



# MAGSPEC

AIRBORNE SURVEYS



Ultra low level and  
regional survey  
specialists.



Airborne Geophysical Survey



Logistics Report

## Southern Cross Bore Project

Survey carried out on behalf of

**DAVENPORT RESOURCES LIMITED**

(Reference Number: 1060)

31/07/2017

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## 1. SURVEY EQUIPMENT

### 1.1 Aircraft

The aircraft used was a Cessna 210, specially modified for geophysical survey with a tail boom and various other survey configuration modifications.

Registration - VH-MDG



### 1.2 Data Acquisition System

High speed digital data acquisition system.

- Sample rates up to 20 Hz
- Integrated Novatel OEM GPS receiver providing positional information that is used to tag incoming data streams in addition to providing pilot navigation guidance
- High precision Caesium vapour magnetometer
- Visual real time on-screen system monitoring / error messages to limit re-flights due to equipment failure

### 1.3 Magnetometer

Single sensor tail boom mounted.

- Model / Type - G-822 Caesium vapour magnetometer
- Resolution - 0.001 nT resolution
- Sensitivity - 0.01 nT sensitivity
- Sample Rate - 20 Hz ( $\approx$ 3.5 metre sample interval)
- Compensation - 3-axis fluxgate magnetometer

### 1.4 Gamma-Ray Spectrometer

Two Radiation Solutions RSX-4 spectrometers were used.

- Total Crystal Volume Down - 32 L
- Channels - 1024
- Sample Rate - 1 Hz
- Multi-peak automatic gain stabilisation.

### 1.5 Altimeters

Bendix/King KRA 405 radar altimeter.

- Resolution - 0.3 m
- Sample Rate - 20 Hz
- Range - 0-760 m

Barometric pressure sensor.

- Accuracy - RSS  $\pm$ 0.25% FS (at constant temp)
- Range - 600-1100 hPa

### 1.6 Magnetic Base Stations

Scintrex Envi-Mag & Geometrics G-856 proton precession base station magnetometer.

- Resolution - 0.1 nT
- Accuracy - 0.5 nT
- Sample Rate - 0.2 – 0.5 Hz

The Scintrex Envi-Mag sampling at 2 seconds was used for all corrections.

## **2. NAVIGATION AND FLIGHT PATH RECOVERY**

Integrated Novatel OEM615 GPS receiver:

- L1/L2 + GLONASS Dual Frequency
- 120-channel

Navigation information supplied to the pilot via an LCD steering indicator. All data were synchronised to a one pulse per second triggered by the GPS time.

## **3. CALIBRATIONS AND CHECKS**

### **3.1 Magnetometer**

A compensation box was flown prior to survey. The compensation consisted of a series of pitch, roll and yaw manoeuvres in reciprocal survey headings at high altitude. The measured output from the 3-axis fluxgate magnetometer was recorded and used to resolve a compensation solution. This solution was applied when post-compensating all survey magnetometer data to remove manoeuvre effects and heading error.

### **3.2 GPS**

GPS accuracy tests were performed by accumulating GPS readings for approximately 5 minutes whilst the aircraft was static. All readings (X, Y, Z) were within 5 meters.

### **3.3 Altimeters**

Prior to commencement of survey production, the radar altimeter was checked for linearity by way of a swoop test over flat terrain.

## **4. QUALITY CONTROL**

### **4.1 During Flight**

During survey the pilot is notified of any deviation in system health by prompts overlaid onto the navigation screen. Should errors occur, the flight is aborted and survey does not recommence until system errors are resolved.

The diurnal base station was monitored by ground crew.

## 4.2 Post Flight

Upon completion of each flight all survey data were transferred from the acquisition system to the infield data processing computer. Using customised techniques, the data were checked for any errors and compliance with specifications.

All profiles were visually checked. The flight path was plotted with colour-coded indicators of any out of specification height or cross-track. The data were gridded and visually inspected for errors and compared for continuity with previous flights.

The summed 256-channel spectra were plotted and inspected. The test line and pre- and post-flight ground calibration data were tabulated and reviewed.

## 5. DATA PROCESSING

### 5.1 Magnetism

The following steps were performed during the magnetism processing:

- Review or application of compensation
- Parallax correction
- Diurnal filtering and subtraction
- IGRF correction using the updated current IGRF model
- Tie line levelling
- Micro levelling

Compensation of the magnetometer data was applied using the recorded XYZ fluxgate data using Geometrics MagComp Airborne compensation software. A suitable compensation flight (comp box) was processed to obtain the optimum compensation solution which was then applied to all survey data.

The base station magnetometer data were reviewed, de-spiked if necessary and filtered with an 11-point non-linear filter. These data were then subtracted from the measured aircraft data using time that was synchronised to both the acquisition system and the base mag unit.

The IGRF correction was applied using the updated IGRF 2015 model adjusted for height of the aircraft. This correction was calculated and applied at each point.

Tie line levelling was applied by way of a least squares minimisation procedure using a polynomial fit of order 0 over the cross over errors calculated between the traverse and tie line intersections. A fit to ties process was selectively applied and constrained by several parameters such as cross over height differences and maximum and minimum allowable corrections.

Using MAGSPEC Airborne Surveys' proprietary micro levelling techniques, some selective micro levelling was carefully applied and the resulting channel was then considered final.

At all stages of processing the data were stringently checked against and compared to the previous processing stage to ensure the integrity of the data were protected and no detail was removed or altered.

## 5.2 Radiometrics

Radiometric processing consisted of the following steps:

- 256 channel spectral noise reduction in the form of NASVD
- Dead time, cosmic and background radiation corrections
- Energy recalibration
- Channel interaction correction (stripping) and extraction of ROIs
- Height corrections using STP altitude to the nominal survey height
- Radon removal using the Spectral Ratio method
- Levelling if required

### Gamma-ray Spectrometric Data Processing

The raw spectra were first smoothed using the Noise Adjusted Singular Value Decomposition (NASVD) method, (Hovgaard and Grasty, 1997).

For the NASVD process twenty (20) principal components were generated. These components were visually inspected and the final number of components for reconstructing the spectra were determined. Eight (8) components were used to reconstruct the spectra.

For all spectrometers, spectral drift was checked, by monitoring the potassium and thorium channel positions from average spectra along flight lines. The procedure for determining peak positions was the same as used during calibration. If the thorium peak is found to move more than 1 channel or the potassium peak by more than 0.5 channel, energy calibration is performed to determine the count rates in the standard windows.

Both the aircraft 256-channel background spectra and the scaled 256-channel cosmic spectra were subtracted from the 256-channel data.

Deadtime corrections were applied to each spectrum channel or window.

Radon background removal was performed using the Minty Spectral Ratio method (1992).

In areas of significant topographic variation, the altimeter data were first lightly filtered to smooth sudden jumps that can arise when flying over steep terrain (which cause problems

when height-correcting the data). These data were then converted to effective height ( $h_e$ ) at standard temperature and pressure (STP).

The background-corrected count rates in the 3 windows were stripped to give the counts in the potassium, uranium and thorium windows that originate solely from the potassium, uranium and thorium decay series. The window stripping ratios  $\alpha$ ,  $\beta$ ,  $\gamma$ ,  $a$  and  $g$  were estimated from measurements over calibration pads, where:

$\alpha$  - is the thorium into uranium stripping ratio, (equal to the ratio of counts detected in the uranium window to those detected in the thorium window from a pure thorium source);

$\beta$  - is the thorium into potassium stripping ratio for a pure thorium source;

$\gamma$  - is the uranium into potassium stripping ratio for a pure uranium source;

$a$  - is the reversed stripping ratio, uranium into thorium, (equal to the ratio of counts detected in the thorium window to those detected in the uranium window from a pure source of uranium);

$g$  - is the reverse stripping ratio, potassium into uranium for a pure potassium source.

The 3 principal stripping ratios ( $\alpha$ ,  $\beta$  and  $\gamma$ ) increase with altitude above the ground as shown in the Table 1.1.

