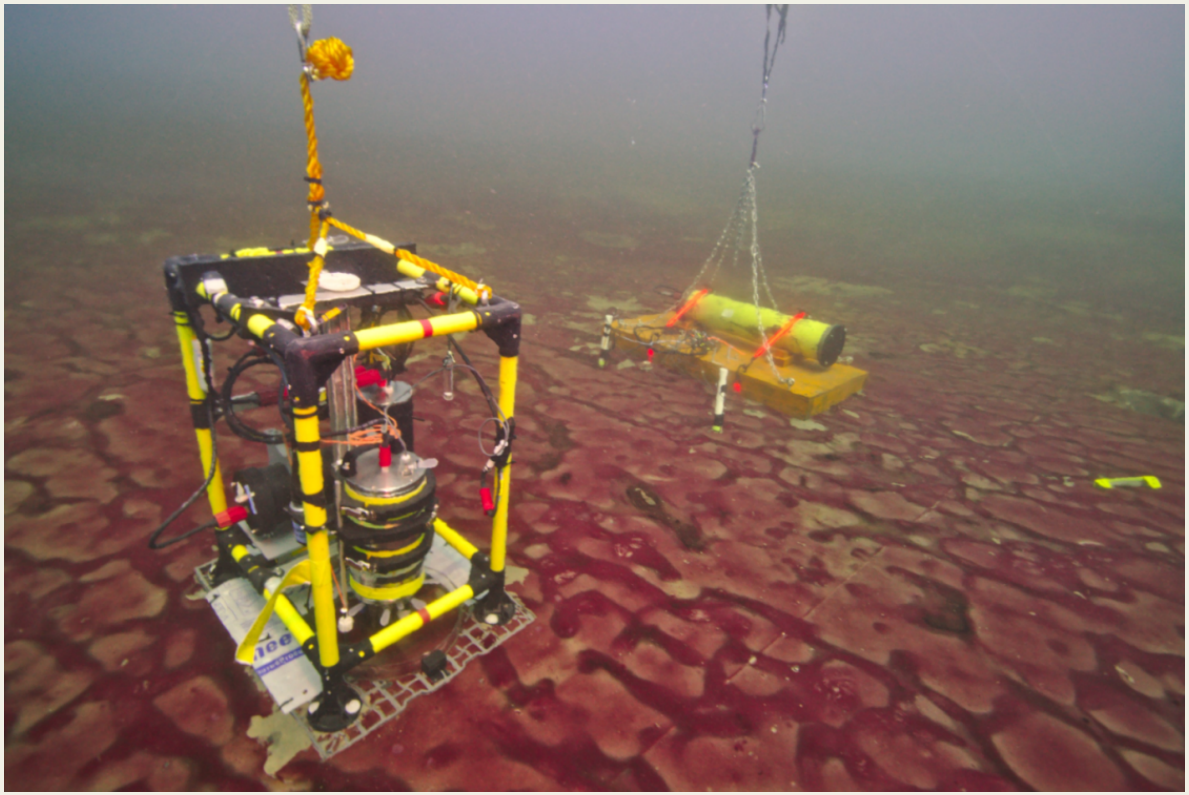
Use of microsensors in sediments and mats



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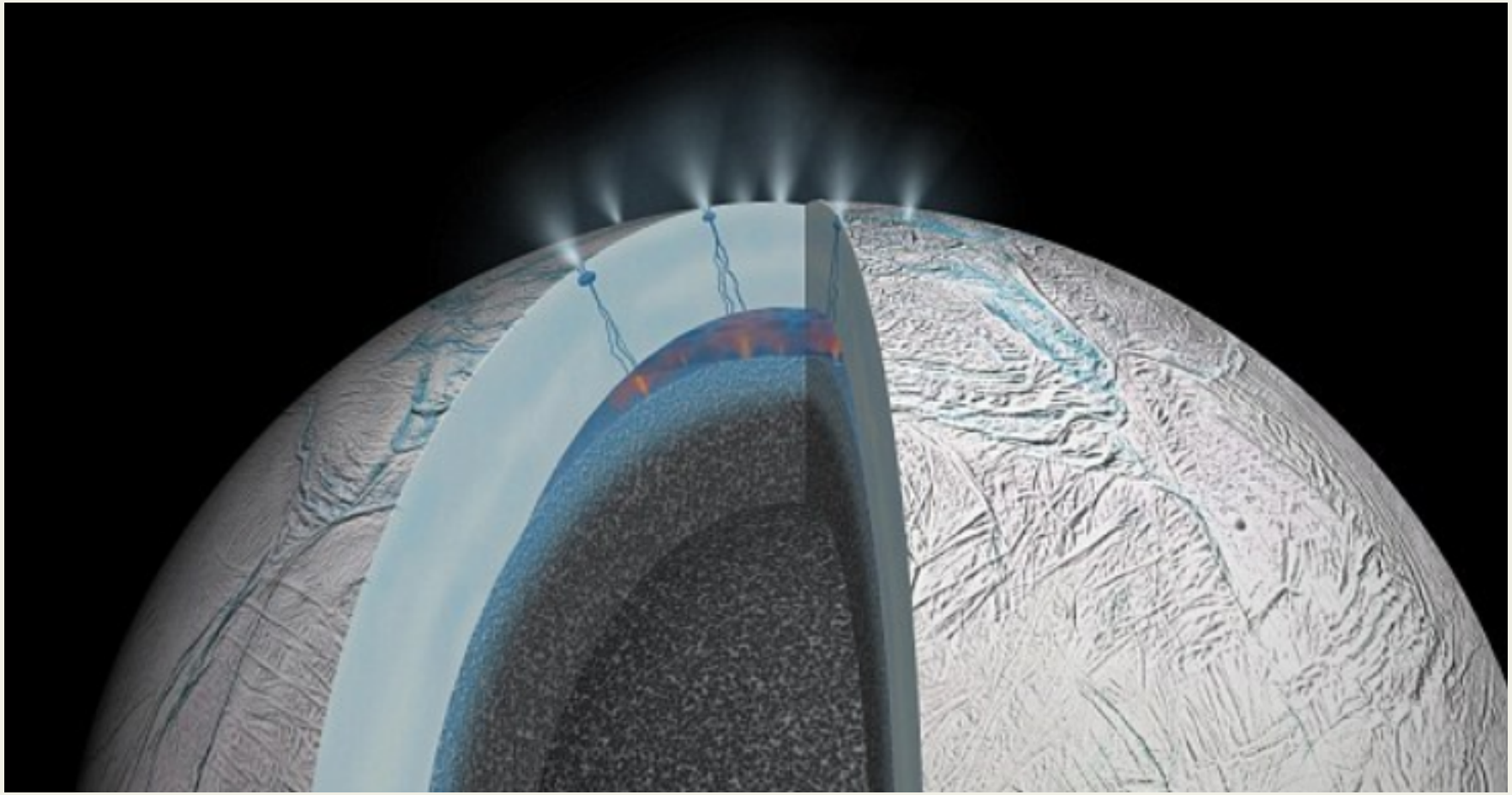
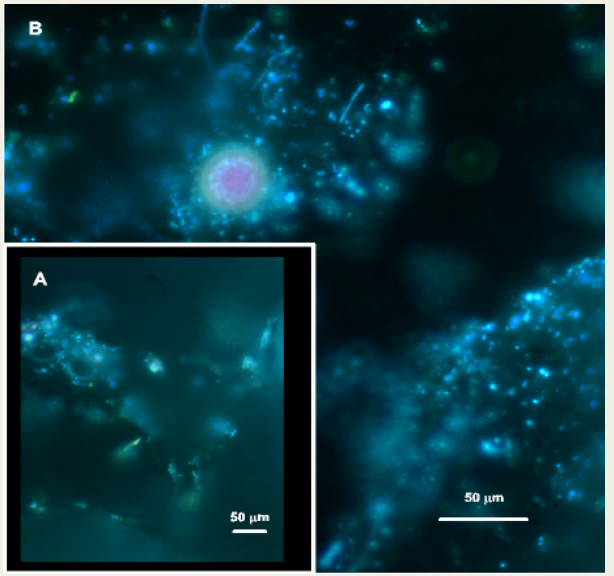


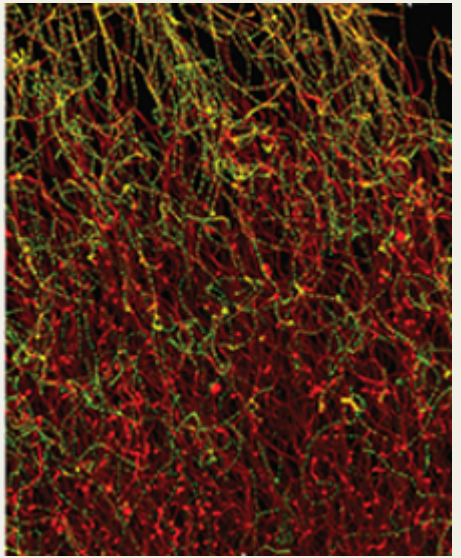
Where is life and what controls it?

