Final Report

Helicopter Aeromagnetic Survey In New Mexico and Colorado

submitted to

U.S. Geological Survey
PO Box 25046
Denver Federal Center
Denver, CO 80225

Order No. 05CRQQ0140

from

Geophex, Ltd.
605 Mercury Street
Raleigh, NC 27603-2343
Tel: (919) 839-8515
Fax: (919) 839-8528
Website: www.geophex.com

Dak Darbha
January 2006

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SUMMARY

This report describes the results of an airborne geophysical survey carried out for the U.S. Geological Survey in New Mexico and Colorado. The survey was flown in two blocks: one near Santa Fe, New Mexico, and the other near the Questa- San Pedro areas of New Mexico and Colorado. Total linear coverage of the survey amounted to about 7,242 kilometers (4,526 miles). The survey was flown from December 02, 2005 to December 15, 2005.

The purpose of the survey was to provide information that could be used to map the groundwater geology of the survey area. This was accomplished by using a helicopter-stinger-mounted cesium-vapor magnetometer. The information from the sensor was processed to produce maps that display the magnetic properties of the survey area. A GPS electronic navigation system ensured accurate positioning of the geophysical data.

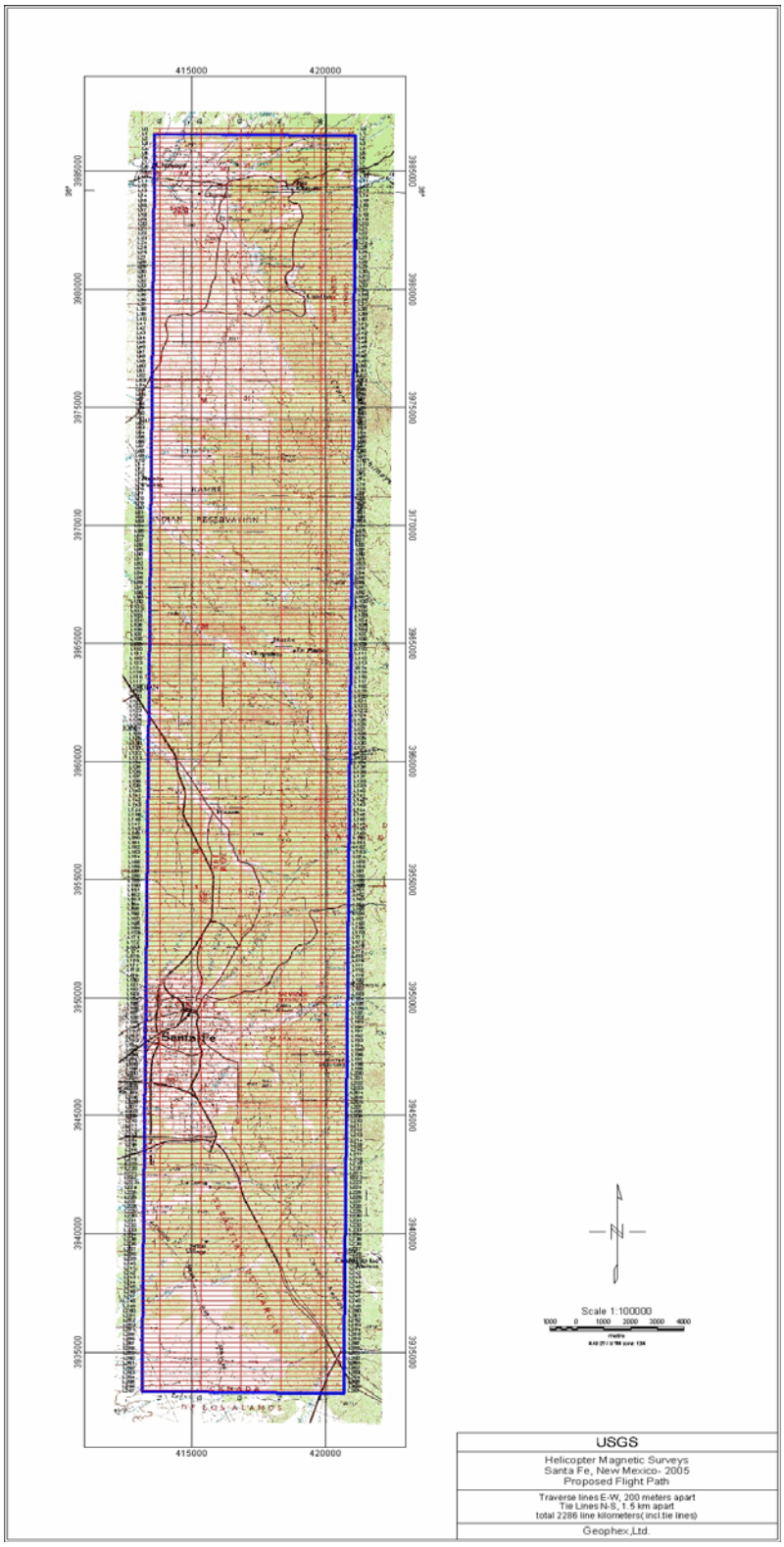
1. INTRODUCTION

