Hydrothermal vents and deep subsurface biosphere in the Indian Ocean

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IIOE-2 Workshop

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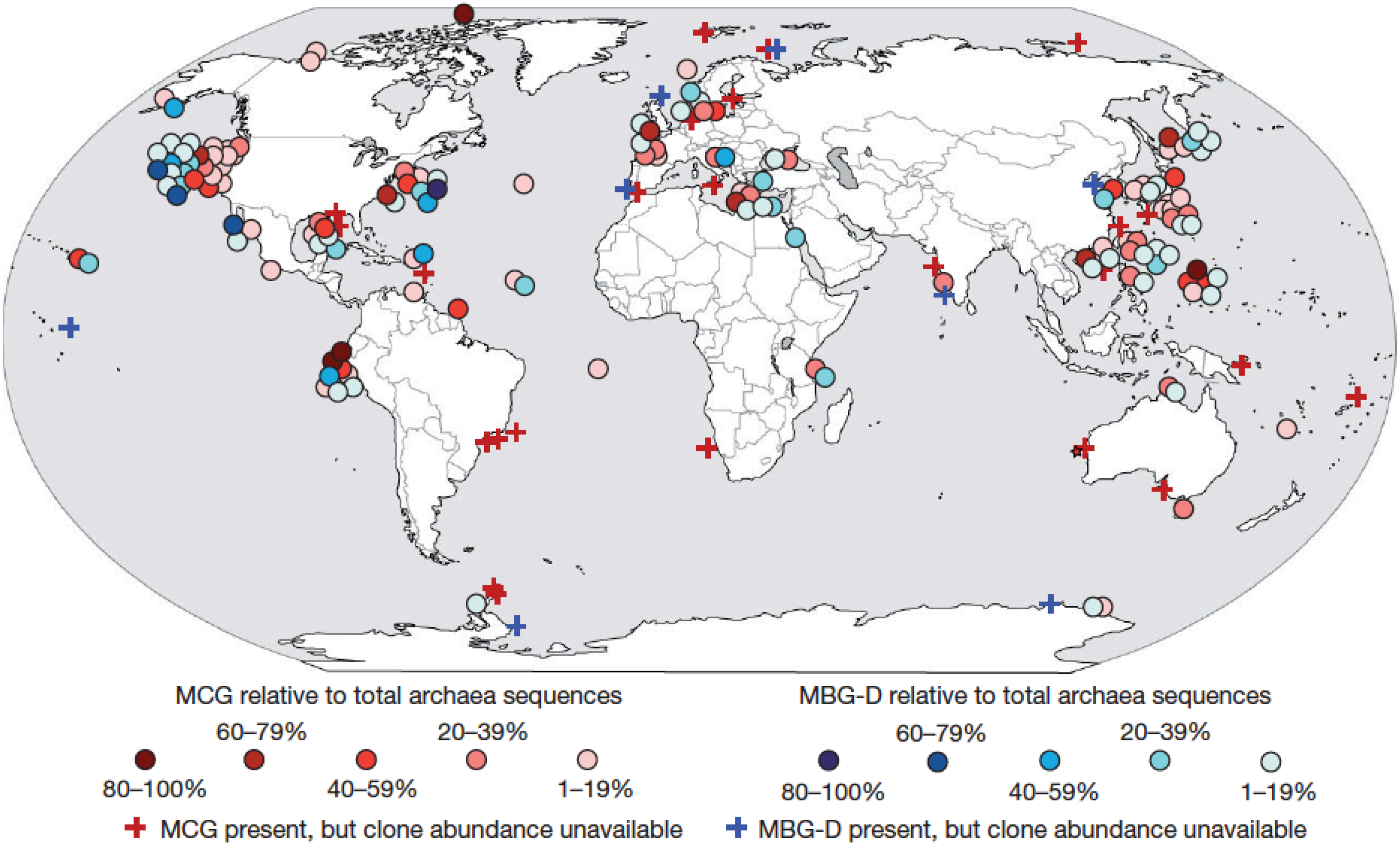
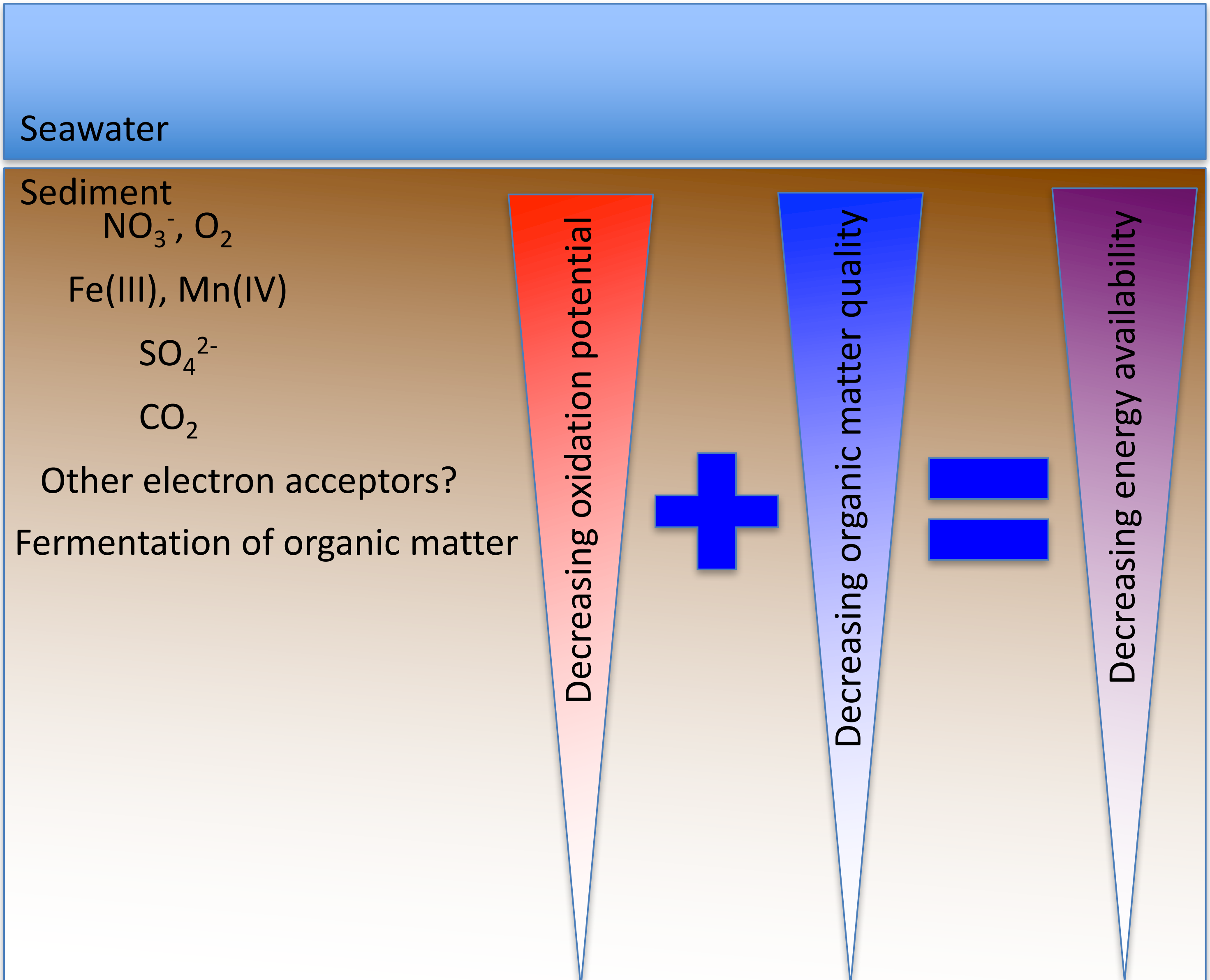
I am NOT an expert on the deep biosphere of the Indian Ocean.

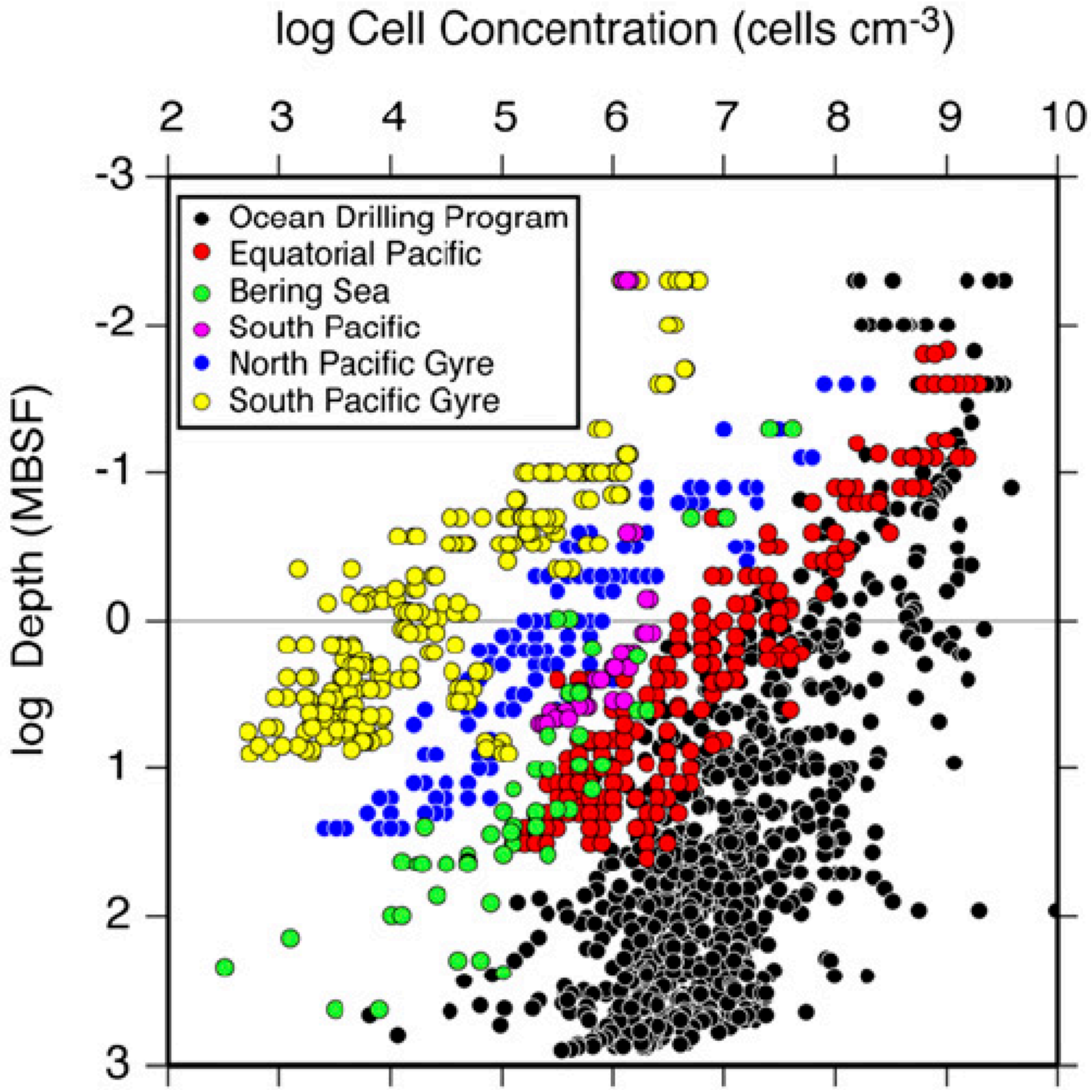
There are very few marine sediment microbiological studies from the Indian Ocean.



