

**Airborne Geophysical Survey
Chilling, Northern Territory**

November 2008

Survey Operations and Logistics Report

For

CROSSLAND URANIUM MINES LIMITED

Survey Flown by:



GPX Airborne

Project 2314

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1 GENERAL SURVEY INFORMATION

1.1 INTRODUCTION

In November 2007, GPX Airborne commenced a fixed wing airborne magnetic and radiometric survey for Crossland Uranium Mines Limited in Chilling. The survey was flown using a Cessna 210 operated by Ozshore Pty Ltd. This report summarizes the procedures, details and equipment used by GPX Airborne in the acquisition, verification and processing of the airborne geophysical data.

Client:	Crossland Uranium Mines Limited
GPX Project Number:	2314
Survey Area:	Chilling, Northern Territory
Data Processing Base:	Batchelor, Northern Territory
Mobilisation:	8 th November 2007
Production:	9 th November 2007 to 4 th December 2007
Demobilisation:	5 th October 2007
Line km surveyed:	18875.1 km

1.2 SURVEY BRIEF

Aircraft equipment installation, ground tests and radiometric calibration flights were carried out during August 2006 in Perth, Western Australia. On 8th November 2007 the GPX Airborne crew mobilised to Batchelor. The crew were based in Batchelor at the Rum Jungle Resort for the duration of the project. The Chilling survey commenced on 9th November 2007 and was completed on 4th December 2007.

The line spacing of the survey area was changed mid-survey by the client due to concern of moisture affecting the radiometric data. Any lines that were removed by the client from the original flight plan were not re-flown. This affects the north of the survey which was flown prior to the alteration of the flight plan. There are several flight lines and partial lines that were scrubbed but never re-flown due to these flight plan changes.

1.3 SURVEY PERSONNEL

The following personnel were involved on this project:

Operations and Safety Manager:	Bob Blizzard
Project Leaders	Don Copley Dan Ting
Technical Support:	Bob Taylor
Operators:	Phil Kitto Jeff Ibbotson Greg Sell
Pilots:	Chris Hursd Mike Nelson Anthony Connor
Data Processing:	Phil Robinson

1.4 SURVEY EQUIPMENT

Survey Platform:	Cessna 210
Data Acquisition System:	Pico Envirotec AGIS PC104
Magnetometer Processor:	Pico Envirotec MMS-4 Magnetometer Processor
Magnetometer Sensor:	Geometrics G-822A
Fluxgate Magnetometer:	Billingsley Ultra Miniature TFM 100G2
Base Magnetometer:	Pico Envirotec G-Mag with Scintrex CS-3 Cesium Vapour Sensor
Gamma-Ray Spectrometer:	Pico Envirotec GRS-410 Spectrometer
Temperature and Humidity Sensor:	Vaisala HMP233 Temperature and Humidity Sensor
Barometric Pressure Sensor:	Vaisala PTB220 Digital Barometer
GPS and DGPS Receiver:	CSI DGPS MAX
Radar Altimeter:	Rockwell Collins ALT-50A
In-field Computer:	Toshiba Notebook
In-field Software:	Pico Envirotec PEIView, ChrisDBF



Figure 1: Cessna 210 VH-MNN

2 SURVEY EQUIPMENT SPECIFICATIONS

2.1 DATA ACQUISITION CONSOLE

The Data Acquisition console is a Pico Envirotec AGIS PC104. This is a versatile multi-function system that is capable of operation in many different configurations, depending on platform type, navigation and system requirements. The AGIS PC104 provides the following functions:

- Navigation / flight control
- Data recording
- Display of real-time collected data and status monitoring
- Data retrieval access



Figure 3: Real-time monitor and navigation console

2.1.1 Navigation / Flight Control

The AGIS PC104 is used to guide the aircraft on a pre-defined flight plan that can be generated in UTM or Latitude/Longitude coordinates. The pre-defined flight plan can be designed to file prior to the start of the project, entered or altered in the AGIS system or delineated 'on-the-fly' e.g. while in the air flying the boundary and entering corner coordinates. Co-ordinates can only be entered in the WGS84 datum system, this has been implemented to avoid confusion and eliminate possible conversion errors. Normal survey altitude and ground speed, with pre-set tolerances are also entered.

The pilot display consisted of a 2-line strip display that is driven directly from the AGIS PC104 console.

The desired flight line is selected from the operator interface, which will either be a keyboard or touch-screen.

2.1.2 Data Recording

The AGIS PC104 relates all acquired data to the instant position from the GPS receiver and records the collected data to three separate data files. The data is recorded in compressed binary format, to a commercial solid-state hard disk.

The flight path file is recorded from AGIS program start-up to shutdown and cannot be turned off by the operator. It contains position, timing, altitude and basic data.

The data file is recorded whenever the acquisition system is "On-line". It contains all navigation data plus "enabled" data.

2.1.3 Display of real-time collected Data and status monitoring

The AGIS displays flight path and geophysical data as it is acquired aiding the data quality control and real time navigation guidance. The user is presented with graphical representations of the survey area, flight lines, navigation status, and sensor data. The spectra data was also displayed.

Several other status indications are also provided which will either change state indicating a major system malfunction, such as a magnetometer or spectrometer failure, or will change state during normal operation, indicating data being written to a file etc

2.1.4 Data Retrieval

The AGIS PC104 provides facility to transfer the recorded data from the internal solid-state disk to compact flash media immediately following the completion of the survey flight. Recorded data is not deleted from the main disk until this "retrieved" data has been verified "error free".

2.2 MAGNETOMETER PROCESSOR

2.2.1 Pico Envirotec MMS-4 Magnetometer Processor

The Magnetometer Processor is a Pico Envirotec MMS-4 Magnetometer Processor. This is an advanced frequency-measuring device that can support four continuous signal magnetometers (Cs, He, K). It is a hardware-software designed system, exhibiting simplicity, easy interfacing and substantial versatility. Magnetometer readings are synchronized with the PPS (Pulse Per Second) signal derived from the GPS for accurate timing.

The MMS-4 contains 8 channels of analog differential inputs. The first 4 analog channels are sampled synchronously with MMS-4 at up to 50 samples per second. The remaining 4 analog channels are sampled at 10 samples per second. Analog data is integrated into the magnetometer data stream.

