Numerous nano-sized magnetite and hematite inclusions in muscovite in loess

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Magnetic enhancement of Chinese loess–paleosol sequences has been used extensively as a proxy for the East Asian summer monsoon. This magnetic enhancement occurs due to neoformation of pedogenic ferrimagnets. However, these ferrimagnets are difficult to extract; consequently, how they are formed is not well understood. Here, we show the shape of the crystals and the presence of nano-sized pedogenic magnetic particles using electron microscopy, a synchrotron radiation X-ray diffraction technique, and rock magnetic methods. The magnetic particles comprise pedogenic magnetites, detrital magnetites with maghemite shells, and detrital/pedogenic hematites. Among the fraction samples, the medium grain-size (1–10 μm) fraction was responsible for most of the magnetic enhancement of the paleosols. Magnetic extraction experiments revealed that muscovites and chlorites in the paleosol samples showed weak spontaneous magnetization. In the medium grain-size paleosol fraction, we found a weathered muscovite grain that included many hundreds of nanometer-sized magnetite and hematite particles in aggregates with biotites, which are Fe-bearing silicates. There were similar aggregates surrounding muscovite and chlorite fragments. The concentration of pedogenic magnetite/hematite inclusions was much higher in this muscovite grain than in the submicron-sized iron oxides found on the silicate surfaces. The nano-sized magnetite/hematite inclusions must be responsible for the weak spontaneous magnetization of the muscovites and chlorites, significantly contributing to the magnetic enhancement of the mature paleosols. These magnetite inclusions are mainly responsible for the paleosol pseudo-single-domain magnetic properties extensively observed across the Chinese Loess Plateau. The protective silicates account for the low extraction efficiency and the near absence of oxidation by surrounding air.

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