Biology Working Groups' Summary

- Geomicrobiology
- Evolutionary & Genomic Biology

Minneapolis, July 22, 2005

WG and Relevant Biological Advances

WGs completed a good draft in Feb-Mar

Amer Soc Microbiol mtg in June, T.C. Onstott talked on DUSEL at session on major infrastructure important to microbiology

(Intl) Subsurface microbiology meeting in August in Yellowstone. This is the majority of the DUSEL relevant microbiology community.

NAI (NASA Astrobiology Inst), workshops and activities on early life

Biological Features at DUSEL Site(s)

- Very low populations but scales to large total populations
- Very low metabolic rate
- Very low generation times, long cell lifetimes
  (solution to aging?)
- Patchy distribution, tracks energy and water
- Autotrophic (CO_2) and lithotrophic physiology expected
- Biological novelty expected due to isolation and unique selection conditions.

Major Questions in Biology

Did life on earth start underground?

Does the deep subsurface harbor primitive life processes today?
What "signs of subsurface life" should we search for on Mars?

How bioavailable is Earth's aphotic interior?

What are the temperature, pressure, nutrient and energy restrictions on subsurface or **dark life**?
How does microbial activity affect rock strength and permeability and vice versa?

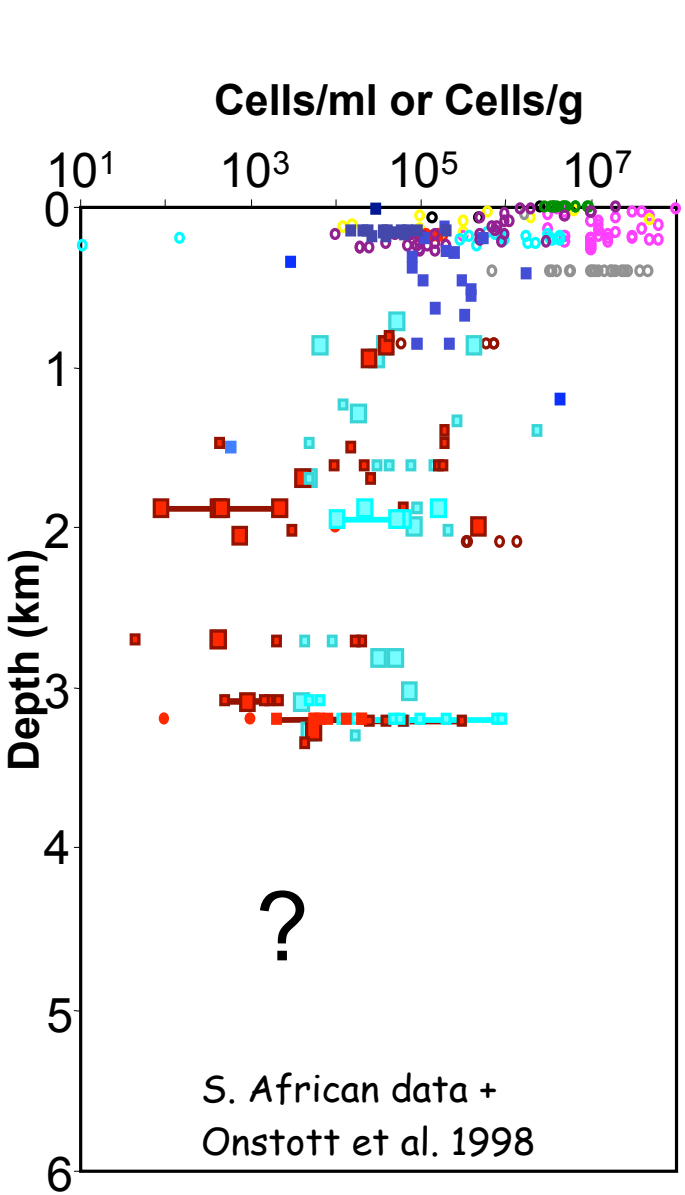
What are the genome dynamics of dark life?

