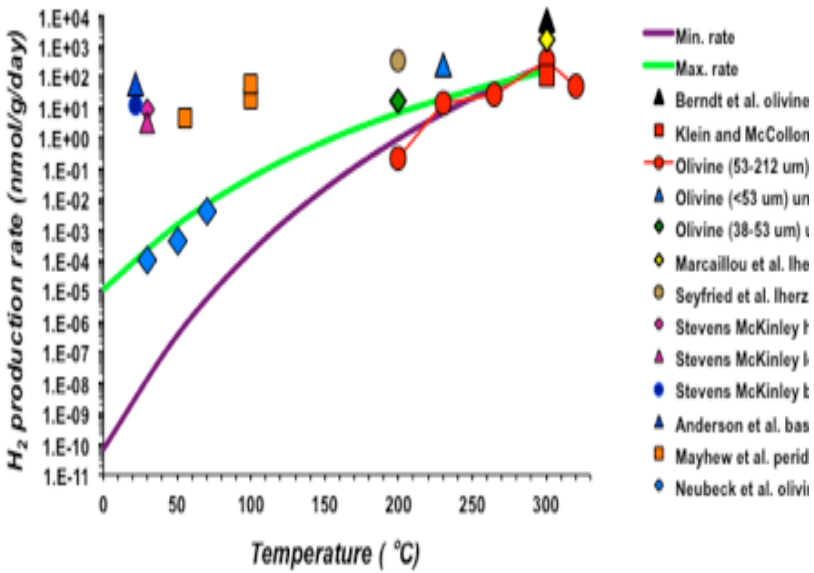
$$4H_2 + CO_2 \rightarrow CH_4 + 2H_2O$$

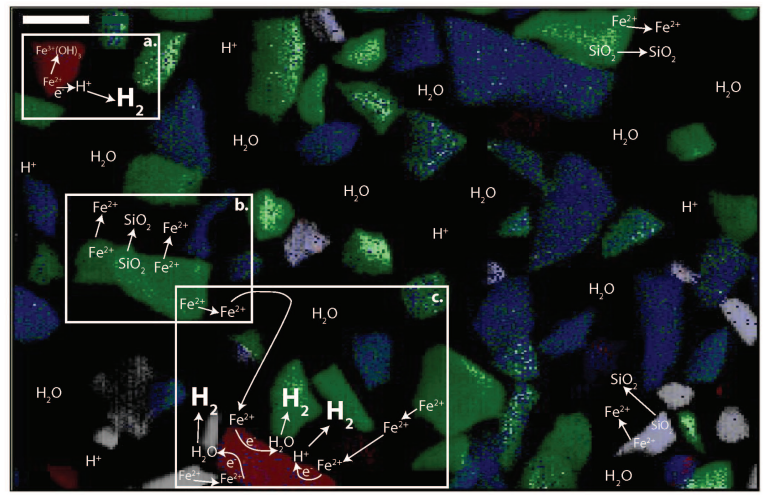
e.g. microbial methanogenesis

*Habitability and life activity **in-situ** during **low-temperature serpentinization?***

RPL "Conundrums"

Rates, pathways and extent of low-T H_2 generation?





