A Case History: Kimberlite Diamond Exploration in Rondonia State, Western Brazil.

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1) INTRODUCTION:

This work relates to a kimberlite diamond exploration case in Brazil, which has been carried out in Rondônia state during 1994 to 1996 by RTDM. Processing and interpretation techniques on magnetic and radiometric airborne and on ground magnetic surveys were used. Only a selected window of the full survey, precisely the most promising one, is shown here. The real ground coordinates of the maps have been changed, in order to save the airborne contractor secrecy.

2) AIRBORNE SURVEY ACQUISITION:

The airborne survey was acquired by GEOMAG, with the following specifications: ground elevation = 80±(15)m; line directions = N-S (survey lines) and E-W (control lines); line spacing = 300m (survey lines) and 3,000m (control lines); sample rate = 10/s (mag) and 1/s (gamma); aircraft speed = 200Km/h.

The employed equipment were: aeromagnetic digital compensator RMS AADC-II, with a 3-Axis fluxgate magnetometer Develco; Cesium vapour magnetic sensor Geometric G822A; Gamma ray spectrometer Geometrics GR800, with 2048 CuIn GAX 1000 sensor; RMS DGR-33 acquisition system; GPS Trimble (base and mobile station) TANS II; King KRA-10 altimeter; Rosemount barometer; Scintrex V-95 Cesium vapour base magnetometer.

3) LITHOLOGY UNITS:

Basically, the windowed area exhibits two lithologic units of the paleozoic sediments of the Pimenta Bueno graben (Siqueira, 1989): Fazenda da Casa Branca Fm. (PCcb), up to 80m thickness in the area, and Pimenta Bueno Fm. (SDpb). The Potassium radiometric airborne data (Figure (1)) clearly indicate two distinct gamma ray patterns: the Pimenta Bueno Fm. (around 140 counts/s) and the Casa Branca Fm. (around 40 counts/s). The gamma ray method is in fact a very good way to delimitate the contact between these two lithologies.

4) AEROGEOPHYSICS PROCESSING AND INTERPRETATION:

The airborne geophysical survey was interpolated using bicubic splines. Figure (2) shows the corresponding total field magnetic map, where it is not possible to see many punctual and high frequency anomalies that are typical of the classical kimberlite response. Next, some high pass filters were applied.

4.1) Vertical First Derivative:

The first derivative is one of the most important operations in kimberlite prospecting, because it enhances the high frequencies. Figure (3) shows the first vertical derivative of the total field magnetic survey (nT/m), where it is possible to see many anomalies that can be selected for further studies. Fifteen of them were selected.

4.2) Analytic Signal:

Nabighian (1972, 1984) developed the notion of analytic signal of magnetic anomalies. MacLeod et al (1993) showed that this operation is particularly important in low magnetic latitude regions, producing maxima over magnetic contacts regardless the direction of magnetization. Roest et al (1992) showed that the analytic signal can easily be expressed by:

$|A(x,y)| = [(dM/dz)^2 + (dM/dx)^2 + (dM/dy)^2]^{1/2}$ **(Eq. 1)** , where M is the observed magnetic field.

Figure (4) shows the analytic signal map (nT/m), and once more we can see many potentially favourable anomalies to follow-up.

4.3) Upward Continuation and residue:

One of the most efficient low pass filters is through upward continuation, a particulary useful method for regional mapping using magnetics. The high frequencies due to superficial magnetic bodies are attenuated and the resultant grid enhances the deeper regional structures. The frequency domain operator is:

$F(u,v) = e^{\sqrt{u^2+v^2}.z_0}$ **(Eq. 2)**, where z_0 is the altitude to be continued (negative upward), and *u* and *v* are wavenumbers corresponding to N-S and E-W direction.

In kimberlite exploration, the opposite is required: a high pass filter, which can be obtained from the same equation **(Eq. 2)**, employing positive z_0 values (downward continuation). However, this also enhances the background noise and may not be feasible in practice. An alternative technique is to calculate the upward continuation and then subtract it from the original grid. The residue of this subtraction works as a high pass filter that is particularly useful when magnetic basement crops out, like in the adjacent areas of the used window. In such areas, the kimberlite high frequency anomalies are better recognized by this method than with the first vertical derivative operation.

Figure (5) shows a low pass filter map based on a 300m upward continuation of the total field magnetic survey. It is possible to still see the large structures, while the high frequency data have been severely attenuated. Figure (6) shows the residue constructed subtracting the Figure (2) grid from the Figure (5) upward continuation grid, and it is easy to see many potencially favourable anomalies, as in Figures (3) and (4) .

4.4) Anomaly selection.

Fifteen anomalies were selected by the above mentioned methods, and each one was followed-up with a ground magnetic survey. They are shown in Figure (3).

Three of the anomalies are located on SDpb lithology (anomalies 1, 2 and 3), and the other twelve are on CPcb lithology. The first three correspond to previously known and outcropping kimberlite bodies, while for the twelve others no evidence of possible pipes can be found at the surface. The intrusions probably occurred within the time interval after the deposition of the Pimenta Bueno Fm., but before the deposition of the Casa Branca Fm. This case history is a good one to demonstrate the efficiency of magnetics to search for hidden magnetic bodies in a covered area. The twelve pipes occuring below the sedimentary cover of the Casa Branca Fm. could not have been detected through normal geological or geochemical methods.