Specifications:

Input:	Coaxial - Larmour signal over DC Power Supply
Resolution:	0.0002 nT (Gamma) = 0.2 picoTesla
Sampling rates:	5, 10, 20, 25, 50, 100 Hz
Dynamic range:	15,000 to 100,000nT
Synchronization:	GPS – PPS (Pulse Per Second)

2.3 MAGNETOMETERS

2.3.1 Scintrex CS3 Cesium-Vapour

The Magnetometer Sensor is a Scintrex CS3, which employs an optically pumped cesium-vapour atomic magnetic resonance system that functions as the frequency control element in an oscillator circuit.

Specifications:

Model:	Scintrex CS3
Type:	Cesium Vapour Magnetometer
Operating Range:	15,000 – 105,000 nT
Sensitivity:	0.002nT P-P in 0.1-1Hz bandwidth
Heading Error:	± 0.25nT inside the optical axis to the field direction angle range 20° to 70° and 110° to 160°
Output:	Larmour frequency, 3.498577 Hz/nT

2.3.2 Billingsley Ultra Miniature TFM 100G2

The Fluxgate Magnetometer is a Billingsley Ultra Miniature TFM 100G2. This unit is a low noise, high sensitivity unit, packaged into a compact housing. An analog DC output voltage is produced for each of the measured X, Y and Z orthogonal components of the current magnetic field.

Specifications:

Model:	Billingsley TFM 100G2
Axial Alignment:	Orthogonality better than ±1°
Sensitivity:	100uV / nT
Noise:	20pT RMS / Hz @ 1Hz
Output:	± 100uT = ± 10V

2.4 MAGNETIC BASE STATION

2.4.1 Pico Envirotec G-Mag with Scintrex CS-3 Cesium Vapour Sensor

The Earth's diurnal activity was monitored using a Pico-Envirotec G-Mag Base Station Magnetometer. The portable unit has a built-in GPS receiver and records the signal from a Scintrex CS3 Cesium Vapour sensor to a compact flash disk.

Specifications:

Model:	Pico Envirotec PGIS Base Station Magnetometer
Sensor:	Scintrex CS3
Type:	Cesium-Vapour Magnetometer
Operating Range:	15,000 – 105,000 nT
Resolution:	0.001nT at 10 Hz
Sampling Rate:	5, 10, 20, 25, 50 and 100 Hz

Location

The base station at Batchelor was located at:

Longitude: 131° 1'50.90"E
Latitude: 13° 3'01.97"S



Figure 4: Sketch of the base station location at Batchelor
(Image courtesy of Google Earth)

2.5 GAMMA-RAY SPECTROMETER

2.5.1 Pico Envirotec GRS-410 Spectrometer

The GRS-410 Radiometric Data Acquisition System is an advanced spectrometer utilizing NaI detectors. It is a hardware-software design system, with advanced individual detector signal processing reducing the potential hazards (or complex circuitry) of "zero base shift" and practically eliminating "dead time".

The GRS-410 records real time calibrated summed 256 channel spectra. In addition, a "raw" 512-channel spectrum from each individual crystal is also recorded. This allows the data from individual crystals to be post-processed to achieve better energy calibration and as a result, a high-resolution 512 channel summed spectra.

Specifications:

Spectra Resolution:	256 or 512 channels
Data Sampling:	Corrected 1.0 sec (512 ch)
Energy Spectra:	50 keV to 3 MeV
Threshold:	Adjustable from 0 keV to 0.5 MeV
Cosmic:	Energies above 3 MeV are detected as Cosmic Rays
Spectra Tracking:	Individual detectors
Spectra Correction:	Automatic after system calibration
Tracking Stabilisation:	Typically 30sec on the ground, <2 minutes in the air at 100m altitude (4 litre of individual detector volume). In case of a system re-start old tracking parameters (not aged more than 15 min) are used till new tracking is re-established.
Dead time:	For normal detection rates negligible
Configuration(s):	33.56 litres - 8 individual detectors in 2 boxes

2.6 AIRBORNE SENSORS

2.6.1 Vaisala HMP233 Temperature and Humidity Sensor

The Temperature and Humidity transmitter is a Vaisala HMP233. The unit provides both a digital RS232 output and Analogue voltage or current output directly proportional to the measured Temperature and Humidity. The unit is a commercial grade device housed in a rugged aluminium enclosure.

Specifications:

Model:	HMP233
Humidity Range:	0 – 100% RH
Humidity Accuracy:	±1 %RH (0...90 %RH) ±2 %RH (90...100 %RH)
Temperature Range:	-40 to +80°C
Temperature Accuracy at +20°C:	± 0.1°C
Analog Output Accuracy:	±0.05 % full scale

2.6.2 Vaisala PTB220 Digital Barometer

The Barometric Pressure transmitter is a Vaisala PTB220. The unit provides both a digital RS232 output and Analogue voltage or current output directly proportional to the measured Barometric Pressure. The unit is a Class "A" commercial grade device housed in a rugged aluminium enclosure.

Specifications:

Model:	PTB220
Pressure Range:	500 – 1100 hPa
Resolution:	0.01 hPa
Pressure Accuracy at +20°C:	± 0.1 hPa

2.7 GPS AND DGPS RECEIVER

2.7.1 CSI DGPS Max

The GPS and DGPS receiver is a CSI DGPS MAX, which is a 12-channel combined GPS/DGPS unit. The DGPS MAX is able to use differential corrections received through an internal WAAS demodulator, VLF beacon receiver, or the OmniSTAR DGPS Service.

Specifications:

Receiver:	CSI DGPS MAX
GPS Position update rate:	5Hz
GPS Input frequency:	L1
DGPS Update rate:	Typically every 6 seconds
DGPS Solution Used:	OmniSTAR VBS
Antenna:	Fugro L1/Differential Wideband

2.8 RADAR ALTIMETER

2.8.1 Collins ALT-50A

The Radar Altimeter is a Rockwell Collins ALT-50A two-antenna unit operating at a centre frequency of 4300MHz. The voltage output to the data system is directly proportional to the aircraft flying height with an output characteristic of 20mV/ft up to 500ft, then 10.4V + 3mV/ft above 500ft.

