

Gulf Mines Pty. Ltd.

Airborne geophysical Survey
Wollogorang area
Northern Territory

by
Fugro Airborne Surveys



Quality Control Report
by
Steve Webster P/L

November, 2006

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1 Introduction

An airborne magnetic and radiometric survey was conducted over the Wollogorang area in the Northern Territory during August - September, 2006. The survey, contracted by Gulf Mines P/L to **Fugro Airborne Surveys** (FAS), was based out of the Wollogorang cattle property. One requirement of the Contract was to merge the survey data with equivalent data from the Hartz Range survey, to the south-east, flown in 2005. The contract was prepared and supervised with quality control by Steve Webster P/L.

A separate **Operations and Processing Report** has been prepared by FAS to outline the procedures taken to complete the project.

This report, by Steve Webster P/L, provides additional technical information on:

- i) equipment calibration, operations and contract performance
- ii) certain processing procedures needed to enhance the data and map presentation

2 Survey progress

The survey area is located in the east of the Northern Territory and the survey flight plan is shown in figure 1, with North - South flight lines spaced 100m apart and East - West tie lines spaced 1,000m apart for a total of 17,913 km.

The boundaries of the Wollogorang survey area as defined in the Contract were:

Table 1

GDA94	Zone53
East	North
782,000	8,111,000
819,000	8,111,000
819,000	8,076,000
785,000	8,076,000
785,000	8,052,000
776,000	8,052,000
776,000	8,090,000
782,000	8,090,000

The aircraft and crew based at Wollogorang station during August and September, 2006. The survey statistics, as itemised in the accompanying table 2, show that the progress of the survey included 14 production days (2 x 5hour flights/day) and 8 days were lost due to aircraft maintenance or repairs. Thus in operation mode the survey averaged 1,321 km per production day but the survey duration was protracted.