5) GROUND GEOPHYSICS:

The fifteen selected anomalies were located on ground and regular grids were planned with line spacing between 50m (small anomalies) to 200m (large anomalies). Then, the grids were covered with ground magnetics with 12.5m station spacing using GEM GSM19 overhouser magnetometers (base and mobile stations).

The expected magnetic anomaly due to a kimberlite body in these geomagnetic conditions (inclination = -1° and declination = -10°) was a single and localized negative peak. Two distinct groups of anomalies have been found, one of them as expected. However, dipolar anomalies with a low magnetic feature in the north and a high magnetic feature in the south were also detected. The ‘negative peak’ anomalies are: 9, 10, 11, 13 and 15. The ‘dipolar’ anomalies are: 1, 2, 3, 4, 5, 6, 7, 8, 12 and 14. Figure (7) shows the ground magnetic map of anomaly 9 (‘negative peak’ one) and Figure (8) shows the ground magnetic map of anomalies 7 and 8 (‘dipolar’ ones).

The igneous rocks corresponding to the ‘negative peak’ anomalies exhibit essentially induced magnetization, while those corresponding to the ‘dipolar’ anomalies exhibit strong remanent magnetization. After drilling, it was verified (Teixeira et al, 1995) that the ‘negative peak’ anomalies correspond to olivine-melillite pipes, and the dipolar anomalies correspond to kimberlite pipes. The diamond sampling analysis results revealed null grades for the olivine-melillites and small but **positive grades** for kimberlites.

Future surveys in the same area, in order to find diamond mines, will give priority to the examination of dipolar anomalies.

6) CONCLUSIONS:

The airborne magnetic data processing, in order to select high frequency anomalies, was in this case a very good technique to explore for primary source diamonds. The ground magnetic interpretation was able to discriminate two different groups of anomalies, each one corresponding to a different rock type, and these results are important in order to indicate priorities for drilling. ‘Dipolar’ magnetic anomalies are potentially favourable to kimberlite exploration in the study area, while ‘negative peak’ magnetic anomalies are not. The conclusions can also be extrapolated to the surroundings of the windowed area, saving time and money in subsequest exploration programs.

7) ACKNOWLEDGMENTS:

We would like to thank Rio Tinto Desenvolvimento Minerais (RTDM) for the results of its airborne survey of the Rondonia area.

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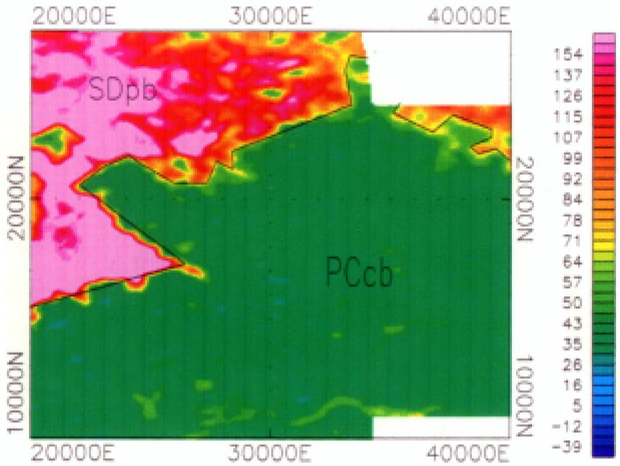
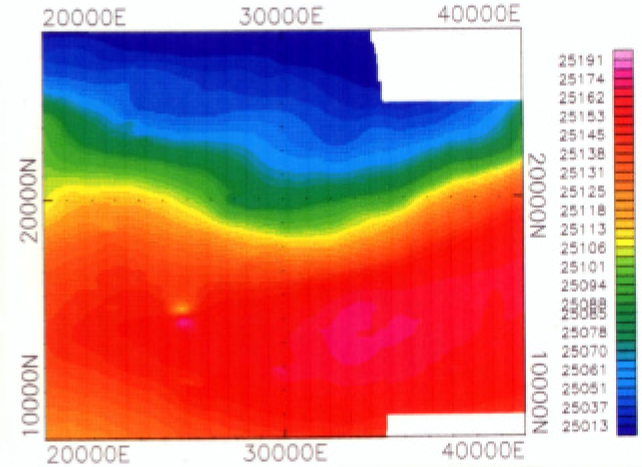
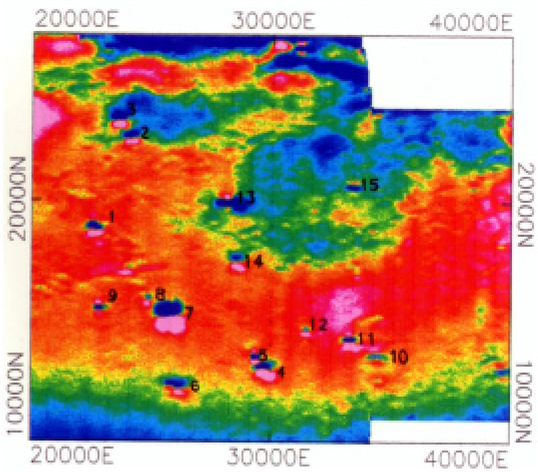