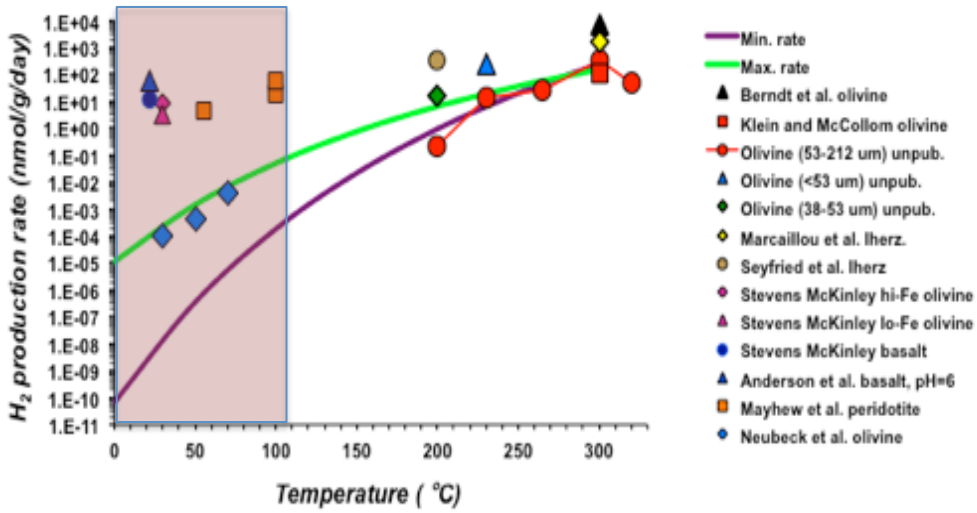
Mayhew et al. 2013

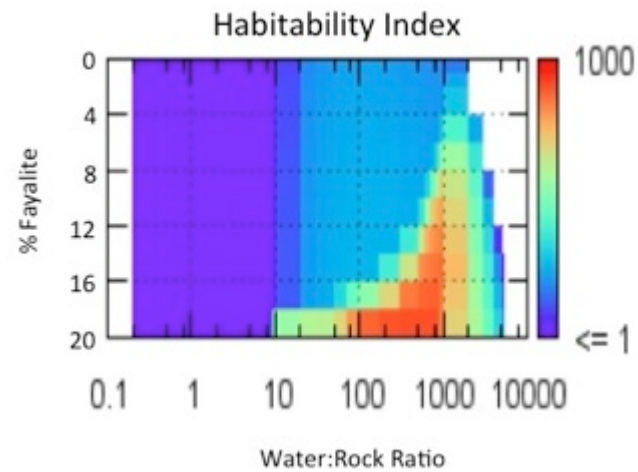
Theoretical vs. experimental measures of H_2 production rate

Mechanistic models for Fe(II)-driven interfacial electron transfer

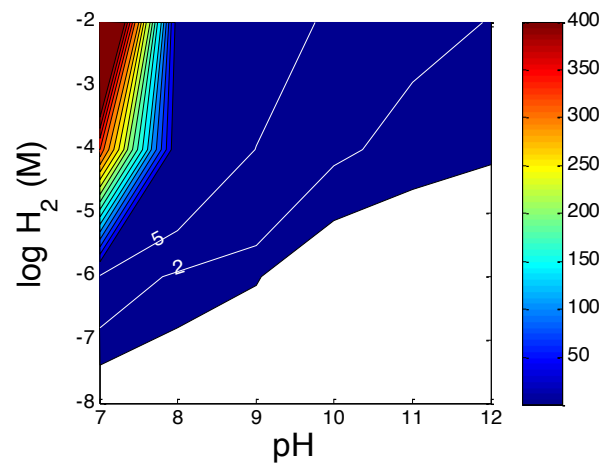
RPL "Conundrums"

Rates of electron transfer → Impact on habitability



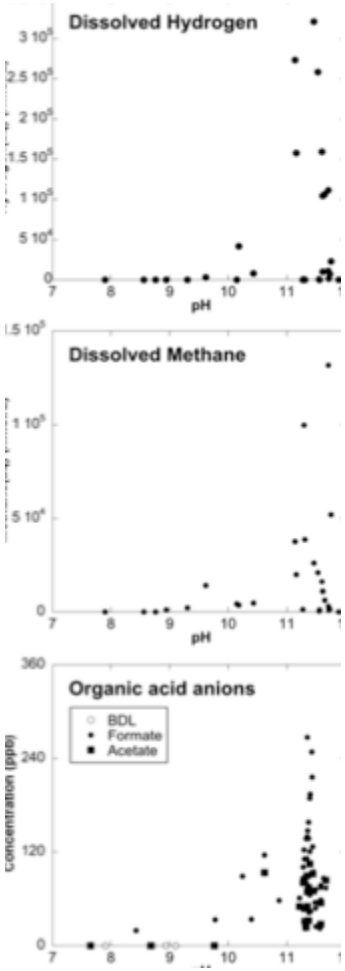


Capacity of low-temperature systems to generate habitable conditions – and are they inhabited?



