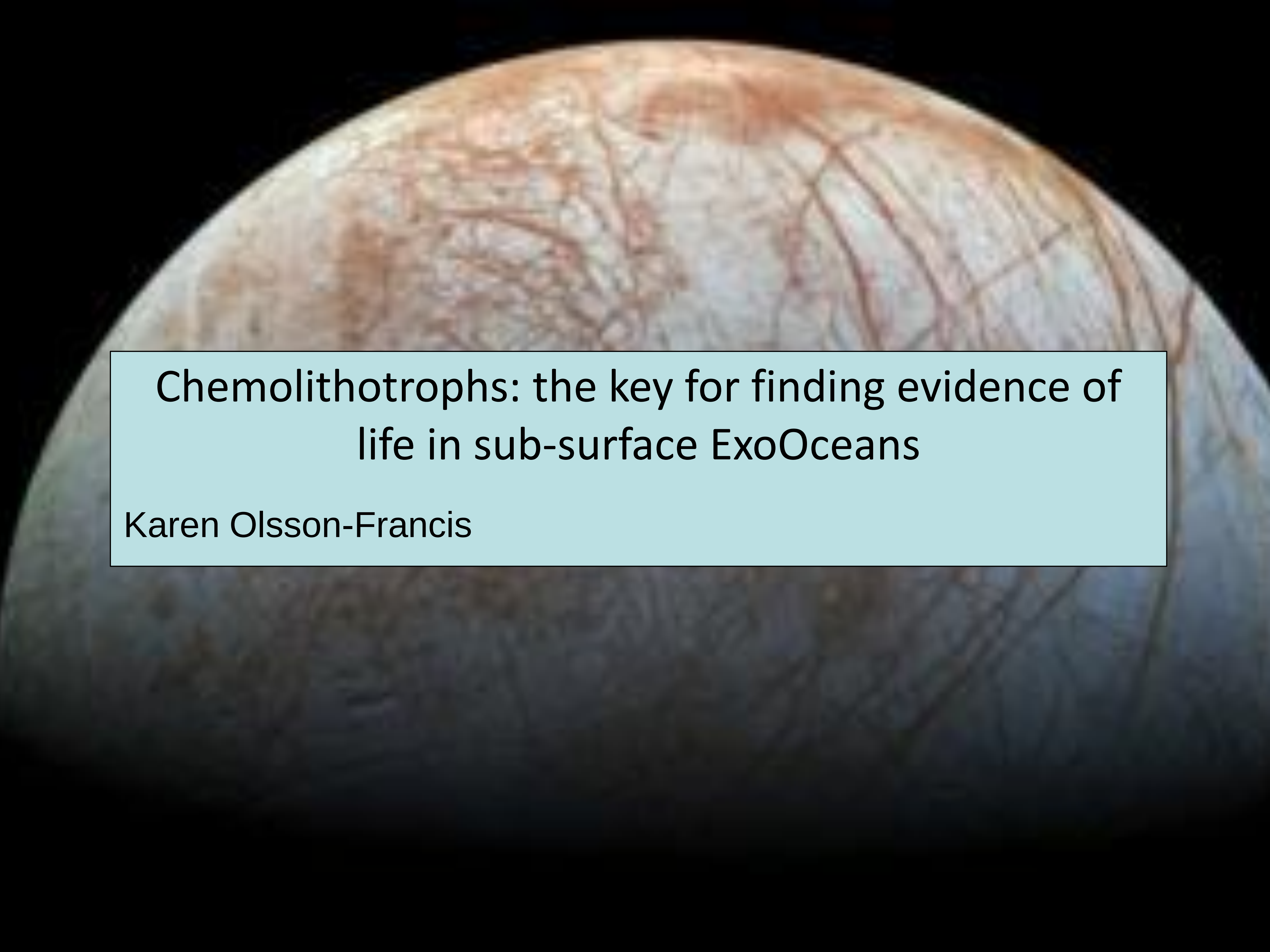


Chemolithotrophs: the key for finding evidence of life in sub-surface ExoOceans

Karen Olsson-Francis

Content

- Requirements for life and metabolism
- Potential life in ExoOceans
- Analogue experiments

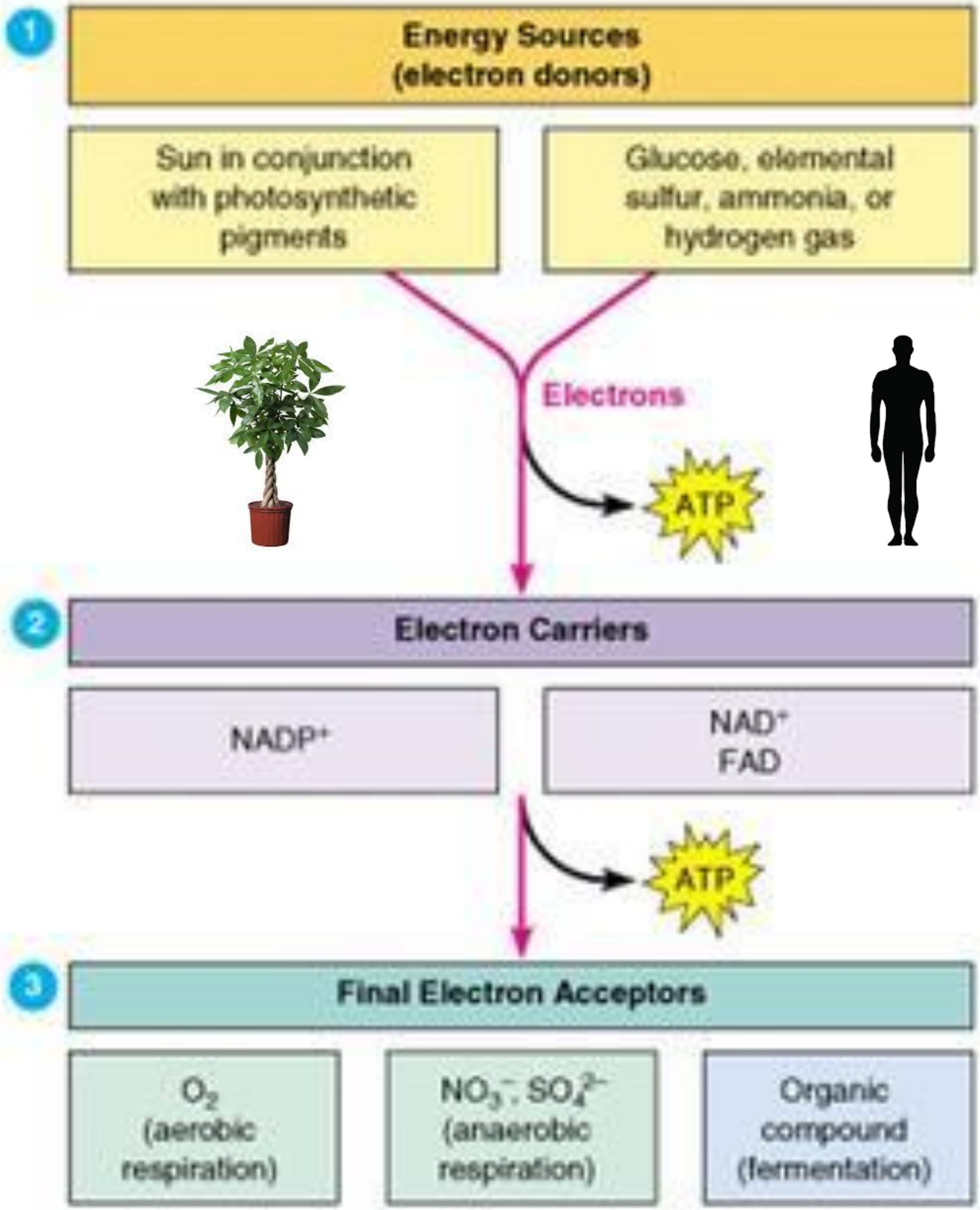
1: Requirements for life


Microbes are everywhere

mistry for life

Chemotrophs & Phototrophs

- Chemoorganotrophs: reduced organic electron donor for energy and electrons.
- Chemolithotrophs: reduced inorganic electron donor for energy and electrons.
- Phototrophs: use light energy and an electron donor molecule (H_2O, H_2S, organic).