- water
- thermodynamic disequilibrium that drives redox reactions
- cycling of essential elements (tectonics)

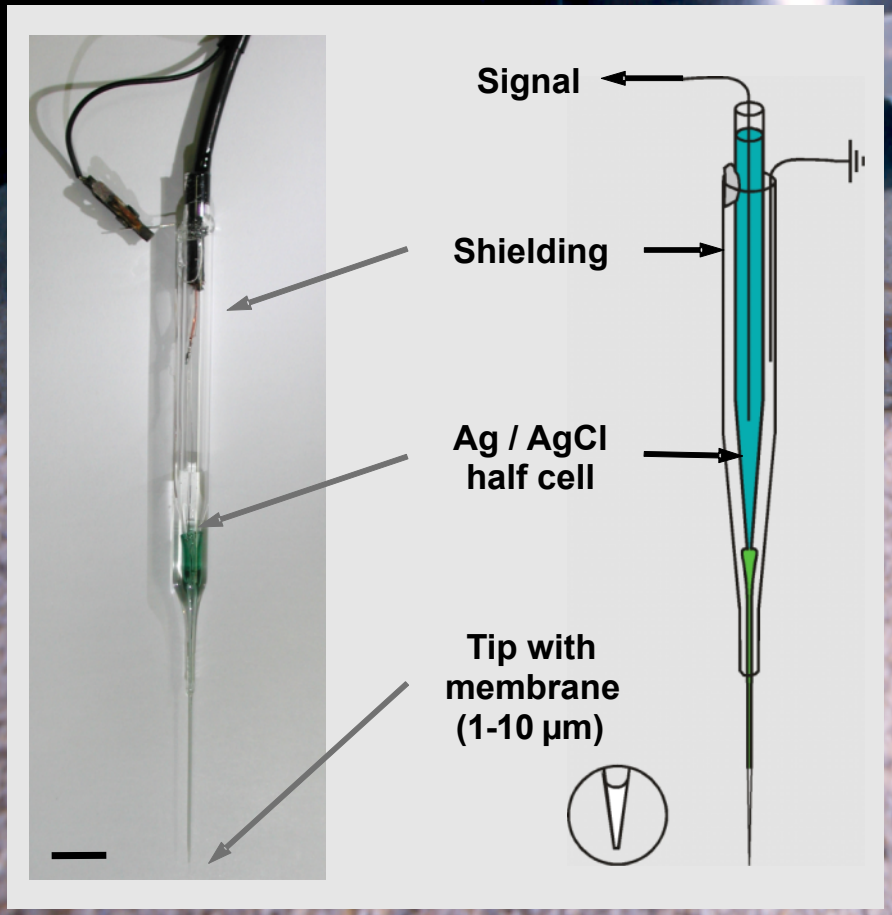
- seawater: 10^2-10^5 cells/ml
- deep biosphere: 10^2-10^7 cells/ml
- sediments/mats: 10^9-10^{11} cells/ml