Lloyd et al., 2013 Nature

Microbes in the oceanic subsurface are energy-limited





Kallmeyer et al. 2012, *Proc. Nat. Acad. Sci*

Reasons to study the deep sediment biosphere

- It is one of Earth’s largest biomes, but little is known about it.
- It is Earth’s largest reservoir of organic carbon.
- The microbes that inhabit it are very different from known microbes and may have exciting novel properties.

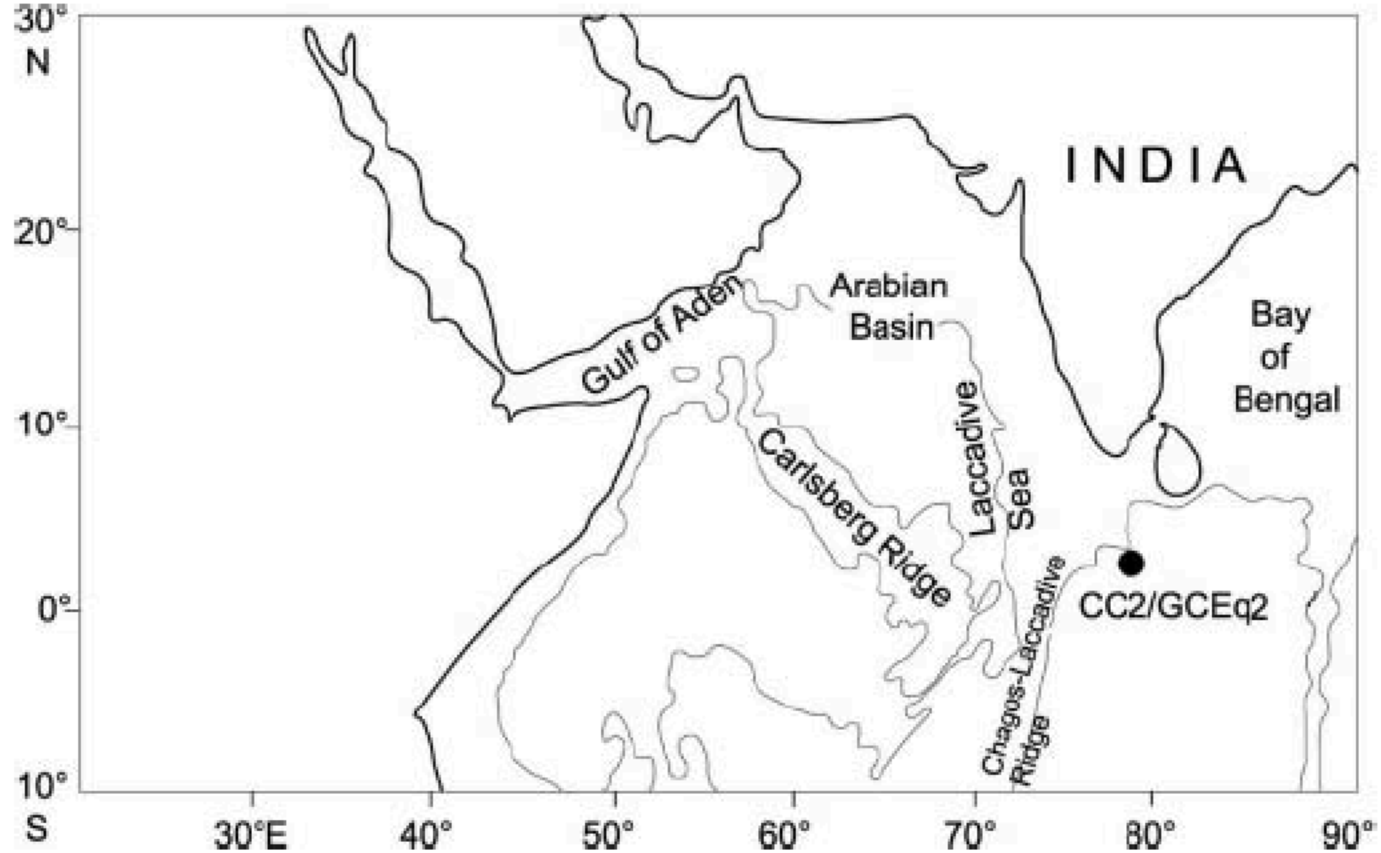
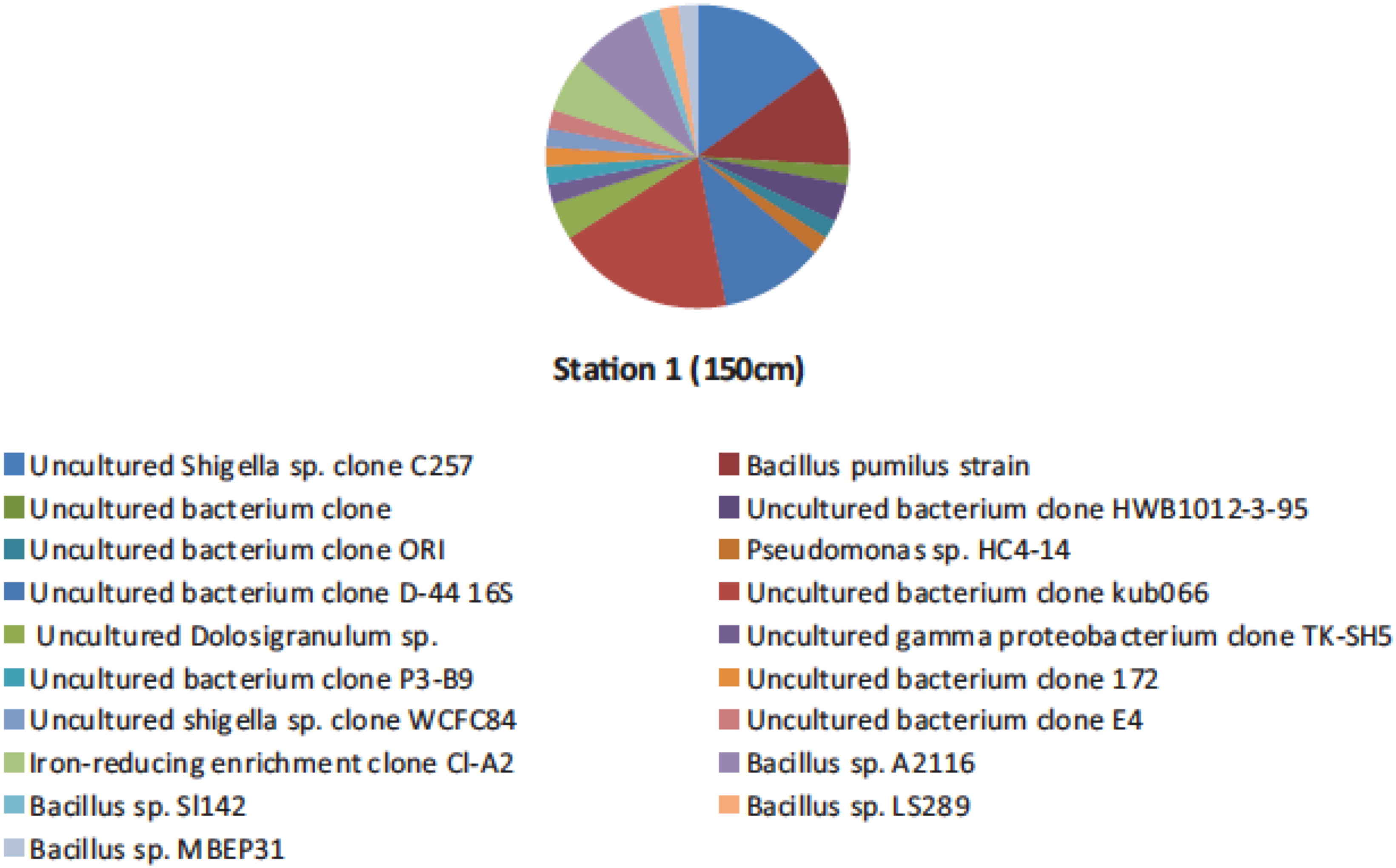


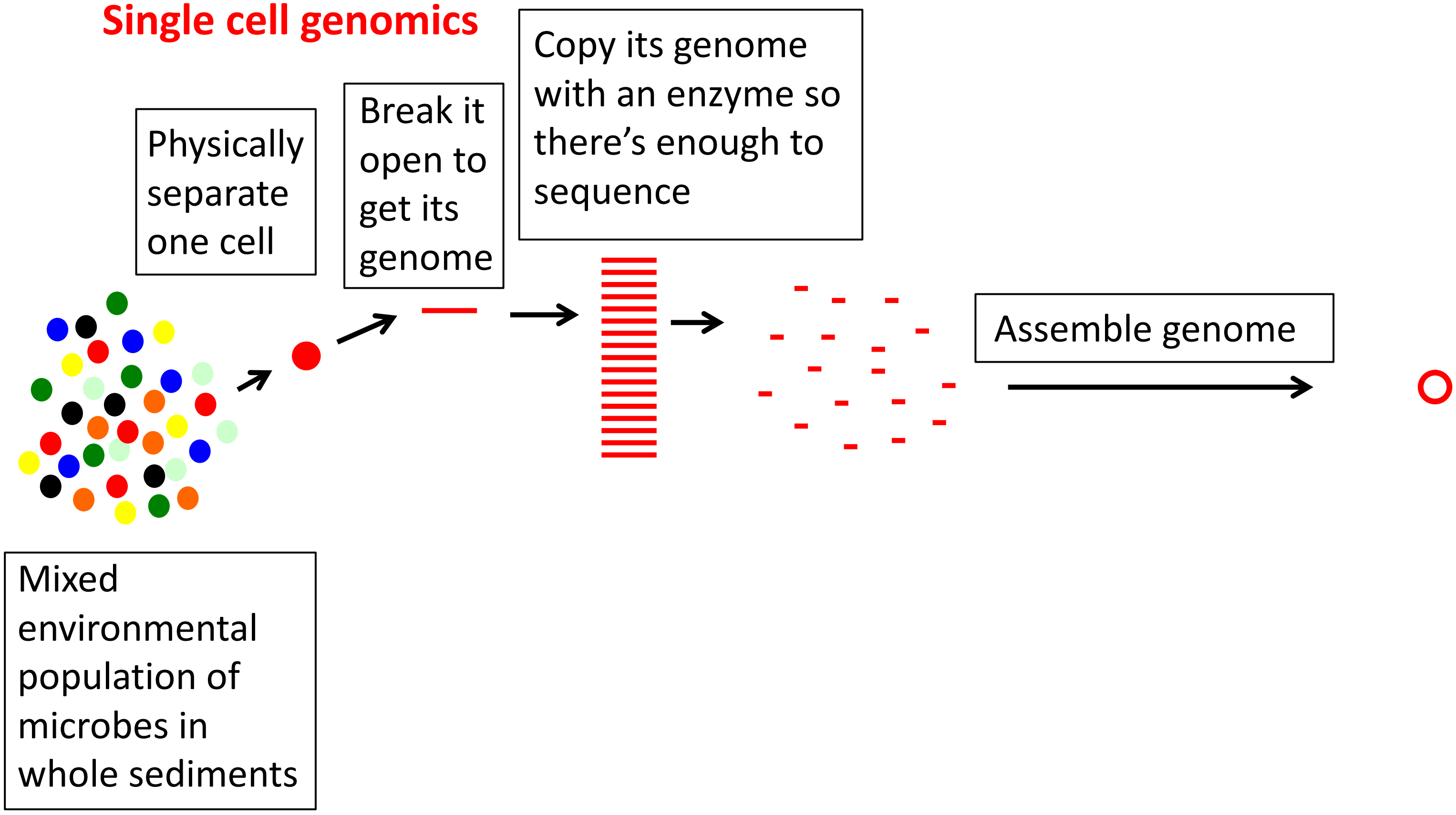
Fig. 1. Sampling location at Afanasy Nikitin seamount.