Table 1.1. Stripping ratio increase with Aircraft altitude at STP.

Stripping Ratio	Increase per metre
$\alpha$	0.00049
$\beta$	0.00065
$\gamma$	0.00069

Each of the 3 main stripping ratios were adjusted for altitude before stripping was carried out. If 5 stripping ratios are used, then the stripped count rates in the potassium, uranium and thorium channels ( $N_K$ ,  $N_U$ ,  $N_{Th}$ ) are given by:

$$N_K = \frac{[n_{Th}(\alpha\gamma - \beta) + n_U(a\beta - \gamma) + n_K(1 - a\alpha)]}{A}, \quad (A5)$$

$$N_U = \frac{[n_{Th}(g\beta - \alpha) + n_U - n_K g]}{A}, \quad (A6)$$

$$N_{Th} = \frac{[n_{Th}(1 - g\gamma) - n_U a + n_K a g]}{A}, \quad (A7)$$

where

$$A = 1 - g\gamma - a(\alpha - g\beta). \quad (A8)$$

The background-corrected and stripped count rates were corrected for variations in the altitude of the detector using the equation:

$$N_{corr} = N_{obs} e^{-\mu(h_0-h)}, \quad (A9)$$

where: -

- $N_{corr}$  = the count rate normalized to the nominal Survey altitude,  $h_0$ ;
- $N_{obs}$  = the background corrected, stripped count rate at STP height  $h$ ;
- $\mu$  = the attenuation coefficient for that window.

Where the STP height above ground level exceeds 200 m, a revised value for value of  $\mu$  is used in equation A9.

The resulting potassium, uranium, thorium and total count (cps) were converted to concentrations using the coefficients derived from the Carnamah radiometric test line. Refer to Appendix 2 – Calibrations.

Where required, tie line levelling is applied to the Total Count and Uranium channels to remove any effects caused by residual radon background. A least-squares/median filter procedure applied over the calculated cross over errors at each intersection of the flight and tie lines generated a correction value. A new tie-line levelled channel is then output by application of this correction value to the original channel.

Where required, using MAGPSEC Airborne Surveys' proprietary micro levelling techniques, some selective micro levelling is carefully applied and the resulting channel is then considered final.

At all stages of processing the data were stringently checked against and compared to the previous processing stage to ensure the integrity of the data was protected and no detail was removed or altered.

### 5.3 Digital Elevation Model

DEM processing consisted of the following steps:

- Inspection of height channels
- Parallax correction of radar altimeter
- Subtraction of radar altimeter from GPS height
- Tie line and micro levelling

The GPS and radar heights were visually inspected for errors and any spikes were carefully corrected.

The Radar Altimeter data were then subtracted from the GPS height to create the Digital Elevation channel.

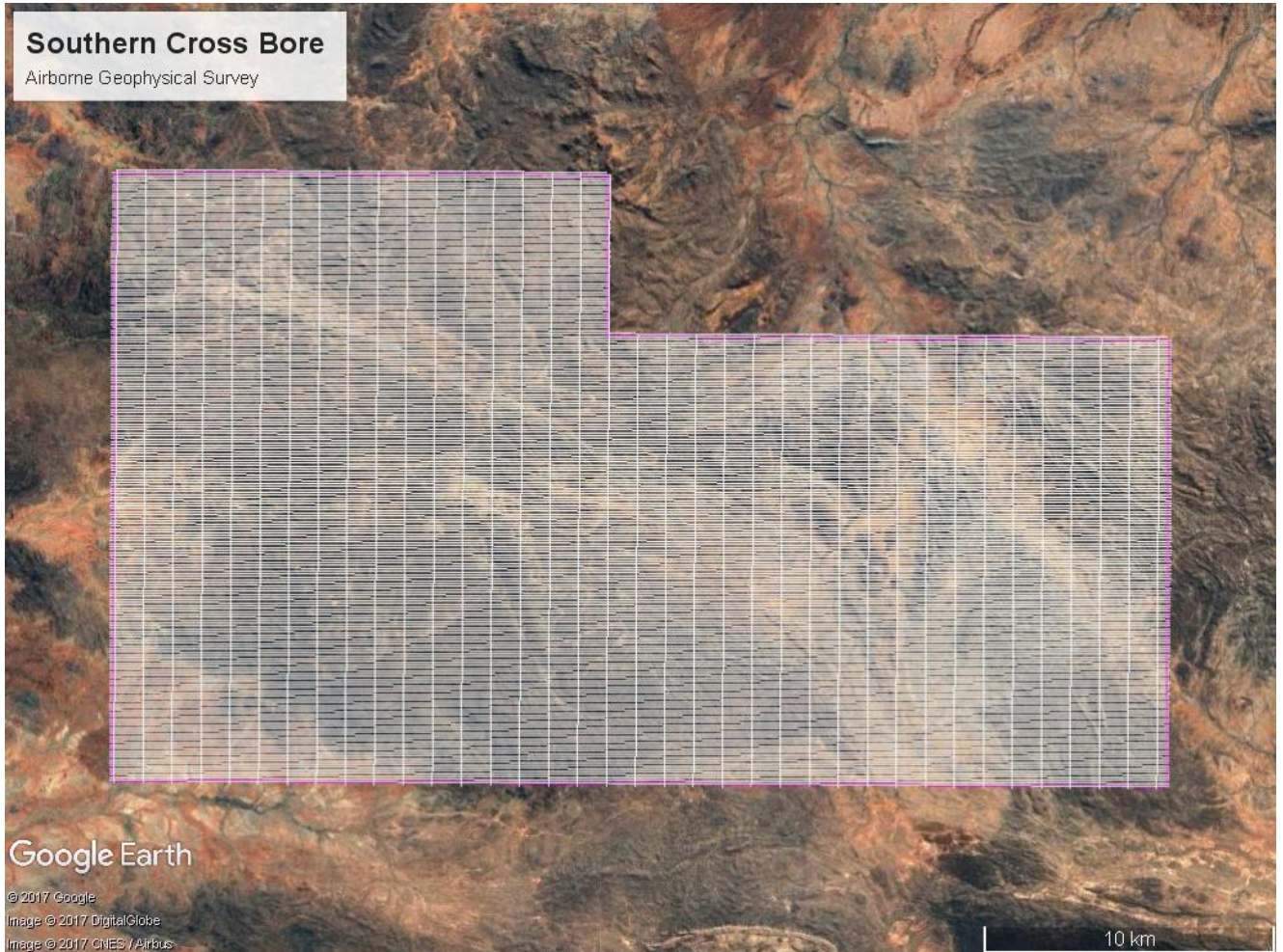
Tie line levelling was applied by way of a least squares minimisation procedure using a polynomial fit of order 0 over the cross over errors calculated between the traverse and tie line intersections.

Using MAGSPEC Airborne Surveys' proprietary micro levelling techniques, some selective micro levelling was carefully applied and the resulting channel was then considered final.

At all stages of processing the data were stringently checked against and compared to the previous processing stage to ensure the integrity of the data was protected and no detail was removed or altered.

## APPENDIX 1 - SURVEY AREA

### Survey Area Diagram



Southern Cross Bore

**Survey Area Coordinates and Flight Specifications**

**Southern Cross Bore Project**

WGS84

SUTM Zone 53

Easting	Northing
393700	7451000
410700	7451000
410700	7445500
430100	7445500
430100	7430200
393700	7430200

Area Name	Traverse Line spacing (m)	Traverse Line Direction (deg)	Tie Line Spacing (m)	Tie Line Direction (deg)	Sensor Height* (m)	Line Kilometres
Southern Cross Bore	100	090-270	1,000	000-180	50	7,290

**Total Survey Line Kilometres - 7,290**

## APPENDIX 2 - FIELD OPERATION AND PROJECT MANAGEMENT

### Operational Base

The aircraft and crew were based in Alice Springs, Northern Territory for the duration of the survey. Production of the survey started on the 13<sup>th</sup> July 2017 and ended on the 23<sup>rd</sup> July 2017. On 21<sup>st</sup> July there was no production, due to helicopter mustering within the survey block.