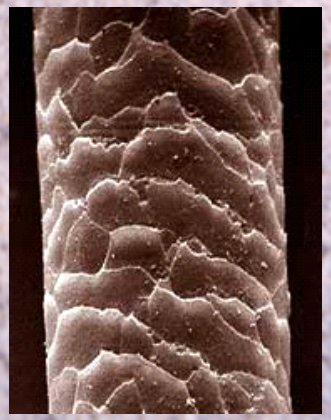
sediments and mats





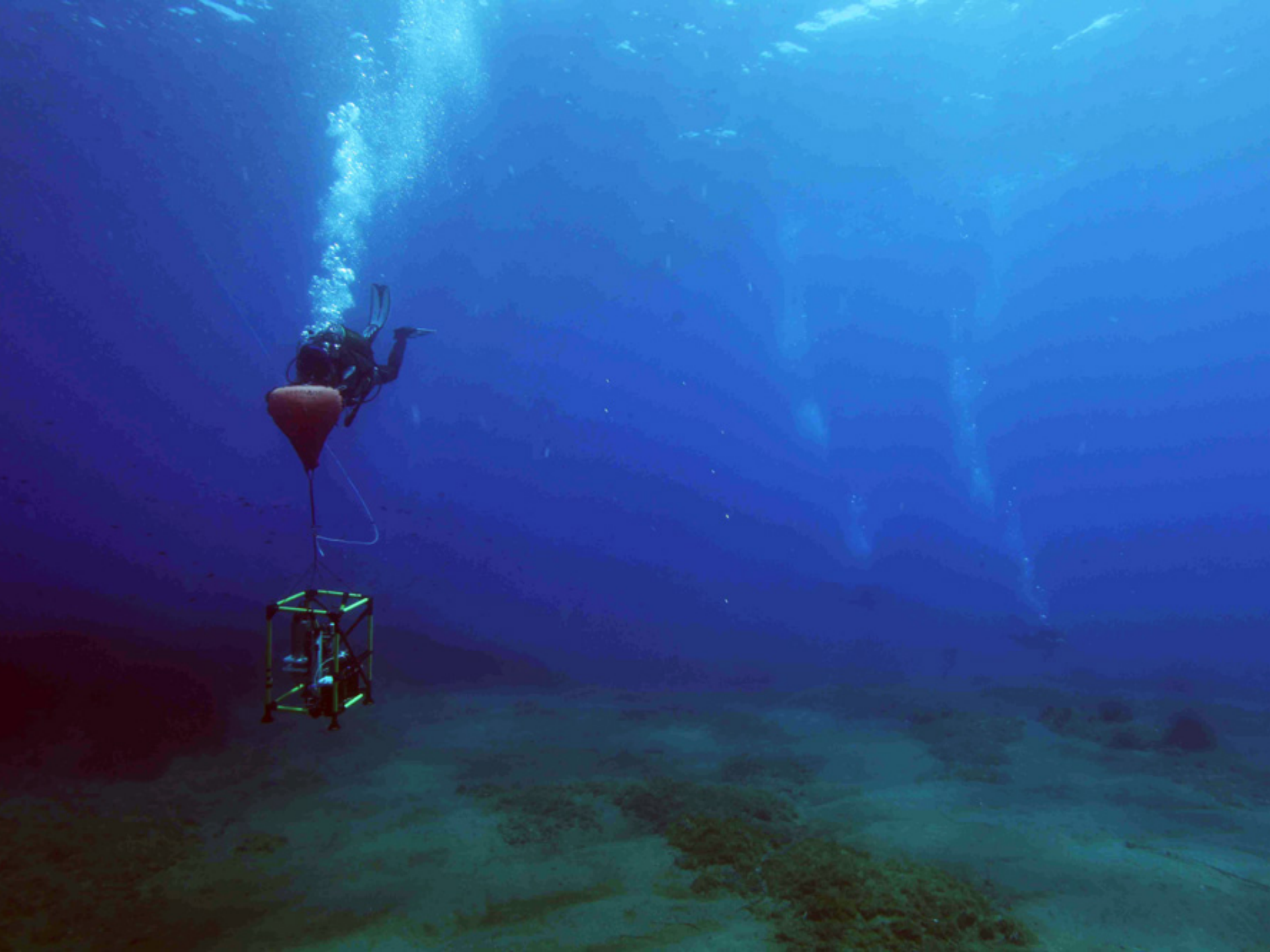
Microsensors

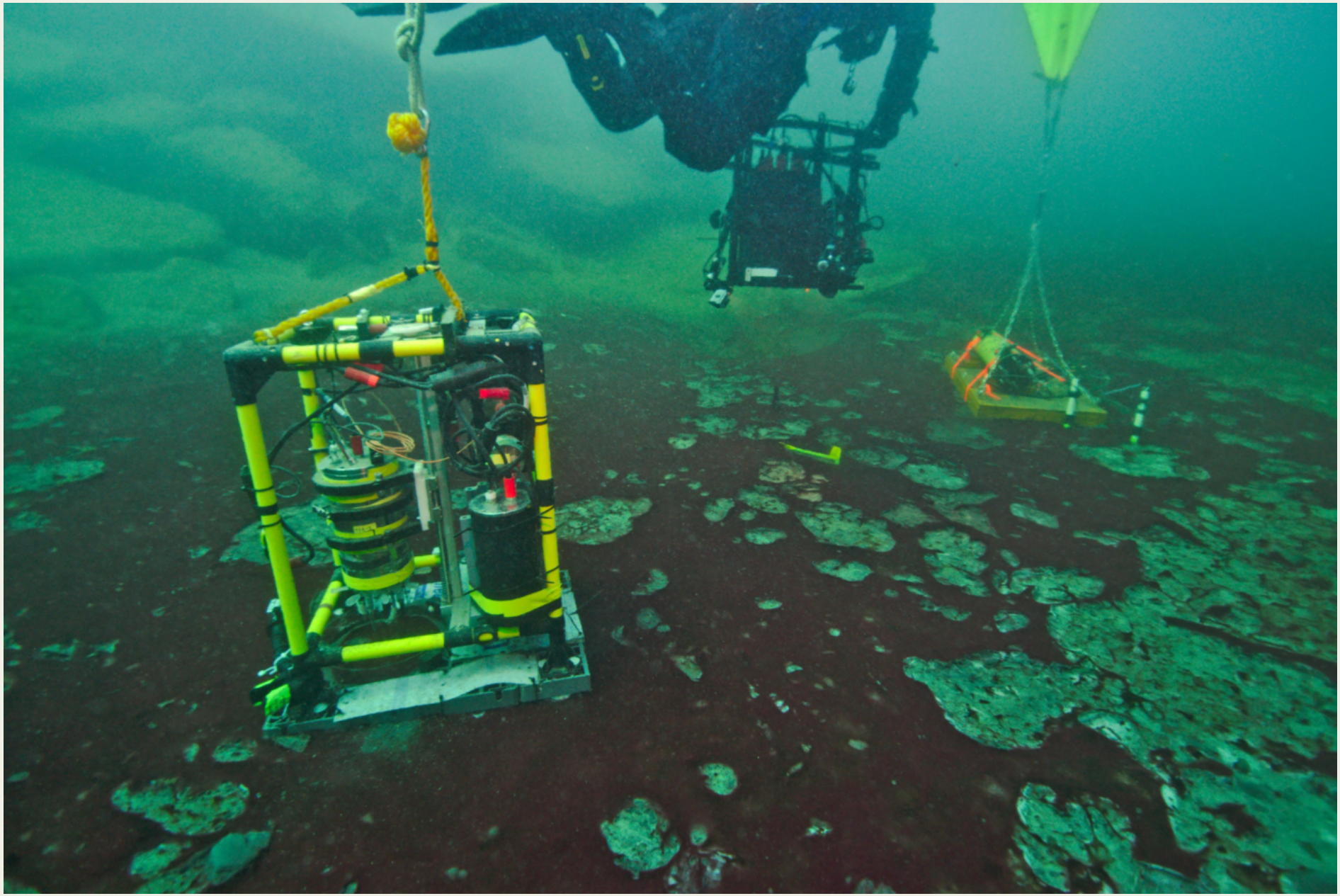




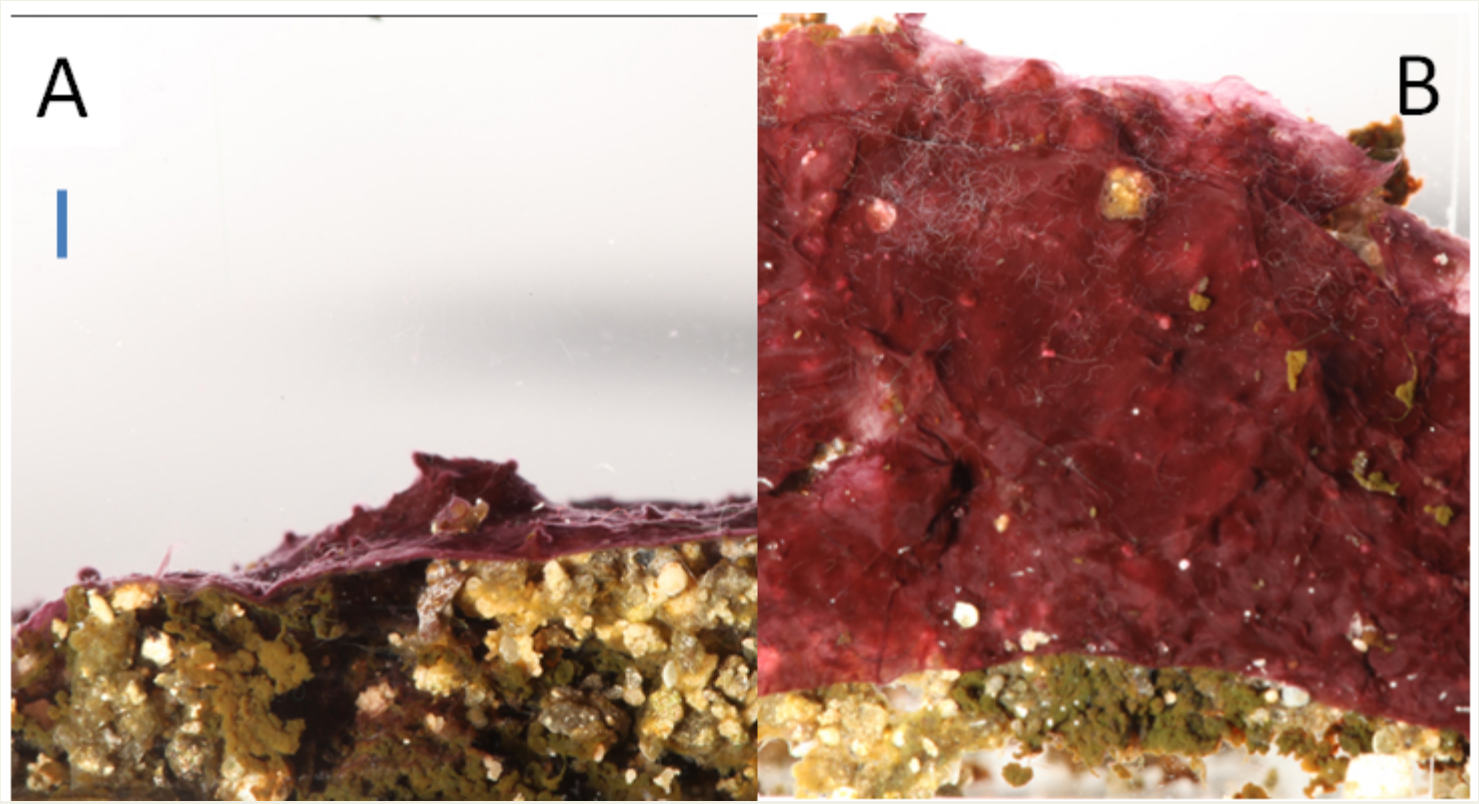
Amperometric, optical, potentio-metric and bio-microsensors

- **C** CO_2, CO_3^{2-}, CH_4, glucose
- **H** H^+, H_2
- **O** O_2, H_2O_2
- **N** NH_4^+, NO_3^-, NO_2^-, NO, N_2O
- **S** S^{2-}, H_2S
- **P** -
- Ca^{2+}, redox potential, temperature, light, diffusion/flow, HClO

