Aerogeophysical data to refine geological mapping: A semi-quantitative approach

Diogo Luiz de Oliveira Coelho ON/MCTI, Felipe Guadagnin UFES

This paper was prepared for presentation during the 13th International Congress of the Brazilian Geophysical Society held in Rio de Janeiro, Brazil, August 26-29, 2013.

Abstract

This paper presents a geophysical investigation to improve the geological mapping. We used aeromagnetometric and aeroradiometric methods to correlate with the prior geological mapping. The geophysical data was previously calibrated and after processed and adjusted. The database adjusted was used to generate maps of the magnetometric and radiometric anomalies limited for the Espírito Santo State shape in scale of 1:100.000. All processing described was made according routines of processing embedded in OASIS MONTAJ version 6.4.1. When we compile the geophysical maps with the geological map we gain more reliability in our interpretation and we can trace the contacts in areas covered by quaternary sediments and in area with difficulty access.

Introduction

In geological mapping, basically a description of available outcrops in surface, doubts to trace the lithological contacts are common. The major problems to delimitate the lithological contacts are: (a) local geological complexity, (b) lack of detail geologic studies, (c) scarcity of outcrops, and (d) difficulty to access the area work in your totality. To finish with these doubts is necessary to incorporate other data, both from direct or indirect analysis.

The area is located in south of Espírito Santo state, near at Alegre city, as shown in the Figure 1. The area is within of a bounding rectangle with vertices: northwest 7706402 N and 27600 E, and southeast 7702968 N and 282350 E. The region is called the Itaóca sierra. Geologicaly is situated in zone of confluence of Araçuaí Belt (Almeida, 1977) or Araçuaí-Congo Occidental Orogen (Alkmim et al, 2007) with Ribeira Belt (Hasui et al,1975 e Tupinambá et al.,2007). In the investigated area the structural trend NE-SW and controls the regional and local geomorphology.

In the region of Itaóca occurs para- and orthoderivate rocks, with medium and high metamorphic degree, with intense deformation, and undeformed plutonic igneous rocks. The para- and orthoderivate rocks are intruded for dikes and veins with granitic and amphibolitic composition. The structural framework is complex and show brittle and ductile structures.

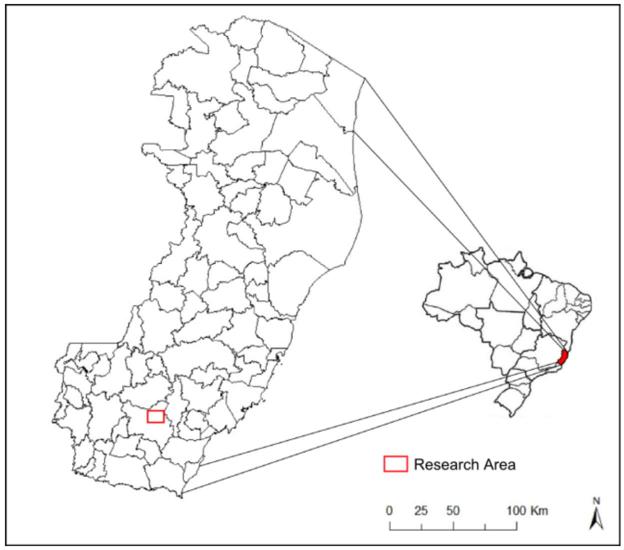

Figure 1: Image mosaic showing the Brazil map and the location of the research area.

This study was compost for a field work and a microscopic data analysis that divided the observed lithologies in seven geological units: (1) Tonalitic orthogneiss, (2) Calc-silicate gneiss, (3) Ultramafic rocks, (4) Marbles, (5) Leucogranite, (6) Gabbro, and (7) Quaternary sedimentary cover, as observed in the Figure 8.

In this area have uncertainties of where one lithology terminates and where begins another. The main factors for it happen is the differential weathering that provokes a lack of reliable outcrops of some units and the quaternary deposits that cover an expansive area, as shown in the Figure 2. Then must be aggregate more data to reduce the error and enhance the confiability of the mapping.

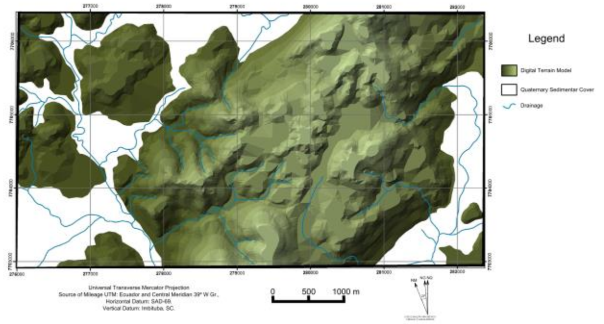

Figure 2: Digital Terrain Model showing the sedimentary cover.

