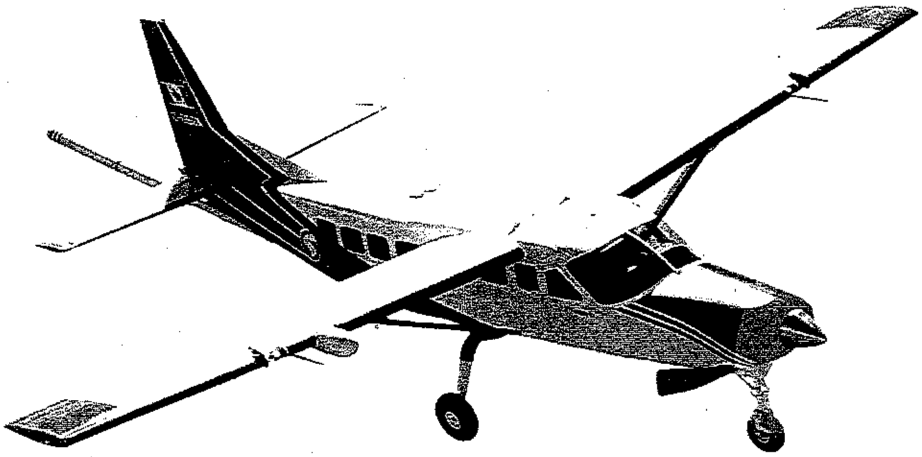
# PROJECT REPORT
# AEROMAGNETIC/SPECTROMETER SURVEY
# USGS TEXAS - 2002



For:

**United States Geological Survey**

**Flown by:**

**SANDER GEOPHYSICS LIMITED**

John Paasche, B.Sc. & Martin Bates, Ph.D.
Geophysicists

**May 2003**

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# I. INTRODUCTION

Sander Geophysics Limited (SGL) conducted a high-sensitivity aeromagnetic and gamma-ray survey over Big Bend National Park in Texas under contract with the United States Geological Survey. Please refer to *Appendix I* for a Company Profile on Sander Geophysics Limited. *Figure 1* shows the geographical position of the Survey Area. Production flights took place from November 7 to December 26, 2002. Thirty-one flights were required to complete 19,221 kilometres of planned survey lines (*see Appendix II*).

Survey operations were conducted from the Alpine-Casparis Municipal Airport in Alpine, Texas. The survey block was located approximately 160 km southeast of the airport. The aircraft used for this survey was SGL's Cessna 208B Grand Caravan, registration C-GSGL. The Big Bend survey was flown with traverse lines spaced at 400 m and oriented at 75° and control lines spaced at 3,200 m and oriented at 345°. The mean terrain clearance was 150 m and the survey flying speed was approximately 115 knots (KIAS).

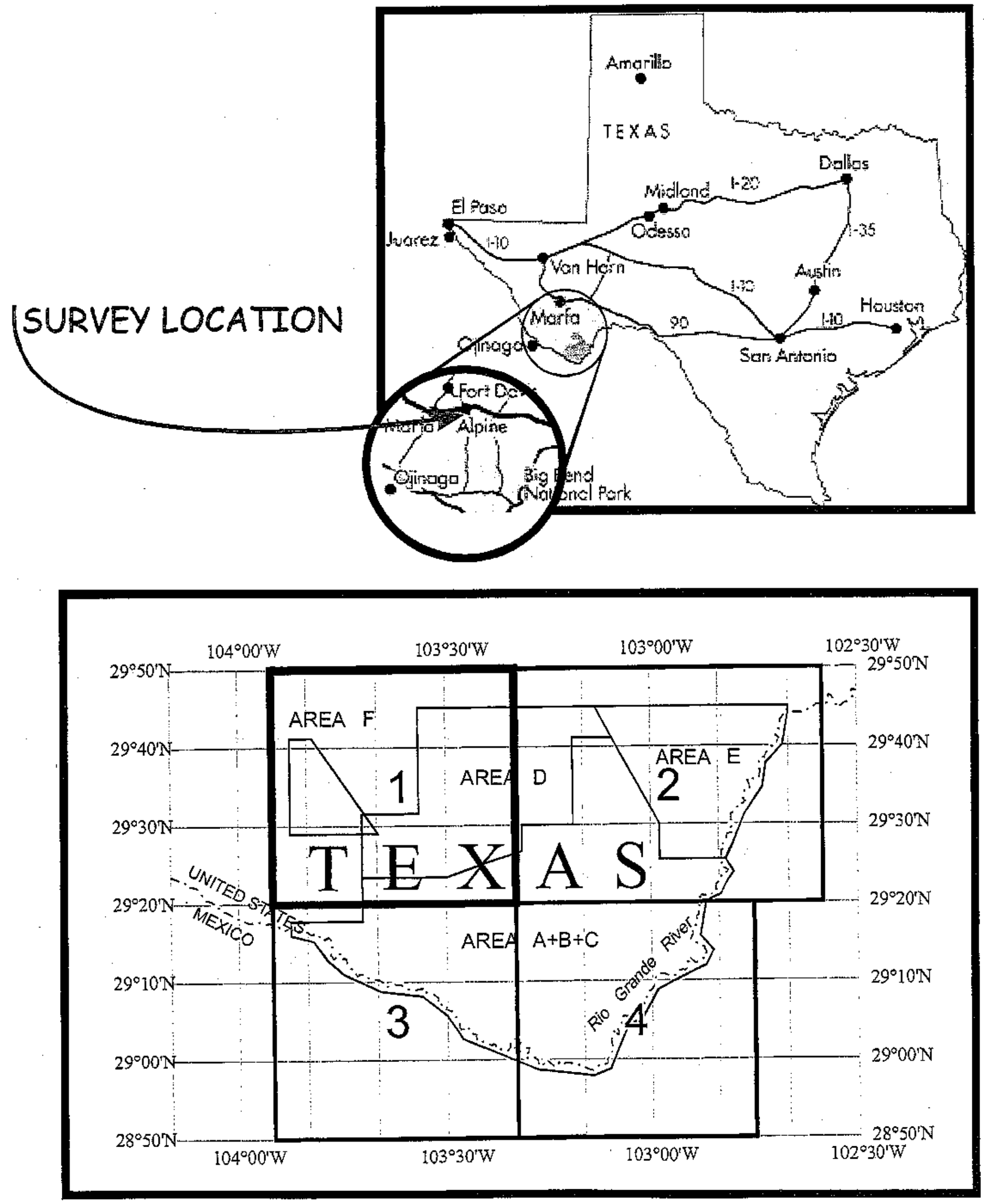
# II. SURVEY AREA

The survey block is situated in west Texas, USA, approximately 325 km to the southeast of El Paso and immediately adjacent to the Mexican Border. The terrain within the survey block is semi arid with only sparse vegetation. The topography of the survey block is variable with elevations ranging from 540 m at the eastern end of Boquillas Canyon to 2,385 m atop Emory Peak in the Chisos Mountains. The only infrastructure in the area consists of a few roads and park facilities.

Line coordinates of all survey lines are listed in *Appendix III*.

The Block is defined by the following coordinates in UTM zone 13N referenced to the WGS-84 datum (*see Table 1*).

**Figure 1: Map of Survey Area Showing Survey Blocks and Final Product Map Sheets 1 to 4**



## Table 1: Coordinates in WGS-84 UTM 13N

| Corner | X (m) | Y (m) | Corner | X (m) | Y (m) |
|---|---|---|---|---|---|
| 1 | 638594 | 3291944 | 38 | 686163 | 3211708 |
| 2 | 725558 | 3293363 | 39 | 684313 | 3207540 |
| 3 | 725593 | 3291608 | 40 | 680541 | 3205707 |
| 4 | 724260 | 3286516 | 41 | 675204 | 3206178 |
| 5 | 724501 | 3284174 | 42 | 672823 | 3206789 |
| 6 | 720682 | 3279737 | 43 | 671333 | 3206471 |
| 7 | 719881 | 3275285 | 44 | 669395 | 3206831 |
| 8 | 718149 | 3274642 | 45 | 667757 | 3206695 |
| 9 | 717461 | 3271801 | 46 | 665801 | 3208256 |
| 10 | 716472 | 3269453 | 47 | 664022 | 3208822 |
| 11 | 713953 | 3266762 | 48 | 661400 | 3210503 |
| 12 | 714524 | 3263964 | 49 | 658951 | 3210321 |
| 13 | 712752 | 3261029 | 50 | 652732 | 3212805 |
| 14 | 712050 | 3257061 | 51 | 650970 | 3214666 |
| 15 | 713742 | 3253988 | 52 | 648360 | 3215666 |
| 16 | 711456 | 3251598 | 53 | 646743 | 3219007 |
| 17 | 710846 | 3248722 | 54 | 643046 | 3221436 |
| 18 | 707258 | 3246643 | 55 | 641571 | 3223892 |
| 19 | 706333 | 3241415 | 56 | 636943 | 3224445 |
| 20 | 705478 | 3238498 | 57 | 633918 | 3225277 |
| 21 | 707611 | 3237022 | 58 | 631211 | 3225209 |
| 22 | 708661 | 3235451 | 59 | 627736 | 3227035 |
| 23 | 708350 | 3233856 | 60 | 624391 | 3227589 |
| 24 | 707451 | 3232491 | 61 | 620763 | 3231781 |
| 25 | 705778 | 3231759 | 62 | 619159 | 3231800 |
| 26 | 704127 | 3231600 | 63 | 617838 | 3232674 |
| 27 | 702875 | 3229988 | 64 | 617626 | 3235996 |
| 28 | 701499 | 3229854 | 65 | 613188 | 3237539 |
| 29 | 699466 | 3228303 | 66 | 609459 | 3238002 |
| 30 | 696445 | 3228601 | 67 | 609427 | 3241289 |
| 31 | 695580 | 3226129 | 68 | 626021 | 3241461 |
| 32 | 693113 | 3221376 | 69 | 625790 | 3262238 |
| 33 | 692427 | 3219683 | 70 | 609227 | 3262066 |
| 34 | 688426 | 3218267 | 71 | 609008 | 3284505 |
| 35 | 687529 | 3216572 | 72 | 614170 | 3284557 |
| 36 | 687378 | 3214850 | 73 | 626352 | 3266862 |
| 37 | 685703 | 3213973 | 74 | 638902 | 3267010 |

# III. SURVEY EQUIPMENT

SGL provided the following instrumentation for this survey. See *Appendix IV* for further details.

**Aerial and Ground Magnetometers**

*Geometrics G-822A*

Both the ground and airborne systems used a non-oriented (strap-down) optically-pumped cesium split-beam sensor. These magnetometers have a sensitivity of 0.005 nT, and a range of 15,000 to 100,000 nT with a sensor noise of less than 0.02 nT. The airborne sensor was mounted in fibreglass stinger installed on the tail of the aircraft. Total field magnetic measurements were recorded at an interval of 0.1 s in the aircraft and 0.5 s in the ground system.

**Automatic Aeromagnetic Digital Compensator**

*RMS AADC MkII*

The RMS AADC Mk II compensator is a fully automatic, 27-term compensator system utilizing a 3-axis fluxgate magnetometer for heading information. Magnetic information was output to the serial port at 0.1 s intervals, with a resolution of 0.001 nT. The system provides a complete real-time compensation of the aircraft manoeuvre noise.

**Gamma Ray Spectrometer System**

*Exploranium GR820 with Crystal Detector Packs GPX-1024/256 (2 packs, 10 crystals)*

The Exploranium spectrometer system includes an on-board computer for real-time signal processing and analysis, which allows automatic gain control for individual crystals using the natural thorium peak, and multi-channel recording and analysis. The system utilized a (Tl)NaI detector volume of 42.00 l consisting of 8 downward-looking and two upward-looking parallelepipedic crystals of 4.2 l each, housed in two detector packs. Data was recorded in 256 channel spectral mode and windowed data mode at an interval of 1 s.

**Navigation And Flight Path Recovery System**

*NovAtel 3951R*

Navigation and flight path recovery were provided by the SGL NavDAS system. The system utilizes a NovAtel GPSCard 3951R 12-channel GPS receiver mounted in the navigation computer with a sampling rate of 0.5 s. In addition to providing essential post-mission positional data, the navigation computer processes user-received GPS or real-time differentially corrected GPS (RDGPS) data and compares the data to the coordinates of a theoretical flight plan in order to guide the pilot along the desired survey line in three dimensions.

**Real-Time Differential GPS**

*Omnistar 3000LR*

The Omnistar 3000LR receiver provides real-time differential GPS for the NavDAS on-board navigation system. The differential data set was relayed via a geosynchronous satellite serving North America to the aircraft where the receiver optimized the corrections for the current location.

