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1.0 INTRODUCTION

This report describes the specifications and operations of an airborne geophysical survey carried out for the United States Geological Survey (USGS) by Spectra Exploration Geoscience Corp., from March 5, 2001 to April 2, 2001. The crew was released by the USGS April 4, 2001. The survey was conducted by Spectra Aviation Services, a wholly owned subsidiary of Spectra Exploration Geoscience Corp., and is located at Suite 2610, 520 - 5th Avenue SW, Calgary, Alberta T2P 3R7. Telephone (403) 777-9280, fax (403) 777-9289, and email: spectra@nucleus.com.

The purpose of a survey of this type was to acquire high resolution, high sensitivity aeromagnetic data over an area in south - central Texas. The end result of the HRAM data processing was to provide detailed data to assess the area for anomalies and magnetic features pertaining to their relevance in the local geology.

To achieve this purpose, the survey area was systematically traversed by an aircraft carrying geophysical instruments along parallel flight lines (traverses) spaced 0.25 miles (400 meters) apart in an east-west alignment. Tie lines were flown normal to the traverses spaced at 5 miles (8000 meters). Subsequent to data quality assessment, Spectra recommended in-fill tie lines be flown at 2.5 mile offset. The final tie line spacing is 2.5 miles (4000m). The nominal flying height was a best–fit draped 500 feet (150 meters) above the terrain surface.

2.0 SURVEY AREA

The survey area is located in south-central Texas, USA, and is bounded by the following Latitude/Longitude coordinates, which were provided by the USGS:

Corner No.	Latitude	Longitude
1	29°37'30"	-100°02'00"
2	29°37'30"	-98°45'00"
3	29°12'30"	-98°45'00"
4	29°12'30"	-100°02'00"

A map of the project area is in the Appendix to this report.

3.0 EQUIPMENT SPECIFICATIONS

3.1 AIRCRAFT

The survey was carried out using Spectra's Piper Navajo PA 31-310C aircraft, registration C-FYTT, configured with a specially designed rigid-mount tail boom for geophysical survey operations. The aircraft is equipped with a high sensitivity magnetometer and a full on-board real time compensation recording computer, and related equipment. It is a twin-engine aircraft with full avionics, including real time GPS with real-time and forward-looking flight path display.

The aircraft has been extensively modified to conduct airborne geophysical surveys. Considerable effort has been made to remove all ferruginous materials near the sensor and to ensure that the aircraft electrical systems do not create any noise. With these modifications this aircraft represents one of the quietest magnetic platforms in the industry with a figure of merit of 1.43 nT compensated at this survey location using Geological Survey of Canada standards.

The aircraft is operated by Spectra Aviation Services Corp. under full M.O.T approval and certification for specialty flying including airborne geophysical surveys. The aircraft is maintained at base operations by a regulatory AMO Facility, Baker Aviation Inc. and in the field by a Spectra Aviation Services Corp. AME in association with Baker Aviation, AMO.

The following table lists the relevant aircraft flight parameters for conducting HRAM surveys to March 31 for C-FYTT and February 28 for C-FZHG. In addition, there is an aircraft specifications sheet in the Appendix.

TYPE	R/N	TSO-* HOURS	FUEL CAPACITY	CRUISE (kts)	SURVEY ENDURANCE
PIPER NAVAJO	C-FYTT	LE 356.5 RE 622.3	192 gallons, AVGAS 100/130	176 knots survey:160 stall: 71	5.5 hours
PIPER NAVAJO	C-FZHG	LE 838.6 RE 697.4	242 gallons** AVGAS 100/130	176 knots survey:160 stall: 71	6.5 hours

Normal Climb/Descent Gradient	1,445 FPM ***
Survey Fuel Consumption	~ 30.5 gph

* TSO = Time Since Overhaul
** This aircraft has Nayak wing-locker tanks for additional duration.
*** This is best rate of climb at SL at gross weight as indicated in the Piper pilots operating manual; short duration rate of climb is much higher, dependent on outside temperature.

3.2 AIRBORNE GEOPHYSICAL EQUIPMENT

The airborne geophysical system has one high sensitivity, cesium vapor magnetometer. Ancillary support equipment include tri-axial fluxgate magnetometer, video camera, video recorder, radar altimeter, barometric altimeter, GPS receiver and a navigation system which includes a left/right indicator and a screen showing the survey area with real time flight path and forward flight-path projection. All data are collected and stored by the data acquisition system. The following provides the detailed equipment specifications.