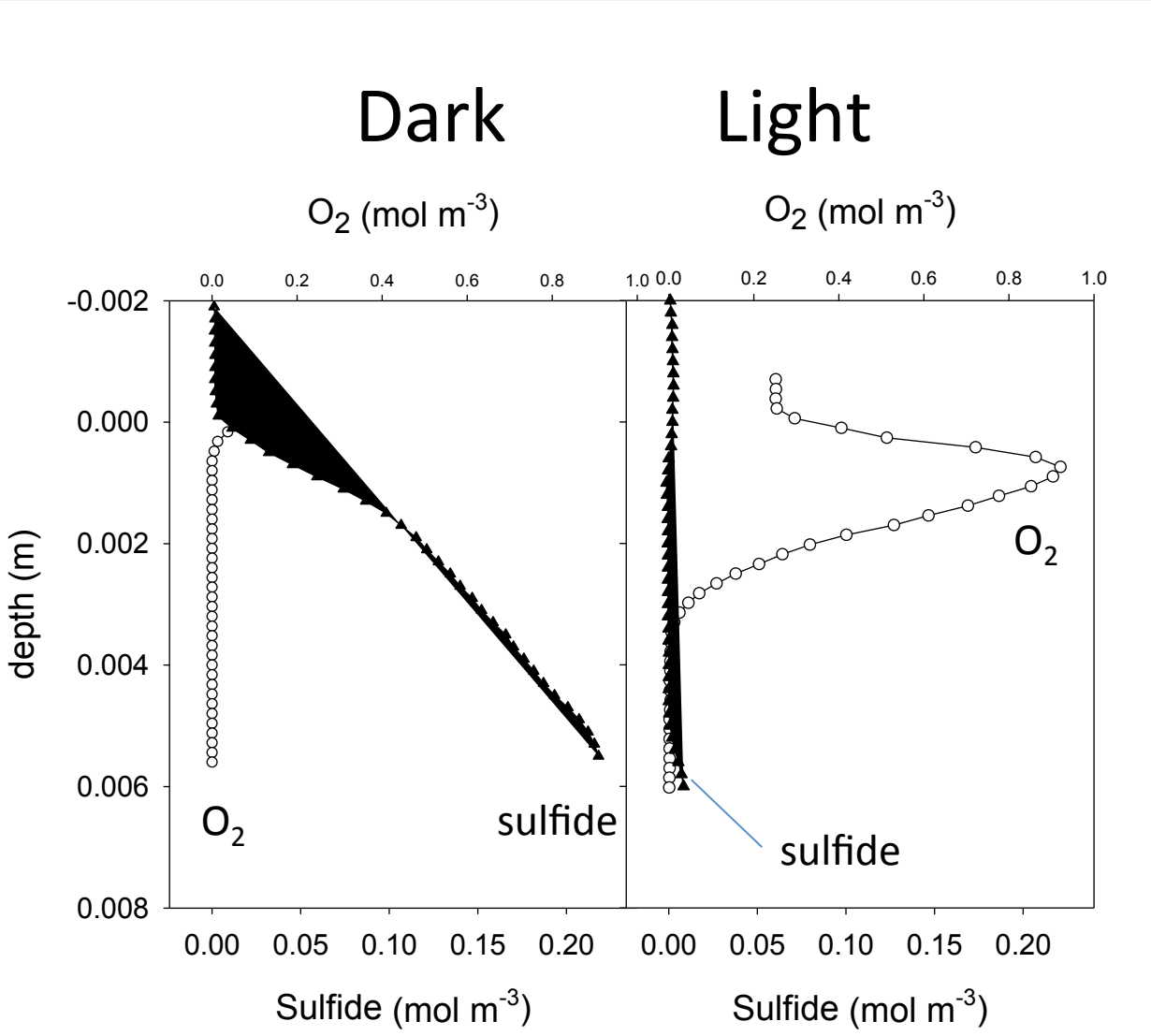




B

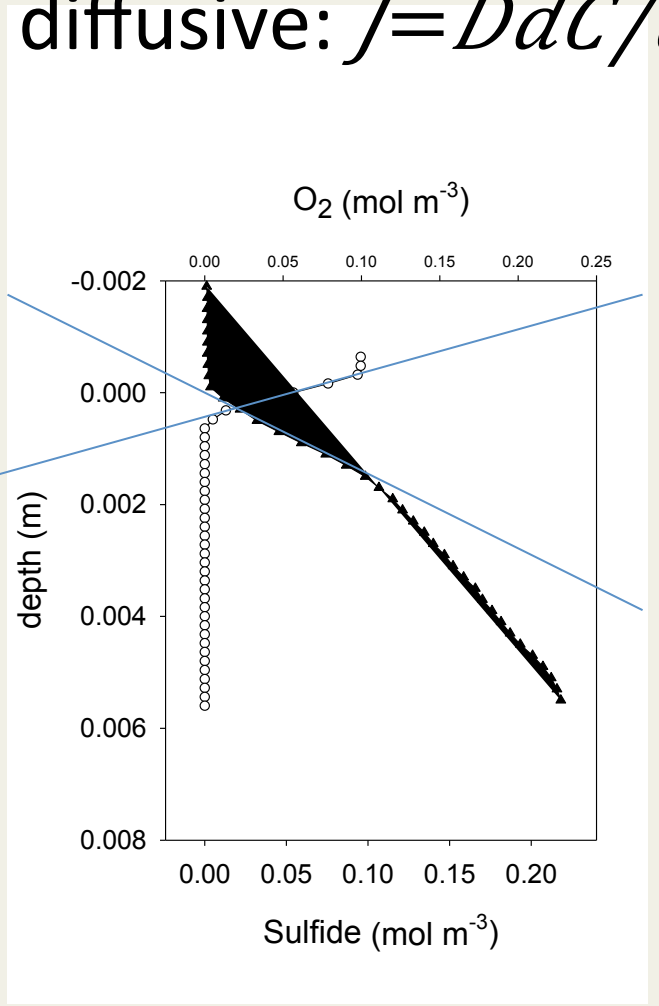


Microbial mats



Interfacial fluxes

transport is diffusive: $J = DdC/dx$



$dO\downarrow 2\ /dx$

$d(sulfide)/dx$

$D(O_2) \approx 2 \times 10^{-9}\ m^2 s^{-1}$

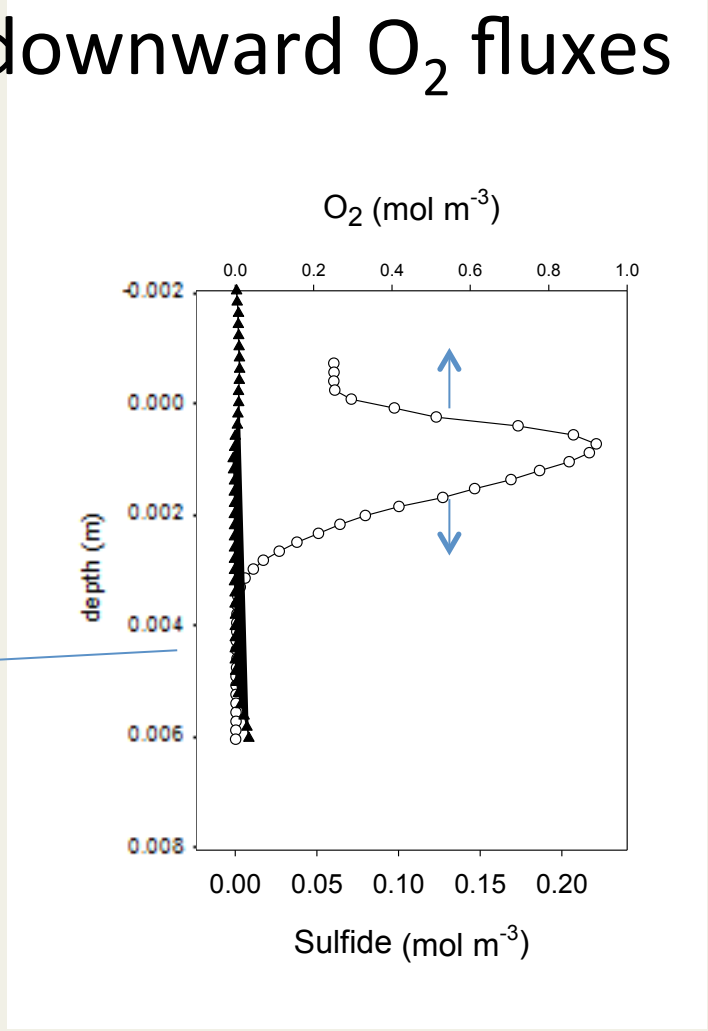
$D(sulfide) \approx 1.2 \times 10^{-9}\ m^2 s^{-1}$

$J_{O2} >> J_{sulfide}$

photosynthesis rate

total OP: upward + downward O_2 fluxes

gap O_2-H_2S (AP)

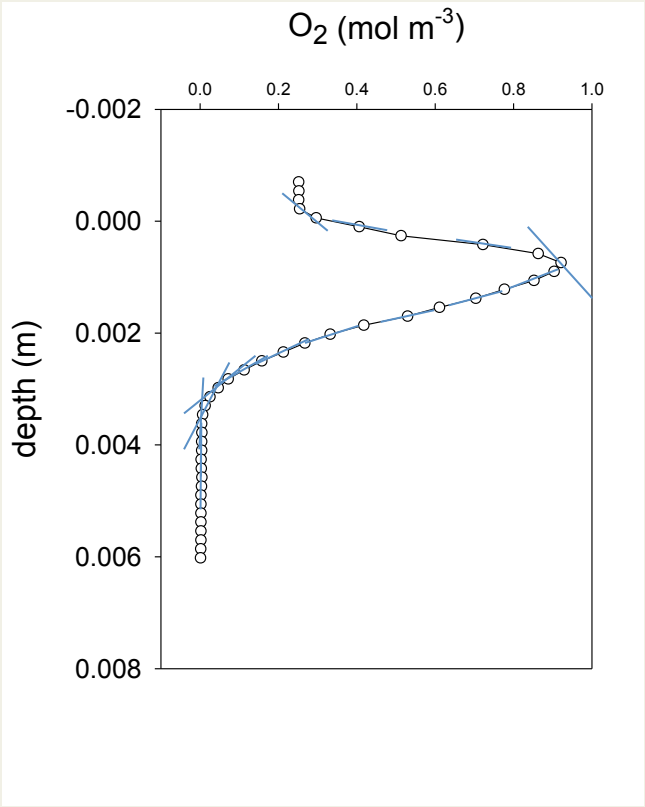


High spatial resolution analysis

Local mass balances:

Subtract adjacent J‘s:

$\Delta J_{i,j}/\Delta x_{i,j}=R_{i-j}$ (mol m^{-3} s^{-1})