A helicopter aeromagnetic survey was flown for the U.S. Geological Survey from December 02 to December 15, 2005 over two survey blocks located in New Mexico and Colorado as shown in Figure 1-1. Survey coverage consisted of approximately7,242 km including tie lines. Flight lines were flown in an E-W direction with a line separation of 200 m (0.124 mi), and tie lines were flown in a N-S direction at 1.5 km spacing . A nominal survey altitude of 130-150 meters was maintained, where possible, with due regard to the aircraft safety. However, since the survey areas contained rugged mountains, the proposed altitude limits could not be maintained in certain sections where the mountains raise above 10,500 ft.

Santa Fe Regional Airport was used as the base for the first block, and Questa municipal airport for the second block.. Dr. Tien Grauch of USGS is the technical liaison for this survey.

The survey employed a stinger-mounted cesium magnetometer system shown in Figure 1-2. Ancillary equipment consisted of radar altimeter, barometric altimeter, video camera, digital recorder and an electronic navigation (DGPS) system. The instrumentation was installed in a Hughes 369D helicopter (Registration N124AL), which was provided by Airlift Helicopters Inc. of Reno, Nevada. The helicopter flew at an average airspeed of 130 kilometer per hour.

Figure 1.2 Geophex Stinger mounted Heli-borne Magnetometer


415000
420000
Santa Fe
Scale 1:100000
USGS
Helicopter Magnetic Surveys
Santa Fe, New Mexico- 2005
Proposed Flight Path
Traverse lines E-W, 200 meters apart
Tie Lines N-S, 1.5 km apart
total 2286 line kilometers(incl.tie lines)
Geophex,Ltd.

