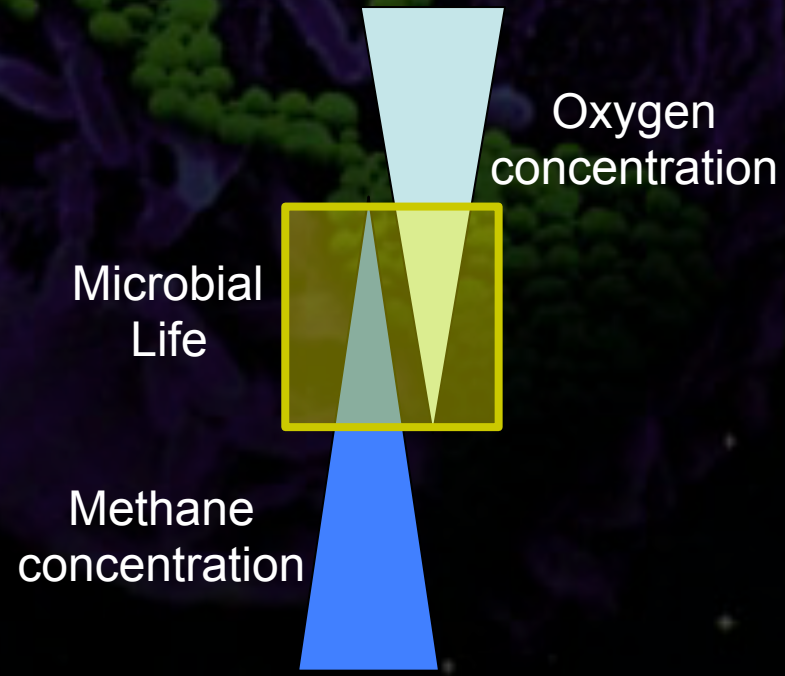
# Lessons from Earth

If life exists elsewhere, it is likely microbial

Life responds to, and thrives in, gradients

Chemical

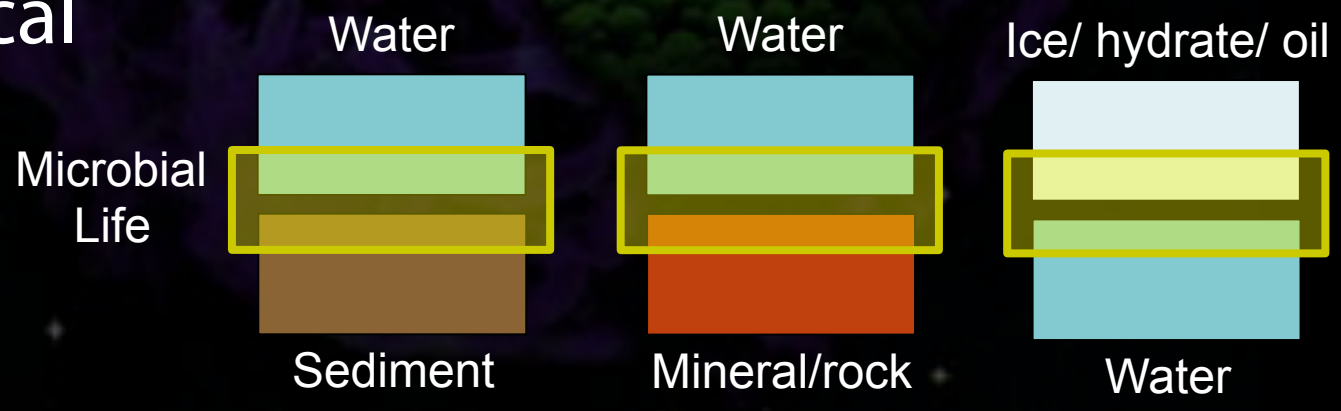


# Lessons from Earth

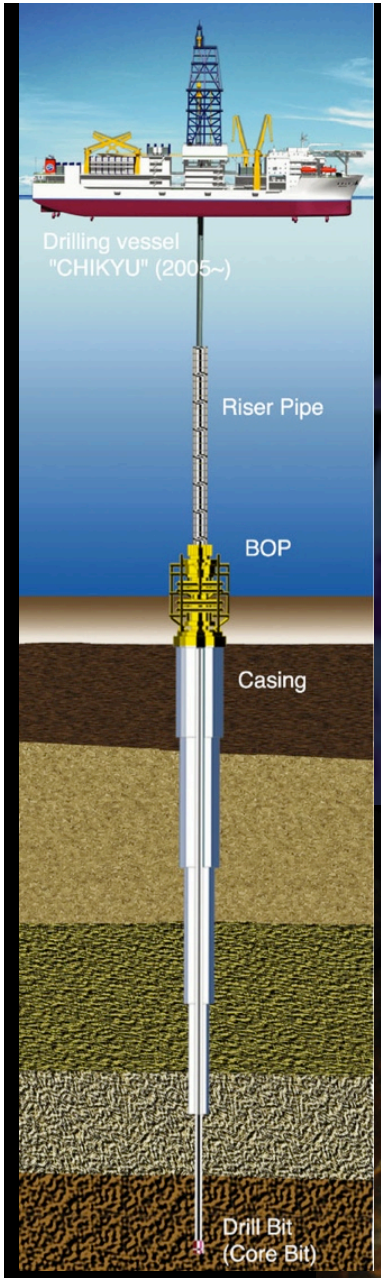
If life exists elsewhere, it is likely microbial