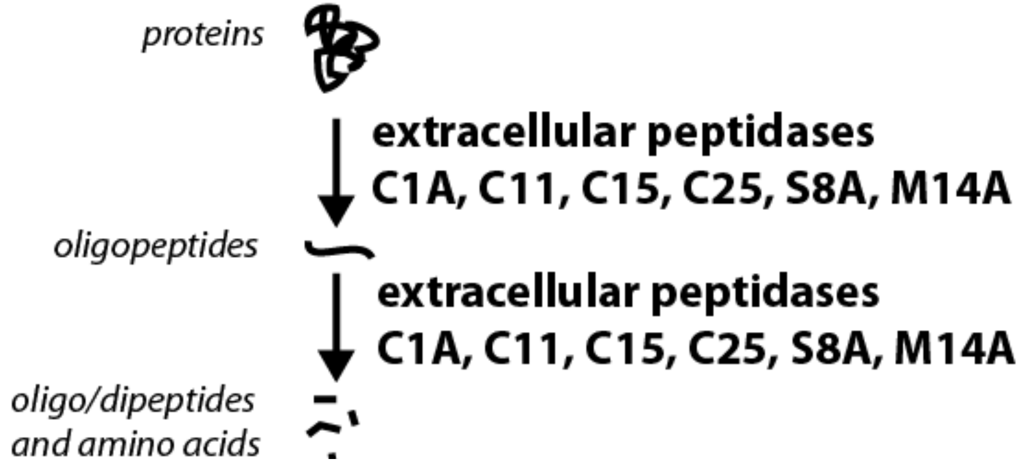
Khandeparker et al. 2014, Geomicrobiology Journal



Khandeparker et al. 2014, Geomicrobiology Journal

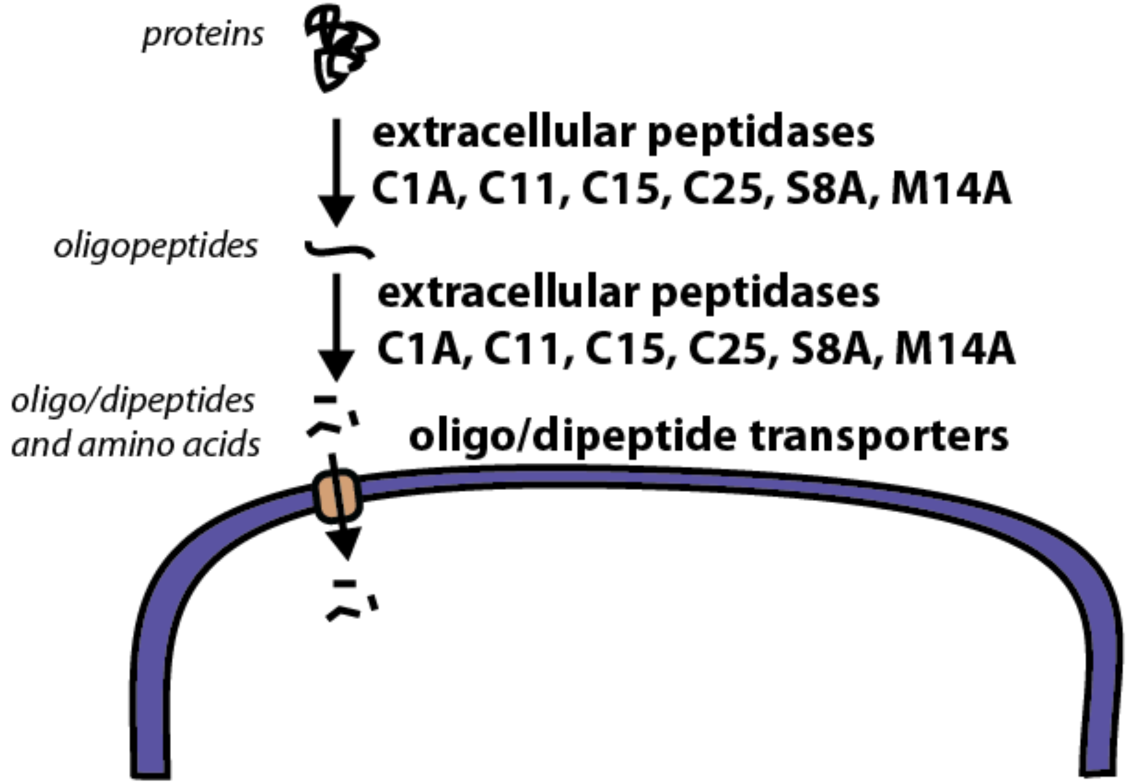
Single cell genomics



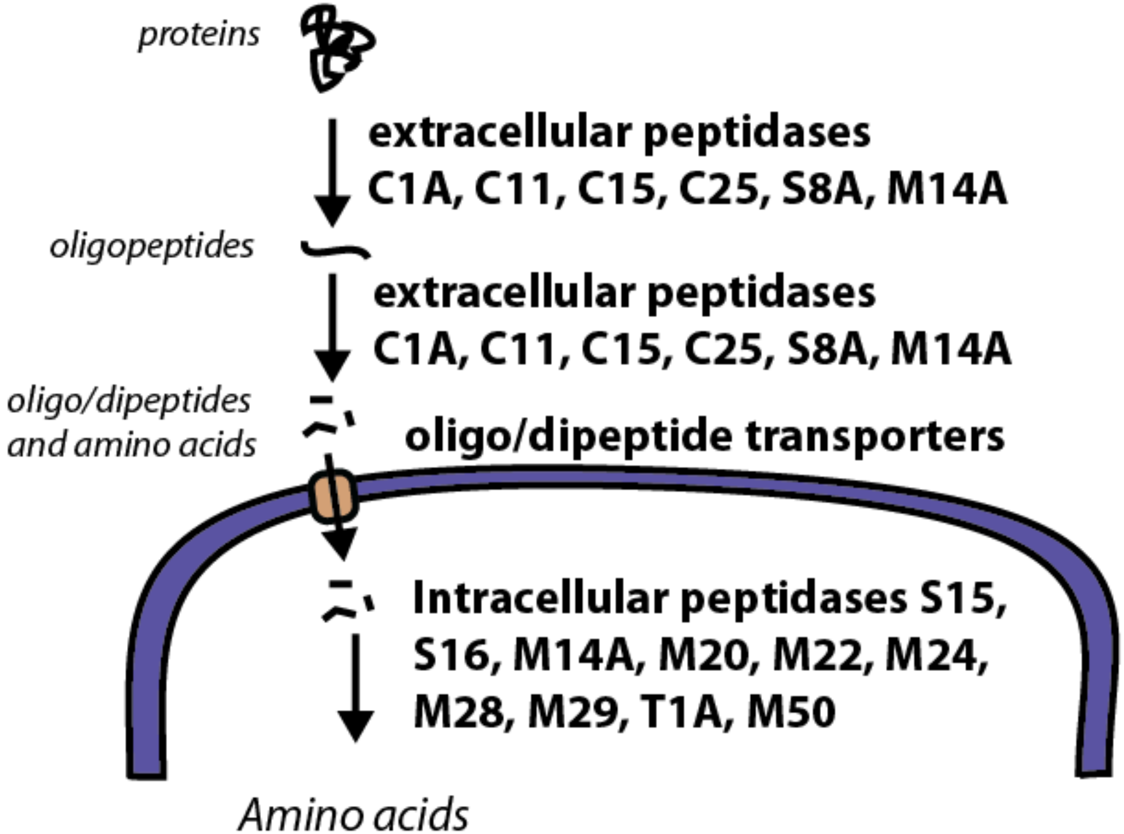


- Gene homologues of these cysteine peptidases are all extracellular, and degrade proteins/peptides for cellular nutrition in bacteria.
- They require high Ca^{2+} concentrations and anoxic conditions to be functional – perfect for the deep subsurface!