**Airborne Data Acquisition Systems**

*Sander NavDAS*

The NavDAS is the latest version of airborne data acquisition computers developed by SGL. It displays all incoming data on a flat panel screen for real time monitoring. The data is recorded on a solid-state internal hard drive and copied to a removable hard drive post-mission for transfer of data to the field office. The NavDAS incorporates a magnetometer coupler, an altimeter analogue to digital converter and a GPS receiver. The UTC time base of the NavDAS system is automatically provided by the GPS receiver.

**Ground Data Acquisition System**

*SGL Gnd-Acq*

The ground data acquisition computer is a portable PC-Pentium with a Sander Cesium magnetometer frequency counter to process the signal from the magnetometer sensor and an internal GPS card. The ground station magnetometer sensor is mounted on a 2 m pole in a specially constructed composite cap. The noise level of the base station is less than 0.1 nT. The GPS receiver automatically provides the UTC time base for both the ground and airborne systems, ensuring accurate synchronization of the two data sets. The ground data acquisition computer displays all incoming data on an LCD flat panel screen and data was printed in real-time on a line printer during each flight. The magnetic and GPS data was recorded on the internal hard drive of the computer, and copied to a removable hard drive post-mission for transfer of data to the field office. The entire ground data acquisition system is fully automatic and was set for unattended recording and printing.

**GPS Base Station Receiver**

*NovAtel Millennium*

The NovAtel Millennium 12-channel receiver forms an integral part of the SGL GND-ACQ system. It provides averaged position and raw range information of all satellites in view, sampled every 1.0 s. The comparative navigation data supplied during all production flights allows for post-processed differential GPS (DGPS) corrections for the every survey flight.

**Video System**

*Costar CV 950N camera*

*Sanyo SRT-612DC-12V24Hr VCR*

The video camera is mounted in the floor of the aircraft and oriented to look vertically below while in flight. An intervalometer and fiducial marking system required for flight path verification are incorporated. The video information was recorded on VHS videotapes in NTSC format.

**Altimeters**

*Thompson TRT ERT-530A Digital Radar Altimeter*

The TRT radar altimeter measures height above ground to a resolution of 0.5 m and an accuracy of 1% over a range up to 10,000 ft. The radar altimeter data is sampled at 4Hz.

*Sander Digital Barometric Pressure Sensor*

The barometric pressure sensor measures static pressure to an accuracy of ± 4 m and resolution of 2 m over a range up to 30,000 ft above sea level. The barometric altimeter data is sampled at 4Hz.

**Outside Air Temperature System**

The outside air temperature is sampled at 4Hz with a resolution of 0.1°C. The temperature sensor has a range of +/-50°C and an accuracy of +/-0.2°C. The temperature sensor is mounted in an air inlet duct at the point where the wing strut attaches to the right hand wing.

**Survey Aircraft**

*Cessna 208B, Grand Caravan (C-GSGL)*

The Cessna 208B Grand Caravan is an all-metal, high wing, single-engine aircraft powered by a Pratt & Whitney Canada PT6A-114A engine driving a constant speed, fully feathering, reversible propeller. The aircraft is equipped with full de-icing equipment and sufficient avionics for instrument flying (IFR) including flight control system and weather radar. The Caravan is certified for IFR flights in known icing conditions.

A rigid aluminium and composite material stinger is attached to the tail of the aircraft, designed to accommodate the magnetometer sensor in a location 3.2m behind the tail of the aircraft well removed from potential sources of magnetic interference. A window in the belly of the aircraft allows a vertically oriented field of view for the video camera. A complete description of the aircraft is given in *Appendix V*.

**Data Processing Hardware and Software**

The following equipment was used in the field office:

**Hardware:**

(a) "P3-4" PIII, 933 MHz computer with 1024 MB RAM, two 36.4 GB hard drives, Exabyte Tape drive and CD-RW drive.
(b) "Note-30" PIV, 933 MHz laptop computer with 250 MB RAM, 30 GB hard drive.
(c) Epson 1520 colour inkjet printer capable of producing 14" wide continuous plots.

**Software:**

(a) SGL data processing and imaging software
(b) SGL Differential GPS processing software

# IV. SURVEY SPECIFICATIONS

## Data Recording

The following parameters were recorded during the course of the survey:

- **Aircraft altitude**: measured by the barometric altimeter at intervals of 0.25 s;
- **Terrain clearance**: provided by the radar altimeter at intervals of 0.25 s;
- **Airborne outside air temperature**: recorded at intervals of 0.25 s;
- **A continuous video tape record of the terrain passing below the aircraft;**
- **Time markers**: synchronously impressed on the video and digital data;
- **Airborne GPS positional data**: altitude, longitude, height, time and raw range from each satellite being tracked) recorded at intervals of 0.5 s;
- **Airborne total magnetic field**: recorded at intervals of 0.1 s;
- **Airborne spectrometer data**: recorded at intervals of 1.0 s.
- **Ground total magnetic field**: recorded at intervals of 0.5 s;
- **Ground based GPS positional data**: (latitude, longitude, height, time and raw range from each satellite being tracked) recorded at intervals of 1.0 s;

## Flight Specifications

The following technical specifications were adhered to:

a) A higher elevation than the specified flight elevation can be used locally (for safe flight) to permit a terrain clearance up to 500 feet (150 m).

b) Deviations from the planned (pre-flight) paths shall not exceed 10 percent of the designated flight line spacing. Gaps between adjacent flight lines greater than 1.5 times the designated flight line spacing for more than 2 linear miles (3.2 km) require fill-in intermediate flight lines.

c) Maximum vertical deviations as indicated by the barometric altimeter shall be ±200 feet (61 m) from the pre-planned draped flight surface except as given by (a) above.

d) A pre-planned draped flight surface is required. The contractor shall use real-time, differentially corrected GPS during flight to maintain this pre-planned surface within 200 feet (61 m) or better, safety permitting.

e) The aircraft shall be capable of a sustained climb and decent gradient of 5% or better.

f) Airborne survey data shall not be acceptable when gathered during magnetic storms or short term disturbances of magnetic activity at the ground station used that exceeds the following:

1. Monotonic changes in the magnetic field of 5 nT in any five-minute period.
2. Pulsations having periods of 5 minutes or less shall not exceed 2 nT.
3. Pulsations having periods between 5 and 10 minutes shall not exceed 4 nT.
4. Pulsations having periods between 10 and 20 minutes shall not exceed 8 nT.

The period of a pulsation is defined as the time between adjacent peaks or troughs. The amplitude of a pulsation is one-half the sum of the positive and negative excursions from trough to trough or peak to peak.

**Survey Line Specifications**

Survey lines were flown with the following specifications:

| | **Line Direction** | **Line Spacing (m)** |
|---|---|---|
| **Traverse Lines** | **75°** | **400** |
| **Control Lines** | **345°** | **3200** |

**Drape Surface**

The survey block was flown by following a pre-planned drape surface to achieve a mean terrain clearance of 150 m wherever practical. Digital Elevation Model (DEM) data for the survey area was obtained from the USGS web site for Texas, and from Sitesafe Inc. for Mexico, as 3 arc second by 3 arc second grids of elevations referred to the WGS-84 ellipsoid. The DEM was draped with a surface designed to accommodate climb rates of 304 ft/nm in the traverse line direction and 400 ft/nm in the control line direction for all elevations in the survey block.

# V. SYSTEM TESTS

**AADC Compensation**

Compensation tests determine the magnetic influence of aircraft manoeuvres and the effectiveness of the RMS compensator to mitigate these effects. The aircraft performed sets of three pitches (±5°), rolls (±10°) and yaws (±5°), while flying in each of the four flight line directions at high altitude over a magnetically quiet area. A solution to compensate for the noise generated by the manoeuvres is determined by the AADC and the solution is tested, by repeating the same set of manoeuvres. The total compensated signal noise that results from the twelve manoeuvres, referred to as the Figure of Merit (FOM), is calculated from the maximum peak-to-peak value resulting from each manoeuvre. A compensation test was flown north of Fort Stockton, Texas on November 11th 2002 and a solution with an FOM of 0.74 nT was obtained. After changing the airborne magnetometer, a second compensation test was flown in the same location on November 13th 2002 and a solution with an FOM of 0.95 nT was obtained. Traces of the compensation test flight data can be found in *Appendix VI.*

**Magnetometer Calibration and Heading Error Test**

A calibration and heading error test was performed on October 29th 2002 over the Geological Survey of Canada (GSC) calibration range at Bourget near Ottawa. The test comprised of two passes in each of the four cardinal directions over a point of known magnetic intensity, corrected for diurnal variation using the nearby Ottawa Geomagnetic Information Node at Mer Bleu. The average error for the Bourget tests assumes a difference of –556 nT between the GSC ground station data and the airborne data. The test result is given in *Table 2.*

The test determined that the airborne system has a heading error of -0.3 nT in the East-West direction, a heading error of 0.9 nT in the North-South direction, and an overall absolute calibration error of only -1.1 nT.

## Table 2: Aeromagnetic Survey System Calibration

AEROMAGNETIC SURVEY SYSTEM CALIBRATION AT BOURGET, ONTARIO

Mag Sensor #1

Aircraft type : Cessna Grand Caravan
Registration : C-GSGL
Organization : Sander Geophysics Limited
Pilot : Steve Gebhardt
Co-Pilot : Dave Vipond
Instrument Operator : n/a
Observer : n/a

Date : 29 Oct 2002
Height flown : 500 feet
Magnetometer type : GEOMETRICS G-822A
Compensator: RMS AADC II
Sampling rate : 10/s
Data acquisition system : Sander ADAC computer
Camera : video
Camera sampling rate : continuous

| Dir | Line # | GMT | Total field Aircraft T1 | Grnd Stn Prev Min T2 | Grnd Stn Subs Min T3 | Interpolated Reading T4 | Calculated T5 | Error Value T6 | Variation from Average |
|---|---|---|---|---|---|---|---|---|---|
| N | 1 | 19:33:00 | 55,331.8 | 55,888.1 | 55,888.9 | 55888.3 | 55332.3 | -0.5 | 0.6 |
| S | 2 | 19:45:12 | 55,332.3 | 55,889.9 | 55,889.4 | 55889.5 | 55333.5 | -1.2 | -0.1 |
| E | 3 | 19:29:41 | 55,329.8 | 55,887.2 | 55,887.0 | 55887.1 | 55331.1 | -1.3 | -0.2 |
| W | 4 | 19:41:46 | 55,333.0 | 55,890.0 | 55,889.6 | 55889.7 | 55333.7 | -0.7 | 0.4 |
| N | 5 | 19:38:57 | 55,332.6 | 55,890.1 | 55,889.4 | 55889.9 | 55333.9 | -1.3 | -0.1 |
| S | 6 | 19:51:45 | 55,329.4 | 55,887.9 | 55,887.9 | 55887.9 | 55331.9 | -2.5 | -1.3 |
| E | 7 | 19:36:20 | 55,332.6 | 55,889.5 | 55,889.2 | 55889.4 | 55333.4 | -0.8 | 0.3 |
| W | 8 | 19:48:16 | 55,331.9 | 55,888.9 | 55,887.9 | 55888.7 | 55332.7 | -0.8 | 0.4 |
| | | | | | | | Total : | -9.0 | |
| | | | | | | | Average: | -1.1 | |

Average North-South Heading Error 0.9 nT

Average East-West Heading Error : -0.3 nT

### Instrumentation Lag

The lag in the magnetometer system was determined by flying a test on October 29th 2002 over a bridge on the Ottawa River. The test involved flying in opposite directions over the bridge and measuring the apparent positional shift of associated sharp magnetic anomaly. The shift in the location of the raw data reflects the time taken for the magnetic field measured by the magnetometer in the stinger to be recorded on the acquisition computer, and the physical offset between the sensor and the GPS antenna. The data is corrected by applying a time shift or "lag" correction to the magnetometer values. The lag correction was found to be 0.74 seconds, which is consistent with previous tests using the Grand Caravan airborne system. The lag correction was automatically applied to the magnetic data during processing.

## Stripping Ratios

The stripping ratios for the gamma-ray spectrometer were determined before the aircraft departed for the survey using the GSC calibration pads which are stored at the SGL hangar in Ottawa. The tests were performed with the crystal pack installed in survey configuration onboard the aircraft.

The following procedure was carried out:

1) Cesium stabilization carried out.
2) Thorium stabilization carried out.
3) Pre-pads source test, one thorium source below pack.
4) Stabilization on thorium taken off.
5) Pads test carried out in order: background, potassium (six minutes recording each).
6) Re-stabilize on thorium.
7) Stabilization on thorium taken off.
8) Pads test carried out in order: uranium, thorium, and background (six minutes recording each).
9) Stabilization on thorium put on.
10) Post-pads source test, one thorium source below pack

Due to a faulty power supply on the Spectrometer GR-820 s.n. 8246 initially installed in the aircraft, it was removed and replaced with Spectrometer GR-820 s.n. 8245. The second spectrometer was used for flights 014 – 031. After the survey was complete, the aircraft returned to Ottawa and stripping ratios were determined for the second system using the same procedure as above. *Table 3* contains the stripping ratio test results for the crystal Packs used for this survey.