Life thrives at interfaces

Physical

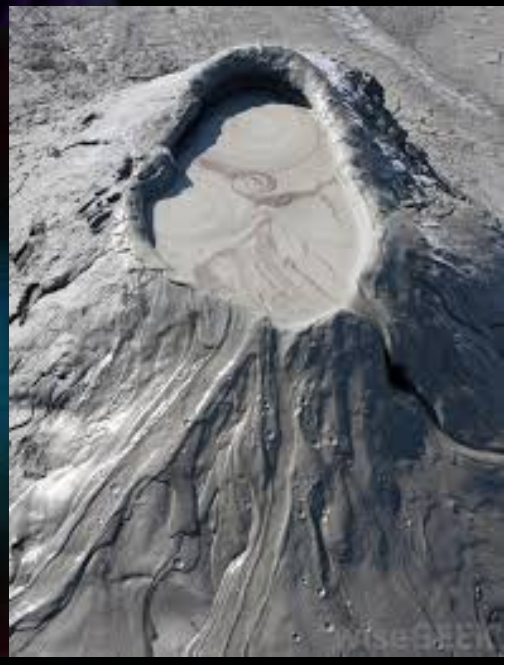


# Access to the deep biosphere

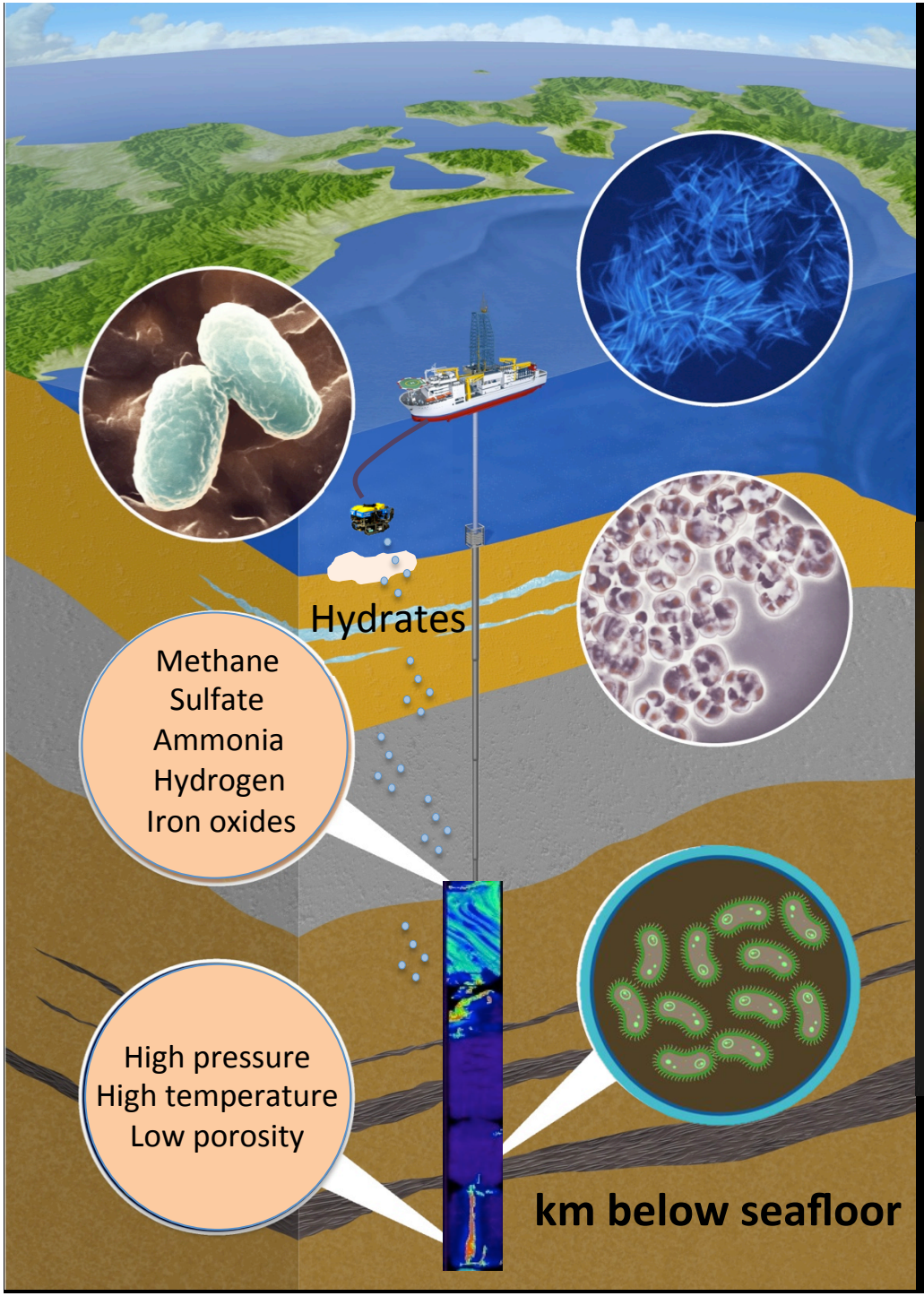


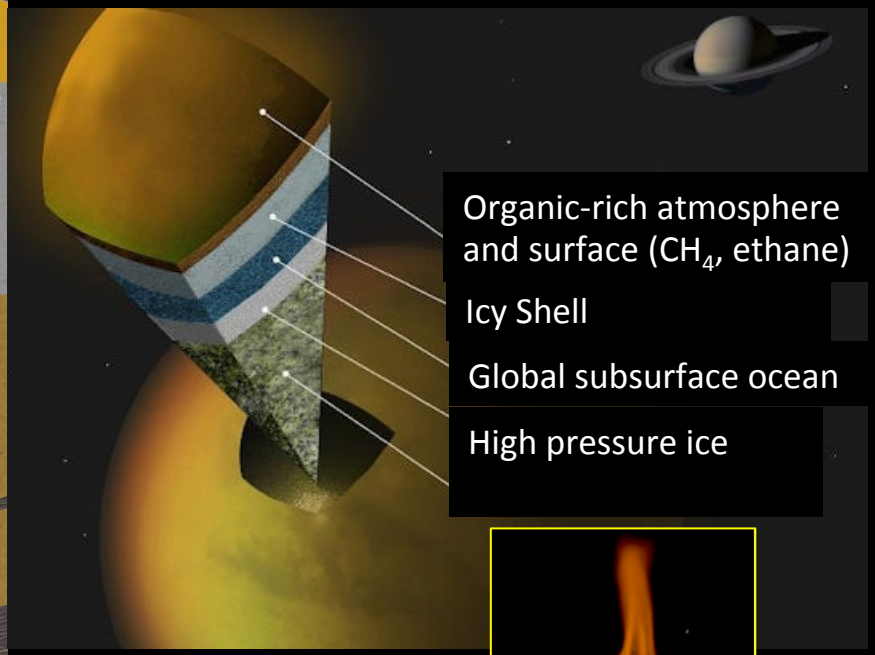

- Drilling

- Surface expressions of deep fluids
  'windows to subsurface'