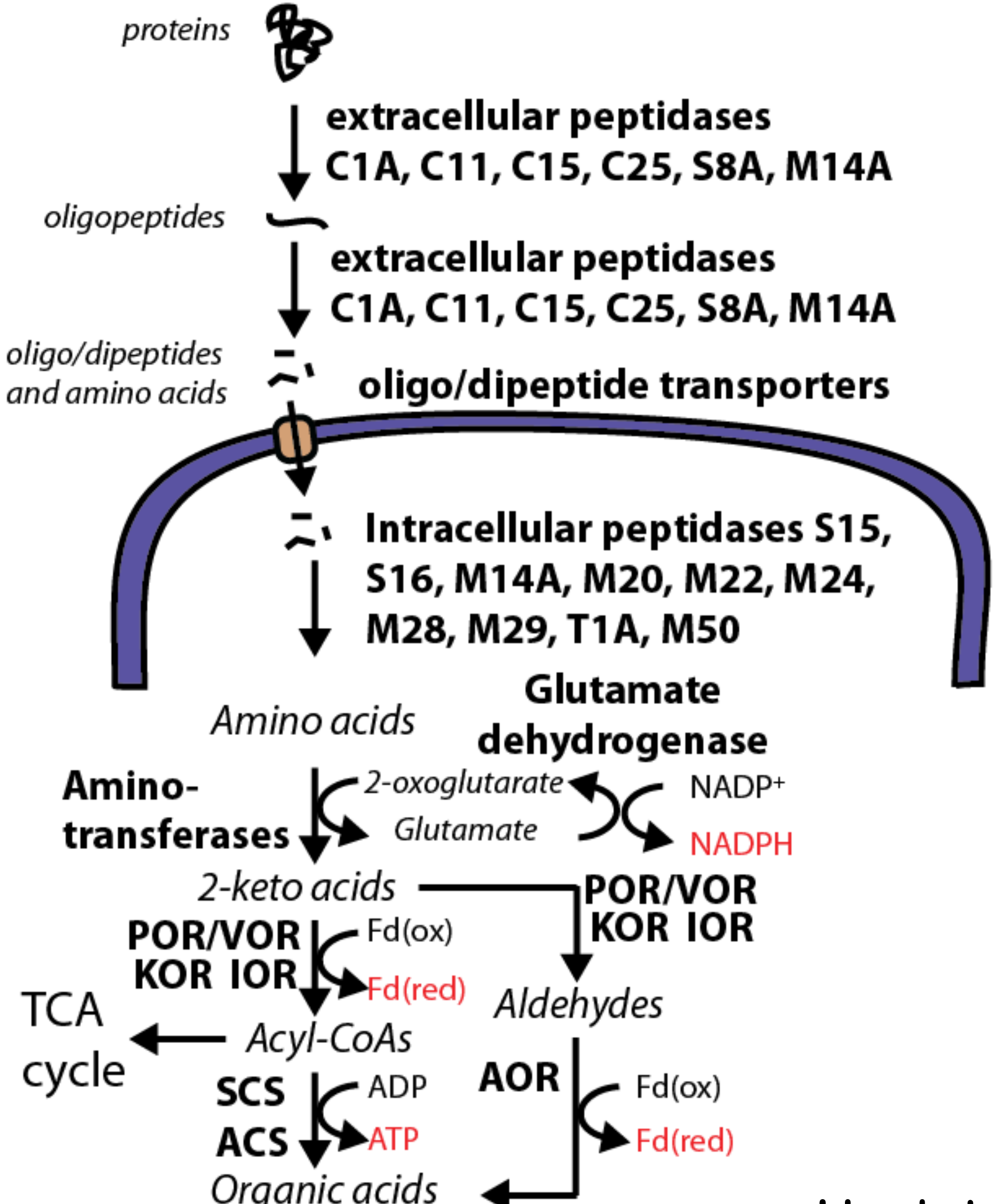
Lloyd et al. 2013, Nature



Lloyd et al. 2013, Nature

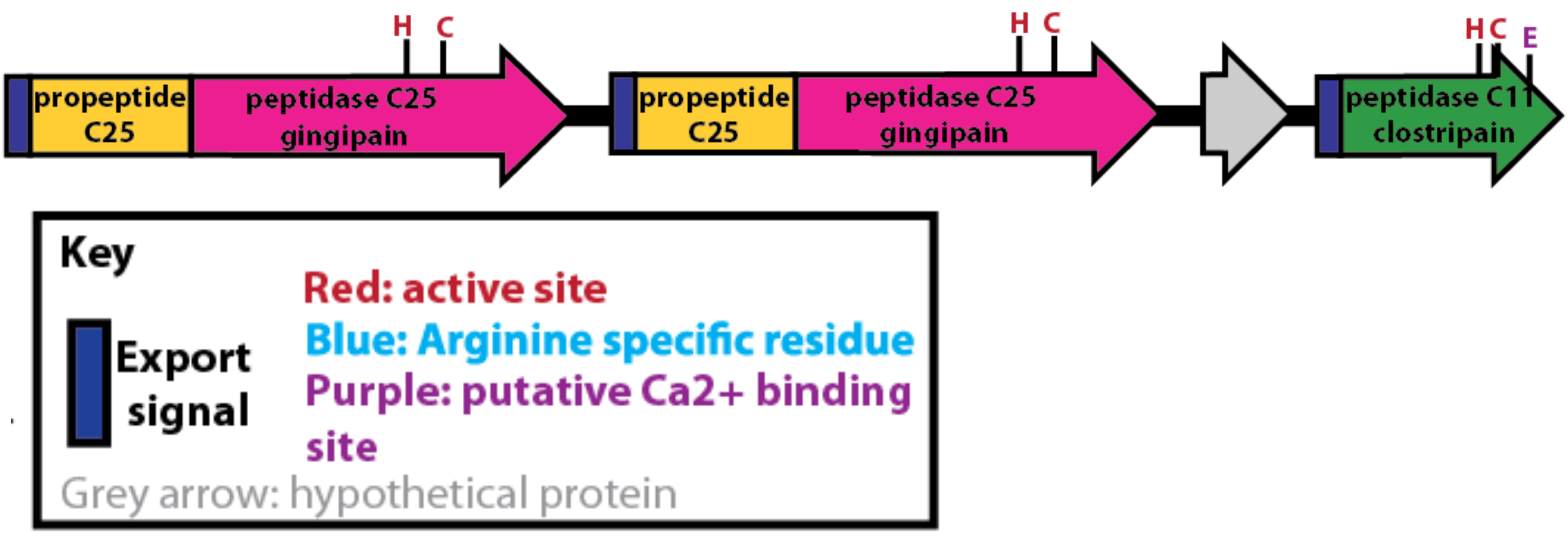


Lloyd et al. 2013, Nature



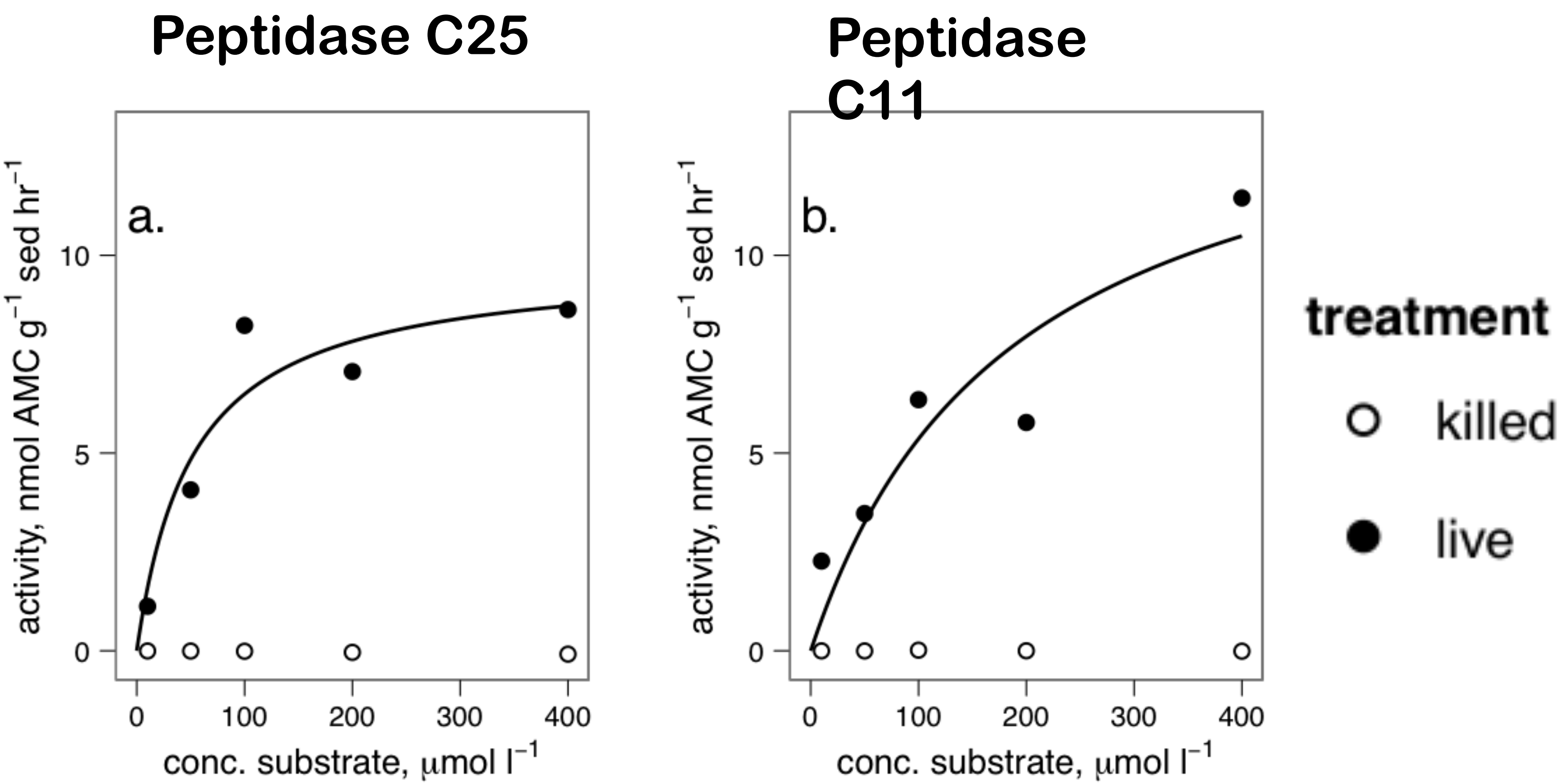
Lloyd et al. 2013, Nature

- These cysteine peptidases have intact functional groups, extracellular transport signals, and cofactor binding sites.
- They also occur in clusters on the genome.



Lloyd et al. 2013, Nature

The substrates of these cysteine peptidases are readily hydrolyzed in Aarhus Bay sediments.



Lloyd et al. 2013, Nature

Hydrothermal vents:
Hot spots of life
in the deep sea

Why study hydrothermal vents?

- They are an important input of heavy metals to the oceans. ~9% of iron and 14% of copper in the deep ocean came from vents (Sander & Koschinsky 2011).
- They are the formation zones of new seafloor.
- People are looking into mining them for precious metals.
- They harbor some of the most interesting life on Earth that appears to function without inputs from sunlight.

Hydrothermal Vents are an extreme environment

- High temperatures (up to 1000°C) and low pH (down to pH 2)
- High concentrations of potentially toxic constituents: Heavy metals and sulfide
- High pressure (up to 500 atm)
- Rapidly fluctuating conditions, with potential loss of carbon and energy sources

Why study extremophiles?

