Integrated analysis of multi-sources data: Application in Ni exploration at Ipiaú region, Southeast of Bahia State, Brazil.

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Abstract

This paper presents the integration of geological and geophysical (magnetic and gamma-ray spectrometric) data that covers the Ipiaú Topographic Chart, SD.24-YB-II, by generating lithogeophysical maps. The use of these data revealed important information about the tectonic and litho-structural units in the area, aiming to map circular or elongated bodies, known to host nickel, and define the expression of regions which may contain potential prospective areas. Starting from the integration of multi-sources data, was delimitated a long strip, in which is inserted the Santa Rita mine, that follows the regional trend and is related to highly variable magnetic field, composed of well-defined anomalous areas and low levels of radioelements, becoming interesting from the prospective viewpoint.

Introduction

The Itabuna-Salvador-Curaçá Belt is an important segment of the Archean crust, located in the northern portion of the São Francisco Craton, which has been the subject of numerous geological investigations due to its metallogenetic potential for mineralizations of Ni, Cu, PGE, among others. These mineralizations occur in paleoproterozoic undisturbed mafic-ultramafic intrusions at the high-grade metamorphic basement. In this context, the integration of multi-sources data is very important because allows us to obtain Ni- mineralization patterns at terrains with thick weathered mantle and scarcity of outcrops, as well as mapping the actual extent of the possible hosts of mineralized intrusive bodies.

This paper aims to present the processing, analysis and integrated interpretation of geological and geophysical (magnetic and gamma ray spectrometric) data that covers the Ipiaú Topographic Chart.

Geological Setting

The São Francisco Craton, defined by Almeida (1977) as an established geotectonic unit in the end of the Paleoproterozoic Orogenic event (2.0-1.8 Ga), is composed of four distinct crustal segments (Barbosa and Sabaté, 2004). The oldest portion is the Gavião block in the west-southwest, composed of granitic, granodioritic and migmatitic continental crust, including remnants of 3.4 Ga TTG terrains and associated Archean greenstone belts. In the south-southwest, the Archean Jequié block comprises granulitic migmatites with inclusions of supracrustal rocks, intruded by charnockite plutons. To the northeast, the Archean Serrinha block is composed of orthogneisses and migmatites, which form the basement for Paleoproterozoic greenstone belts. The youngest segment is the Archean and Paleoproterozoic age Itabuna-Salvador-Curaça belt, extending from southeast of the Bahia state along the atlantic coast to the Salvador city, then northwards into northeast, separating the Gavião and Jequié Blocks from the Serrinha Block.

During the Paleoproterozoic Orogeny (2.3-2.0 Ga), the Jequié, Serrinha and Gavião Blocks and the Itabuna-Salvador-Curaçá Belt collided resulting in the formation of an important mountain belt called Itabuna-Salvador-Curaçá Orogen, that is mainly composed of a low K calcalkaline plutonic suite with intercalated metasediments and ocean floor and/or back-arc basin gabbro and basalt.The beginning of the collision resulted in a tectonic superposition of the Itabuna-Salvador-Curaçá Belt above the Jequié Block, and both upon the Gavião Block (Barbosa & Sabaté 2002).

The Paleoproterozoic high grade metamorphism in the central portion of Itabuna-Salvador-Curaçá Orogen was granulite facies and amphibolite and green-schist facies on the borders (Barbosa & Sabaté 2003). The southern part of the Itabuna-Salvador-Curaçá Belt resembles modern volcanic arc or magmatic active continental margin associations (Barbosa 1990). Island arcs, back-arc basins and subduction zones were the predominant environments during the original construction of this belt (Barbosa & Sabaté 2002).

