The Deep Sub-Seafloor Biosphere

Bo Barker Jørgensen

Max Planck Institute for Marine Microbiology, Celsiusstr. 1, 28359 Bremen, Germany
and Center for Geomicrobiology, Ny Munkegade, Bld. 1535, Aarhus University, 8000 Århus C, Denmark

The discovery of microorganisms in several million year old sedimentary deposits, and even in basement rock, has profoundly changed our perspective on the limits of life. It is now apparent that processes in the geosphere may provide a driving force for life and that, vice versa, the sub-surface biosphere has a large impact on geological processes. The current database on prokaryotic cells in deep sediment cores indicates that the deep biosphere may comprise 10-30% of all living biomass and more than half of all microorganisms on Earth. The population densities, 10^5-10^7 cells per cm^3 down to >1 km depth in sediments of >100 million years old, vastly exceed those found in ocean water where nearly the entire marine carbon cycle takes place.

With increasing depth and age of marine sediments, microbial cells become increasingly energy limited. At several hundred meters below the sea floor population sizes are still large, yet the energy flux and the theoretical growth rate of the bacteria are orders of magnitude below anything we can understand from research on cultivated microorganisms. Thus, the sub-seafloor communities comprise a "starving majority" among the prokaryotes on Earth. Sustained supply of energy is a fundamental requirement for life, yet the quantitative constraints on the "energetic habitability" of ecosystems, or planets, are unknown. Understanding the minimum energy requirements for growth and survival may offer a means of interpreting the distribution, composition, and activity of deeply buried communities. How is it possible to maintain complex functions in prokaryotic cells at an energy flux that barely allows cell growth over thousands of years? Do these organisms have properties beyond our current understanding of microbial life, or are energy sources available that have not yet been identified? Are the deeply buried communities just relicts of a time when the sediment was originally deposited or do they respond to the modern sedimentary environment?

The search for alternative, cryptic energy sources has focused on molecular hydrogen. Interestingly, energy released from the decay of natural radio-nuclides of potassium, thorium or uranium (^{40}K, ^{232}Th, ^{238}U) everywhere in the seabed dissociates water molecules into free radicals and molecules such as H_2. This nuclear energy is therefore not only destructive to microbial cells but may also support their metabolic activity. It does not even require an external oxidant. Concurrently with H_2, water radiolysis produces oxidants such as O_2 which may be directly used for the energy generating re-oxidation of H_2.