Chemolithotrophs

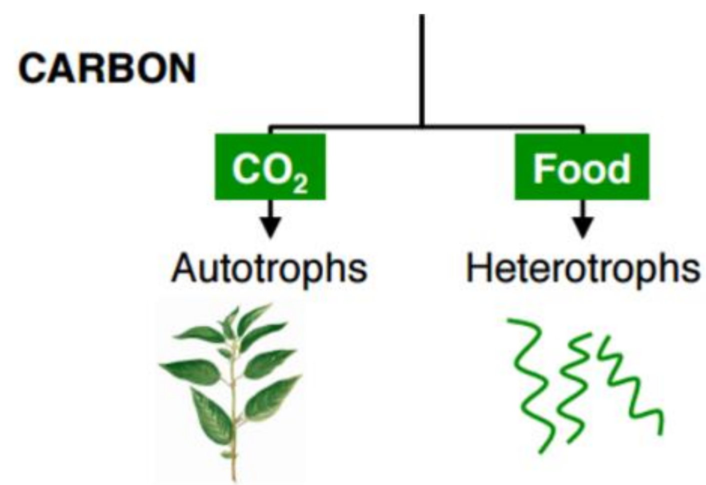
The Open University

- Electron donors

Reaction
$H_2 + {}^1/_2\,O_2 \longrightarrow H_2O$
$NO_2^- + {}^1/_2\,O_2 \longrightarrow NO_3^-$
$NH_4^+ + 1{}^1/_2\,O_2 \longrightarrow NO_2^- + H_2O + 2H^+$
$S^0 + 1{}^1/_2\,O_2 + H_2O \longrightarrow H_2SO_4$
$S_2O_3^{2-} + 2O_2 + H_2O \longrightarrow 2SO_4^{2-} + 2H^+$
$2Fe^{2+} + 2H^+ + {}^1/_2\,O_2 \longrightarrow 2Fe^{3+} + H_2O$

Hydrogen oxidisers e.g methanogens
Sulfur oxidisers
Iron oxidisers
Nitrifying bacteria

- Electron acceptors
  - Oxygen
  - Nitrate
  - Iron (III)
  - Manganese (IV)
  - Sulfate
  - Carbon dioxide
  - Some chlorinated solvents



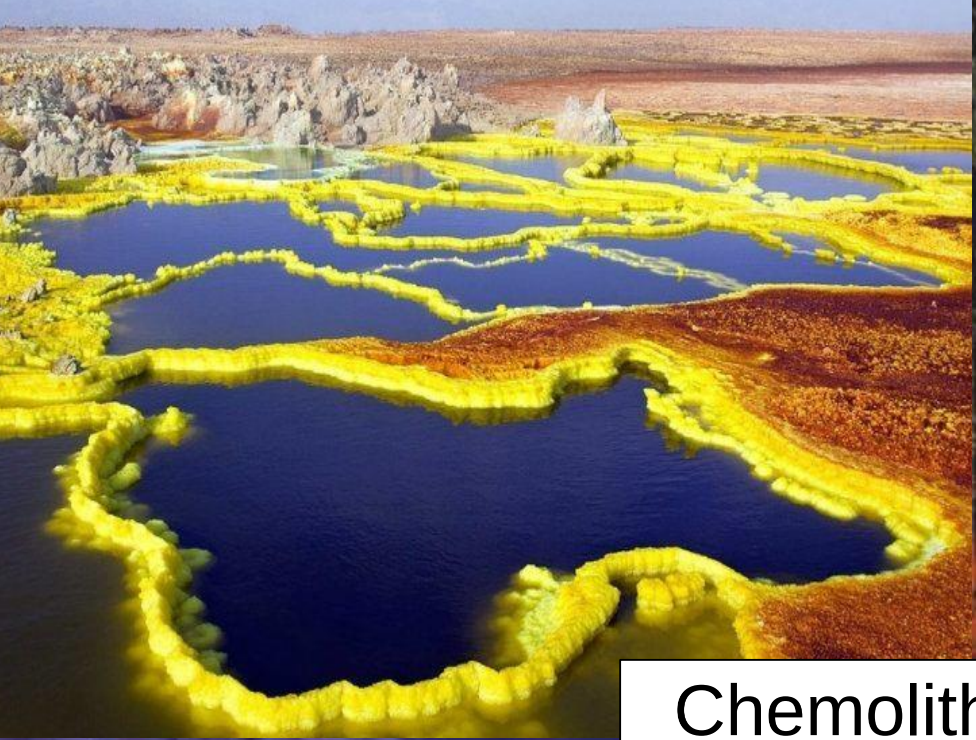
Chemoorganotrophs

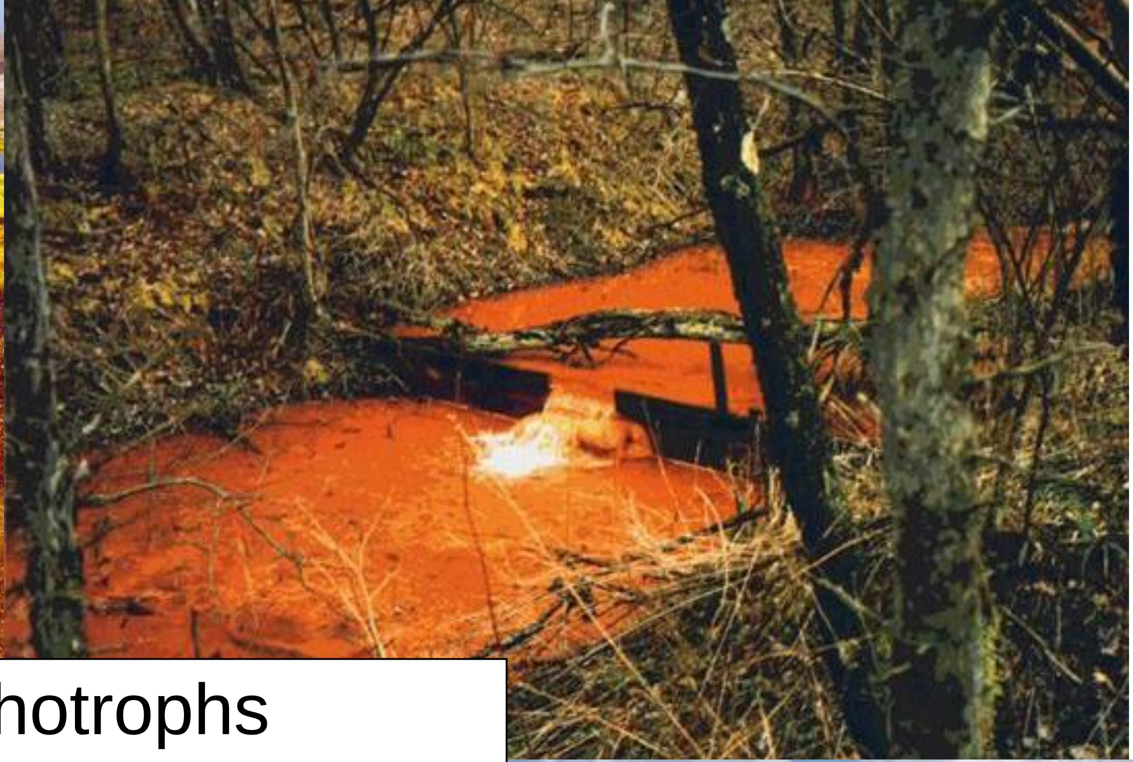
- Methanotrophs:
  - Metabolise methane as their sole source of carbon and energy
  - Can grow aerobically and anaerobically
  - Found in diverse environments

