Paleomagnetic tests to distinguish the origin of ALH84001 magnetite

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The magnetite crystals within Martian meteorite ALH84001 carbonate are putative microfossils because of their striking resemblance to magnetite produced by magnetotactic bacteria [1, 2]. If these crystals were in fact formed biologically they would be entrained within the carbonate through a depositional process. An alternative, abiotic, origin hypothesis involves the generation of this magnetite from the chemical alteration of the iron-bearing carbonate that hosts it [3, 4]. These scenarios are distinguishable paleomagnetically.

The Fuller test of NRM measures the efficiency of magnetization of a sample [5, 6]. For samples which have a magnetization from a depositional process, as would be the case for magnetite crystals produced prior to entrainment, the efficiency of the magnetization is ~100 times weaker as compared to magnetization acquired through chemical alteration. This is due to gravity and brownian motion which act on the crystals in the water column during deposition. The ARM susceptibility test probes the interparticle interactions within a sample [7]. Magnetite crystals formed prior to deposition are likely to clump together upon deposition [8]. These clumped crystals will have large interparticle interactions, as opposed to evenly distributed particles formed chemically.

With help of K. Thomas-Keprta we extracted four pieces of magnetite bearing carbonate from ALH84001 and using high resolution scanning SQuID microscopy applied these two tests. We find that the magnetite crystals are strongly interacting. However, we also observe that the efficiency of magnetization is high, consistent with a chemical origin in an Earth-strength field, or potentially, deposition in a much stronger field as may have been the case on Mars at 4 Ga.

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