### Personnel

Client Contacts	-	Chris Bain
	-	Karen Gilgallon
Pilot	-	Daniel Wright
Operations	-	William Bennett
Project Management	-	Peter Spencer
Data Processing	-	Cameron Johnston

### Base Station Magnetometer Positions

The base station magnetometers were located near the Alice Springs airport.

Base station 1 location co-ordinates:

WGS84      386037E, 7365883N Zone 53 (flights 1-3)  
              386454E, 7367670N Zone 53 (flights 4-10)

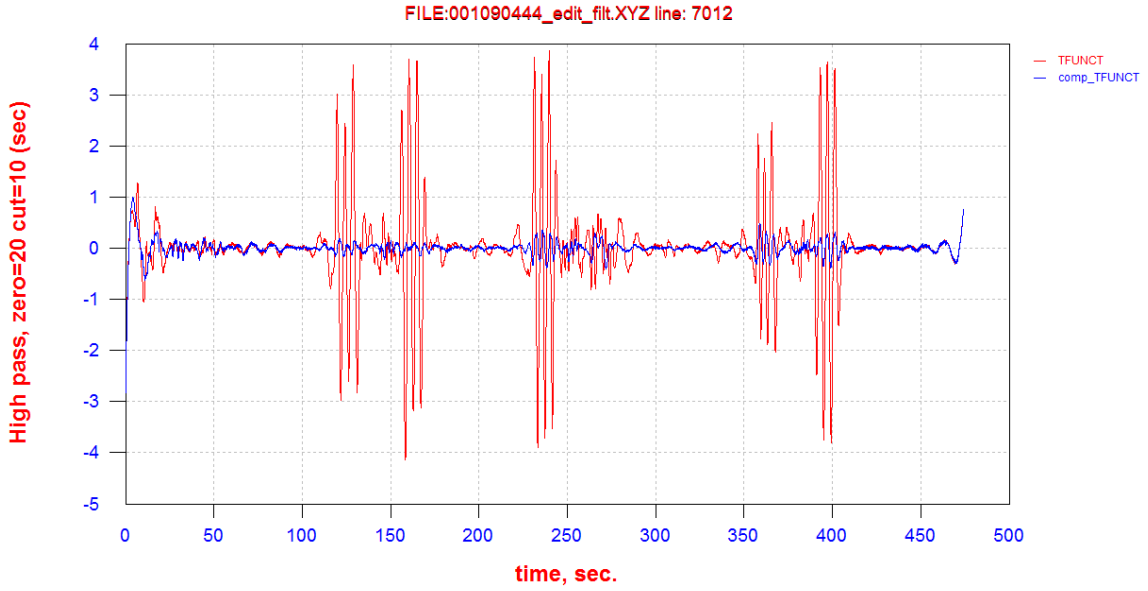
Base station 2 location co-ordinates:

WGS84      386053E, 7365900N Zone 53 (flights 1-3)  
              386459E, 7367601N Zone 53 (flights 4-10)

*Base station 1 was used for all diurnal correction.*

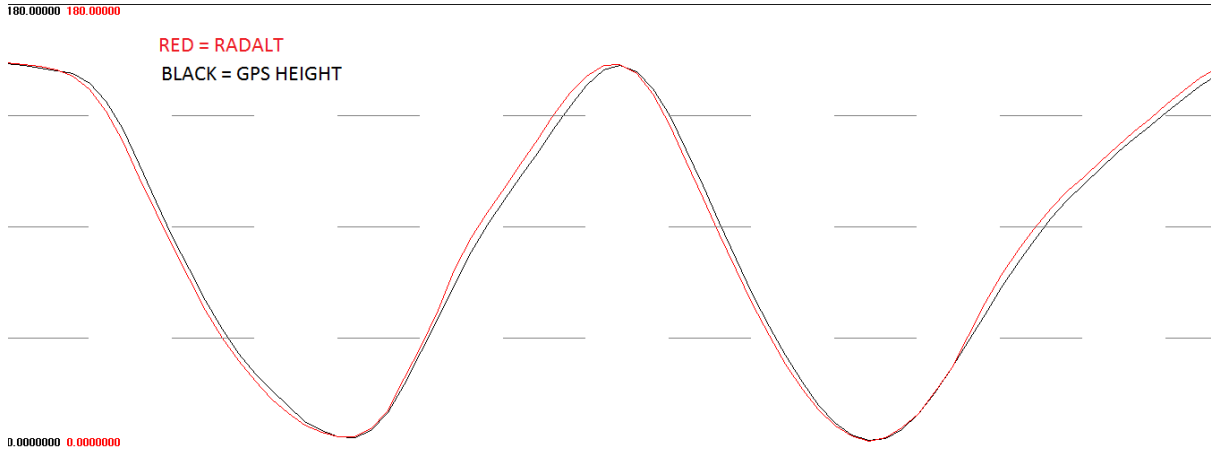
## APPENDIX 3 – CALIBRATIONS

### Magnetometer Compensation

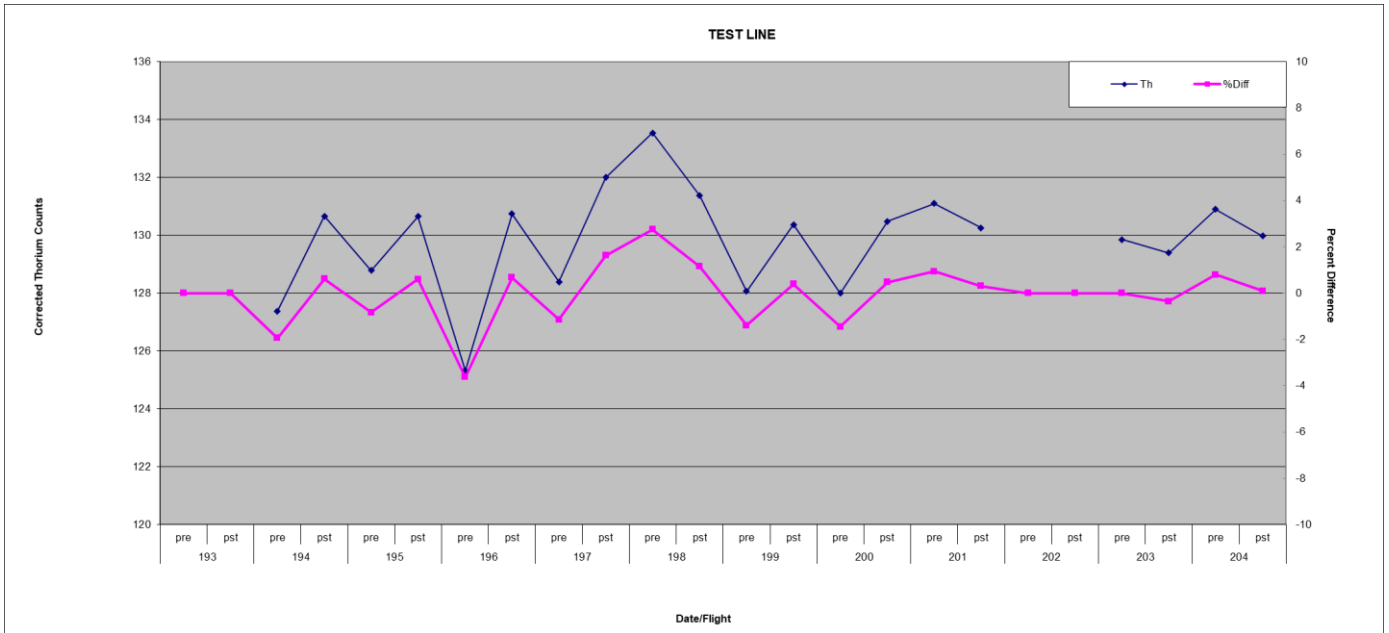
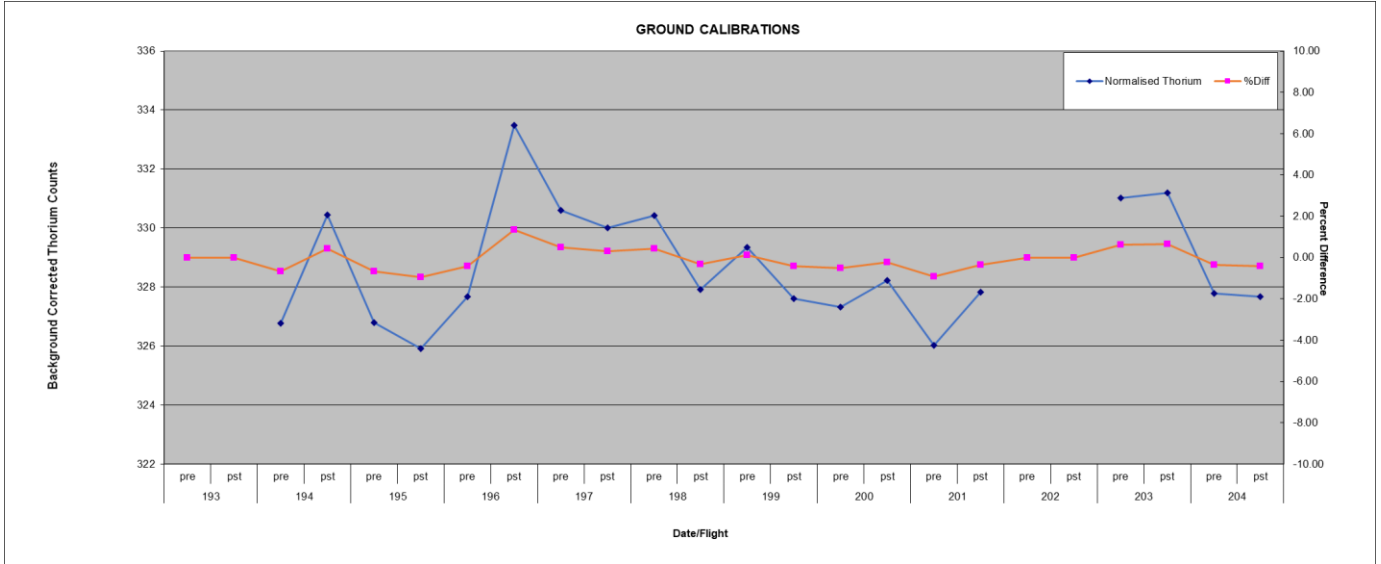


