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Frequency-dependent susceptibility of rocks, soils and environmental materials: multi-frequency model relationship to magnetic granulometry

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In palaeoclimatology and environmental science, the frequency-dependent susceptibility of rocks, soils and environmental materials is traditionally interpreted as resulting from interplay between superparamagnetic (SP) and stable single domain (SSD) or even multidomain (MD) magnetic particles even though some other phenomena, such as eddy currents, may also play a role mainly at high operating frequencies. The models to investigate the frequency-dependent susceptibility, which were originally developed by Eyre (1997, GJI) and Worm (1998, GJI) for two operating frequencies (470 Hz and 4700 Hz possessed by the Bartington susceptibility meter), were extended to multiple operating frequencies (976 Hz, 3904 Hz, and 15616 Hz possessed by the KLY1-FA Kappabridge and 100000 Hz and 250000 Hz).

The Xfd parameter, quantitatively characterizing the frequency-dependent susceptibility, is the higher the larger is the difference between the logarithms of the operating frequencies used in its determination. From the measuring point of view, it would be best to use very different frequencies. In this case, one can infer whether the SP grains are present or not, but nothing can be said of their size distribution. For this reason, it is better to work at more frequencies than two, because this enables us to decide whether the presumed log-normal distribution of magnetic grains is narrow or wide.

The Xfd parameter measured on the whole rock (soil) may be much lower than that of the ferromagnetic fraction with frequency dependent susceptibility due to the effect of the fractions with frequency-independent susceptibility (typically diamagnetic and paramagnetic fractions). Then, the low value of the Xfd parameter does not necessarily indicate low amount of the SP particles within the ferromagnetic fraction.

A new Xr parameter is introduced that is not affected by fractions with frequency-independent susceptibility and indicates only the ferromagnetic fraction with frequency-dependent susceptibility; for determining it an instrument working at three operating frequencies is necessary. It can trace grain volume changes during progressive processes.

Our modelling provides us at least with theoretical basis for comparing the data by the MFK1-FA Kappabridge and the Bartington MS2 instrument and, moreover, it enables us to investigate whether multiple frequencies have at least theoretical advantages compared to two frequencies approach used till now and helps us to answer the question whether spending energy in developing high frequency instruments is reasonable.