Table 2

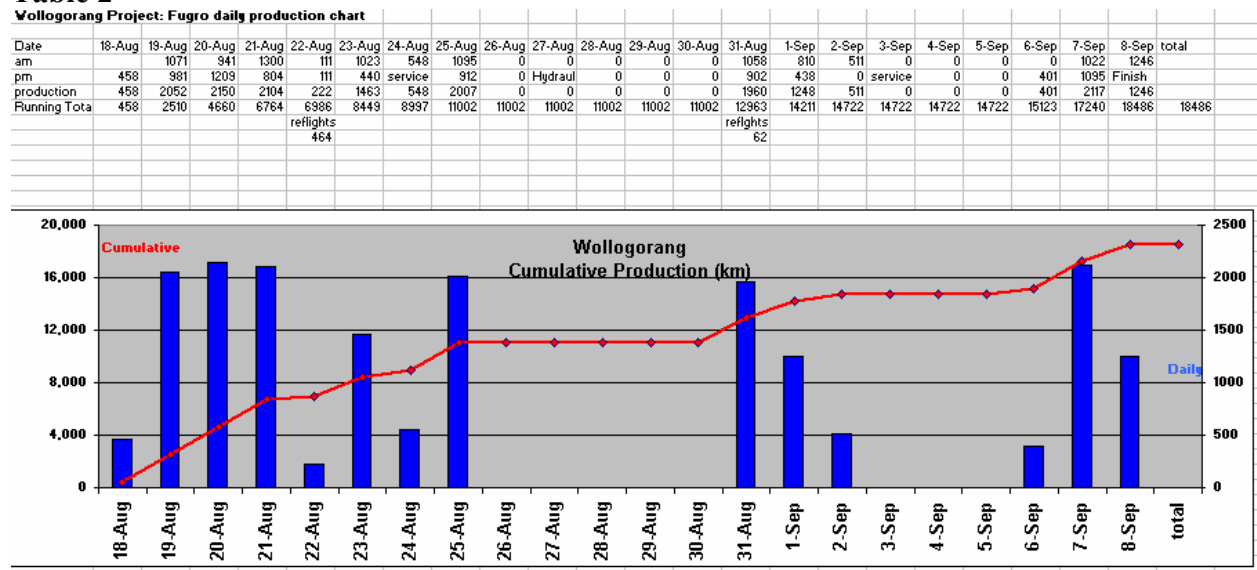


Figure 2a. Graph of daily and cumulative flight production

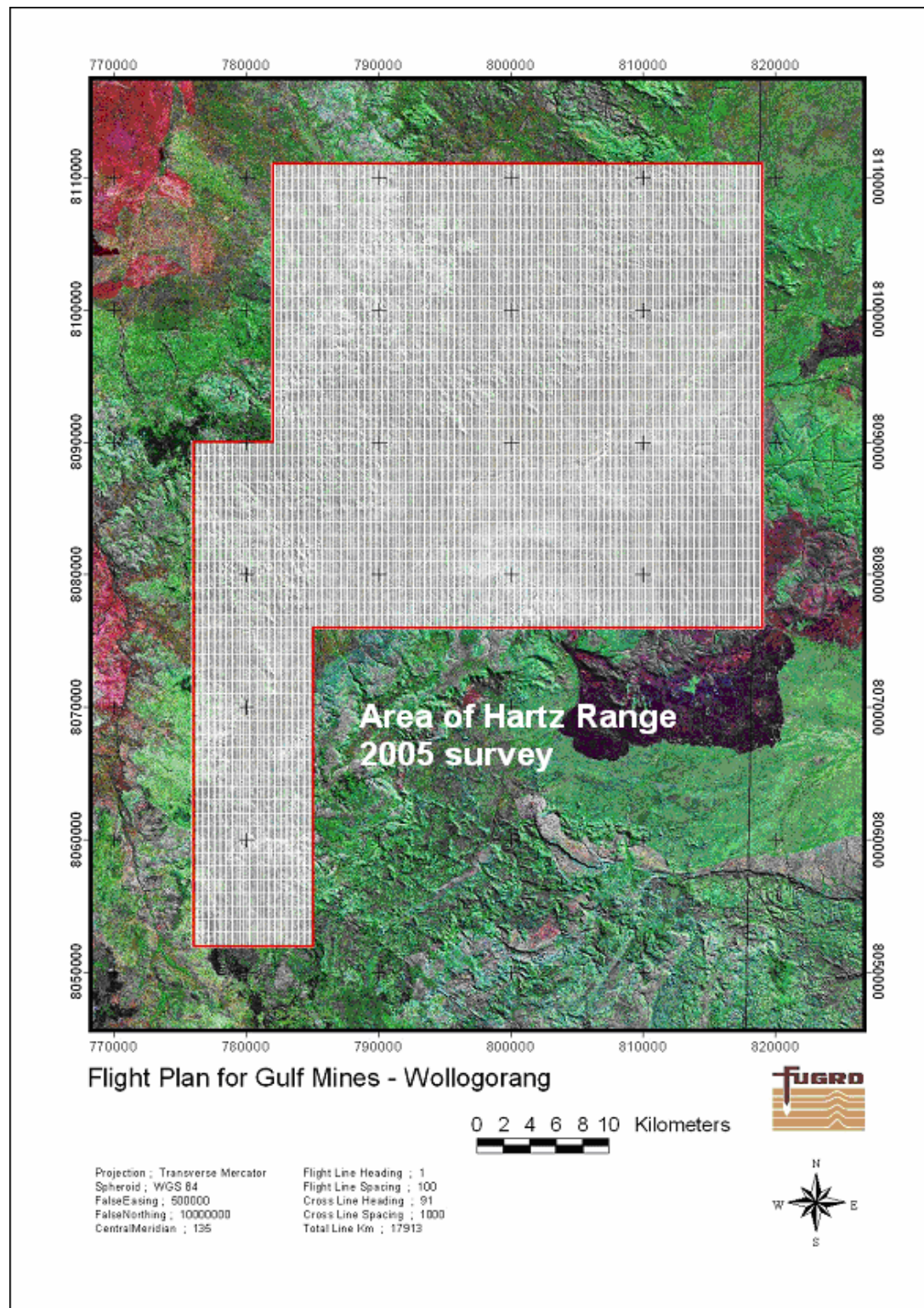


Figure 1. Proposed flight plan of Wollogorang airborne geophysical survey

3 Survey Equipment and basic data processing

The survey equipment was installed in Perth on a Shrike Aero-commander aircraft (VH -WAM) and radiometric calibrations were carried out over the standard calibration range. A separate report by Fugro discussing the results of this calibration and including the correction coefficients for height, cosmic, aircraft background and stripping ratios is included as the Appendix and will not be included here.

