

The discovery and comparative genome characterizations of magnetosome-bearing bacteria from a deep-sea metal sulfide chimney

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Magnetotactic bacteria (MTB) are known to produce magnetosomes: single-domain magnetite (Fe_3O_4) and/or greigite (Fe_3S_4) encapsulated in cytoplasmic membrane. To orient cells along the geomagnetic field, magnetosomes are aligned into chains for strong dipole moment. Although intensive studies have been conducted for MTB inhabiting terrestrial and shallow marine sediments, MTB have not been found from deep-sea environments, despite the frequent detection of magnetofossils in deep-sea sediments. In this study, a metal sulfide chimney formed on the seafloor of South Mariana Trough was investigated for the occurrence of MTB. During magnetic separation from non-magnetic material, magnetic particles mainly composed of vivianite [$\text{Fe}_3(\text{PO}_4)_2 \cdot 8\text{H}_2\text{O}$] attracted magnetic cells. After further separation of magnetic cells from vivianite particles, the visualization of microbial cells by catalyzed reporter deposition-fluorescence in situ hybridization and transmission electron microscopy unveiled the occurrence of metabolically active bacteria associated with magnetosomes from the metal sulfide chimney. Teardrop shaped magnetosomes and dominant 16S rRNA gene sequences related to *Nitrospirae* MTB in the metal sulfide chimney suggest the magnetosome-bearing cells might belong to *Nitrospirae*. However, the lack of magnetosome chains in the observed cells is distinct from those observed in *Nitrospirae* MTB. A near-complete genome that is representative of the dominant chimney *Nitrospirae* was reconstructed after metagenomics analysis of a whole microbial community. In contrast to the fact that previously known MTB have magnetosome-related genes bundled within magnetosome island, magnetosome-related genes were sparsely positioned in the reconstructed *Nitrospirae* genome. As homologous genes involved in the formation of magnetosome chains were deficient in the *Nitrospirae* genome, it is likely that the *Nitrospirae* genome is reconstructed from microbial cells associated with magnetosomes without chains. The ecological function of unaligned magnetosomes is speculated to attach magnetic vivianite particles for phosphate uptake, because phosphate is generally scarce in deep-sea environments. The further ecological and genomic investigations will shed light on the antiquity and evolutionary history of MTB.