



Logistics Report

for a

DETAILED AIRBORNE MAGNETIC, RADIOMETRIC AND DIGITAL TERRAIN SURVEY

for the

CAMERON PROJECT

carried out on behalf of

Mount Isa Mines Limited

(UTS Geophysics Job #UT150018)

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GENERAL SURVEY INFORMATION

In July to September of 2015, UTS Geophysics conducted a low level airborne geophysical survey for the following company:

Mount Isa Mines Limited
 Private Mail Bag
 Mount Isa
 QLD 4825

Acquisition for this survey commenced on the 19th of July and was completed on the 30th of September 2015.

SURVEY SPECIFICATIONS

The area surveyed was centered approximately 62km East North East of Mount Isa in Queensland, the survey was flown using the WGS84 and the AMG84 coordinate system (a Universal Transverse Mercator projection) derived from the Australian Geodetic Datum and was contained within zone 54 with a central meridian of 141 degrees. Details of the datum and projection system are provided in Appendix B of this report. Survey boundary coordinates are listed in Appendix C.

The survey data acquisition specifications for each area flown are specified in the following table:

PROJECT NAME	LINE SPACING	LINE DIRECTION	TIE LINE SPACING	TIE LINE DIRECTION	SENSOR HEIGHT	TOTAL LINE KM
Cameron	50	090-270	500m	000-180	30m	24,125
TOTAL						24,125

The specified sensor height for the magnetic samples is as stated in the above table. This sensor height may be varied where topographic relief or laws pertaining to built up areas do not allow this altitude to be maintained, or where the safety of the aircraft and equipment is endangered

3 AIRCRAFT AND SURVEY EQUIPMENT

A specialised geophysical survey aircraft fitted with a flight control computer, data acquisition system, and geophysical sensors was used, the list of geophysical and navigation equipment used for the survey is as follows:

General Survey Equipment

- PAC-750XL fixed wing survey aircraft.
- AgNav line navigation system.
- RMS DAARC500 data acquisition system
- Novatel 12 Channel differentially corrected GPS.
- Bendix King KRA-405B radar altimeter.

Magnetic Data Acquisition Equipment

- UTS/Geotech tail stinger mounted magnetometer installation.
- Geometrics G822 Cesium Vapour total field magnetometer.
- Billingsley Fluxgate three component vector magnetometer.
- RMS DAARC500 magnetic compensator.
- Diurnal monitoring magnetometer (Scintrex Envimag and/or Geometrics G-856).

Radiometric Data Acquisition Equipment

- RSI RSX500 gamma ray detector packs.
- Barometric altimeter (pressure measurements).
- UTS Geophysics temperature and humidity sensor.

3.1 Survey Aircraft

The aircraft used was a PAC-750XL fixed wing survey aircraft, operated by UTS Aviation Pty Ltd, registration VH-UTW. The specifications for this aircraft are as follows:

Power Plant

- Engine Type Pratt and Whitney PT6A-34
- Shaft Horse Power 750 SHP
- Fuel Type JET-A1

Performance

- Cruise speed 155 Kn
- Survey Speed 140 Kn
- Stall speed 50 Kn
- Range 1628 Km
- Fuel tank capacity 1436 litres



3.2 Data Positioning and Flight Navigation

Survey data positioning and flight line navigation was derived using real-time differential GPS (Global Positioning System).

Navigation was provided through an AgNav electronic pilot navigation system providing computer controlled navigation information displayed on a LCD screen as well as cross-track guidance on an LED light-bar.

The same GPS derived positions displayed to the pilot as real-time aircraft navigation information were also recorded by the acquisition system to locate the survey data.

The GPS system used for the survey was:

- Aircraft GPS Model Novatel 39xx series
- Sample rate 0.1Seconds(10Hz)
- GPS satellite tracking channels 12 parallel
- Typical differentially corrected accuracy 1-2metres(horizontal)
3-5 metres (vertical)

3.3 RMS Instruments Data Acquisition System and Digital Recording

All geophysical sensor data and positional information measured during the survey was recorded using an RMS Instruments DAARC500 acquisition system. The magnetic data was recorded at 20hz and the radiometric at 1hz, ancillary instruments were recorded at various sub-multiples of the magnetic sample rate. Survey data was downloaded from acquisition system on completion of each survey flight for data and line navigation quality control checks.