The magnetometer was in mounted in a stinger (as shown in accompanying photographs) located at the rear of the aircraft to remove it as much as possible from the magnetic effects of the aircraft. These effects were further reduced by on-site calibrations that allow real-time computations of the magnetic effects of aircraft maneuvers—described in the following section 4. Two identical base station magnetometers were setup near the base landing strip, as shown in figure 3b, to observe diurnal variation as required in the Contract.

The various instruments, data processing and acquisition units are incorporated into a system rack, as shown in figure 3c, that is mounted behind the pilot's seat. The 33 litres of radiometric detectors are mounted behind the acquisition rack.

Basic data processing and leveling are similar to produce the main products of Total Magnetic Intensity (TMI), four channels of radiometric data (Total Count, Potassium, Uranium and Thorium) and digital terrain model (DTM) once each had had individual corrections applied.

These include:

- Magnetics: compensation for aircraft maneuvers
 Correction for system parallax, spike removal and diurnal correction
 IGRF computation for each value
- Radiometric: noise filtering using the NASVD method, background removal, cosmic correction,
 spectral stripping and Radon removal by the spectral ratio technique.
 Height correction and conversion to equivalent concentrations.
- DTM: post processing of GPS altitude, correction of radar altimeter

For all products, the corrected data are tie-line leveled using least-square procedures until errors are minimized then micro-levelling techniques are applied to remove residual errors. The data are gridded and preliminary grids examined for errors by the quality control nominee to ensure that the processing has not introduced artifacts. The survey data were merged with the data from the Hartz Range airborne geophysical survey flown in 2005 and final product maps produced, as shown in the attached sample maps.

An example of the quality control is provided by examination the radiometric test line which was flown on each flight to monitor daily variation (which can be seen in the attached graph, figure3) where radon contamination can be observed in three channels while the thorium channel (green line) is constant within set standards. Data processing can compensate the data for these daily variations.