According Lowrie (2007) the magnetic surveying consists of measuring the terrestrial magnetic field at predetermined points, correcting the measurements for known changes, and comparing the resultant value of the field with the expected value at each measurement station. The expected value of the field at any place is taken to be that of the International Geomagnetic Reference Field (IGRF). The difference between the observed and expected values is a magnetic anomaly.

According Milsom (2003) the radioactivity of rocks is monitored using gamma-ray scintillometers and spectrometers. Although most radiometric instruments were developed with uranium search in mind, other uses were soon found. Among these were regional geological mapping and correlation, exploration for some industrial minerals and *in situ* determinations of phosphates.

In this abstract we use the aerogeophysical data, both magnetometric and radiometric, to aid the interpretation and refine of geological mapping, principally in areas with absence of information.

Geophysical Data

The data were obtained by the aerogeophisical acquisition of the Espírito Santo State, realized by CPRM (Geological Survey of Brazil). Such a collection corresponds to aeromagnetometric and aeroradiometric data. The parameters of the acquisition are summarized as follow:

- Direction of the flight lines: N-S;
- Spacement between the flight lines: 0,5 km;
- Direction of the control lines: E-W;
- Spacement between the control lines: 10 km;
- Interval between the consecutive geophysical measurements: 0,1 s (magnetometer) and 10 s (gamaspectometer);
- Flight Average height: 100 m;
- Flight approximate velocity: 270 km/h.

The work flux after the data collected is summary in the flowchart shown in Figure 3:

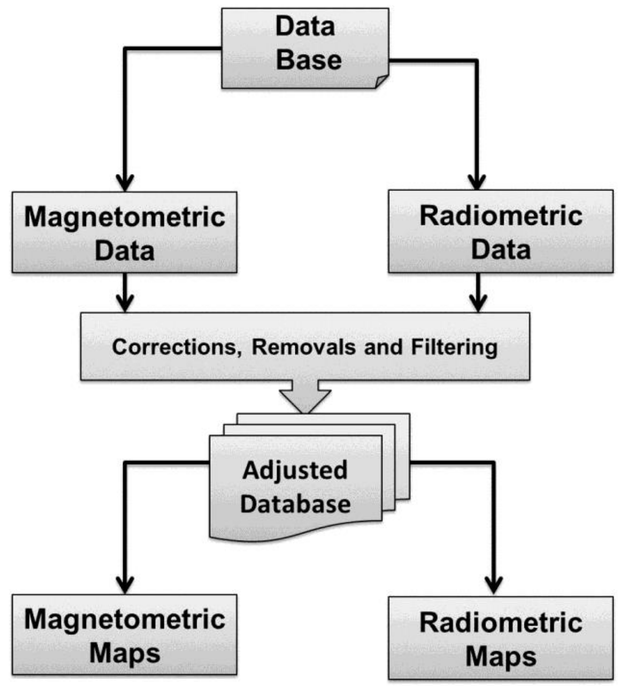

Figure 3: Flowchart showing the work steps in processing data.

The essential corrections in magnetometric method are: diurnal, latitude and altitude corrections. The diurnal correction is easy to calibrate. Before the start of survey day, other magnetometer is installed like a base, and this is used to remove the diurnal variation.

Lowrie (2007) shows that the altitude correction is given by the vertical gradient of the magnetic field only differentiate the intensity B_t with respect to radius r :

$$\frac{\partial B_t}{\partial r} = -3\frac{\mu_0 m}{4\pi}\frac{\sqrt{1+\cos^2\theta}}{r^4} = \frac{3}{r}B_t \,,$$

where:

B_t = magnetic field;

θ = polar angle;

r = Earth's radius.

The vertical gradient of the field is found by substituting r = R=6371 km and an appropriate value for B_t. In regional studies the corrections for latitude and longitude are inherent in the reference field that is subtracted.

In a survey of a small region, Lowrie (2007) says that the latitude correction is given by the north–south horizontal gradient of the magnetic field, obtained by differentiating B_t with respect to polar angle:

$$-\frac{1}{r}\frac{\partial B_t}{\partial \theta} = \frac{\mu_0 m}{4\pi}\frac{1}{r^4}\frac{\partial}{\partial \theta}\sqrt{1+3\cos^2\theta} = \frac{3B_t \sin\theta\cos\theta}{r(1+3\cos^2\theta)}$$

The latitude correction is zero at the magnetic pole (θ=0) and magnetic equator (θ=90) and reaches a maximum value of about 5 nT per *kilometer* (0.005 nT m^{-1}) at intermediate latitudes. It is insignificant in small-scale surveys.

