Lessons from Earth

If life exists elsewhere, it is likely microbial

Life responds to, and thrives in, gradients

Chemical

Microbial Life

Oxygen concentration

Methane concentration
Lessons from Earth

If life exists elsewhere, it is likely microbial

Life thrives at interfaces

Physical

Microbial Life

Sediment

Mineral/rock

Ice/ hydrate/ oil 

Water
Access to the deep biosphere

- Drilling

- Surface expressions of deep fluids ‘windows to subsurface’
Deep subseafloor Research on Earth

Methane hydrates

- Methane
- Sulfate
- Ammonia
- Hydrogen
- Iron oxides

High pressure
High temperature
Low porosity

Hydrates

km below seafloor

Organic-rich atmosphere and surface (CH\textsubscript{4}, ethane)
Icy Shell
Global subsurface ocean
High pressure ice

Methane hydrate
Deep subseafloor biosphere
“Life in the slow lane”

Geothermal gradient
22.5°C/Km

WATER
SEDIMENT

<1%

Buried organic matter

Primary productivity

Energy limitation and slow growth
Cell abundance in deep subseafloor sediments

South Pacific Gyre

Global average (productive margin settings)

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

Labeled Release (LR) Experiments

Measuring microbes ‘breathing’ conversion of organics to CO$_2$

Martian Soil sample collection

$^{14}$C-labeled organics (food)

Soil sample incubation

$^{14}$C detection (CO$_2$)

$^{14}$C detection (CO$_2$)

L. Chaisson

Levin, G et al (1976)
Using amino acid racemization to model microbial turnover in the deep biosphere

Aspartic acid racemization


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

http://csls-text.c.u-tokyo.ac.jp/active/01_04.html
Deep subseafloor microorganisms characterized by slow metabolic rates and growth

Calculated cellular metabolic rates assume all cells are equally active

Aspartic acid Racemization

Turnover time
100’s-1000’s yrs


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

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

Deuterated Water $^2\text{H}_2\text{O}$

Trembath-Reichert et al. (PNAS)
Coal SIP incubations
45°C
100-1000 cells/ cm³

Cell size range
0.3-0.9µm
length

Generation time estimates for single cells from deep coal incubations
(D₂O and ^15N-ammonium or methylamine)

2H biomass generation time (years)

15N biomass generation time (years)
Dead? Active? Dormant? Persisting? Growing?