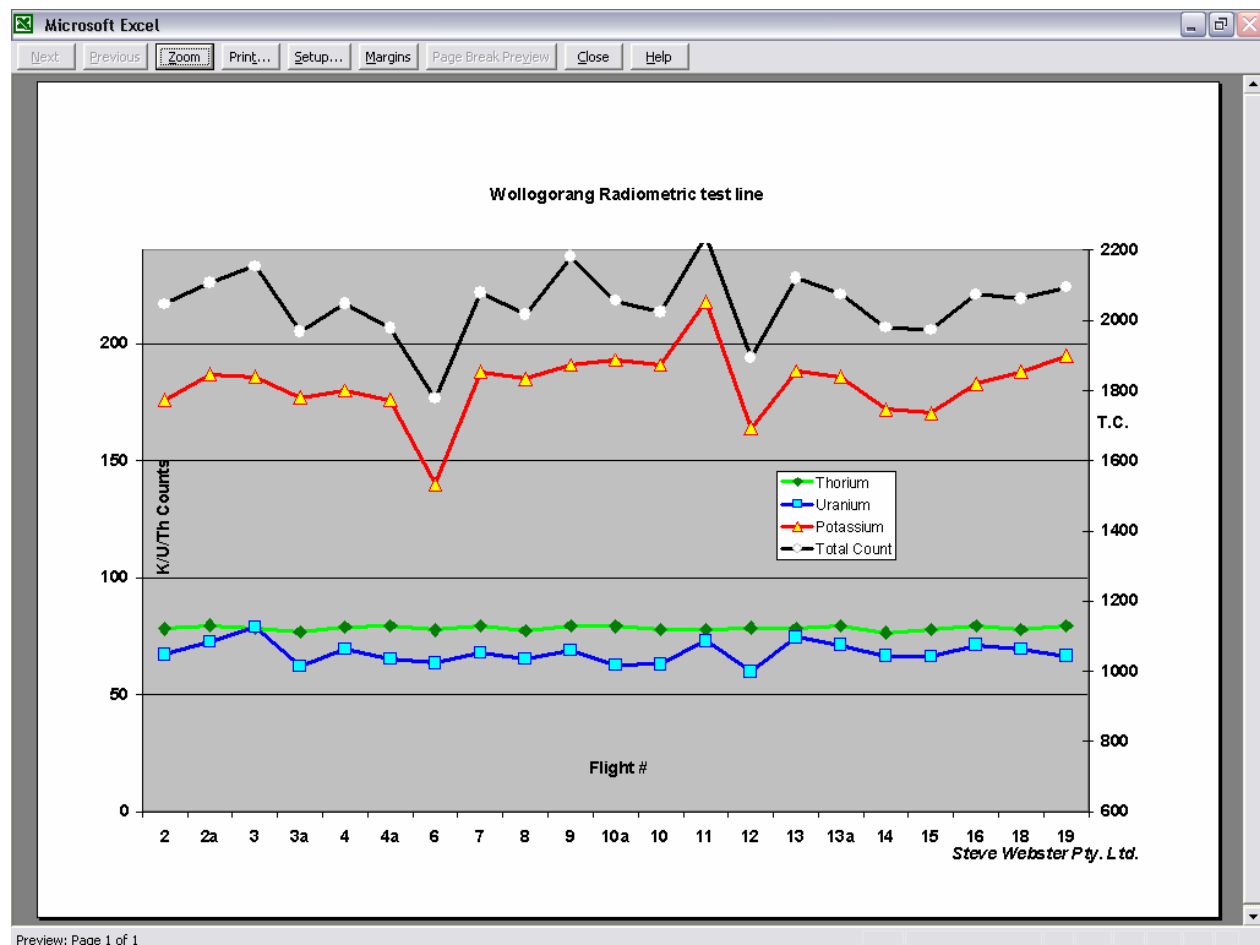


Figure 3 Graph of daily variation recorded along radiometric test line



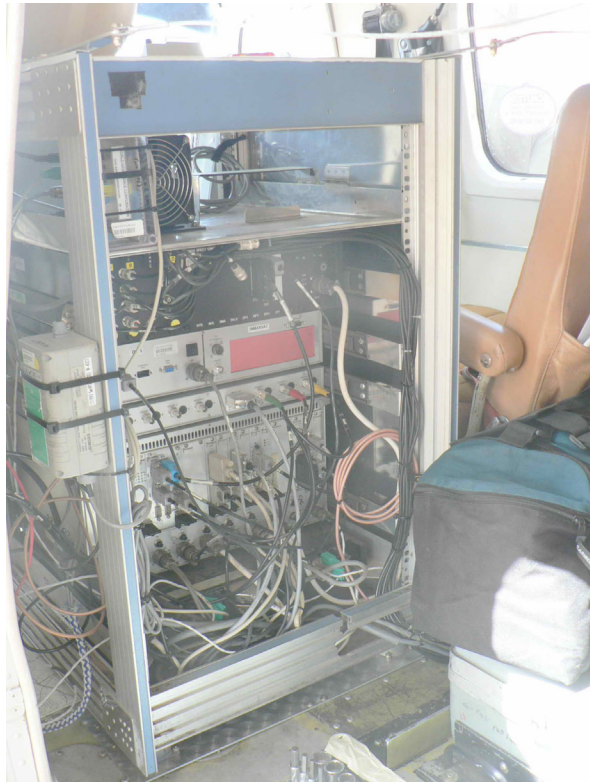
Figure 3a Aircraft with rear stinger instrument mount



Figure 3b Base station magnetometer



Figure 3c Fugro data acquisition unit



4 QUALITY CONTROL

4a Airborne magnetic survey Figure of Merit

The only quantitative parameter utilised in airborne magnetic surveys as an estimate of survey data quality is the Figure of Merit (**FOM**). This parameter is an estimate of the compensation required to correct the airborne magnetic measurement for the effects induced by the aircraft manoeuvres as it acquires data.

Modern surveys for mineral exploration are designed to measure a wide range of responses from shallow sources through to basement responses and a new relationship needs to be used to quantify the compensation of high frequency anomalies. The standard compensation data can be analysed to derive the high frequency component of the manoeuvre noise and the reduction obtained by mathematical computation. The data are high-pass filtered to remove the geology derived signal and the noise level is then computed by Standard Deviation analysis.