The radiometric data need more corrections than the magnetometric data. There are several important steps in the conversion of the airborne counts to ground concentrations of potassium, uranium and thorium. These corrections are necessary because the layer that the radioactive minerals appears is thin and can be reworked easily by surface agents. And the elements can be their value altered by many factors, like instrumental errors, contamination data and others related with the acquisition.

Many calibrations are necessary apply before the corrections. Milsom (2003) suggests that the corrections and calibrations to be applied in radiometric data are the dead time, some geometrical considerations, and background variations. The International atomic energy agency (IAEA, 2003) says that the calibrations to be applied are:

- High-altitude aircraft/cosmic background flights;
- Ground calibration using radioactive pads;
- Calibration range flights;
- Radon background calibration flights;
- Calibration frequency.

According the IAEA (2003) the role of data processing is to correct the observed data for those influences that are not related to the geology, and then reduce the airborne count rates to estimates of the ground concentrations of the radioelements.

According Grasty and Minty (1995) the corrected window count rate data should be converted to ground concentrations of potassium, uranium and thorium using the following expression:

$$C = \frac{N}{S},$$

where:

C = concentration of the radioelement;

N = broad source sensitivity for the window;

S = count rate for each window, after dead-time, background, stripping and height correction.

After the processing, we interpolate the adjusted data and we did the contour maps. The contour maps were made from a regular grid. They were interpolated by a square mesh with size 125 m x125 m. This is equivalent to a quarter of the spacing between flight lines. Due the resolution of the acquisition the minor value found without errors in the lines is 125 meters. Larger values show gaps in the contour map.

To discriminate the anomalies is necessary subtract the found value of the regional background. Lowrie (2007) says that a magnetic anomaly originates in the magnetization contrast between rocks with different magnetic properties. However, the shape of the anomaly depends not only on the shape and depth of the source object, like gravimetric method, but also on its orientation to the profile and to the inducing magnetic field, which itself varies in intensity and direction with geographical location.

According Khameis and Nigm (2010), a useful interpretational tool is the analytic signal. He produces a particular type of calculated magnetic anomaly enhancement map used for defining in a map sense the edges “boundaries” of geologically anomalous magnetization distributions. The analytic signal is defined as:

$$A(x,y) = \frac{\partial \Delta T}{\partial x} i + \frac{\partial \Delta T}{\partial y} j + \frac{\partial \Delta T}{\partial z} k$$

Results obtained of data processing generate maps of the magnetometric and radiometric anomalies limited for the Espírito Santo State shape in scale of 1:100.000. These maps are: Total magnetic field, analytic signal of total magnetic field, radiometric of total count, radiometric of potassium, radiometric of thorium, radiometric of uranium, and ternary radiometric.

All processing described above was made according routines of processing embedded in OASIS MONTAJ version 6.4.1.

Geological Data

The research consists of a total of forty-four points, and the majority of outcrops were at quarries, both active and inactive.

The geological mapping was elaborated in scale 1:25000. The structural and petrographic data were observed in outcrops and thin section. This stage involved geometrical and kinematic analysis of the structures and the classification of the lithological units according compositional and structural/textural criteria.

Results

Khameis and Nigm (2010) say that the interpretation of the magnetic maps is based on a fact that, the intensity and size of the associated magnetic anomalies depend of the depth, thickness and size of the causative magnetic bodies. The basic and ultrabasic intrusives are associated with intense positive magnetic anomalies, while, acidic intrusives as granites and granodiorites are associated with relatively negative anomalies.

The Figure 4 shows the total magnetic field in research area. We can see in the northwest portion a concentration of positive anomalies that report a presence of plutonic bodies. According the prior geological mapping and because the anomalies are positives these intrusives bodies can be classified as basic, probably gabbro.

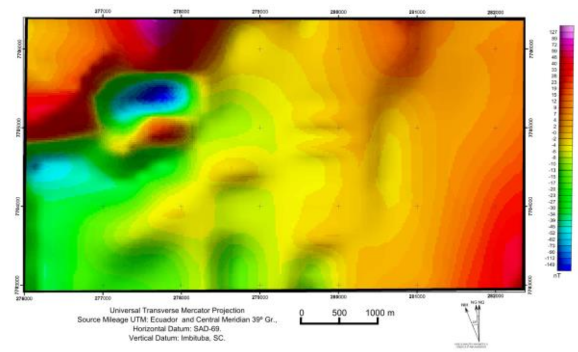

Figure 4: Pseudo-illuminated map of the total magnetic field reduced of IGRF. (Luminous source azimuth: 315º, Inclination: 45º).