3.4 Altitude Readings

Survey height above the terrain was measured using a Bendix King radar altimeter installed in the aircraft. The height of each survey data point was measured by the radar altimeter and stored by the RMS data acquisition system.

- Radar altimeter models Bendix King KRA-405B
- Accuracy +/- 5%
- Resolution 0.1 metres
- Range 0 - 762 metres
- Sample rate 0.1 Seconds (10Hz)

The digital terrain model is calculated by subtracting the terrain clearance (radar altimeter) from the differentially corrected GPS height,

The GPS height data had the ellipsoid to geoid separation “N” values applied to it real time and is relative to the geoid and as such the resulting calculated digital terrain height is relative to the Australian Height Datum or AHD.

3.5 UTS Geophysics Stinger Mounted Magnetometer System

The installation platform used for the acquisition of magnetic data was a tail mounted stinger. This stinger system was constructed of carbon fibre and designed for maximum rigidity and stability.

Both the total field magnetometer and three component vector magnetometer are located within the tail stinger.



3.6 Total Field Magnetometer

Total field magnetic data readings for the survey were made using a Geometrics G822 Cesium Vapour Magnetometer. This precision sensor has the following specifications:



- Model G822
- Sample Rate 0.05 seconds (20Hz)
- Resolution 0.001nT
- Operating Range 15,000nT to 100,000nT
- Temperature Range -40°C to +50°C

3.7 Three Component Vector Magnetometer

Three component vector magnetic data readings for the survey were made using a Fluxgate Magnetometer. This precision sensor has the following specifications:

- Model Billingsley
- Sample Rate 0.05 seconds (20Hz)
- Resolution 0.1nT
- Operating Range 20,000nT to 100,000nT
- Temperature Range -20°C to +50°C

3.8 Aircraft Magnetic Compensation

At the start of the survey the systems were calibrated for reduction of magnetic heading error. The heading and manoeuvre effects of the aircraft on the magnetic data were removed using an Data Acquisition & Adaptive Aeromagnetic Real-Time Compensator (DAARC500).

Calibration of the aircraft heading effects were measured by flying a series of pitch, roll and yaw manoeuvres at high altitude while monitoring changes in the three axis magnetometer and the effect on total field readings. A 26 term polynomial model of the aircraft magnetic noise covering permanent, induced and eddy current fields was determined. These coefficients were then applied to the data collected during the survey in real-time. The coefficients are listed in Appendix F.

The compensation flight data was recorded and then checked to ensure the acquisition of the compensation solution was without artifacts. A testbox flight was then recorded repeating the series of pitch, roll and yaw manoeuvre on all cardinal headings as with the compensation flight but now using the approved solution stored in the DAARC500. This testbox flight data was then processed to test the validity of the compensation for all cardinal headings, north, south, east and west.

3.9 Diurnal Monitoring Magnetometer

A base station magnetometer was located in a low gradient area beyond the region of influence of any man made interference to monitor diurnal variations during the survey.

The specifications for the magnetometers used are as follows:

- Model Scintrex Envimag
- Resolution 0.1 nT
- Sample interval 2 seconds (0.5 Hz)
- Operating range 20,000nT to 90,000nT
- Temperature -20°C to +50°C



3.10 Barometric Pressure

An Air DB barometric altimeter was installed in the aircraft so as to record and monitor barometric pressure. The data was recorded at 0.10 second intervals and is used for the reduction of the radiometric data.

- Model PTB200 barometric altimeter
- Accuracy 2 metres
- Height resolution 0.1 metres
- Height range 0 - 3500 metres
- Maximum operating pressure 5000 mb
- Pressure resolution: 0.01 mb
- Sample rate 10 Hz

3.11 Temperature and Humidity

Temperature and humidity measurements were made during the survey at a sample rate of 10Hz. Ambient temperature was measured with a resolution of 0.1 degree Celsius and ambient humidity to a resolution of 0.1 percent.

3.12 Radiometric Data Acquisition

The gamma ray detectors used for the survey were two Radiation Solutions Inc RSX500 crystal packs, each pack contains four thallium activated sodium iodide crystals each with its own micro-spectrometer which are self stabilising in order to minimise spectral drift, the radiometric data was recorded in a 256 channel spectrum format.

Thorium source measurements were made each survey day to monitor system resolution and sensitivity. A calibration line was also flown at the start and end of each survey day to monitor ground moisture levels and system performance.