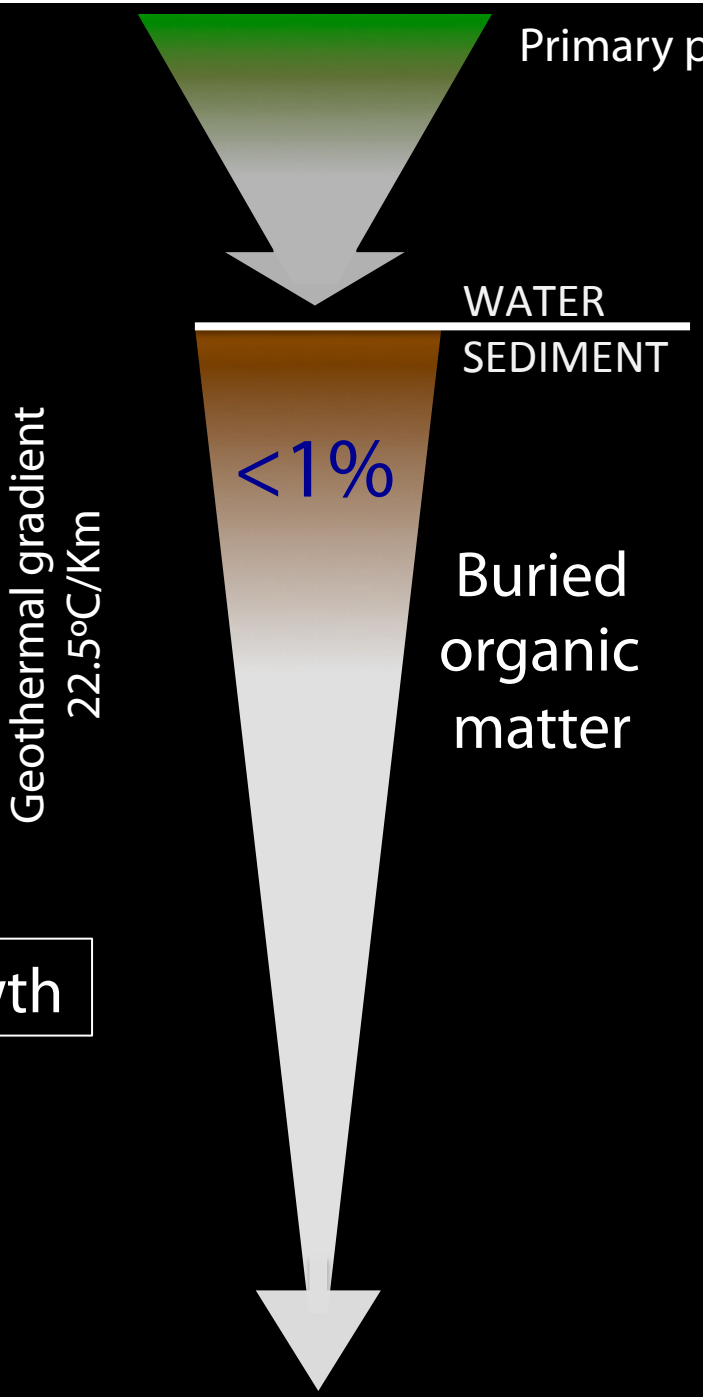
# Deep subseafloor Research on Earth



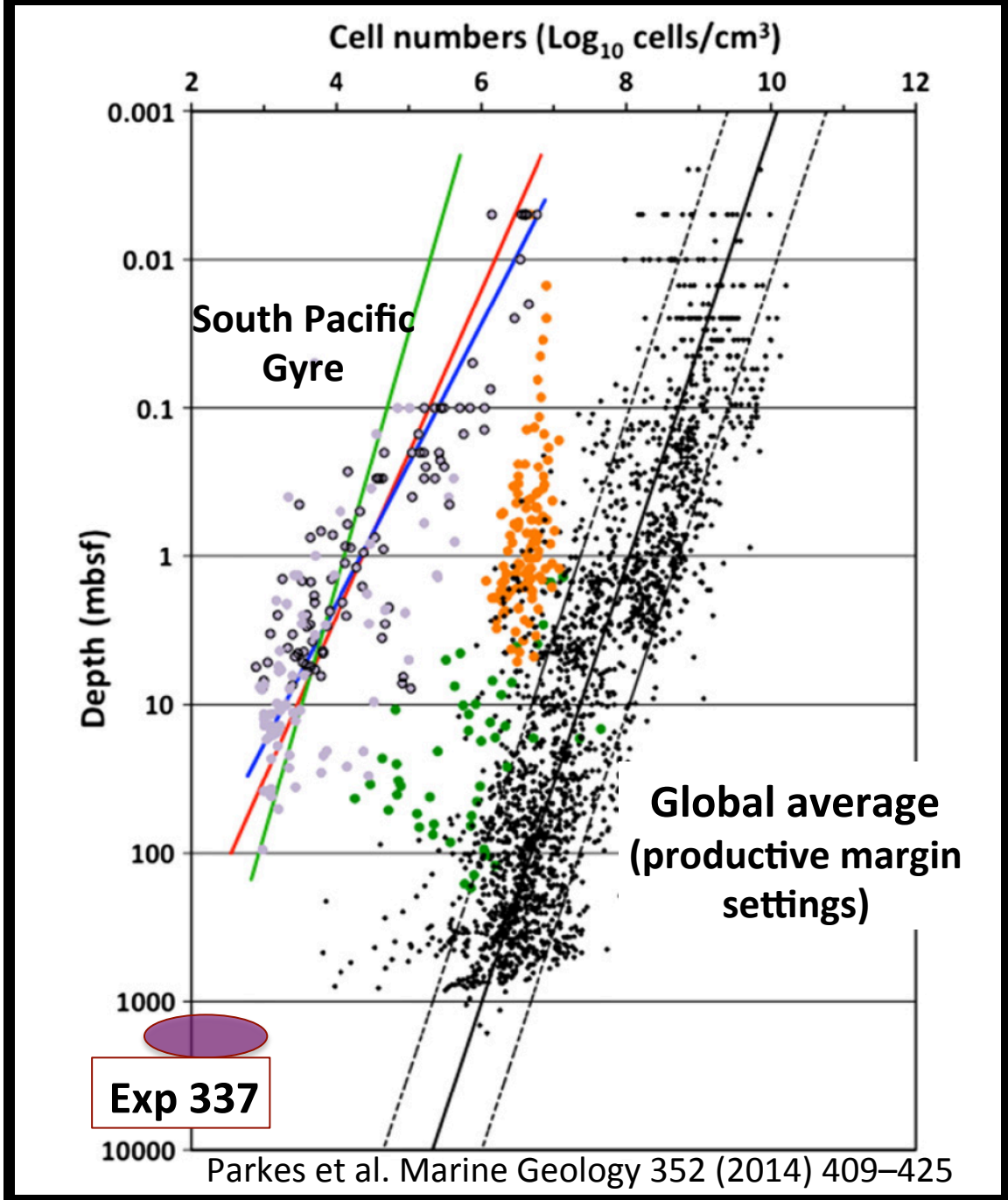

Methane hydrate

Deep subseafloor biosphere
"Life in the slow lane"




