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Environmental significance of the maghemite/hematite relationship in aerobic soils

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Soil formation usually enhances magnetic signals (e.g. low-field mass magnetic susceptibility, χ), mainly through neoformation of fine-grained magnetite and/or maghemite. Recent studies have provided evidence that magnetic enhancement in aerobic soils not affected by thermal transformation of iron oxides or detrital magnetic inputs is mostly due to the neoformation of maghemite, which is later transformed into hematite. The idea that maghemite and hematite are formed concomitantly is consistent with (i) the observation that soils in which goethite but not hematite was formed during pedogenesis are generally much less magnetically enhanced that are their hematitic counterparts, and (ii) recent *in vitro* experiments that showed 2-line ferrihydrite doped with ligands commonly found in the soil solution (e.g. phosphate or citrate) to be transformed in aerobic conditions into a maghemite-like phase ("hydromaghemite") that grew from the superparamagnetic (SP) into the single domain (SD) grain size before its rapid conversion into hematite.

If the ferrihydrite → maghemite → hematite model applies to soil, the grain size distribution (GSD) for maghemite and the hematite/maghemite (Hm/Mh) ratio should depend logically on the duration of pedogenesis and the rates of (1) weathering of Fe-bearing minerals to ferrihydrite; (2) transformation of ferrihydrite into hydromaghemite; (3) growth of hydromaghemite particles from the SP to the SD region; and (4) transformation of SD hydromaghemite into hematite. These rates are dictated in turn by pedoenvironmental factors (e.g. composition of the soil solution, and tem-

perature and moisture regimes). Our recent studies on the Fe oxides of Chinese Loess Plateau paleosols and modern soils in areas with cold temperate, Mediterranean, and tropical climate provide evidence that the values of percent frequency-dependent χ (χ_{FD}%) —a good proxy for GSD of maghemite— and the Hm/Mh ratio can be rationalized on the basis of soil (paleo)climate and degree of evolution. Moreover, the combination of χ_{FD}%, the Hm/Mh ratio, and several indicators of the degree of weathering provides a better tool for paleoclimatic reconstructions than does the current use of χ alone.