- Spectrometer model RSX 500
- Detector volume 34 litres
- Sample rate 1 Hz



The following table lists the spectral windows used.

Window Name	Total Count	K	U	Th
Energy Range (MeV)	0.4-2.81	1.370-1.570	1.660-1.860	2.410-2.810

4 PROJECT MANAGEMENT

Mount Isa Mines Limited

John Carew
Terry Harvey

UTS Geophysics Field

Operators

Peter McDonald
Hayley Kelly

Pilots:

Matthew Borgas
Johann Schutte

UTS Geophysics Office

Project Manager:

Rod Fowler

Data Processing:

Adam Schubert

Final Data QA/QC:

Geoffrey Plastow

5 DATA PROCESSING PROCEDURES

5.1 *Data Pre-processing*

The raw binary survey data was downloaded from the aircrafts acquisition system after each flight and transferred to the field processing computer. Using UTS Geophysics developed software the data was then trimmed to the correct survey boundary extents and corrections were made to the data positions with respect to time to remove fixed system parallax or lag offsets, the magnetic and radar altimeter data was adjusted by -0.3 seconds, and the radiometric data by -1.4 seconds for each flight.

The trimmed and parallax corrected data was then exported as located ASCII data and imported into field databases for further quality control procedures which included visual scrutinisation of channel profiles and grid images.

5.2 Magnetic Data Processing

The diurnal base station data was checked for spikes and steps, and suitably filtered prior to the removal of diurnal variations from the aircraft magnetic data.

The filtered diurnal measurements were subtracted from the diurnal base field and the residual corrections applied to the survey data by synchronising the diurnal data time and the aircraft survey time.

The X and Y positioning of the data was then checked for spikes before applying the IGRF correction. Any spikes in the positions were manually edited. The updated IGRF 2015 correction was calculated at each data point (taking into account the height above sea level).

This regional magnetic gradient was subtracted from the survey data points.

Tie line levelling was applied to the data by least squares minimization, using a polynomial fit of order 0, of the differences in magnetic values at the crossover points of the survey traverse and tie line data.

In order to remove any residual long wavelength variations in the tie line leveled data along the traverse lines, polynomial levelling was then applied.

Final micro-levelling techniques were then selectively applied to the tie line leveled data to remove minor residual variations in profile intensity

Located and gridded data were generated from the final processed magnetic data.

5.3 Radiometric Data Processing

Statistical noise reduction of the 256 channel data was performed using the Noise Adjusted Singular Variable Decomposition (NASVD) method described by Hovgaard and Grasty (1997).

Noise-adjusted singular value decomposition is performed, and the number of components to be used is determined by inspection of plots of the spectral components and by a statistical analysis of the contributions of the components. If the spectral shapes show any unusual characteristics, further analysis of the concentrations of the spectral components in the line data is performed in order to identify and eliminate any corrupt spectra. If such spectra were eliminated, the NASVD process is re-performed, in order to obtain spectral components free of any bias from corrupt spectra.

Only the dominant spectral shapes (identified as described above) were used in the spectral reconstruction process. The first 8 NASVD components were used for this process.

Channels 20-240 only are spectrally smoothed, as these contain the regions of interest and are not dominated by the lower end of the Compton continuum. The energy spectrum between the potassium and thorium peaks was recalibrated from the spectrally smoothed 256 channel measurements.

The aircraft background spectrum and the scaled unit cosmic spectrum were then subtracted from the 256 channel data. This 256 channel data was then windowed to the 5 primary channels of total count, potassium, uranium, thorium and low-energy uranium. Dead time corrections were then applied to the data. Radon background removal was performed using the Minty Spectral Ratio method (1992).

The radar altimeter data was corrected to standard temperature and pressure, and height corrected spectral stripping was then applied to the windowed data. Height attenuation corrections based on the STP radar altimeter were then performed to remove any altitude variation effects from the data.

The Uranium and Total Count channels were tie-leveled to remove the effects of residual radon background. The tie-levelling process employed was a least-squares/median filter procedure, which generated a single correction for each line of data. Mis-matches were calculated at each tie-traverse intersection and the median mismatch for each flight line was calculated as the residual levelling error for that line.

5.4 *Digital Terrain Model Data Processing*

The radar altimeter data was subtracted from the GPS altimeter data leaving digital terrain data.