**Table 3 Stripping Ratios**

| | STRIPPING RATIOS (#8246) | STRIPPING RATIOS (#8245) |
|---|---|---|
| Thorium into Uranium (Alpha) | .2265 | .2240 |
| Thorium into Potassium (Beta) | .3710 | .3678 |
| Uranium into Potassium (Gamma) | .7181 | .7011 |
| Uranium into Thorium (A) | .0498 | .0398 |
| Potassium into Thorium (B) | .0000 | .0000 |
| Potassium into Uranium (G) | .0054 | .0050 |

## Attenuation Coefficients

The exponential height attenuation coefficients for the first spectrometer (s.n. 8246) were calculated using the data acquired during a pre-survey test flight over the GSC test range at Breckenridge, Quebec on October 15th 2002. The calibration flights were carried out from approximately 50 m to 250 m mean terrain clearance at 25 m intervals. A series of background measurements were made at the same altitudes over the Ottawa River to determine the background due to cosmic radiation, radon decay products in the air and the radioactivity of the aircraft and equipment. Results of this test are given in *Table 4.*

**Table 4: Spectrometer Calibration Test Data, s.n. 8246**

| Altitude at STP (m) | Total counts (Cps) | Potassium (cps) | Uranium (cps) | Thorium (cps) |
|---|---|---|---|---|
| 57.83 | 1062.9 | 108.450 | 6.713 | 30.507 |
| 86.55 | 1053.2 | 107.872 | 6.922 | 29.845 |
| 116.48 | 1044.0 | 107.217 | 7.686 | 28.282 |
| 143.97 | 1052.7 | 107.273 | 6.839 | 29.111 |
| 171.88 | 1059.7 | 105.545 | 6.566 | 29.905 |
| 199.48 | 1050.7 | 104.023 | 7.774 | 29.531 |
| 228.82 | 1059.7 | 111.622 | 6.539 | 30.186 |

The attenuation coefficients for the second system (s.n. 8245) were determined from a test flow in Texas on the 24th December 2002 using the daily test line (T7000.00) flown at 50 ft. intervals from 150 ft. to 700 ft. and 100 ft. intervals from 700 to 2000 ft.

After correction for background and stripping, the variation in count rate with effective height was used to determine the attenuation coefficients. The results of the two attenuation tests are shown in *Table 5.*

**Table 5: Attenuation Coefficients**

| | S.N.8246 | S.N.8245 |
|---|---|---|
| Total | -0.006975 | -0.006834 |
| Potassium | -0.008651 | -0.009376 |
| Uranium | -0.007682 | -0.007205 |
| Thorium | -0.006712 | -0.006293 |

**Spectrometer System Sensitivity**

Sensitivities were determined during the pre-survey test flight over the GSC test range at Breckenridge, Quebec on October 15th 2002. The test flight served to determine system sensitivities through comparison of airborne data with data acquired on the ground, as well as to determine the variation of the window counts with aircraft altitude (attenuation coefficients, see above).

The ground measurements were made with an Exploranium portable gamma ray spectrometer. Measurements were acquired at 28 different sites along the 10 km length of the calibration range. Measurements were also made with the portable spectrometer on the Ottawa River to determine background radiation due to cosmic radiation, radon decay products in the air and any radioactivity of the equipment. The background was subtracted from the ground measurements and the ground concentrations of potassium, uranium and thorium were determined by calibration of the portable spectrometer using the GSC calibration pads located at Ottawa Airport.

The sensitivities of the airborne system to potassium, equivalent uranium, and equivalent thorium were calculated by dividing the average count rates corrected to an effective height of 150 m above ground by the ground concentrations of the test range. Results are presented in *Table 6*.

**Table 6: System Sensitivities**

| | Average counts at 150 m (cps) | Ground Concentrations | SGL Sensitivities | Units |
|---|---|---|---|---|
| Potassium | 107.4289 | 2.0299785 % | 52.9212 | % |
| Equivalent Uranium | 7.005571 | 1.3291285 ppm | 5.2708 | ppm |
| Equivalent Thorium | 29.62386 | 8.6799671 ppm | 3.4129 | ppm |

The sensitivities for the second spectrometer were determined by comparing the average stripped count rate for the test line flown during the survey with each of the two systems. The difference in sensitivity is directly related to the change in mean count rate, so that a simple scale factor may be applied to determine the sensitivities of the second system. The sensitivities for potassium, equivalent uranium and equivalent thorium are 56.6732 cps/%, 4.8247 cps/ppm and 3.1230 cps/ppm respectively. In addition, the total count rate for the second system was scaled by a factor of 1.056068.

## Cosmic and Aircraft Background

A cosmic and aircraft background test was performed for the spectrometer system s.n. 8246 on October 15th 2002 near the Ottawa International Airport, Canada. The test was repeated for the spectrometer system s.n. 8245 on January 7th 2003 in the same location. The test flights consisted of flying at heights of 2000 ft to 4500 ft above sea level at 300 ft intervals, recording data for 10 minutes at each level. Coefficients are determined by linear regression of cosmic counts versus each spectral window as described in the IAEA Report 323 (1991). Graphs of cosmic counts versus each spectral window are given in *Figure 2*. *Table 7* lists the computed cosmic and aircraft background coefficients.

**Table 7: Cosmic Coefficients**

| | Cosmic Coefficient | | Aircraft Background | |
|---|---|---|---|---|
| | **s.n.8246** | **s.n.8245** | **s.n.8246** | **s.n.8245** |
| Total | 0.7877 | 0.6896 | 35.22 | 33.16 |
| Potassium | 0.0434 | 0.0391 | 4.35 | 4.83 |
| Uranium | 0.0317 | 0.0317 | 2.29 | 0.88 |
| Thorium | 0.0428 | 0.0370 | 0.00 | 0.00 |
| Upward | 0.0126 | 0.0088 | 0.94 | 0.14 |

## Radon Corrections

Radon background was monitored through the use of upward facing detectors. Coefficients relating the count rate in the uranium window from the upward detectors to the count rate in the potassium, uranium, thorium and total count windows from the downward facing detectors were determined using the test line data. Consistent thorium count rates (see "Spectrometer Data Test Line") indicated that conditions remained consistent on the test strip during the survey. Therefore, daily variation in the upward uranium window count rate above its minimum observed value was assumed to be due to the presence of varying amounts of atmospheric radon; variations in the count rates from the downward windows were correlated to calculate the radon coefficients.

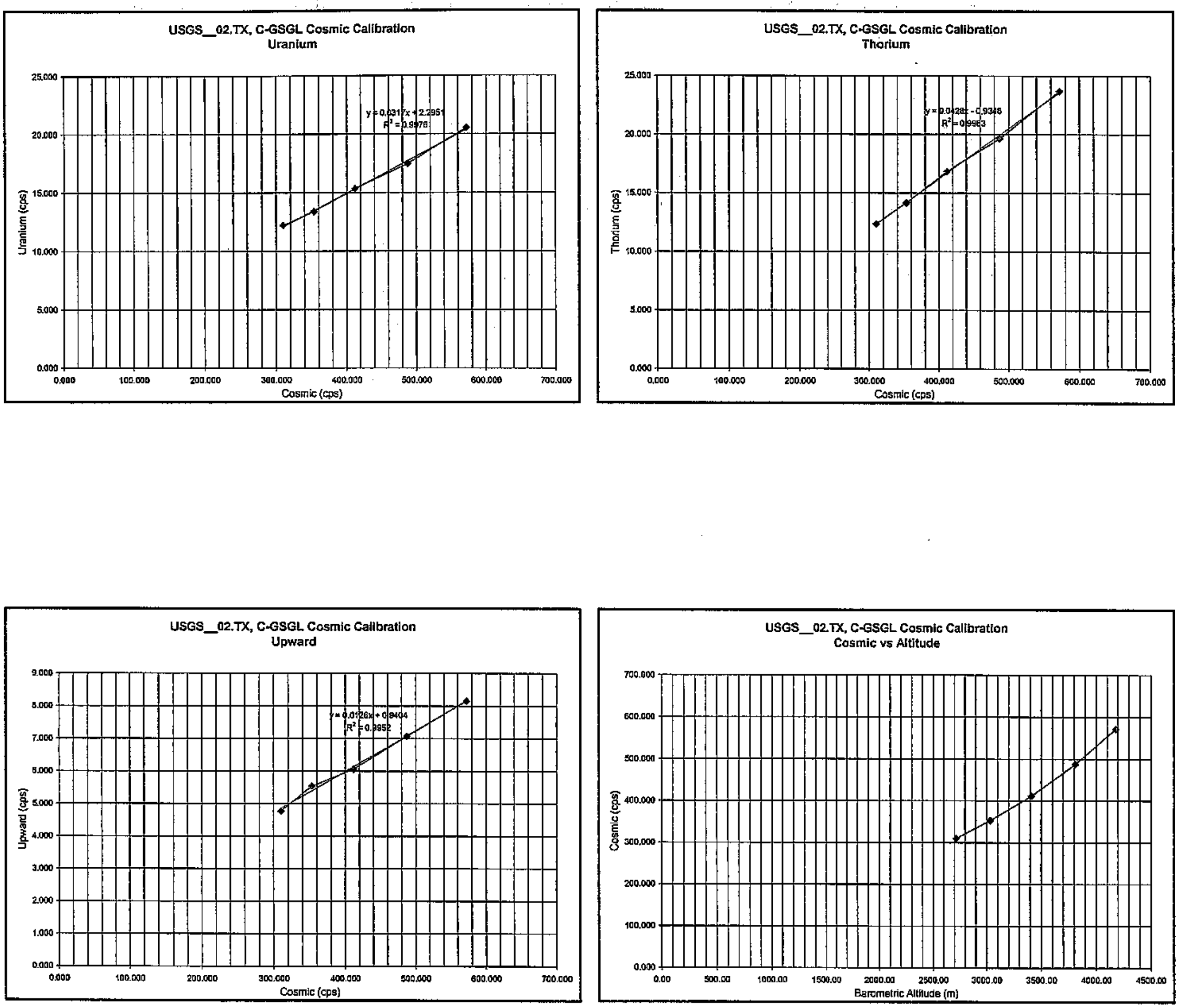
## Ground Component Coefficients

The ground component coefficients are used to quantify the response of the upward looking detector to radiation from the ground. The IAEA Report 323 describes a technique that involves computing two separate coefficients based on the counts in the uranium and thorium windows. This method was used to derive ground coefficients for each of the systems used. The ground component coefficients used for this project are listed in *Table 8*.

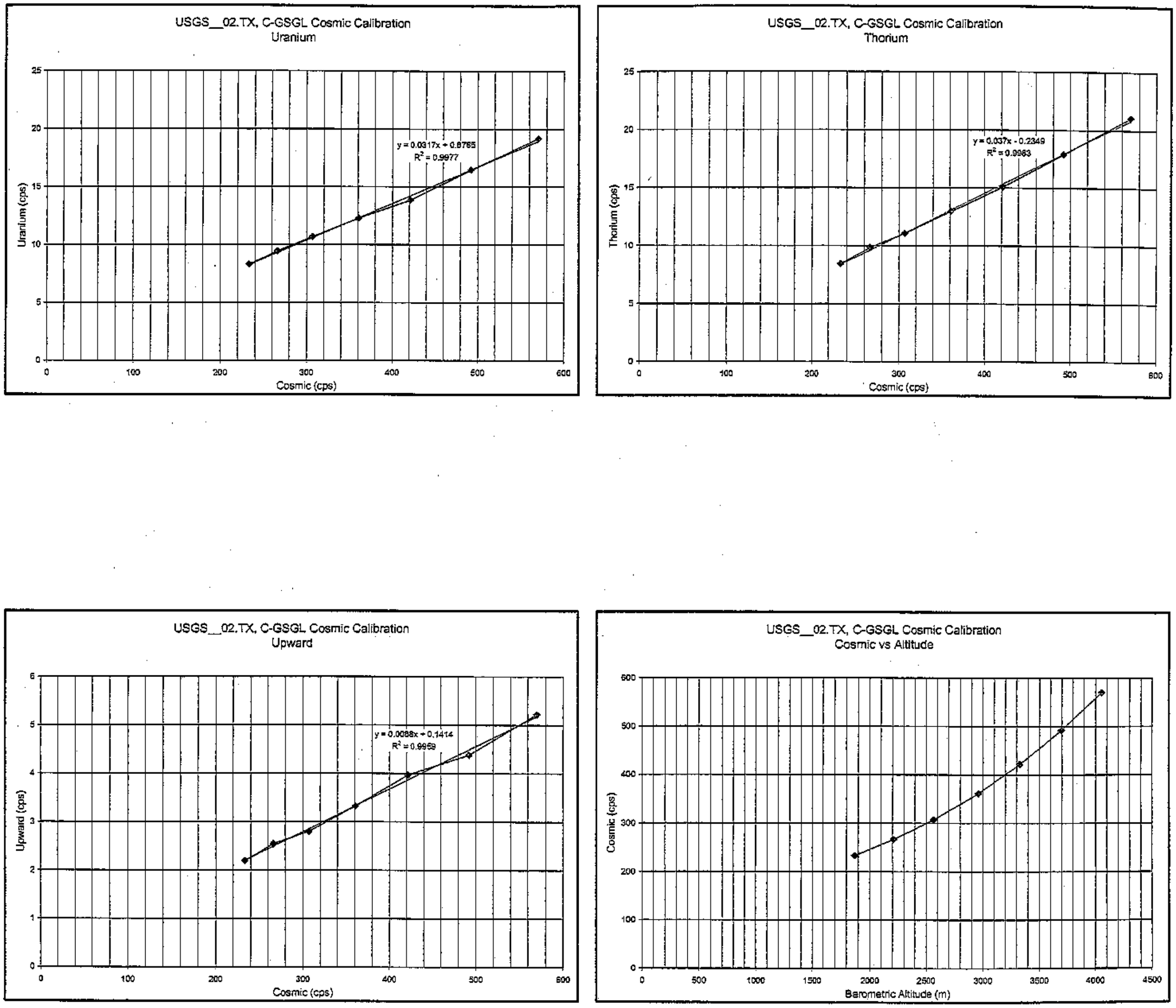
**Table 8: Ground Component Coefficients**

| System | A1 (uranium) | A2 (thorium) |
|---|---|---|
| s.n. 8246 | 0.1365 | 0.0259 |
| s.n. 8245 | 0.0762 | 0.0019 |