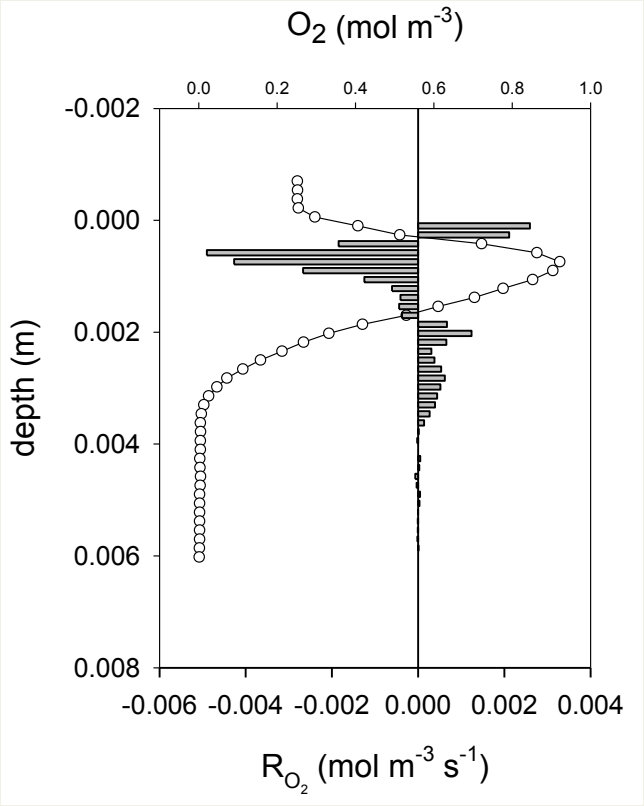


Reaction rates

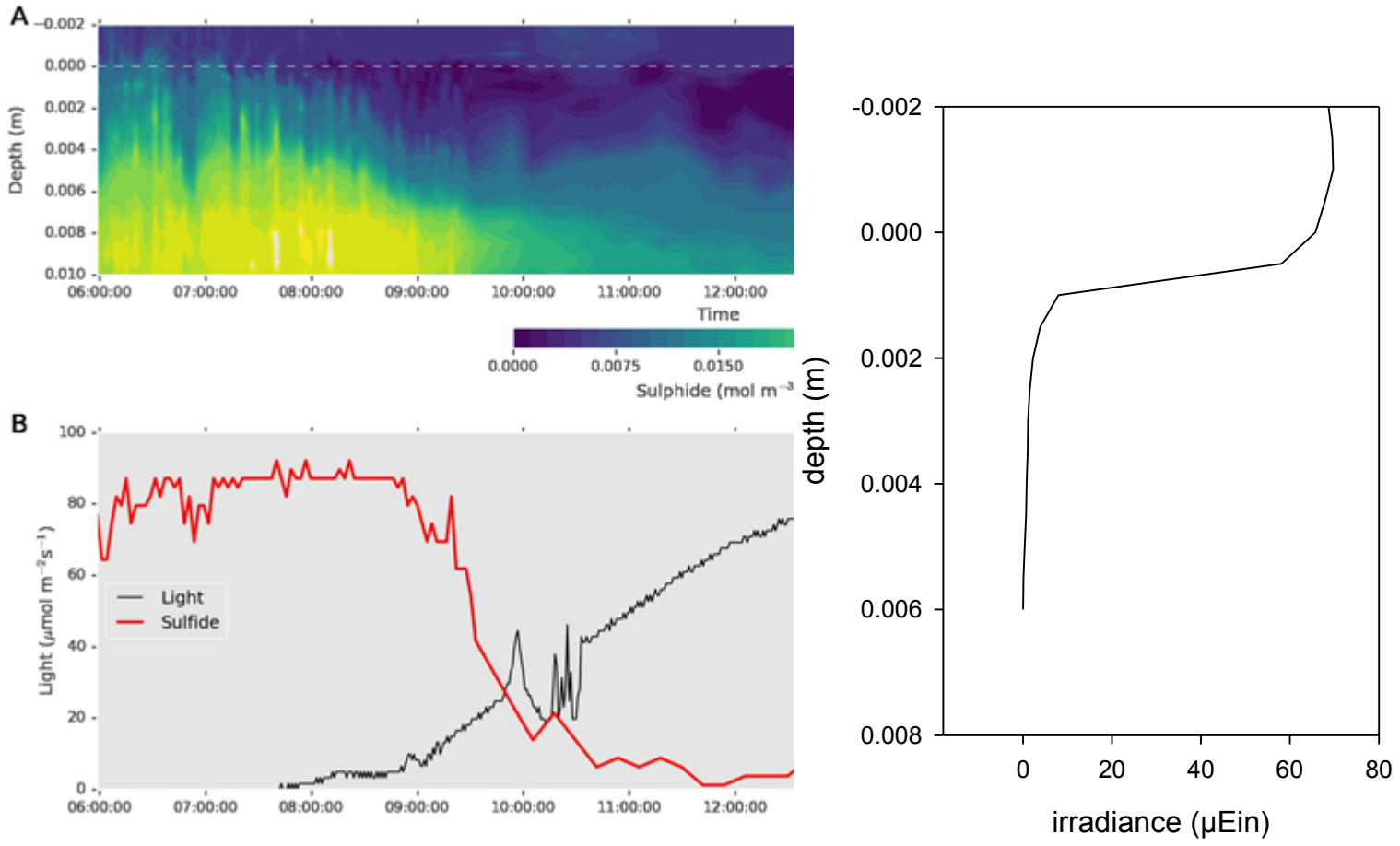
High resolution activity

+ R respiration

- R net photosynthesis

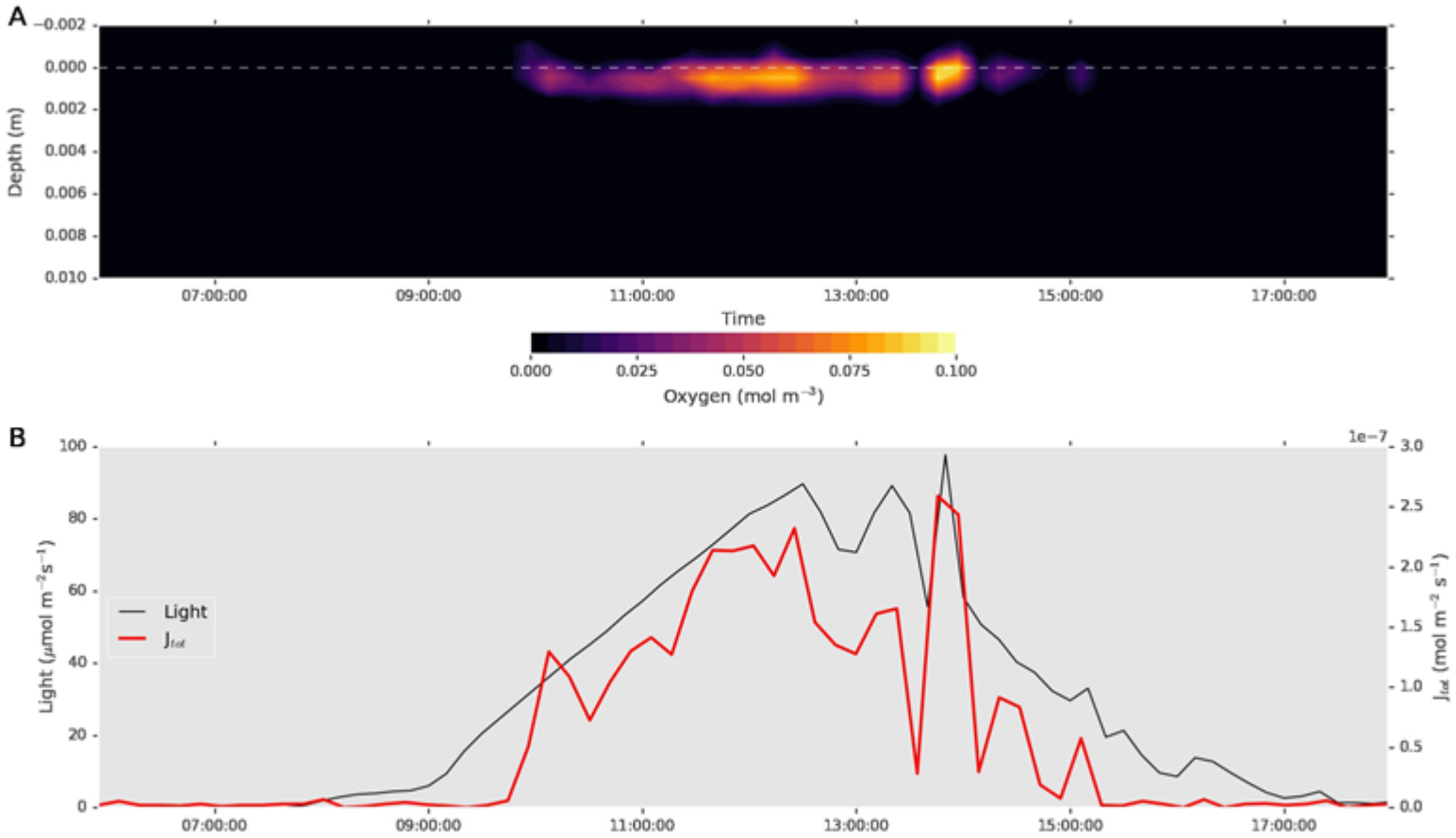


Sulfide contour plot



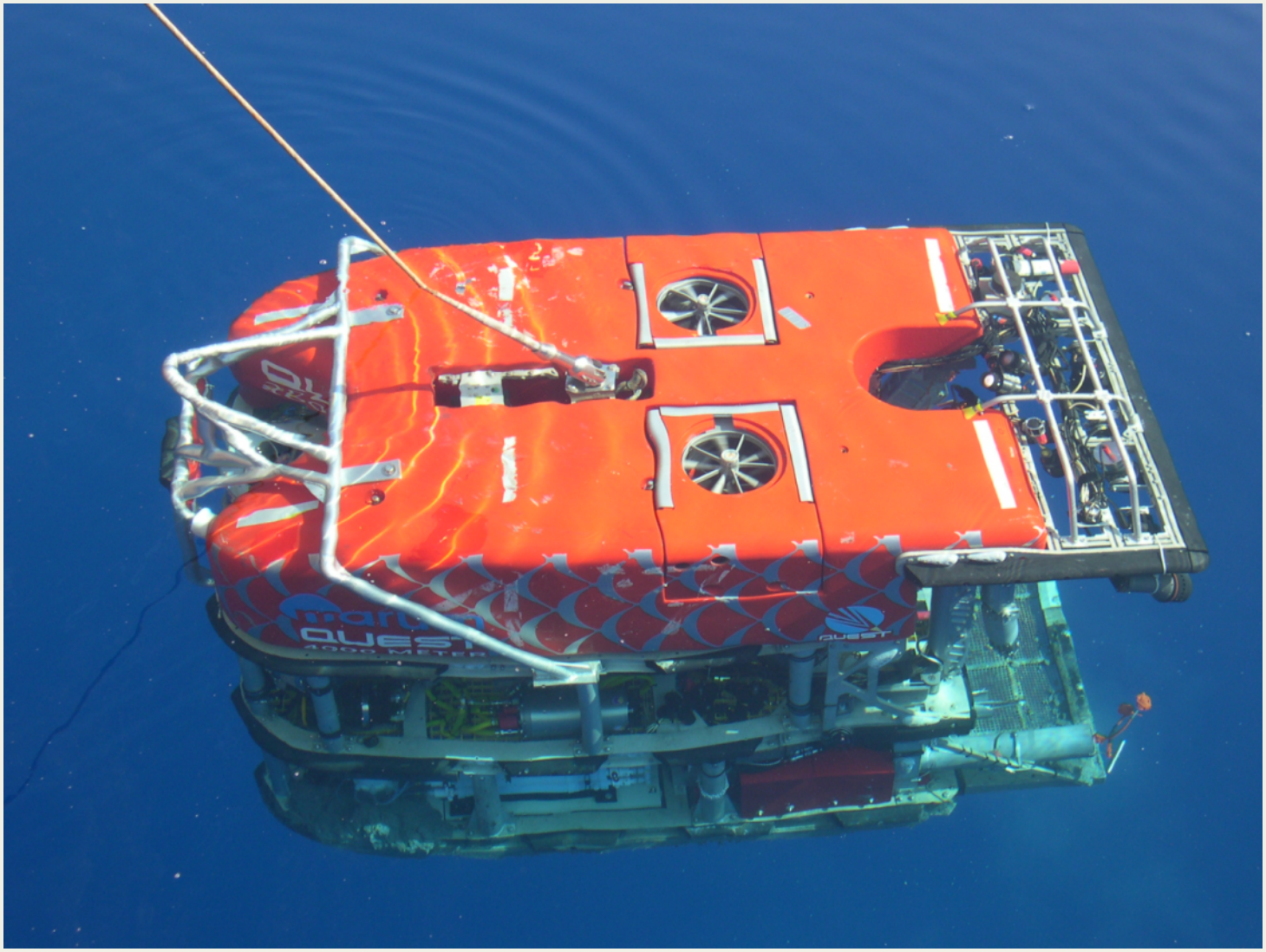
red line: sulfide at 1 cm depth responds instantly to light