The digital terrain data thus derived was tie line leveled and gridded. Tie line leveled data was then examined and selectively microleveled to produce a grid without line dependent artifacts.

For further information concerning the survey flown, please contact the following office:

Head Office Address:

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Unit 2/17 Oxleigh Drive
Malaga, WA 6090

Tel: +61 8 6310 4000
Fax: +61 8 9249 8894

Postal Address:

UTS Geophysics
P.O. Box 2721
Malaga, WA 6944

Quoting reference number: UT150018

APPENDIX A - LOCATED DATA FORMATS

MAGNETIC LOCATED DATA

FIELD FORMAT DESCRIPTION			UNITS
1	I8	LINE NUMBER	
2	I4	FLIGHT/AREA NUMBER	AAFF (Area/Flight)
3	I9	DATE	YYYYMMDD
4	F10.1	TIME	sec
5	I9	FIDUCIAL NUMBER	
6	I4	UTM ZONE	
7	F12.6	LATITUDE (WGS84)	degrees
8	F12.6	LONGITUDE (WGS84)	degrees
9	F12.2	EASTING (WGS84)	metres
10	F12.2	NORTHING (WGS84)	metres
11	F8.1	RADAR ALTIMETER HEIGHT	metres
12	F8.1	GPS HEIGHT (WGS84)	metres
13	F8.1	TERRAIN HEIGHT (WGS84)	metres
14	F10.3	RAW MAGNETIC INTENSITY	nT
15	F10.3	DIURNAL CORRECTED TMI	nT
16	F10.3	DIURNAL AND IGRF CORRECTED TMI	nT
17	F10.3	TIE LINE LEVELLED TMI	nT
18	F10.3	FINAL TOTAL MAGNETIC INTENSITY	nT
19	F9.3	FINAL TRANSVERSE MAG GRADIENT	nT/m
20	F9.3	FINAL LONGITUDINAL MAG GRADIENT	nT/m

RADIOMETRIC LOCATED DATA

FIELD FORMAT DESCRIPTION			UNITS
1	I8	LINE NUMBER	
2	4	FLIGHT	FF
3	I9	DATE	YYYYMMDD
4	F10.1	TIME	sec
5	I9	FIDUCIAL NUMBER	
6	I4	UTM ZONE	
7	F12.6	LATITUDE (WGS84)	degrees
8	F12.6	LONGITUDE (WGS84)	degrees
9	F12.2	EASTING (WGS84)	metres
10	F12.2	NORTHING (WGS84)	metres
11	F8.1	RADAR ALTIMETER HEIGHT	metres
12	F8.1	GPS HEIGHT (WGS84)	metres
13	I5	LIVE TIME	milli sec
14	F8.1	PRESSURE	hPa
15	F6.1	TEMPERATURE	Degrees Celcius
16	I6	TOTAL COUNT (RAW)	Counts/sec
17	I6	POTASSIUM (RAW)	Counts/sec
18	I6	URANIUM (RAW)	Counts/sec
19	I6	THORIUM (RAW)	Counts/sec
20	I6	COSMIC (RAW)	Counts/sec
21	F8.1	TOTAL COUNT (CORRECTED)	Counts/sec
22	F8.1	POTASSIUM (CORRECTED)	Counts/sec
23	F8.1	URANIUM (CORRECTED)	Counts/sec
24	F8.1	THORIUM (CORRECTED)	Counts/sec
25	F9.4	DOSE RATE	nGy/hr
26	F9.4	POTASSIUM GRND CONCENTRATION	%
27	F9.4	URANIUM GRND CONCENTRATION	ppm
28	F9.4	THORIUM GRND CONCENTRATION	ppm

GRIDDED DATASET FORMATS

Gridding was performed using a bicubic spline algorithm.

The following grid formats have been provided:

- ER-Mapper format

LINE NUMBER FORMATS

Line numbers are identified with a six digit composite line number and have the following format - AALLLLB, where:

A or AA	Survey area number
LLLL	Survey line number 0001-8999 reserved for traverse lines 9001-9999 reserved for tie lines
B	Line attempt number, 0 is attempt 1, 1 is attempt 2 etc..

UTS FILE NAMING FORMATS

Located and gridded data provided by UTS Geophysics uses the following 8 character file naming convention to be compatible with PC DOS based systems.