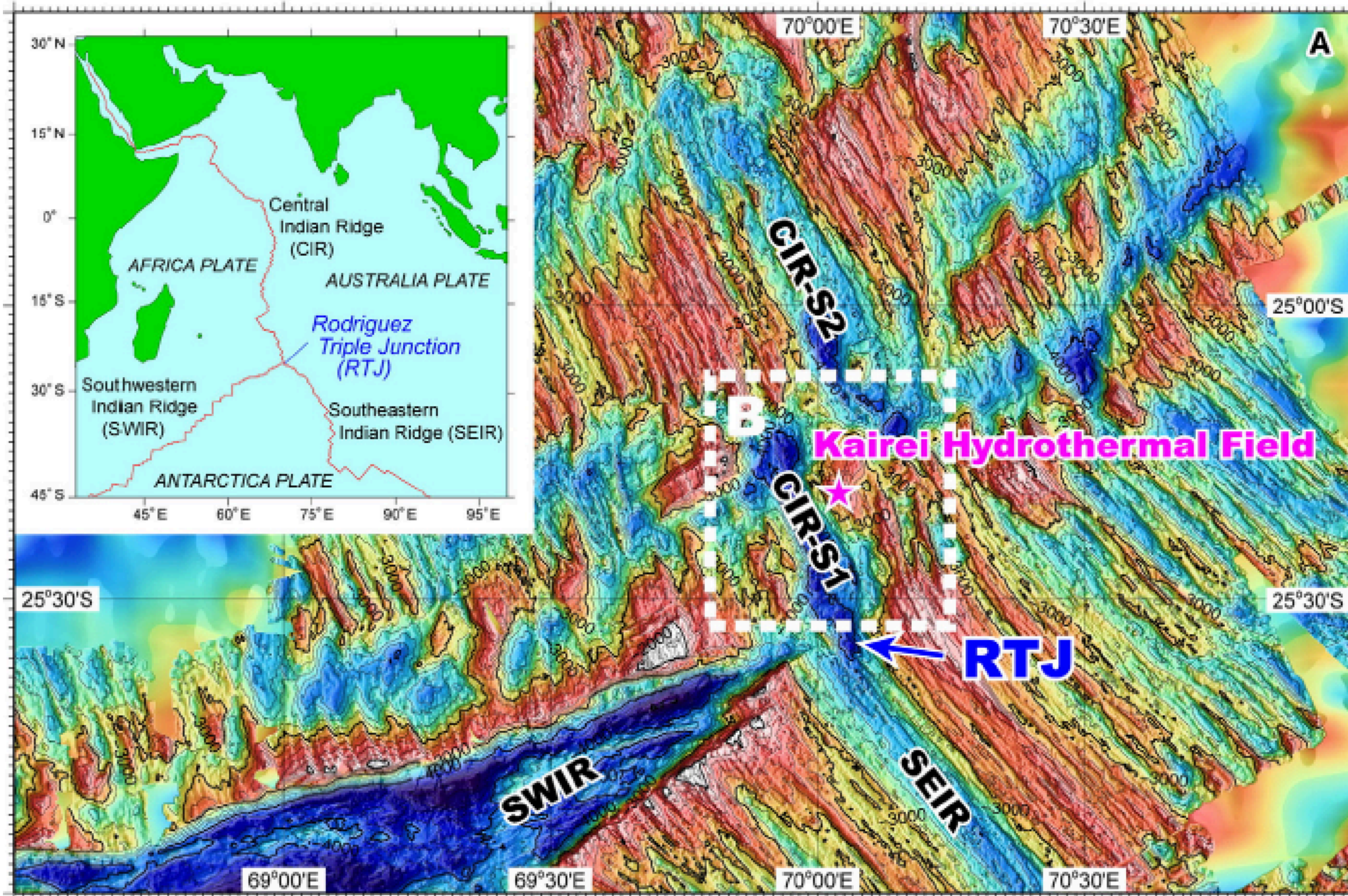
Novel properties – unique enzymes

Use in bioremediation

Models for early Earth, space environments

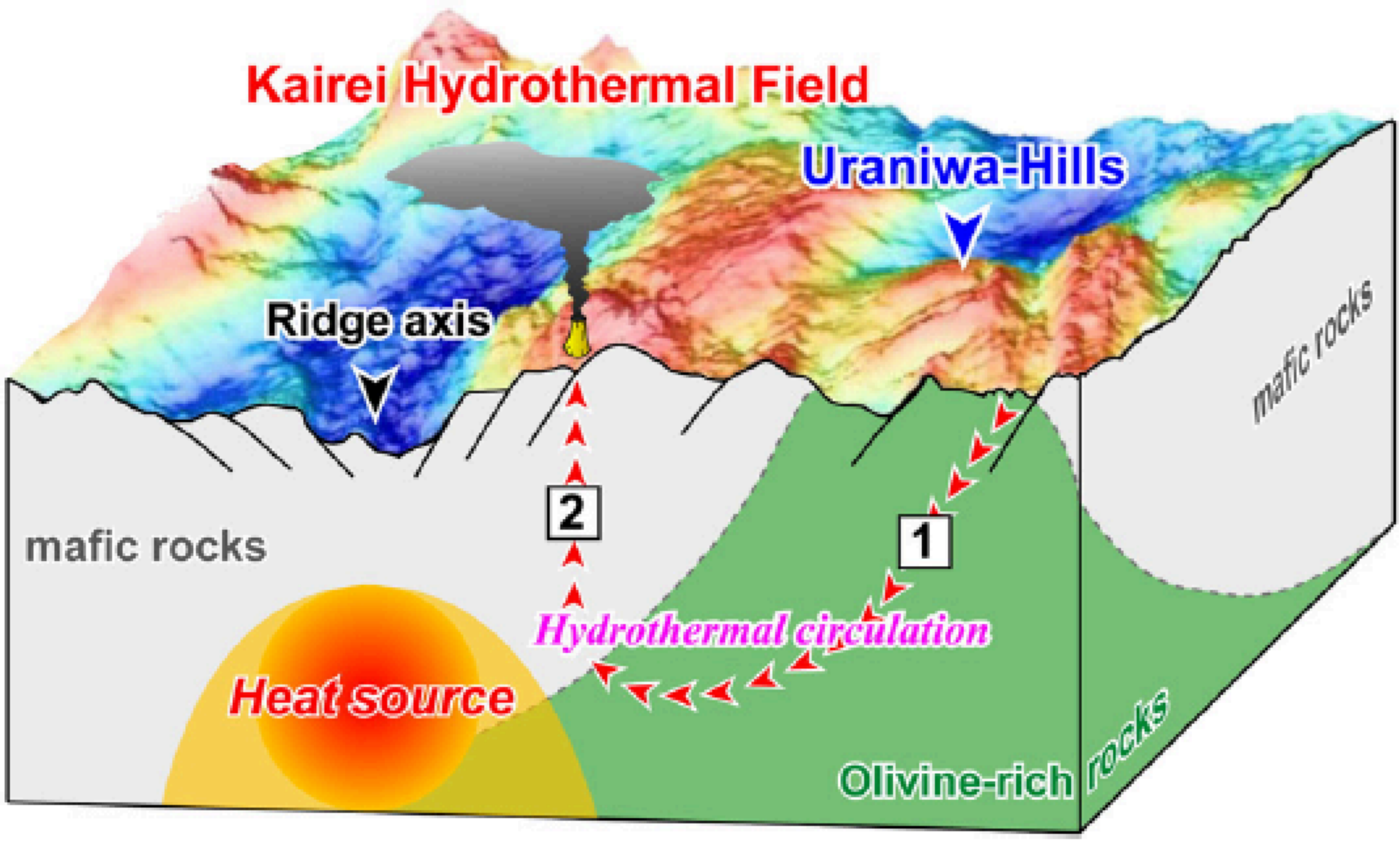
Extreme environments include extremes of temperature, pH, acid, salt, pressure

Expansion of our definition of "habitable"



Nakamura et al. 2009 Earth Planet. Sci. Lett.

