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3D inversion of lithospheric magnetic data with self-constraint from Curie point depth estimation

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We present a constrained inversion method to recover a 3D magnetization (or susceptibility) model by sequentially estimating bottom depth of magnetic sources and inverting magnetic data. The method is designed for automated application to lithospheric magnetic model. As a testbed for the method, we choose the lithospheric magnetic data over North Xinjiang in China, a region contains strong geological contrasts like Junggar basin and Tian Shan. The lithospheric magnetic anomaly used is the second version of the World Digital Magnetic Anomaly Map (WDMAM) of which the longest wavelengths (spherical harmonic degree smaller than 185) are replaced with LCS-1 model.

First, we use a synthetic forward modelling test to illustrate that a 3D model, with magnetization variations in the depth direction, should be utilized when the altitude of magnetic data is 5 km above the WGS84 ellipsoid. Then, we estimate the Curie point depth (CPD) (i.e. bottom of the magnetic sources) by spectral analysis of the above magnetic data. And there is a close correspondence between the estimated CPD and the published information about geothermal states derived from measured surface heat flow and other geophysical researches such as seismic shear wave velocity models. Last we choose a least squares algorithm, using an L2-norm measure of the misfit of the observed and the predicted magnetic data, to recover the lithospheric magnetization model. A model objective function using L2-norm Tikhonov regularization is added to stabilize the solution, and the method for determining the optimal regularization parameter is generalized cross validation (GCV). The research region is divided into tesseroids within constant and isotropic susceptibility in geocentric spherical coordinates. A depth-weighting function is introduced to normalize the sensitivity to the magnetic data of tesseroids in different depths. It should be noted that the above estimated CPD would be incorporated into the inversion as a priori information to constrain the bottom of the magnetic sources.

The CPD constraints integrated in the inversion of lithospheric magnetic data can improve the quality of inverted images and help to obtain more geologically reasonable models. This method can be applied to construct a 3D magnetization model effectively from local scale for mineral exploration to continental scale for tectonic and geodynamic researches. When the total magnetization directions of the magnetic sources are known, the method can also be applied in study regions where strong remanent magnetization is presented, like mid-ocean ridges.

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