Processed Compensation Box

### Radar Altimeter Swoop Test

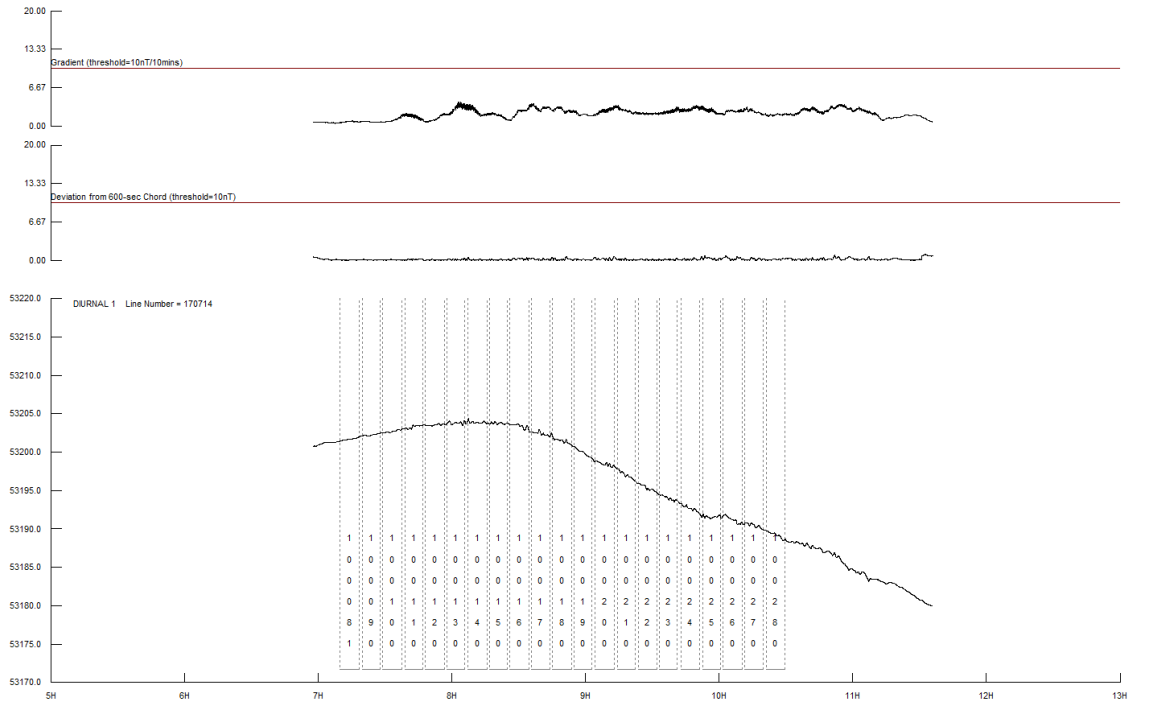
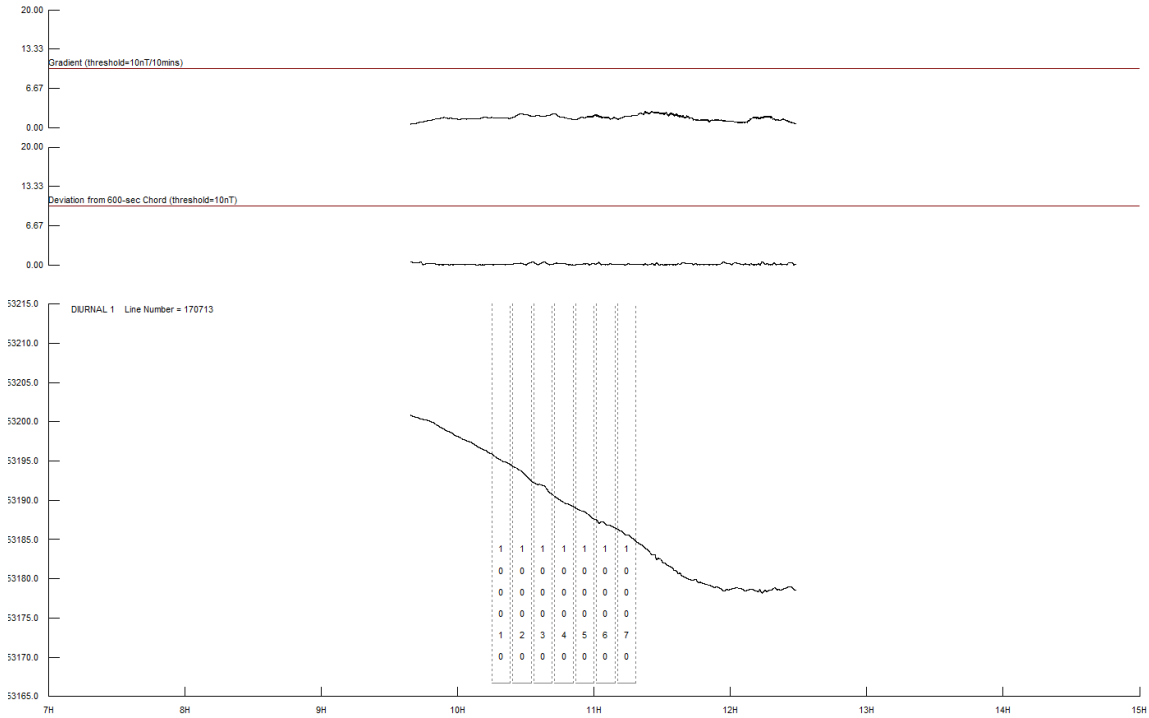