# Figure 2: Cosmic Counts vs. Each Spectral Window



# Figure 2: Cosmic Counts vs. Each Spectral Window Cont'd



## Spectrometer Data Test Line

High and low altitude spectrometer test lines were flown at 610 m and 150 m above ground level on the ferry out to the survey block. High altitude test lines were given line numbers 8001 – 8031, whilst low altitude test lines were given line numbers 9001 – 9031. Pre-flight test lines were given line extension .00, while post-flight test lines were given line extension .01.

The 23 km long low altitude test line was flown for each flight at survey altitude and survey speed. The test line was flown using a pre-planned flight line from N29:53.22 W103:36.99 to N29:40.93 W103:36.99, and employed GPSNav for real-time navigation guidance. Corrected thorium data for the test lines were within +/-10% of the average (*Figures 3a and 3b*) therefore no correction for changes in ground conditions was considered necessary.

**Figure 3a: Test Line Averages s.n. 8245**

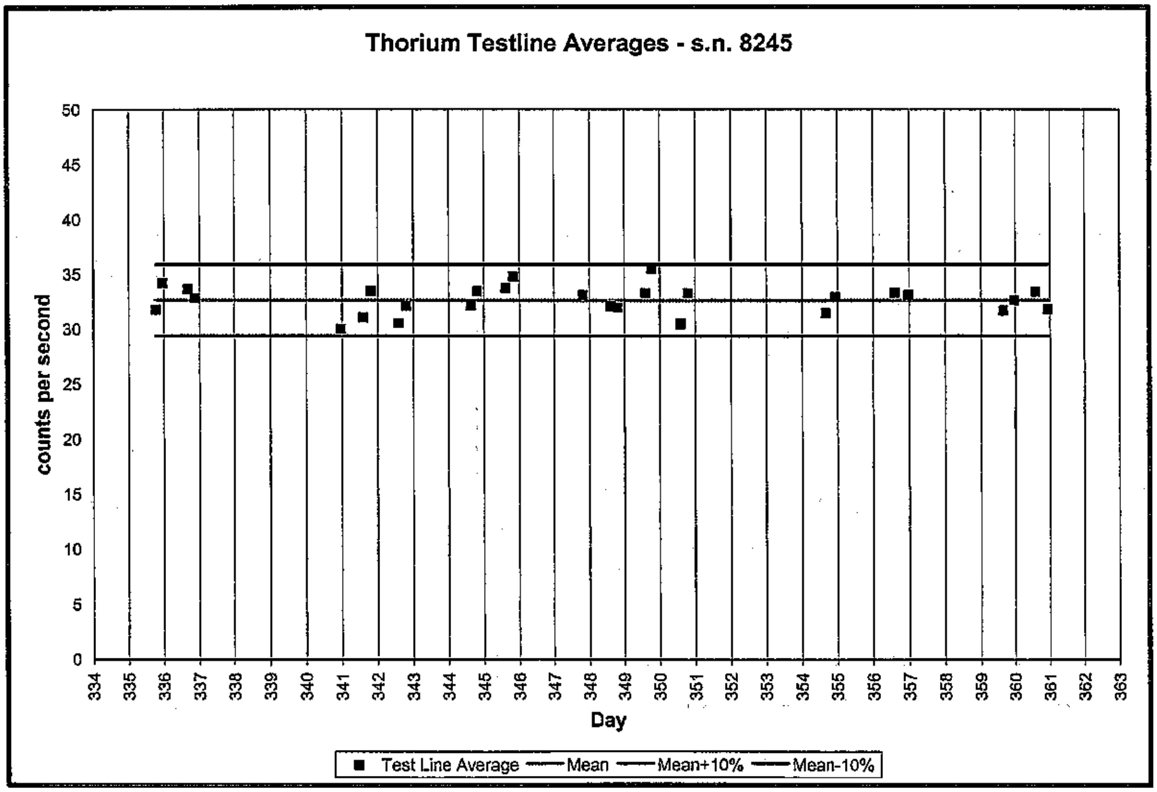
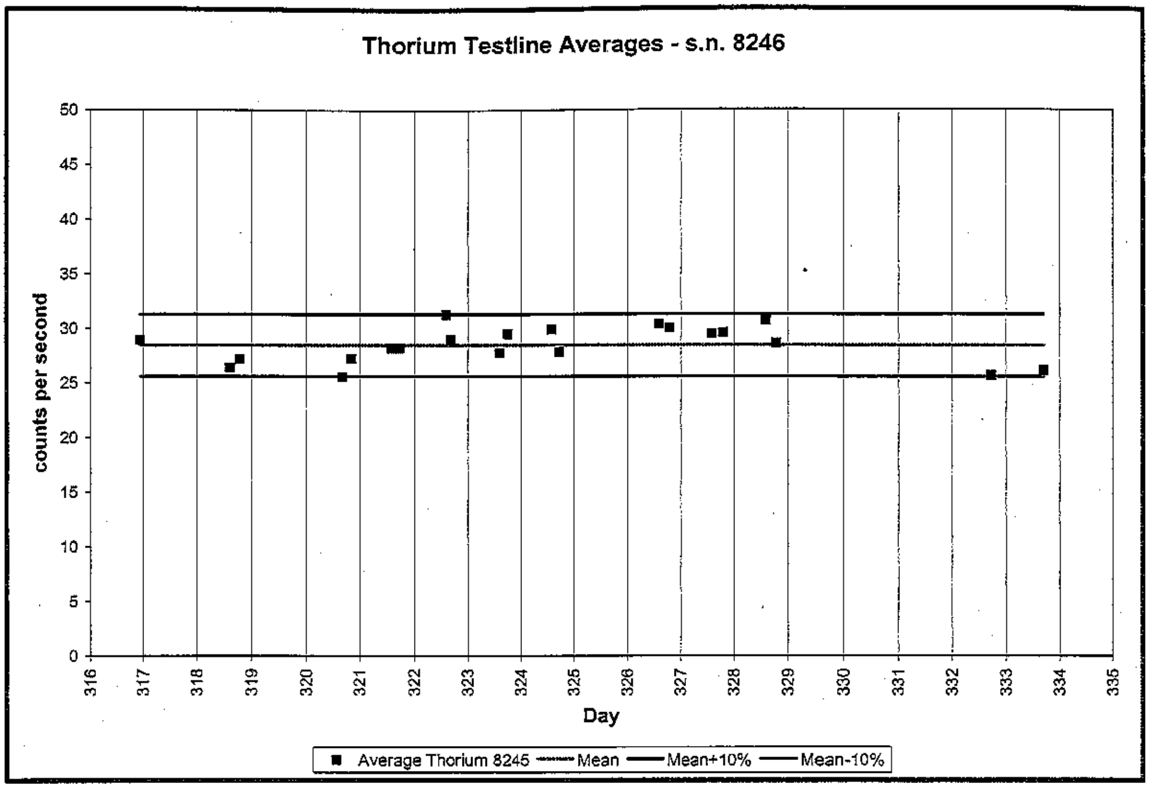


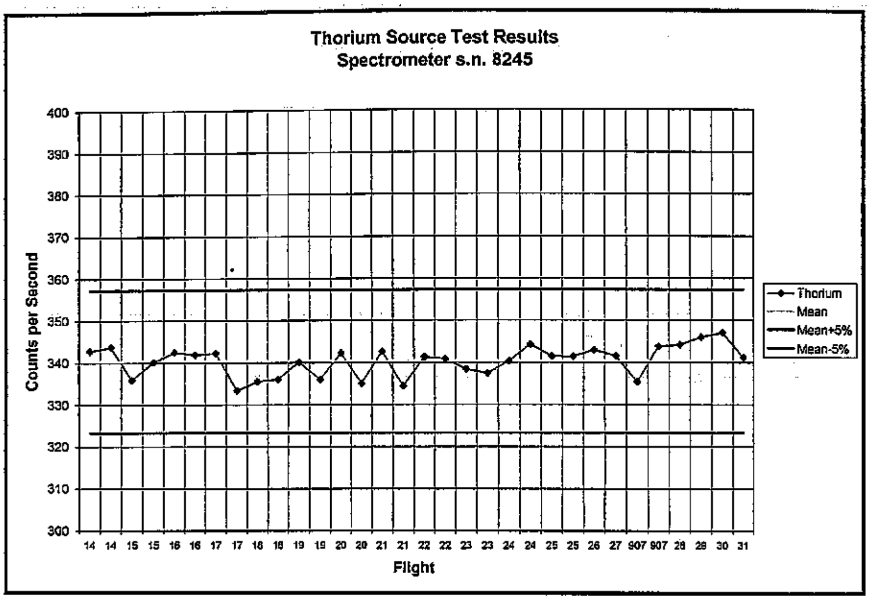
**Figure 3b: Test Line Averages s.n. 8246**

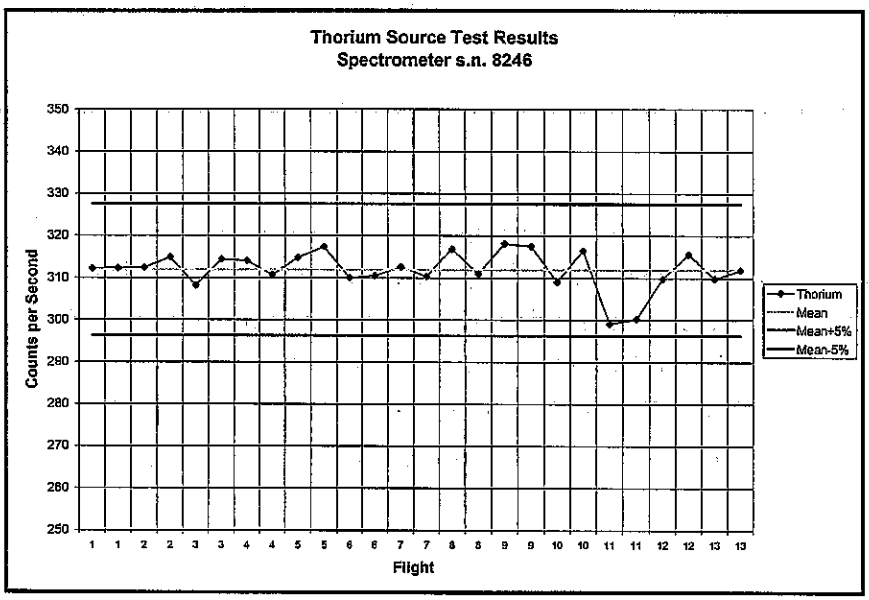



## Source Tests

Thorium source tests were performed before and after each flight. A source was hung beneath the crystal pack using a specially designed holder to ensure consistent placement. Uranium, thorium, and background windows were averaged and recorded for 120 seconds during each test. Recorded data was dead time and background corrected before the statistics were compiled. For each spectrometer system used, thorium source test results were within +/-5% of the mean value (*Figure 4*) which indicates that the systems were operating correctly.