During the Paleoproterozoic deformation were emplaced the Mirabela and Palestina layered intrusions, subordinated to a sin to late tectonical system associated with a crustal thickening (Abram & Silva 1992). These rocks are intrusive along a structural lineament that extends for more than 100 km adjacent to the west side of the Itabuna-Salvador-Curaçá Belt (Silva et al 1992). The Fazenda Mirabela and Fazenda Palestina mafic-ultramafic intrusions were emplaced into the cores of antiformal structures near the western margin of the Itabuna-Salvador- Curaça belt, within a previously deformed sequence of charnockite, enderbite, gneisses, meta-norite, and banded iron formations. Intrusion followed peak granulite facies metamorphism during the terminal Paleoproterozoic transpression in the southern part of the belt at ca. 2.08 to 2.06 Ga (Barbosa and Sabaté, 2004) and was localized in the cores of antiformal structures in response to westward thrusting.

Data

The data used in this work were the original magnetometry and gamma spectrometry aerial surveys performed by Fugro and contractors by CBPM. The airborne data were acquired using 500 m spaced flight lines with orthogonal tie lines flown every 5.000 meters at 100 meters above the ground surface.

The cartographic data used were the geological map on the scale 1.2,500,000 (Bizzi et al., 2003), the geological map of Ipiaú Chart, scale 1:100,000 (Barbosa, 2007) and the map of the mafic-ultramafic body of Fazenda Mirabela, scale 1:25,000 (Cunha et. al., 1992).

The georeferenced database system prepared for this work includes all products derived from geophysical data, geological maps, rock types and structures mapped in the field, digital elevation models and mineralized occurrences available in the literature.

Methods

This section gives an overview of the processing of airborne geophysical data in the Ipiaú Topographic Chart, referring to different methodologies used in this work. The geophysical data used in this study were processed and visualized using the Oasis Montaj software, version 7.2 of GEOSOFT™, licensed for the "Laboratório de Geofísica Aplicada" (Geophysics Applied Laboratory) of the University of Brasília.

The magnetic data was expressed as the anomalous magnetic field (AMF), after pass by corrections of diurnal variation, the main geomagnetic field (IGRF) and leveling errors. The gamma spectrometric data were discriminated into energy channels with reference to the total energy (total count channel, which was expressed in mR/hr), while the potassium channels were expressed in percentage. The uranium and thorium channels were expressed as micro-equivalents. The data was interpolated in a regular grid, using the appropriate algorithms to maintain data fidelity to the original sample locations. The interpolation method more efficient for the magnetic data was the bi-directional (implemented in Oasis Montaj as bi-grid) with square cell of 250 meters. For the gamma ray spectrometric data the interpolation method more efficient is the minimum bend, with the same size of square cell.

For the treatment of the magnetic data, linear transformations were used, principally that dealing with the amplitude of the analytic signal (ASA), which are important products to locate the spatial distribution of magnetic sources and to determinate geometrical parameters, such as the geological and structural boundaries. The derivatives of the anomalous magnetic field, principally the first vertical (Dz), helped to determine the spatial position of these sources and were also extremely useful to characterize structural features. The horizontal derivatives allowed the mapping of lateral limits of these sources.

The integrated interpretation of the gamma ray spectrometric and magnetic images was performed in a GIS environment, using ArcGIS 9.3 (ESRI), like all maps prepared for this work. The images in 2,5 D were made with the program ENVI 4.7, using the RGB ternary composition and digital elevation model (DEM) in the intensity channel. The figure 1 shows all the products generated for the magnetic and gamma ray spectrometric data.