Anomolously high H_2 and SiO_2 and low CH_4



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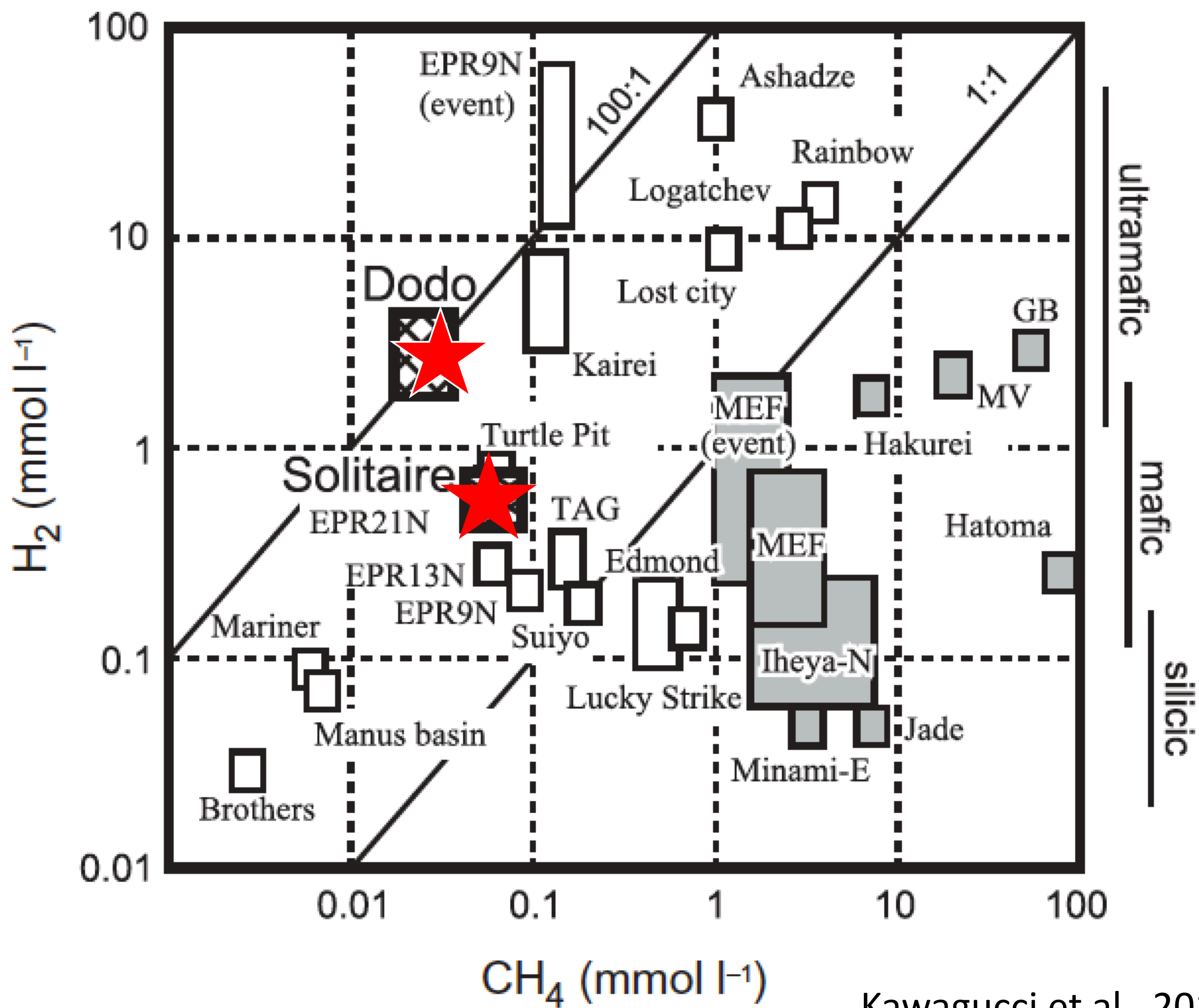
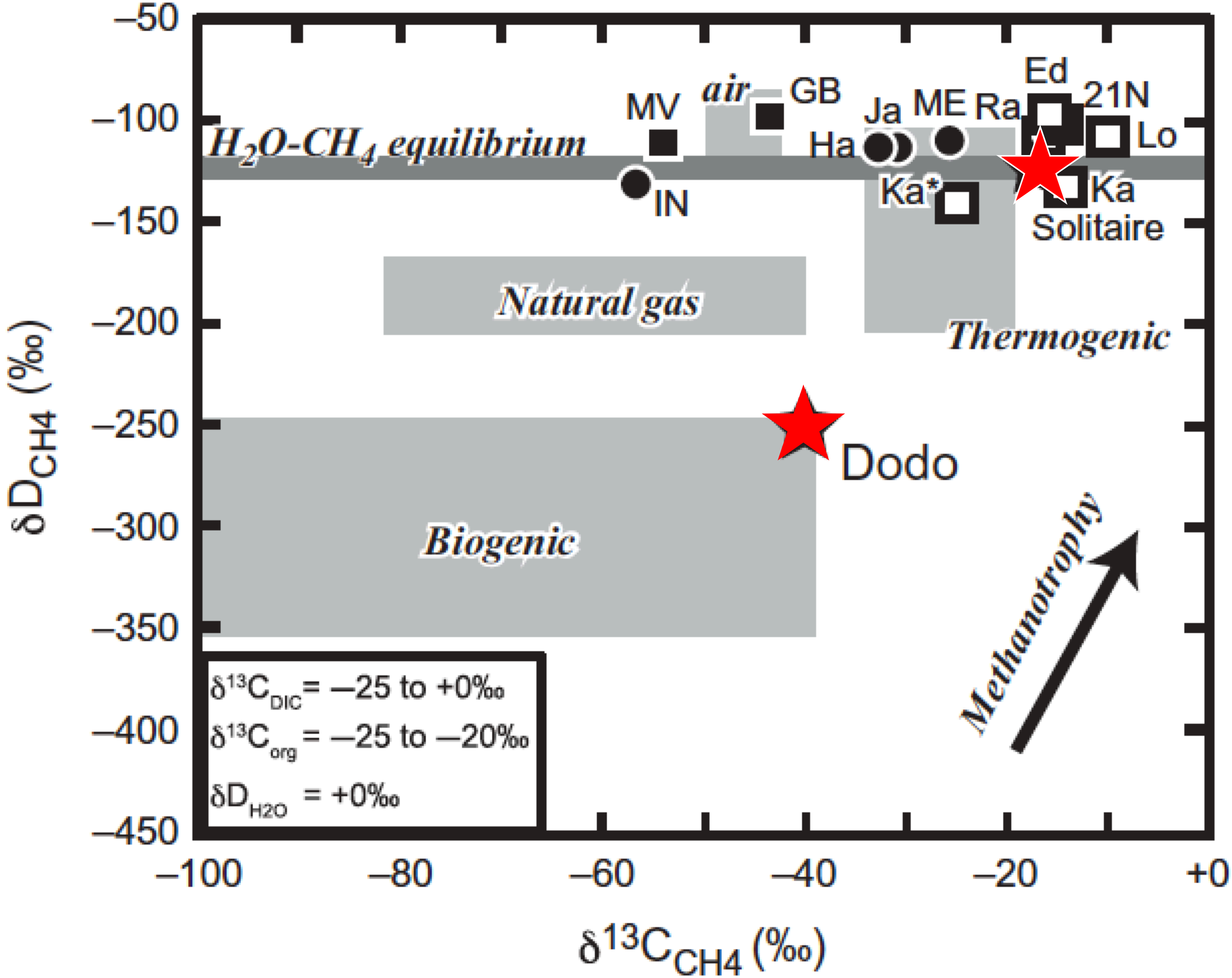
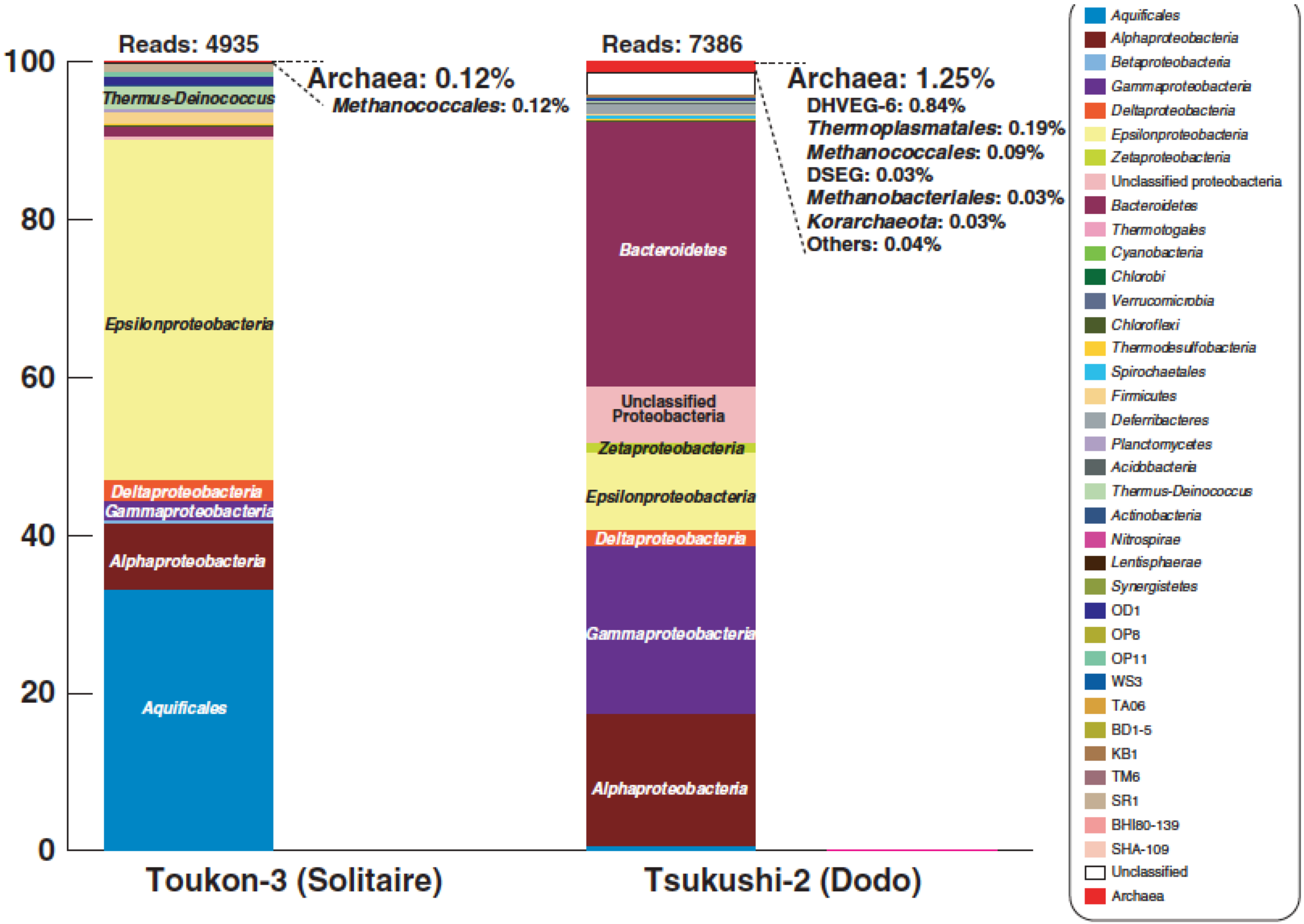


Kawagucci et al., 2016 Geofluids



Kawagucci et al., 2016 Geofluids



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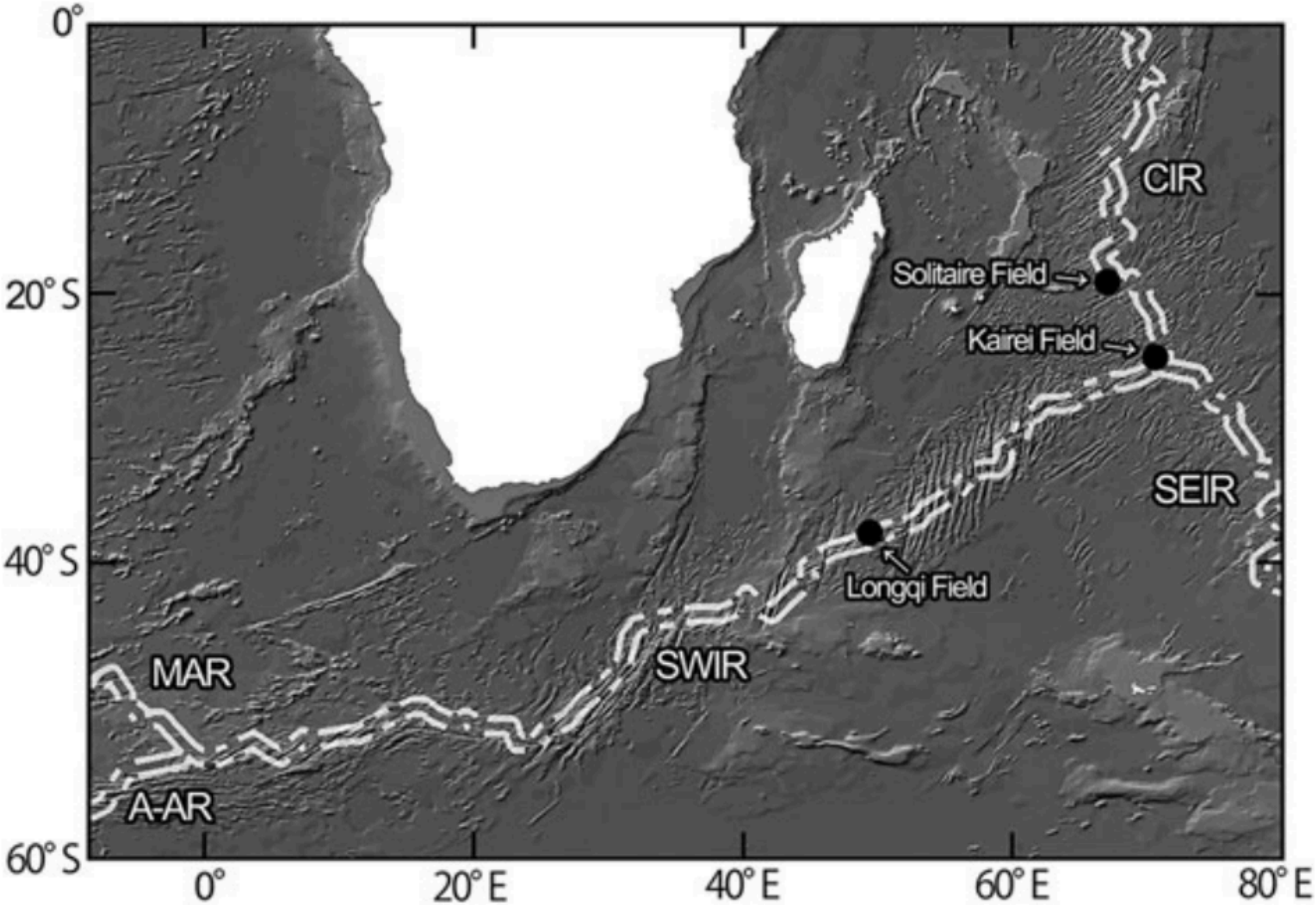