Fugro AS has a standard procedure, termed a '*compensation box*', to estimate a **FOM** parameter and this requires the aircraft to be put through a set of 5 pitches (of 10° to 20°), 5 rolls (up to 10°) and 5 yaws along line and 5° and 10° from both sides of line direction. Thus five sets of readings are averaged for each manoeuvre in the four principal directions. For the **Gulf Mines Wollogorang** project, the FOM determination was made at the start of the flying programme and the FOM parameter was of the order of 5 times noise reduction to a level of +/- 0.02nT.

4b Wollogorang magnetic Comp-box

The compensation flights (Comp-box) were flown, at altitude, in two large circles to determine the compensation parameters then in cardinal directions with two segments of 8 – 10 seconds each, as shown in the attached figure 4a. The data profiles for the 8 segments are shown as green lines for uncompensated data and red lines for compensated data plus the (4th difference) filtered data spread (reflecting instrumental noise which should be the same in all directions) which is basically reduced to zero.

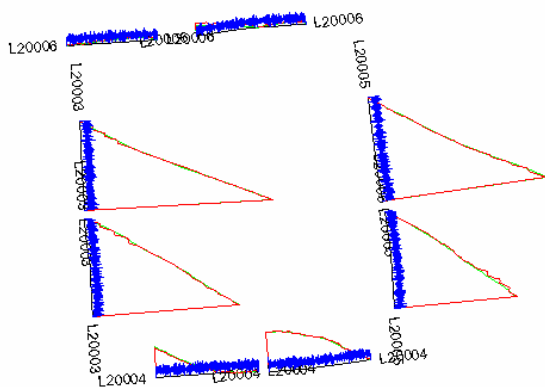


Figure 4a. Flight path of lines flown in cardinal directions for FOM comp-box.

The eight data sets were analysed to determine the standard deviation of high-pass filtered magnetic residuals—required as the magnetic variation is different in each direction with maximum change in the N-S or S-N direction and much less change in E-W or W-E direction.

Direction	Line#	# samples	S.D.(Uncomp)	S.D.(Comp)	Ratio
N-S	3.1	680	0.1758	0.0227	7.7445
	3.2	760	0.1560	0.0233	6.6953
W-E	4.1	790	0.0390	0.0176	2.2159
	4.2	770	0.0524	0.0189	2.7725
S-N	5.1	700	0.1495	0.0238	6.2815
	5.2	740	0.1256	0.0235	5.3447
E-W	6.1	770	0.0855	0.0193	4.4301
	6.2	640	0.0708	0.0192	3.6875
			0.1068	0.0210	4.8965

The data table shows a residual uncompensated data range from 0.039nT to 0.176nT, depending on direction, with a standard deviation of 0.107nT. The compensated data range is from 0.018nT to 0.023nT with a standard deviation of 0.021nT, which is a 5.1 times reduction in noise to an acceptable level. Figure 4b shows the data for one of the S-N flights with magnetic intensity increasing by more than 30nT to the north and the effects of the maneuvers as an oscillating wave (central plot of high pass filtered data). The bottom plot shows the uncompensated filtered data with the effects of the various maneuvers clearly evident (green line) and the filtered compensated data (red line) showing a reduction in noise to less than +/- 0.1nT.

For the Wologorang survey data, the averaged 'raw' SD value is 0.11nT and compensated (average) SD is 0.021nT. The absolute value of 'raw' SD of 0.1nT is encouraging, but the noise reduction factor of 5 times reduction to the order of 0.02nT is significant. To maintain this accuracy, for final corrected data, requires low noise levels in the raw magnetic data and high compensation parameters to reduce the noise to much less than the nominated minimal noise signal.