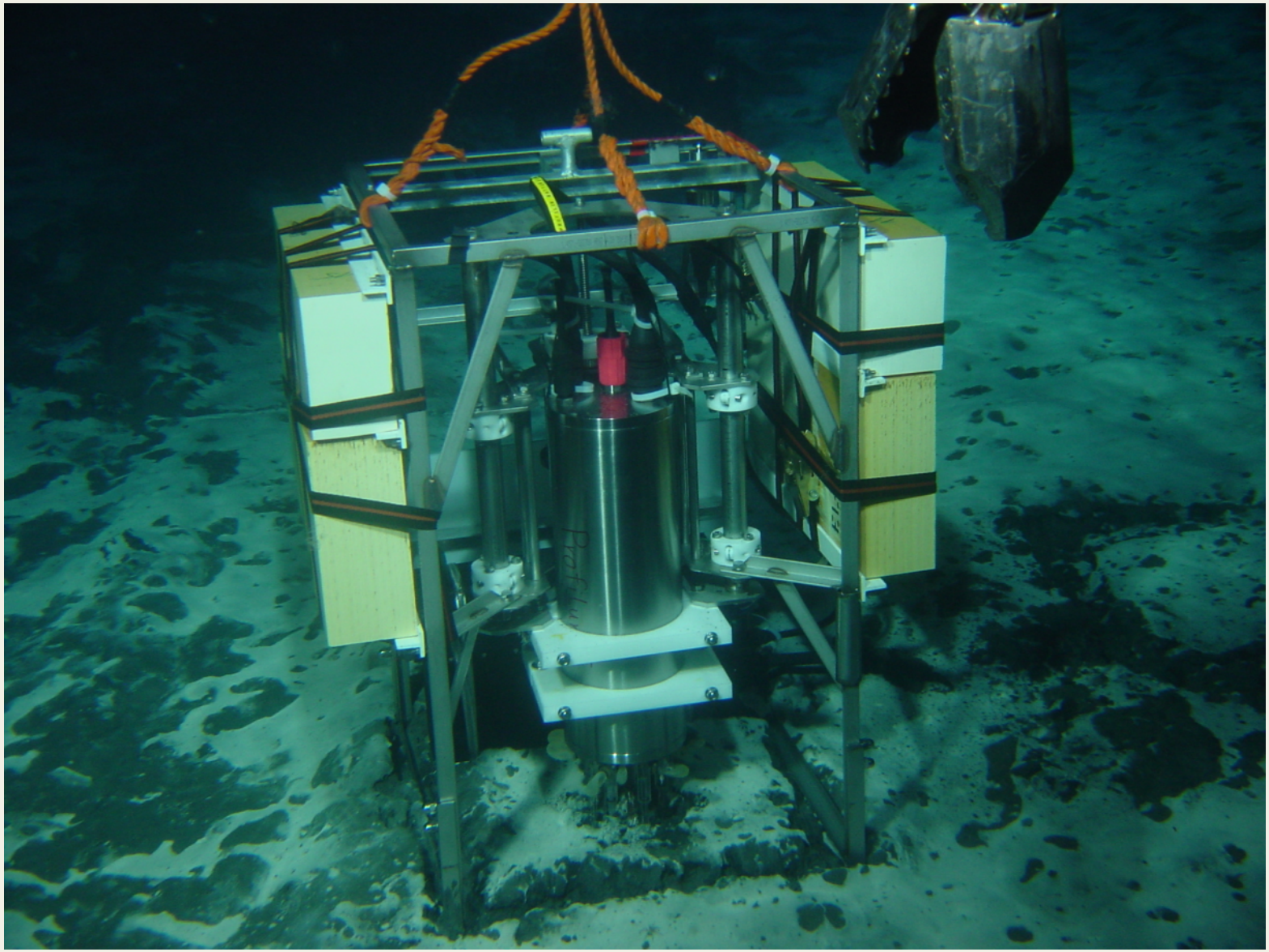
Oxygen contour plot



Oxygen production starts after sulfide is consumed by AP

Deep sea seeps





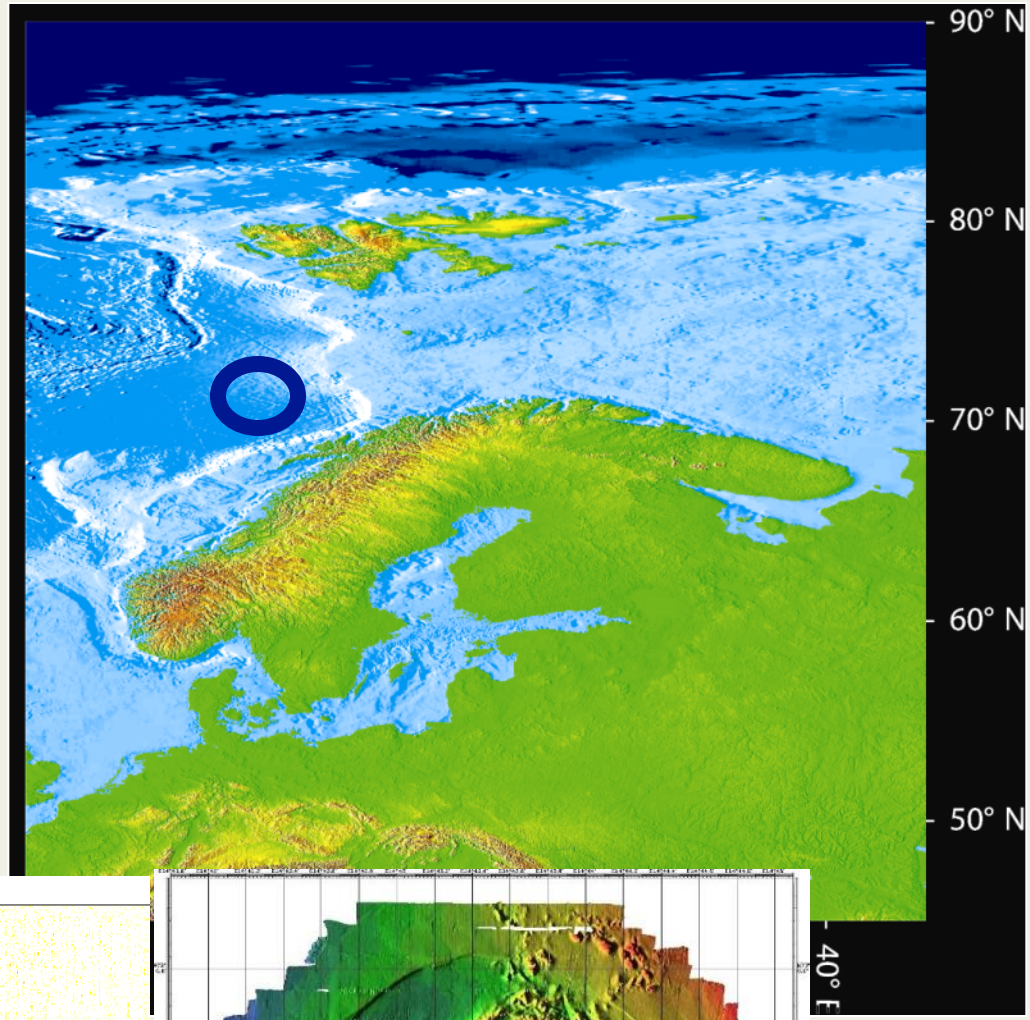
Håkon Mosby Mud Volcano

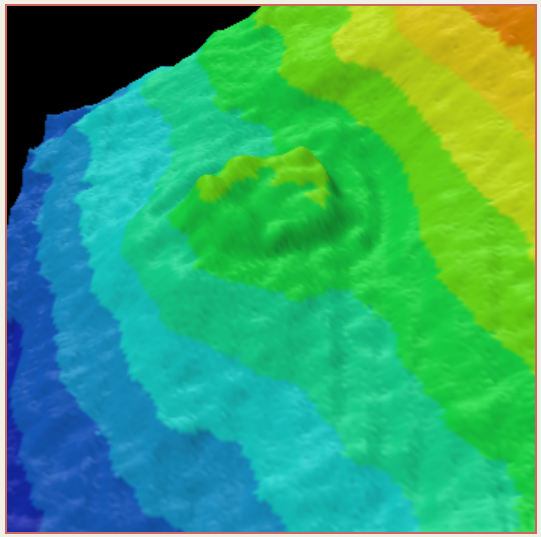
-Norwegian margin, 1250 m depth

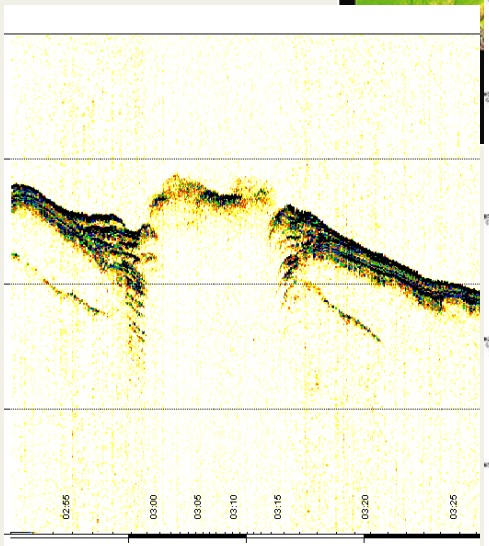
-methane emitting geostructure

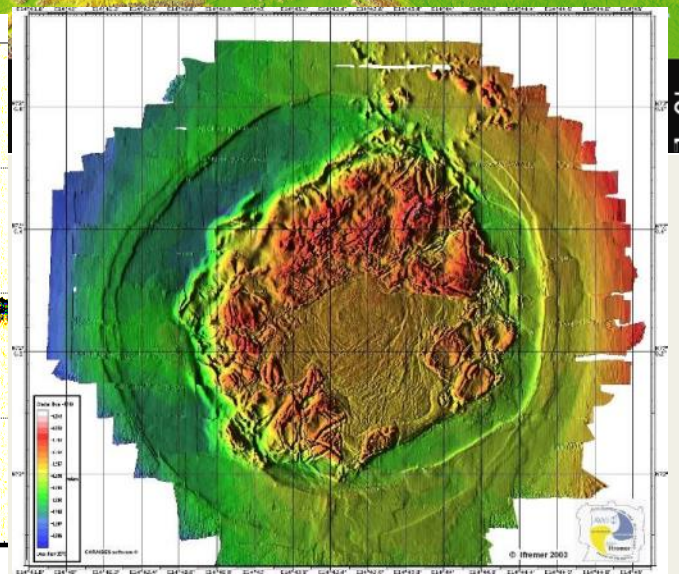
-hydrate reservoir

-chemosynthetic ecosystem