Chen et al. 2015, J. Molluscan Studies

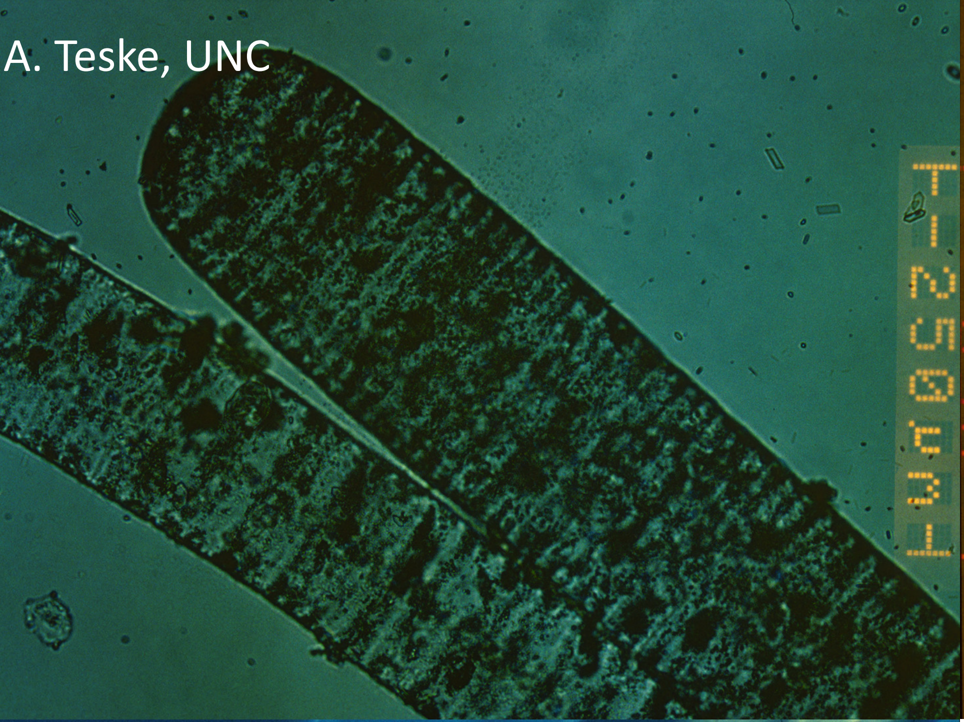
Scaly-food gastropod

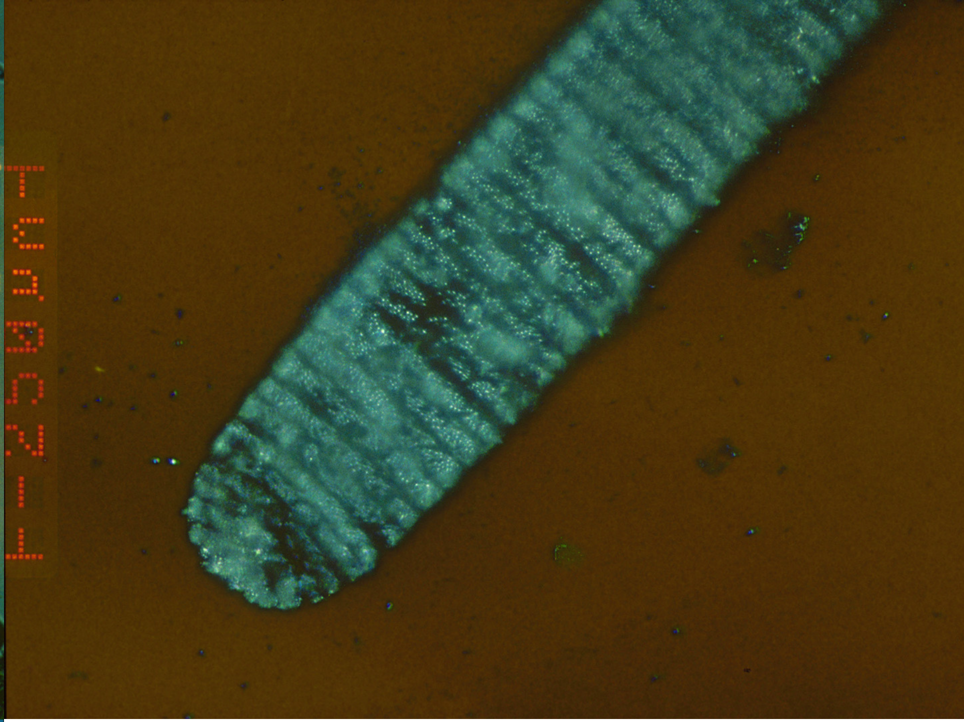
Chen et al. 2015, J. Molluscan Studies

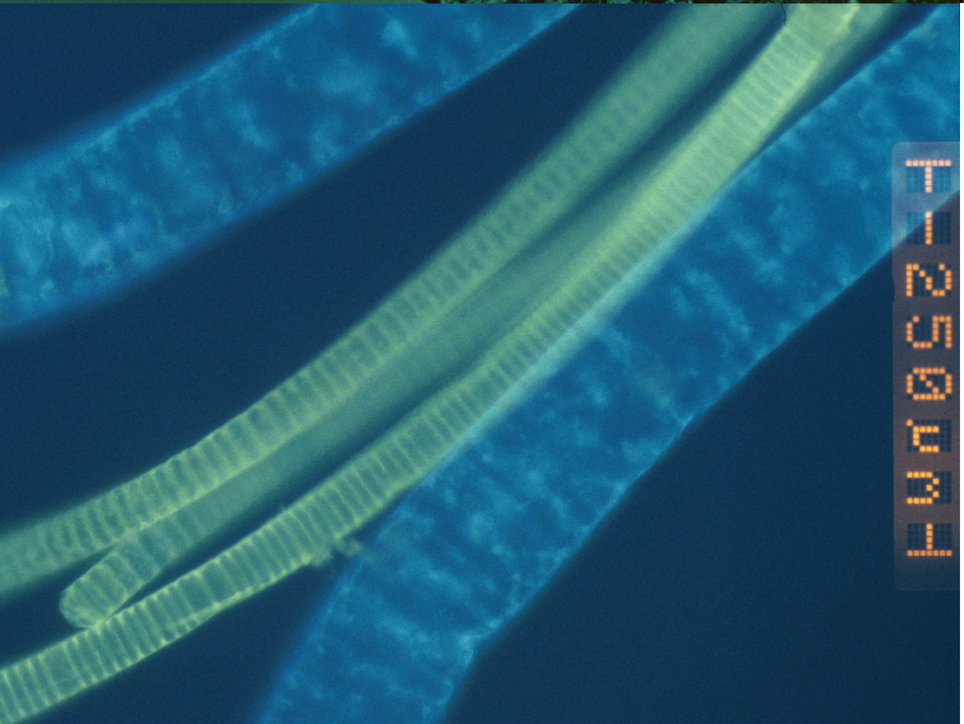
Tim Shank,
WHOI 1998

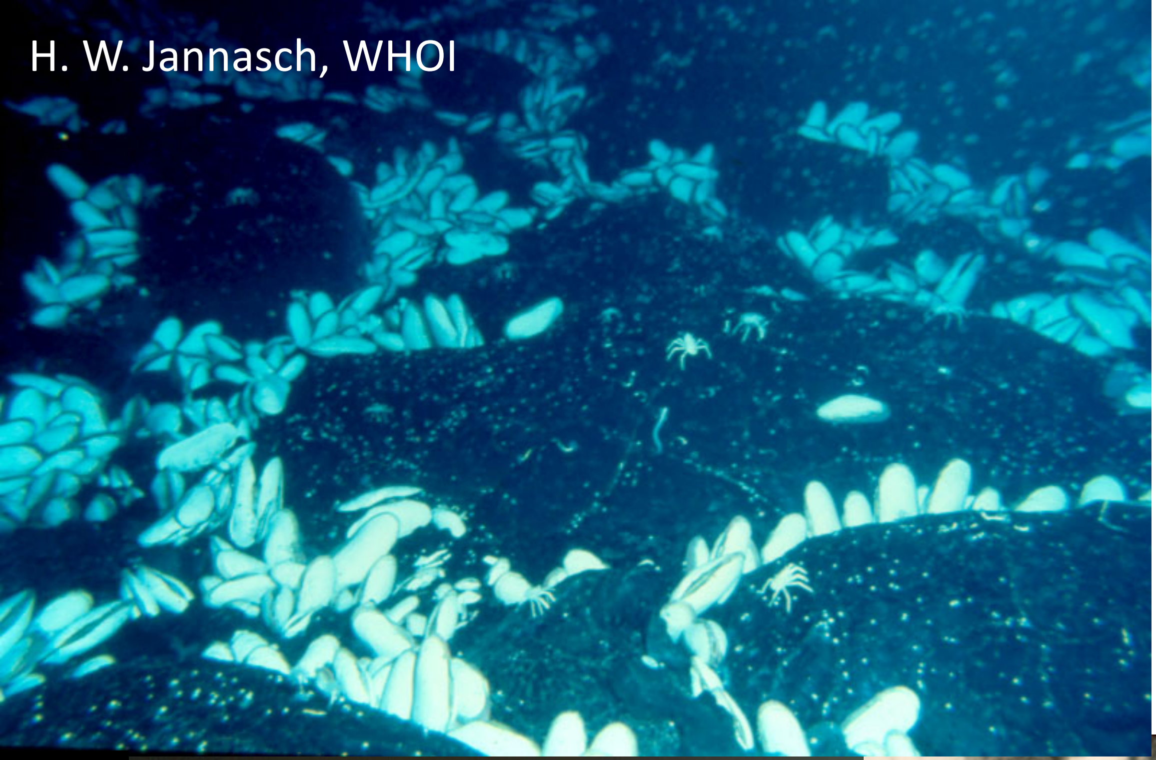
Riftia pachyptila **gills take up O_2 from seawater and hydrogen sulfide from warm vent fluents**

