POWER LIMITS FOR THE DEEP BIOSPHERE. D. E. LaRowe[1] and J. P. Amend[1,2], [1]Department of Earth Sciences, University of Southern California, 3651 Trousdale Pkwy., Los Angeles, CA 90089 USA, larowe@usc.edu, [2] Department of Biological Sciences, University of Southern California, 3616 Trousdale Pkwy., Los Angeles, CA 90089 USA, janamend@usc.edu.

Introduction: Considerable effort has been channeled into finding how extremes in temperature, pressure, pH, salinity and other compositional and physical variables may hinder or prevent microbial activity. This is partly in response to the relatively recent realization that microorganisms inhabit a far greater diversity of environments than previously appreciated. Many of these environments can be described as low-energy systems that host little-known organisms growing at rates far slower than what was thought possible. However, of all the variables that have been investigated as limiting life, one of the most fundamental has received much less attention: energy, and, by extension, the rate at which it is needed, power. The goal of this presentation is to demonstrate how power may constrain microbial activity, biomass and, ultimately, biogeochemical processes with the larger endgame of deciphering the power limits of life. Marine sediments are an attractive test case for this approach because they comprise a broad spectrum of energy levels and varying amounts of biomass, and they are one of Earth's largest habitats [1],[2].

Approach: In order to stay viable, microorganisms must catalyze reactions that yield enough energy (J mol^{-1}) at a rate (mol s^{-1}) that is sufficient to reach a power (J s^{-1}) level that they require under a given set of circumstances. The amount of energy available from a given catabolic reaction is a function of the temperature, pressure and composition of the environment in which it is occurring. With this information, the Gibbs energy of that reaction can be computed. Because numerous environments have been described using these parameters, it is possible to calculate Gibbs energies for a large number of catabolic reactions in a large number of settings.

Arriving at reaction rates in situ is more complicated. Typically, some form of modeling must be used to convert chemical profiles describing a system into consumption rates, e.g., [3]. In this presentation, we focus on heterotrophy and utilize a reactive continuum model to compute rates of organic matter degradation in marine sediments.

We then combine these reaction rates and Gibbs energies to show how much power is being used in a sediment core from the South Pacific Gyre (SPG), an ultra-low energy setting [4]. Furthermore, we have applied a reaction transport model to global marine sediments in order to better understand how power availability influences the amount of biomass in marine sediments on a planetary scale.

Results: We show a direct link between power consumption in SPG sediments and the amount of biomass (cells cm^{-3}) found in it. The power supply resulting from the aerobic degradation of particular organic carbon (POC) at IODP Site U1370 in the South Pacific Gyre is between ~ 10^{-12} and 10^{-16} W cm^{-3}. In addition, we have combined cell count data and calculated power supplies to determine that, on average, the microorganisms at Site U1370 require 50 – 3500 zW cell^{-1}, with most values under ~300 zW cell^{-1}. Furthermore, we carried out an analysis of the absolute minimum power requirement for a single cell to remain viable to be on the order of 1 zW cell^{-1}.

The global organic degradation model reveals the fate of all particulate organic carbon, POC, deposited at the seafloor and buried in marine sediments over the last 2.6 million years. Masses and fluxes of POC to and through various sediment horizons are calculated, as are the rates at which microorgansims degrade POC as a function of sediment depth. Calculated Gibbs energies of POC oxidation reveal that traditional, laboratory-measured rates of microbial energy utilization do a poor job of estimating the number of microbial cells in marine sediments [5].

Both the site specific study in the South Pacific Gyre and the global model developed here illustrate that microorgansisms in low energy environments can persist on exceedingly small power levels (on the order of zeptowatts cell^{-1}). These very small power levels allow us to imagine microbial life on other planetary bodies where power levels are also low. However, with such minimal activity levels, these organsims process ultra tiny amounts of substrate and therefore produce little signal of their metabolic activities.

References:

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