Cesium Vapor Magnetometer:

Manufacturer	Scintrex
Model	CS-2
Resolution	0.001 nT counting @ 0.1 per second
Sensitivity	+/-0.005 nT
Dynamic Range	15,000 to 100,000 nT
Fourth Difference	0.02 nT

Tri-Axial Magnetic Field Sensor (for compensation, mounted in the forepart of the tail stinger):

Manufacturer	Bartington Instruments Ltd.
Model	MAG-03MC
Internal Noise	at 1 Hz - 1 kHz; 0.6 nT rms
Bandwidth	0 to 1 kHz maximally flat, -12 dB/octave roll off beyond 1 kHz
Frequency Response	1 HZ - 100 Hz: +/- 0.5% 100 Hz - 500 Hz: +/- 1.5% 500 Hz - 1 kHz: +/- 5.0%
Calibration Accuracy:	+/- 0.5%
Orthogonality	+/- 0.5% worst case
Package Alignment	+/- 0.5% over full temperature range
Scaling Error	absolute: +/- 0.5% between axes: +/- 0.5%

Video Camera (camera mounted in belly of aircraft):

Manufacturer	Sanyo
Model	VDC-2982 (colour)
Specifications	1/2”, 470 hr, 1.3LX. 12VDC, C/CS,EI/ES, backlite comp
Lens	Pentax, F1.8-360, auto iris

Video Recorder (strapped to computer rack/floor plate):

Manufacturer	Orion (or equivalent)
Model	TV/VHS combination

Radar Altimeter:

Manufacturer	King
Model	KRA-10A
Accuracy	5% up to 2,500 feet
Calibrate Accuracy	1%
Output	Analogue for pilot; Converted to digital for data acquisition

Barometric Altimeter:

Manufacturer	Sensym
Model	LX18001AN
Source	Coupled to aircraft pitot static system

Differential GPS Receiver (# 511 aircraft certified antenna mounted on top of the cabin roof):

Manufacturer	Novatel
Model	Novatel Card for magnetic system; King KLN-89B for pilot (interfaced)
Serial Number	GPS 511
Type	Continuous tracking, L1 frequency, C/A code (SPS), 12 channel (independent)
Position Sensitivity	once per second
Accuracy	position (SA implemented) 100 meters, position (no SA) 30 m, velocity 0.1 knot, time recovery 1 pps, 100 nsec pulse width
Data Recording	all GPS data and positional data logged by Picodas Unit

Navigation Interface (with pilot and operator readouts):

Manufacturer	Picodas Group Inc.
Model	PNAV
Data Input	Real time processing of GPS output data
Pilot Readout	Left/Right indicator / forward line projection screen
Operator Readout	Screen modes: map, survey and line
Data Recording	All data recorded in real time by Helimag

Data Acquisition System :

Manufacturer	Picodas Group Inc.
Model	PDAS 1000 – Helimag & PNAV / PDAS 2000
Operating System	MS-DOS
Microprocessor	80486dx - 66 CPU
Coprocessor	Intel 8048dx
Memory	On board up to 8 MB, page interleaving, shadow RAM for BIOS, support EMS 4.0
Clock	real time; hardware implementation of MC14618 in the integrated peripherals controller
I/O Slots	5 AT and 3 PC compatible slots

Display	Electro – luminescent 640x400 pixels
Graphic Display	Scrolling analog chart simulation with up to 5 windows operator selectable; freeze display capability to hold image for inspection
Recording Media	Standard 540 Mbyte hard disk with extra shock mounts; Standard 1.44 Mbyte floppy disk; Standard tape backup
Sampling	Selectable for each input type; 1, 0.5, 0.25, 0.2 or 0.1 seconds
Inputs	12 differential analog input with 16 bit resolution
Serial Ports	2 RS-232C (expandable)
Parallel Ports	Ten definable 8 bit I/O; Two definable 8 bit outputs

The Helimag also contains the magnetometer processor boards, one for each cesium vapor magnetometer installed

Manufacturer	Picodas Group Inc.
Model	PCB
Input Range	20,000 - 100,000 nT
Resolution	0.001 nT
Bandwidth	0.7, 1 or 2 Hz
Microprocessor	TMS 9995
Firmware	8 Kbit EPROM board resident
Internal Crystal	18,432 kHz
Absolute Crystal Accuracy	<0.01%
Host Interfacing	8 Kbyte dual port memory
Address Selection	Within 20 bit addressing in 8 Kbyte software selectable steps
Input Signal	TTL, CMOS, Open collector compatible or sine wave with decoupler
Input Impedance	TTL>1K Ohm

Magnetic compensation for aircraft and heading effects is done in real time. Raw magnetic values are also stored and thus if desired, compensation with different variables can be run at a later time.

Other Boards:

Analog Processor	PCB - provides separate A/D converter for each analog input with no multiplexing; each channel is sampled at a rate of 1,000 samples per second with digital processing applied.