  - Aerobically
    - Combine methane and oxygen to form formaldehyde

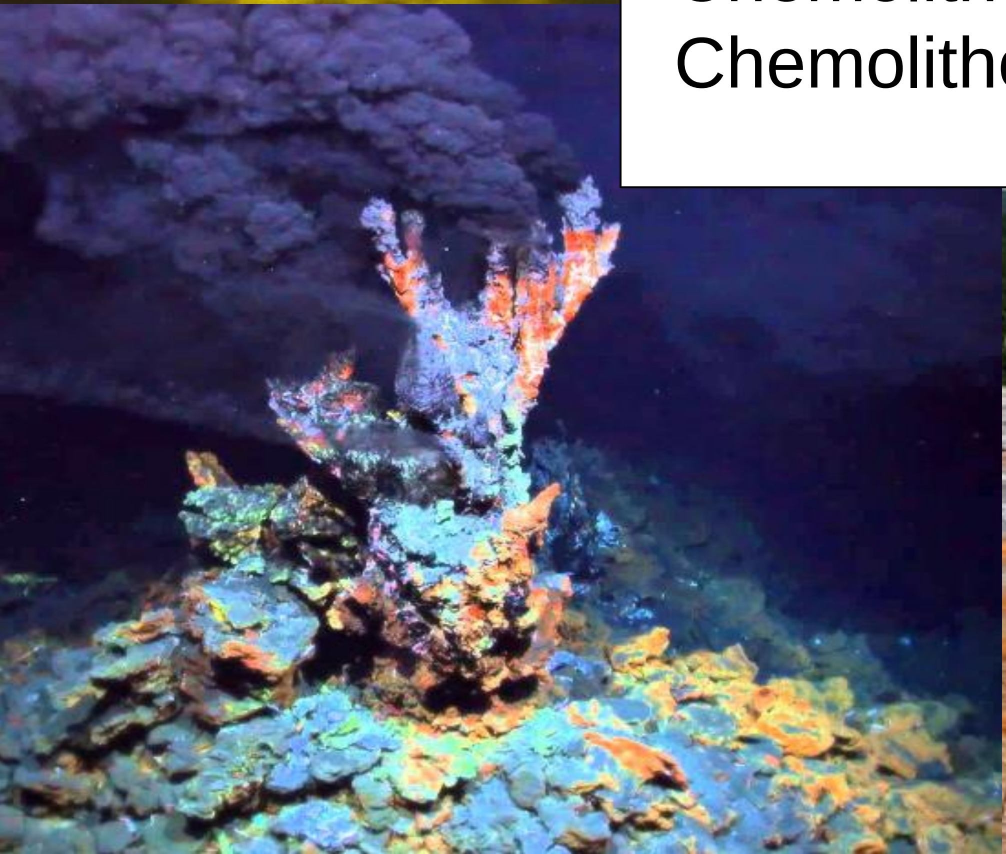
  - Anaerobically
  - Consortia


Phototrophs





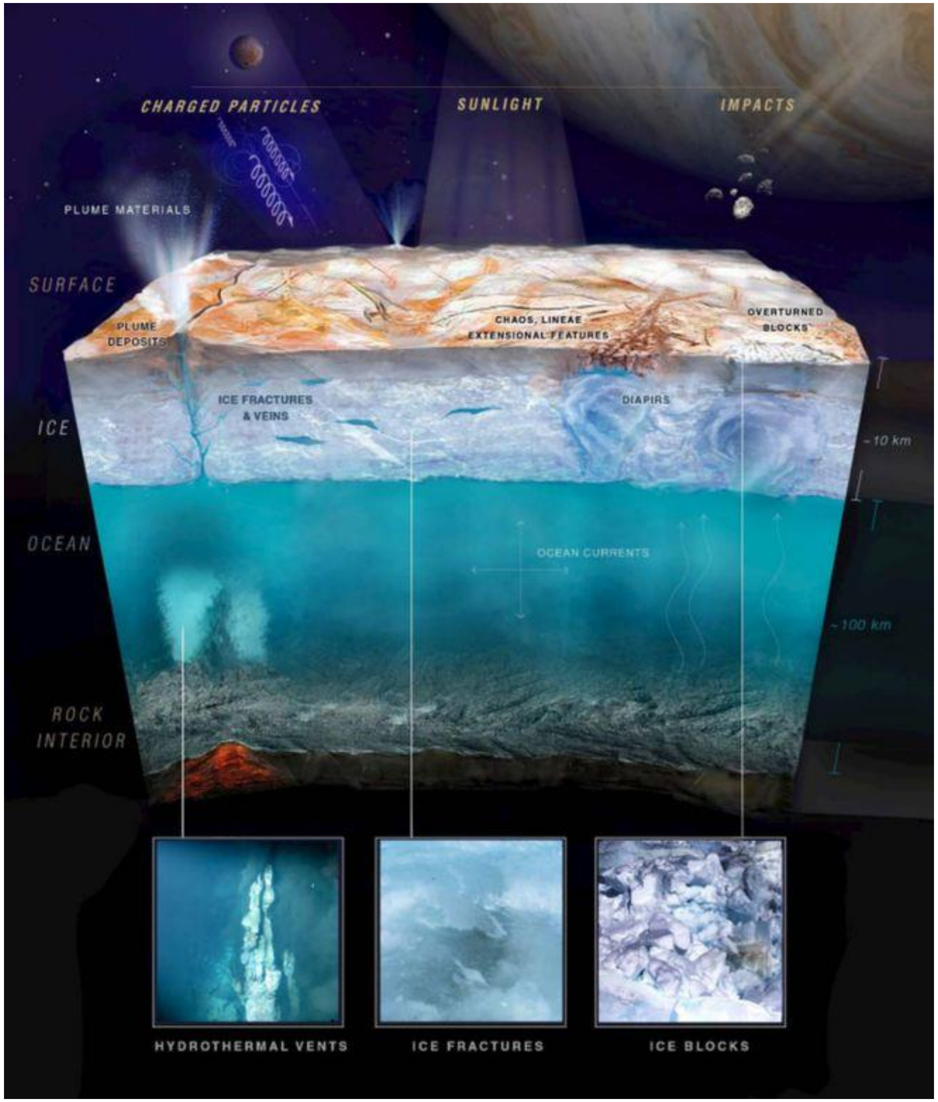
Chemolithotrophs
Chemolithoorganotrophs



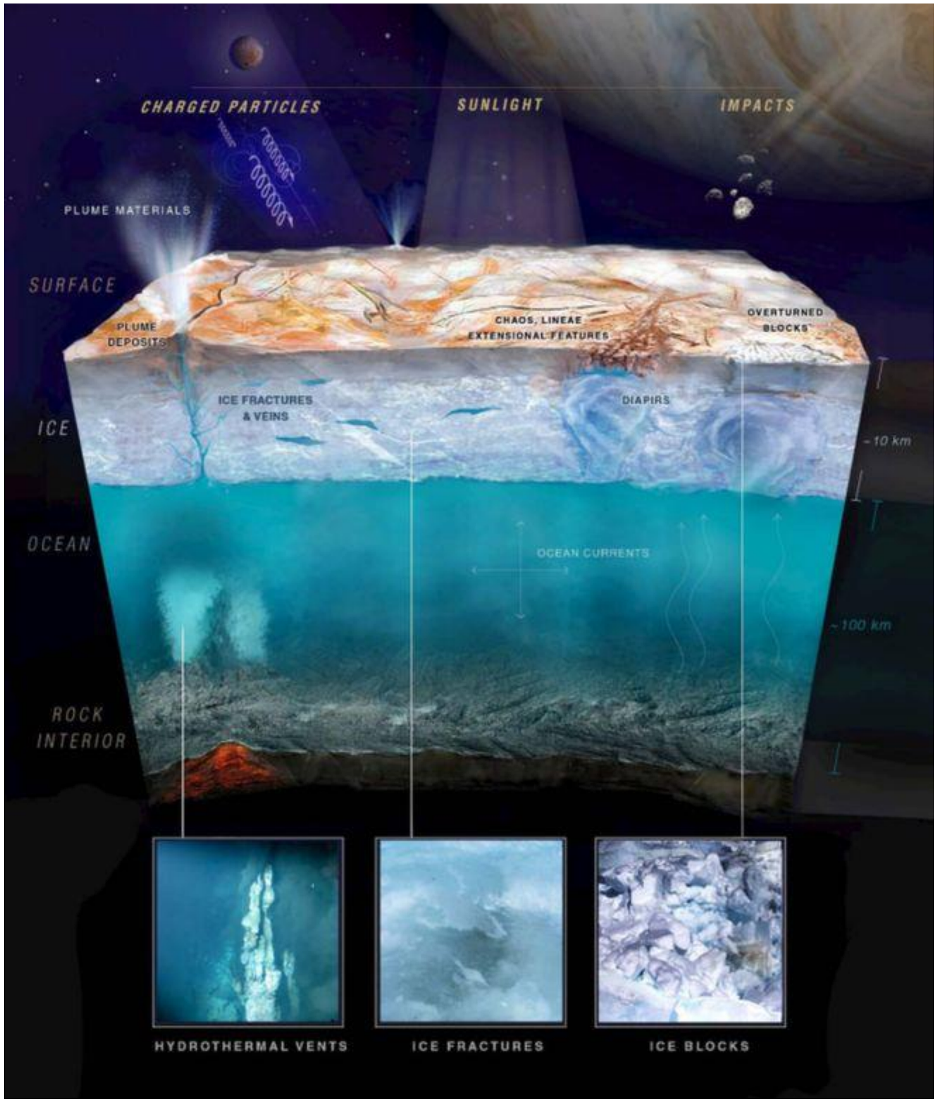
1: Potential life in ExoOceans

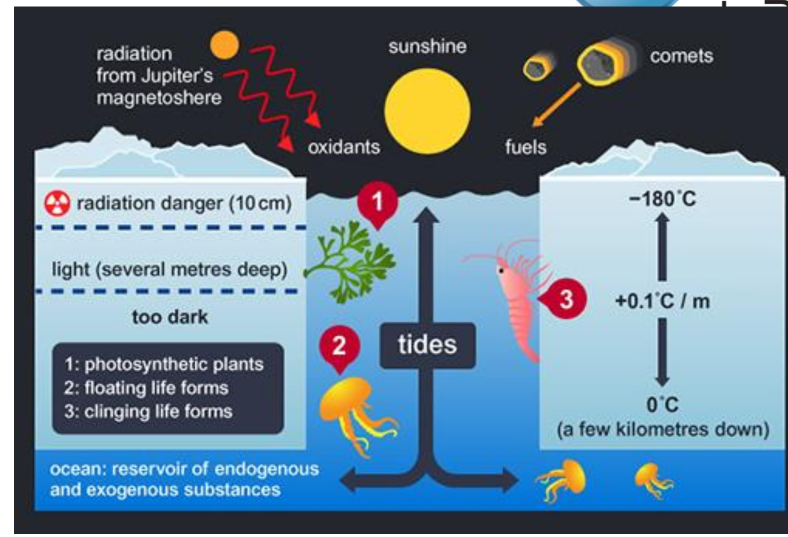
Habitability of the icy moons

- Assumptions:
  - Liquid water below the ice sheet
  - Heated from below
  - Rocky core e.g. Enceladus LL Chondrite
  - Hydrothermal activity?
  - Potential hydrothermal system
  - Saline brine (varying between icy moons)
    - Mg-Na-SO_4 Europa?
    - Na-Cl-CO_3 Enceladus?
  - Temperature gradient
  - pH varies e.g Enceladus slightly alkaline
  - Key essential elements present
  - Life would be microbial