### Ground Calibration Checks and Test Lines



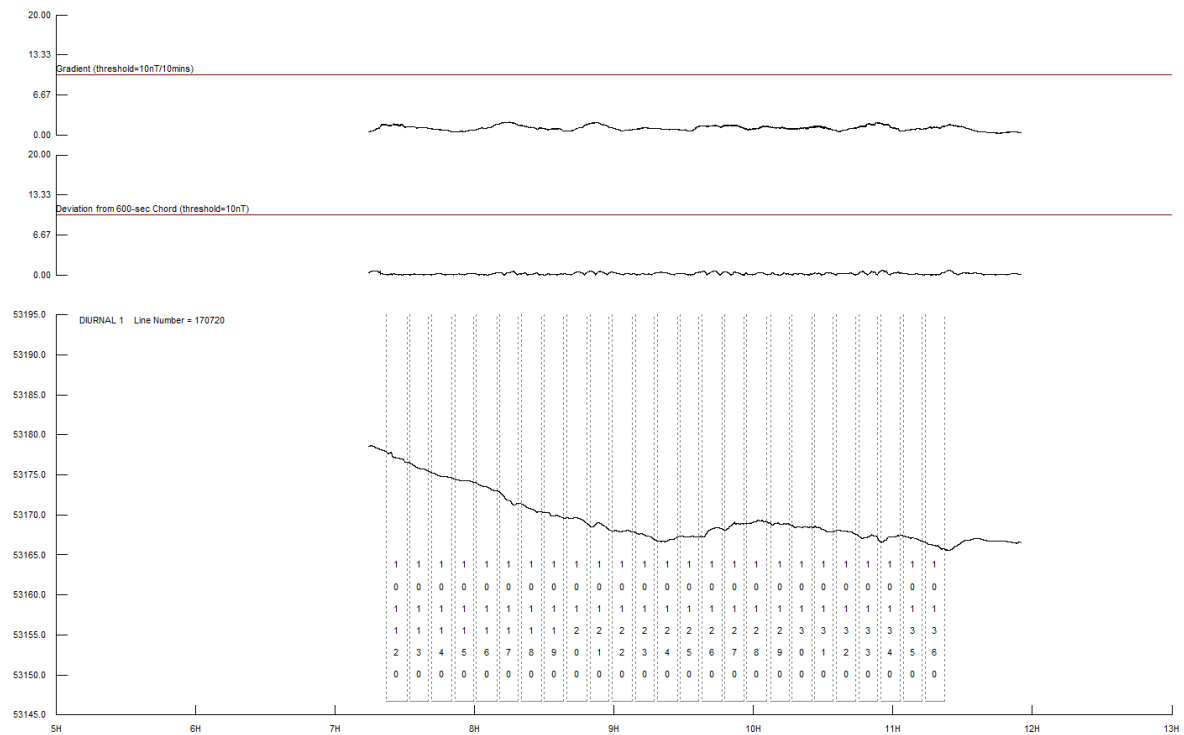
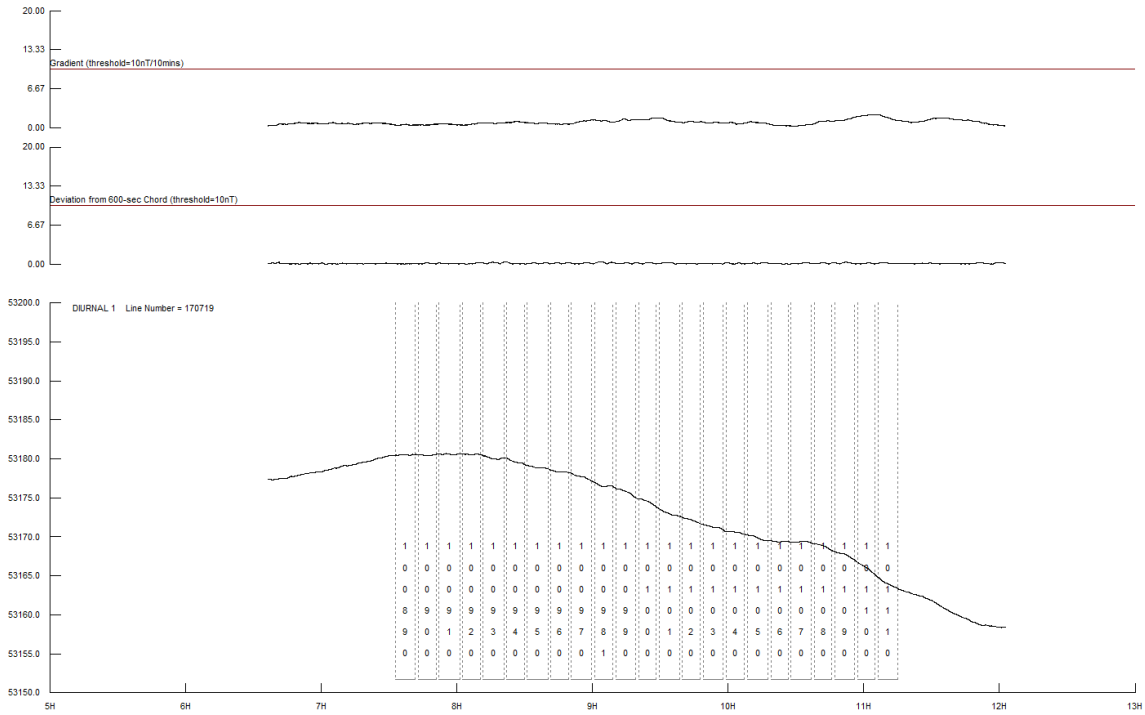
## APPENDIX 4 – DIURNAL BASE STATION PLOTS

Diurnal 1 Line Number = YYMMDD











## APPENDIX 5 – PROCESSING PARAMETERS AND DELIVERABLES

Average Diurnal      53,188 nT

### IGRF Correction Parameters

Year:                    2017.55  
Height:                835 m  
Zone:                    53  
Hemisphere:        South  
Latitude:             -23.1519296 °  
Longitude:          134.1256471°  
Total Field:        52 728.44 nT  
Declination:        4.5915 °  
Inclination:        -54.6630 °

### Radiometric Correction Parameters

#### *Height Attenuation Coefficients*

Total Count:            -0.0074  
Potassium:            -0.0094  
Uranium:                -0.0084  
Thorium:               -0.0074

#### *Aircraft Background Coefficients*

Total Count:            51.287  
Potassium:            11.921  
Uranium:                0.249  
Thorium:                0.000

#### *Cosmic Correction Coefficients*

Total Count:            1.0989  
Potassium:            0.0634  
Uranium:                0.0518  
Thorium:                0.0649

### Radiometric Stripping Coefficients

Alpha:                 0.2845  
Beta:                    0.4517  
Gamma:                0.7986  
a:                        0.0470

## Radiometric Concentration Coefficients

Total Count:	36.63
Potassium:	120.26
Uranium:	12.51
Thorium:	6.89

## Located and Gridded Data

ASCII Located data were supplied in ASEG-GDF format and Geosoft GDB  
Gridded data were supplied in ERMapper format.

