Identification of magnetotactic bacteria and their fossils with ferromagnetic resonance

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Whereas most biomineralizing bacteria produce minerals extracellularly as a metabolic byproduct, with crystal properties controlled abiotically, magnetotactic bacteria produce intracellular magnetic crystals (of either magnetite or greigite) under biological control within membrane-bounded organelles (magnetosomes). Because the bacteria use the crystals to orient themselves, natural selection has acted to optimize the amount of magnetic moment produced for the number of iron atoms used.

Magnetosome crystals thus typically have an array of distinctive physical properties. In particular, their size and shape fall within narrow distributions. The crystals are almost always single domain and frequently elongate. In addition, they are almost always arranged in chains.

Classical rock magnetic techniques allow the identification of single domain particles and some assessment of their size distribution. Ferromagnetic resonance spectroscopy (FMR) allows assessment not only of the size and shape distribution, but also of crystal elongation and chain arrangement.

Our measurements of the magnetotactic bacterial strains MV-1 (which produces chains of elongate magnetite crystals) and AMB-1 (which produces chains of equidimensional magnetite crystals), as well as of AMB-1 mutants that produce isolated equidimensional and elongate crystals, allow identification of the contributions of elongation and chain structure to the ferromagnetic resonance spectra of magnetotactic bacteria.

All magnetotactic bacteria measured so far fall in a distinct region of the space defined by absorption peak position, width, and asymmetry. Lysed bacteria can produce spectra that resemble those of sediments in which magnetization is largely carried by diagnetically altered magnetosome crystals. Measurements of modern and ancient sediments indicate that FMR can distinguish sediments with magnetic mineralogy dominated by biogenic magnetite from those with magnetic mineralogy dominated by detital input.