Specifications:

Model:	Collins ALT-50A Radio Altimeter System
Accuracy:	± 3ft - 0 to 150ft range ± 2% of indicated altitude – 150 to 500ft range ± 3.5% of indicated altitude – 500 to 2000ft range
Measurement Rate:	10Hz minimum

3 EQUIPMENT CALIBRATIONS AND DATA ACQUISITION CHECKS

3.1 DYNAMIC MAGNETOMETER COMPENSATION

Aircraft compensation tests were flown at high altitude on the 4 survey line headings and also at +/- 15° to the line headings (to accommodate for cross wind flying conditions). The data for each heading consists of a series of aircraft manoeuvres with large angular excursions: specifically pitches, rolls and yaws. This is done to artificially create the worst possible attitudes and rates of attitudinal change likely to be encountered while on line and compensate for any magnetic noise created by the aircraft's motion within the earth's magnetic field. This data is processed to obtain the REAL TIME COMPENSATION terms of which the aircraft used the standard 17-term model. These terms include permanent, induced and eddy values. These coefficients may be applied in real time or during post processing. Note that this form of compensation will only remove those noise effects modelled in the manoeuvres test flight. External noise sources and random motions of the stinger with respect to the aircraft airframe generally establish the noise floor for this type of installation. The surveyor's goal is to achieve a 4th difference noise level on the order of 0.01 nT RMS during normal surveying conditions. In general, this noise level was routinely achieved or bettered as a matter of course.

3.2 HEADING ERROR CHECK

Historically, heading error checks have been an essential part of the aeromagnetic data acquisition procedure but their importance now has diminished. GPX Airborne now corrects for these effects using the dynamic aircraft magnetic compensation system and specially developed software. In the past, repeatable heading errors of less than one nanotesla (1.0 nT) were considered good. Dynamic compensation typically yields heading errors in the order of 0.1 to 0.3 nT, which are effectively eliminated by modern data levelling techniques.

3.3 SYSTEM PARALLAX TESTS

One of the processing parameters required to process digital data was the parallax or offset time, between the time the digital reading was taken by the instrument and the time the position fix for the fiducial of the reading was obtained. Each instrument - magnetometer, altimeter - may have a different parallax, so the parallax must be computed for each instrument.

The parallax correction derived is the correction to be applied to each survey line. A positive parallax indicates the instrument reading is ahead of the position of the fiducial. Each integer fiducial represents one second so the parallax can be expressed in either fiducial or seconds.

The correct fiducial is computed by:

$$\text{Parallax corrected fid} = \text{Fid for recorded reading} - \text{Instrument parallax}$$

Results of parallax test

A summary of the parallax corrections is shown below.

Data	Parallax applied (seconds)
GPS Position	1.5
Magnetic data	0.5
Radiometric data	0.0
Altimeter data	0.5

Table 1: Parallax test summary

3.4 ALTIMETER CALIBRATIONS

The height of the aircraft above ground is recorded by a radar altimeter as a voltage every 0.1 second. The voltage data is converted to height via a lookup table determined by calibration with the GPS altitude.

3.5 RADIOMETRIC PRE SURVEY CALIBRATIONS

Pre-survey gamma-ray spectrometer calibration results are summarised below.

The calibration methods are as generally described by Grasty and Minty (1995).

VH-MNN	Window	Value
Aircraft Background	TC	110
	K	11.66
	U	3.7
	Th	2.77
Cosmic Background	TC	2.01
	K	0.1024
	U	0.095
	Th	0.0881
Stripping Coefficients	Alpha	0.2683
	Beta	0.4002
	Gamma	0.7653
	a	0.0424
Height Attenuation Correction Coefficients	TC	0.0075
	K	0.009268
	U	0.008277
	Th	0.007415

Table 2: Gamma-ray spectrometer calibration summary

3.6 TIME SYNCHRONIZATION

The magnetic base station is synchronised to GPS time so there is no time drift in the system.

3.7 SURVEY LINE NUMBERING SYSTEM

The first digit in any line number represents the area number, i.e. 10050 is area no. 1.

The next three numbers are the line number it self, i.e. 11030 is line number 103.

All Tie lines begin with the digit 7, i.e. 17020.

The fifth digit of any line number represent the attempt number, i.e. 10010 is the first attempt.

4 IN-FIELD DATA VERIFICATION

All data verification and preliminary processing and map production was conducted at the field office using a Toshiba Notebook computer. ChrisDBF was the primary field quality control software.

At the conclusion of each days survey all magnetic, radiometric, altimeter, flight path and diurnal data was transferred via compact flash memory onto the office computer for preliminary data verification.

4.1 IN-FIELD VERIFICATION OF ALTIMETER DATA

Radar Altimeter Data

The radar altimeter is verified to check that a reasonably constant height above the terrain specified in section 1.6 was flown; readings during the course of the survey did not exceed the specified tolerances. The radar altimeter data is used in the production of digital terrain maps.

Parallax Correction

The aircraft system parallax is also checked prior to project commencement. A parallax error correction of 0.0 second was used for in field verification.

GPS Height Data

The aircraft's height above mean sea level each second was determined by data from the post-processed GPS. The GPS height of the aircraft is verified to check for data masking and for equipment reliability. The GPS height data is used in the production of digital terrain maps.

Digital Terrain Data

After verification the radar altimeter height was subtracted from the GPS height to give the elevation of the terrain above mean sea level.

Gridding and Inspection

The digital terrain data was gridded and grid image enhancements were computed and displayed on screen. These were viewed also with the aid of crossline sun angles and inspected for inconsistencies and errors and appropriate corrections were made if required.

4.2 IN-FIELD VERIFICATION OF FLIGHT PATH DATA

The flight path is plotted daily to ensure it was within survey specifications. Any data not within specification was re-flown. The aircraft GPS recorded the data in the WGS84 datum.

4.3 IN-FIELD VERIFICATION OF MAGNETIC DATA

The raw un-edited magnetic data was checked to identify noise and spikes. Single reading spikes were manually edited and if the noise exceeded the contract specifications, the line was re-flown.

Magnetic Diurnal Data

Diurnal data recorded every 1 second from the primary base station was downloaded from the magnetometer's memory onto the field processing computer via a RS232 dump cable. The diurnal data was then checked and corrected for spikes. Single reading spikes were manually edited and multiple erroneous readings flagged as invalid. If invalid diurnal data occurred whilst survey data was being acquired the affected section was re-flown. The diurnal data was also checked to see that the change in diurnal readings during the course of the survey did not exceed the specified tolerances. When this occurred the affected survey lines were re-flown.

Diurnal Correction

The synchronized digital diurnal data collected by the base station was first subtracted from the corresponding airborne magnetic readings to calculate a difference. The resultant difference was then subtracted from the base value to produce diurnally corrected magnetic data.

