Airborne Geophysical Survey **Survey** Report

Moolyella Project

Survey carried out on behalf of

Lithium 1 Pty Ltd

(Reference Number: 1341)

9 January 2023

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Contents

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

Survey Aircraft

1.2 Data Acquisition System

High speed digital data acquisition system.

- Sample rates up to 20 Hz
- Integrated Novatel OEM DGPS receiver providing positional information, 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-fights due to equipment failure

1.3 Magnetometers

Tail sensor mounted in a stinger housing.

- Model / Type - G-823A caesium vapour magnetometer
- Resolution - 0.001 nT resolution
- Sensitivity - 0.01 nT sensitivity
- Sample Rate - 20 Hz (approximately 3.5 m)
- Compensation - 3-axis fluxgate magnetometer

1.4 Gamma-Ray Spectrometer

RSI RS-500 gamma-ray spectrometer incorporating 2x RSX-4 detector packs.

- Total Crystal Volume - 32 L
- Channels - 1024
- Sample Rate - 2 Hz (approximately 35 m)
- Stabilisation Multi-peak automatic gain

1.5 Altimeters

Bendix/King KRA 405 radar altimeter.

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

Renishaw ILM-500R laser altimeter.

- Resolution - 0.01 m
- Sample Rate - up to 20 Hz
- Range - 0-500 m

Barometric pressure sensor.

- Accuracy - RSS ±0.25% FS (at constant temp)
- Range - 600-1100 hPa

1.6 Magnetic Base Stations

GEM GSM-19 Overhauser & Scintrex Envi-Mag proton precession base station magnetometers.

- Resolution - 0.01 / 0.1 nT
- Accuracy - 0.1 / 0.5 nT
- Sample Rate - 1.0 / 0.5 Hz

The GEM GSM-19 sampling at 1 second was used for all corrections.

2. NAVIGATION AND FLIGHT PATH RECOVERY

Integrated Novatel OEM719 DGPS receiver:

- L1/L2 + GLONASS Multi Frequency
- 555-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 Magnetometers

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 2 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 monitored system health from prompts on the navigation screen.

The diurnal base stations were 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 Magnetics

The following steps were performed during the magnetics 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 2020 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 MAGPSEC 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.

5.2 Radiometrics

Radiometric processing consisted of the following steps:

- 256-channel spectral noise reduction using the NASVD method
- 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 where 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 α, β, γ, *a* and *g* were estimated from measurements over calibration pads, where:

> α - 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);
>
> ß - is the thorium into potassium stripping ratio for a pure thorium source;
>
> γ - 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 (α, ß and γ) 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
α	0.00049
β	0.00065
γ	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:

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

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

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

Where:

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

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

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

where: -

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

Where the STP height above ground level exceeds 300 m, a value of h =300 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 was 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 radar altimeter and GPS heights were visually inspected for errors and any spikes were carefully corrected.

The altimeter data were then subtracted from the GPS height to create the Digital Elevation channels.

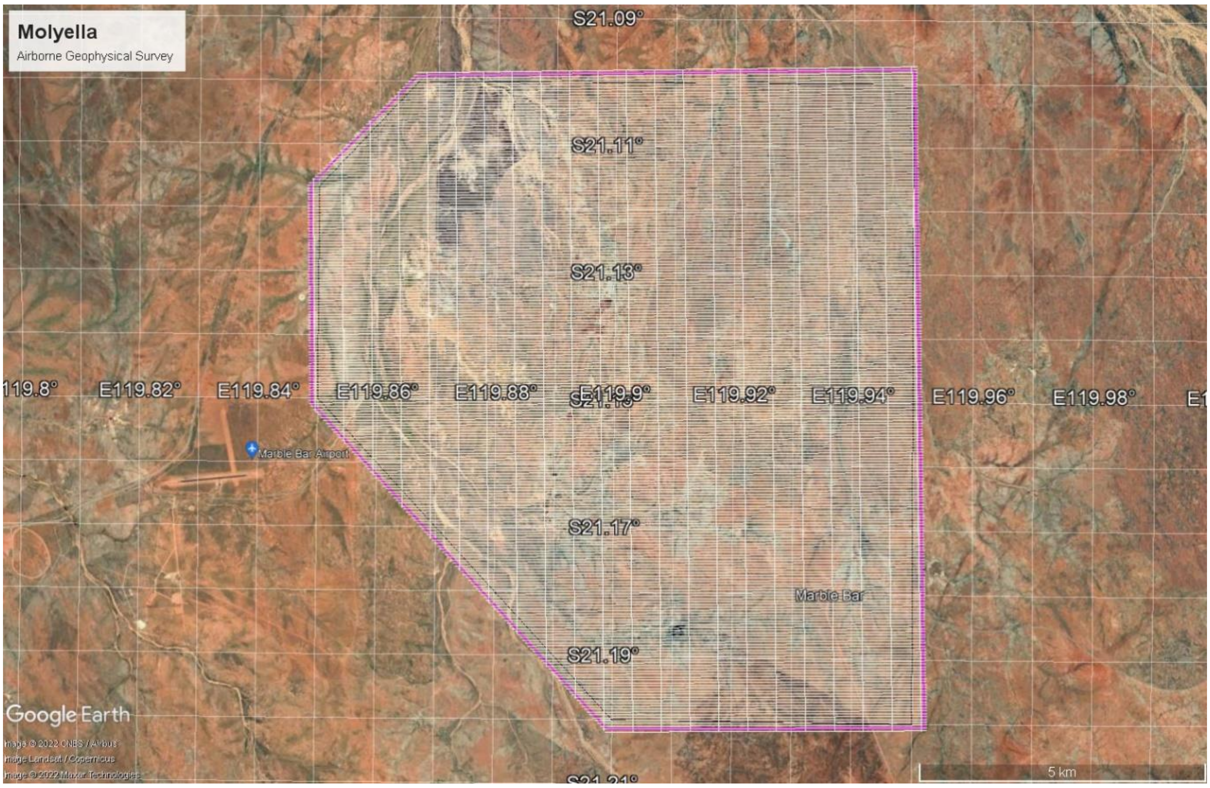
Tie line levelling was applied by way of a least squares minimisation procedure using a polynomial fit of order 0 over the cross over errors calculated between the traverse and tie line intersections.