Energy limitation and slow growth

# Cell abundance in deep subseafloor sediments

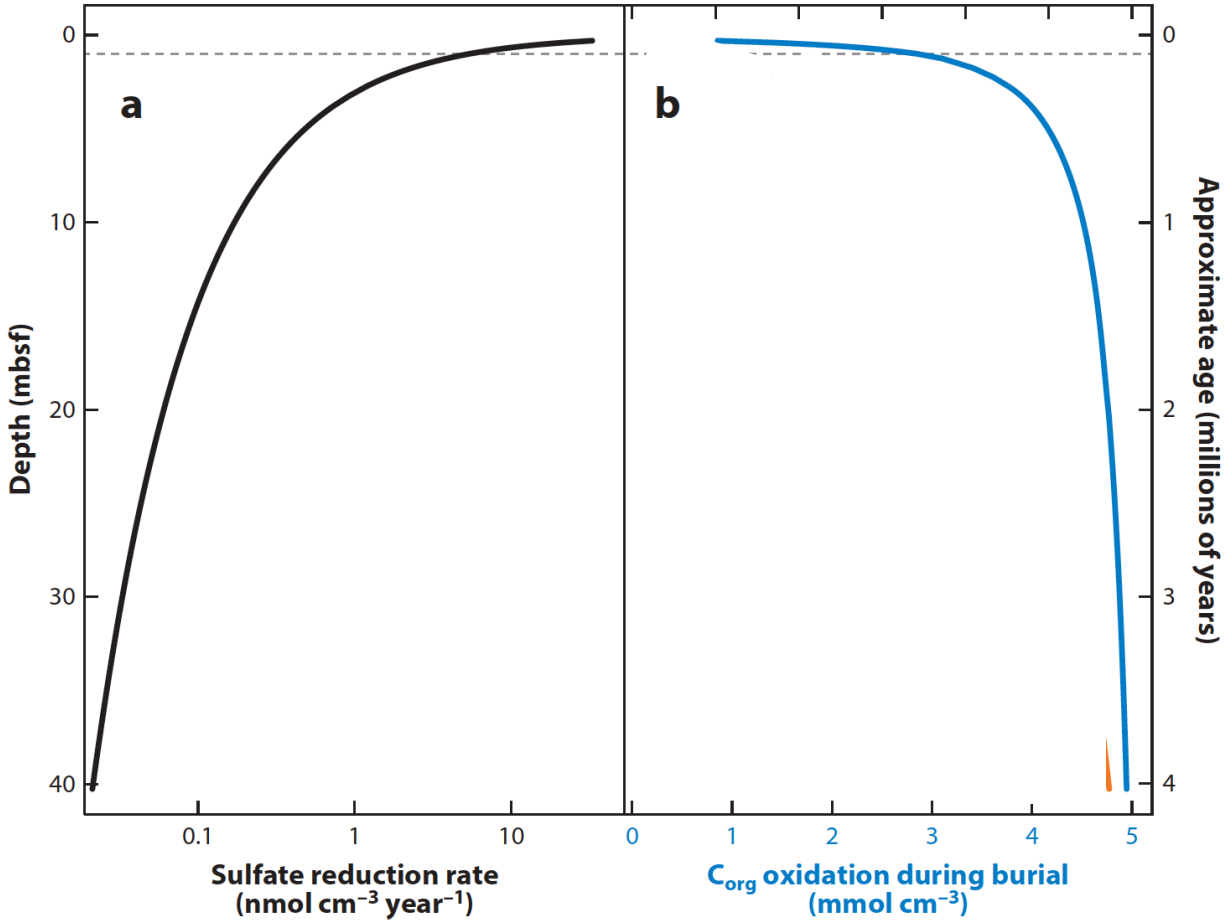



Parkes et al. Marine Geology 352 (2014) 409–425

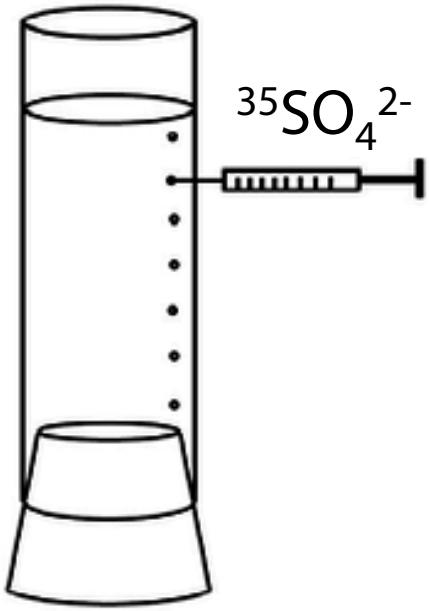

Tracking the growth and metabolic activity of subseafloor microorganisms
Dead?
Active?
Dormant?
Persisting?
Growing?

# Geochemical-based estimates of microbial activity in the deep subseafloor porewater profiles and reaction transport modeling

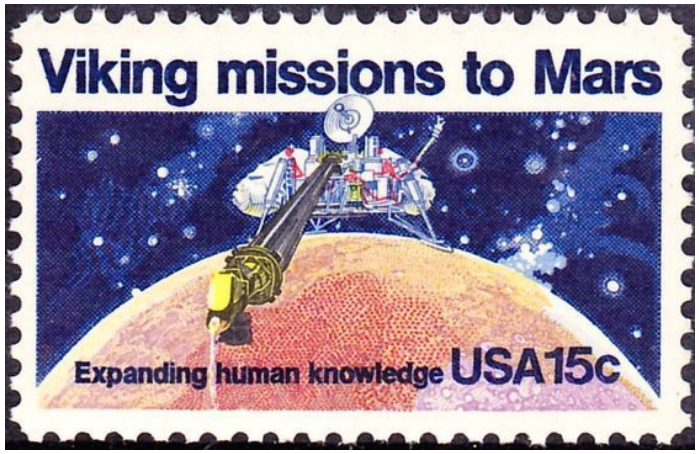
Geochemical profiles



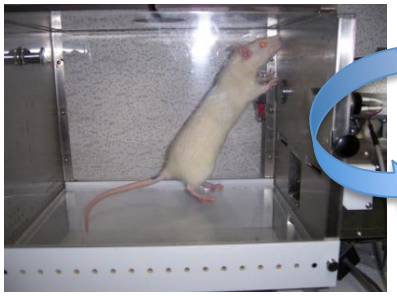

Radiotracer rate measurements




Jorgensen and Marshall (2016) Annual Reviews Marine Sci.

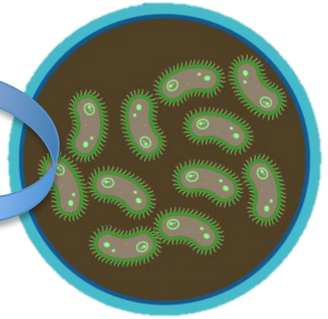



# Measuring microbes 'breathing' conversion of organics to $CO_2$

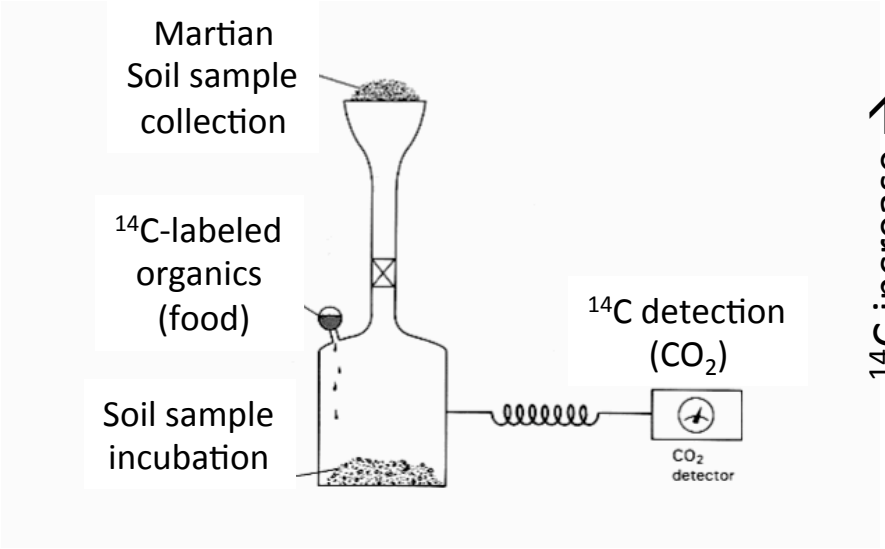


organic carbon (food)