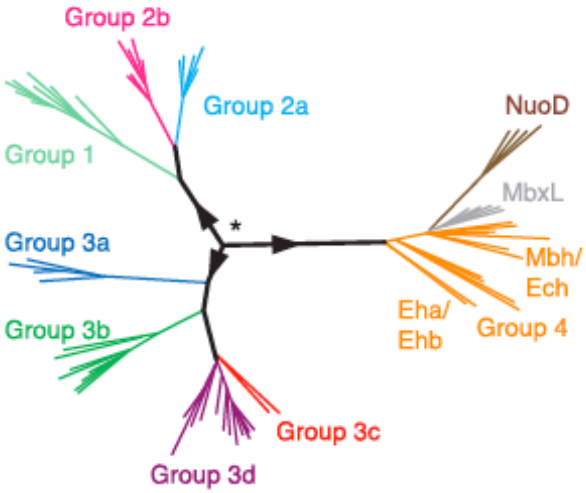
RPL "Conundrums"

Explanation for high H_2, CH_4 and organic acids in low-T systems?
Microbial H_2 production or consumption?
Where are the methanogens in serpentinites?
Biochemical pathways under oxidant limited conditions?

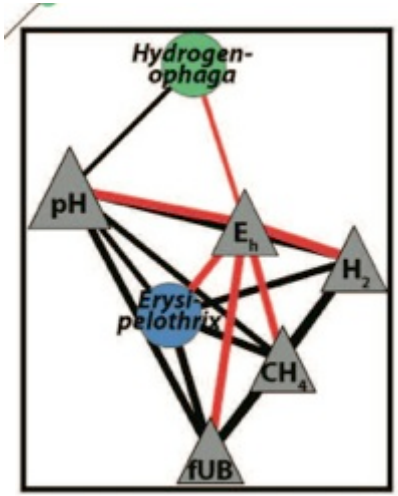


H_2, CH_4 and organic acids in Oman springs
Canovas et al.,(in prep), Robinson et al. (in prep)

Hyperalkaline spring



([Ni-Fe]-hydrogenase large subunit phylogenetic tree)
Boyd et al. 2014



Geochemical correlations for Hydrogenophaga and Erysipelothrix in Tablelands:
Brazelton et al. 2013