Using MAGPSEC 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



Survey Area (Google Earth)

Survey Area Coordinates and Flight Specifications

WGS84
SUTM Zone 50

EASTING	NORTHING
797800	7664200
806500	7664200
806500	7652800
801000	7652800
795900	7658500
795900	7662300

Area Name	Traverse Line spacing (m)	Traverse Line Direction (deg)	Tie Line Spacing (m)	Tie Line Direction (deg)	Sensor Height* (m)	Total Line Kilometres
E4505573	50	090-270	500	000-180	30	2,358
					Total	**2,358**

APPENDIX 2 - FIELD OPERATION AND PROJECT MANAGEMENT

Operational Base

The aircraft and crew were based in Nullagine, Western Australia for the duration of the survey. Production of the survey started on 8th December 2022 and ended on 11th December 2022.

Personnel

Client Contacts	-	Lester Kemp
	-	Arnel Mendoza
Pilot	-	Brett Niewand
Operations	-	William Bennett
QC/QA	-	Andrew Taylor
Data Processing	-	Cameron Johnston

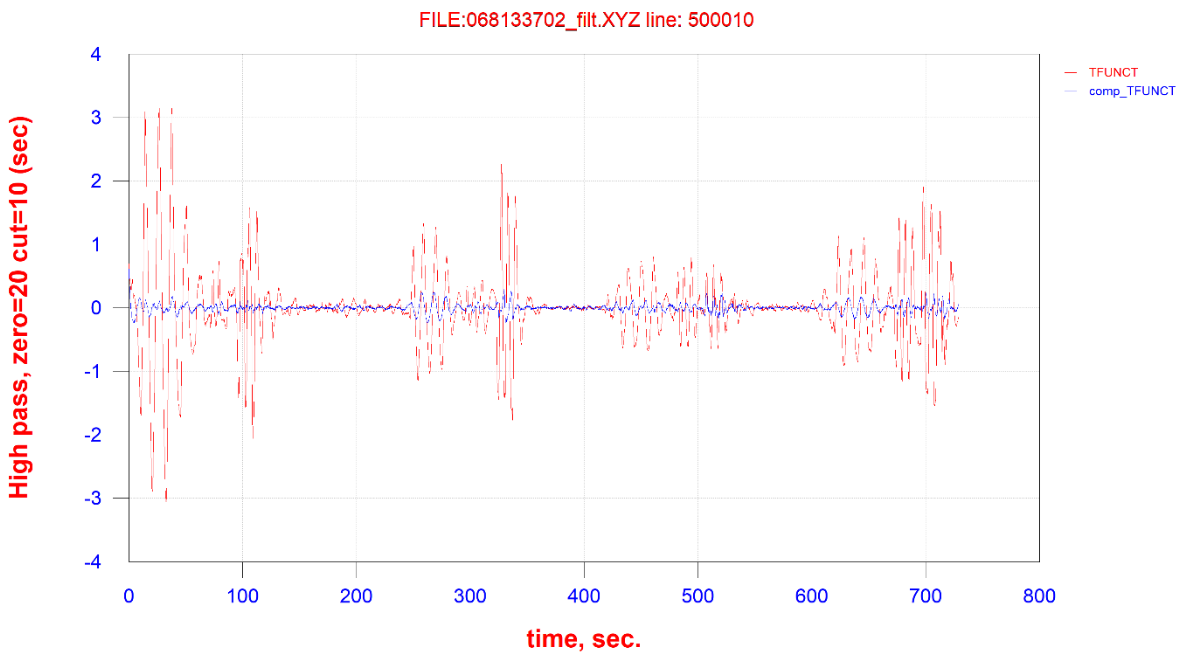
Base Station Magnetometer Position

The base station magnetometer was located near the Nullagine Airstrip.