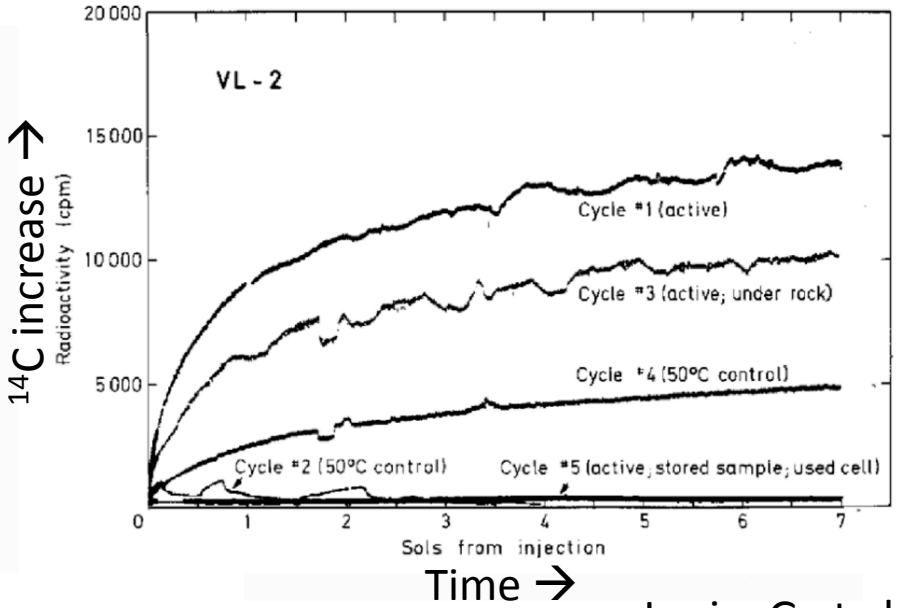
carbon dioxide ($CO_2$)



# Labeled Release (LR) Experiments



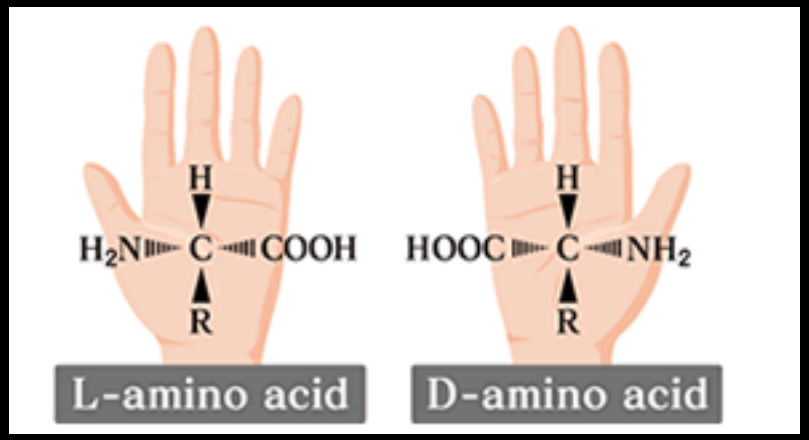

12.1 The Viking Mission




Levin, G et al (1976)