# Figure 4: Source Tests

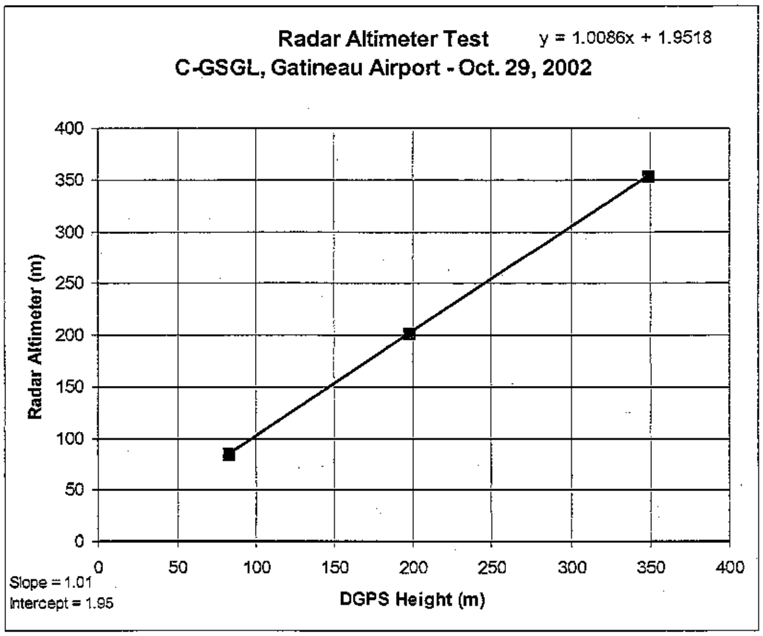


## Radar Altimeter Calibration

A radar altimeter calibration was done by flying at different altitudes over the runway at the Gatineau airport in Quebec, Canada. The results of the radar altimeter and differentially corrected GPS heights were plotted on an XY graph *(see Figure 5)*. The plot of the radar calibration data points shows an approximation to a straight line with a slope of 1.01 and an intercept of 1.95 m.

## Figure 5: Radar Altimeter Test



# VI. FIELD OPERATIONS

Operations were conducted from the Alpine-Casparis Municipal Airport located just north of Alpine, Texas. The field office was established at the Antelope Lodge in Alpine, Texas.

A combined magnetic/GPS ground station was set up in the storage shed at Alpine Municipal Airport. The GPS antenna was located 100 ft west of the storage shed and the magnetometer was located 200 ft northwest of the shed. The position of the ground station was determined precisely by applying a differential correction with respect to the IGS reference station at Fort Davis (Mdo1) using data from Julian days 333 and 334 of year 2002.

A second "remote" base station was installed outside the Round House storage facility for the Big Bend National Park located at Panther Junction. The GPS antenna and the magnetic sensor were set up on a small hill with the magnetometer 150 m northwest of the computer and the GPS antenna approximately 45 m to the northeast. The position of the ground station was determined precisely by applying a differential correction with respect to the differentially corrected Alpine base station location using data from Julian days 314 and 316 of year 2002.

The coordinates of the ground stations with respect to WGS-84 are:

| | | |
|---|---|---|
| Alpine Municipal Airport Ground Station | Latitude: | N30:23.1948 |
| | Longitude: | W103:40.7056 |
| | Elevation: | 1333.288 m |

| | | |
|---|---|---|
| Panther Junction Remote Ground Station | Latitude: | 29:19.1659 N |
| | Longitude: | 103:12.4834 W |
| | Elevation: | 1154.22 m |

The Alpine base station was used to apply post-mission differential corrections to the GPS position of the aircraft for all flights except 1 and 3 to 10, which used data from the Panther Junction base station.

The weather during the survey was generally clear and cool in the mornings with cumulus clouds and wind building throughout the day. Please refer to the Weekly Reports in *Appendix VII* for a description of the weather each day.

**Field Personnel**

The following technical personnel participated in field operations:

| | |
|---|---|
| Geophysicist/ Party Chief: | John Paasche |
| Pilots: | Steve Gebhardt, Laurent Geslin, Jan Kristiansen |
| Aircraft Engineer: | Brian Clarke |
| Technician: | Lee Duncan |

# VII. DIGITAL DATA COMPILATION

All preliminary data compilation such as editing and filtering was performed in the field. Preliminary processing for on-site quality control was performed as each flight was completed. Final data processing was performed at SGL head office in Ottawa.

**Radiometric Data**

Please refer to *Figure 6* for a summary of the spectrometer data compilation process.

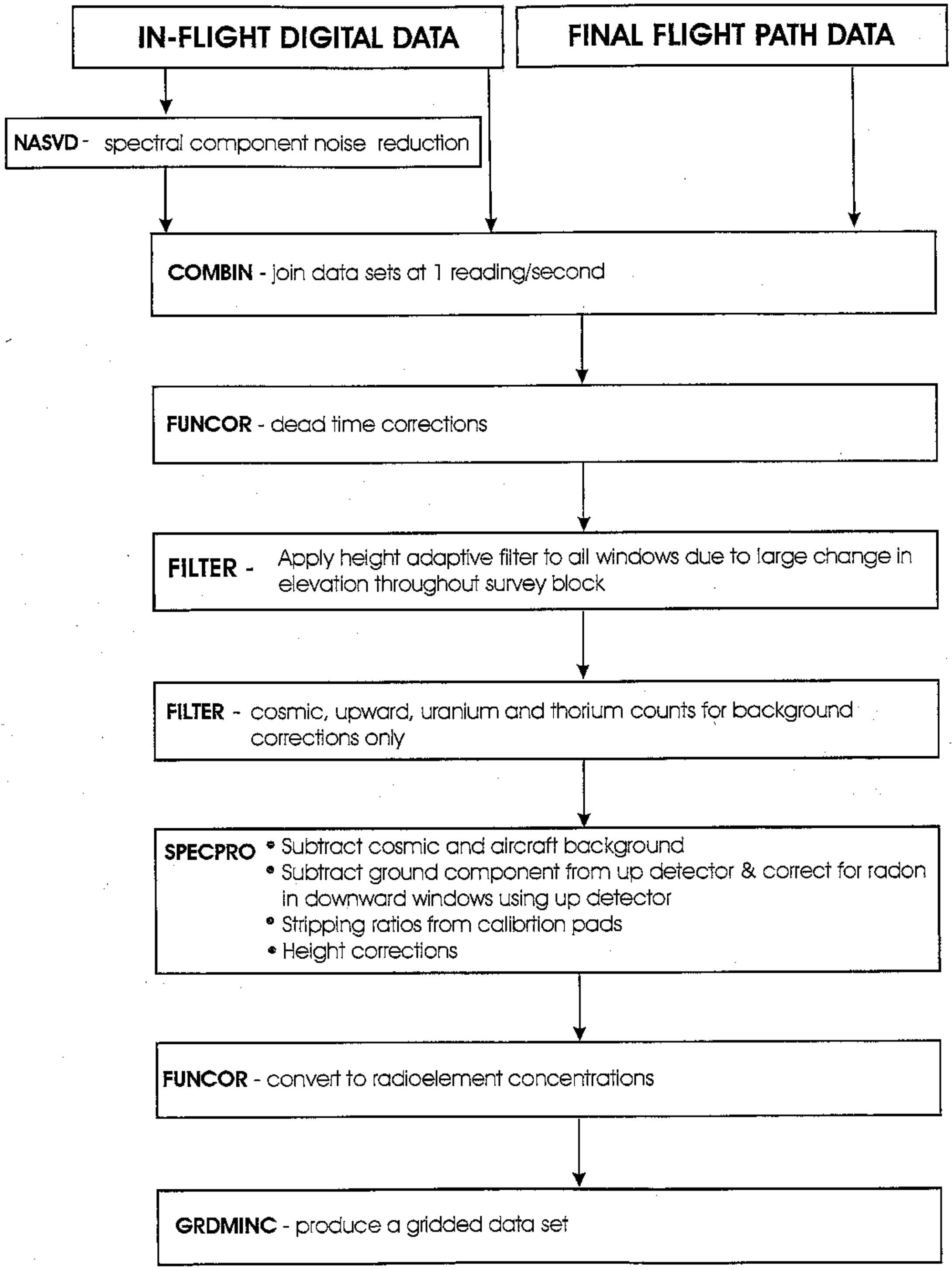
**Spectral Component Analysis**

Raw 256 channel spectrometer data is analysed using the noise adjusted singular value decomposition method (NASVD; J. Hovgaard and R L. Grasty paper 98, Geophysics and Geochemistry at the Millennium, Proceedings of the 4th Decennial International Conference on Mineral Exploration, 1997). NASVD is similar to principal component analysis in that it identifies the spectral shapes or "components" that comprise the recorded data. However, data must be normalized with respect to count rate since channels with low count rates will have naturally higher statistical variation than those with high count rates. If this is not done, components will describe variation dominated by changes in single channels. Normalization is achieved by dividing each measured spectra by the square root of the best fit of the mean spectra (known as component zero). The NASVD method then determines the components in order of significance with respect to the amount of variance in the data they describe. Each component is a spectrum with 256 channels and there are in theory as many components as there are channels (i.e. 256). Variation in the signal is accounted for by the first components to be identified, whereas variation due to noise is accounted for by the higher order components. Inspection of the components allows us to determine which components describe the signal, so that noise components may be discarded. Spectra are then reconstructed from the signal only components, and the count rates in the standard windows are recalculated.

For the second spectrometer (s.n. 8245) signal is contained within the first 12 components, so that components 13 and higher are discarded. NASVD was not applied to the data collected with the first spectrometer (s.n. 8246); the method was initially used but was not found to be beneficial.

**Figure 6: Spectrometer Data Processing**

## SPECTROMETER DATA PROCESSING



## Standard Radiometric Data Processing

Spectrometer data is corrected as documented in the Geological Survey of Canada Open File No.109 and the IAEA report "Airborne gamma-ray spectrometer surveying; Technical Report Series No. 323 (International Atomic Energy Agency, Vienna).

The gamma-ray spectrometer processing parameters are described in *Table 9 and 10.*

**Table 9: Spectrometer Processing Parameters – Texas, USA**

**USGS__02.TX, SPECTROMETER GR-820 SN.8246, 8 DOWN & 2 UP, USE FOR FLIGHTS 1 – 13**

| WINDOW | COSMIC | STRIPPING (B) | AIRCRAFT (A) | |
|---|---|---|---|---|
| Total | 0.7877 | 35.22 | Total | Count = A + B * COSMIC |
| Potassium | 0.0434 | 4.35 | Potassium | |
| Uranium | 0.0317 | 2.29 | Uranium | |
| Thorium | 0.0428 | 0.00 | Thorium | |
| Cesium | 0.0000 | 0.00 | Cesium | |
| Upward | 0.0126 | 0.94 | Upward | |

| RADON COMPONENT | A | B | Ur =Uranium component due to radon | (U over test line after Cosmic & a/c backgrounds have been removed) |
|---|---|---|---|---|
| Total (Ir) | 14.7950 | 0.0000 | Ir = Ai*Ur + Bi | |
| Potassium (Kr) | 0.7212 | 0.0000 | Kr = Ak*Ur + Bk | |
| Thorium (Tr) | 0.0617 | 0.0000 | Tr = At*Ur + Bt | |
| UP (ur) | 0.3371 | 0.0000 | ur = Au*Ur + Bu | |

| GROUND COMPONENT | A1 | A2 | |
|---|---|---|---|
| UP(ug) | 0.1365 | 0.0259 | ug = A1*Ug + A2*Tg |

| STRIPPING RATIOS | (GR820) | INCREASE IN HEIGHT(per meter) |
|---|---|---|
| alpha | .2265 | 0.00049 |
| beta | .3710 | 0.00065 |
| gamma | .7181 | 0.00069 |
| a | .0498 | |
| b | .0001 | |
| g | .0054 | |

| ATTENUATION COEFFICIENTS | |
|---|---|
| Total | -0.006975 |
| Potassium | -0.008651 |
| Uranium | -0.007682 |
| Thorium | -0.006712 |

| SENSITIVITIES | | | C = N / S | N-count |
|---|---|---|---|---|
| Potassium | 52.9212 | cps per % | | S-Sensitivity |
| Uranium | 5.2708 | eU ppm | | C-Concentrations |
| Thorium | 3.4129 | eTh ppm | | |