In the Figure 5 the analytic signal map shows two magnetic contacts in the area, one in northwest and other in southeast. These contacts, likely, can be frontier areas between the marble and the plutonic bodies. Another information that we can be seen on this map is the large amount of small anomalies inside the marble. These small anomalies can represent the intrusive acids bodies found inside the marble.

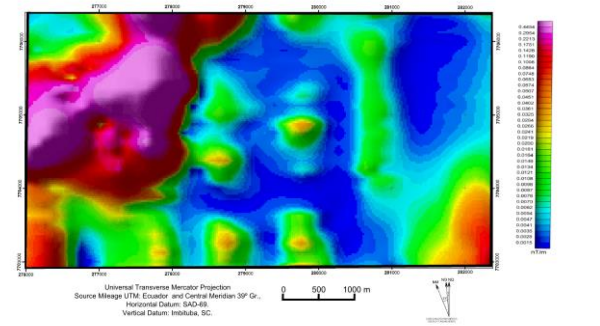

Figure 5: Map of analytic signal of total magnetic field reduced of IGRM. (Luminous source azimuth: 315º, Inclination: 45º).

Corroborating with the idea that the small anomalies inside the marble are intrusive acids bodies the **Figure 6** and **Figure 7** show anomalies in total count and in potassium inside the region where the large lens marble is localized.

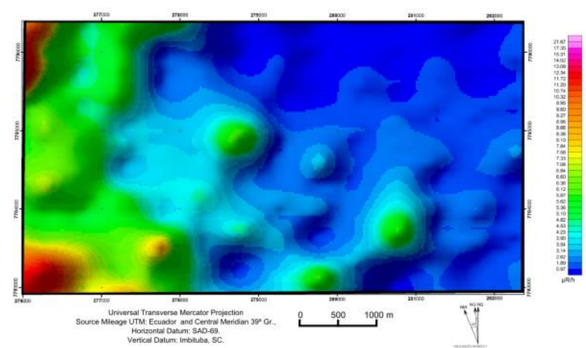

Figure 6: Radiometric map of the rate of exposition of the channel of count.

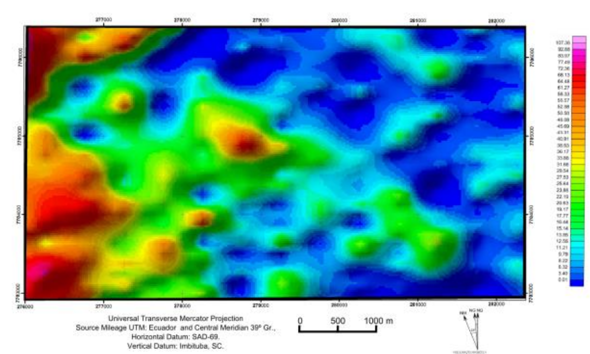

Figure 7: Potassium anomalies inside the research area.

Conclusions

Comparing the geophysical maps with the geological map (Figure 8) we can trace the contacts with more reliability. Principally where have so many areas covered by quaternary sediments.

More conclusions about the area are difficult to say because the resolution of the geophysical acquisition is low and need more calculus with the geophysical data, as inversions and others.

References

Alkmim F.F., Pedrosa-Soares A.C., Noce M.C., Cruz S.P. 2007: Sobre A Evolução Tectônica Do Orógeno Araçuaí-Congo Ocidental. GEONOMOS 15(1): 25 – 43.

Almeida, F.F.M. 1977. O Cráton São Francisco. Rev.Bras.Geoc. , 7: 349-364.

Hasui Y., Carneiro C.D.R., Coimbra A.M. 1975. The Ribeira folded belt. In: Karniol T.R., Tectônica da onexão do Cinturão Ribeira com a Faixa Araçuaí – Divisa Rio de Janeiro-Espírito Santo. Tese de doutorado. 2008.

IAEA. 2003. Guidelines for radioelement mapping using gamma ray spectrometry data, IAEA-TECDOC- 1363, Vienna, Austria. pp. 173.

Karniol, T.R. 2008. Tectônica da conexão do cinturão Ribeira com a Faixa Araçuaí - divisa Rio de Janeiro/Espírito Santo. Tese (Doutorado em Geoquímica e Geotectônica) - Instituto de Geociências da USP.

Khameis, A. A. 2010. Magnetic interpretation of north Gebel El Shallul area, central Eastern Desert, Egypt. The Egyptian Journal of Remote Sensing and Space Science, Volume 13, Issue 1, June 2010, pp 53–62.