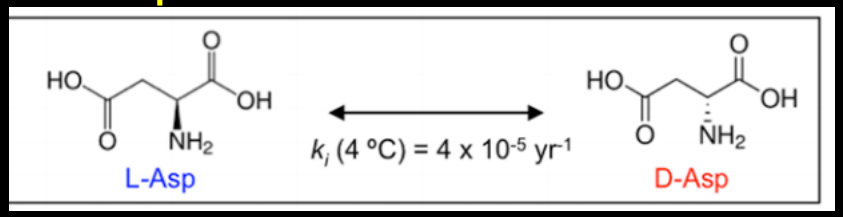
L. Chaisson

# Using amino acid racemization to model microbial turnover in the deep biosphere

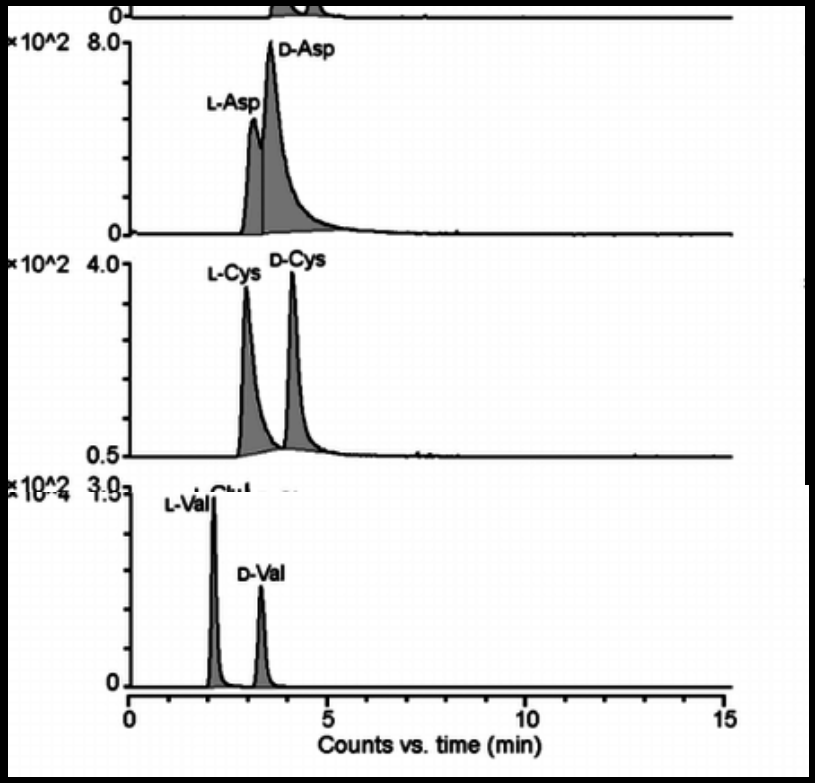



http://csls-text.c.u-tokyo.ac.jp/active/01_04.html

## Aspartic acid racemization




Steen et al., (2013) PLoS ONE 8(8): e71648

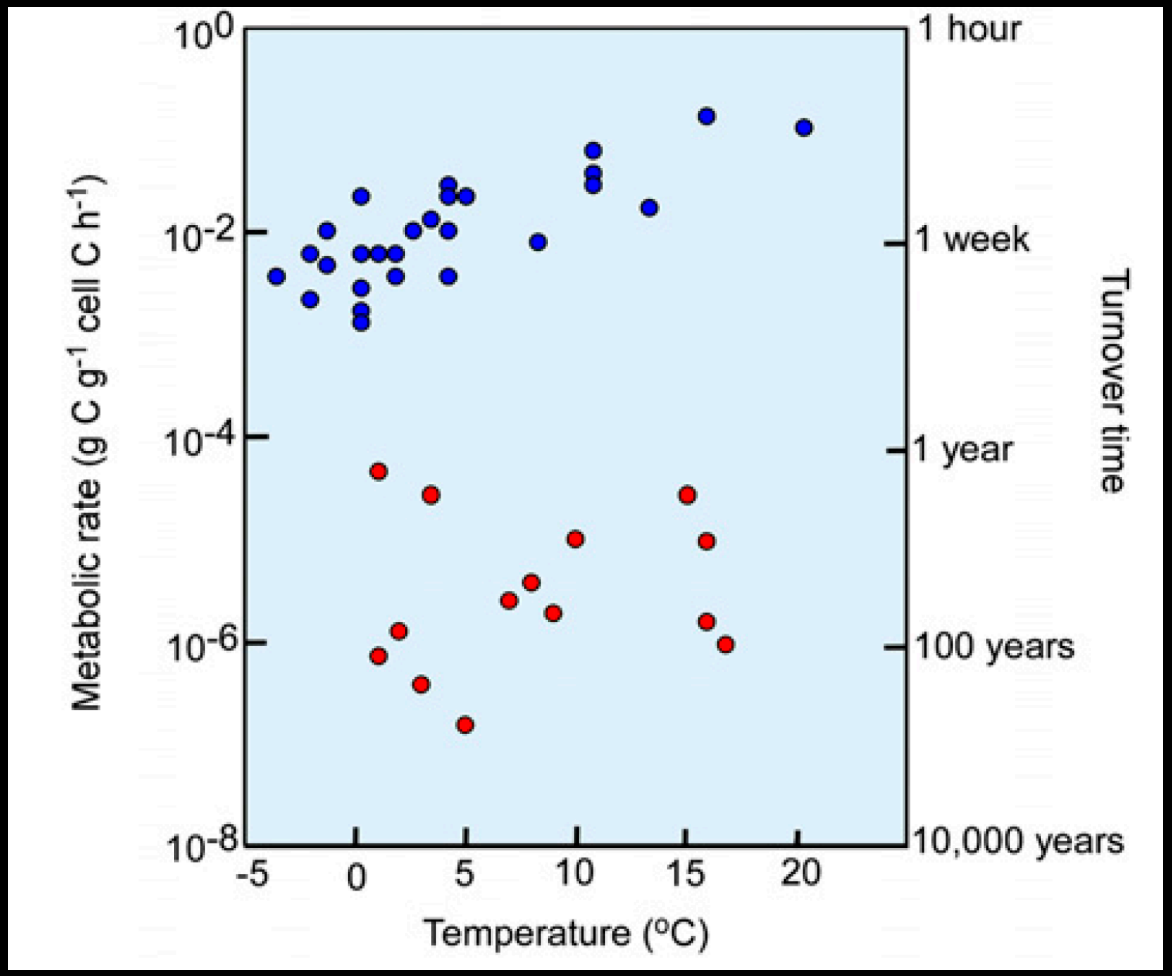



Taujenis et al., (2014) J. Agric. Food Chem

<u>Key parameters</u>

- rate constant L:D Aspartic acid
- estimated cellular C content

# Deep subseafloor microorganisms characterized by slow metabolic rates and growth




Jorgensen (2011) PNAS & Price and Sowers (2004) PNAS

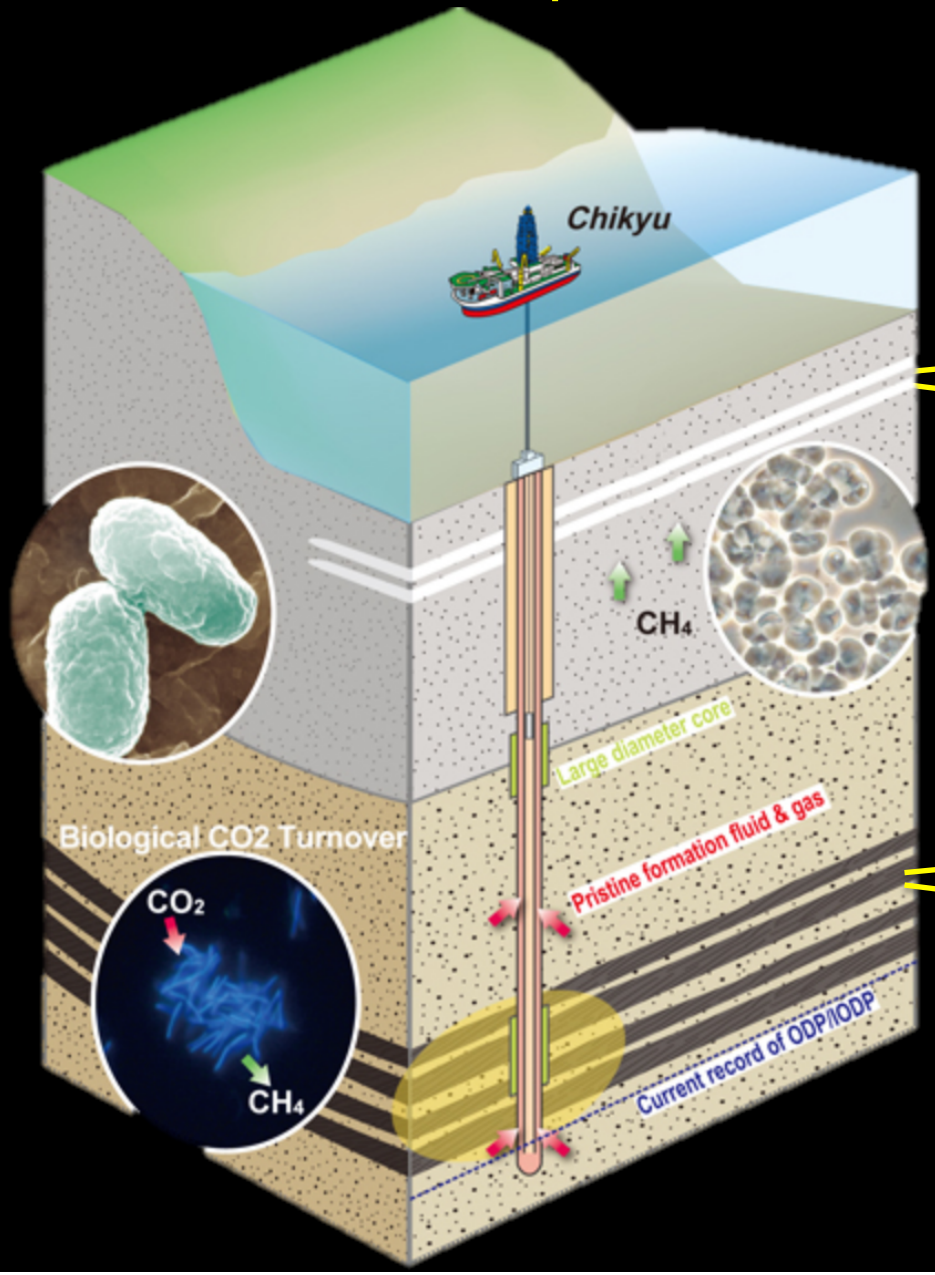
Aspartic acid Racemization

Turnover time 100's-1000's yrs

Lomenstein et al., (2012) Nature Peru Margin IODP site 1227

*Calculated cellular metabolic rates assume all cells are equally active*

# Shimokita Peninsula: Investigations of the viability and activity of deep subseafloor microorganisms




cruise CK06-06 (2006)