Parallax Correction

The aircraft system parallax is also checked prior to project commencement. A parallax error correction of 0.0 second was used for in field verification.

Gridding and Inspection

The magnetic data was gridded and grid image enhancements were computed and displayed on screen. These were also viewed with the aid of crossline sun angles and inspected for inconsistencies and errors and appropriate corrections were made if required.

4.4 IN-FIELD VERIFICATION OF RADIOMETRIC DATA

Spectra Verification

The 512-channel radiometric data is viewed to confirm that the spectra peaks are correctly calibrated. The following peak locations are checked daily.

- Potassium 1460 keV
- Uranium 1760 keV
- Thorium 2614 keV

Parallax Correction

The aircraft system parallax is also checked prior to project commencement. A parallax error correction of 0.0 second was used for in field verification.

Gridding and Inspection

The radiometric data was gridded and grid image enhancements were computed and displayed on screen. These were also viewed with the aid of crossline sun angles and inspected for inconsistencies and errors and appropriate corrections were made if required.

4.5 DIGITAL ARCHIVES

All raw aircraft, and diurnal base data were backed up on CD-ROM disk at the end of each day's survey. A further backup of all raw and edited data remained on the field-processing computer for the entire duration of the project. A copy of each days flying was transferred to the company's ftp site for further verification.

5 FINAL DATA PROCESSING

All final data processing of the data was performed in the offices of GPX Airborne. Raw field data was transferred to the offices and processed to produce the final data. No field-processed data was used in the making of the final data. The final processing of the data follows the same quality control checks that are made in the field.

5.1 FINAL PROCESSING OF ALTIMETER DATA

Radar Altimeter Data

The radar altimeter is verified to check that a reasonably constant height above the terrain specified in section 1.6 was flown; readings during the course of the survey did not exceed the specified tolerances. The radar altimeter data is used in the production of digital terrain maps.

GPS Height Data

The aircraft's height above mean sea level each second was determined by data from the post-processed GPS. The GPS height of the aircraft is verified to check for data masking and for equipment reliability. The GPS height data is used in the production of digital terrain maps.

Parallax Correction

A parallax error correction as described in section 3.3 was applied to the coordinate data.

Tie Line Levelling

A crossover program was used to compute the height difference between each tie line and the traverse line intersection. These differences were then applied to level the traverse lines to the tie lines.

Micro Levelling

Micro levelling was used to remove residual differences with a long wavelength along line and short wavelength across line. Application of the micro levelling process removed the streaks that were sometimes visible when using various grid enhancements.

Digital Terrain Data

After verification the radar altimeter height was subtracted from the GPS height and the Geoid – Ellipsoid separation correction applied to give the elevation of the terrain above mean sea level.

Gridding and Inspection

The digital terrain data was gridded and grid image enhancements were computed and displayed on screen. These were viewed also with the aid of crossline sun angles and inspected for inconsistencies and errors and appropriate corrections were made if required.

5.2 FINAL PROCESSING OF MAGNETIC DATA

The raw un-edited magnetic data was checked to identify noise and spikes. Single reading spikes were manually edited.

Magnetic Diurnal Data

The diurnal data was then checked and corrected for spikes. Single reading spikes were manually edited and multiple erroneous readings flagged as invalid.

Diurnal Correction

The synchronized digital diurnal data collected by the base station was first subtracted from the corresponding airborne magnetic readings to calculate a difference. The resultant difference was then subtracted from the base value to produce diurnally corrected magnetic data.

Parallax Correction

A parallax error correction as described in section 3.3 was applied to the magnetic data.

IGRF correction

The magnetics data has been corrected for the regional gradient by subtracting the calculated IGRF (2005 model) computed continuously over the whole area. The calculation of these corrections used the GPS flying height. An IGRF base of 50960 nT was added.

Tie Line Levelling

A crossover program was used to compute the magnetic difference between each tie line and the traverse line intersection. These differences were then applied to level the traverse lines to the tie lines.

Micro Levelling

Micro levelling was used to remove residual differences with a long wavelength along line and short wavelength across line. Application of the micro levelling process removed the streaks that were sometimes visible when using various grid enhancements.

Gridding and Inspection

The magnetic data was gridded and grid image enhancements were computed and displayed on screen. These were also viewed with the aid of crossline sun angles and inspected for inconsistencies and errors and appropriate corrections were made if required.

5.3 FINAL PROCESSING OF RADIOMETRIC DATA

512 Channel Individual Crystal Energy Calibration

Airborne spectrometers measure the gamma radiation emitted by the nuclear decay of the naturally occurring radioactive isotopes. The GRS410 radiometric data acquisition system records *raw 512 channel spectra from each individual crystal*. It also records real time calibrated summed 256 channel spectra. If the individual crystals are not perfectly calibrated in real time the resultant summed 256 channel spectra cannot be reliably recalibrated during post processing. Even slightly inaccurate energy calibration of each crystal in real time produces non-Gaussian peaks in the summed spectra. For this reason we post process the 512 channel individual crystal spectra to achieve better energy calibration and a resultant 512 channel summed spectra which has much better resolution than the real time 256 channel summed spectra.

It is accepted that the energy response of each individual crystal is non linear so it is therefore not sufficient to use the high energy thorium and potassium peaks alone for energy calibration. From the peaks listed below, at least one of the uranium peaks from the low energy part of the spectra must be used to perform the energy calibration.

- Uranium 352 keV
- Uranium 609 keV
- Uranium 1120 keV
- Potassium 1460 keV
- Thorium 2614 keV

All peaks are contaminated to varying degrees by other elements. There is thorium in uranium peaks, uranium in thorium peaks and uranium and thorium in the potassium peak however given these intensities are small relative to the peak in question they can still be effectively used for this process which is why a least squares solution is the best method to use. The amount of theoretical interference will be somewhat dependent on the geology of the survey area although in practice this has never proved to be a real problem. It is quite easy to determine which peaks to use. Over water and high altitude flights require careful peak selection. Excellent aircraft background corrections and cosmic stripping ratios are achieved from high altitude calibration flights. After careful analysis and examination a manually defined or computed value at channel 0 for each crystal is derived which ensures accurate extrapolation at the low energy end of the spectra. This is necessary because the energy responses from all airborne survey radiation detector systems are non linear.