**Table 10: Spectrometer Processing Parameters – Texas, USA**

**USGS__02.TX, SPECTROMETER GR-820 SN.8245, 8 DOWN & 2 UP, USE FOR FLIGHTS 14 – 31**

| WINDOW | COSMIC STRIPPING (B) | AIRCRAFT (A) | | |
|---|---|---|---|---|
| Total | 0.6896 | 33.16 | Total | Count = A + B * COSMIC |
| Potassium | 0.0391 | 4.83 | Potassium | |
| Uranium | 0.0317 | 0.88 | Uranium | |
| Thorium | 0.0370 | 0.00 | Thorium | |
| Cesium | 0.0000 | 0.00 | Cesium | |
| Upward | 0.0088 | 0.14 | Upward | |

| RADON COMPONENT | A | B | Ur =Uranium component due to radon (U over test line after | |
|---|---|---|---|---|
| Total (Ir) | 14.5330 | 0.0000 | Ir = Ai*Ur + Bi | Cosmic & a/c backgrounds |
| Potassium (Kr) | 1.0324 | 0.0000 | Kr = Ak*Ur + Bk | have been removed) |
| Thorium (Tr) | .1064 | 0.0000 | Tr = At*Ur + Bt | |
| UP (ur) | .2596 | 0.0000 | ur = Au*Ur + Bu | |

| GROUND COMPONENT | A1 | A2 | |
|---|---|---|---|
| UP(ug) | 0.0762 | 0.0019 | ug = A1*Ug + A2*Tg |

| STRIPPING RATIOS | (GR820) | INCREASE IN HEIGHT(per meter) |
|---|---|---|
| alpha | .2240 | 0.00049 |
| beta | .3678 | 0.00065 |
| gamma | .7011 | 0.00069 |
| a | .0398 | |
| b | .0000 | |
| g | .0050 | |

| ATTENUATION COEFFICIENTS | |
|---|---|
| Total | -0.006834 |
| Potassium | -0.009376 |
| Uranium | -0.007205 |
| Thorium | -0.006293 |

| SENSITIVITIES | | | C = N / S | |
|---|---|---|---|---|
| Potassium | 56.6732 | cps per % | | N-count |
| Uranium | 4.8247 | eU ppm | | S-Sensitivity |
| Thorium | 3.1230 | eTh ppm | | C-Concentrations |

Before gridding the following corrections are applied to the spectrometer data in the order shown:

**1) Dead time correction**

The system live time is recorded by the spectrometer and represents the time that the system was available to accept incoming gamma radiation pulses. Live time is reduced, and dead time increased, as count rates increase and the time taken by the spectrometer to process measured pulses increases. The dead-time correction is applied to each window in both the upward and downward looking detector data, except the cosmic channel data that is processed by separate circuitry in the GR820 spectrometer, using the following equation:

$$N = n / t$$

where: N = the corrected count rate in each channel
n = the raw count recorded in each second
t = the recorded live time (fraction of a second).

**2) Calculation of effective height above ground level (AGL)**

A 21-point low pass filter *Figure 7* is applied to 4Hz radar altimeter data, and a 131-point low pass filter (*Figure 8*) is applied to 4Hz barometric altimeter data (the barometric altimeter data contained dropouts which were manually edited prior to filtering). The barometric altimeter data is then converted to equivalent pressure, and used with the digitally recorded temperature to convert the radar altimeter data to effective height at standard pressure and temperature (STP) as follows:

$$h_e = h \times \frac{273.15}{T + 273.15} \times \frac{P}{1013.25}$$

where: $h_e$ = the effective height
$h$ = the observed radar altitude in metres
$T$ = the observed air temperature in degrees Centigrade, and
$P$ = the observed barometric pressure in millibars.

**3) Height Adaptive Filter**

By convention, data collected at terrain clearance greater than 300m is considered unreliable due to the low count rates and consequent low signal to noise ratio. The severe terrain in parts of the survey area resulted in parts of the survey being flown above this clearance. In order to extend the range of useable data, a filter is applied to data flown at altitude which whilst reducing resolution increases the signal to noise ratio to acceptable levels. The degree of filtering applied depends on the clearance as follows:

| Clearance | Filter |
|---|---|
| below 300m: | none |
| 300m to 350m: | 3 point average on 1 Hz data |
| above 350m: | 9 point average on 1 Hz data |

After full processing (see below), data was gridded and inspected for coherency. Based on this procedure, different data sets were set to null above different terrain clearances as follows:

| | |
|---|---|
| Uranium | above 400m |
| Potassium | above 450m |
| Thorium & Total | above 500m |

**4) Removal of cosmic radiation and aircraft background radiation**

A 67 point low pass filter (*Figure 10*) is applied to 1 Hz cosmic radiation data to reduce statistical noise. Cosmic radiation and aircraft background radiation are removed from each spectral window using the cosmic coefficients and aircraft background radiation values determined from test flight data using the following equation:

$$N = a + bC$$

where: $N$ = the combined cosmic and aircraft background in each spectral window,

$a$ = the aircraft background in the window,

$b$ = the cosmic stripping factor for the window, and

$C$ = the cosmic channel count.

**5) Radon background corrections**

A low pass filter with a cosine tapered ramp between 15 and 25 points is applied to 1Hz downward uranium, downward thorium and upward uranium count data for the purposes of the radon correction only. The radon component in the uranium window is calculated using the radon coefficients determined from test flight data and ground coefficients determined from the survey data using the following equation:

$$U_r = \frac{u - a_1 U - a_2 T + a_2 b_T - b_u}{a_u - a_1 - a_2 a_T}$$

where: $U_r$ = the radon background measured in the downward uranium window,

$u$ = the filtered observed count in the upward uranium window,

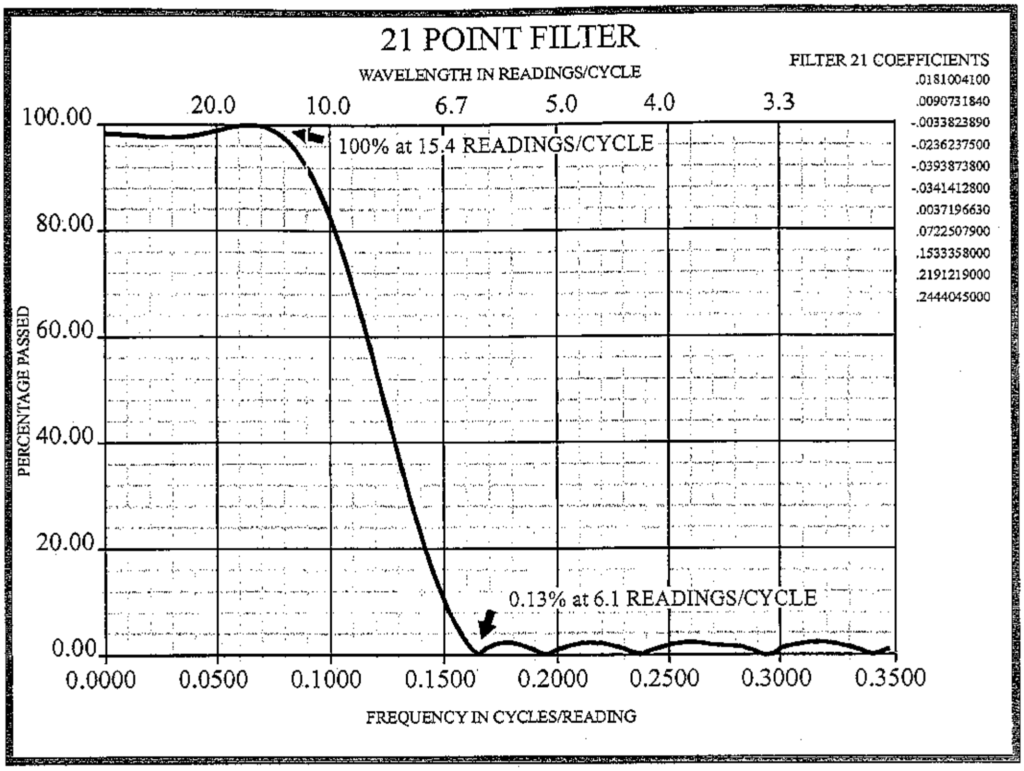
| | | |
|---|---|---|
| $U$ | = | the filtered observed count in the downward uranium window, |
| $T$ | = | the filtered observed count in the downward thorium window, |
| $a_1$ and $a_2$ | = | the ground coefficients, and |
| $a_u$, $a_T$ , $b_u$ and $b_T$ | = | the radon coefficients for uranium and thorium. |

The radon counts in the total count, potassium and thorium downward windows are then calculated from $U_r$ using the following equations:

$$u_r = a_u U_r + b_u$$
$$K_r = a_K U_r + b_k$$
$$T_r = a_T U_r + b_T$$
$$I_r = a_I U_r + b_I$$

| | | | |
|---|---|---|---|
| where: | $u_r$ | = | the radon component in the upward uranium window, |
| | $K_r$, $U_r$, $T_r$ and $I_r$ | = | the radon components in the various windows of the downward detectors, and |
| | various $a$ and $b$ coefficients | = | the radon calibration coefficients. |

## Figure 7: 21 Point Filter




## Figure 8: 131 Point Filter

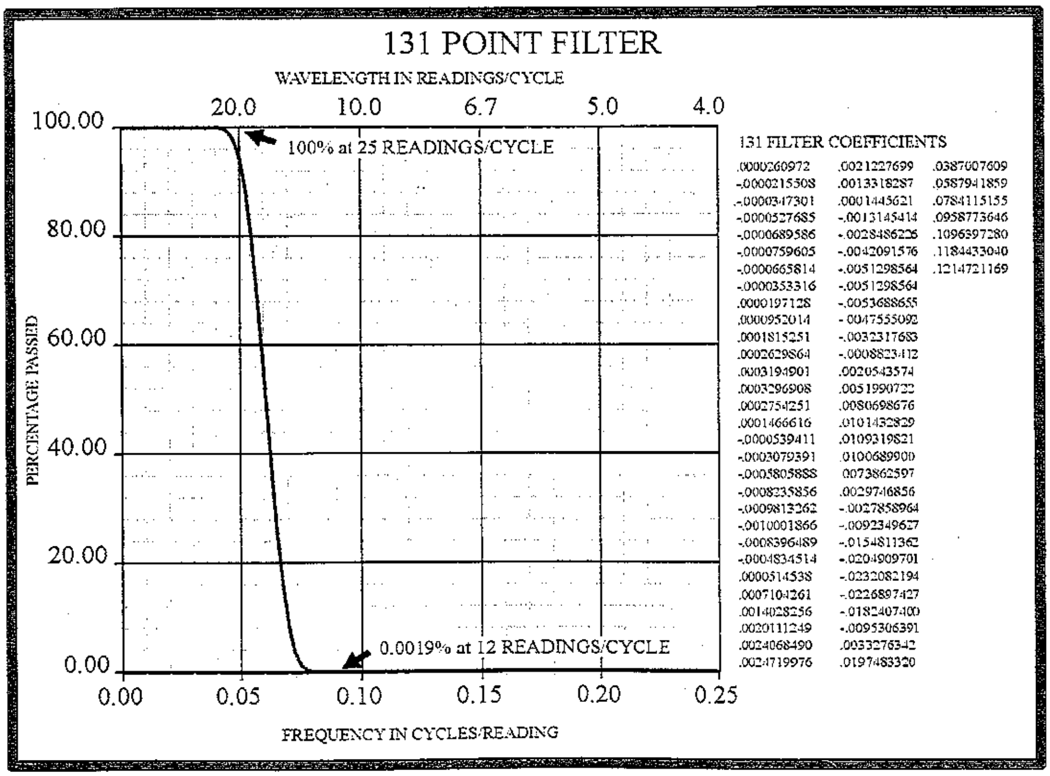
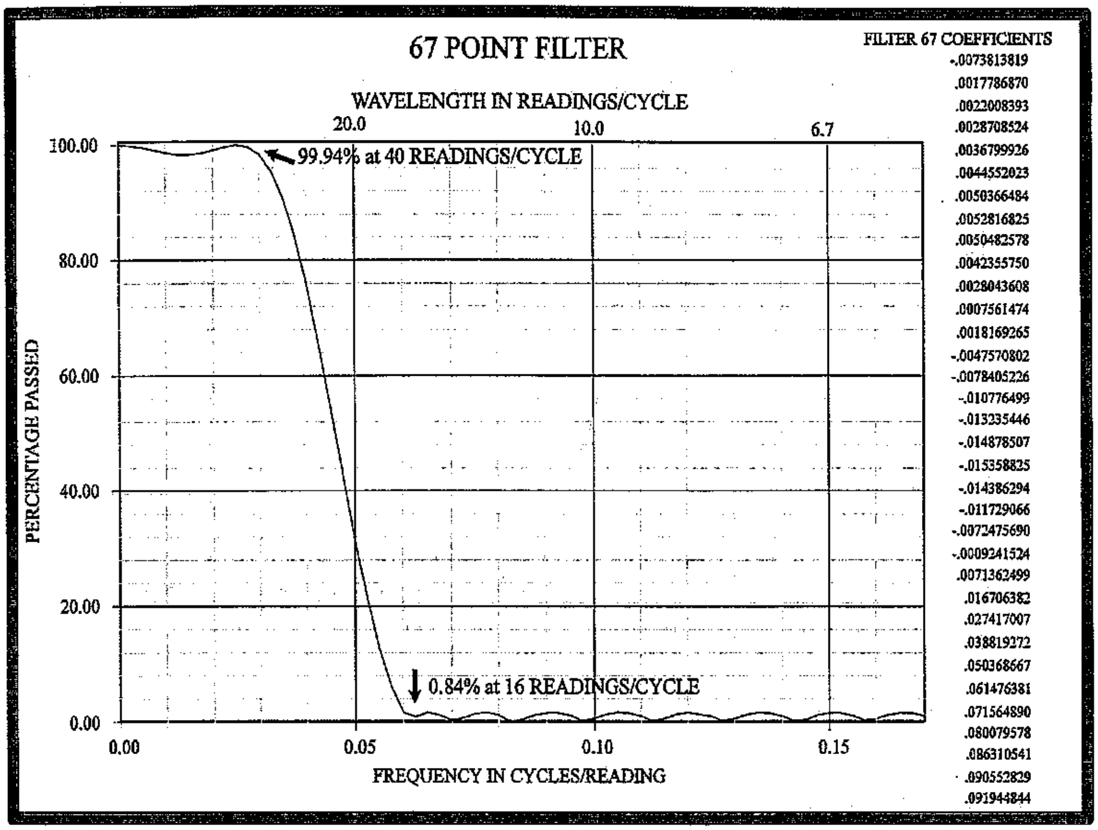