Lowrie, W. 2007. Fundamentals of Geophysics (2nd Edition). Cambridge University Press, 381pp.

MILSOM J. 2003. Field Geophysics – The Geological Field Guide Series. 3 ed. London: Wiley, 249 pp.

Tupinambá, M et al. 2007. Geologia da Faixa Ribeira Setentrional: Estado da Arte e conexões com a Faixa Araçuaí. GEONOMOS 15(1): 67 - 79.

Acknowledgments

The authors wish to express their gratitude to CPRM for available the geophysical data.

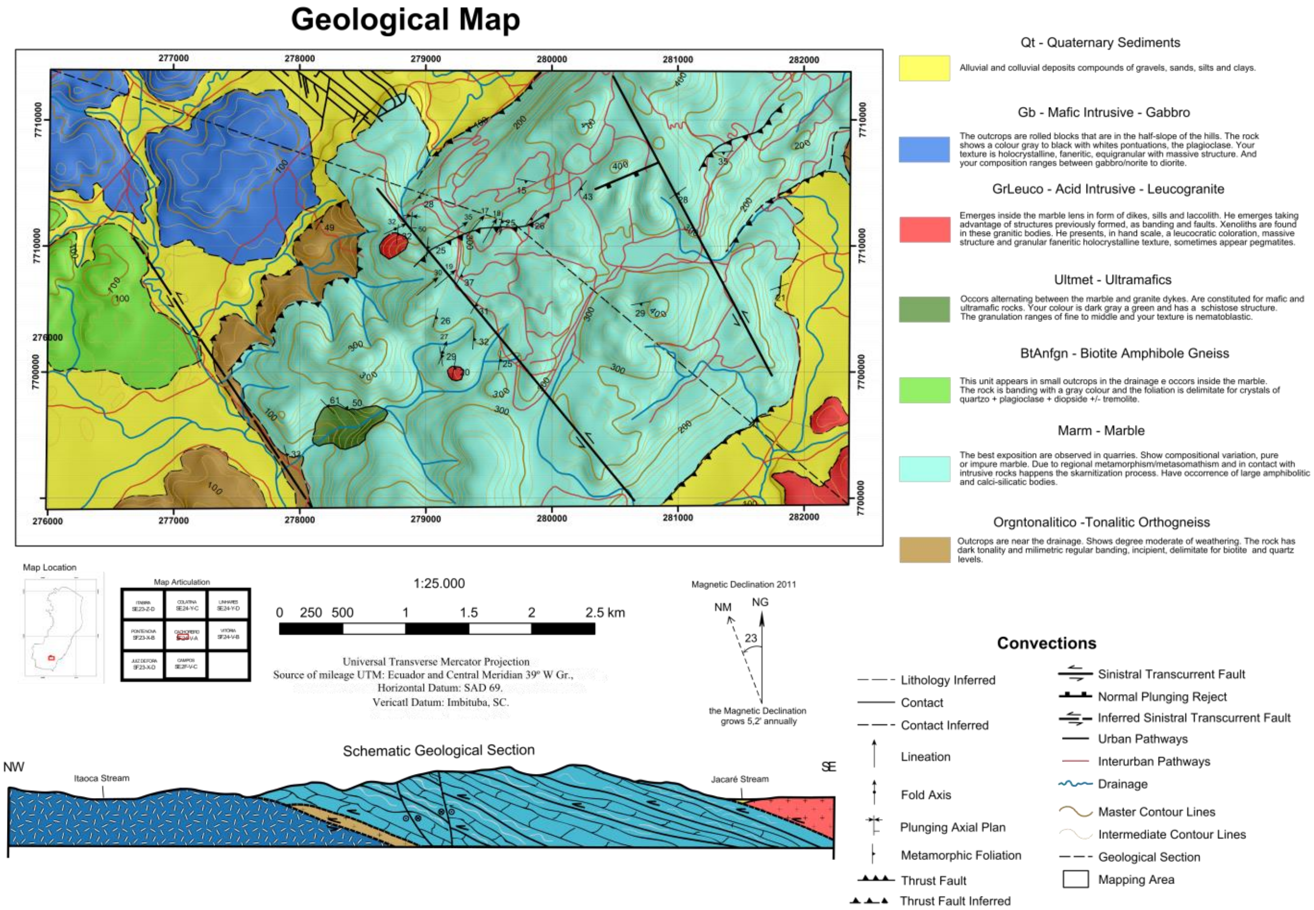

Figure 8: Geological map of the Sierra of Itaóca.