Interpolation residual of airborne magnetic data: an example from Ponta Grossa Dyke Swarm, Paraná, Brazil.

Luizemara Soares Alves Szameitat*, SGB-CPRM, UERJ; Oderson Antônio de Souza Filho, Geological Survey of Brazil, CGA/SGB-CPRM; Saulo Pomponet Oliveira, UFPR; Jeferson de Souza, SEED-PR.

Abstract

Interpolation of geophysical data is a widely used technique for data visualization. Unavoidably, interpolation methods leave behind some high frequency data, but this effect is unnoticed for most of geophysical interpreters. However, such kind of data can be significant for mapping shallow magnetic bodies. In the case of a dyke swarm, for instance, it led us to identify thin shallow dykes. In this work, we inspect a region over Ponta Grossa Dyke Swarm in Southern Brazil, whose airborne magnetic data were gridded by minimum curvature and bidirectional methods. We focus on the wasted high frequency in the interpolation process, using unpretentious comparison between raw and interpolated magnetic data, and variations on cell size. We conclude that the residual of the interpolation is an unexploited data resource, which can be used for further mapping of shallow dykes along that regional structural feature, and other near-surface magnetic targets.

Introduction

Datasets are intrinsically discontinuous in space and, therefore, the gap between values is approximated by a function. In this process, most of interpolation methods will exclude peaks of positive and negative values, in order to obtain a smoothed surface. However, sharp peaks may correspond to shallow magnetic sources, based in the assumption that high frequencies are related to them (Blakely, 1996). In near-surface magnetic targets, it implies in loss of significant information. This work aims to recover part of the wasted amplitudes due to the interpolation process.

Magnetic methods are essential for mapping dykes, for mapping lateral continuation or detecting unknown bodies. We chose a study area in the Ponta Grossa Dyke Swarm (PGDS), Southern Brazil. In this region, dyke occurrences have been associated to water resources, since the damage zone may play a role as fractured reservoirs (Cavalvante et al., 2020).

The basement has prominent NE-SW structural trend, given by oriented terranes, thrusts and shear zones (Basei et al., 1992; Silva et al., 2005). On the other hand, PGDS follows long-lived NW-SE structural trend (faulting and arching) of Paraná Basin basement (e.g., Ferreira *et al.*, 1981; Pinto, 2019). PGDS is located in the SW flank of Ponta Grossa Arch (PGA), a crustal anticline N45W oriented (Alves, 2006). Magmatic events related to PGDS were related to the Mesozoic evolution of South Atlantic Ocean.

The studied area comprises the Paranapiacaba-Ribeira Sul Orogen (650-600 Ma; CPRM, 2004), as part of the Mantiqueira Orogenic Province. The northwestmost geological unit is the Castro Group (CG), a Neoproterozoic-Eopaleozoic volcanoclastic basin (Moro, 1993; Prazeres Filho, 2000, 2005). To the southeast, the Cunhaporanga Granitic Complex (CGC) limits the CG. The CGC is formed by Neoproterozoic intrusions of highly differentiated granitic magmas (Guimarães, 2000; Siga Jr. et al., 2003; Prazeres Filho, 2000, 2005). The southeastern CGC limit forms an irregular boundary with the Itaiacoca Group, a complex metasedimentary unit, which also contain significant volcanic components (Siga Jr. et al., 2003). The Itaiacoca Group is located between CGC and the Três Córregos Granitic Complex (TCGC), with strike-slip faulting limit with TCGC. The Neoproterozoic batholith TCGC (Guimarães, 2000; Siga Jr. et al., 2003; Prazeres Filho, 2000, 2005) have discontinuous outcrops, with several granitic calc-alkaline lithotypes and some metamorphic enclaves. Further in southeast, TCGC also intruded the Mesoproterozoic Água Clara Formation (Weber et al., 2004) which comprises medium-grade metasedimentary rocks and amphibolite.

Methods

The airborne magnetic dataset was extracted from the Paraná-Santa Catarina Aerogeophysical Project (CPRM, 2011). For this area, the median value for sensor altitude is 112 m. The data was grided with the bidirectional gridding and minimum curvature implemented in the Oasis Montaj™.

For this database, the maximum sampling interval is 500 m (Δx), which correspond to the averaged flight line spacing along N-S direction. According to the Nyquist sampling theorem, the minimum cell size is 250m (½ Δx). However, the application of this minimum value in airborne data gridding results in in-line aliasing, due to insufficient sampling (Billings and Richards, 2000). As a result, a ¼ Δx cell-sized grid (125x125 m) can be used for balancing the in-line and cross-line aliasing effects.

We observe the 2D Fourier spectrum (Figure 1) for 250 (½ Δx) and 125 m (¼ Δx) of grid spacing, generated by bidirectional (BIDIR) and minimum curvature (MC) interpolation methods. The 2D Fourier grids in Figure 1 demonstrate the influence of interpolation artifacts for each interpolated method, where hot colors are related to frequency concentration. The cross-shaped noising along N-S and E-W axis is because the magnetic anomalies are distributed according to the natural (non-periodic) geological setting, and the high frequency of raw data along flight lines (Billing and Richards, 2000). Similarly, geological trends from Ribeira Sul orogenic belt (Basei et al., 1992; Silva et al., 2005) and Ponta Grossa Dyke Swarm give the NE-SW and NW-SE orientation on frequency distribution, respectively. From the 2D spectrum grids (Figure 1), the data grid with MC method and 125x125 cell-sized seems to have less heterogeneous distribution of frequencies.