Computing a least squares second order polynomial through the selected peak locations as a function of true peak energies, provides a quadratic lookup table to calibrate the energy response of each crystal. Inclusion of the low energy peaks ensures more accurate energy calibration at the lower end of the spectra and allows extrapolation across the entire spectra. After energy calibration, the removed high end of the spectra contribute to the cosmic counts for each crystal. This fine adjustment to the cosmic count is important, since the corrections for total count, potassium, uranium

and thorium use this cosmic count. This procedure ensures accurate calibration of the entire spectra, not just the portion from potassium to thorium. After accurate energy calibration, any full spectra processing method such as NASVD or MNF will result in significantly improved resolution. The improved accuracy of the low energy part of the spectra ensures that the uranium peaks at 609 keV and 352 keV can be used with much greater confidence for radon removal. All stages of the energy calibration procedure are summarised by a series of plots for each individual crystal and the final summed spectra.

This method of energy calibration eliminates the need to fly high level and low level test lines for each data collection sortie. The only purpose of these lines is to check that the spectrometer is working correctly. Post processing of the raw individual crystal data allows us to verify the correct operation of the spectrometer for each flight line. The data quality is also verified by computing and plotting the individual crystal and the summed spectra resolutions (the width of the peak at half the maximum amplitude) for the potassium and the thorium peaks for each flight line. The only on ground GRS410 system check requirement is to ensure that the thorium peak is sufficiently below the correct channel to allow for crystal drift mainly caused by temperature change over the duration of the flight which is performed by using a thorium sample button on the ground immediately before each flight. There is no need for a post flight test as any lines with a problem will be identified during energy calibration and will be immediately reflown.

This unique ability to guarantee good quality data without time consuming test flights and on ground sample tests results in accurate quality control of all production flight data. It should be noted that the traditional methods of quality control rarely check the production data and mostly rely on the premise if all appears well at the beginning and end of each flight the production data in between is also well. This can and has been an incorrect assumption.

By permanently storing the individual raw and energy calibrated crystal data, our radiometric data acquisition system will allow reprocessing of the data set in the event of newly developed processing methods which can occur many years later and should therefore ensure a much longer shelf life than would otherwise be expected.

IAEA Processing

The processing of the radiometric data is summarised below.

1. Energy recalibrate the 512 channel spectra and re-window the data.
2. Noise Adjusted Singular Value Decomposition (NASVD).
3. Remove spikes from the altimeter, temperature and pressure values.
4. Correct radiometric data to standard temperature and pressure.
5. Remove the aircraft background, apply the cosmic correction, remove radon, apply the stripping values and finally apply the height correction.

Energy Recalibration

Spectra analysis was performed on each line of data and the position of the thorium and potassium peak positions determined and compared to their theoretical positions. The original spectra data was then mapped to the correct peak positions and new windowed data created for each of the standard IAEA windows as follows.

Window	Peak Energy (KeV)	Energy Window (KeV)		
Total Count		410	-	2810
Potassium	1460	1370	-	1570
Uranium	1760	1660	-	1860
Thorium	2615	2410	-	2810
Cosmic		3000		

512 Channel Noise Reduction

The two most common processing methods are:

1. Noise adjusted Singular Value Decomposition (NASVD). This was developed specifically for radiometric processing.
2. Maximum Noise Fraction (MNF). This was developed for removing noise from satellite images and subsequently used in radiometric processing.

Both methods use Principal Component Analysis (PCA) with the only difference being in the estimation of noise in the raw spectra and subsequent scaling before PCA.

We have implemented and extensively used both methods but prefer NASVD because it is simpler, requires one less pass of the data and less observations for a good join when adjacent data sets are merged. However the 2 methods give almost the same result and both work well.

Careful analysis of the eigenvalues and eigenvectors of the PCA is required to ensure the process has worked correctly. We use the 7 most significant principal components to reduce the data with the remainder considered to be noise. If this is not the case, as seen from eigenvalue and eigenvector plots, then there is a problem with the data. So this is an excellent quality control tool as well as a noise reduction method. There are strong theoretical reasons for this approach and if less than 7 components are used some signal is likely to be removed. On large surveys we have found it is best to use 7 components globally rather than having to make difficult decisions for different segments of the survey as this provides a globally consistent result.

As final proof the method has worked correctly, residual line profiles and images of potassium, uranium and thorium must confirm that no signal is present. Also the ternary potassium, uranium and thorium image must be sharp. If signal has been removed this image will be blurred.

Standard Temperature and Pressure correction

The data was converted to effective altitude at standard temperature and pressure (STP) using the expression:

$$Alt(STP) = BA \times \left(\frac{P}{1013} \right) \times \frac{273}{(T + 273)}$$

Alt(STP) = Effective altitude at STP

BA = Barometric Altitude

P = Pressure

T = Temperature in °C

Cosmic Correction

The aircraft background radiation was removed by subtracting the aircraft background values from the Total Count, Potassium, Uranium and Thorium windows. The effect of cosmic radiation was removed from each window by multiplying the cosmic channel by the cosmic stripping factor for each window and subtracting the result from the window data.

Radon Background Removal

Although in the past upward looking crystals have often been used as an acceptable method of correcting for the effects of atmospheric radon in airborne radiometric surveys, we now consider this method to be inadequate to provide the data quality required by modern processing techniques for the following reasons.

The crystal volume of the upward looking detectors is usually small relative to that of the primary downward looking detectors (typically 1 or 2 upward detectors for 4 downward detectors). For this reason, noise dominates signal in the spectra obtained from the upward looking detectors. Consequently the ability of these detectors to accurately reflect coincident (i.e. non geological) responses in the primary detectors is severely compromised. The low signal to noise ratio has the added effect of compromising spectral calibration of the upward looking detectors, further eroding their ability as indicators of coincident events.

More importantly, the very nature of airborne radon distribution renders this method inherently inaccurate, as atmospheric radon does not exist in uniform distributions but rather in radon clouds that have a distinctly non uniform density distribution. Sensors receiving signal from different directions will therefore detect different radon responses.

Another problem with upward looking crystals is preventing contamination effects from ground signal. This is especially a problem for low level surveys or for areas with significant terrain variation where aircraft attitude movements will allow ground signal to be recorded by the upward looking crystals.

It is clearly evident that any effective radon correction method should use the downward looking crystals only.

For this reason we prefer to use the spectral ratio method for radon removal. This method uses the 352 keV uranium peak as a substitute for upward crystals. The only time upward crystals may be needed is where cesium contamination affects the use of the 352 keV uranium peak. The use of the low energy uranium peak at 352 keV instead of the 609 keV uranium peak should make even this use of upward crystals redundant. The 352 keV uranium peak is an extremely good detector of radon gas because very little radiation from the ground will reach the aircraft at this low energy. Also the thorium peak close to the 352 keV peak has much less intensity than the thorium peak close to the 609 keV uranium peak.