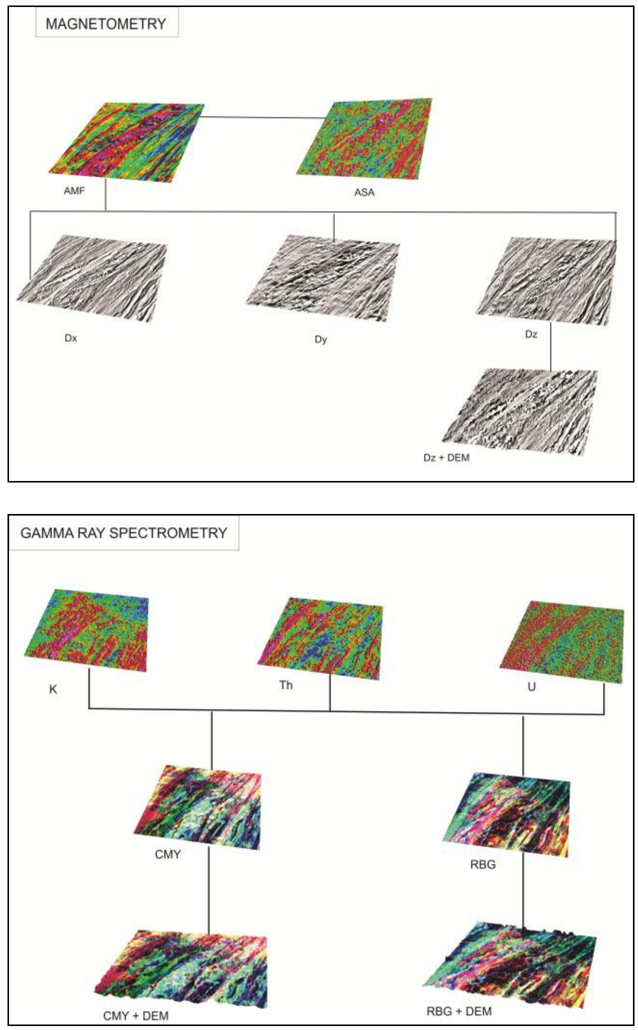

Figure 1: Flowcharts illustrating the steps of processing, analysis and interpretation of the magnetic and gamma ray spectrometric geophysical data.

Integration of geophysical and geological data

From the reading and analysis of the anomalous magnetic field products was produced the magnetic interpretation map, shown in Figure 2. The guidelines could be divided into 4 groups, which were presented together with the magnetic units. The groups and magnetic units are characterized below:

- Group 1: This group consists of structures oriented toward WNW-ENE, which were interpreted mostly as sinistral shear zones. These structures are well marked on the first vertical derivative and also in the amplitude of the analytic signal maps. They are associated with the last deformational phase that affected the area and truncated the structures of the groups 2 and 3.

-Group 2: This group consists of structures oriented N-S generating closed, isoclinal, rootless folds. They are well marked by the first vertical derivative magnetic lineaments, highlighted the magnetic relief and are distributed over the entire area, especially in the central portion of the map. The deformational phase responsible for these structures was compressional, with tangential and vergent movements for west, where the shear zones made possible the construction of recumbent folds associates, with duplex oriented in N-S direction.

- Group 3: This group is composed of magnetic lineaments with orientation NE-SW and N-S, consistent with the regional structure of the study area, generated by Paleoproterozoic orogeny. Structures are well marked at all magnetic products generated.

- Group 4: This group corresponds to the E-W oriented structures, which are restricted to the central portion of the map. These structures are few and are well marked by the first vertical derivative, also associated with high topographic levels. Just above the Mafic-Ultramafic Mirabela Complex can be seen one of these structures.

- Magnetic Units: These units are relating to areas of high amplitude in ASA, which detaches from units around. They follow the NNE-SSW trend of magnetic lineaments delimited. These units correspond mostly to mafic basement units that are rich in magnetite, such as mafic granulites or iron formations.

After the interpretation of the magnetic lineaments it was observed that most structures follow the regional trend NNE-SSW, consistent with the efforts of Paleoproterozoic orogeny. Closed folds in N-S direction indicate that a phase of ductile deformation and sinistral shear zones are representatives of the subsequent brittle deformation phase. These results were obtained from the integration of geophysical products with field observations. Mafic-Ultramafic Mirabela Complex was preserved of this strain, as can be seen in the map of magnetic lineaments, without deformation structures associated, agreeing with the post-tectonic character of this Complex.