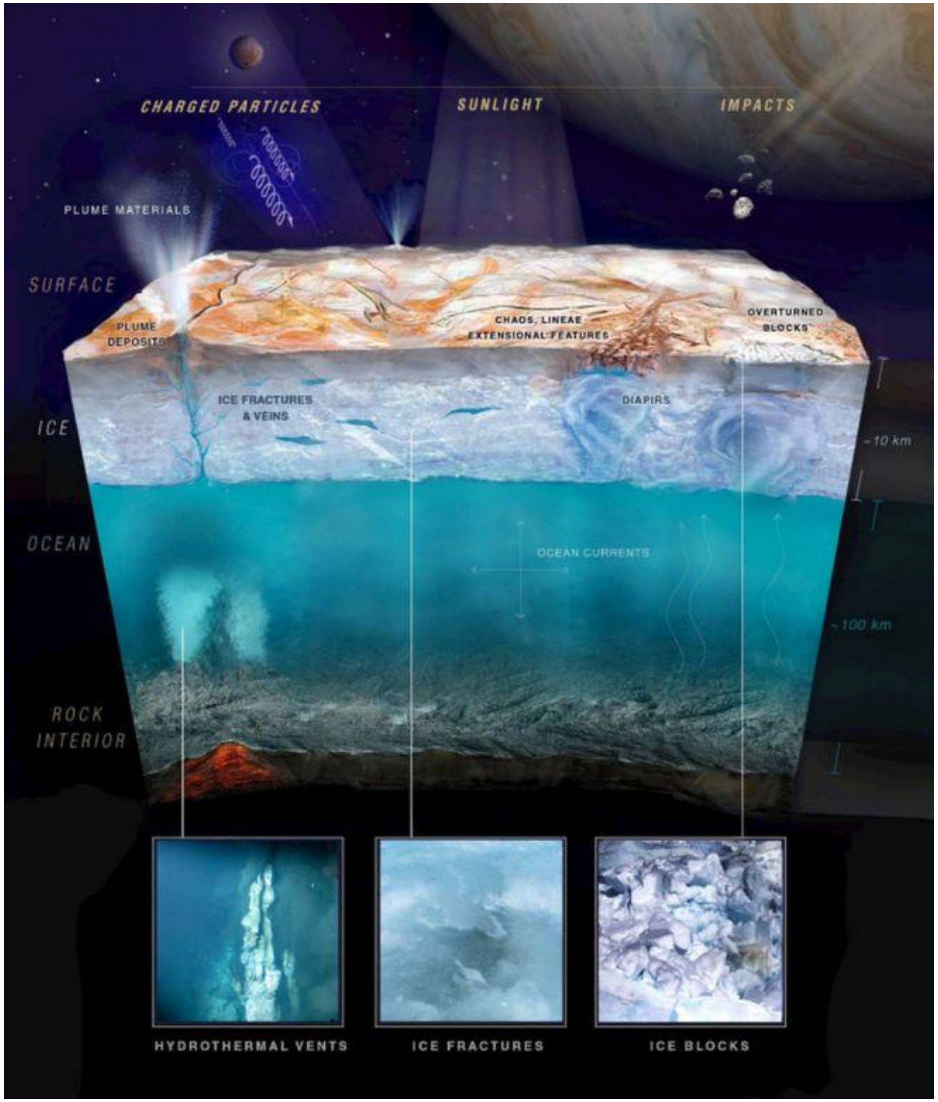
Potential life

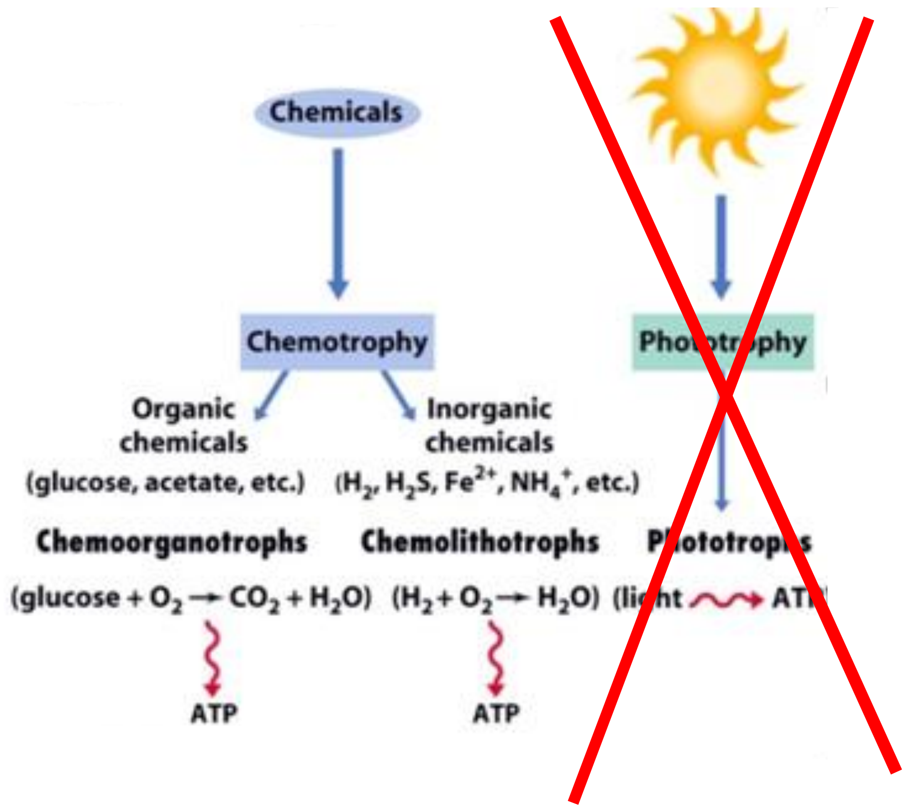




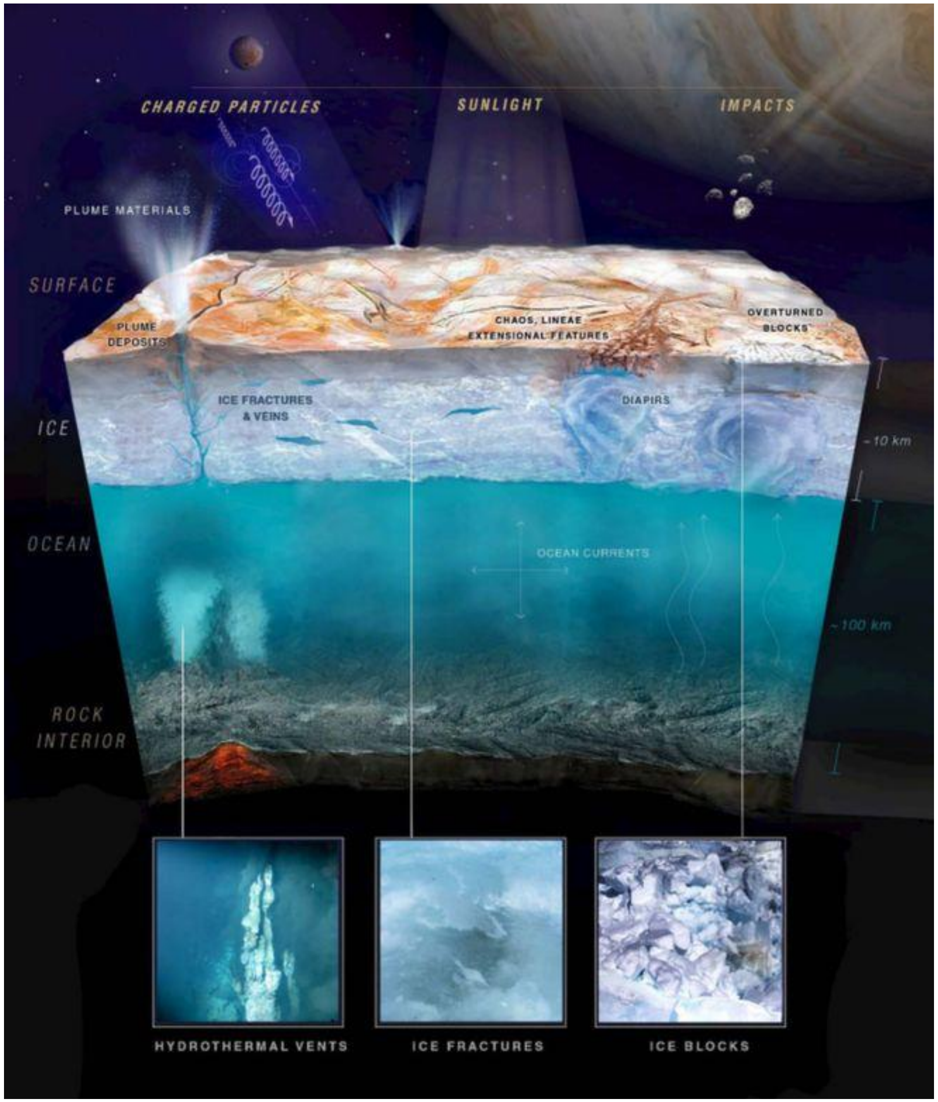
Potential life

The Open University





Environmental conditions



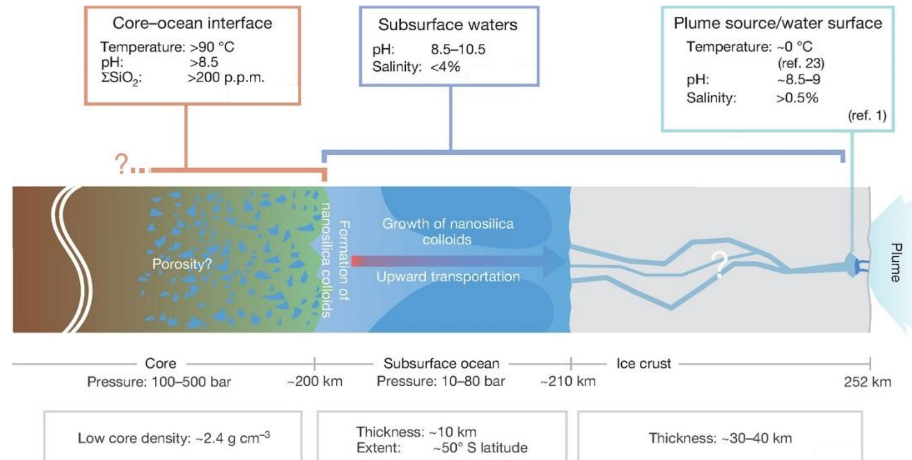
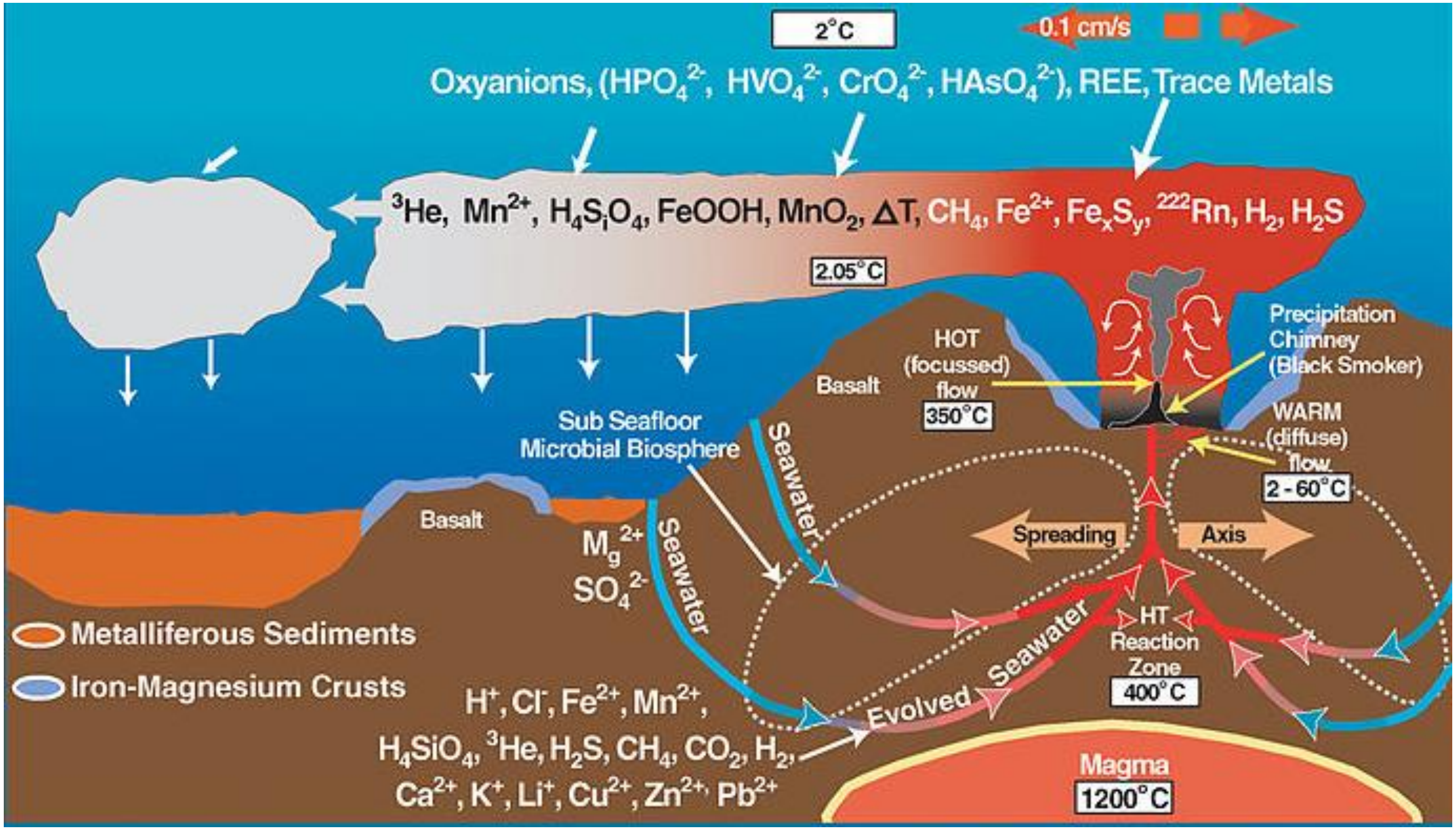


Figure adapted from Hsu, H.W, et al, (2015) Ongoing hydrothermal activities within Enceladus, *Nature.* Vol. 519(7542), p207-210.