With the GRS-410 512 channel spectrometer the resolution of low energy photopeaks is far superior to current 256 channel spectrometers. This is very important because low energy windows are narrow compared with high energy windows and the spectral ratio method requires the removal of the Compton background from the low energy 352 keV and/or 609 keV uranium window. Using NASVD noise reduction on the 512 channel spectra also provides a much better estimate of the Compton background.

Stripping

The radiometric spectra of potassium (K), uranium (U) and thorium (Th) series overlap. To evaluate any one spectral window, which is designed to detect one radioelement, requires removal of the spectral overlap. This process of removal of the spectral overlap is known as stripping. The stripping procedure uses spectral stripping ratios determined experimentally using concrete calibration pads of known K, U and Th concentration.

Parallax Correction

A parallax error correction of 0.0 seconds was applied to the radiometric data.

Micro Levelling

Micro levelling was used to remove residual differences with a long wavelength along line and short wavelength across line. Application of the micro levelling process removed the streaks that were sometimes visible when using various grid enhancements.

Gridding and Inspection

The radiometric data was gridded and grid image enhancements were computed and displayed on screen. These were also viewed with the aid of crossline sun angles and inspected for inconsistencies and errors and appropriate corrections were made if required.

5.4 DIGITAL TERRAIN MODEL DATA

Digital Terrain Model Calculation

The radar altimeter data was subtracted from the GPS heights to provide a digital elevation model which is height above the WGS84 spheroid.

Data Reliability

This Digital Terrain Model (DTM) has been computed from data generated during the course of an airborne geophysical survey flown at a nominal spacing of 100m and data has been interpolated between such lines. Every effort has been made to make this model a useful general reference. This DTM model is not a true representation of height above sea level as it still remains in the WGS84 Spheroid and can contain radar altimeter responses from buildings and in some instances dense timber. Users of the product should be aware of the topographic limitations mapped here within. Do not use this DTM for navigation purposes.

5.5 FINAL DIGITAL ARCHIVES

The final digital data was written out as a flat ASCII located data file. The format and channel description can be found in Appendix A. Grids of the final data were created in ERMapper format.

6 IMAGES

6.1 FLIGHT PATH IMAGE

The flight path of the aircraft is shown on the map below.

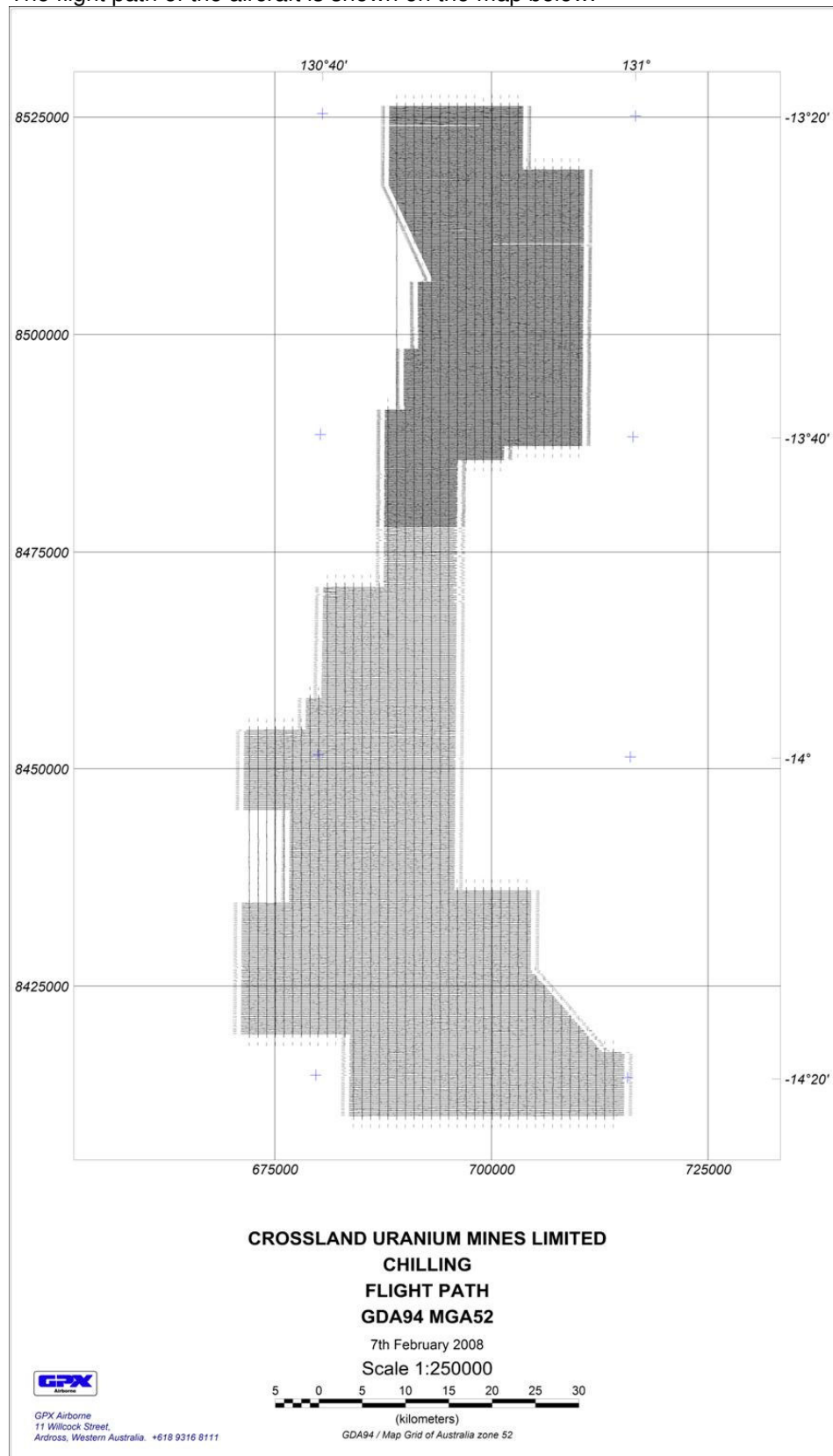


Figure 5: Flight path over Chilling survey area.