How does microbial life evolve in (extreme) isolation within the subsurface and from the surface gene pool?
Are there microbial cells that are 10^2 to 10^7 years old and if so, how do their genomes differ from microbes with normal lifetimes?

Is there dark life as we don't know it?

Does unique biochemistry, e.g. non-nucleic acid based, and molecular signatures exist in isolated subsurface niches?
Is the subsurface a reservoir for unexpected and biotechnologically useful enzymes?

Variation of Life with Depth



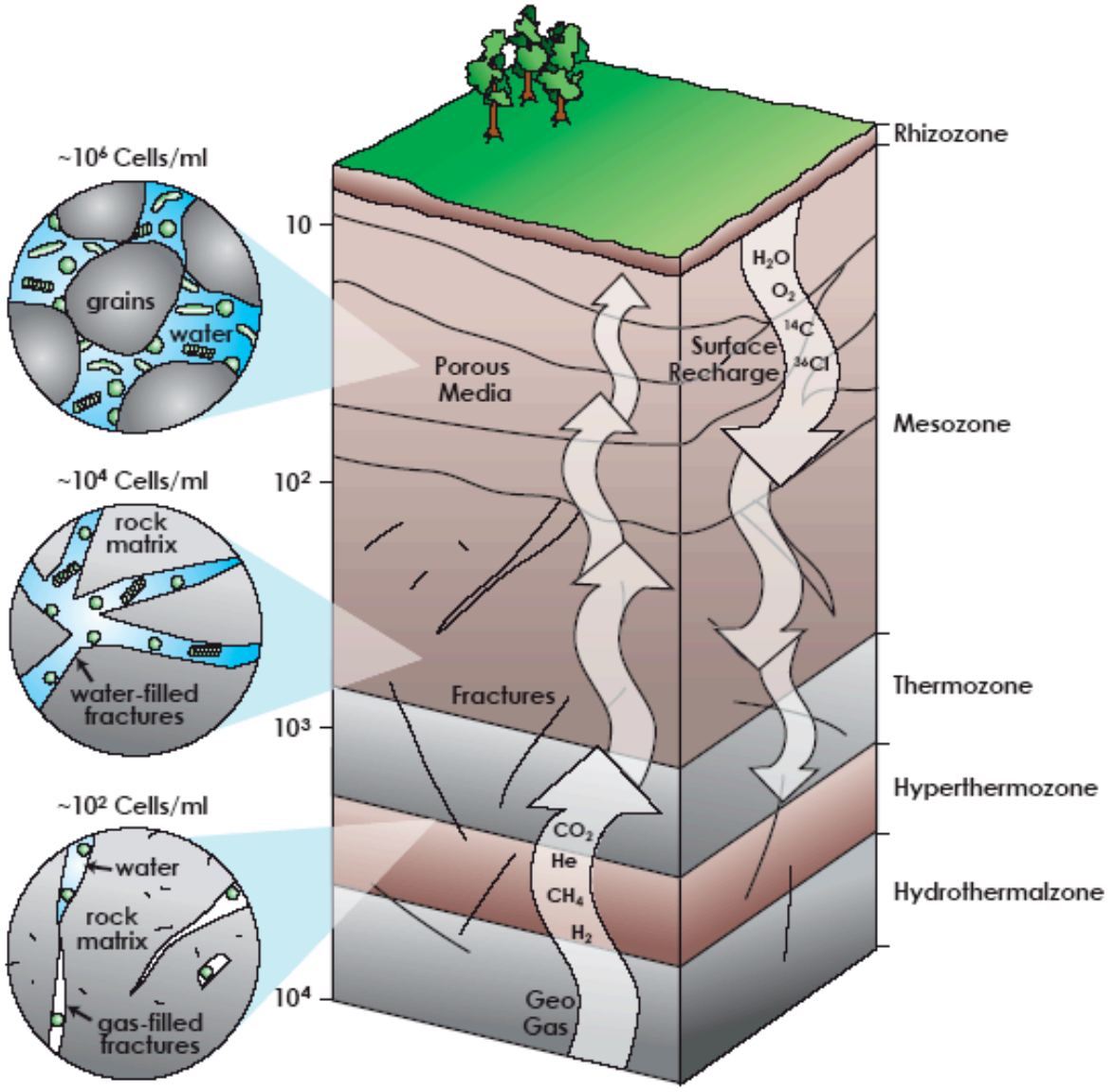


Fig. 2 of Earthlab report

Major Questions in Geomicrobiology

How deeply does life extend into the Earth?

What are the lower limits of life in the biosphere? What is the temperature barrier, the influence of pressure, the interplay of energy restrictions with the above? The subsurface biomass may be the most extensive on earth but samples so far are too few.

What fuels the deep biosphere?

Do deep microbial ecosystems exist that are dependent upon geochemically generated energy sources ("geogas": H_2, CH_4, etc.) and independent from photosynthesis. How do such systems function, their members interact to sustain the livelihood?