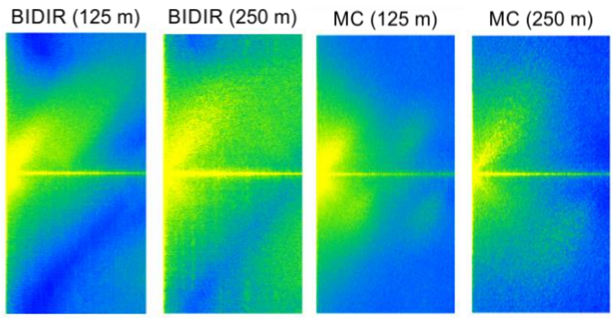

Figure 1 – Spatial frequency distribution (2D Fourier power spectrum) from 125 and 250 m cell-sized grids, and interpolation methods: minimum curvature (MC) and bidirectional (BIDIR).

Results

The interpolation residual analysis (IRES) was based in the potential response of magnetic bodies of linear shape and sudden boundaries, which tends to be as sharp as the shallower the source (Blakely, 1996). Therefore, the interpolation residual is obtained by subtraction of interpolated data from the raw airborne dataset.

The working grid for interpolation residual analysis is the MC 125x125 m grid (Figure 2). The misfit between interpolated grid and raw dataset is illustrated by proportional-sized symbols on Figure 3.B. In addition, we performed a fine gridded map of misfits (15m cell-sized, MC method) in order to represent the magnetic peaks. From the interpolation misfit grid, we manually defined lineaments of interpolation residual, for positive and negative contributions (Figures 3.C, 3.D).

The spatial distribution of misfit symbols shows conspicuous NW-SE alignments, which concentrates relative high values of magnetic anomaly misfits. The orientation and location of those magnetic lineaments have a clear correlation with the geological setting of the Ponta Grossa Dyke Swarm. Other geological boundaries are also highlighted by aligned signs, on the both boundaries of Cunhaporanga Complex with Castro Group to northwest and partially with Itaiacoca Group to southeast (geological map in Figure 3.A).

Discussion

We have noticed the geological coherence between the interpolation residual and dykes from the Ponta Grossa Dyke Swarm, and partially along the geological boundary of Cunhaporanga Granitic Complex. Consequently, symbol alignments obtained from the interpolation residual are considered as part of the geophysical response of those geological features.

The abundance of high misfit values on IRES maps illustrate the lacking of magnetic amplitudes due to interpolation process. Of course, changing the methods and cell size may vary the residual amplitudes. In relation to the MC and BIGRID performance, we observe similar statistical values for both outputs (average, median and standard deviation, for example), which implies similar accuracy of those methods. However, the loss of raw magnetic amplitude is unavoidable, due to the need of smooth surfaces for representing geophysical data. Since high-frequency content is valuable for mapping near-surface magnetic bodies, IRES maps can be an alternative way for mapping such kind of lost magnetic peaks.

In the case of CGC unit, we observe a lack of outcropping dykes (Figure 3.A). Conversely, original and residual maps shows the uninterrupted lateral continuation of PGDS. In this case, those dykes can be hard to access, highly intemperized or covered by sedimentary packages.

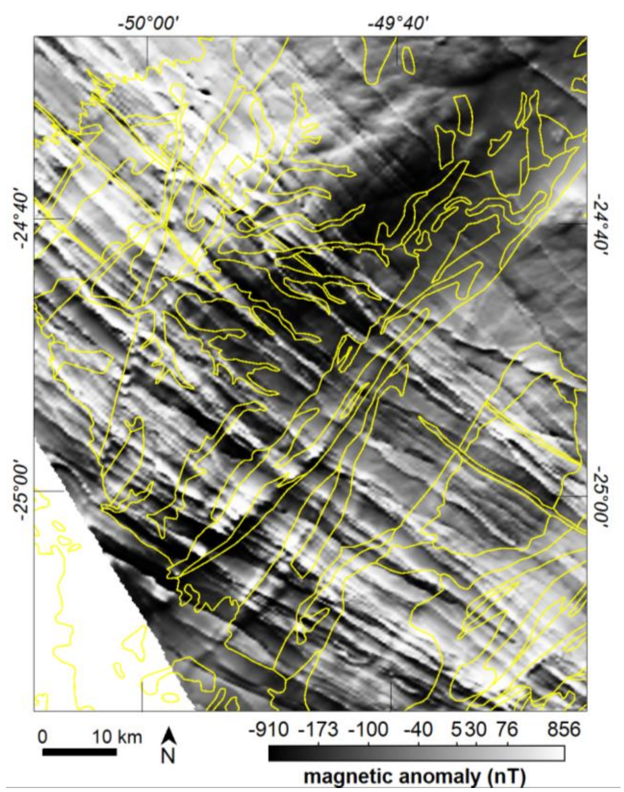

Figure 2 – Selected grid (MC 125x125m) of total field magnetic anomaly. Yellow lines: geological contour (CPRM, 2004).

