Forward and inverse modeling of magnetic data under complex magnetism effects: Remanence, self-demagnetization and magnetic anisotropy

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Natural remanent magnetization, self-demagnetization on high-susceptibility bodies and magnetic anisotropy (magnetic fabric) are three important factors affecting magnetic data forward and inverse modeling. We propose a framework for the inversion and interpretation of magnetic anomalies, in which significant remanent magnetization, self-demagnetization and magnetic anisotropy are present. The framework is based on the assumptions that the external applied field and internal self-demagnetization field are uniform, and the deflection of self-demagnetization in the total magnetization direction is negligible. First, the magnetization vector distributions are obtained from magnetic data by estimating the magnetization direction, then inverting for the magnetization intensity distribution, using the inferred magnetization direction as a constraint. Based on a priori information about the Koenigsberger ratio derived from petrophysical measurements, the direction and intensity of the remanent magnetization are obtained. The self-demagnetization factor is then computed using the finite volume method. Finally, the true-susceptibility distribution is achieved by correcting for the self-demagnetization effect.

The computational processes involved in estimating the direction and intensity of magnetic remanence and the susceptibility are not entirely stable. Generally, the best results are obtained with large Koenigsberger ratios ($Q \geq 1$). When $Q \leq 1$, the computed errors may be amplified, leading to unstable remanence directions and intensity estimations. The level of instability depends on the physical relationships between the remanence, induced and total magnetization. Some sensitivity parameters are used to assess the stability of the results. In general, larger Koenigsberger ratios are beneficial to extract more reliable remanence and susceptibility information.

The magnetic anisotropy of crustal rocks provides important evidence for studying the geological processes such as mineralization, magmatic emplacement and deep crustal stress, as it is closely related to directional recrystallization, directional alignment and stress-strain of magnetic minerals caused by sedimentation, magmatic activity, tectonic stress and metamorphism. Magnetic structure information is the physical basis for changes in the magnetic field. This magnetic anisotropic information would generate a corresponding magnetic field response that is included in the observed multi-scale magnetic data. In this study, based on the main line of relationship between magnetic anisotropy and magnetic field responses and using numerical simulations, physical model construction and field data, we first studied the magnetic field response regularities under magnetic anisotropy conditions. Based on prior information constraints such as geology, rock magnetism and geophysics, we carried out an inversion of magnetic data under magnetic anisotropy conditions and further extracted magnetic anisotropy information from inversion results.

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