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Novel Lineage of Archaea Dominates Inside an Inactive Deep-Sea Sulfide Chimney

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Origin of life is presumed to emerge from deep-sea hydrothermal vents according to theory of surface metabolism. It is known that microbial habitat is harbored at oxidative condition in inactive metal sulfide deposits formed at deep-sea hydrothermal vents. However the dissolution of metal sulfides is exceedingly slow under anaerobic conditions. It has distrusted the habitat of microbe in such structure, which requires physiological adaptation for microbial life to thrive within metal sulfides. Recent studies have revealed microbial life is also harbored under extremely oligotrophic conditions represented to the crustal biosphere. There might be interaction between anoxic water, metal sulfide, and microbial life. Previous studies of metal sulfide deposits at deep-sea hydrothermal vents have clarified that after the cessation of hydrothermal venting, microbial communities are shifted from thermophilic to psychrophilic microorganisms. However, the dominant microbial populations inside the metal sulfide structures remain to be clarified, because dominant bacterial and archaeal lineages are different between Central Indian Ridge (CIR) and Southern Mariana Trough (SMT). An inactive metal sulfide chimney was collected from SMT and characterized by mineralogical methods such as X-ray diffraction (XRD) pattern analysis and scanning electron microscopy (SEM) coupled to energy-dispersive spectroscopic (EDS) analysis, by which a CIR sample has been characterized. Pyrosequencing of 16S rRNA gene sequences of prokaryotes inside and outside the metal sulfide chimney coupled to quantitative PCR analysis of archaeal populations revealed that the interior and the exterior of the chimney structure were dominantly colonized by bacteria of Nitrospirae phylum and archaea of deep-sea hydrothermal vent euryarchaeal group (DHVE) 6, respectively. As Nitrospirae bacteria are also dominant in CIR, Nitrospirae bacteria are clarified to be cosmopolitan residents in inactive metal sulfide chimneys. This notion is important, because Nitrospirae bacteria are abundantly found in the deep terrestrial crust. DHVE 6 archaea are found in inactive metal sulfide chimneys in SMT, while DHVE 6 archaea are not detected in a mineralogically identical chimney in CIR. As the construction of maximum likelihood trees and the calculations of bootstrap values revealed that most of DHVE 6 sequences from SMT formed a firm monophyletic clade and distinct from other localities and environments, DHVE 6 archaea from SMT are likely adapted to thrive in anaerobic metal sulfide structures. The observations of microbial cells in the interior of the metal sulfide structure without oxidative alteration supports this inference. The existence of anaerobic microbial life in inactive metal sulfide structures has implications for the crustal biosphere and potentially for the emergence of life on the early Earth, because of the analogy to physicochemical conditions around metal sulfide minerals.

Keywords: deep-sea hydrothermal vent, metal sulfide deposit, Archaea, DHVE6