Base station location co-ordinates (WGS84): -21.9101743° S; 120.1953209° E

APPENDIX 3 – CALIBRATIONS

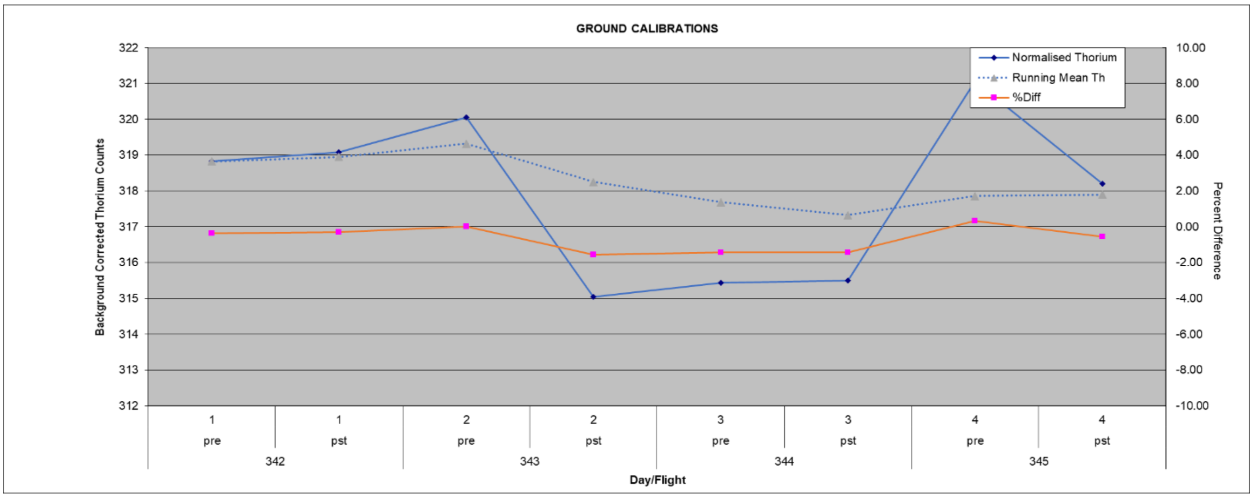
Magnetometer Compensation

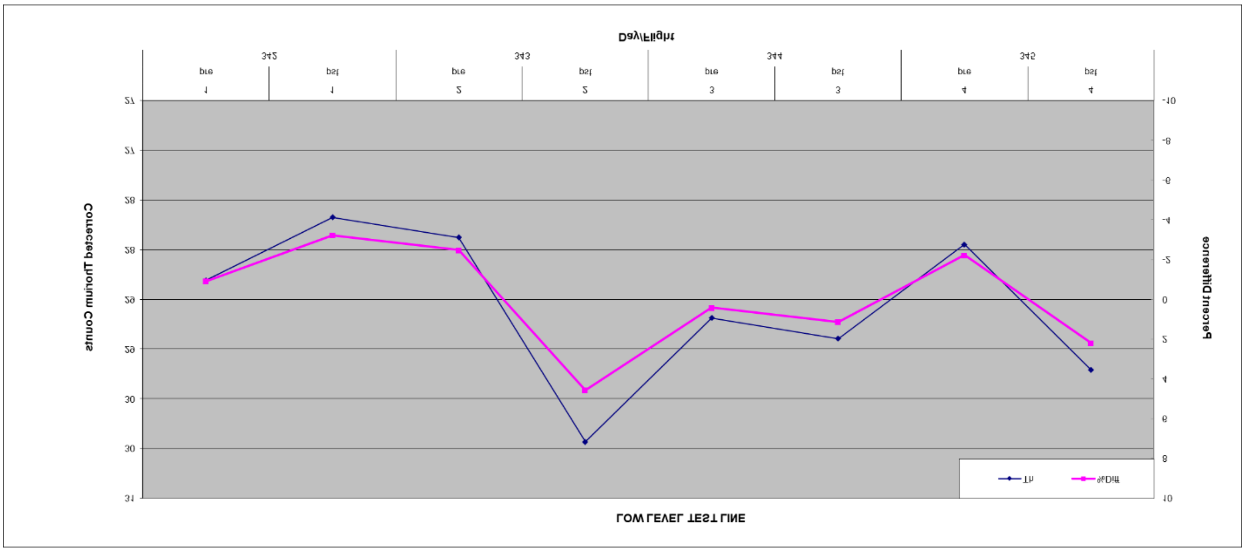


Processed Compensation Box

Sensor	Line	Original RMS	Compensated RMS	Improvement Ratio
Tail	500010	0.625	0.063	9.861

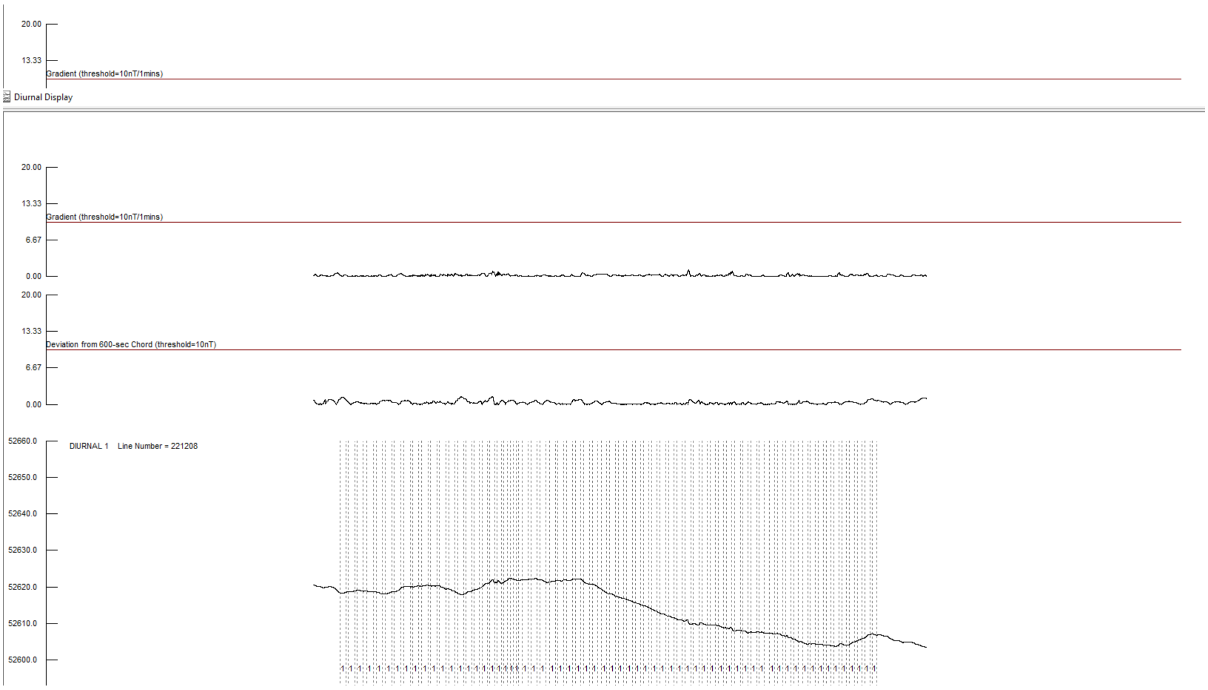
Ground Calibration Checks and Test Lines