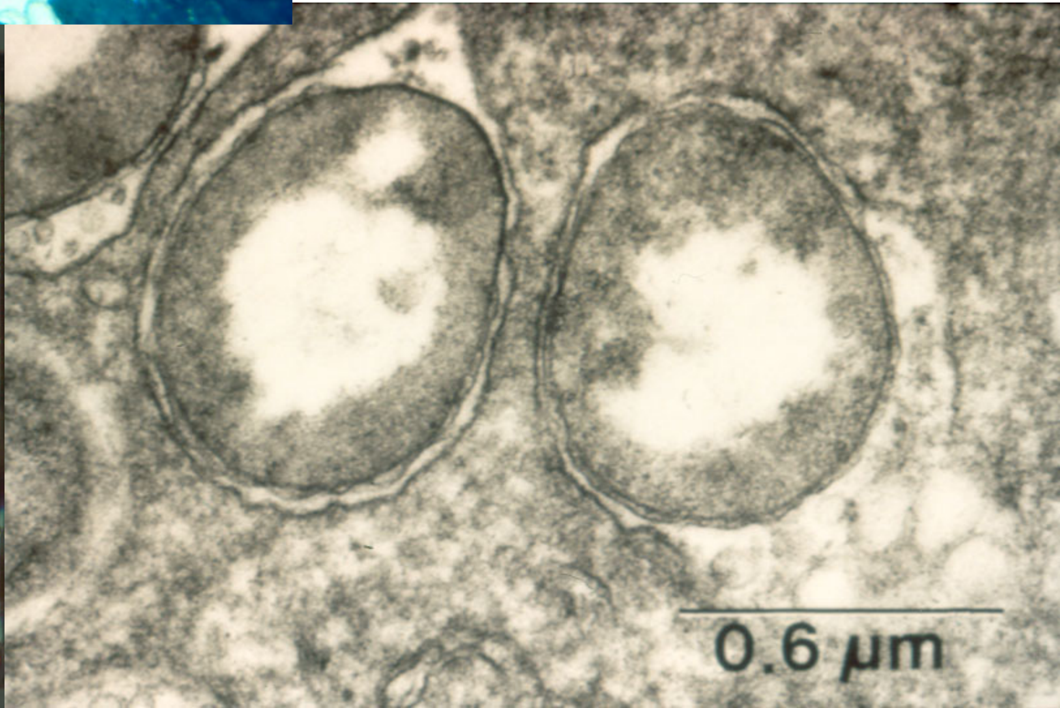
A. Teske, UNC

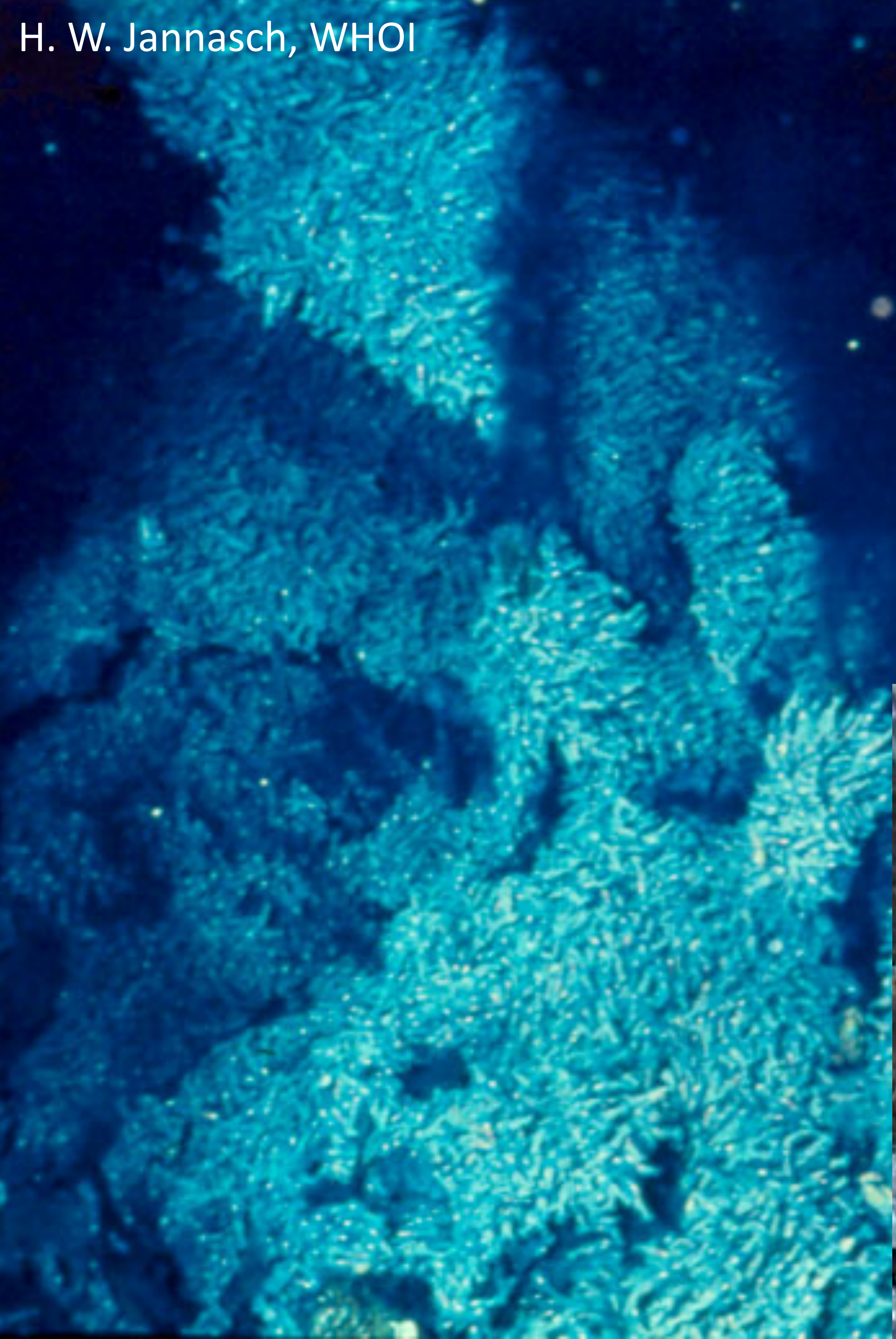







H. W. Jannasch, WHOI


0.6 µm

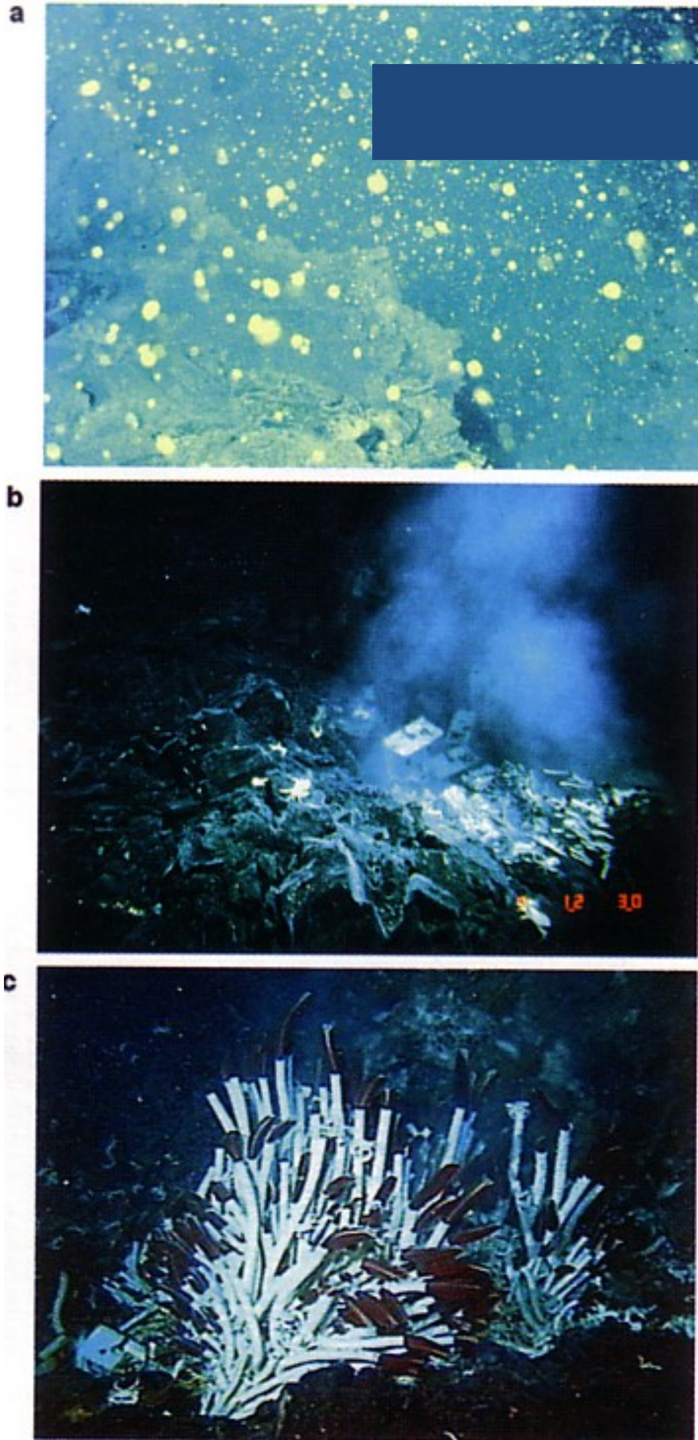


Mid-Atlantic Ridge hydrothermal vent chimneys, covered with shrimp

Recently also discovered at Indian Ocean vents (Kairei)

Alvinella pompeijana,
a vent polychaete
living in chitinaceous
tubes in vent chimney
walls.
The head (with tentacles)
reaches out and feeds;
the hind end is exposed
to hot temperatures
in the chimney wall
(up to 80°C ?).
Note the conspicuous
bristles on the back.

Life and Death of a vent (9°N East Pacific Rise)



April 1991:
Vigorous hydrothermal circulation:
No animals present,
abundant microbial flocs

March 1992:
Fissure is colonized by the tube worm ***Tevnia jerichonana***

December 1993:
Tube worm ***Riftia pachyptila*** **has formed a dense colony**

d e f

October 1994:
Further growth of the
Riftia pachyptila colony

November 1995:
Riftia colony alive, but stained with Fe oxides;
the result of a change in vent chemistry
(less sulfide, more Iron)

November 1997:
Noticeable decline of *Riftia* colony
due to sulfide limitation

Shanks et al. 1998. Deep Sea Research II 45, pp. 465-515