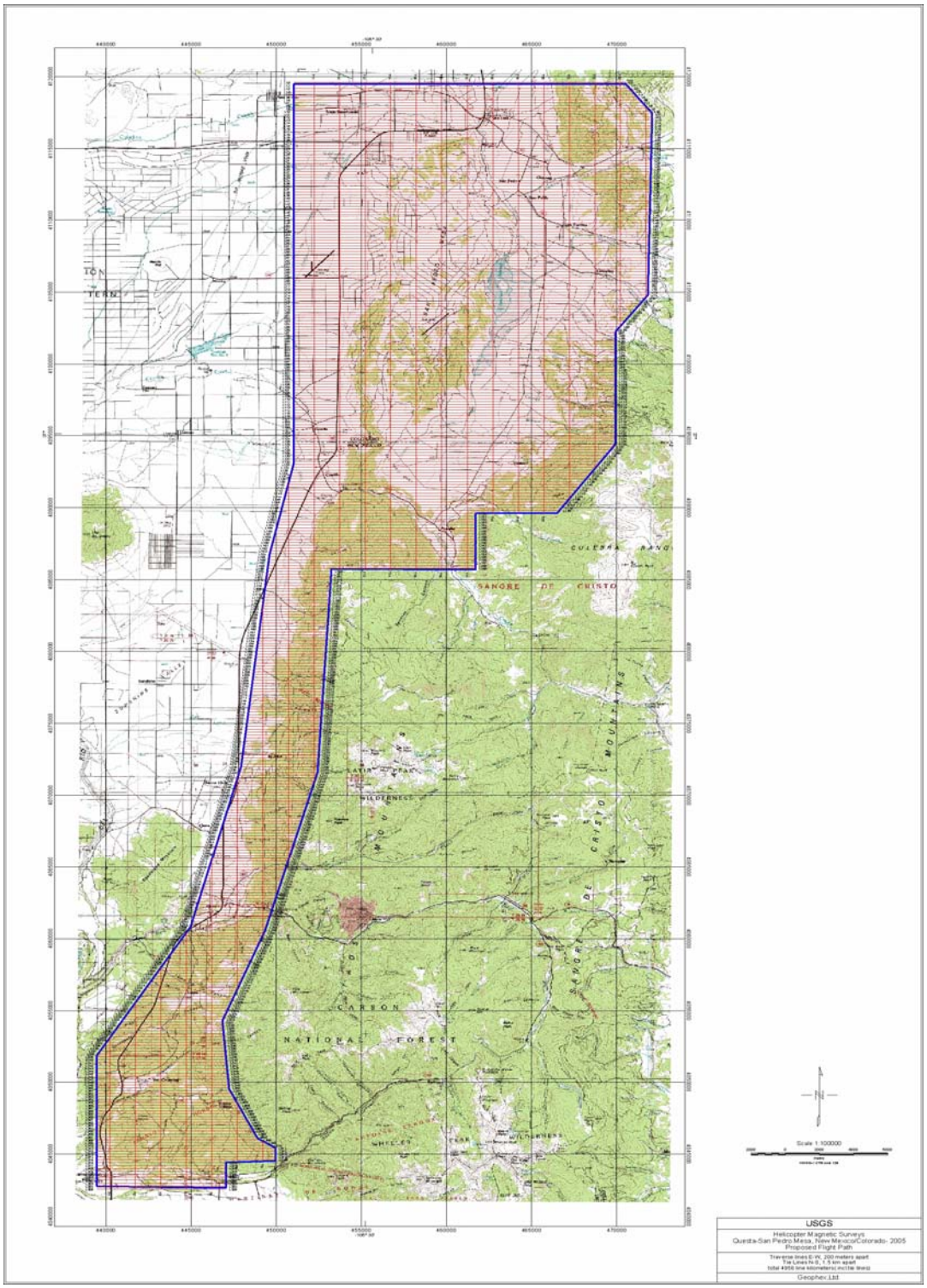


Figure 1-1. Location map for the survey.

2. SURVEY EQUIPMENT

This section provides a brief description of the geophysical and auxiliary instruments used to acquire the survey data:

Magnetometer

The following magnetometer was installed inside the stinger

Model: Geometrics G823A
Type: Airborne cesium-vapor magnetometer
Sensitivity: 0.01 nT
Sample rate: 10Hz

Magnetic Compensator:
An MMS4 Magnetic compensator of Pico Envirotec Inc. was used. Real time or post-mission compensation is optionally available with the MMS-4 processor. Compensation is achieved by combining the frequency measurement from any continuous reading sensor (Cs, K, He) with the measurements of analog outputs of a tri-axial fluxgate magnetometer. Proprietary algorithm combines these measurements and eliminates most of the influence caused by airframe movement through the magnetic field – pitch, roll yaw and aircraft heading.

Magnetic Base Station

Model: Geometrics G823A
Type: portable Cesium magnetometer
Sensitivity: 0.01nT
Sample rate: 1Hz

A digital recorder is operated in conjunction with the base station magnetometer to record the diurnal variations of the earth's magnetic field. The clock of the base station is synchronized with that of the airborne system, using GPS data, to permit subsequent removal of diurnal drift. For the Santa Fe block the ground magnetometer base station is located in Santa Fe airport at a remote location, 35 37.0520 N and 106 04.8214 W. **Figure 2-3A** shows the base station deployed at Santa Fe.

Figure 2-3A. The magnetic base station with GPS RF-link in Santa Fe Airport

For the Questa-San Pedro block, the ground magnetometer base station is located in Questa airport at a remote location, 36 47.56382 N and 105 35.96622 W. **Figure 2-3B** shows the base station deployed at Questa.

Figure 2-3B. The magnetic base station with GPS RF-link in Questa Airport

.

Altimeters

Radar altimeter

Manufacturer:	Terra
Type:	TRA 3000 Radar Altimeter and TRI 40 Indicator
Sensitivity:	5% @ 200ft

Barometric altimeter

Manufacturer:	Vaisala
Type:	PTB 220
Sensitivity:	+/- 0.15hPa @ 20C

Digital Data Acquisition System

Manufacturer:	Geophex
Model:	WinGEM

Tracking Camera

A wide angle video lens connected to a Plextor MPEG4 video converter provided the image. Using a video overlay board (Overlaand Technology Inc.) the GPS time is recorded continuously and is displayed on the margin of each image. This procedure ensures accurate correlation of digital data with respect to visible features on the ground.

