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Physical and magnetic microstructure and three-dimensional arrangement of greigite crystals in magnetotactic bacteria

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Magnetotactic bacteria comprise a number of aquatic species that orient and migrate along geomagnetic field lines. This behavior is based on the presence in the cells of magnetosomes, membrane-enclosed mineral grains of magnetite (Fe_3O_4) or greigite (Fe_3S_4). Whereas the structural and magnetic properties of magnetite magnetosomes have been studied extensively, the properties of greigite magnetosomes are less well known. Here, we report the first application of energy-filtered transmission electron microscopy (EFTEM), electron tomography (ET) and off-axis electron holography (EH), to study the elemental composition, three-dimensional arrangement, crystallography, morphology and magnetic microstructure of greigite grains in uncultured magnetotactic bacteria. Two cells, collected from a sulfidic salt marsh pool near Morro Bay, California, were selected for study: a cell with a single flagellum, and a cell undergoing division. The greigite magnetosomes in each cell are arranged in a multiple chain-like structure. However, both the morphologies and the orientations of the crystals are more irregular than in magnetite-producing bacteria. Crystals along the main axis of the magnetosome chain appear to be more strongly magnetic than crystals at the ends of the chain and those further from the chain axis. The three-dimensional morphologies and arrangements of the greigite crystals are correlated with the overall magnetic properties of each cell.