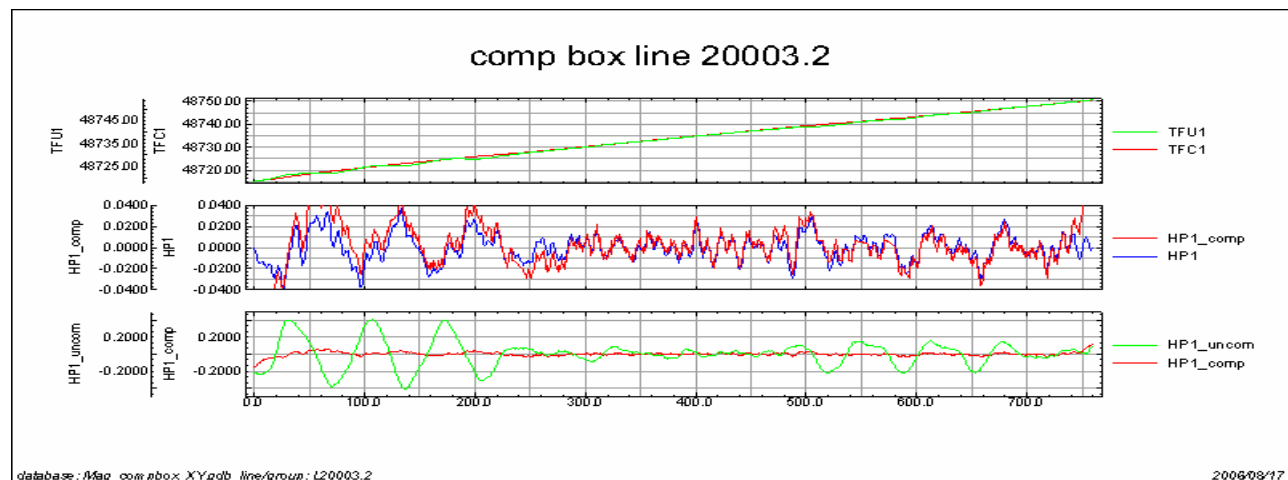


Figure 4b. Plot of uncompensated and compensated magnetic data, Wologorang FOM

4c Diurnal variation in magnetic field

As mentioned above, the daily variation in the magnetic field was observed using two identical magnetometers (one as backup) recording magnetic field strength at 5 second intervals to 0.1nT resolution. The two magnetometers were synchronized daily with the aircraft acquisition system. The monitoring software allows in-field checking of the magnetic field to detect magnetic storms that produce field variations outside of Contract specifications (5nT in 5 minutes). The attached figure 4c shows the magnetic field variation (lower graph) with the time interval of various flights superimposed so that the impact of abnormal disturbances can be recognized. Also shown is the rate of change (upper curve) that rapidly identifies the segments that are above specifications. Flight lines that are impacted by these problems are then scheduled for re-flying, however, for the Wollogorang survey there was little magnetic storm activity and few re-flights were required.

