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Recovering old geophysical surveys: The case of the Uraricoera Project

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ABSTRACT

Great improvement was achieved in reprocessing aerial geophysical data for a portion of the Amazon region. Problems with IGRF removal and gamma spectrometric corrections were identified and corrected by the use of simple computer programs. A procedure for atmospheric correction is proposed, based on the measured data, involving non linear regression among counts and flight height. Multivariate classification of the recovered data, supported by remote sensing imagery analysis, improved substantially the available geologic map for the NW portion of Roraima State and neighboring portions of Amazonas State and Venezuela.

INTRODUCTION

During the 70's, large portions of Brazil were covered by airborne geophysical surveys. Many of these projects were developed in the Amazon region, with problems related to the generally dense vegetation cover. Problems in using old surveys data were discussed by Parker (1993) for regions with moderate vegetation cover.

Vegetation cover affects airborne geophysical surveys in several ways:

1. Radar altimeters operating in the K-band (~30GHz) to C-band (~5GHz), can penetrate only a few millimeters in vegetation. As the main consequence the flight height is underestimated, affecting corrections in magnetic and gamma spectrometric data;
2. Vegetation retains humidity and control air temperature, which affects the atmospheric attenuation coefficient in gamma spectrometry;
3. Vegetation absorbs soil produced gamma radiation in direct relation to biomass;
4. Positioning of flight lines was performed using 35mm B&W photographs from tracking cameras and comparison with SLAR images or aerial photographs. However, the extreme uniformity of the forest turned this activity a difficult task.

Today, the use of GPS positioning and conjugate radar and laser altimetry can minimize most of these effects. However, for turning old surveys data useful, they must be reprocessed in order to correct these problems partially and in a semi quantitative fashion. Another common problem in the old (and recent) Brazilian projects is the lack of adequate calibration of gamma spectrometers. With only one exception, the gamma spectrometry data is presented in cps, without conversion to surface concentrations. This inhibited the geochemical use of the results, the main power of gamma spectrometry. Moreover background and air attenuation corrections were generally not adequately performed. In some projects gross errors were identified, requesting additional corrections.

The main general consequence of these problems was the poor quality of the resulting data for geological applications.

THE URARICOERA PROJECT

This project was developed by Prospec Co. for CPRM from January to April, 1977 and covered most of the western portion of Roraima State. Small portions of Amazonas State and neighboring Venezuela were also surveyed (Moraes,1978). Two aircrafts, both equipped with C-band radar altimeters, tracking cameras, G-803 Geometrics proton magnetometers, DIGRs 3001 Exploranium gamma spectrometers (831 cu. in. crystals) and magnetic recorders. Flight lines were 2km apart, with an average clearance of 150m, controlled visually and by a Doppler navigation system. Gamma spectrometric background removal was based on measurements at 760m above ground, performed in the beginning and end of each productive cycle. Diurnal magnetic variation and effects of magnetic storms were corrected with fixed station measurements. Atmospheric attenuation coefficients were based on repetitive flights along a selected line. However, the results for both aircrafts did not coincided and one was selected, based on better coherence of the results. Stripping coefficients were obtained by unclear criteria, using measured values for selected portions of the project. For the selected area, the coefficients adopted, were:

$$\mu_{Th} = 0.00669\ .m^{-1}\ \mu_{U} = 0.00658\ .m^{-1}\ \mu_{K} = 0.00824\ .m^{-1}\ \mu_{TC} = 0.00734.m^{-1}$$

$$\alpha = 0.2826 \quad \beta = 0.8253 \quad \gamma = 0.3900$$

Magnetic data was corrected for diurnal variation, block adjustment and removal of the IGRF. For gamma spectrometry, processing involved background removal, stripping correction, atmospheric attenuation correction and leveling to the standard height of 150m. The corrected data was stored in magnetic tapes and later processed for plotting several geophysical maps.

For the IGRF removal the 1965.0 field, with m = n = 8 spherical harmonic coefficients and 900 m altitude, was used. The values were calculated for the corners of each of the 1: 100,000 scale maps that comprise the project area, a second order polynomial adjusted, and then interpolated for correction of each data point.

Positioning of flight lines was based in tracking camera 35mm B&W photographs (scale 1:8,300) and comparison with airborne 1:250,000 scale SAR images (Radambrasil Project). Navigation was visually controlled supported, when possible, by the Doppler system. However, the project's final report describe difficulties in positioning due to the differences among characteristics and scale of both types of images. In the case of detected problems lines were flown again. This explains the "patchwork" character of the files.

In order to develop the MS thesis project for one of the authors (SSC), CPRM provided magnetic disks with data arranged by flight line, containing for each measuring point: UTM coordinates, cpsTh, cps U, cps K, total count, height above ground and residual magnetic field.