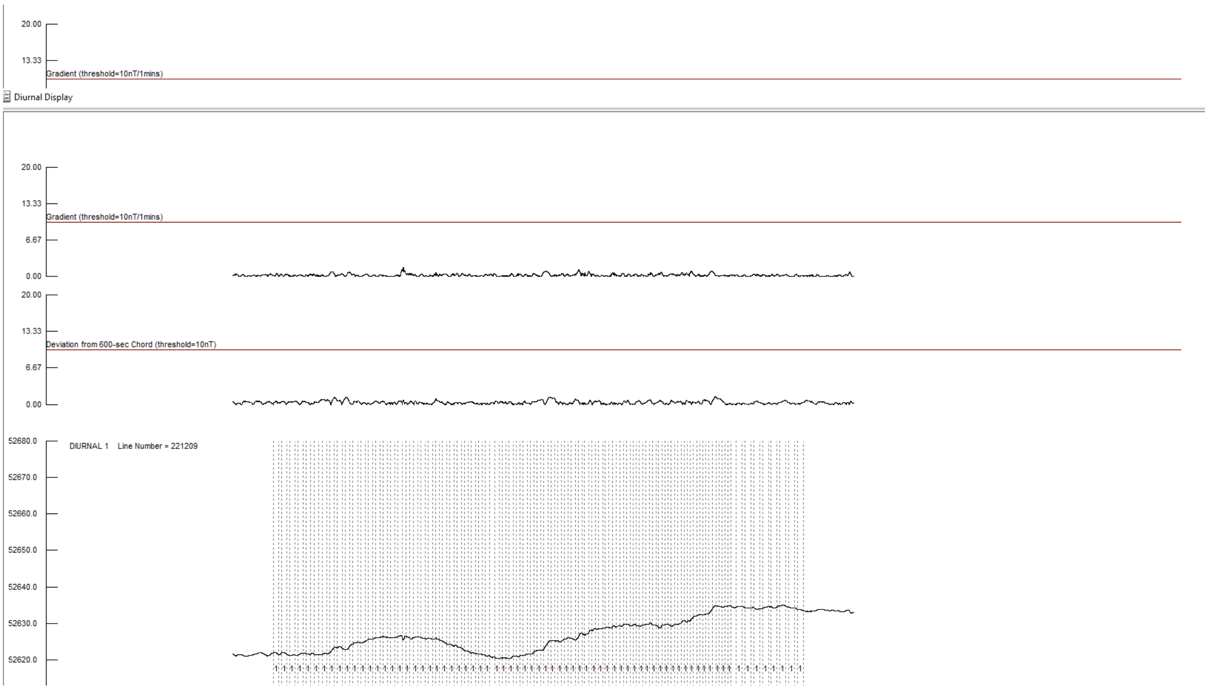


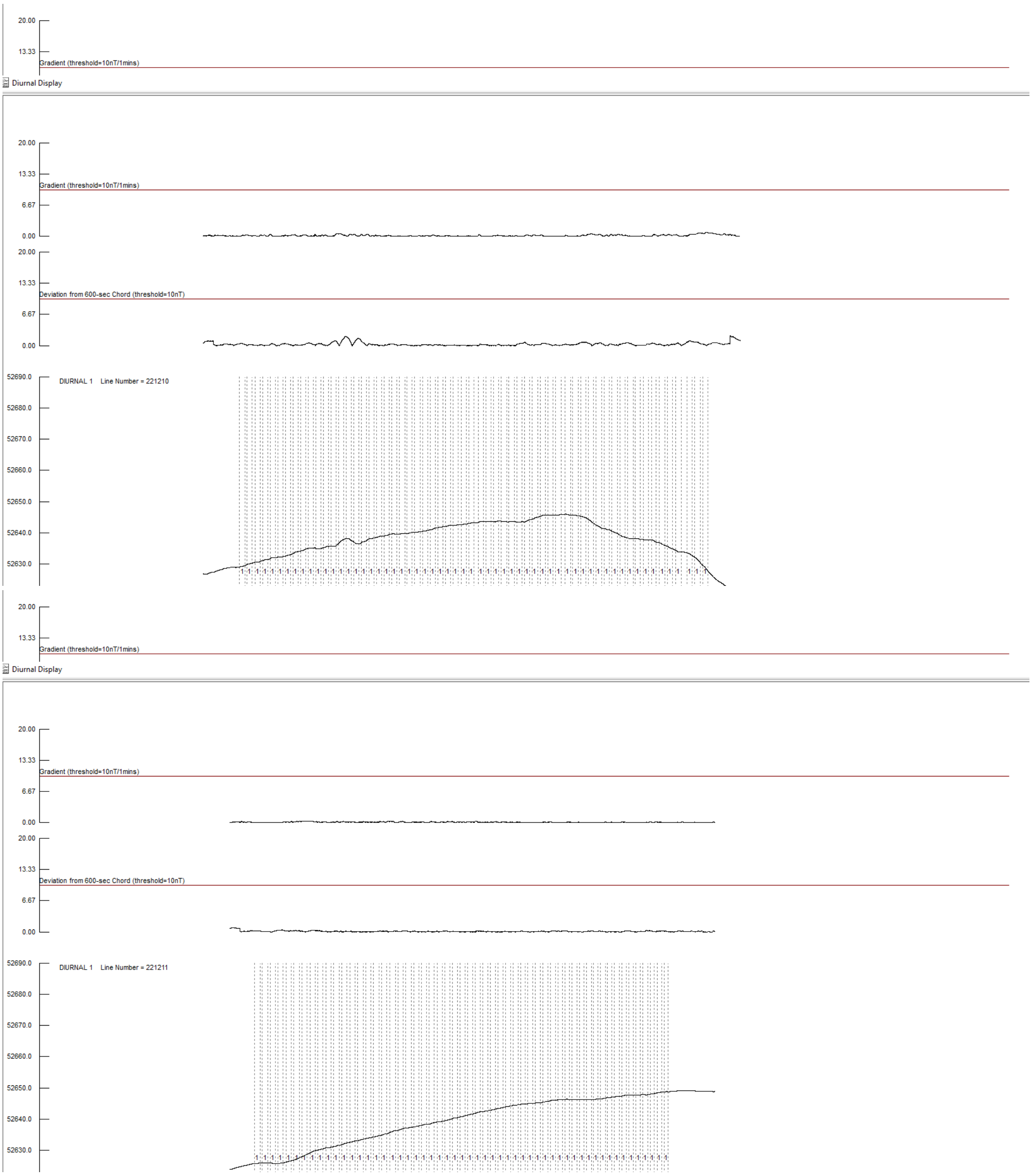


APPENDIX 4 – DIURNAL BASE STATION PLOTS

Diurnal 1 Line Number = YYMMDD






Gradient (threshold=10nT/1mins)
Diurnal Display
Gradient (threshold=10nT/1mins)
Deviation from 600-sec Chord (threshold=10nT)
DIURNAL 1 Line Number = 221210
Gradient (threshold=10nT/1mins)
Diurnal Display
Gradient (threshold=10nT/1mins)
Deviation from 600-sec Chord (threshold=10nT)
DIURNAL 1 Line Number = 221211

APPENDIX 5 – PROCESSING PARAMETERS AND DELIVERABLES

Magnetics

Average Diurnal 52,615 nT

IGRF Correction Parameters

Year: 2022.94
Height: 230 m
Zone: 50
Latitude: -21.1456994 °
Longitude: 119.9058457 °
Total Field: 52240.65 nT
Declination: 1.2837 °
Inclination: -52.8618 °

Radiometrics

Radiometric Correction Parameters

Radiometric Stripping Coefficients

Alpha: 0.2998
Beta: 0.4813
Gamma: 0.7945
a: 0.0442

	Height Attenuation	***Aircraft Background***	***Cosmic Corrections***	**Concentration Coefficients**
Total Count	-0.0074	60.892	1.0737	42.47
Potassium	-0.0094	11.547	0.0611	145.13
Uranium	-0.0084	2.023	0.0464	14.80
Thorium	-0.0074	0.000	0.0657	8.00

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=SUTM50 Easting
Northing:F12.2:NULL=99999999.99:UNIT=metres:NAME=SUTM50 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=SUTM50 Easting
Northing:F12.2:NULL=99999999.99:UNIT=metres:NAME=SUTM50 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 Tl208
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
DOSE_RATE:F9.4:NULL=999.9999:UNIT=nGy/hr:NAME=Dose Rate
POTASSIUM_PERCENT:F9.4:NULL=999.9999:UNIT=percent:NAME=Potassium Percent
URANIUM_PPM:F9.4:NULL=999.9999:UNIT=PPM:NAME=Uranium PPM
THORIUM_PPM:F9.4:NULL=999.9999:UNIT=PPM:NAME=Thorium PPM
Raw_spec:256F6.0:NULL=99999:UNIT=cps:NAME=Raw_spec