## ASCII Located Data File Formats and Channels

### MAGNETICS

Line:I8:NULL=9999999:NAME=Line number  
 Flight:I4:NULL=999:NAME=Flight number  
 Date:I9:NULL=99999999:UNIT=YYYYMMDD:NAME=Date  
 Time:F11.2:NULL=9999999.99:UNIT=seconds:NAME=Time  
 Fid:I9:NULL=99999999:NAME=Fiducial number  
 Zone:I4:NULL=999:NAME=WGS84 Zone  
 Latitude:F12.6:NULL=9999.999999:UNIT=degrees:NAME=WGS84 Latitude  
 Longitude:F12.6:NULL=9999.999999:UNIT=degrees:NAME=WGS84 Longitude  
 Easting:F12.2:NULL=99999999.99:UNIT=metres:NAME=MGA53 Easting  
 Northing:F12.2:NULL=99999999.99:UNIT=metres:NAME=MGA53 Northing  
 Radalt:F8.2:NULL=99999.9:UNIT=metres:NAME=Radar altimeter  
 Laseralt:F8.2:NULL=99999.9:UNIT=metres:NAME=Laser altimeter  
 Gpsht:F8.2:NULL=99999.9:UNIT=metres:NAME=GPS Height  
 DTM:F8.2:NULL=99999.9:UNIT=metres:NAME=Digital terrain model  
 Diurnal:F10.3:NULL=999999.999:UNIT=nT:NAME=Diurnal  
 IGRF:F9.2:NULL=99999.99:UNIT=nT:NAME=IGRF  
 Raw\_TMI:F10.3:NULL=99999.999:UNIT=nT:NAME=Raw total magnetic intensity  
 Mag\_Dnl:F10.3:NULL=99999.999:UNIT=nT:NAME=Diurnal corrected TMI  
 Mag\_Dnl\_IGRF:F10.3:NULL=99999.999:UNIT=nT:NAME=Diurnal and IGRF corrected TMI  
 Tlev\_TMI:F10.3:NULL=99999.999:UNIT=nT:NAME=Tie Line Levelled Total Magnetic Intensity  
 Mlev\_Final\_TMI:F10.3:NULL=99999.999:UNIT=nT:NAME=Mlev Final Total Magnetic Intensity

## RADIOMETRICS

Line:I8:NULL=9999999:NAME=Line number  
Flight:I4:NULL=999:NAME=Flight number  
Date:I9:NULL=99999999:UNIT=YYYYMMDD:NAME=Date  
Time:F11.2:NULL=9999999.99:UNIT=seconds:NAME=Time  
Fid:I10:NULL=9999999:NAME=Fiducial number  
Zone:I4:NULL=999:NAME=WGS84 Zone  
Latitude:F12.6:NULL=9999.999999:UNIT=degrees:NAME=WGS84 Latitude  
Longitude:F12.6:NULL=9999.999999:UNIT=degrees:NAME=WGS84 Longitude  
Easting:F12.2:NULL=99999999.99:UNIT=metres:NAME=MGA53 Easting  
Northing:F12.2:NULL=99999999.99:UNIT=metres:NAME=MGA53 Northing  
RAD\_ALT:F8.2:NULL=99999.9:UNIT=metres:NAME=Altitude  
GPS\_height:F8.2:NULL=99999.9:UNIT=metres:NAME=GPS Height  
Live\_Time:I5:NULL=9999:NAME=Live time  
Baro\_pres:F8.1:NULL=99999.9:UNIT=hPa:NAME=Baro pressure  
Temp:F6.1:NULL=999.9:UNIT=degrees C:NAME=Temperature  
Humid:F6.1:NULL=999.9:UNIT=percent:NAME=Humidity  
RAW\_TOT:I6:NULL=99999:UNIT=CPS:NAME=Raw Total count  
RAW\_POT:I6:NULL=99999:UNIT=CPS:NAME=Raw K40  
RAW\_URA:I6:NULL=99999:UNIT=CPS:NAME=Raw Bi214  
RAW\_THO:I6:NULL=99999:UNIT=CPS:NAME=Raw TI208  
Cosmic:I6:NULL=99999:UNIT=CPS:NAME=Cosmic  
TOTAL\_COUNT:F9.2:NULL=99999.99:UNIT=CPS:NAME=Corrected Total Count  
POTASSIUM:F9.2:NULL=99999.99:UNIT=CPS:NAME=Corrected Potassium  
URANIUM:F9.2:NULL=99999.99:UNIT=CPS:NAME=Corrected Uranium  
THORIUM:F9.2:NULL=99999.99:UNIT=CPS:NAME=Corrected Thorium  
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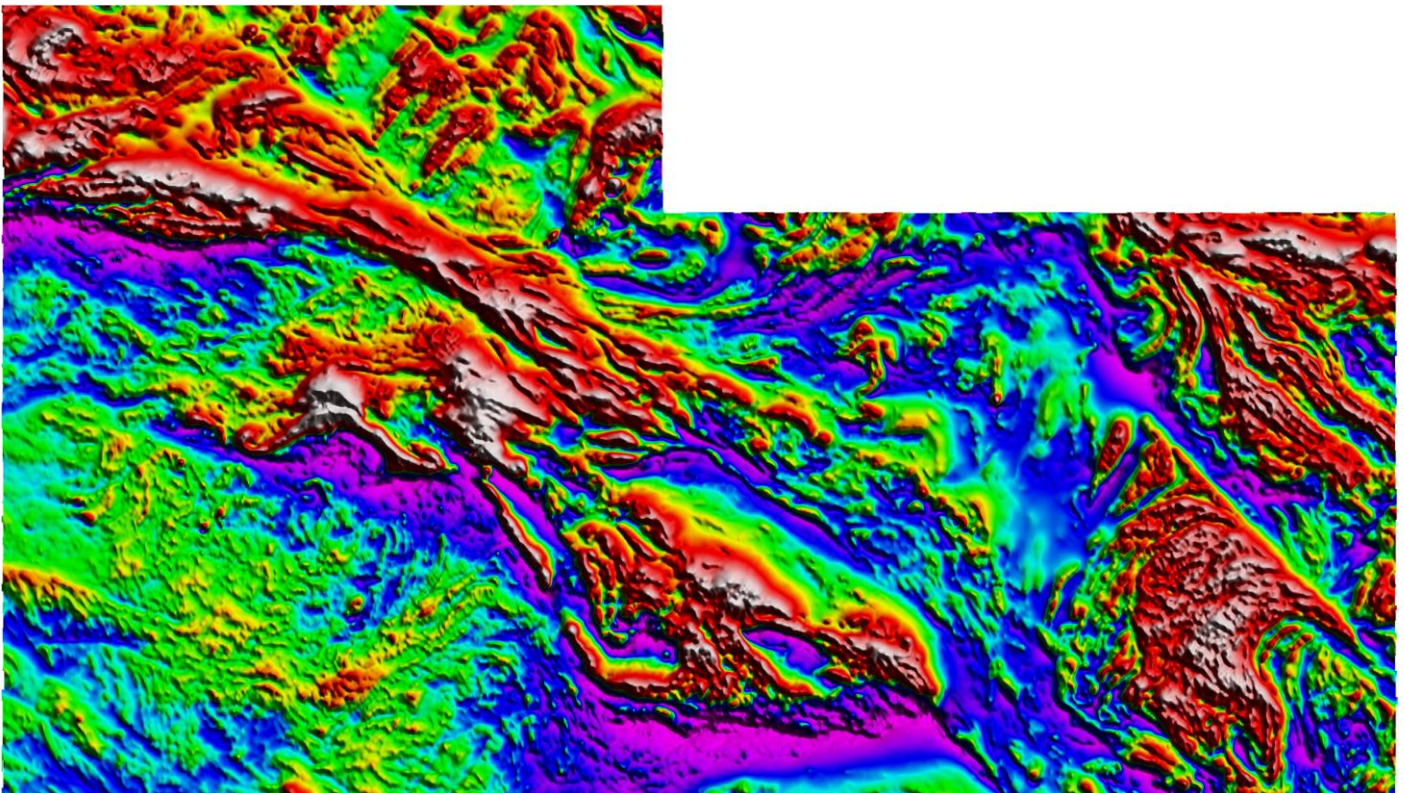
## DVD/USB Contents

