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The complex magnetic phenomenology of the ilmenite-hematite solid-solution series

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In their importance to rock magnetism, solid solutions in the hematite-ilmenite system, Fe_2O_3-$FeTiO_3$, are second only to those of magnetite-ulvöspinel, Fe_3O_4-Fe_2TiO_4. Naturally occurring $(1-X)Fe_2O_3$-X $FeTiO_3$ solid solutions exhibit complex magnetic properties owing to exsolution and cation ordering that are presumably induced by slow cooling. Studying the magnetic properties of synthetic single-phase samples can help to elucidate the properties of the more complex natural intergrowths, that exhibit extraordinary magnetic properties, such as lamellar magnetism and large low-temperature exchange bias. The magnetism of $FeTiO_3$-rich solid solutions may be of fundamental importance in interpreting the magnetism of cold dead planets and asteroids, which formed in environments that are more reducing than Earth's. The low-temperature meta-stable phase diagram of the ilmenite-hematite solid-solution series is known to contain several magnetic transitions and cross-overs. We present new magnetic data to define these boundaries. These comprise Curie temperatures, frequency- and amplitude-dependent susceptibility, magnetic viscosity and hysteresis data. The measurements shed new light on low-temperature spin-glass properties, superparamagnetic behavior of ilmenite-rich solutions, and on internal variations within the ferrimagnetic region between $X \approx 0.4$ and $X \approx 0.87$. Physical models of exchange-coupling networks can be used to understand the observed variations in terms of percolation thresholds or exchange-link clusters. Morevover, clear magnetic differences have been observed between samples of identical composition but varying synthesizing conditions below or above the order-disorder transition.