RECOVER PROCEDURES AND DISCUSSION

In order to obtain a reliable geological map for the NW portion of Roraima State, airborne magnetic and gamma spectrometric data was used in conjunction with Landsat TM and airborne SAR imagery (Costa, 1999). The first procedure was the conversion of gamma spectrometry cps data into ground concentrations. The resulting eTh ppm image was in accordance to the known general geology of the area. The eU ppm image was similar but with strong noise along flight lines, interpreted as resulting from radon effects. The K% image was very poor (Figure 2a), with high values along a strong escarpment at the southern portion of the area and almost without contrast over known potassium rich granites and other characteristic lithologies (low potassium basic rocks). With topographic effects in mind, graphics of counts versus flight height were prepared for Th, U , K and Total Count channels (see example for U in Figure 1a). All the graphs presented a similar pattern with increasing counts with height, in opposition to what should be expected, indicating bad atmospheric attenuation corrections. Moreover, the converted values from cps to concentrations were anomalous, suggestive for inadequate stripping correction. As mentioned earlier, IGRF removal was also problematic.

Due to these problems all the transformations, except gamma spectrometry background corrections, were removed, recovering the "raw" data.

For IGRF removal, the 1977.3 field was used. However, positive values dominate, contrary to expectations. The resulting shape of the anomalies was similar but around 1000 nT higher. This was probably caused by the lack of magnetic observatories in the whole Amazon, which caused a poor adjustment of the spherical harmonics to the local geomagnetic field. Due to that, the better option was the removal of a second degree polynomial from the total field data for obtaining the residual field. Several previously known and additional basic intrusions were clearly displayed in the resulting images. This residual field has average near zero and almost symmetrical distribution of positive and negative values, as expected.

Raw data graphs for cps versus flight height presented the expected results, with a negative exponential relation between counts and height. This relation can be expressed by:

$$C = A \,.\, e^{-\mu.H} \qquad [1]$$

Where C is the number of counts at flight height H, μ is the atmospheric attenuation coefficient and A , the number of counts at the surface. Using logarithmic transformation, equation [1] is transformed in:

$$lnC = lnA - \mu.H \qquad [2]$$

Equation [2] can be solved by simple least squares linear regression. The resulting intersection with the lnC axis is lnA and the angular coefficient, μ. This was done for data of the four spectrometric channels in order to obtain the atmospheric attenuation coefficients for each of them. The fit was very good (determination coefficient less than 0.94) resulting in the new coefficients:

$$\mu_{Th} = 0.00519\ .m^{-1} \quad \mu_U = 0.00445\ .m^{-1} \quad \mu_K = 0.00335.m^{-1} \quad \mu_{TC} = 0.00378\ .m^{-1}$$

Application of these values resulted in "normal" cps vs. height graphs, without apparent relationship among them (Figure 1b). Figure 1a indicates that the above procedures should be applied for each flight line, which are shown as curved arrangement of points. The need for this customized correction is supported by the variation of atmospheric conditions (temperature, humidity, pressure, etc.) during different flights. This procedure is time consuming and is being applied to each flight line of the entire project.

For the stripping coefficients (α, β and γ) we calculated model values based on the crystal volume and flight height, respectively 0.40506, 0.51535 and 0.92167. Similar results, within the uncertainty interval ($\pm$ $counts^{½}$) , were obtained swapping the β and γ used in the original data.

Finally, cps values for the Th, U and K channels were converted to surface concentrations using the procedures of Amaral & Pascholati (1998). The used sensitivities, were:

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$$S_{Th} = 1.333 \text{ cps/ppm} \quad S_U = 2.101 \text{ cps/ppm} \quad S_K = 18.361 \text{ cps/\%}$$

The main result of these corrections was a general improvement of magnetic and gamma spectrometric data. Total count, uranium and potassium images are affected by noise parallel to flight lines, probably due to variations in atmospheric radon. As this is still a problem in recent surveys, it was corrected simply by directional filtering which has the effect of error redistribution.

Statistics of concentration values are in good agreement with the known geology of the area, taking into account weathering, soil moisture and vegetation effects. Due to that, Th, U, K concentration data and magnetic analytic signal were classified using the ISODATA algorithm, which resulted in great improvement of the available geologic maps. This improvement was also supported by analysis of Landsat TM and airborne SAR images.

CONCLUSIONS

Airborne geophysical surveys data, acquired near 20 years ago, can be recovered using simple methods. The first step involve a careful analysis of the original procedures and removal of previous corrections. In cases where inadequate coefficients were applied new ones should be calculated and used. Atmospheric attenuation coefficients can be obtained from the original "raw" data, by simple non linear (geometric) regression. Stripping coefficients should be checked and, if necessary, substituted. If the original data was in cps, they must be converted to surface concentrations using theoretical sensitivities. For magnetic data, only the IGRF model should be checked and changed if necessary. Generally the best results were obtained by removal of a second order polynomial from the total field data.