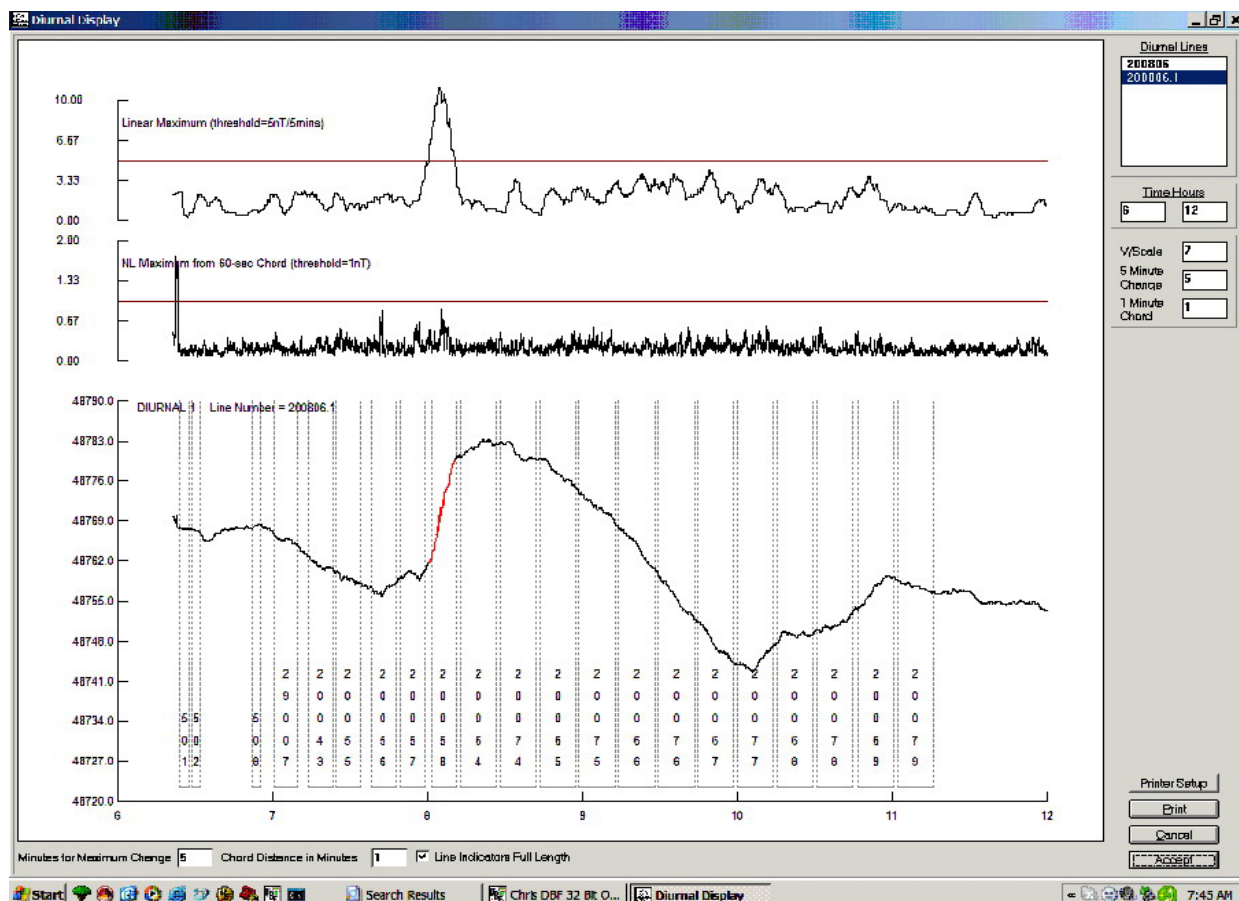


Figure 4c. Example of magnetic diurnal check plot

5 Additional Processing--Reduction to Pole

Magnetic anomalies can vary considerably in pattern depending on several factors, including:

- i) inclination of the inducing Magnetic Field vector, which changes with latitude
- ii) the presence and attitude of any **magnetic Remanence** component
- iii) strike and dip of the magnetic source material.

The inclination of the earth's magnetic field varies from vertical at the poles to horizontal at the equator. As shown in the sketch, the lines of (Primary Field) force may be assumed to intersect the susceptible body at the angle of inclination and polarise the source to generate a secondary magnetic field. This secondary field will either add to or subtract from the Primary Field producing an anomaly that is measured by the magnetometer in the aircraft.

The resulting anomaly patterns for a symmetrical body may be grouped into three types, as shown in the accompanying sketch:

Polar: with vertical inclination, the secondary field will be adding to the primary field over the source and subtracting from the primary only at some distance from the source. Thus the pattern is for a strong *positive anomaly over the source* with a weak flanking negative aureole.

Equatorial: with a horizontal primary field the pattern will be reversed as the secondary field will add to the primary *over the source giving a negative anomaly* with a flanking positive aureole.

Mid-latitude: for other latitudes the primary field will be intersecting the polarisable body at an angle giving rise to an asymmetric secondary field that will be mainly positive at steep inclinations and mainly negative at shallow inclinations. The positive and negative pattern is termed a dipolar anomaly.

The *reduction to pole* technique is a filtering procedure that recomputes the observed data set to that which would have been observed if the inclination were vertical, ie at the pole. The result is to remove the negative component of the anomaly and re-locate the positive peak to a position over the source with a symmetrical shape. The RTP data set should be easier to interpret as the patterns are less complicated and superimposed anomaly patterns, ie shallow upon deep sources, more easily separated. Also, if there is a remanent component in the magnetic anomaly pattern then the RTP process will not totally remove the dipole pattern and an asymmetric anomaly will still be evident.

In the attached figure 4, showing part of the TMI and RTP data for the Wollogorang (**inclination = -47° S**), there are several anomaly patterns that illustrate the benefit of the procedure by shifting the anomaly lows to enhance the boundaries of sub-blocks and giving a uniform colour distribution throughout the block.