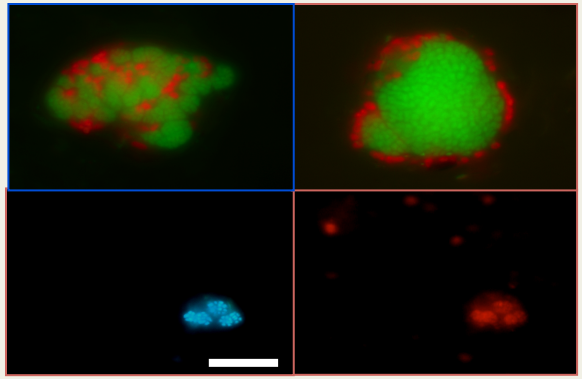








Microbial processes

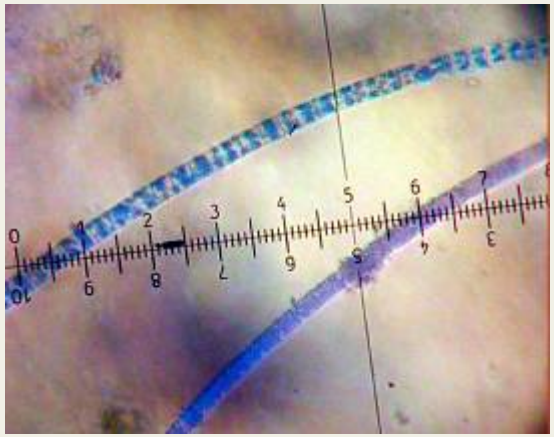


scale bar: 10 µm

AOM

Archea SRB

$CH_4 + SO_4^{-2} \rightarrow HCO_3^- + HS^-$



Beggiatoa

$HS^- + O_2$ or $NO_3^- \rightarrow$ S(0)

$\rightarrow \rightarrow SO_4^{-2}$ + **biomass**

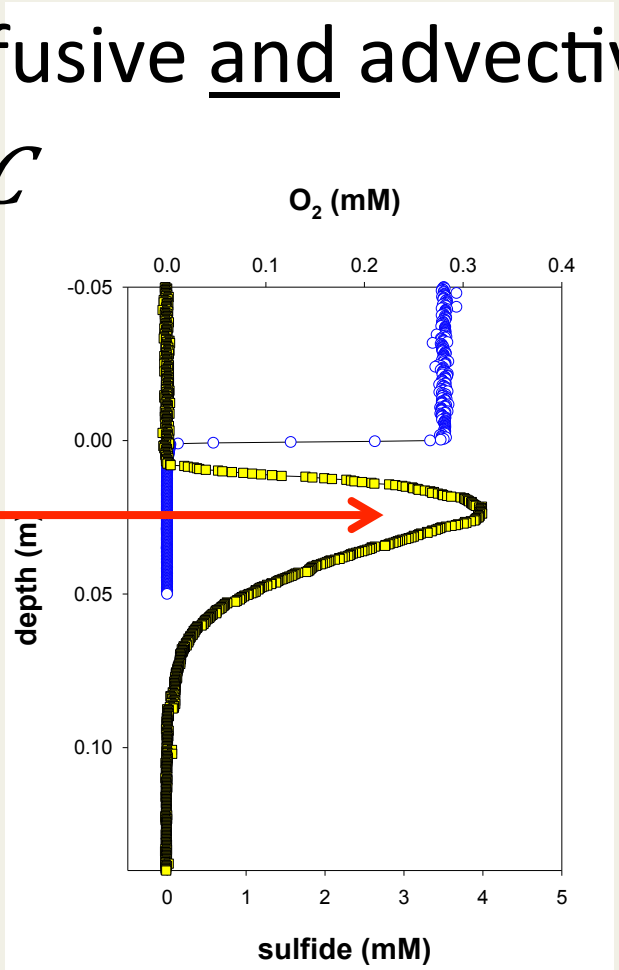
primary production

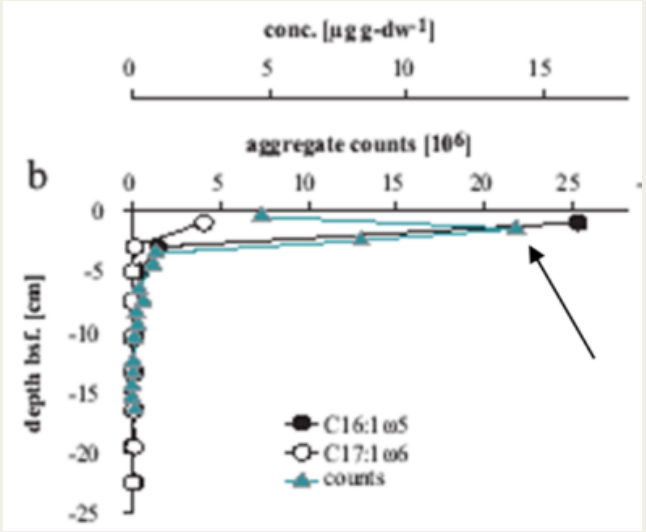
Deep sea seep (mud volcano)