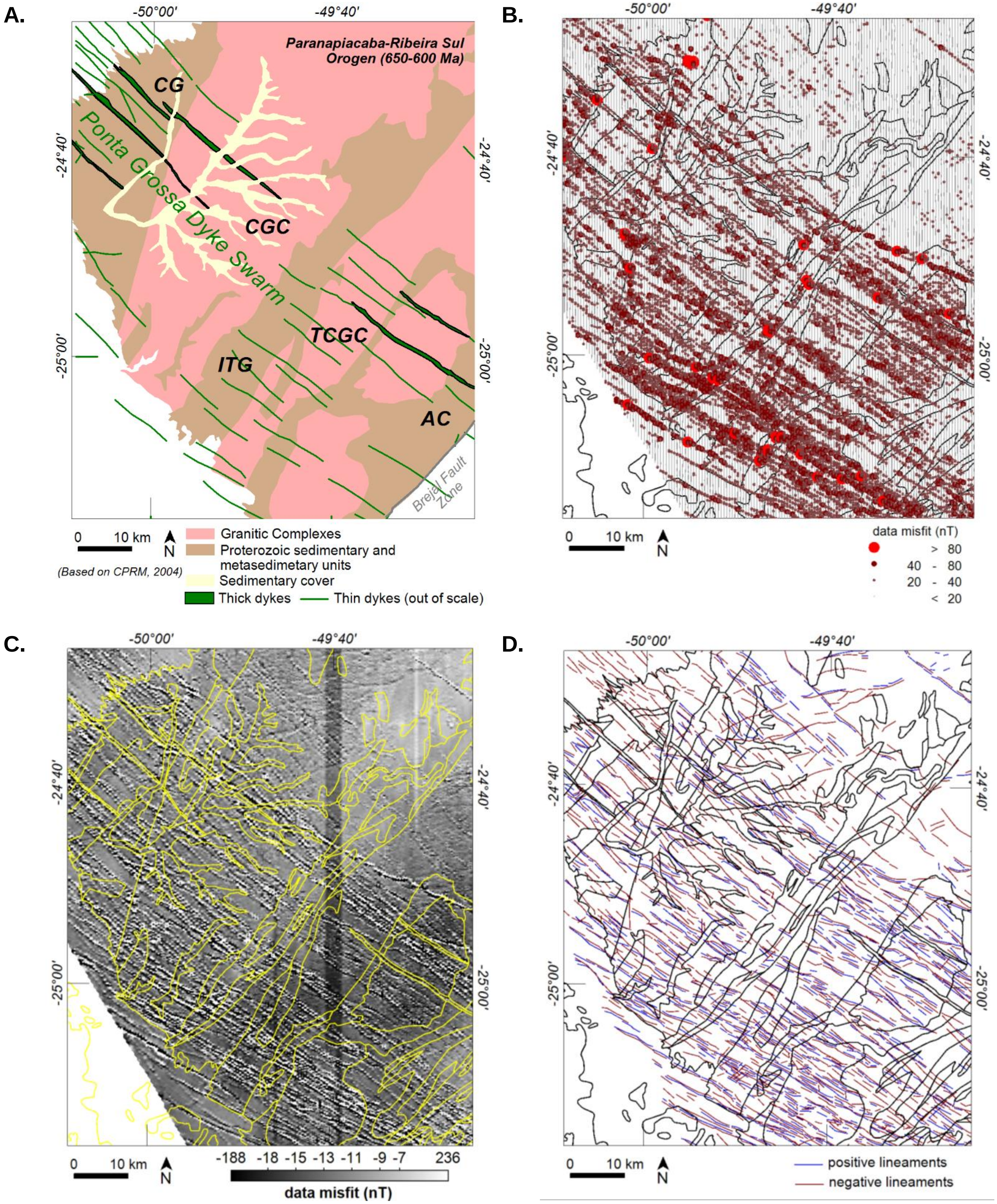

Figure 3 – Simplified geological map (A), and interpolation residual (IRES) representation as proportional symbols (B) and gridded values (C). From B and C, we can define oriented gradients of positive and negative residuals (D). CG: Castro Group. Granitic Complexes are Cunhaporanga (CGC) and Três Corregos (TCGC). ITG: Itaiacoca Group. AC: Água Clara Formation.

In summary, we consider that interpolation misfit values could be applied for mapping lateral continuation of outcropping or near-surface dykes and other linear magnetic bodies. These maps are readily applicable in groundwater prospection as corroborated by findings of Cavalcante *et al*. (2020), where clustering of shallow dikes are likely related to the most productive rocks than deeper clusters.

Acknowledgements

This work is part of SGB-CPRM internship activities of Luizemara S. A. Szameitat, Project: Supporting Sustainable Groundwater Supply Management in Brazil. This project is funded by Fundação Araucária (PIN2020141000001) in the fellow program: Newton International Impact Scheme (NFIS-537134315), Fundo Newton – CONFAP cooperation.

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