Hints of ~3.4 billion-year-old magnetofossils: Possible early coevolution of life and the geodynamo

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Evidence for a relatively strong Paleoarchean to Hadean geomagnetic field from single crystal paleointensity studies (Tarduno et al., Science, 2010, 2015; Tarduno et al., PNAS, 2020) is important for our understanding of the evolution of life because of the role magnetic shielding plays in planetary habitability. The presence of the geomagnetic field also implies that magnetotaxis could have been employed by bacteria billions of years older than the oldest reported putative magnetofossils. Here we investigate this possibility. We use rock magnetism, electron microscopy, and ferromagnetic resonance to test for the presence of bacterial magnetite particles in micro-paleo-redox environments of the ~3.40 Ga Buck Reef Chert of the Barberton Greenstone Belt, South Africa. Magnetic hysteresis properties of bulk samples show a variety of rock magnetic behaviors, including multidomain, pseudo-single domain, single domain, and wasp-waisted curves; the latter indicate grain and/or compositional mixtures. Electron microscopy of magnetic separates and in-situ particles from the Buck Reef Chert show cubo-octahedral to quasi-rectangular and hexagonally shaped grains that fall within a stable single domain range typical of biogenic magnetite. Ferromagnetic resonance spectra from bulk samples appear asymmetrical and skew towards low fields, suggesting a magnetic anisotropy that is similar to the spectra seen from some strains of modern magnetotactic bacteria. Thus, while there is clearly a mixture of magnetic particles within the Buck Reef Chert, as expected for typical sediments, our data suggest one component could be ancient relic magnetosomes. Thus, these observations lend support for an early coevolution of magnetotactic bacteria and the geodynamo.

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