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# Modelling sedimentary remanent magnetizations using the Discrete Element Method

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In the past, investigations of the formation mechanisms of sedimentary remanent magnetizations were mainly based on laboratory redeposition and consolidation experiments. These analyses provided some empirical understanding of the influence of grain size, lithology and consolidation state on remanent magnetization, but left the relevant microscale processes of mobilization, orientation and fixation of the magnetic carriers unknown. We present a series of numerical models based on the Discrete Element Method (DEM) which are used to investigate the influence of magnetic particle shape, compaction, van der Waals forces, bioturbation and seismicity upon sediment remanence acquisition.
The Discrete Element Method provides a description of the behavior of a numerical granulate material subject to a variety of different forces. This makes DEM suitable for modelling sediment above, at and below the sediment-water interface. In the case of modelling sediment behavior, gravity, particle-particle contacts, friction, magnetic torque, van der Waals forces and overlying pressure can be taken into consideration. Our model consists of a two-dimensional container filled with particles based on spheres with a grain-size range typical of ocean sediments. Particle-particle and particle-container collisions are represented by a linear relationship for viscoelastic contacts. Within the particle population, a certain number of particles (10%) are assumed to be magnetic and experience a magnetic torque in the presence of an external field. Using this simple model configuration, a number of aspects of sedimentary remanences can be investigated.
Including van der Waals forces in our model, it can be observed that for grain-sizes typical of those found in ocean sediments, particle flocs are produced in the water column and a highly porous fabric forms below the sediment-water interface. If flocs

contain randomly oriented magnetic particles, as might be expected in turbulent water, the resulting sedimentary remanence is less than 10% of the potential maxiumum value. If, instead, the magnetic particles are given the opportunity to align to the field before forming flocs, as might be expected in still water, the resulting magnetization varies between 30 and 40%. This shows the influence of pre-depositional disturbance processes on the level of acquired sedimentary remanence.

Compacting the sediment with an overlying pressure causes a dispersion of the magnetic particles' orientations and a shallowing of the mean magnetization direction. This shallowing corresponds to an inclination error and is a function of pressure and magnetic particle aspect-ratio. By tilting the base of the model container, deposition onto a slanted bedding plane can be simulated, making inclination a function of both field direction and bedding plane angle.

By generating expanding and contracting particles at random positions within an existing sediment pack we simulate a microbe passing through the model plane. This provides a method to assess the effects of bioturbation on remanent magnetization at the sediment-water interface. Seismicity provides another potential form of sediment disturbance. Vibrating the walls of the model container allows simulated waves with different frequencies to move through the sediment.

Our model results show that the strength of the DEM method in representing interacting systems of particles makes it a powerful tool for modelling particle behavior above, at and below the sediment-water interface.