How does the interplay between biology and geology shape the subsurface?

For example,

- Mineral precipitation/dissolution reactions
- Geochemical evolution of groundwater
- Contaminant migration
- Physical effects?

Major Questions in Microbial Evolution

What are subsurface genomes telling us?

Microbes living isolated from the surface gene pool for very long periods of time, with small population sizes, may have evolved very differently. Answers to the following questions would provide new insight into the evolution of life and its variations.

* What is the tempo and mode of evolution? Tests of Neutral Theory of Evolution, genetic drift
* How does microbial life evolve in (extreme) isolation? Rampant microdiversification, little homogenization?
* What are the evolutionary adaptations to minima - "life in the slow lane"
* What are the genome "dynamics" under low pop densities & slow growth, e.g. DNA uptake, different stresses, lack of biowarfare, role of phage)

Major Questions About Life's Origin

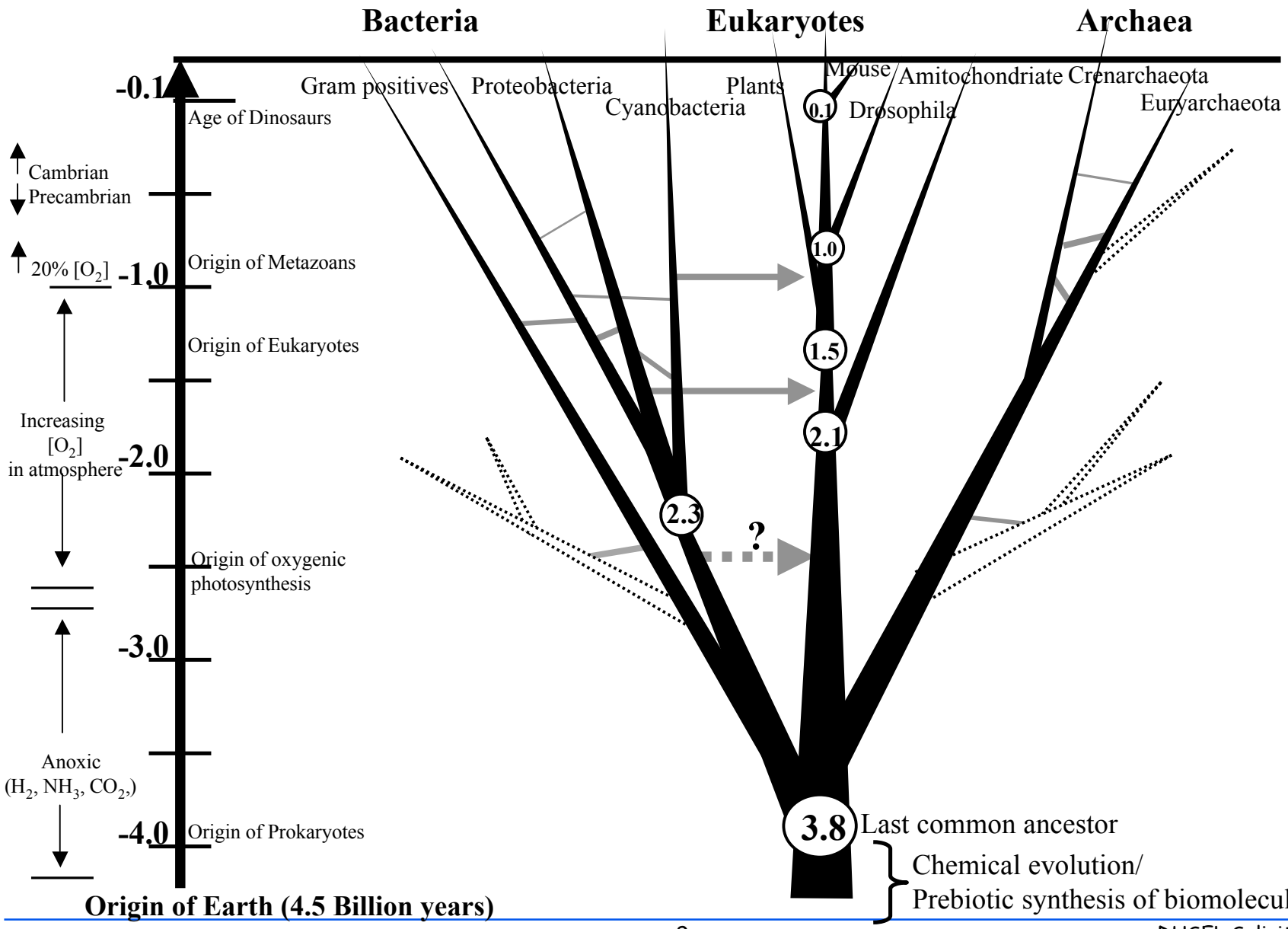
Did life on the earth's surface come from underground?

