



Out-of-phase magnetic susceptibility and environmental magnetism

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Presence of ultrafine magnetic particles in rocks, soils and environmental materials is traditionally investigated by frequency-dependent susceptibility (fdMS) consisting of susceptibility measurement at two or more operating frequencies and the preferred orientation of these particles can be investigated through anisotropy of frequency-dependent susceptibility (fdAMS).

In the instruments that measure the susceptibility in alternating magnetic field, the measured susceptibility can be resolved into a component that is in-phase with the applied field (ipMS) and a component that is out-of-phase (opMS). For materials in which the opMS is due to viscous phenomena (presence of magnetic particles on transition between superparamagnetic and stable single domain states with sufficiently wide range of relaxation times), there is theoretical relationship between fdMS and opMS, called the $\pi/2$ law. Approximate formulas exist for the conversion of the opMS into the fdMS and vice versa and their validity is tested on various loess/palaeosol samples. Consequently, the opMS, which is measured simultaneously with the ipMS during one measuring process, can be used in indicating the ultrafine magnetic particles even the measurement is made at one frequency, only. The width of the particle size interval investigated by the fdMS is controlled by the operating frequencies used. In case of opMS, the interval is slightly narrower than that in the fdMS and depends also on the operating frequency used.

The preferred orientation of magnetically viscous particles can be investigated through the fdAMS and, newly, also through the anisotropy of out-of-phase susceptibility (opAMS). While the correlations between fdMS and opMS in loess/palaeosol sequences are excellent, the relationship between fdAMS and opAMS is more complex. Nevertheless, the opAMS has large potential for investigating preferred orientation of magnetically viscous particles, mainly, as it is measured simultaneously with the ipAMS.