File names have the following general format – JJJJJAA_BBB.EEE, where:

JJJJJ	UTS Geophysics Job number														
AA	Area number if the survey is broken into blocks														
BBB	<table> <tr> <td>mag</td> <td>Magnetic data</td> </tr> <tr> <td>spec</td> <td>Radiometric data</td> </tr> <tr> <td>TC</td> <td>Total count data</td> </tr> <tr> <td>K</td> <td>Potassium counts</td> </tr> <tr> <td>U</td> <td>Uranium counts</td> </tr> <tr> <td>Th</td> <td>Thorium counts</td> </tr> <tr> <td>DTM</td> <td>Digital terrain data</td> </tr> </table>	mag	Magnetic data	spec	Radiometric data	TC	Total count data	K	Potassium counts	U	Uranium counts	Th	Thorium counts	DTM	Digital terrain data
mag	Magnetic data														
spec	Radiometric data														
TC	Total count data														
K	Potassium counts														
U	Uranium counts														
Th	Thorium counts														
DTM	Digital terrain data														
EEE	File name extension														
DAT	Located digital data file														
DFN	Located data definition file														
ERS	Ermapper gridded data header file Ermapper data portion has no extension														
GRD	Geosoft gridded data file														

APPENDIX B - COORDINATE SYSTEM DETAILS

Locations for the survey data are provided in both geographical latitude and longitude and Universal Transverse Mercator metric projection coordinate systems.

WGS84

Coordinate Type
Semi Major Axis
Flattening

World Geodetic System 1984

Geographical
6378137m
1/298.257223563

AMG84

Coordinate Type
Semi Major Axis
Flattening

Australian Map Grid 1984

Universal Transverse Mercator Projection Grid
6378160m
1/298.25

APPENDIX C - SURVEY BOUNDARY DETAILS

Area Name: Cameron
Coordinates in WGS84
Grid Zone: 54S

Easting Northing

395546	7779226
399123	7779226
399123	7773676
400923	7773676
400923	7760776
402673	7760776
402673	7758976
404473	7758976
404473	7751476
401073	7751476
401073	7736826
408073	7736826
408073	7731326
409823	7731326
409823	7725757
413285	7724026
425473	7724026
425473	7718376
420323	7718376
420323	7707338
413380	7705376
404634	7705376
402934	7712726
397623	7712726
397623	7723676
388873	7723676
388873	7727487
390591	7731226
392223	7731226
392223	7751426
390673	7751426
390673	7764326
388623	7764326
388623	7768090
395546	7779226

APPENDIX E - PROCESSING PARAMETERS

Magnetic Processing Parameters

IGRF Date: 2015.7
 Average Declination: 5.998 degrees
 Average Inclination: -50.765 degrees
 Average IGRF field: 50518.00 nT
 Average diurnal: 51037.00 nT