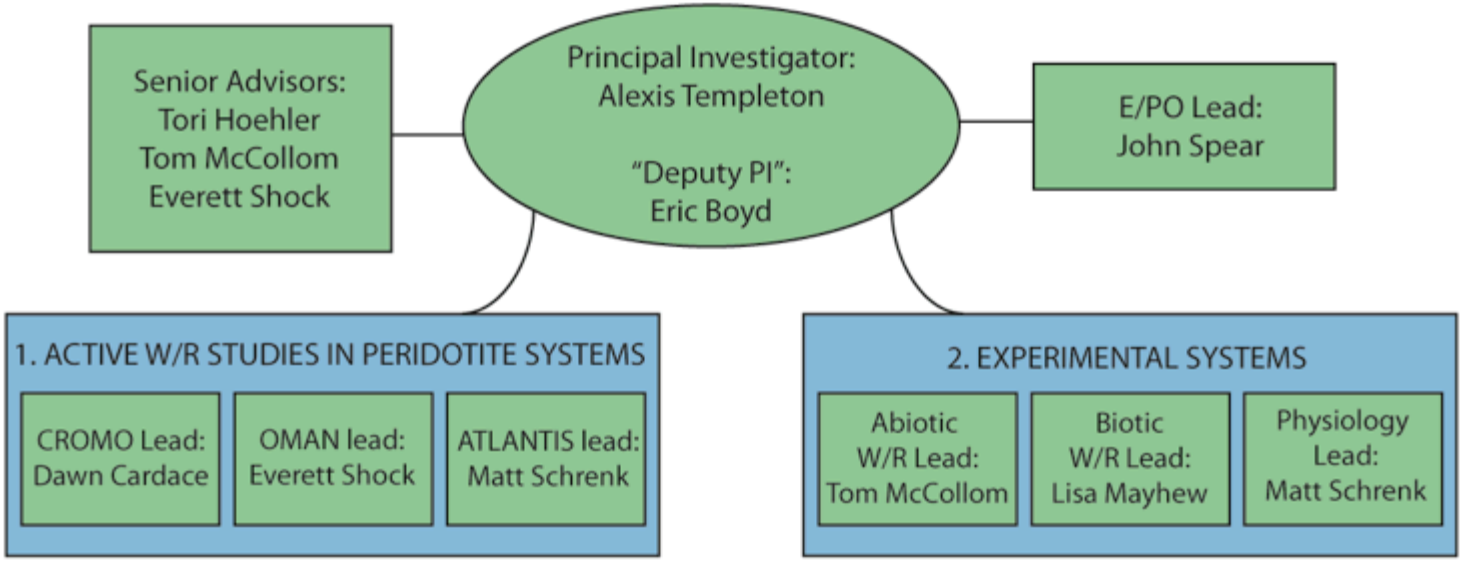
Rock-Powered Life NAI Objectives

- Defining the pathways that control how energy is released from ultramafic rocks as they react with low-temperature fluids
- Identifying and interpreting the process rates and ecology in systems undergoing low-temperature serpentinization
- Characterizing microbial communities within rock-hosted ecosystems and evaluating their metabolic activities
- Quantifying the geochemical and mineralogical progression of water/rock reactions in the presence and absence of biology
- Developing and testing predictive models of biological habitability during water/rock interaction

Rock-Powered Life NAI Team

- **Theme 1:** Systems undergoing low-temperature serpentinization as test-beds for determining habitability.

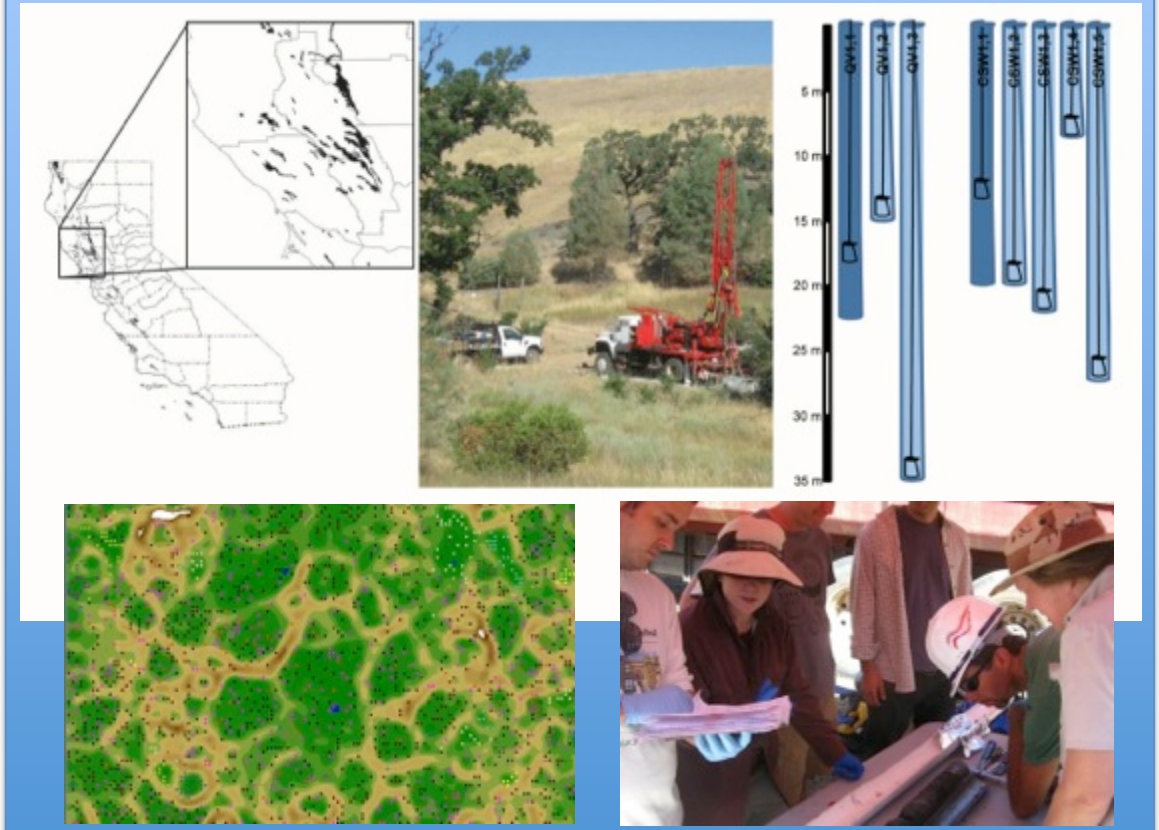
- **Theme 2:** Experimental constraints on pathways of W/R interaction, in the presence and absence of biological processes.



