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Automated measurement of viscous decay of magnetic remanence: a tool for extending the grain-size interval for magnetic granulometry

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In some geological and environmental processes, such as diagenesis, very low grade metamorphism, pedogenesis, anthropogenic pollution, new ultra-fine magnetic minerals may be formed. The variation in content of these minerals is routinely investigated by frequency-dependent magnetic susceptibility. However, the size interval of magnetic particles detectable by this method is relatively narrow. Using the most common instruments, the MS2B susceptibility meter (Bartington Instruments) and the MFK1-FA Kappabridge (Agico), this interval in blocking volumes ranges from 1.7 $\times$ 10-24 m3 to 2.3 $\times$ 10-24 m3 in magnetite. Using lower operating frequency, for example 10 Hz in the 7130 AC susceptometer (Lake Shore Cryotronics), the upper limit of the blocking volume can be shifted to 3.1 $\times$ 10-24 m3. Using higher operating frequency, for example 500 kHz in the SM-105 susceptibility meter (ZH-Instruments), the respective lower limit can be shifted to 1.1 $\times$ 10-24 m3. Assuming a broad size distribution of the ultra-fine magnetic particles spanning across the SP/SSD boundary we suggest to assess their presence by quantification of their viscous magnetization decay. For that purpose we use a recently-developed LDA5-PAM1 pulse magnetizer coupled with a JR6 spinner magnetometer (both Agico). Instrument control software is interconnected in such a way that both instruments work in the same time frame, i.e. the exact moment of DC pulse termination is used as a zero time for evaluation of time-dependent viscous decay. Magnetic remanence is then measured repeatedly as a function of time. Exponential decay curves are fitted on the acquired data and the relative ratio of viscous and non-viscous particles is estimated. This method works with much longer relaxation times compared to those of susceptibility measurements, ranging from 20 to 300 s, with the corresponding blocking volumes being 3.9 to 4.4 $\times$ 10-24 m3. Our method is tested on the samples from three loess/paleosol sections located in the Czech Republic. The relative amount of the ultra-fine particles assessed by the suggested viscous decay method can be very well correlated with the results obtained from the frequency-dependent and out-of-phase susceptibility measurements.