6.7 TOTAL MAGNETIC INTENSITY – FIRST VERTICAL DERIVATIVE IMAGE

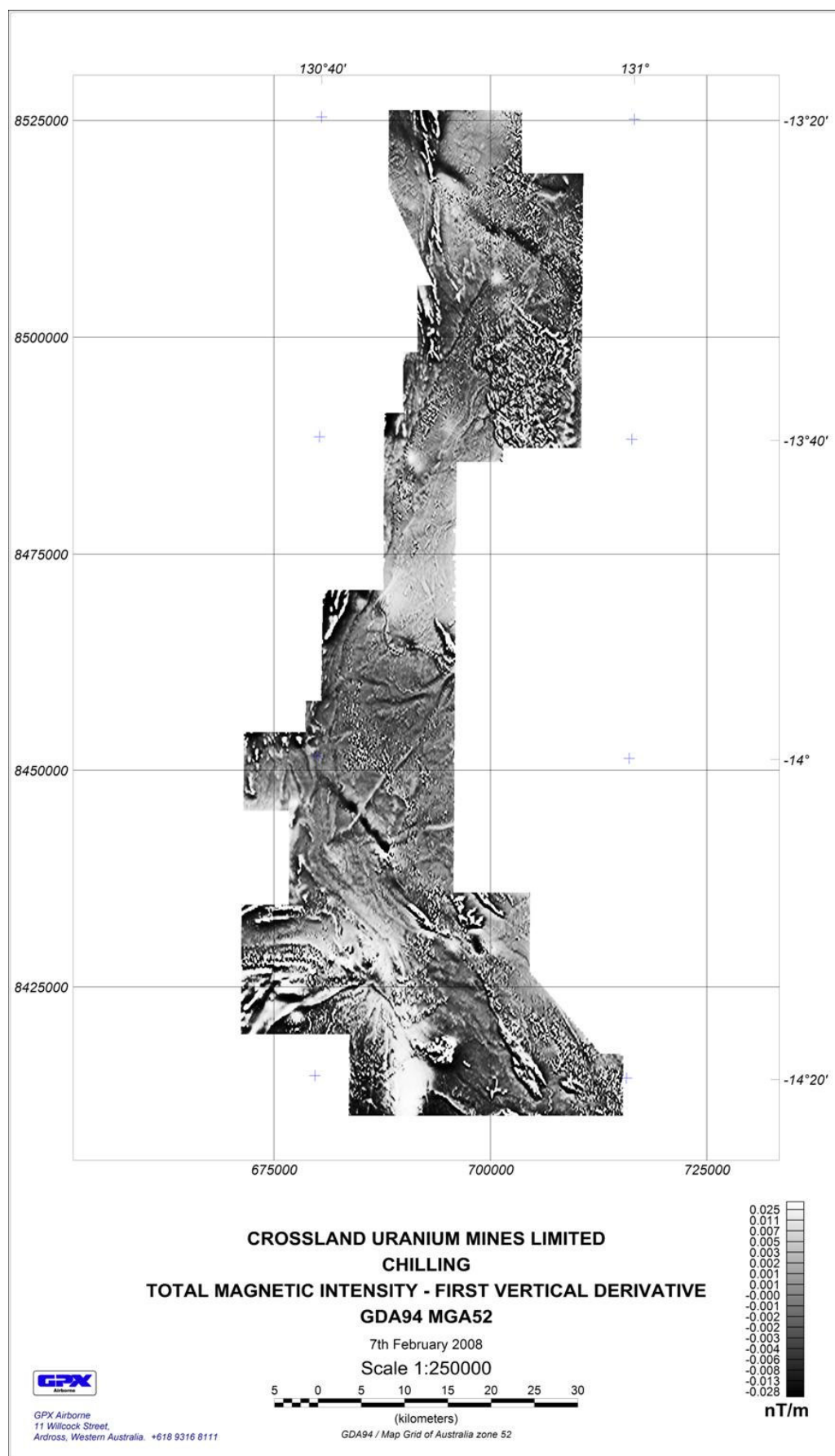


Figure 11: Total magnetic intensity - first vertical derivative image.

7 CONTRACTOR INFORMATION



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8 APPENDIX A: FINAL LOCATED DATA FORMATS

8.1 DESCRIPTION FILE FOR MAGNETIC DATA

GENERAL

Project 2314
 Survey area Chilling
 Located data type 0.1 Second Data

 Surveyed by GPX AEROSCIENCE PTY LTD.
 Creation date January 2008

SURVEY SPECIFICATIONS

Survey flown November to December 2007
 Traverse line spacing 100 & 200 metres
 Traverse line direction 090-270 degrees
 Tie line spacing 2000 metres
 Tie line direction 180-360 degrees

 Survey height 60 metres

LOCATED DATA FORMAT

Variable	Units	Undefined	From	To	Format
Line number		9999999	1	8	I8
Fiducial		99999.99	9	17	F9.2
Flight number		999	18	21	I4
Direction (1=E, 2=N, 3=W, 4=S)		9	22	23	I2
Date (YYYYMMDD)		99999999	24	32	I9
Use flag (0=not used, 1=used)		9	33	34	I2
Time (Local)	seconds	99999.99	35	43	F9.2
Longitude (WGS84)	degrees	999.999999	44	54	F11.6
Latitude (WGS84)	degrees	999.999999	55	65	F11.6
Easting (WGS84)	metres	9999999.99	66	76	F11.2
Northing (WGS84)	metres	9999999.99	77	87	F11.2
Radar altimeter	metres	9999.9	88	94	F7.1
GPS altitude	metres	9999.9	95	101	F7.1
Raw magnetics	nT	99999.999	102	111	F10.3
Post compensated magnetics	nT	99999.999	112	121	F10.3
IGRF 2005	nT	99999.999	122	131	F10.3
Diurnal	nT	99999.999	132	141	F10.3
Final magnetics	nT	99999.999	142	151	F10.3
Down fluxgate	millivolts	99999.9999	152	162	F11.4
Along track fluxgate	millivolts	99999.9999	163	173	F11.4
Cross track fluxgate	millivolts	99999.9999	174	184	F11.4
Final DEM	metres	99999.9	185	192	F8.1

DATA PROCESSING

COORDINATE DATA

All lines are scissored to the following rules:

- 1) A 'smooth' edge outside the area boundary.
- 2) Maximum line overlap of 30 fiducials within the area boundary.