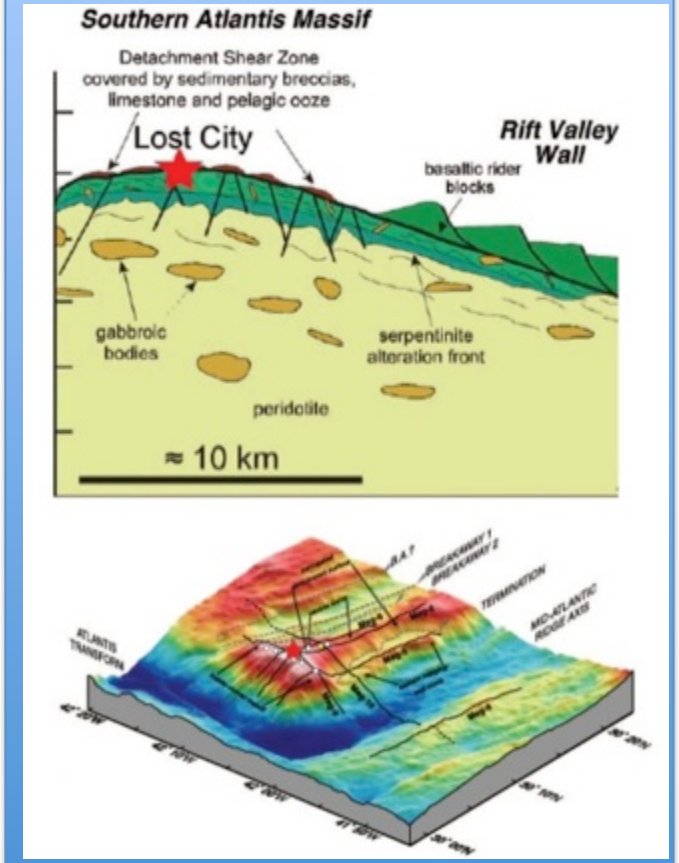
RPL Theme 1

Capitalizing upon unique & timely opportunities to conduct studies in serpentinizing systems in the California Coast Range Ophiolite, the Samail Ophiolite of Oman, and the Atlantis Massif

CROMO (est. by the NAI DDF)