GPS Navigation System

For this survey two GPS systems were used:

Model: WAAS
Type: Airborne
Accuracy: sub-meter

The Geophex's on-board navigation system calculates the flight path of the helicopter while providing real-time flight-path guidance to the pilot

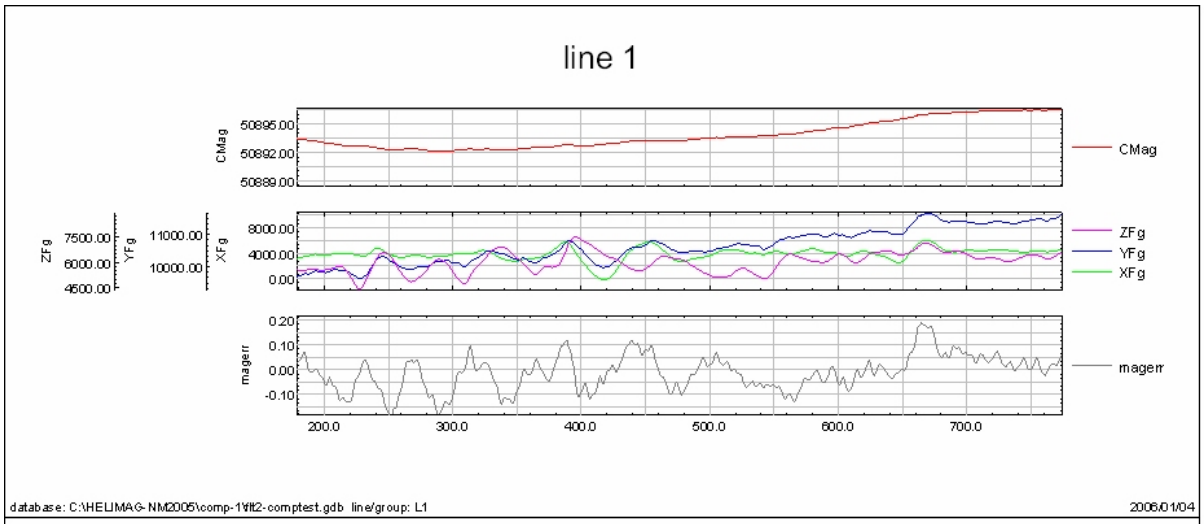
Helicopter and Installations

All data logging instruments, radar altimeter and the video camera were installed in the helicopter. The Cesium magnetometer and the GPS antenna are installed in the stinger as shown in Figure 2.4

Magnetic Compensation tests

Test lines were flown before the survey at Santa Fe, to check the real time magnetic compensation, in four cardinal directions corresponding to the survey line direction. The following Figure 2.1 shows the data. Since Santa Fe is situated at 7700 ft ASL, compensation checks which are normally conducted at ground clearance >7000 ft was not possible. The aircraft safety dictates that the helicopter cannot fly above 10500 ft ASL at the existing temperature conditions. The nominal aircraft altitude for the tests was about 3000 ft above ground and the test data may contain some ground effects. However the data indicates an FOM well below the specifications.