The local projection is a UTM projection based on the WGS84 spheroid with a central meridian of 129 degrees East degrees. System parallax of 1.5 fiducial has been removed.

MAGNETIC DATA

The magnetic data has been corrected for regional gradient by subtraction of IGRF model 2005 computed continuously over the whole area based on the GPS height.

Diurnal magnetic variations have been removed.

System parallax of 0.5 fiducial has been removed.

Tie-line levelling has been applied.

Microlevelling has been applied.

A base value of 0 nT has been added to the data.

DIGITAL ELEVATION MODEL DATA

DIGITAL ELEVATION MODEL CALCULATION

The radar altimeter data was subtracted from the GPS heights to provide a digital elevation model which is height above the WGS84 spheroid. Using interpolation on the 30 second DMA Geoid model, a correction was computed and subtracted from the WGS84 data to convert to height above the geoid.

DATA RELIABILITY

This Digital Elevation Model (DEM) has been computed from data generated during the course of an airborne geophysical survey flown at a nominal spacing of 100 & 200m and data has been interpolated between such lines. Every effort has been made to make this model a useful general reference. No guarantee can be made that this model is a true representation of height above sea level as it can contain radar altimeter responses from buildings and in some instances dense timber. Users of the product should be aware of the topographic limitations mapped herewithin. Do not use this DEM for navigation purposes.

8.2 DESCRIPTION FILE FOR RADIOMETRIC DATA

GENERAL

Project	2314
Survey area	Chilling
Located data type	0.1 Second Data
Surveyed by	GPX AEROSCIENCE PTY LTD.
Creation date	January 2008

SURVEY SPECIFICATIONS

Survey flown	November to December 2007
Traverse line spacing	100 & 200 metres
Traverse line direction	090-270 degrees
Tie line spacing	2000 metres
Tie line direction	180-360 degrees
Survey height	60 metres

LOCATED DATA FORMAT

Variable	Units	Undefined	From	To	Format
Line number		9999999	1	8	I8
Fiducial		99999.99	9	17	F9.2
Flight number		999	18	21	I4
Direction (1=E, 2=N, 3=W, 4=S)		9	22	23	I2
Date (YYYYMMDD)		99999999	24	32	I9
Use flag (0=not used, 1=used)		9	33	34	I2
Time (Local)	seconds	99999.99	35	43	F9.2
Longitude (WGS84)	degrees	999.999999	44	54	F11.6
Latitude (WGS84)	degrees	999.999999	55	65	F11.6

Project 2314, Crossland Uranium Mines Limited, Airborne Geophysical Survey, Chilling, NT

Easting (WGS84)	metres	9999999.99	66	76	F11.2
Northing (WGS84)	metres	9999999.99	77	87	F11.2
Radar altimeter	metres	9999.9	88	94	F7.1
Barometric height	metres	9999.9	95	101	F7.1
GPS altitude	metres	9999.9	102	108	F7.1
Raw magnetics	nT	99999.999	109	118	F10.3
Post compensated magnetics	nT	99999.999	119	128	F10.3
IGRF 2005	nT	99999.999	129	138	F10.3
Diurnal	nT	99999.999	139	148	F10.3
Final magnetics	nT	99999.999	149	158	F10.3
Down fluxgate	millivolts	99999.9999	159	169	F11.4
Along track fluxgate	millivolts	99999.9999	170	180	F11.4
Cross track fluxgate	millivolts	99999.9999	181	191	F11.4
Pressure	millibars	9999.9	192	198	F7.1
Temperature	degrees C	99.9	199	203	F5.1
Humidity	percent	99.9	204	208	F5.1
Raw total count	cps	99999.9	209	216	F8.1
Raw potassium	cps	99999.9	217	224	F8.1
Raw uranium	cps	99999.9	225	232	F8.1
Raw uranium 609keV	cps	99999.9	233	240	F8.1
Raw thorium	cps	99999.9	241	248	F8.1
Raw cosmic	cps	99999.9	249	256	F8.1
Final dose rate	nGy/h	99999.99999	257	268	F12.5
Final potassium	percent	99999.99999	269	280	F12.5
Final uranium	eppm	99999.99999	281	292	F12.5
Final thorium	eppm	99999.99999	293	304	F12.5
Final DEM	metres	99999.9	305	312	F8.1

DATA PROCESSING

COORDINATE DATA

All lines are scissored to the following rules:

- 1) A 'smooth' edge outside the area boundary.
- 2) Maximum line overlap of 30 fiducials within the area boundary.

The local projection is a UTM projection based on the WGS84 spheroid with a central meridian of 129 degrees East degrees. System parallax of 1.5 fiducial has been removed.

MAGNETIC DATA

The magnetic data has been corrected for regional gradient by subtraction of IGRF model 2005 computed continuously over the whole area based on the GPS height.

Diurnal magnetic variations have been removed.

System parallax of 0.5 fiducial has been removed.

Tie-line levelling has been applied.

Microlevelling has been applied.

A base value of 0 nT has been added to the data.

RADIOMETRIC DATA

Raw channel data provided has been energy calibrated
 NASVD has been applied to channel data prior to windowing
 System parallax of 0.0 fiducial has been removed.
 Height attenuated to 60m AGL
 Airborne radon has been removed

AIRCRAFT BACKGROUND

		UNITS
Total Count	110.00	cps
Potassium	11.66	cps
Uranium	3.70	cps
Thorium	2.77	cps

COSMIC STRIPPING RATIOS

Total Count	2.0100
Potassium	0.1024
Uranium	0.0950
Thorium	0.0881

COMPTON STRIPPING RATIOS

alpha	0.2683
beta	0.4002
gamma	0.7653
a	0.0424

HEIGHT ATTENUATION COEFFICIENT

Total Count	0.007500	per metre
Potassium	0.009268	per metre
Uranium	0.008277	per metre
Thorium	0.007415	per metre

SENSITIVITY CONSTANTS

Total Count - nGy/h	23.60	cps
Potassium - 1%	72.45	cps
Uranium - 1ppm	6.70	cps
Thorium - 1ppm	4.52	cps

WINDOW ENERGY LEVELS

	Low Energy	High Energy	
Total Count	410.0	2810.0	keV
Potassium	1370.0	1570.0	keV
Uranium	1660.0	1860.0	keV
Thorium	2410.0	2810.0	keV

DIGITAL ELEVATION MODEL DATA

DIGITAL ELEVATION MODEL CALCULATION

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