Geophysical Research Abstracts
Vol. 14, EGU2012-5783, 2012
EGU General Assembly 2012

Tests for intact and collapsed magnetofossil chains

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In recent years, new techniques for the detection of magnetofossils have been proposed, based on their unique first-order reversal curves (FORC) and ferromagnetic resonance (FMR) signatures. These signatures are related to the non-interacting (FORC) and strongly uniaxial anisotropy (FMR) of isolated chains of magnetic particles. However, little is known about the fate of these signatures in sediments where magnetosome chains collapsed during early diagenetic processes. Due to the impossibility of observing the particle arrangement in-situ, the structure of collapsed chains can only be inferred from TEM images of magnetic extracts and from first-principles consideration on the mechanical stability of magnetosome chains once the biological material around them is dissolved. The magnetic properties of double chains, produced by some strains of cocci, are also not known. According to these considerations, four main magnetofossil structures were taken into consideration: (1) isolated, linear chains, (2) double, half-staggered chains, where the gaps of one chain face the magnetosomes in the other chain, (3) double chains with side-to-side magnetosomes, which might result from a "jackknife" type of collapse of a single, long chain, and (4) zig-zag collapsed chains of elongated crystals, where the magnetosome long axes are perpendicular to the chain axis. The collapsed structures might be relevant in sediments where magnetofossils carry a significant part of the remanent magnetization, because chain collapse tends to cancel the original natural remanent magnetization. Detailed models for the hysteretic and anhysteretic properties of structures (1-4) have been calculated by taking realistic distributions of magnetosome size, elongation, and spacing into account, as inferred from a number of published TEM observations. Model calculations took a total of >2 years continuous running time on two computers in an effort to obtain realistic results, which are shown here for the first time. These results match measurements obtained previously on magnetosome-rich sediments in smallest details, showing that the identification of distinct intact and collapsed chain structures is possible. On the other hand, these results show that caution should be used when interpreting sediment hysteresis properties as mixtures of single domain (SD), multidomain (MD), and superparamagnetic (SP) particles; because some collapsed chain structures closely mimic SD-MD-SP mixing trends in a Day plot, although being made only of SD particles.