Data Contents

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+---IMAGES
|     134101_Moolyella_DEM.tif
|     134101_Moolyella_Ternary.tif
|     134101_Moolyella_TMI-1VD.tif
|     134101_Moolyella_TMI-Grey.tif
|     134101_Moolyella_TMI.tif
|     134101_Moolyella_Total_Count.tif
|
+---MAG
|  +---DATA
|  |  +---ASCII
|  |  |     134101_Moolyella_Magnetics_DEM.DAT
|  |  |     134101_Moolyella_Magnetics_DEM.DFN
|  |  |
|  |  \---GEOSOFT
|  |         134101_Moolyella_Magnetics_DEM.gdb
|  |
|  \---GRIDS
|        134101_Moolyella_DEM
|        134101_Moolyella_DEM.ers
|        134101_Moolyella_TMI
|        134101_Moolyella_TMI-1VD
|        134101_Moolyella_TMI-1VD.ers
|        134101_Moolyella_TMI.ers
|
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   +---DATA
   |  +---ASCII
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   |  |     134101_Moolyella_Radiometrics.DFN
   |  |
   |  \---GEOSOFT
   |        134101_Moolyella_Radiometrics.gdb
   |
   \---GRIDS
         134101_Moolyella_Dose_Rate
         134101_Moolyella_Dose_Rate.ers
         134101_Moolyella_Potassium
         134101_Moolyella_Potassium.ers
         134101_Moolyella_Potassium_Percent
         134101_Moolyella_Potassium_Percent.ers
         134101_Moolyella_Thorium
         134101_Moolyella_Thorium.ers
         134101_Moolyella_Thorium_PPM
         134101_Moolyella_Thorium_PPM.ers
         134101_Moolyella_Total_Count
         134101_Moolyella_Total_Count.ers
         134101_Moolyella_Uranium
         134101_Moolyella_Uranium.ers
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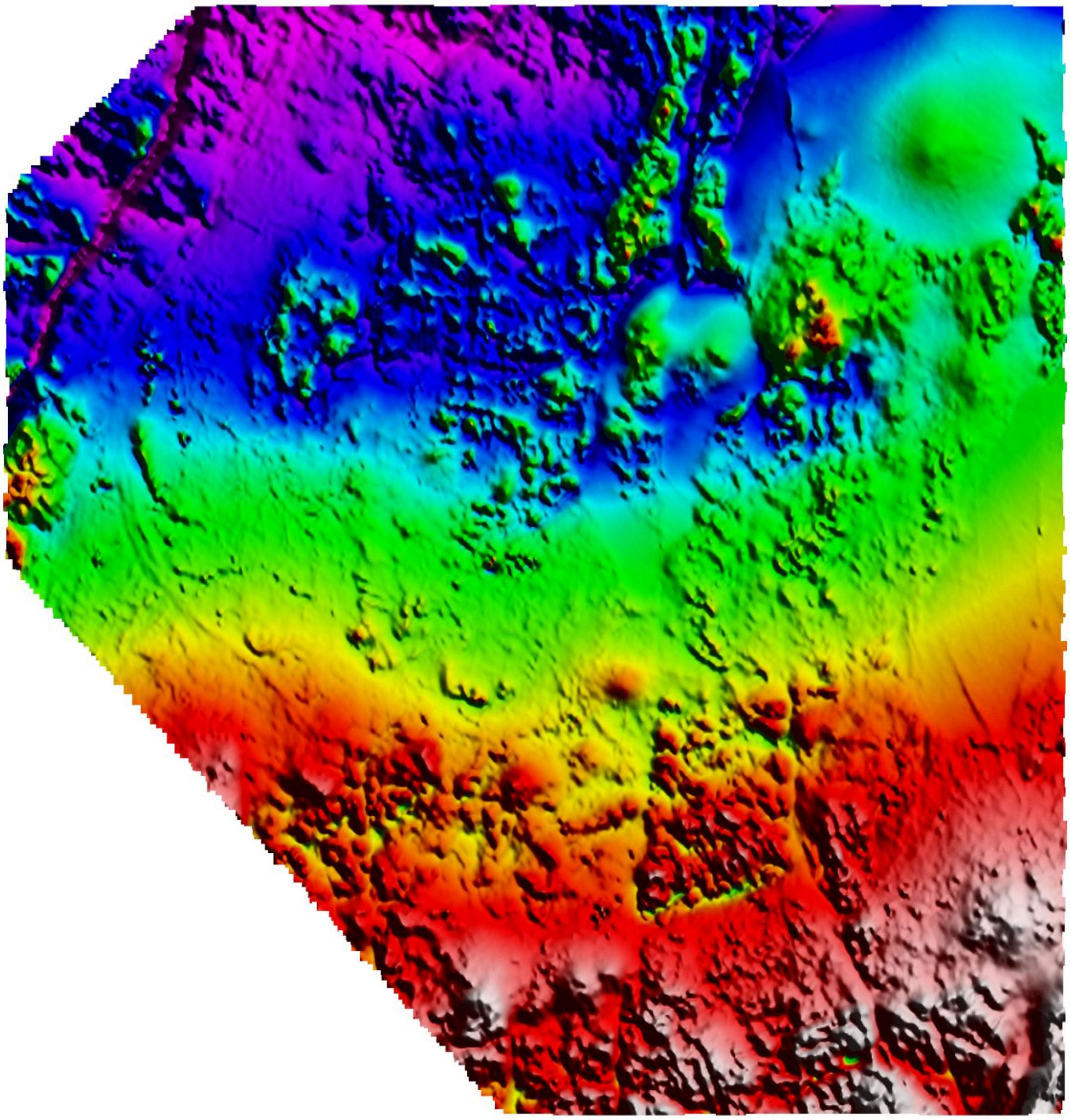
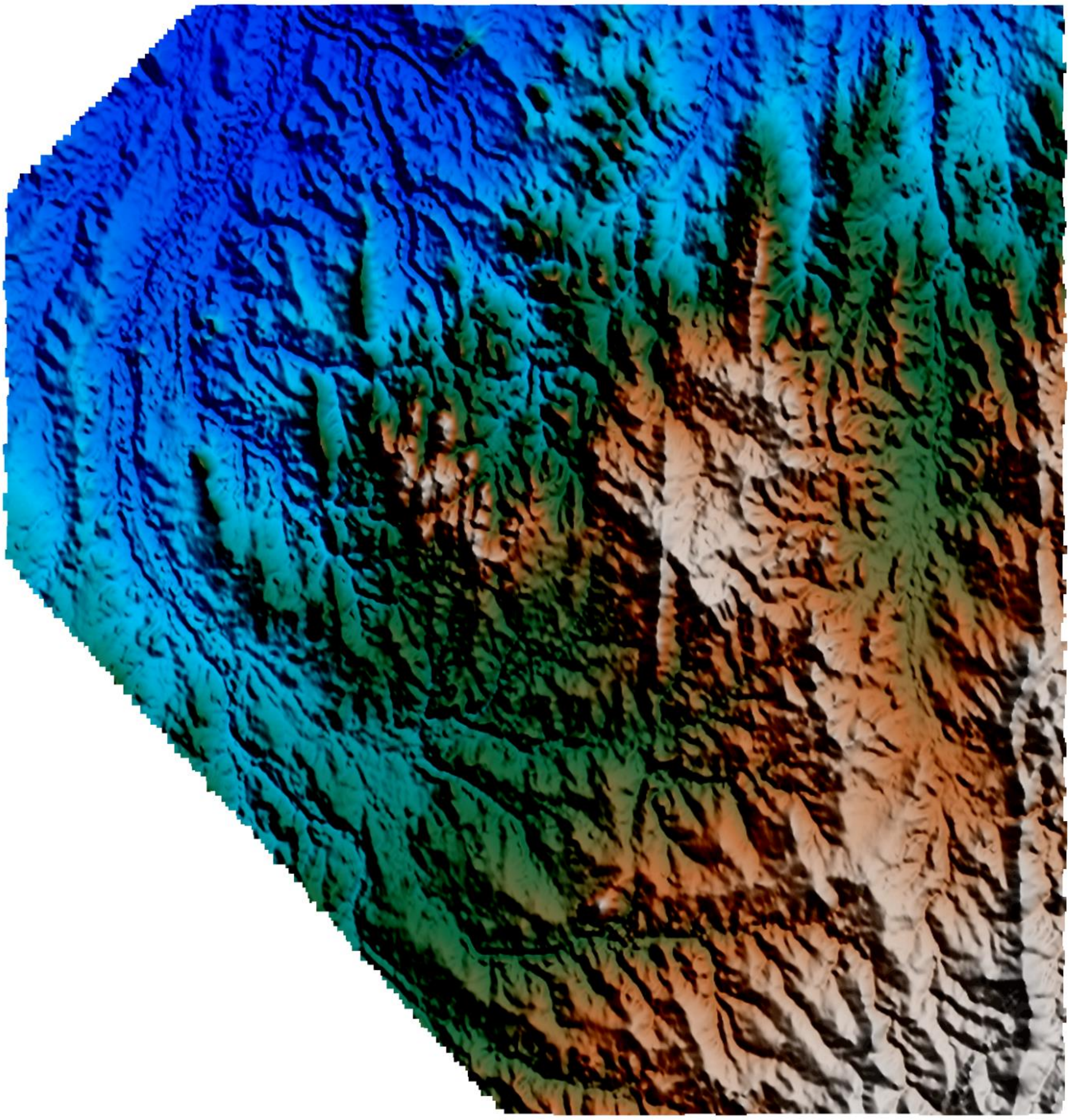
APPENDIX 6 – VERIFICATION IMAGES