Direction	Roll/Pitch/Yaw maneuver error	total
N	0.2,0.2,0.05	0.45
E	0.1,0.1,0.1	0.3
S	0.15,0.1,0.1	0.35
W	0.15,0.25,0.1	0.5
FOM		1.6nT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CMag
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50892.00
50889.00
ZFg
7500.00
6000.00
4500.00
YFg
11000.00
10000.00
XFg
8000.00
4000.00
0.00
magerr
0.20
0.10
0.00
-0.10
200.0
300.0
400.0
500.0
600.0
700.0
CMag
ZFg
YFg
XFg
magerr
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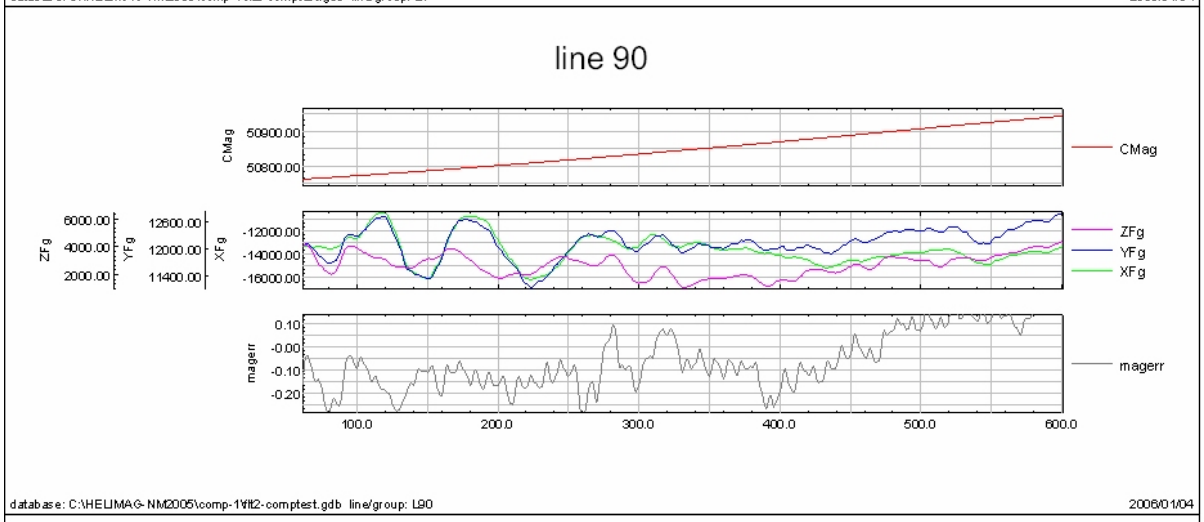
2006/01/04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50900.00
50800.00
ZFg
6000.00
4000.00
2000.00
YFg
12600.00
12000.00
11400.00
XFg
-12000.00
-14000.00
-16000.00
magerr
0.10
0.00
-0.10
-0.20
100.0
200.0
300.0
400.0
500.0
600.0
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XFg
magerr
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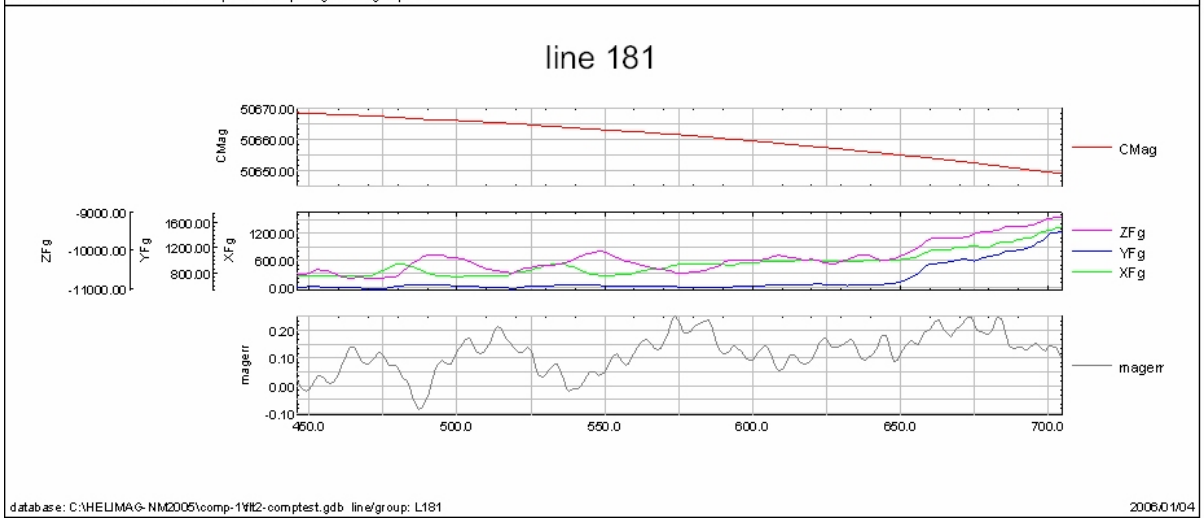
2006/01/04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50660.00
50650.00
ZFg
-9000.00
-10000.00
-11000.00
YFg
1600.00
1200.00
800.00
XFg
1200.00
600.00
0.00
magerr
0.20
0.10
0.00
-0.10
450.0
500.0
550.0
600.0
650.0
700.0
CMag
ZFg
YFg
XFg
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2006/01/04