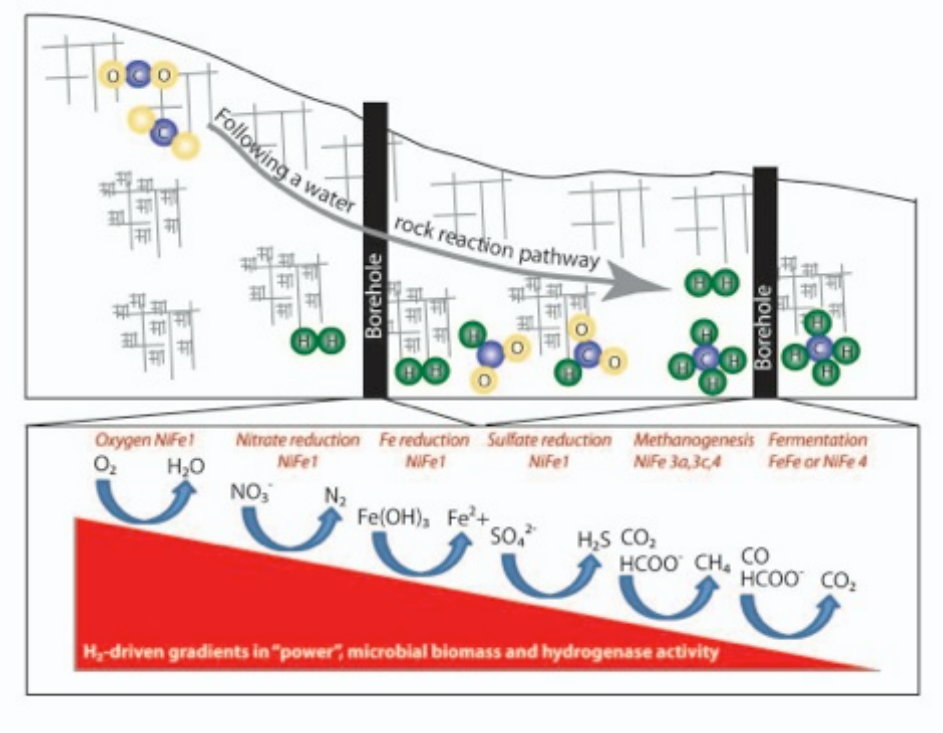
Atlantis Massif (ECORD)



RPL Theme 1

Systems undergoing low-temperature serpentinization
as test-beds for determining habitability

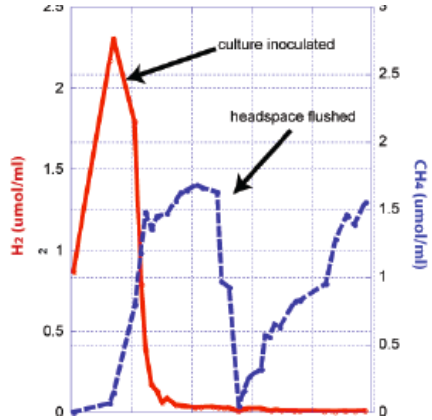
Oman Drilling Project (ICDP, Sloan)
With Kelemen, Matter, Teagle et al.



A down gradient borehole system to develop a full quantitative framework for assessing habitability, quantifying coupled geochemical and biochemical feedbacks, and structuring of the microbial community function and activity, can be rigorously established.

RPL Theme 2

Experimental Constraints on pathways of W/R interaction in the presence and absence of biological processes



Recent successes in cultivation of serpentinite organisms

Generate low flux of H_2 & organic acids during Peridotite/Water Interaction

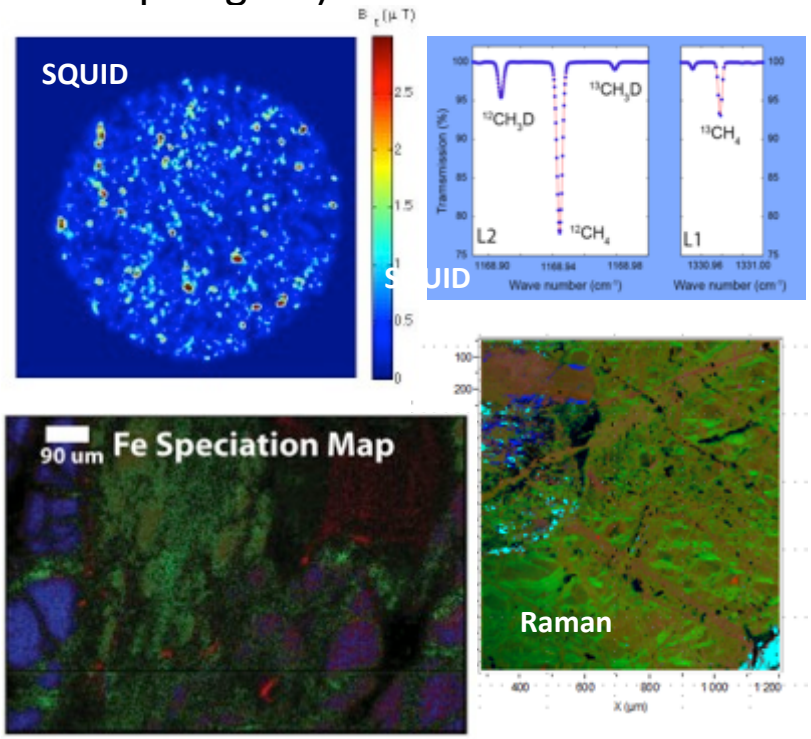
→ ***Experimental inputs/outputs of Habitability modeling***