Confronting the geophysical data with geological notes, we have a refinement of existing geological data. This proves the potential of this technique in geological mapping applied to mineral exploration.

The methodology used in gamma spectrometric data interpretation involved the analysis of the total count channel (TC), for definition of large gamma spectrometric areas and analysis of relative contribution of each of the other channels; image comparison corresponding to each discriminated channel (K, eU and eTh) with the topography, to study the influence of relief on these data; the use of ternary compositions in false color (CMY and RBG) and its spatial study to define units and/or areas with similar gamma spectrometric signatures. The contents of radio-elements were divided according to the RGB composition, through the location of the color in ternary triangle. Each radioelement content was classified as low, medium or high, resulting in nine distinct classes, here called the lithogeophysic units. It is accepted that the levels of radio-elements in acid rocks are larger than in ultrabasic rocks (Ferreira & Souza, 2002).It is remarkable the wealth of detail that the integrated products provides and should be better contemplated with the geological information available.

The interpretation of the products generated by the magnetic and gamma-spectrometric data, considering all geologic information and field observations, result in a lithogeophysic map, in 1:200,000 scale, showed in Figure 3.

Conclusions

The interpretation and integration of aeromagnetic geophysics data provided powerful insights about the structural setting of the study area. The Ipiaú region had suffered an intense deformation during the Paleoproterozoic Orogeny that produced N-NE and N-S structures, which had realigned the magnetic minerals of the basement, erasing almost completely the magnetic signatures of oldest geological events. The intensity of this event was so great that the efforts produced had defined the topography of the area that often coincides with the magnetic and gamma spectrometric structures. The nickel deposits tend to occur associated with basic/ ultrabasic rocks which typically have high magnetic responses. However, due to the high magnetic susceptibility of the basement rocks, mainly iron formations and mafic granulites, the distinction of the mafic/ultramafic intrusions responses becomes more difficult to be recognized. An extensive band that follows the regional trend, which is inserted Santa Rita mine, is related to a highly variable magnetic field, composed of a well-defined anomalous zone and lows concentrations of radio-elements, making it interesting from the prospective point of view. The petrography of the samples located north Mafic Mirabela Complex associated with field observations allowed to define the highly magnetic character of these rocks, caused by high levels of opaque minerals, mainly magnetite. Despite the association of magnetic structures and lithogeophysics units only these results are not sufficient to identify nickel sulphide ore bodies. It is suggested the use of other geophysical methods for the leasing of bodies, particularly electromagnetic methods (which have good response to sulfide mineralization) and geochemical surveys, like stream sediment and/or soil geochemistry, at the interest areas.

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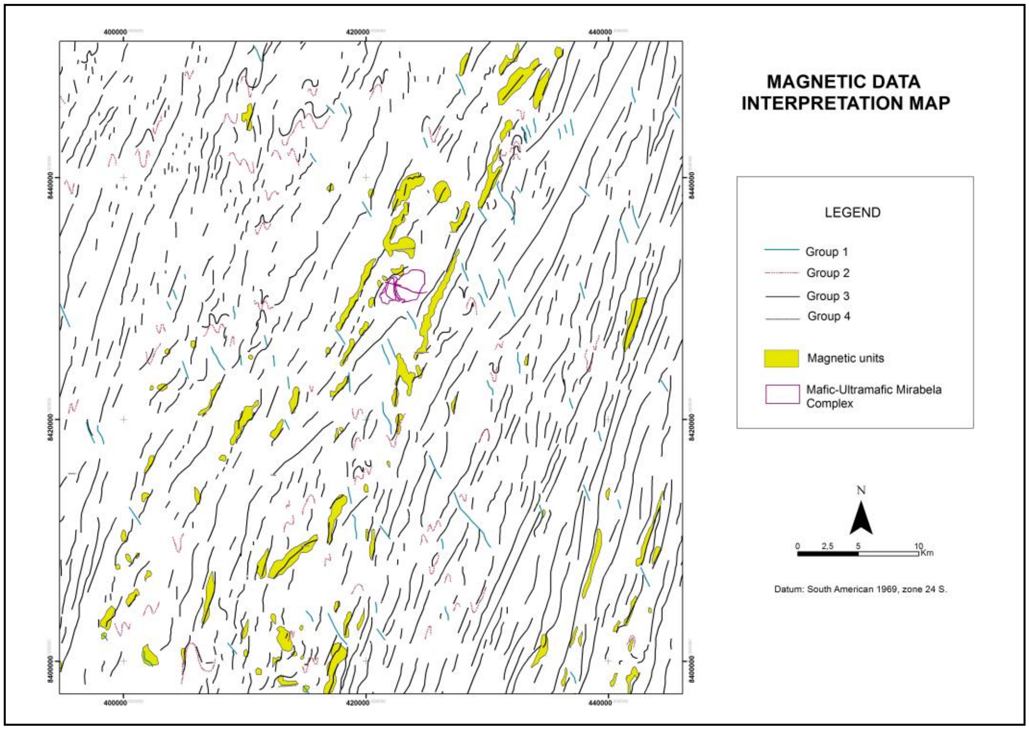