* Is the subsurface a refuge for microbial life? (Catastrophic events on earth, other planets such as Mars)
* Is the origin of life on earth the subsurface?
* Are there primitive life niches in the subsurface? (sulfur disproportionation, H2 metabolism etc.)
* Does the deep subsurface harbor ancient life?

Is there life as we don't know it?

* Unique biochemistry, e.g. non-nucleic acid based, unique energy sources?
* Is the subsurface a reservoir for unexpected biology?
• Are their molecular signatures suggestive of unique life?

The Tree of Life



Why is DUSEL Needed for Biology

4-D access is the key

- Due to heterogeneities, 3-D volume is needed to understand natural processes.
- Critical need to sample process over time
- Better subsite selection and sample targeting
- More comprehensive measurements possible, less restricted by access
- More rapid, time-sensitive measurements possible
- Preventing contamination is key

Biology Site Requirements

- Pristine sampling areas with undisturbed,ancient water; *isolated populations*
- Variation in physical and chemical conditions, hence in biological properties.
- Separated bays and tunnels varied sampling access.
- Facilities for in situ, real-time experiments.
- Sample preparation and clean rooms (microscopy, molecular analyses).
- Low level counting facilities, unique metabolic detection technologies.

Biology Desires

Goal - enhance choices for productive biological investigations.

- Integrate microbiology in the design, development, sampling and sample analysis from time zero in order to guide future drilling and lab design (part of MREFC proposal).
- Pristine sampling areas with undisturbed, *ancient* ground water.
- Variation in chemical (mineralogical) and physical (temperature and porosity) conditions, for biological variation.
- Understand, control and monitor contamination.
- Probe depth of biosphere across (*paleo*) thermal gradient,pressure gradient.

A1 experimental program

1. How deep is the biosphere?

2. What fuels the deep biosphere (dark life)?

3. How does the interplay between biology and geology shape the subsurface?

4. What are the subsurface genomes telling us: about evolution, about life as we don't know it?

Time line