→ ***Microbial physiology, growth & gene expression during water/rock reaction***

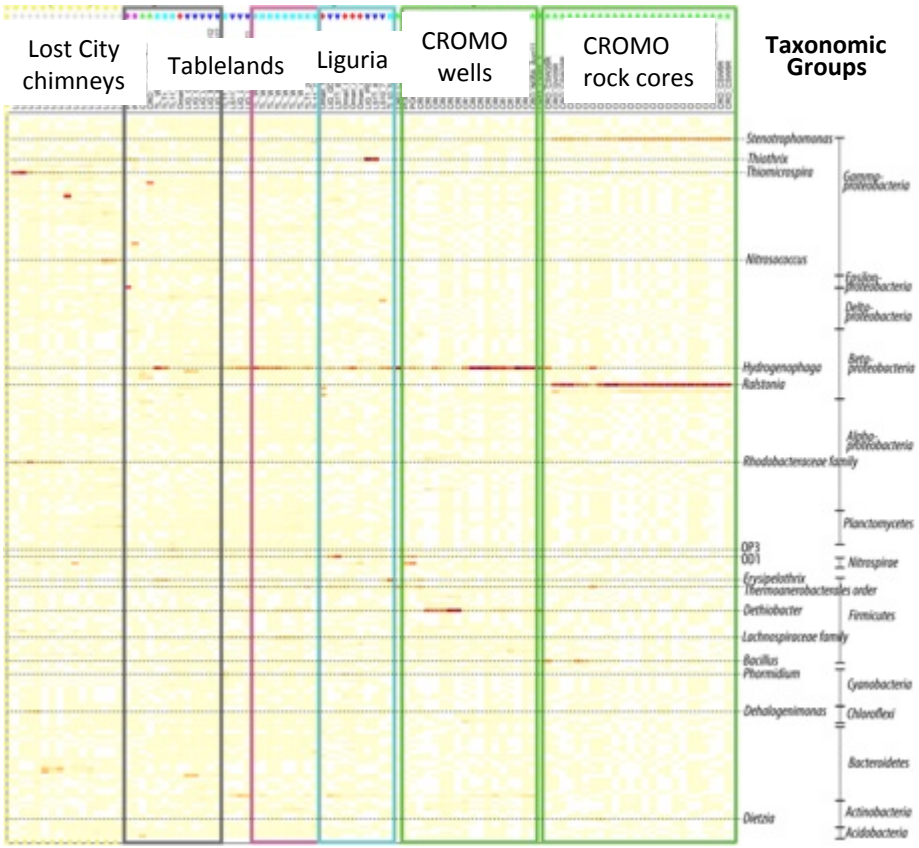
→ ***Geochemical transformation & production of biomarkers***

Tool Development & Application

Chemical imaging & Biomarkers
(X-ray, EDS, Raman, IR, magnetic, isotopologues)