mistry for life

Terrestrial hydrothermal system



Extensive life in terrestrial oceans

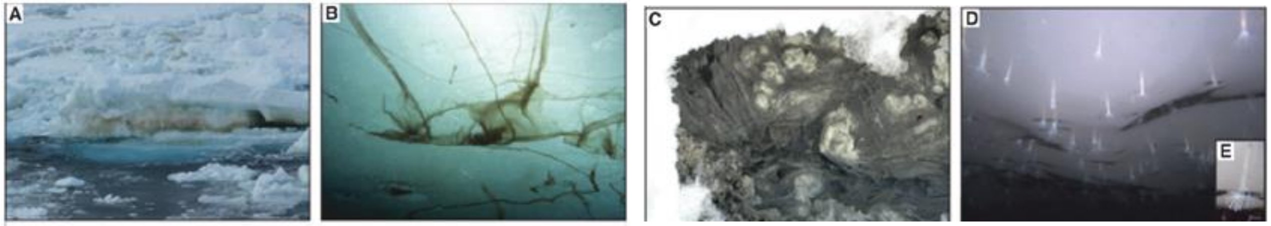
Terrestrial versus icy worlds

Terrestrial oceans

- Mostly solar heated
- Ice-water interfaces support life:
  - Sun derived energy dense congregations
  - Dissolved, reduced S sources drive chemomolithotrophs
  - Putative detrital organic matter supplies ecosystems

