Magnetite Formation in Solution and Magnetotactic Bacteria

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The iron oxide magnetite (Fe_3O_4) is an abundantly occuring mineral in high temperature rocks. However, it also forms through redox processes in Earth surface environments, and it is an important biomineral in a number of organisms. Here we present two mineral formation studies: the nucleation and growth of synthetic magnetite formed by co-precipitation of ferrous and ferric iron in aqueous solution [1]; and the biomineralization in the magnetotactic bacterium *Magnetospirillum magneticum* AMB-1 [2]. Both studies point to a nucleation and growth process that involves the aggregation of nanometric primary particles or clusters.

Cryogenic transmission electron microscopy enabled us to demonstate that 1-2 nm large primary particles without resolvable substructure are precursors to magnetite nanoparticles in water. In the magnetotactic bacteria we observed a phase transformation from ferric (oxyhydr)oxides of similar size and large surface area morphology.

At first glance our experimental observations on nanomagnetite appear inconsistent with classical nucleation-growth models and rather correspond to so-called aggregation-based growth processes [3]. Conventionally, the formation of crystalline materials is described by atoms or molecules assembling directly from solution. To describe aggregational processes of nanoparticle precursors, alternative non-classical growth models have been developed. For our observations we propose a possible treatment approach within the classical thermodynamical framework.

[1] Baumgartner *et al* (2013), *Nat. Mater.* **12**, 310-314
[2] Baumgartner *et al* (2013), *PNAS* **110**, 14883-14888
[3] Banfield *et a.* (2000) *Science* **289**, 751-754