Power Supplies:

1) Power Distribution Unit manufactured by Picodas Group Inc. interfaces with the aircraft power and provides filtered and continuous power at 27.5 VDC to all components.
2) The Helimag contains a 32 volt DC cesium sensor switching power supply for the cesium vapor magnetometers in conjunction with real time magnetometer compensation; also enables interfacing the fluxgate magnetometer and the barometric altimeter; also provides clean power for radar altimeter and ancillary equipment (PC notebook, printer)

3.3 MAGNETOMETER BASE STATION

High sensitivity base station data are provided by a cesium vapor magnetometer, data logging onto a PC 486sx notebook and time synchronization with ground GPS receiver.

Magnetic Sensor:

Identical to magnetometer in aircraft

Magnetic Processor:

Manufacturer	Picodas Group Inc.

Model	PCB
Input range	20,000 - 100,000 nT
Resolution	0.001 nT
Resolution (fdd)	1 pt
Bandwidth	0.7, 1 or 2 Hz
Microprocessor	TMS 9995
Firmware	8 Kbit EPROM board resident
Internal Crystal	18,432 kHz
Absolute Crystal Accuracy	<0.01%
Host Interfacing	8 Kbyte dual port memory
Address Selection	Within 20 bit addressing in 8 Kbyte software selectable steps
Input Signal	TTL, CMOS, Open collector compatible or sine wave with decoupler
Input Impedance	TTL> 1kohm
Clock Stability	2 ppm per year
Absolute accuracy correction	+/- 999x10e-6

Logging Software:

Logging software by Picodas Group Inc. version 5.02 to IBM compatible PC with RS 232 input; supports real time graphics, automatic startup, compressed data storage, selectable start/stop times, automatic disk swapping, plotting of data to screen or printer at user selected scales, and fourth digital difference and diurnal quality flags set by user.

3.4 GPS BASE STATION

Ground GPS data was collected to perform post-flight differential correction to the flight path. The ground GPS base station equipment is described below:

Manufacturer	Novatel
Model	Novatel Card
Type	Continuous tracking, L1 frequency, C/A code (SPS), 10 channel
Position Update	once per second
Accuracy	with SA implemented 100 meters, no SA 30 meters, velocity 0.1 knot, time recovery 1 pps, 100 nsec pulse width
Data Recording	all GPS raw and positional data logged by PDAS 1000

4.0 SURVEY SPECIFICATIONS

4.1 LINES AND DATA

Survey area coverage	contracted: 9,380 survey line miles (15,102 line km) additional: 240 line miles (386 line km) ‘no charge’: 213 line miles (343 line km)
Line Direction	90-270 degrees azimuth.
Line Interval	0.25 miles (400 m).
Tie Line Interval	2.5 miles (4000 m) - flown orthogonal to survey lines.
Terrain Clearance	500 feet (150 meters) drape mode.
Average ground speed	70-80 meters/second (230 – 262 ft/sec).
Data point interval:	Magnetic: 7-8 meters (23’ - 26’) relative ground spacing per sample point.

4.2 TOLERANCES

a) Line spacing: At no point did the traverse or control lines deviate more than 50% of the designated flight line spacing.
b) Terrain clearance: All flight lines were within tolerance of the planned drape surface.

c) Diurnal magnetic variation: As per spec, with data not acquired during magnetic storms or short term disturbances which exceeded:

1. Monotonic changes in the mag field of 5 gammas in any 5 minute period;
2. Pulsations having periods of 5 minutes or less did not exceed 2 gammas;
3. Pulsations having periods between 5 and 10 minutes did not exceed 4 gammas; and
4. Pulsations having periods between 10 and 20 minutes did not exceed 8 gammas.

d) Missing data: Any lines with channels or portions of channels missing from the database or video that was not viewable were reflown

4.3 NAVIGATION AND RECOVERY

The satellite navigation system was used to ferry to the survey site and to survey along each line using latitude/longitude coordinates. The survey coordinates of the survey outline for navigation purposes and flight path recovery were calculated from the project area coordinates listed above.

The navigation accuracy is variable depending on the number and condition of the satellites, however it is generally less than twenty five meters and typically in the ten meter range. Post-flight differential correction of the flight path, which corrects for satellite range errors, improves the accuracy of the flight path recovery to approximately within one to three meters.

A video camera recorded the ground image along the flight path. A video screen in the aircraft cabin enabled the operator to monitor the accuracy of the flight path during the survey. This system also provided a backup system and verification for flight path recovery, if this data is needed in the future.

4.4 OPERATIONAL LOGISTICS

The main base of operations for the Texas HRAM survey was the community of Hondo, Texas. The base station magnetometer and GPS equipment were located in a magnetically quiet location at the airport. The coordinates for the base station were: 29^0 21’ 12.567”, -99^0 10’ 23.478; 276.68 m ASL.