Radiometric Processing Parameters

Height Attenuation Coefficients

Total Count: -0.0133
 Potassium: -0.0180
 Uranium: -0.0103
 Thorium: -0.0134

Cosmic Correction Coefficients

Total Count: 0.9389
 Potassium: 0.0503
 Uranium: 0.0413
 Thorium: 0.0605

Aircraft Background Coefficients

Total Count: 187.583
 Potassium: 30.381
 Uranium: 6.369
 Thorium: 0.000

Sensitivity Coefficients

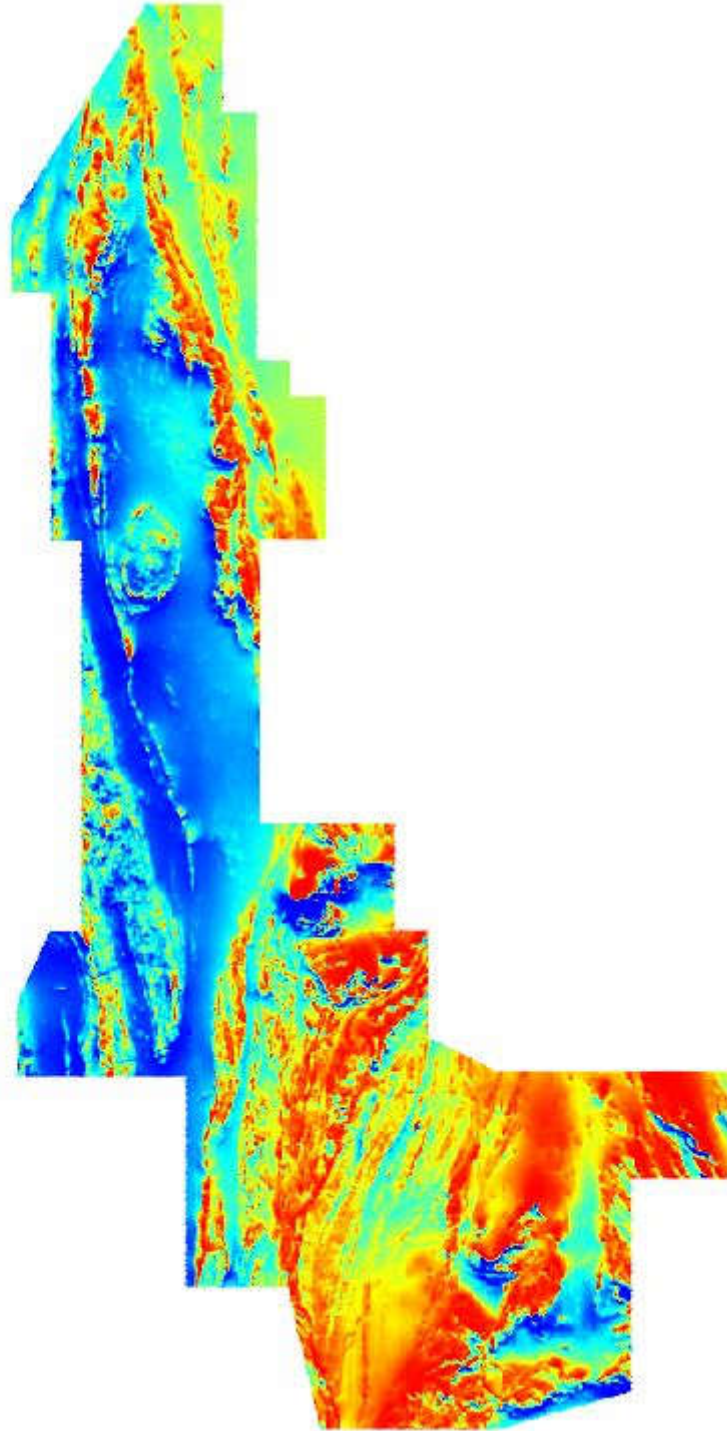
Total Count: 40.53 cps/dose rate
 Potassium: 118.22 cps/%k
 Uranium: 14.91 cps/ppm
 Thorium: 7.35 cps/ppm

Radiometric Stripping Coefficients

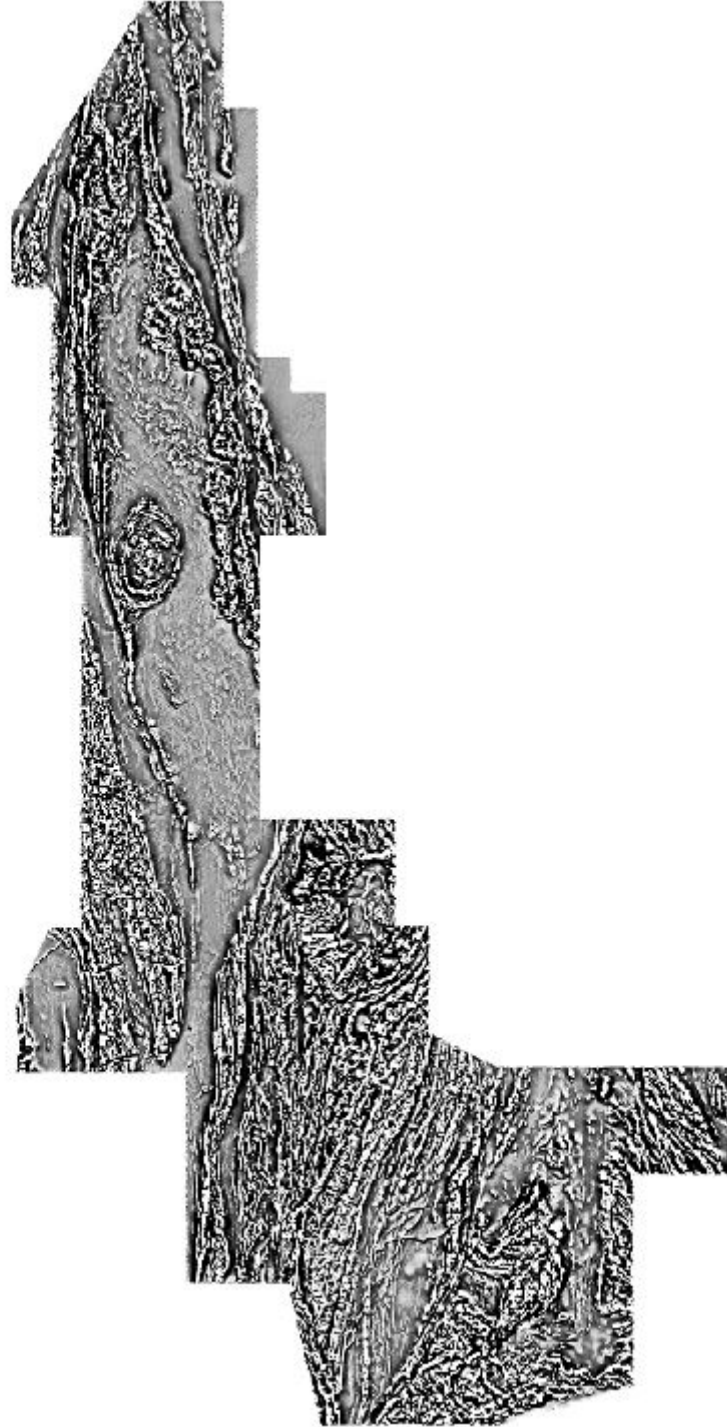
Alpha: 0.2858
 Beta: 0.4715
 Gamma: 0.7595
 a: 0.0352

