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Estimation of the total magnetization direction of approximately spherical bodies

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Abstract. We have developed a fast total-field anomaly inversion to estimate the magnetization direction of multiple sources with approximately spherical shapes and known centres. Our method is an overdetermined inverse problem that can be applied to interpret multiple sources with different but homogeneous magnetization directions. It requires neither the prior computation of any transformation-like reduction to the pole nor the use of regularly spaced data on a horizontal grid. The method contains flexibility to be implemented as a linear or non-linear inverse problem, which results, respectively, in a least-squares or robust estimate of the components of the magnetization vector of the sources. Applications to synthetic data show the robustness of our method against interfering anomalies and errors in the location of the sources' centre. Besides, we show the feasibility of applying the upward continuation to interpret non-spherical sources. Applications to field data over the Goiás alkaline province (GAP), Brazil, show the good performance of our method in estimating geologically meaningful magnetization directions. The results obtained for a region of the GAP, near to the alkaline complex of Diorama, suggest the presence of non-outcropping sources marked by strong remanent magnetization with inclination and declination close to -70.35 and $-19.81°$, respectively. This estimated magnetization direction leads to predominantly positive reduced-to-the-pole anomalies, even for other region of the GAP, in the alkaline complex of Montes Claros de Goiás. These results show that the non-outcropping sources near to the alkaline complex of Diorama have almost the same magnetization direction of those ones in the alkaline complex of Montes Claros de Goiás, strongly suggesting that these sources have been emplaced in the crust within almost the same geological time interval.

1 Introduction

The magnetic method is one of the oldest geophysical techniques and plays an important role in mineral and petroleum exploration. This method underwent great progress after the advent of magnetometers properly developed for airborne surveys. Nowadays, the combination of modern satellite positioning systems and improvements in instrumentation and platform compensation makes the aeromagnetic survey one of the most important data acquisition techniques due to the ability to cover large areas in a relatively short period of time (Blakely, 1996; Nabighian et al., 2005). The main applications of the magnetic method are (i) estimating the average depth of the basement relief, (ii) mapping geological faults and abrupt lithological contacts, (iii) defining the limits of mineral targets, (iv) determining the location of geological bodies like salt domes in sediments and (v) identifying geological oil and gas traps. From the physical point of view, all these geological scenarios can be associated with a magnetization distribution produced by magnetized rocks in the subsurface. These magnetized rocks are the magnetic sources producing a magnetic induction that can be measured on the Earth's surface or near to it. This magnetic induction causes local differences between the measured data and the magnetic induction predicted by global models describing the geomagnetic field. By isolating these local deviations, the interpreter can determine the magnetic induction produced by the magnetic sources making up the exploration targets.

The total field is the most common magnetic data measured in a survey. It is defined as the Euclidean norm of the magnetic induction produced by all surrounding magnetic sources. After removing the Euclidean norm of the magnetic induction predicted by a global model describing