The field crew consisted of:	Dave Fenwick – Survey Pilot Rich Lebell – Equipment Operator Jeremy Weber – Field Data Processor / Field Manager
The processing crew was:	Jim Genereux – Project Manager Paul Klein – Senior Processor, Quality Control

The field crew arrived in Hondo in early March 2001, to set up the base station and establish local support facilities. The first data acquisition flight for the survey was made on March 5, 2001. The final acquisition flight was completed on April 2, 2001. There were a total of 25 flights, including ferry and survey flights, compensation, scrubbed missions, and reflights. The figure of merit (FOM) was measured at 1.34 nT for C-FYTT.

Additional tie lines were flown, with 240 line miles paid for by the USGS and 213 line miles flown at no charge by Spectra.

5.0 DATA PROCESSING

After each mission the flight data was fully field processed and quality-checked, and then forwarded via FTP to the Calgary office for further quality control of each flight line. Each line of data was viewed on-screen, displaying raw mag, compensated mag, ground mag, noise, radar altitude, Lat./Long, flight path, and in-grid/out-of-grid. These, with the digital review, were the basis for the data QC. Any flight lines that exceeded the survey specifications due to aircraft positioning, diurnal variations or noise were noted for reflight, and forwarded to the flight crew for re-collection.

The processing procedure during the survey consisted of the following:

1) Software program C3NAV (by Picodas) was applied to the base and aircraft GPS data in order to provide post-flight compensated GPS location of the flight path.

2) Program C3NAV2TBL (by Geosoft) to produce two table files (UTM-X -Y -Z, and LAT/LON).
3) Use READMAG (by Picodas) on raw binary base (diurnal) magnetic data to create BASEMAG table.
4) Import all flight and base data into Geosoft.
5) Edit BASEMAG channel to remove any uncharacteristic spikes and linearly interpolate across any gaps.
6) Establish table of mean terrain clearances at intersection locations from tie line data to provide elevation guidance for survey line navigation. Grid differences in elevations at intersections of tie and survey lines to provide quality check on elevation control and tag any for reflight.
7) Edit flight path channels to remove any false spikes and linearly interpolate gaps.
8) Edit RAWMAG channel to remove any false spikes and linearly interpolate gaps.
9) Create new channel as MAGDC = (MAG1 - BASEMAG) + base constant (48,400).
10) Perform lag correction and heading correction to MAGDC channel: lag is 0.95 seconds.
11) All data, once processed to this point, were transferred to the USGS via FTP for QC and final approval.
12) Perform tie line leveling using all the survey line data to level the tie lines.
13) Perform survey line leveling using the leveled tie lines; final leveled channel is labeled FINALLEVEL.
14) All data were viewed on the screen on a line-by-line basis using the interactive Geosoft Oasis Montaj database to inspect for quality, required tolerances and data integrity.
15) Produce preliminary flight path map and gridded magnetic intensity map including shadowing.
16) Plot survey line and tie line flight paths and profiles for quality control inspection.
17) Produce final map suite deliverables.

5.1 DATA PRODUCTS

The following 1:250,000 scale map product was generated for the USGS:

- Total Magnetic Intensity map, contoured

In addition, two identical copies of all digital files have been delivered on CD-ROM for any client-specific data processing of the HRAM data. As well, all flight videos form part of the deliverables.

Survey data has been provided on CD-ROM in three formats: Geosoft Oasis Montaj Version 5.0 database (note that this database cannot be opened in earlier versions of Geosoft); Geosoft binary file (gbn, which can be imported into earlier versions of Geosoft); and ASCII format with no "dummies" included and no line headers (for import into UNIX systems). The channel names in the Geosoft database and the Geosoft binary file are outlined along with the description of the fields in the ASCII file provided.
-line (reflights/extensions are labeled as x1 or x2 (i.e., line 21 is a reflight of line 20), tie lines begin at 5000)
-fiducial
-latitude (WGS84)
-longitude (WGS84)
-x (WGS84),
-y (WGS84),
-gpstime

-radaraltitude (meters)
-gpsaltitude (meters)
-basemag
-rawmag
-magdc (diurnal corrected compensated magnetics; base constant added 48,400)
-magdclaghdigrf (corrections: diurnal, lag, heading, IGRF))
-finallevel (tie line leveled and micro-leveled magdclaghdigrf)
-igrf

6.0 SUMMARY

An airborne high sensitivity, high-resolution magnetic survey has been carried out at 500 foot (150 meter) drape mode elevation, 0.25 mile (400 meter) line intervals and with data sample stations at 23-26 feet (7 -8 meters) along the lines. Tie lines were spaced at 2.5 miles (4000 meters). A high sensitivity base magnetic station recorded the diurnal activity throughout the survey and a base GPS station was used to correct range errors in the GPS flight path recovery. Airborne recorded data included one fully compensated magnetometer located in rear stinger, radar altimeter and all attendant GPS data. The magnetic data have been processed, gridded and provided on CD-ROM, and hard-copy plotted at 1:250,000 scale.

SPECTRA EXPLORATION GEOSCIENCE CORP.

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