Icy moon oceans

- Heated from below
- “Steady state” natural chemostat
  - Life limited by oxidants
  - Radiolysis of the ice could react to produce oxidants
  - Sulfite, nitirite, nitrate yielded
  - Electron donor- hydrogen, methane ferrous iron

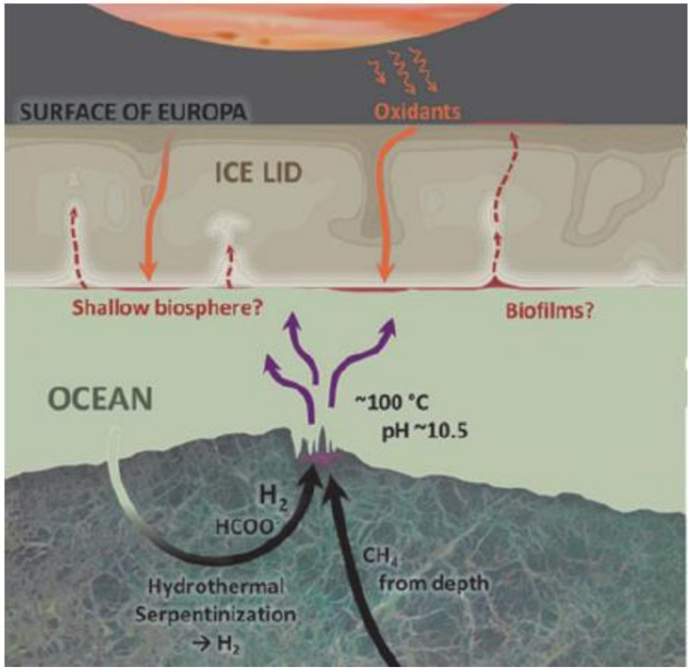


Russell et al., 2017. Astrobiology, 12,

Life in ExoOceans

Chemolithotrophs

Geochemical gradient

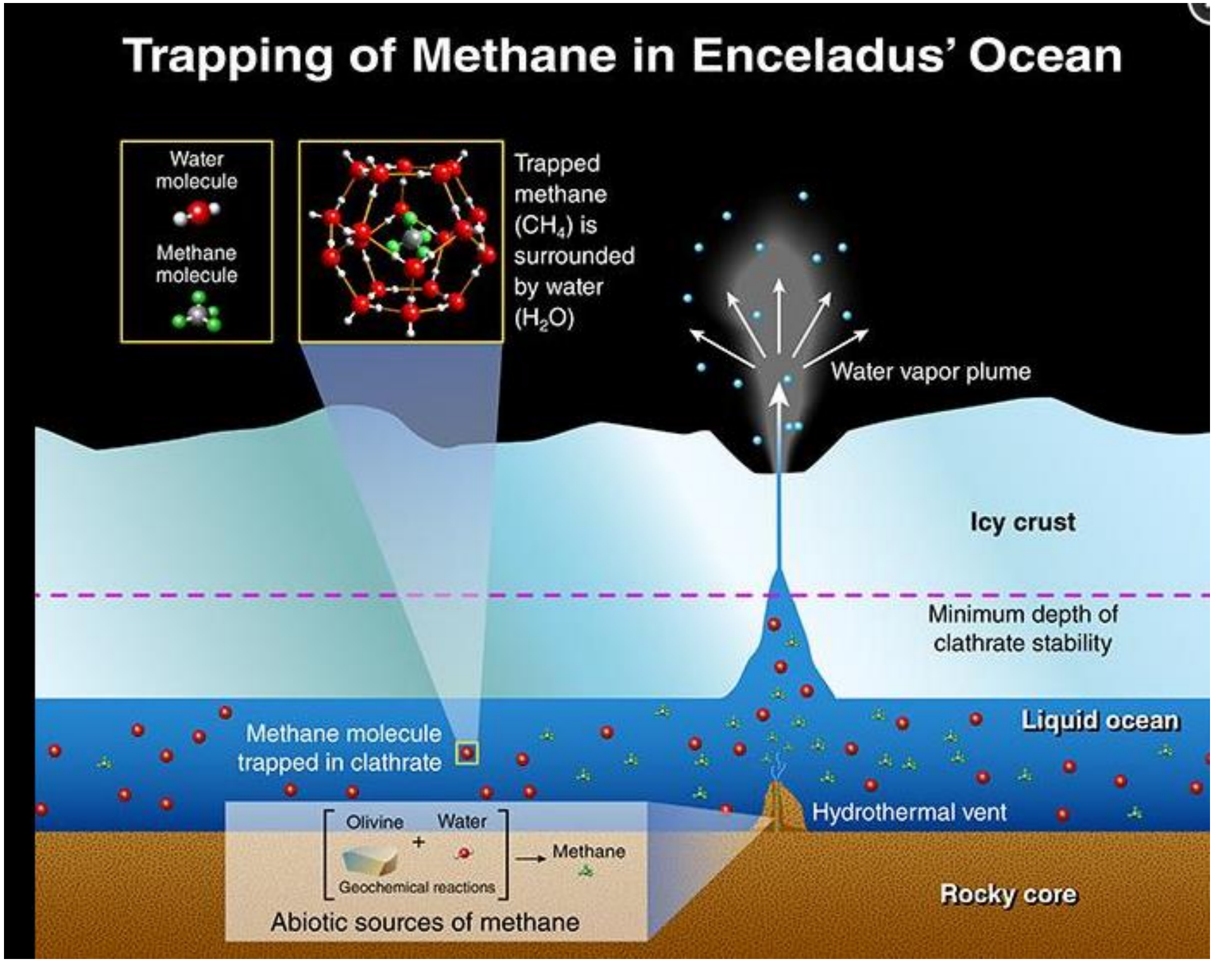


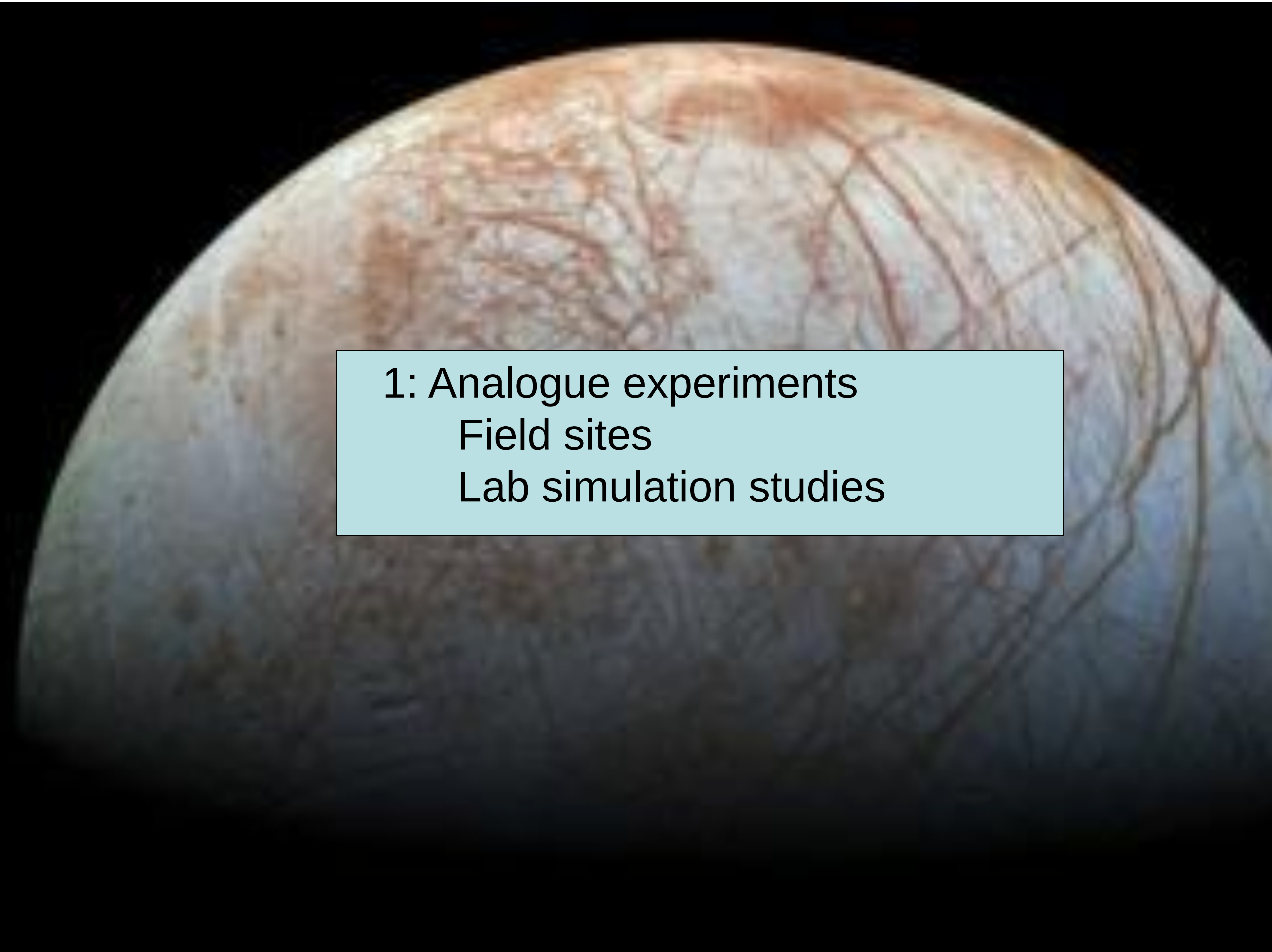
Nutrients in the form of reduced volatiles

Russell et al., 2017. Astrobiology, 12,

Life in ExoOceans

Chemoorganotrophs





1: Analogue experiments

Field sites

Lab simulation studies

Analogue sites for sub-surface oceans

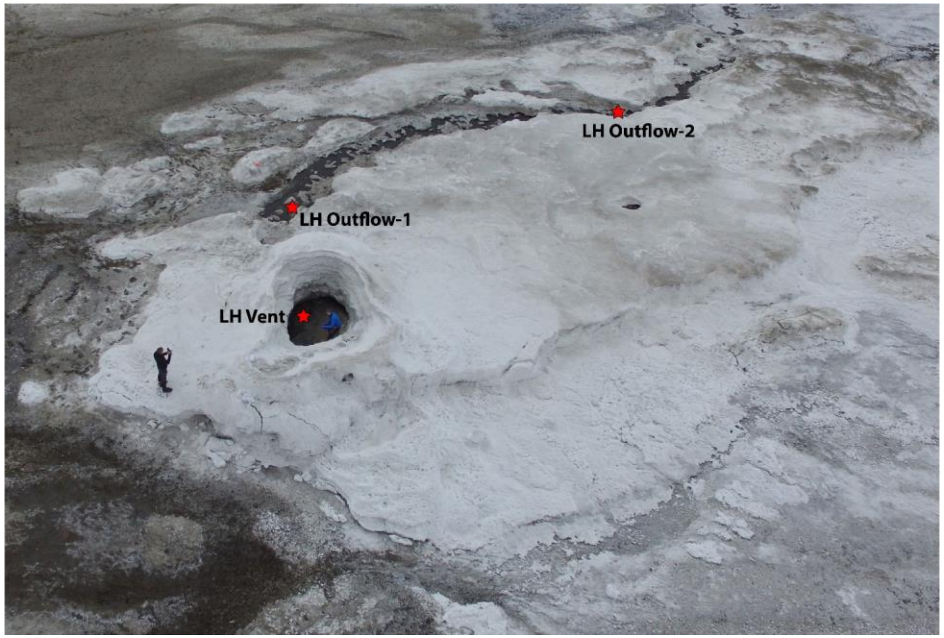
- Sulfate lakes
  - Lake Tirez, Spain: hypersaline Mg, Na, Cl and sulfate rich brine *(Prieto-Ballesteros et al., 2003)*
  - Lost Hammer, Artic
- Ice sealed lakes
  - Lake Vostok
- Alkaline lakes
  - Mono Lake, USA: alkaline soda lake dominated by Na-Cl-CO_3 *(Pikuta et al. 2003)*
- Deep sea
  - Orca Basin, Mexico: deep-sea brine pool, dominated by an anoxic Na-Cl brine *(Shah et al. 2013)*