Figure 2: Magnetic data interpretation map.

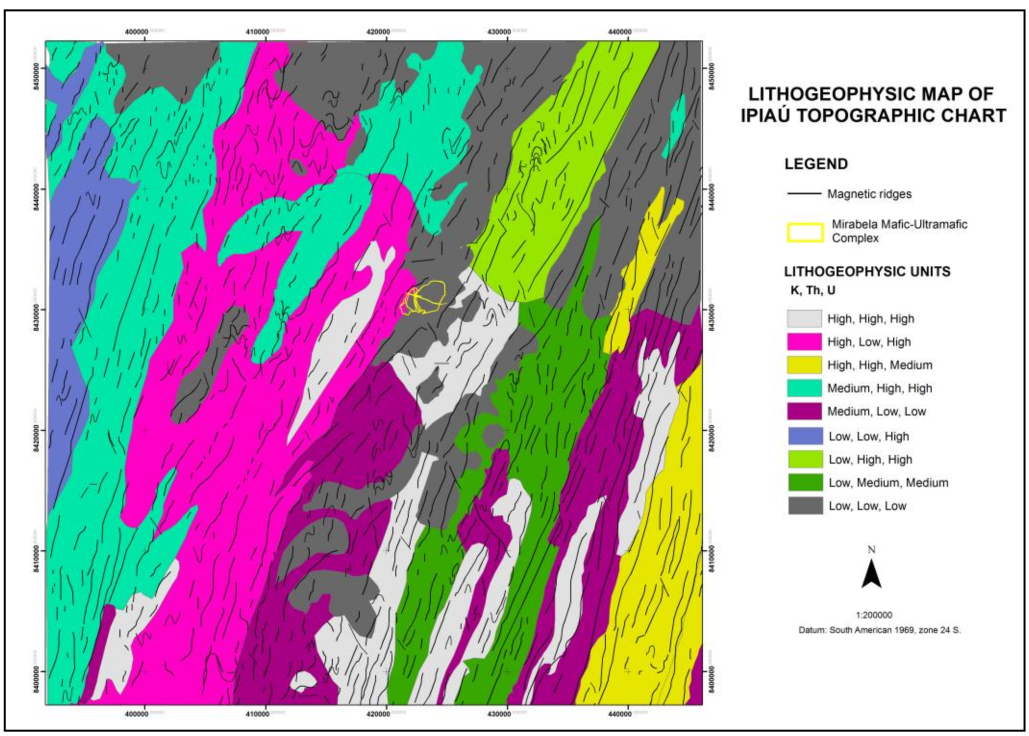

Figure 3: Lithogeophysic map showing the integration of gamma spectrometric and magnetic data.