**Figure 9 : 67 Point Filter**




## 6) Stripping

The stripping ratios for the spectrometer system are determined experimentally. The stripped count rates for the potassium, uranium and thorium downward windows are calculated using the following equations:

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

$$N_U = \frac{n_{Th}(g\beta - \alpha) + n_U(1 - b\beta) + n_K(b\alpha - g)}{A}$$

$$N_{Th} = \frac{n_{Th}(1 - g\gamma) + n_U(b\gamma - a) + n_K(ag - b)}{A}$$

where A has the value:

$$A = 1 - g\gamma - a(\gamma - gb) - b(\beta - \alpha\gamma)$$

and where $n_K$, $n_U$ and $n_{Th}$ = the unstripped potassium, uranium and thorium downward windows counts,

$N_K$, $N_U$ and $N_{Th}$ = the stripped potassium, uranium and thorium downward windows counts,

$\alpha$, $\beta$, and $\gamma$ = the forward stripping ratios, and
$a$, $b$ and $g$ = the reverse stripping ratios.

$\alpha$, $\beta$, and $\gamma$ are adjusted for effective height (as calculated above) by standard factors given in *Table 7*.

**7) Altitude attenuation correction**

This correction normalizes the data to a constant terrain clearance of 150 m above ground level (AGL) at standard temperature and pressure (STP). Attenuation coefficients for each of the downward windows are determined from test flights. The measured count rate is related to the actual count rate at the nominal survey altitude by the equation:

$$N_s = N_m(e^{\mu(h_o - h)})$$

where: $N_s$ = the count rate normalized to the nominal survey altitude, $h_o$,
$N$ = the background corrected, stripped count rate at effective height $h$,
$\mu$ = the attenuation coefficient for that window,
$h_o$ = the nominal survey altitude, and
$h$ = the effective height.

The effective height is determined in step 2) "Calculation of effective height above ground level (AGL)".

**8) Correction for effects of precipitation**

The survey test line averages for potassium, thorium and total count were consistent throughout the duration of the survey (within +/- 10%). No correction for effects of precipitation was deemed necessary.

**9) Conversion to radio element concentration**

Sensitivities are determined experimentally from test flight data. The units of the count rates in each spectral window are converted to "Apparent Radio Element Concentrations" using the following equation:

$$C = N / S$$

| where: | | | |
|---|---|---|---|
| | $C$ | = | the concentration of the element(s) |
| | $N$ | = | the count rate for the window after correction for dead time, background, stripping and attenuation |
| | $S$ | = | the broad source sensitivity for the window. |

Potassium concentration is expressed as a percentage and equivalent uranium and thorium as parts per million of the accepted standards. Uranium and thorium are described as "equivalent" since their presence is inferred from gamma-ray radiation from daughter elements ($^{214}$Bi for uranium, $^{208}$Tl for thorium).

**10) Data gridding**

A minimum curvature gridding algorithm is considered most appropriate in order to preserve detail in the data. The method generates a 2-dimensional grid, equally incremented in x and y, from randomly placed data points. The algorithm (I.C. Briggs, 1974, Geophysics, v 39, no. 1) produces a smooth grid by iteratively solving a set of difference equations that minimize the total second horizontal derivative and attempt to honour input data. Spectrometer data within cells are combined with a cosine weighting function before the minimum curvature surface is fitted.

For the survey block, radiometric data are interpolated to a 100 m grid cell size appropriate for survey lines spaced at 400 m. Control lines and test lines are not included in the grids.

## Magnetometer Data

Please refer to *Figure 10* for a summary of the magnetometer data compilation process.

The airborne magnetometer data, recorded at 10 Hz, were plotted and checked for spikes and noise. Ground magnetometer data was inspected for cultural interference and edited where necessary. All ground station magnetometer data was then filtered using a 67-point low pass filter, *see Figure 11*. Ground station magnetometer data were IGRF corrected using the fixed ground station location and the recorded date for each flight.

The airborne magnetometer data were corrected for diurnal variations by subtracting the filtered and IGRF corrected ground station data and adding back the average residual ground station value (162.61 nT). The average ground station value was calculated from all the ground station data used to correct the airborne data, ensuring that the ground station corrections did not bias the airborne data set. The airborne magnetometer data was

IGRF corrected, using the location, altitude and date of each point. The IGRF was calculated using the IGRF 2000 model.

As part of the levelling procedure, intersections between control and traverse lines were determined. The program extracts the magnetic, altitude, and x and y values of the traverse and control lines at each intersection point. Each control line was adjusted by a specific constant magnetic value to minimize the intersection differences, which were calculated using the following equation:

$\Sigma|i - a|$ summed over all traverse lines

where, $i$ = individual intersection difference

$a$ = average intersection difference for that traverse line.

The influence of anomalous intersections was avoided by calculating local average corrections and applying a threshold to the intersection correction values.

Adjusted control lines were further corrected locally to minimize the difference between individual corrections and the average correction for the line. Traverse line levelling was carried out by a program that interpolates and extrapolates levelling values for each point, based on the two closest levelling values.

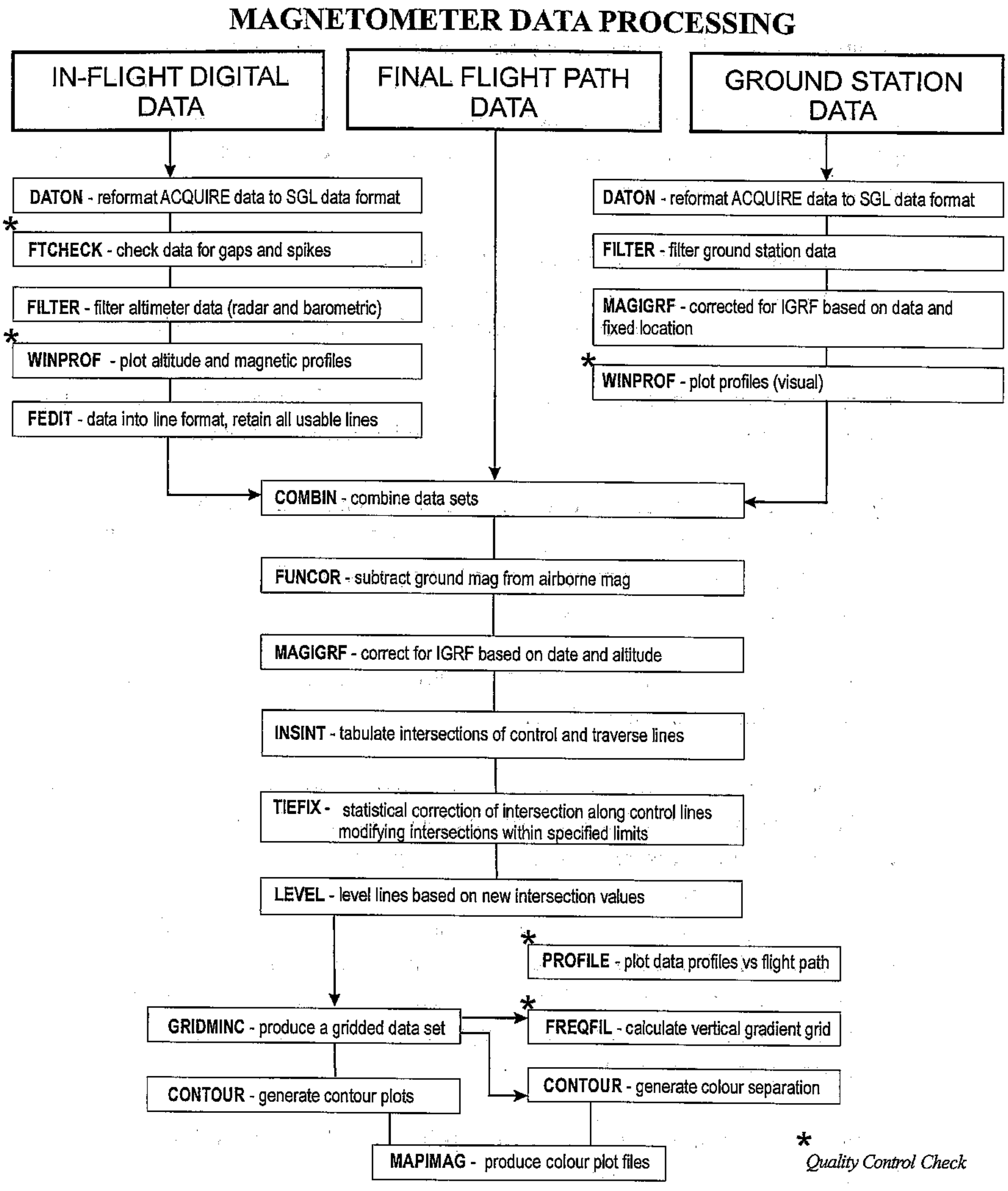
After the traverse lines were levelled, the control lines were matched to them, allowing the use of all data in the final products.

The levelling procedure was checked by inspection of the total magnetic intensity (TMI) and the first vertical derivative of the total magnetic intensity (FVD). Levelling statistics were also examined to ensure that steep correction gradients were minimized.

The filtered magnetic data were gridded using a minimum curvature algorithm to create a two-dimensional grid equally incremented in X and Y directions. The algorithm produces a smooth grid by iteratively solving a set of difference equations minimizing the total second horizontal derivative, while attempting to honour the input data (Briggs, I.C, 1974, Geophysics, v 39, no. 1).

For the survey block, magnetic data are interpolated to a 100 m grid cell size appropriate for survey lines spaced at 400 m.

**Figure 10: Magnetometer Data Processing**



**Radar Altimeter Data**

The terrain clearance measured by the radar altimeter in metres was recorded at 4 Hz. The data were filtered to remove high frequency noise using a 67-point filter (*see Figure 9*). The final data were plotted and inspected for quality.

**Positional Data**

The navigation positional data is re-formatted and recalculated in differential GPS (DGPS) mode. SGL's GPS data processing package, GPSoft was used to calculate DGPS positions from raw range data obtained from the moving (airborne) and stationary (ground) receivers. The ground station GPS receiver positions are themselves differentially corrected with respect to the IGS reference stations. This technique provides a final receiver location with an accuracy of +/- 0.2m. The GPS data from all flights was processed using phase-smoothed code and automatic fixing of the cycle slips.