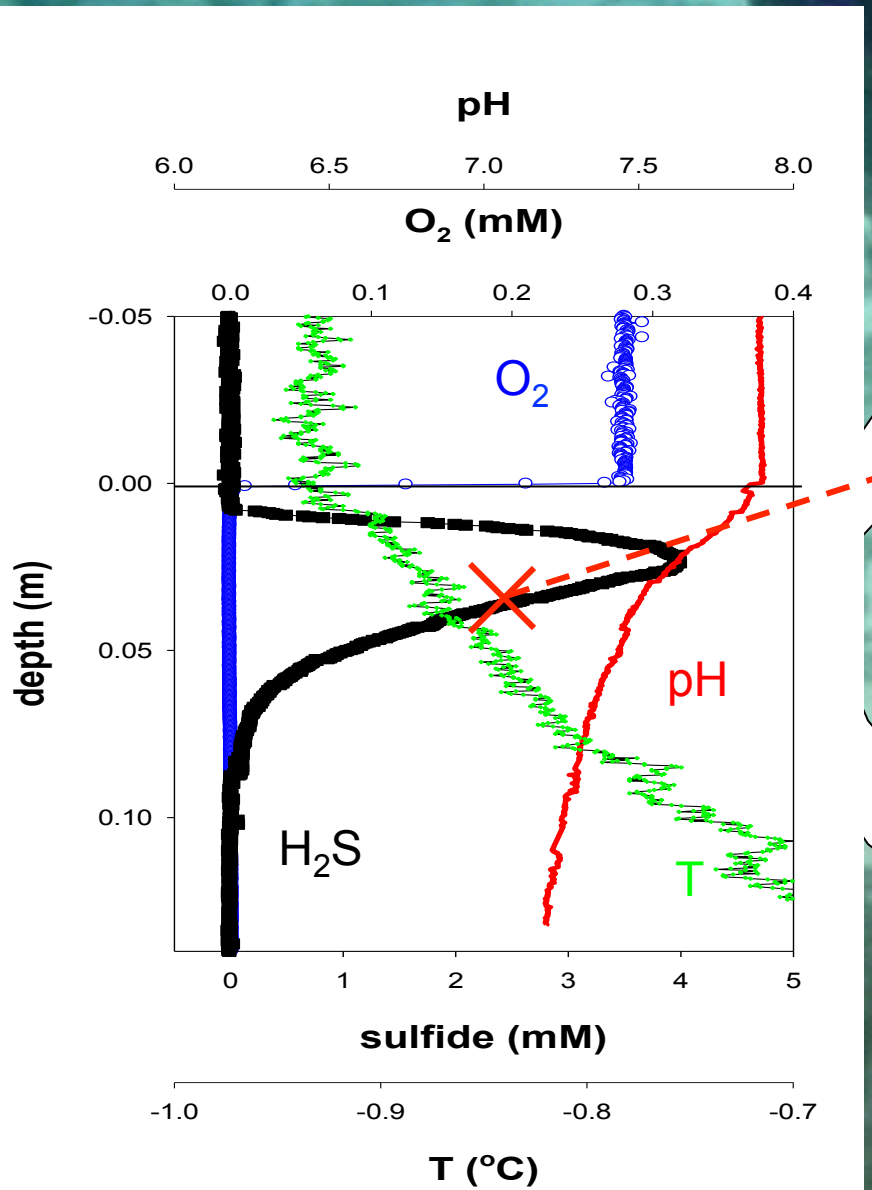
transport is diffusive and advective

$$J = DdC/dx + vC$$

AOM







Peak caused by upward porewater flow

$J = DdC/dx + vC = 0$

$J_{Diffusion} = -J_{Advection}$

$D.dC/dX = -u.C$

or

$u = -J_{Diffusion}/C$

$u \cong -0.1$ µm/s

(3 m/year)

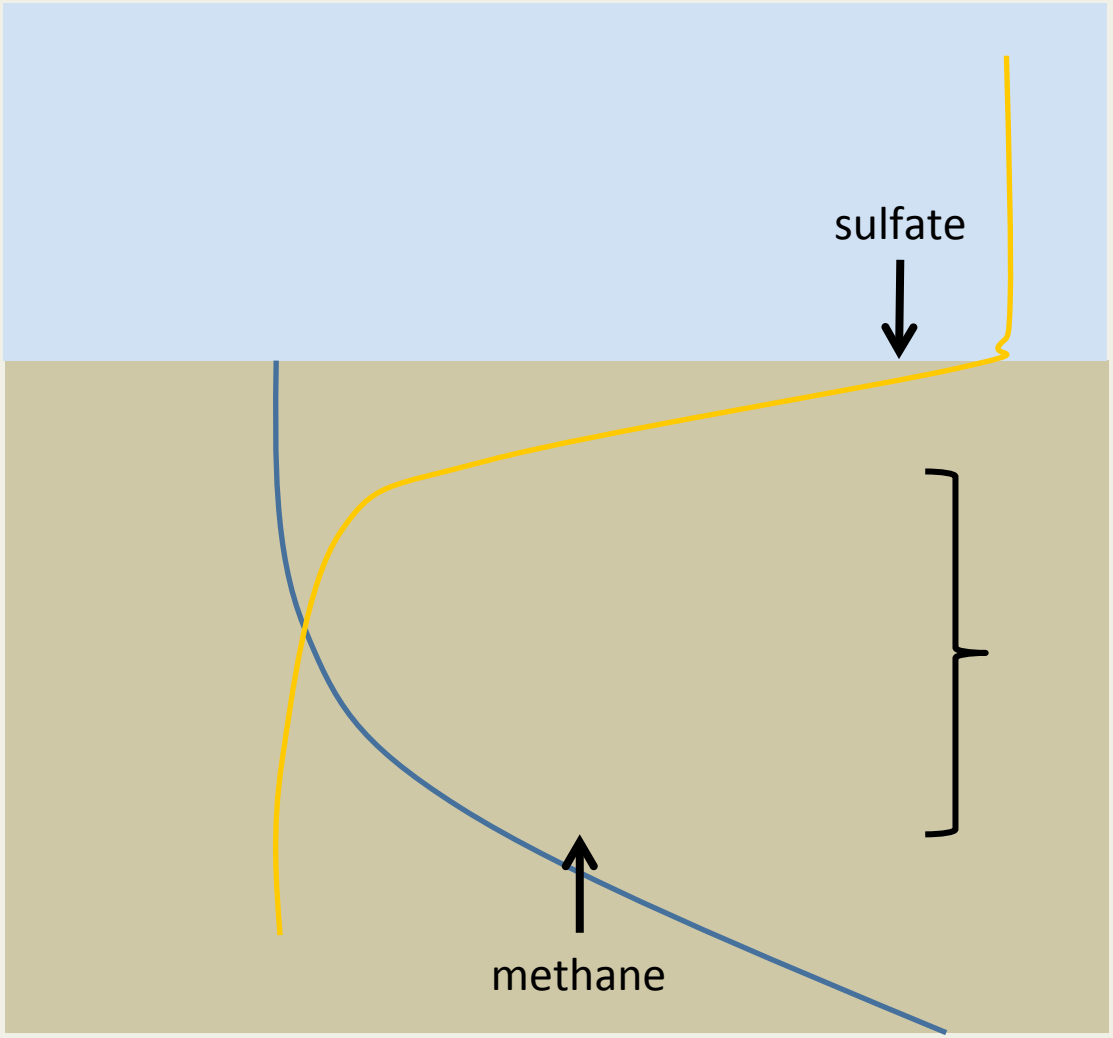
microsensor profiling

- minimally invasive
- sensors pressure insensitive (>11 km ocean depth)
- autonomous measurements possible

- spatial scale relevant for microbes
- data on microenvironments, fluxes, rates


Thanks

Methane-sulfate transition



Anaerobic Oxidation of Methane zone: sulfide production