Sediment 219 mbsf
Age: Pleistocene
460,000 years

IODP EXP 337 (2012)

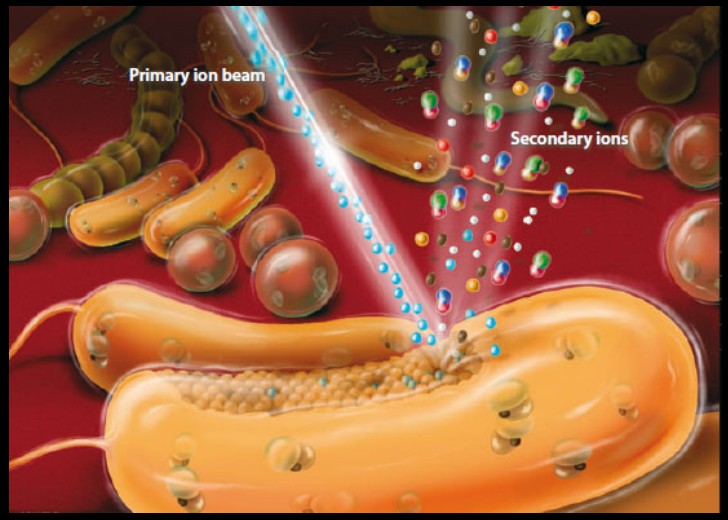
Coal 2,000 mbsf
Age: Miocene
24 Ma

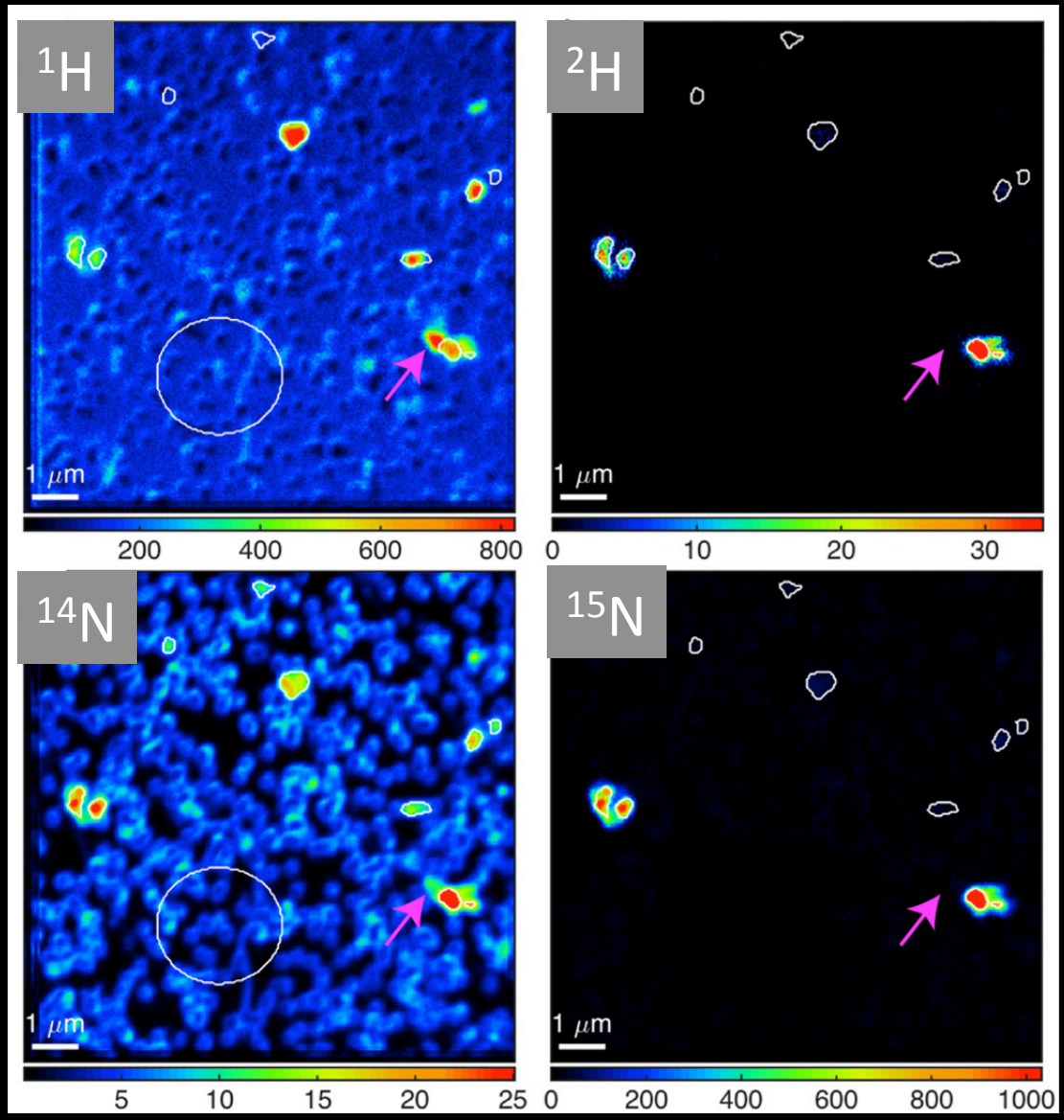
Deep Coalbed Biosphere off Shimokita HACHINOHE 25 July-30 September 2012
EXP337
IODP CHIKYU JAMSTEC

# nanoSIMS analysis of microbial cells from deep coal bed (2 Km)
# Viable microbial cells capable of active growth in the coal matrix