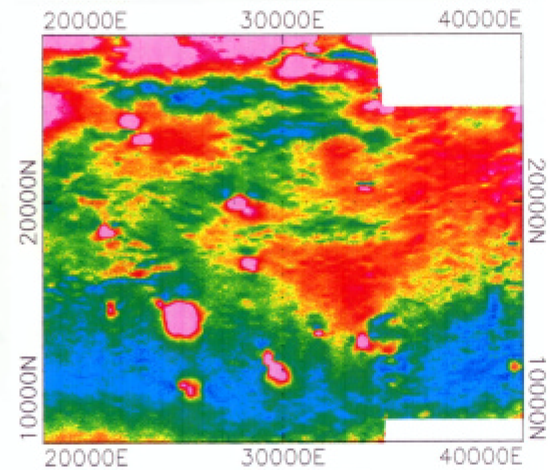
(1) Gamma Ray Potassio Counts.



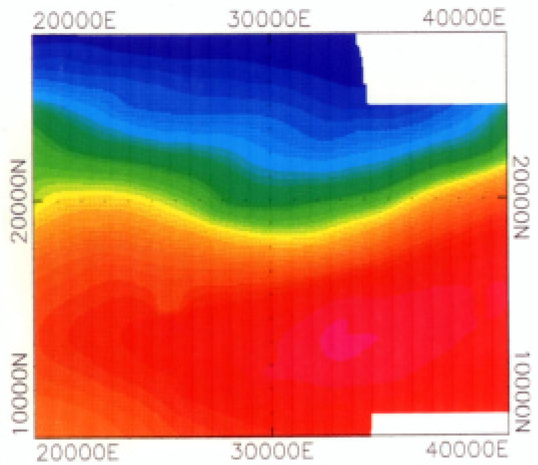
(2) Total Magnetic Field (nT).



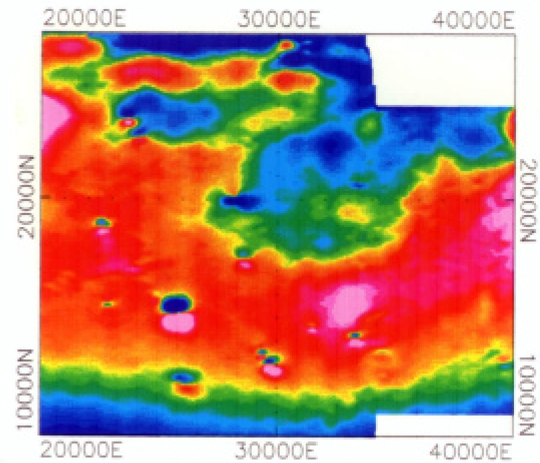
(3) Vertical First Derivative.



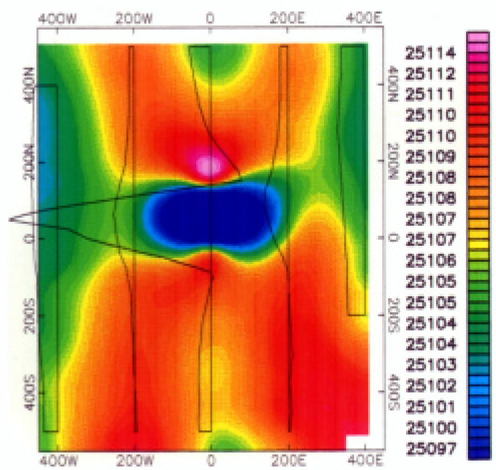
(4) Analitic Signal.



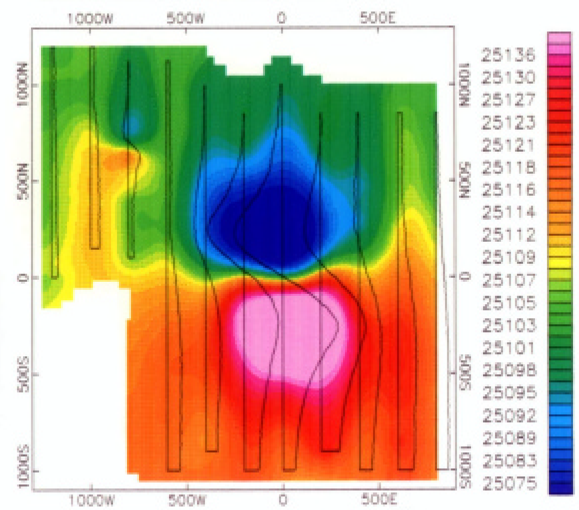
(5) Upward Continuation (300m).



(6) Residue = (Total Field - Upward Continuation).



(7) Anomaly 9 Total Magnetic Field (ground survey).



(8) Anomalies 7 and 8 Total Magnetic Field (ground survey).