  - Lost City, mid-Atlantic ridge: active serpentinization *(Amador et al., 2013)*

Analogue site analysis

- Lost Hammer Springs, Axel Heiberg

- Chemical characterization of the site
- Metagenomics analysis
- Isolation of novel organisms

- Analogue work limited



Simulation experiments

Experiment 1:
Abiotic environment

Initial chemical environment:
- Simulant composition
- Derived brine chemistry

Physical conditions

Altered chemical environment
- Changes to brine chemistry
- Formation of new minerals
- Changes in initial mineral abundances

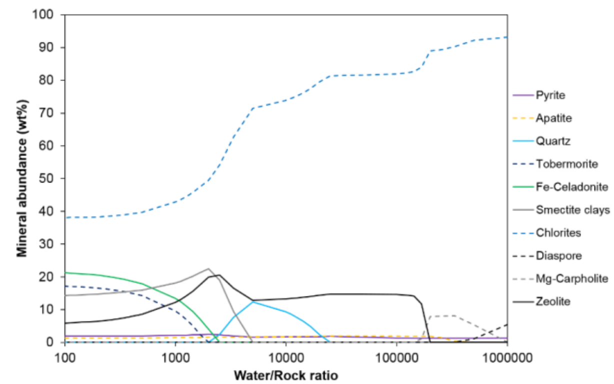
Experiment 2:
Biotic environment

Initial chemical environment:
- Simulant composition
- Derived brine chemistry

Physical conditions

- Ancient fluvial systems
- Modern subsurface

Altered chemical environment identical to abiotic system or resulting from metabolism of the microorganisms



Olsson-Francis et al., 2017, Frontiers in Microbiology.
Doi.org/10.3389/fmicb.2017.01668

Conclusion

- ExoOceans potentially habitable
- Chemolithotrophic and chemoorganotrophic metabolism feasible
- Experiential work need to investigate further