Final Height Reduction - All data reduced to STP height datum 30m

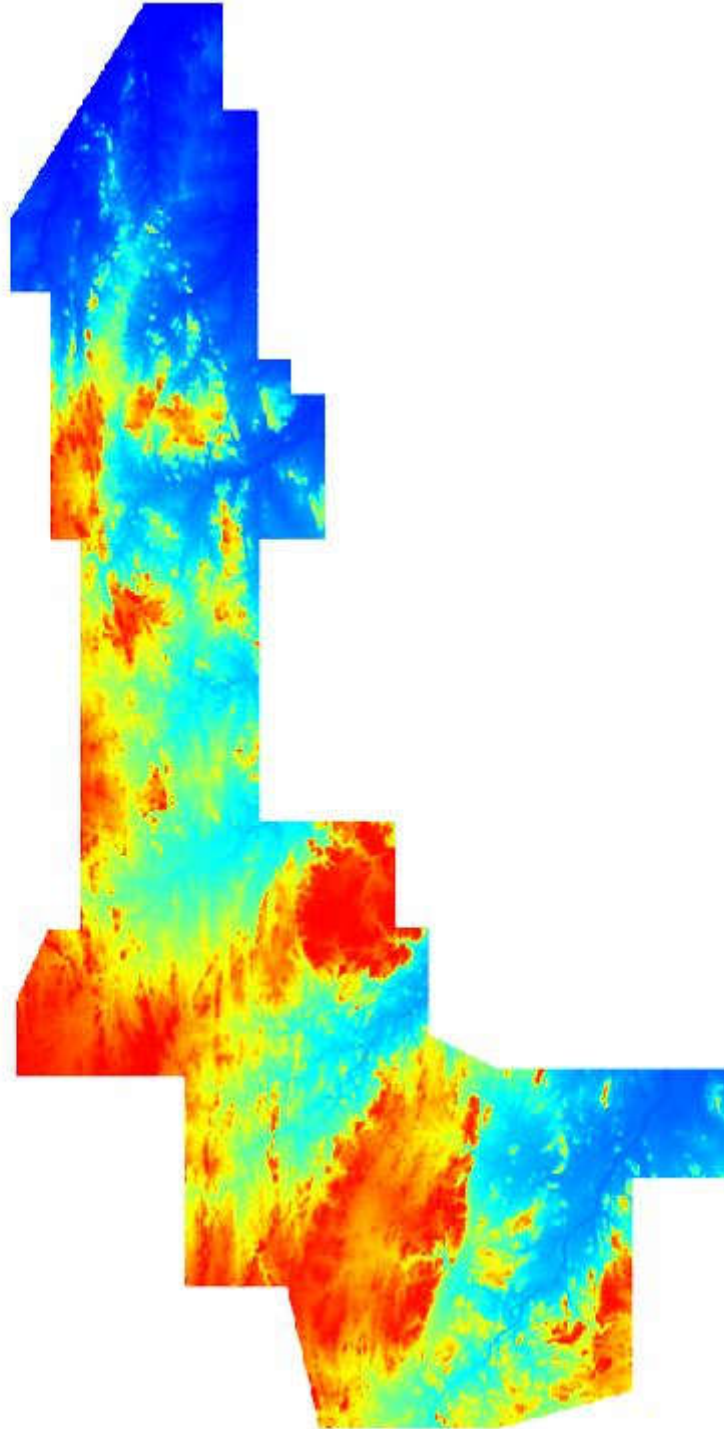
APPENDIX F - IMAGES



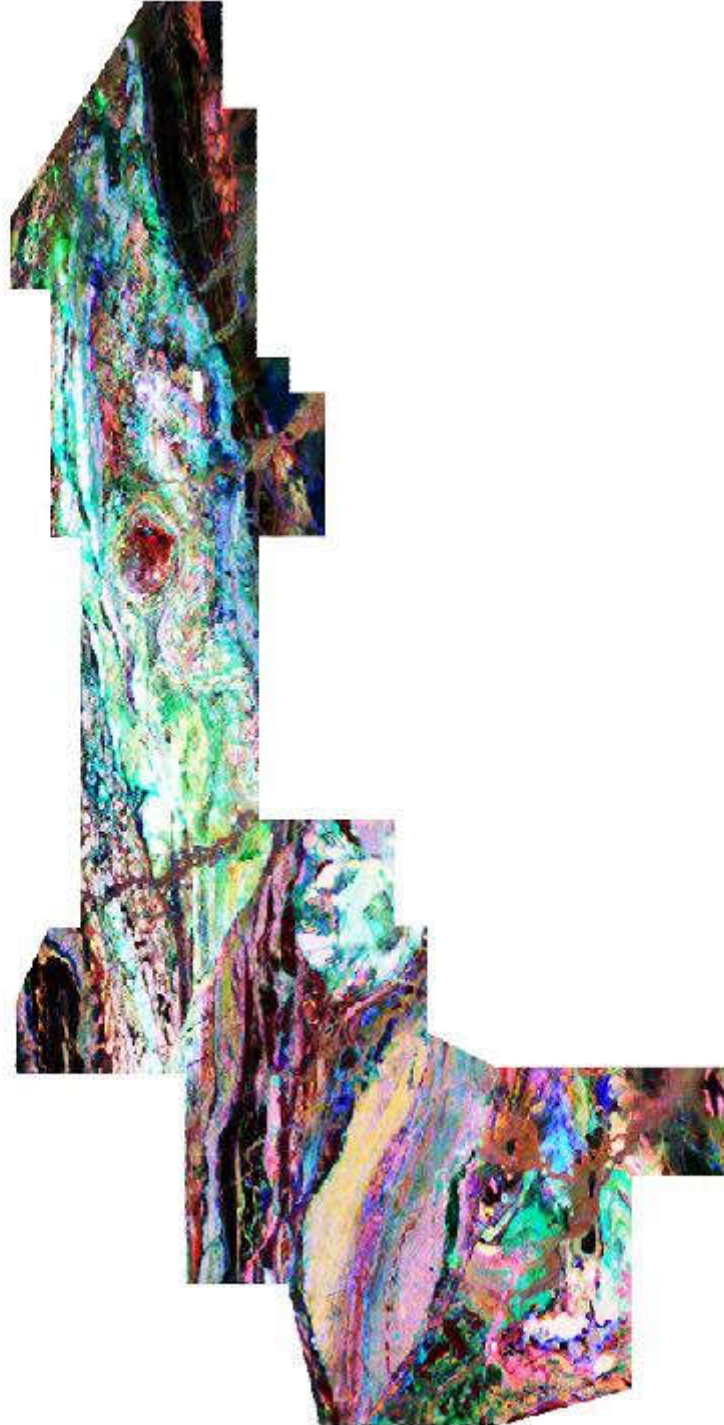
Total Magnetic Intensity



First Vertical Derivative of TMI



Digital Elevation Model



Ternary Radiometrics