$^{13}C$, $^{15}N$, $^{2}H$ labeled substrate addition

Deuterated Water $^{2}H_2O$

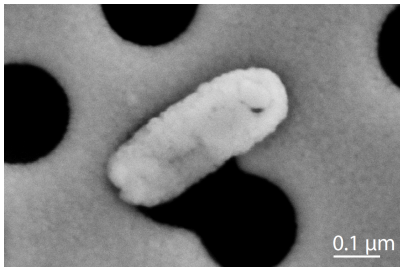



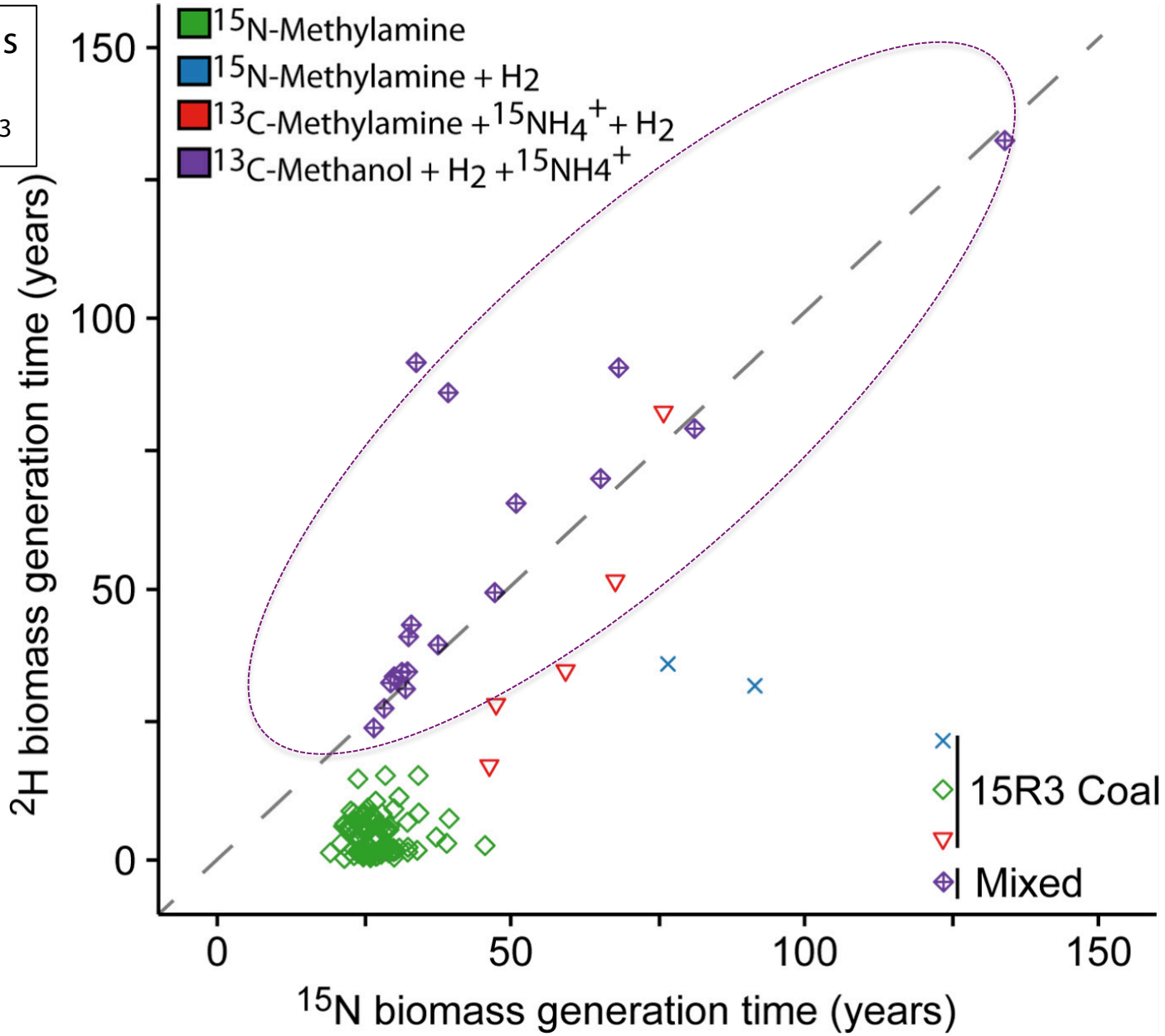

Trembath-Reichert et al. (PNAS)

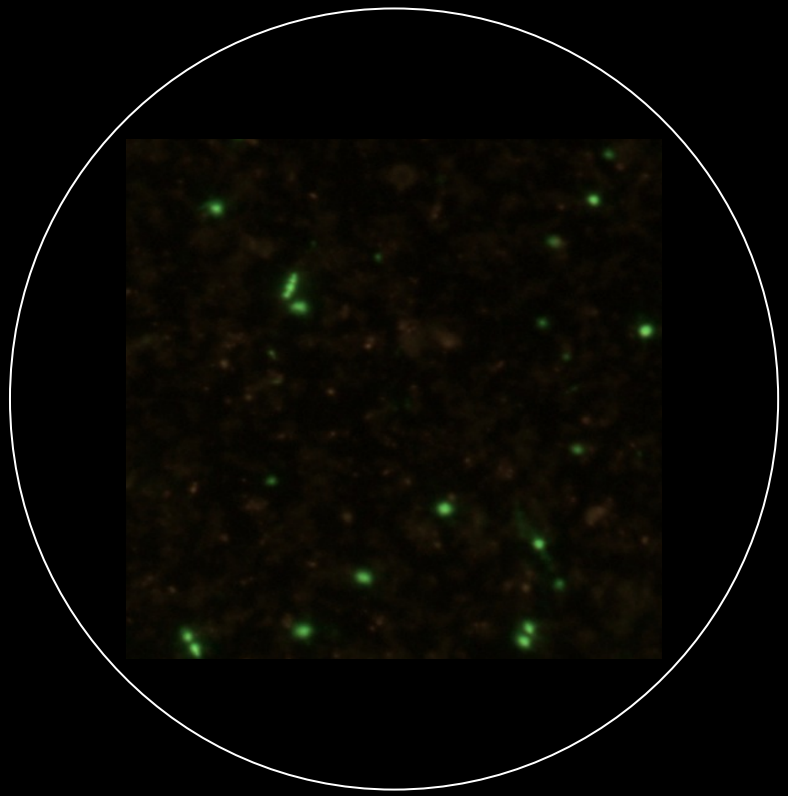
# Generation time estimates for single cells from deep coal incubations ($D_2O$ and $^{15}N$-ammonium or methylamine)

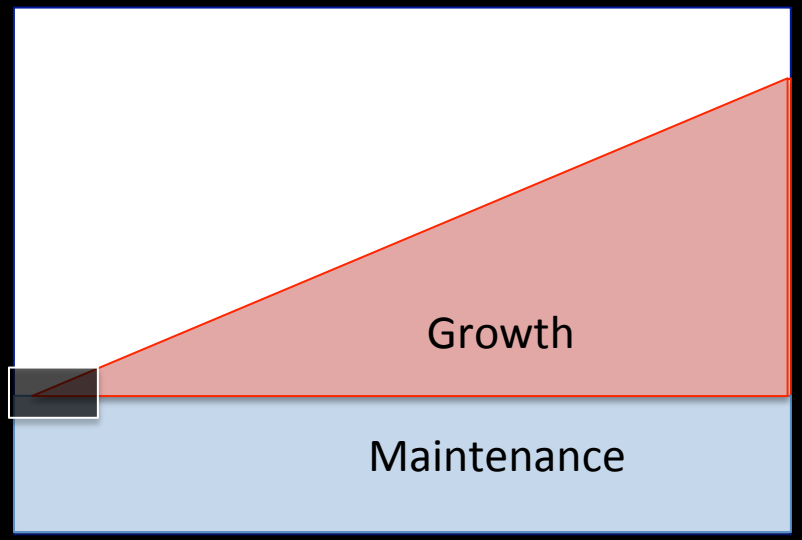
Coal SIP incubations
45°C
100-1000 cells/ $cm^3$




Cell size range
0.3-0.9µm
length








Biomass generation

Dead? Active?

Dormant? Persisting?

Growing?