The general data flow of GPSoft is illustrated in *Figure11.*

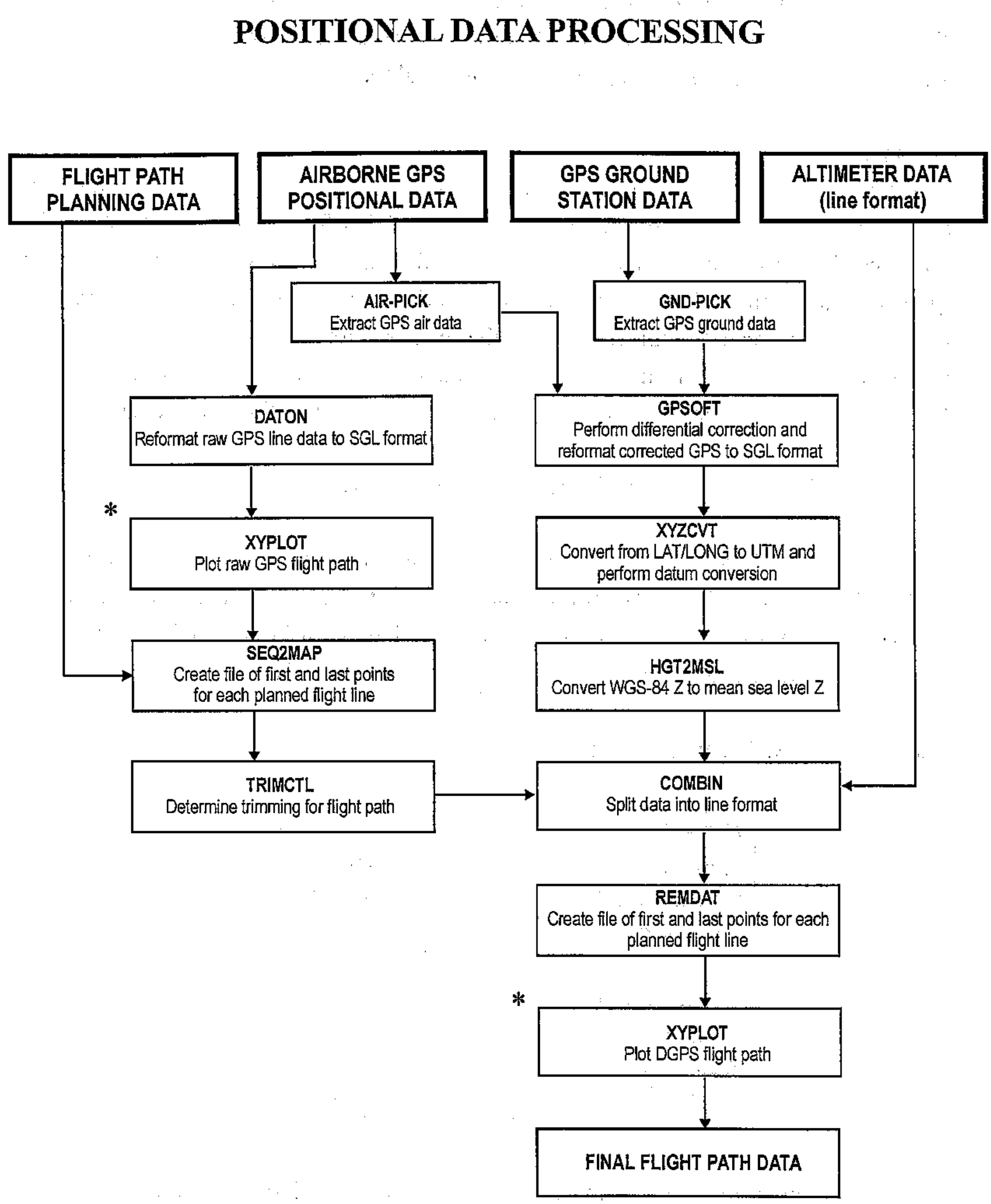
Positional data (X, Y, Z) were recorded in the WGS-84 datum. All processing was performed using data in the WGS-84 datum, but positional data is also provided in the NAD-27-USA-West datum. Positional data is provided both in geographic latitude and longitude, and as x,y locations in the UTM projection Zone 13 North.

Parameters for each datum used are:

| | |
|---|---|
| WGS-84 | |
| Ellipsoid: | GRS-80 |
| Semi-major axis: | 6378137.0 |
| 1/flattening: | 298.257 |
| | |
| NAD-27-USA-West | |
| Ellipsoid: | Clarke-1866 |
| Semi-major axis: | 6378206.4 |
| 1/flattening: | 294.979 |

Transformation from WGS-84 to NAD-27-USA-West is achieved by ellipsoid x, y, z shifts of 8m, -159m and -175m respectively. No ellipsoid rotations are involved.

**Figure 11: Positional Data Processing**




**Quality Control Check*

# VIII. FINAL PRODUCTS

Digital Data

Digital data is provided as a set of five compact disks (CDs) as follows:

Disk 1
spcd256.xyz (Geosoft ASCII format - 256 channel downward detector spectra, data presented with a single header preceding each line).

Disk 2
spcu256.xyz (Geosoft ASCII format - 256 channel upward detector spectra, data presented with a single header preceding each line).

Disk 3
spc_trav.xyz (Geosoft ASCII line data – Radiometric traverse line data)
spc_ctrl.xyz (Geosoft ASCII line data – Radiometric control line data)
spc_test.xyz (Geosoft ASCII line data – Radiometric test line data)

Note: Fully processed data (total counts and equivalent concentrations) are not provided for daily high altitude test lines. Raw data only are presented.

Disk 4
tot.gxf (GXF format grid – Total radiometric counts in cps)
Pot.gxf (GXF format grid – Potassium in per cent)
Ura.gxf (GXF format grid – Equivalent Uranium in ppm)
Tho.gxf (GXF format grid – Equivalent Thorium in ppm)

Disk 5
mag-bigbend.xyz (Geosoft ASCII line data – Magnetics)
tmi.gxf (GXF format grid - Total magnetic intensity)
fvd.gxf (GXF format grid - First vertical derivative of the total magnetic intensity in nT/m)

*Tables 11 and 12* describe the located line data delivered in ASCII format. All data are organized by line.

| **Table 11: Format of ASCII Data – Magnetic Data (spc_*.xyz)** | | | |
|---|---|---|---|
| Name | Description | Format | Units |
| LONG | Longitude WGS-84 | F11.4 | degrees |
| LAT | Latitude WGS-84 | F9.4 | degrees |
| UTMX | UTM X WGS-84 Zone 13N | F9.1 | meters |
| UTMY | UTM Y WGS-84 Zone 13N | F10.1 | meters |
| UTMX_N27 | UTM X NAD-27 Zone 13N | F9.1 | meters |
| UTMX_N27 | UTM Y NAD-27 Zone 13N | F10.1 | meters |
| FID | Fiducial time | F9.1 | seconds |
| DATE | Year, Month, Day | A10 | 'YYYYMMDD' |
| TIME | Hour, Minutes, Seconds | A13 | 'HH:MM:SS.SS' |
| ALT_R | Radar Altimeter | F8.1 | meters |
| ALT_B | Barometric Altimeter | F8.1 | meters |
| ALT_G | DGPS Altitude (WGS-84) | F8.1 | meters |
| GND_IG_C | IGRF Corrected Ground Station | F8.2 | nT |
| REM_IG_C | Magnetic Total Field (Air) | F9.2 | nT |
| MAG-GND | Diurnal Corrected Mag (air) | F9.2 | nT |
| MAG_IG_C | Diurnal & IGRF Corrected Mag (Air) | F9.2 | nT |
| Levmag | Corrected and Levelled Mag (Air) | F9.2 | nT |

**Table 12: Radiometric Data**

| **Name** | **Description** | **Format** | **Units** |
|---|---|---|---|
| L4 | Line No. | A7 | n/a |
| LONG | Longitude WGS-84 | F13.7 | degrees |
| LAT | Latitude WGS-84 | F12.7 | degrees |
| UTMX | UTM X WGS-84 Zone 13N | F9.1 | meters |
| UTMY | UTM Y WGS-84 Zone 13N | F11.1 | meters |
| UTMX | UTM X NAD-27 Zone 13N | F9.1 | meters |
| UTMY | UTM Y NAD-27 Zone 13N | F11.1 | meters |
| FID | Fiducial | I6 | seconds |
| DATE | Date | A9 | YYYYMMDD |
| TIME | Time | A12 | HH:MM:SS.SS |
| EFF | Effective Height | F7.1 | meters |
| TEMP | Temperature | F6.1 | degrees Celsius |
| LIVE | Live Time | F6.1 | per cent |
| COSMIC RAW | Raw Cosmic Window | I6 | counts/second |
| TOT RAW | Raw Total Window Counts | I6 | counts/second |
| K RAW | Raw Potassium Window Counts | I6 | counts/second |
| U RAW | Raw Uranium window Counts | I6 | counts/second |
| Th RAW | Raw Thorium window Counts | I6 | counts/second |
| UP RAW | Raw Upward Window Counts | I6 | counts/second |
| TOT | Corrected Total Counts | I6 | counts/second |
| K | Corrected Potassium Concentration | F8.2 | per cent |
| U | Corrected Uranium Concentration | F8.2 | ppm |
| Th | Corrected Thorium Concentration | F8.2 | ppm |
| UP | Corrected Upward Counts | F8.2 | counts/second |

| Table 13: 256 Channel Spectrometer Data Format | | | |
|---|---|---|---|
| **Name** | **Description** | **Format** | **Units** |
| Time | seconds after midnight UTC | F10.2 | 0.01 sec |
| Blank | | I 14 | n/a |
| channel 0 | Sample Time | I4 | 0.001 sec |
| channels 1-254 | Spectrometer Channels, 12 KeV per channel | I4 | counts |
| Channel 255 | Cosmic Counts | I4 | counts |

# IX. PROJECT SUMMARY

## Part I - Survey

| SURVEY LOCATION | |
|---|---|
| Survey Title: | Airborne Magnetic/Spectrometer Survey – USGS__02.TX, Texas, USA |
| Survey Location: | Big Bend National Park |
| Survey Duration: | November 7 – December 26, 2002 |
| Client: | UNITED STATES GEOLOGICAL SURVEY |
| Address: | Box 25046<br>Denver Federal Center<br>Denver, CO 80225<br>United States of America |
| Client Contact: | Pat Hill, Procurement and Contracts<br>Phone : (303)236-1343<br>Fax : (303)236-1425<br>E-mail: pathill@usgs.gov |
| Field Office Location: | Antelope Lodge |
| ADDRESS: | 2310 W HWY 90<br>Alpine, Texas 79830 |
| TEL: | Phone: (915) 837-2451 |

| SURVEY SPECIFICATIONS | | |
|---|---|---|
| Magnetic Field: | Inclination: 57.7 Declination: 8.3 | Total Field: 47000.1 nT |
| Horizontal / Vertical Datum: | | |
| - Raw Recorded Data | WGS-84 / WGS-84 | |
| - Delivered Data | WGS-84 & NAD-27-USA-West / WGS-84 | |
| Line Direction: | Traverse degrees true | Control |
| - Survey Block | 075° | 345° |
| Total lkm flown: | 19,220.68 km | |
| Survey Speed: | 115 knots | |
| Survey Altitude: | 150 m (Draped) | |
| Survey Flight Numbers: | 001-031 | |
| Flights not used: | | |
| Line Spacing: | Traverse lines<br>400 m | Control lines<br>3200 m |
| Survey Lines Flown: | 1001-1241 | 101 - 140 |

| SURVEY AIRCRAFT AND EQUIPMENT | | | |
|---|---|---|---|
| Aircraft used: | C-GSGL Cessna Grand Caravan | | |
| Radar Altimeter: | TRT ERT-530A | range: | 0-10,000 ft. |
| Barometric Altimeter: | Sander BA 012 | | |
| Magnetometer (Air): | Geometrics G-822A Cesium Mag. | Sample rate: | 10 Hz |
| Magnetometer (local Ground): | Geometrics G-822A | | 2 Hz |
| GPS Receiver (Air): | NovAtel Millennium, 12 channels | | 2 Hz |
| DGPS Receiver (Air): | Omnistar 3000LR | | 2 Hz |
| GPS Receiver (local Ground): | NovAtel Millennium, 12 channels | | 2 Hz |
| Spectrometer: | Exploranium GR-820<br>2 Crystal Detector Packs GPX-1024/256 (8 down looking and 2 upward looking crystals) | | 1 Hz |

| FIELD PERSONNEL | | | |
|---|---|---|---|
| Geophysicist and Party Chief: | John Paasche | Pilots: | Steve Gebhardt, Laurent Geslin, Jan Kristiansen |
| Technician: | Lee Duncan | | |
| Aircraft Engineer: | Brian Clarke | | |

## PART II - Survey Overview- Problems / Solutions

The Big Bend National Park area is a military training zone. Survey flights were scheduled to avoid interaction with these military aircraft. The survey was successfully completed in only thirty-one flights.

## PART III - Data Processing

| DATA PROCESSING – Ottawa, ON, Canada | | | | | |
|---|---|---|---|---|---|
| **PROCESSING FILE LOCATION** | | | | | |
| **PROCESSING** | **COMPUTER** | **DIRECTORY** | **COMMENTS** | **DONE** | **COMPILED BY** |
| Field processing | P3-4 | D:\USGS__02.TX | | X | John Paasche |
| Altimeter data | P4-10 | E:\ USGS__02.TX \Alt | | X | Francis Moul |
| DGPS data | P4-10 | E:\USGS__02.TX\DGPS | | X | Francis Moul |
| Ground Mag data | P4-10 | E:\ USGS__02.TX \Gnd | | X | Francis Moul |
| Air Mag data | P4-12 | D:\ USGS__02.TX \Mag | | X | Dragos Bologa |
| Spec data | P4-10 | E:\ USGS__02.TX \Spec256 | | X | Francis Moul |