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First robust estimates of the fundamental magnetic parameters for greigite

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A small number of fundamental magnetic parameters, such as the spontaneous magnetization (Ms), the magnetic anisotropy constant, and the exchange constant control the magnetic properties of a magnetic mineral and therefore dictate how well it records magnetic information. A detailed understanding of the recording fidelity of magnetic minerals can only be properly obtained by determining the fundamental magnetic parameters. In contrast to magnetite and other common terrestrial magnetic minerals, the fundamental magnetic parameters for the magnetic iron sulphide mineral, greigite (Fe3S4), remained unknown until our recent work. Production of pure greigite samples has made it possible to establish some of the fundamental magnetic parameters. The Ms of greigite was determined to be 59 Am2kg-1 (equivalent of 3.13 μB/formula unit (f.u.)) from magnetic measurements and 3.03 μB/f.u. from neutron scattering. Neutron scattering, Mössbauer spectroscopy and x-ray magnetic circular dichroism have been used to probe the magnetic structure of greigite, which is a collinear ferrimagnetic structure. High-resolution neutron powder diffraction results enable unique determination of sub-lattice magnetizations of the A and B sites. At room temperature, the average magnetic moments on the two sites are almost the same ($\tilde{3}$.0 μB). At 10 K, the average magnetic moments of the A and B sites are 3.0 μB and 3.25 μB, respectively. The magnetic moment of the B sites decreases slightly between 10 K and room temperature, while the A-site moment is relatively stable as a function of temperature; this indicates that greigite is probably an R-type ferrimagnet because of a much weaker A-B exchange interaction in greigite compared to magnetite. We propose that the measured low magnetic moment in greigite is probably caused by an increased degree of covalency between iron and sulphur compared to oxygen ligands, and/or by greater delocalization of the 3d electrons. By measuring the low-temperature Ms and based on the Bloch T3/2 magnetization law, the spin wave stiffness of greigite was determined to be $\tilde{1}$93 meV•Å2, with a corresponding exchange constant JAB of $\tilde{1}$.03 meV. High-field magnetization measurement has enabled a first estimate of the anisotropy constant of greigite. These fundamental investigations provide important new magnetic data for greigite and will benefit efforts to model magnetizations of greigite in a wide range of paleomagnetic and environmental magnetic studies.