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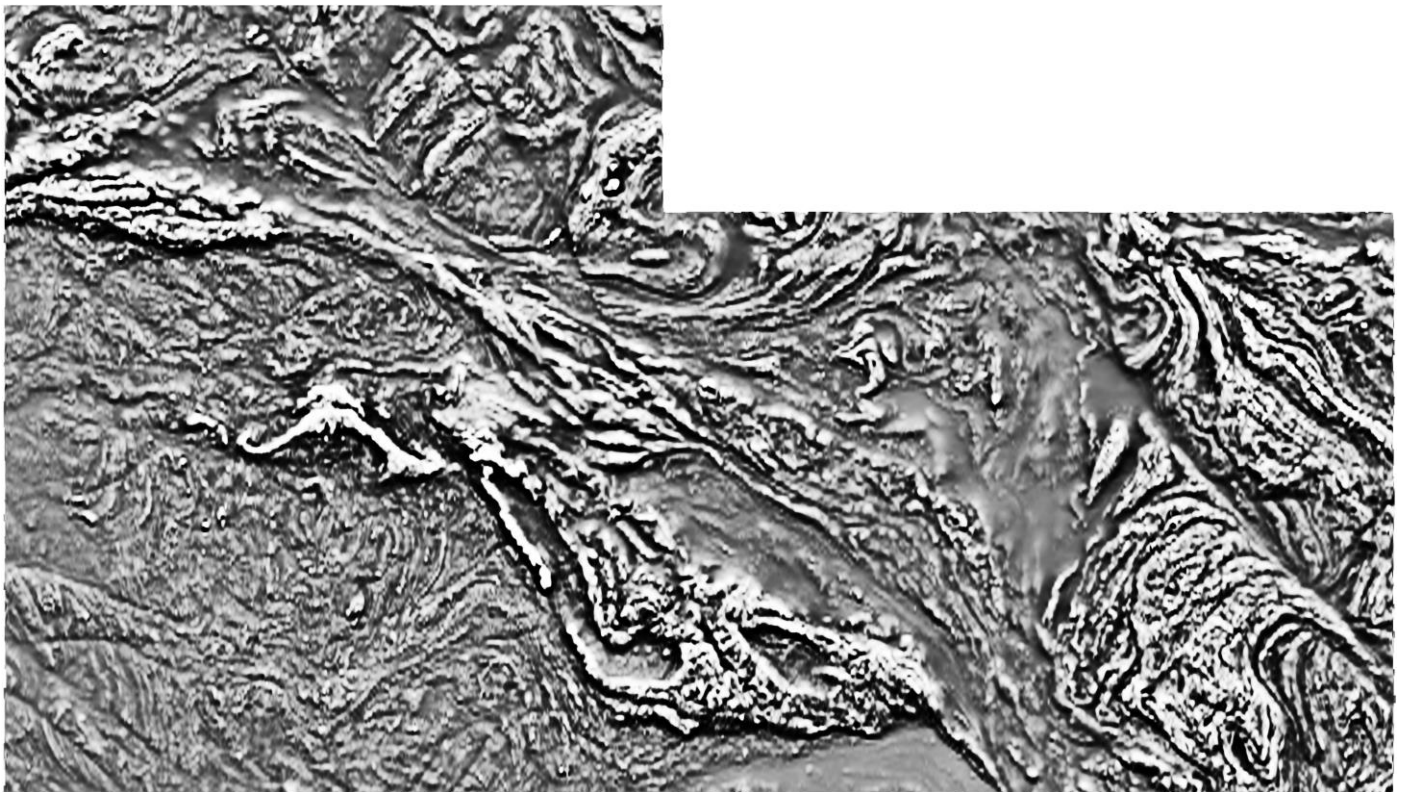
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| | \---GEOSOFT
| | | 1060_Alice_Springs_Radiometrics.gdb
| | |
| | \---GRIDS
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| | | 1060_Alice_Springs_Uranium
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| | | 1060_Alice_Springs_Thorium
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| | | 1060_Alice_Springs_Uranium_PPM
| | | 1060_Alice_Springs_Potassium
| | | 1060_Alice_Springs_Dose_Rate
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| | | 1060_Alice_Springs_Dose_Rate.ers
| | | 1060_Alice_Springs_Uranium.ers
| | |
| |
|
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| +---DATA
| | +---ASCII
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| | \---GEOSOFT
| | | 1060_Alice_Springs_Magnetics.gdb
| | |
| | \---GRIDS
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| | | 1060_Alice_Springs_DEM.ers
| | | 1060_Alice_Springs_TMI-1VD
| | | 1060_Alice_Springs_DEM
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| | | 1060_Alice_Springs_TMI.ers
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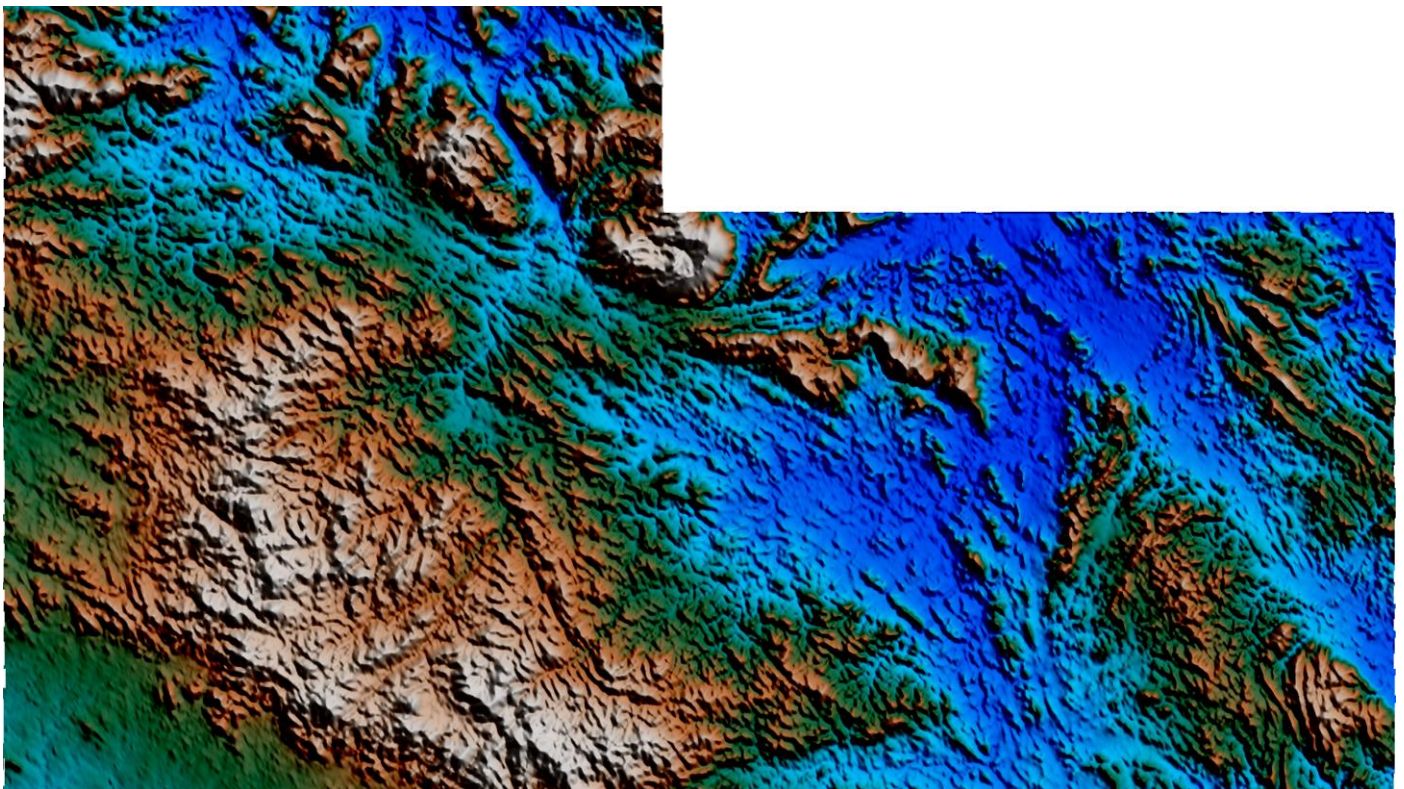
## APPENDIX 6 – VERIFICATION IMAGES



