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Research Article

Microbial survival mechanisms within serpentinizing Mariana forearc sediments

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Abstract

Marine deep subsurface sediment is often a microbial environment under energy-limited conditions. However, microbial life has been found to persist and even thrive in deep subsurface environments. The Mariana forearc represents an ideal location for determining how microbial life can withstand extreme conditions including pH 10–12.5 and depleted nutrients. The International Ocean Discovery Program Expedition 366 to the Mariana Convergent Margin sampled three serpentinizing seamounts located along the Mariana forearc chain with elevated concentrations of methane, hydrogen, and sulfide. Across all three seamount summits, the most abundant transcripts were for cellular maintenance such as cell wall and membrane repair, and the most abundant metabolic pathways were the Entner–Doudoroff pathway and tricarboxylic acid cycle. At flank samples, sulfur cycling involving taurine assimilation dominated the metatranscriptomes. The *in situ* activity of these pathways was supported by the detection of their metabolic intermediates. All samples had transcripts from all three domains of Bacteria, Archaea, and Eukarya, dominated by *Burkholderiales*, *Deinococcales*, and *Pseudomonales*, as well as the fungal group Opisthokonta. All samples contained transcripts for aerobic methane oxidation (*pmoABC*) and denitrification (*nirKS*). The Mariana forearc microbial communities show activity not only consistent with basic survival mechanisms, but also coupled metabolic reactions.

Keywords: IODP, mariana forearc, metatranscriptome, microbial survival, serpentine mud volcano, subsurface sediment

Introduction

The marine deep subsurface covers a vast area of approximately 70% of the Earth's surface. Within the marine deep subsurface there are various environments including abyssal plains, hydrothermal vents, gas hydrates, and tectonic plate interactions, which serve as microbial habitats (Orcutt et al. 2011). Many studies have focused on which microorganisms colonize these types of environments and the potential for their activity (Biddle et al. 2008, Biddle et al. 2011, Brazelton et al. 2012, Reese et al. 2012, Baker and Dick 2013, Orcutt et al. 2013, Labonté et al. 2015, Meyer et al. 2016, Marshall et al. 2018, Tully et al. 2018, Farag et al. 2020). The current estimate for microbial diversity in the marine subsurface is approximately 7.9×10^3 to 6.1×10^5 bacterial amplicon sequence variants (ASV) and 3.3×10^4 to 2.5×10^6 archaeal ASVs (Hoshino et al. 2020), yet there are many microbial groups and metabolic processes awaiting discovery (Hug et al. 2016, Hoshino et al. 2020, Nayfach et al. 2020). A few studies have further elucidated putative activities of *in situ* microbial communities including the Baltic Sea Basin (Zinke et al. 2017) and Peru Margin (Orsi et al. 2013). This dynamic environment offers a unique Earth analog to extraterrestrial exploration due to serpentinization reactions occurring within the Mariana forearc mud volcanoes. Previous studies on accretionary prisms that form mud volcanoes have found microbial activity to use surrounding geochemical resources such as sulfide, sulfate, nitrogen, and methane for energy (Jones et al. 2015). Serpentinization at the Mariana forearc releases methane and hydrogen gas which can be moved upward through these mud volcanoes and be used for metabolic processes by microbial communities. This provides an opportunity to understand how geophysical processes impact the survival of the microbial community.

The Mariana forearc is a nonaccretionary subduction zone that lies less than 100 km west of the Mariana Trench (Uyeda 1982, Curtis et al. 2013, Fryer et al. 2017). The Mariana system consists of an active subduction zone where the Pacific plate is consistently subducting beneath the Philippine plate. A chain of serpentinite mud volcanoes have formed in this forearc along the intersection of faults in the Philippine plate. Modern serpentine mud volcanoes on Earth have only been found along the Mariana forearc thus far (Fryer et al. 2020); however, Earth's geologic record indicates that serpentine volcanism occurred as early as 3.8 billion years ago (Pons et al. 2011, Fryer et al. 2020). The origination of the serpentinite minerals found within the Mariana forearc sediments occurs from the subducted overlying seawater on the Pacific Plate interaction with the ultramafic, olivine-rich minerals contained on the overlying Philippine Plate (Fryer et al. 2020). Faults within the Philippine and Pacific plates permit fluids, mud, and rocks to be transported up through the resulting conduits, cre-

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