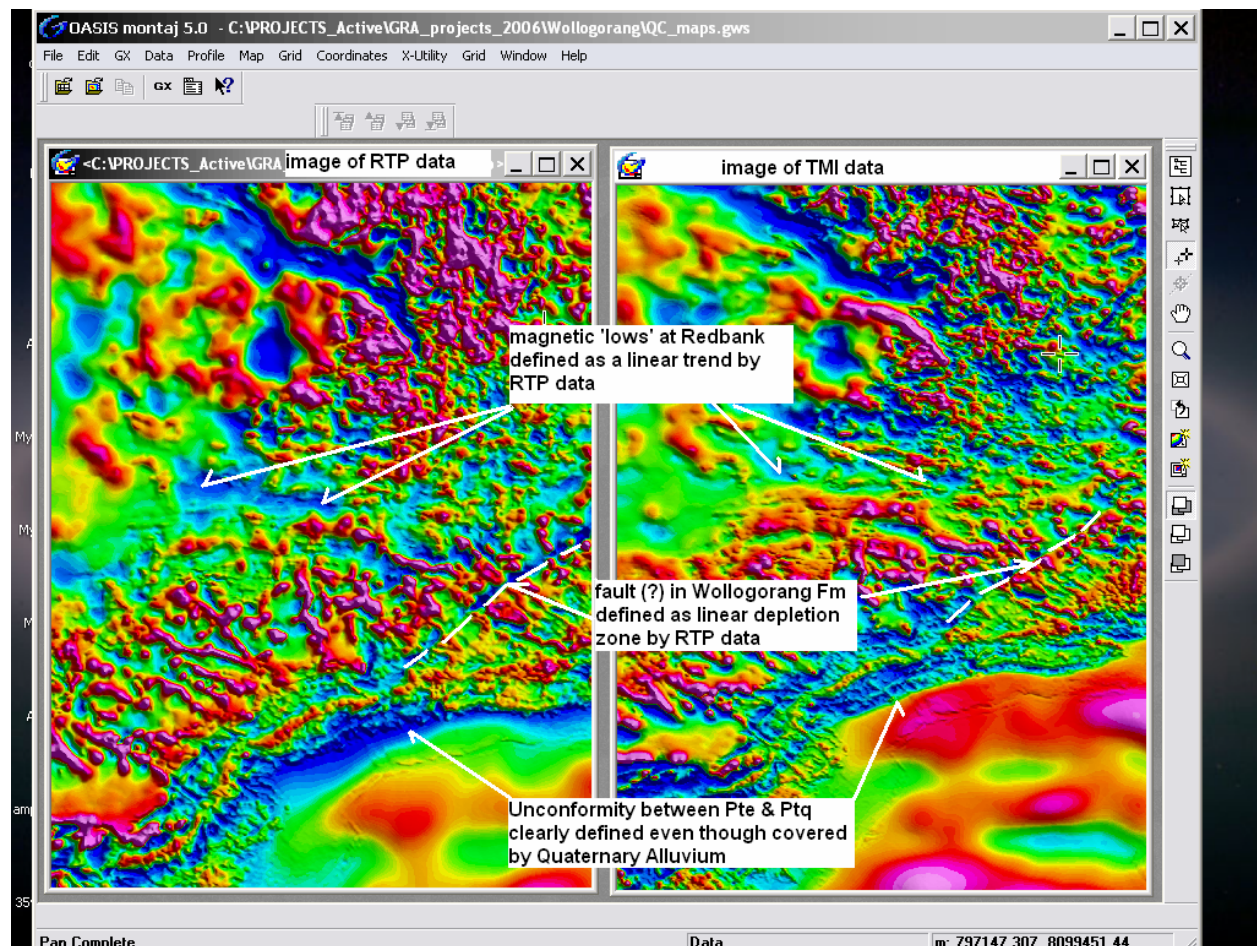


Figure 5. Comparison between Total Magnetic Intensity (TMI) and Reduced to Pole (RTP) magnetic images for the Wollogorang survey area, illustrating the extent of changes in anomaly shape with RTP conversion.

6 Delivered final products by FAS

Maps at 1:100,000 scale of:

- Reduced to Pole magnetic intensity
- Digital Terrain model
- Ternary radiometrics
- First vertical derivative of Total Magnetic Intensity

Grids in ERMapper format of TMI, RTP, 1VD, DTM Total Count, Potassium, Uranium, Thorium and Analytic Signal.

Operations and processing report

7 Conclusions

The Wollogorang airborne magnetic and radiometric survey was carried out by Fugro Airborne Surveys during August - September, 2006 with some aircraft maintenance problems, however, the data are of high quality and the high resolution acquired should allow Gulf MinesP/L to achieve their exploration objectives for the area.