These procedures are being applied to other projects, for the Amazon and other Brazilian regions. The authors are working in obtaining reliable biomass values from remote sensing data (optical and radar), in order to compensate most of the vegetation effects on old surveys over forested areas.

It is strongly recommended that new projects must use combined radar and laser altimetry in order to obtain approximations of biomass values and exact height above ground. Moreover, the spectrometers should be carefully calibrated for obtaining adequate stripping coefficients and sensitivities. Better background (and even radon) correction could be achieved by use of an additional shielded detector and 256 channel spectrometers. GPS positioning would solve most of the location problems. These procedures will enhance the quality of the data, turning them a powerful tool for geological reconnaissance or mapping of remote areas.

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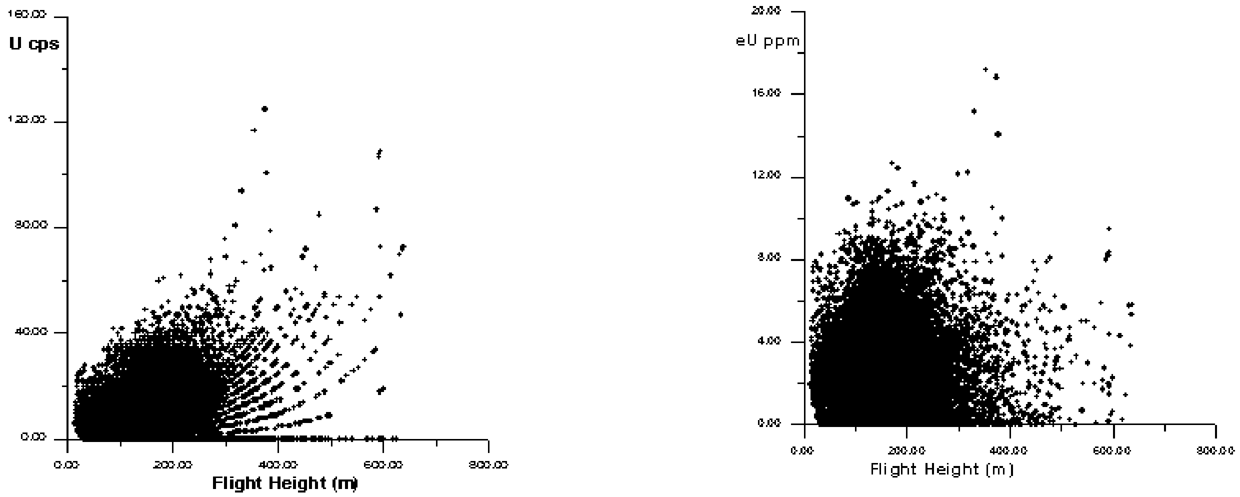

Figure 1 – Left: Plot of cps in the U channel of the original data versus flight height. Right: ppm eU versus flight height after new correction for atmospheric attenuation and conversion to concentrations.

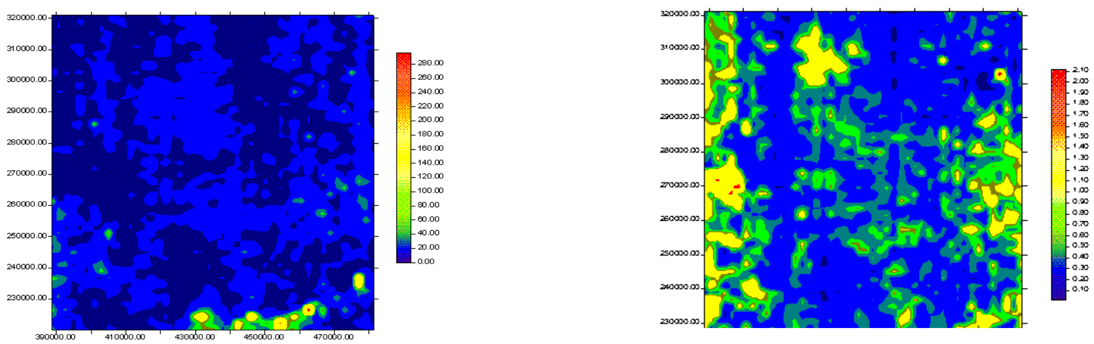

Figure 2 – Left: cps K image with original corrections for atmospheric attenuation and stripping. Right: image after new stripping and atmospheric corrections and conversion to %K. Note, at west and northwest, the potassic granite areas.