Synthetic clay-magnetite aggregates designed for controlled deposition experiments

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The behavior of magnetic particles in fluid environments is key to the acquisition of detrital remanence magnetization and is essential to a multitude of industrial applications. This study introduces a series of synthetic clay-magnetite aggregates whose physical attributes can be tailored for controlled depositional experiments. We describe the mineralogical structure and magnetic behavior of montmorillonite platelets coated with nanometer-scale magnetite crystals using both electron microscopy and rock magnetism techniques. Selected area electron diffraction of the magnetite and the montmorillonite host shows no evidence of preferred orientation or oriented aggregation. Grain size distributions of magnetite in three different clay-magnetite assemblages were directly measured using conventional bright-field transmission electron microscopy. The spacing of the magnetite grains and their three-dimensional distribution around individual clay platelets was imaged using a tomographic reconstruction generated from high-angle annular dark-field (HAADF) images. The grain size distributions determined from the bright-field images and the tomographic reconstruction agree within error with estimates derived from magnetic granulometry techniques based on magnetic hysteresis and low-field susceptibility measurements. All three samples behave superparamagnetically at room temperature, and display increasing levels of single domain behavior as the samples are cooled to liquid nitrogen temperatures (-195°C). Off-axis electron holography images show that superparamagnetic grains are also stabilized into flux closure structures at -195°C. The average spacing between adjacent magnetite crystals and the overall platelet shape of the aggregates creates an anisotropy of magnetic susceptibility that allows assemblages to align with external magnetic fields at

room temperature. By adjusting the dimensions and concentrations of the magnetite grains in these aggregates, we can create well-characterized materials with known grain size distributions that are ideally suited for controlled depositional experiments.