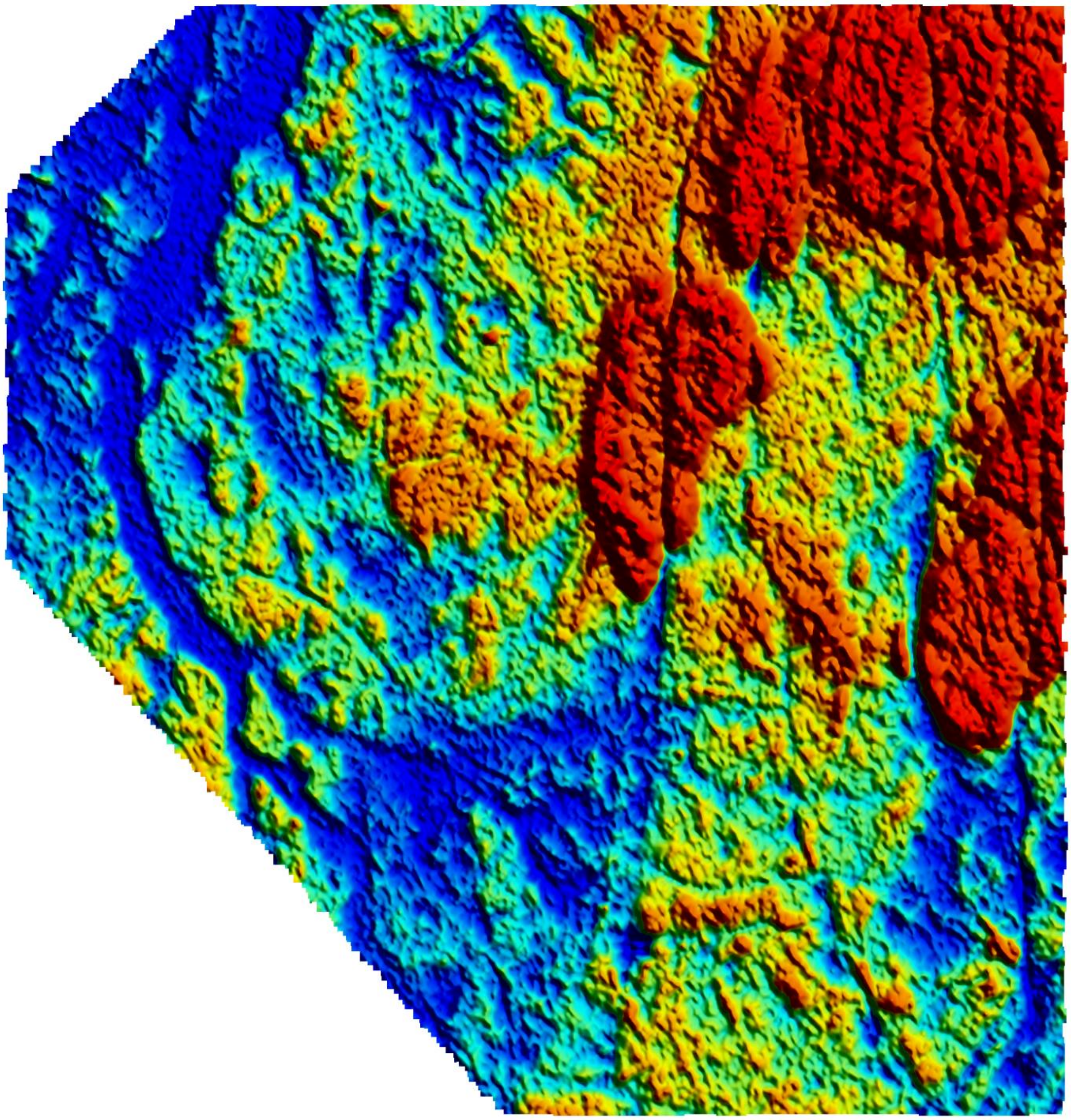


Total Magnetic Intensity

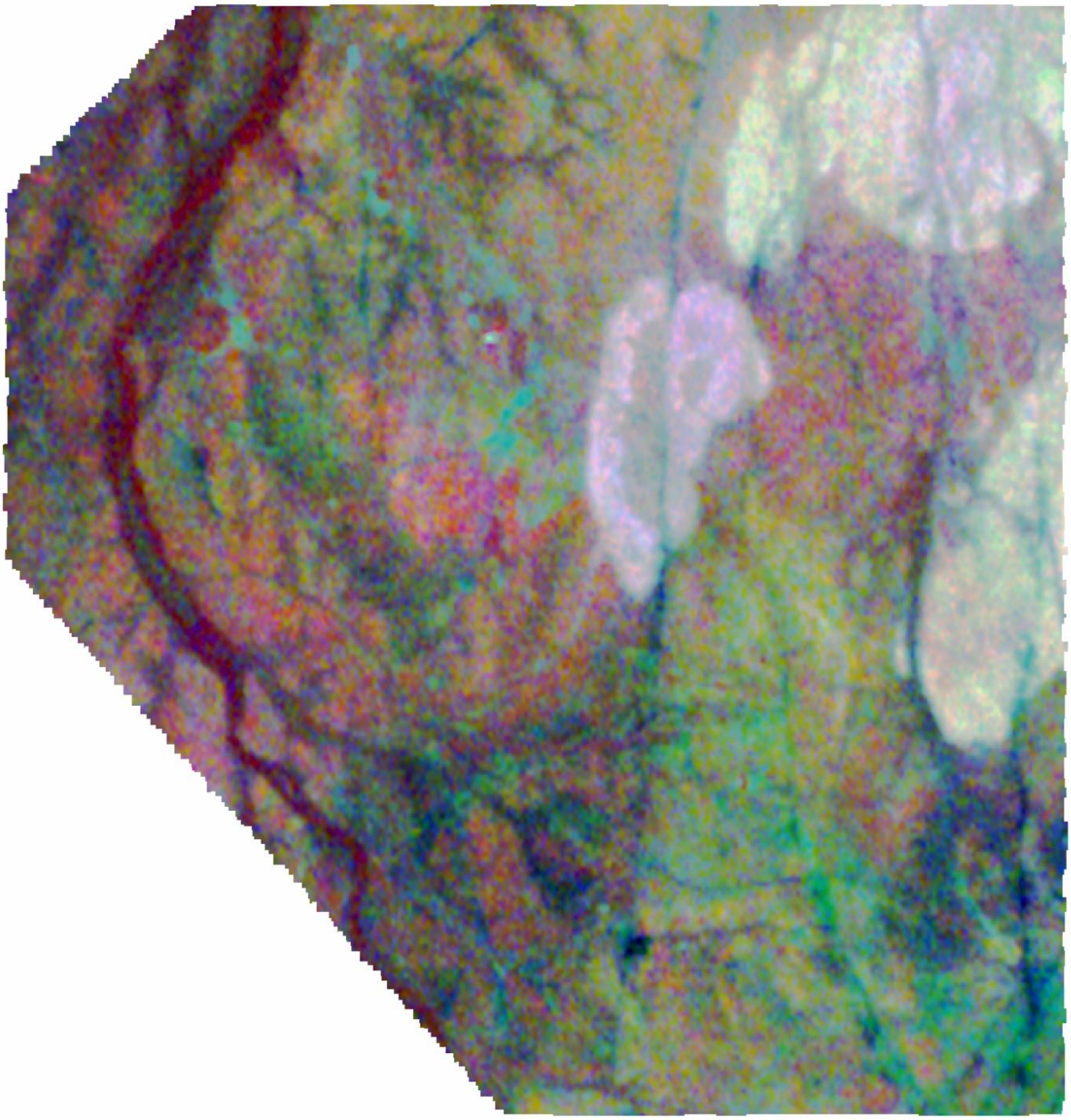
Total Magnetic Intensity - First Vertical Derivative



Digital Elevation Model



Total Count Radiometrics



Ternary Radiometrics