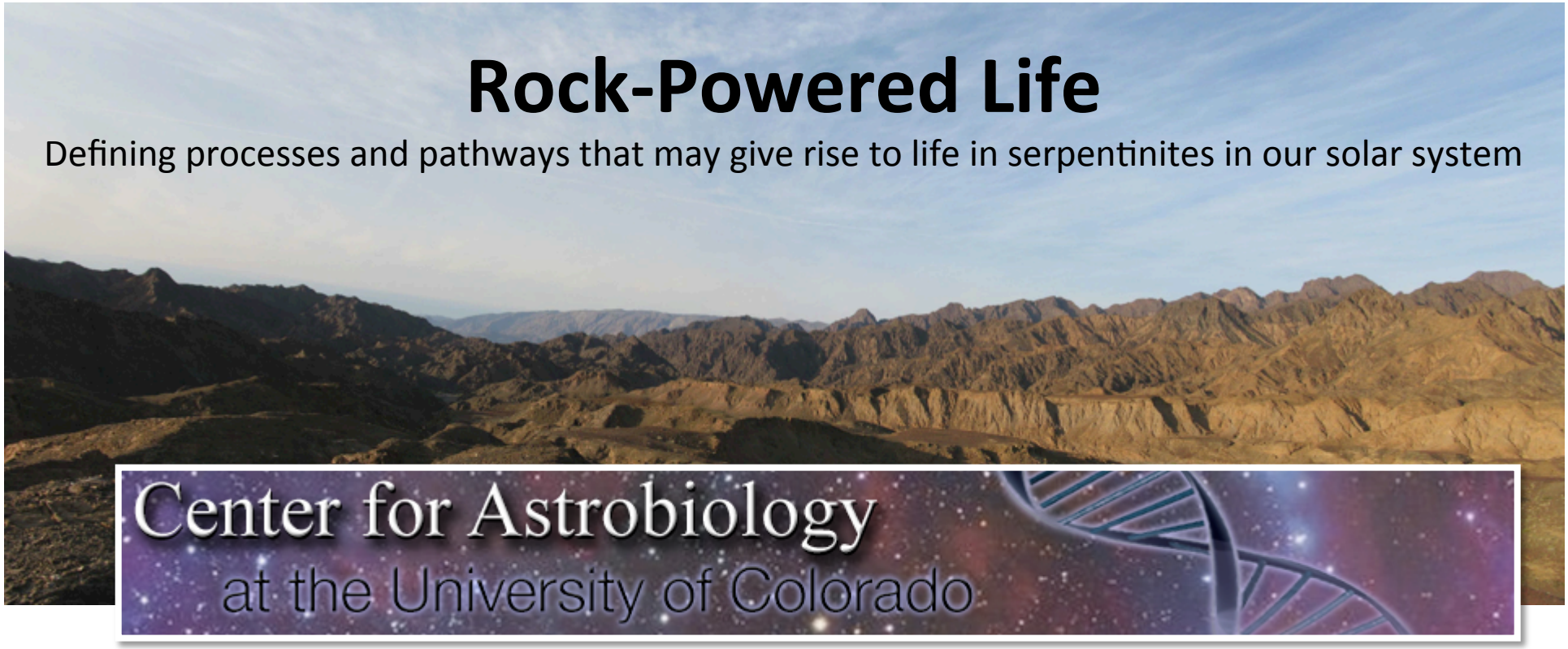
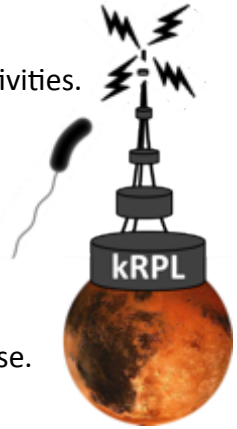


Physiology → "-Omics":
process-rate measurements;
metagenomics and transcriptomics of the RHC;
tracking flows of C and energy at a single-cell level.



Rock-Powered Life

Defining processes and pathways that may give rise to life in serpentinites in our solar system



- Center of astrobiology at CU for 16+ years.
- Participation from >30 faculty and many more students from greater than a half-dozen departments and research institutes spanning the physical sciences, chemistry, the biological sciences, and the humanities.
- Acts as a central umbrella to coordinate undergraduate and graduate astrobiology research, teaching, and outreach activities.
- **<u>CU-CAB will work closely with the Rock Powered Life Team</u>:**
  - Engaging Native American Tribal Colleges to bring astrobiology to the underserved.
  - Construction of a distributed Astrobiology undergraduate 'virtual minor'
  - Expand the graduate certificate program in Astrobiology through CU-Boulder
  - The development of an Astrobiology teaching module for inclusion in the summer International Geobiology Course.
  - The training in effective mentoring techniques of graduate students through the SAGANet mentoring program.