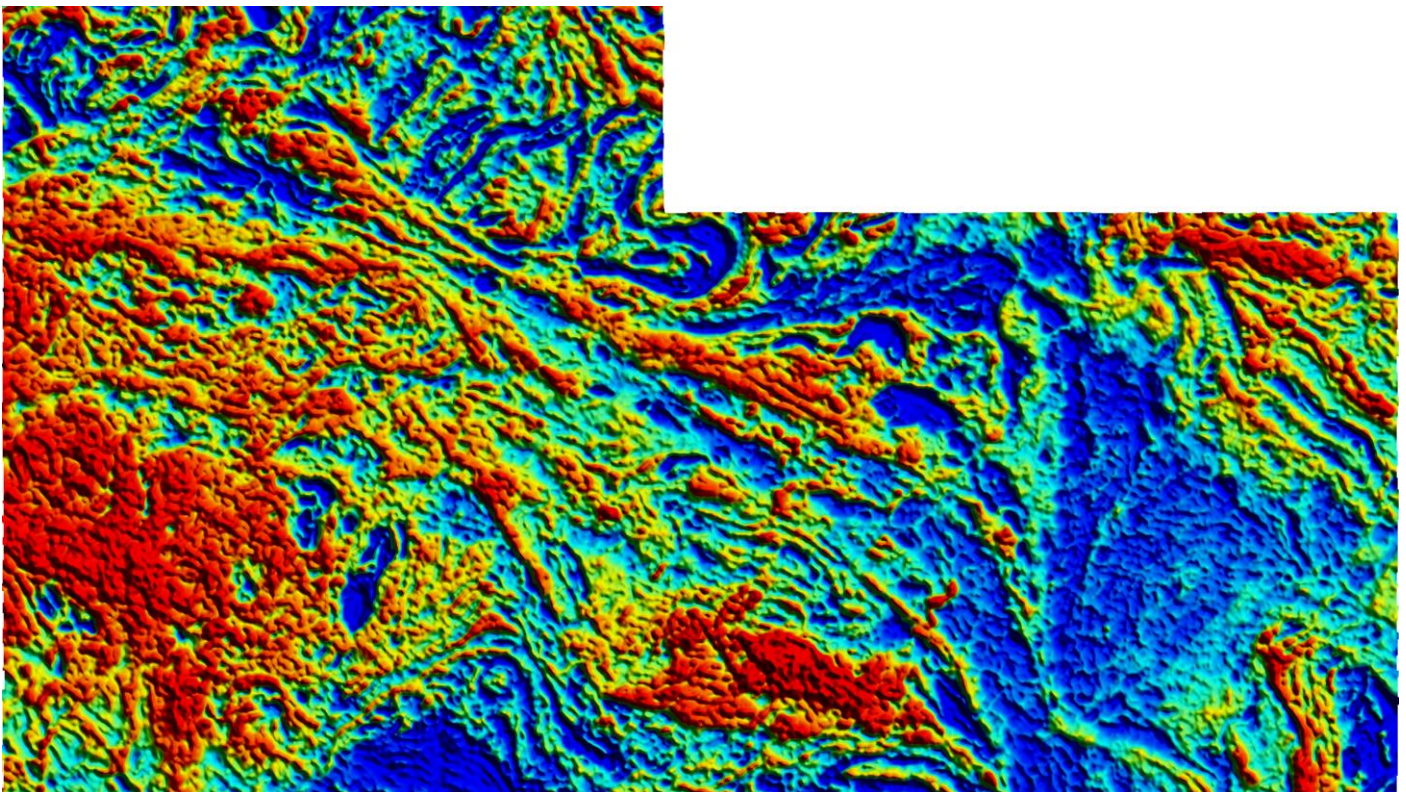
Colour Total Magnetic Intensity



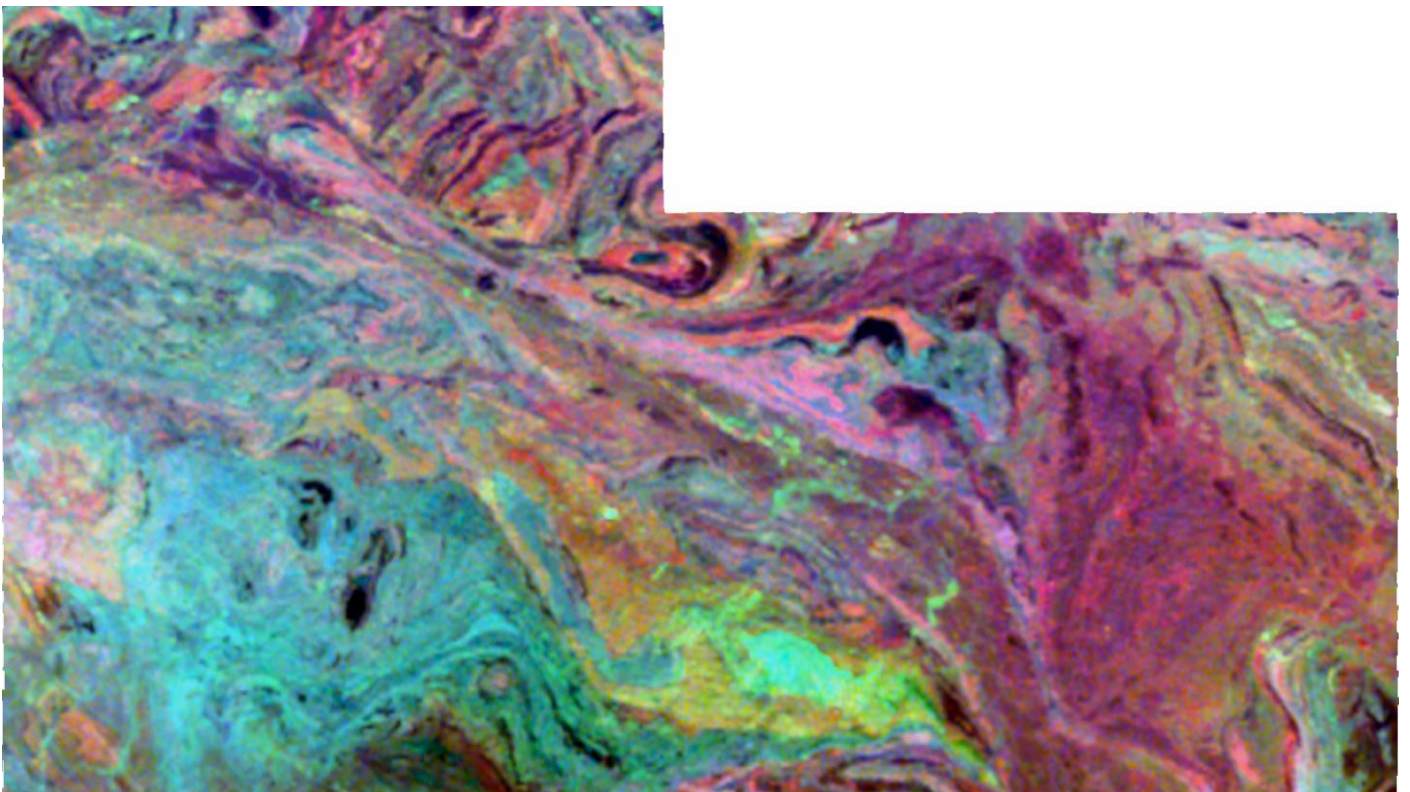
Grey Total Magnetic Intensity First Vertical Derivative



Colour Digital Elevation Model



Colour Total Count



Radiometric Ternary