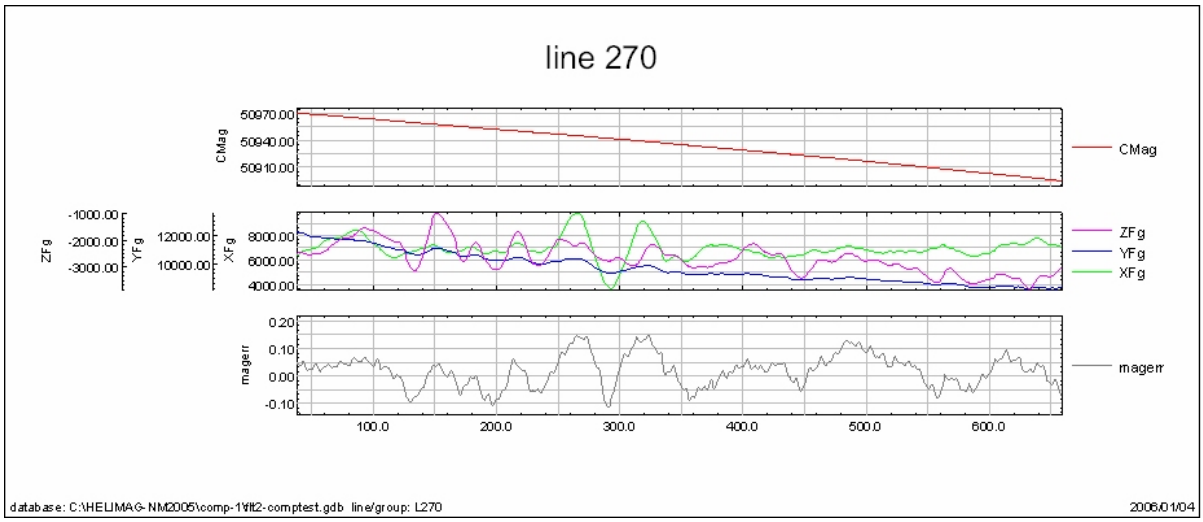

Figure 2.1 Real time magnetic compensation test data in four cardinal directions N,E,S,W.

Figure 2.4 Stinger mounted Helicopter magnetometer survey system

3. PROCESSING TECHNIQUES

Total Field Magnetics

The total-field aeromagnetic data are corrected for the diurnal variation, by subtracting the base station magnetic data (low-pass filtered to remove spikes due to cultural interference). Then the line data was corrected for heading and any remaining small leveling errors. The regional IGRF 2000 has been removed from the data, computed using the GPS location and elevations at each observation point. The geophysical data are interpolated onto a regular grid using a minimum curvature interpolation technique. The grid cell size is 100 m, half the line interval. The gridded data was micro-leveled to remove small amplitude, in between flight line, leveling errors. The resulting grid is suitable for generating contour maps of excellent quality. Two mylar copies of the contour maps of residual total magnetic field map are generated and submitted with the report.

4. SURVEY PRODUCTS

The following products are available from the survey data:

- Digital XYZ archive in Geosoft ASCII format (CD-ROM)
- Digital grid archives in Geosoft format (CD-ROM)
- Contour map of magnetics (1:100,000)
- Survey report
- Flight path video data

5. REFERENCES

Huang, H., and Fraser, D.C., 1999, Airborne resistivity data leveling: Geophysics, **64**, 378-385.

APPENDIX A. LIST OF PERSONNEL

The following personnel were involved in the acquisition, processing, and presentation of data, for a stinger-mounted helicopter airborne geophysical survey carried out for the U.S. Geological Survey over New Mexico and Colorado.

Dak Darbha	Geophysicist – Field operations management and Processing
Frank Funak	Software Engineer – field operator
Brian Grayson	Helicopter Pilot
Mark Geenen	Helicopter Mechanic

All personnel are employees of Geophex, Ltd., except for the pilot and mechanic, who are with Airlift Helicopters, Inc. Dr. Tien Grauch was the technical authority of the project on behalf of the USGS.

APPENDIX B FLIGHT STATISTICS

Date	flights/details	Base
Dec 02,2005	flt2 test flight	Santa Fe
	flt3 survey	
Dec 03,2005	flts 4,5, 6	
Dec 04,2005	flts 7,8,9,10	
Dec05,2005	flts 11,12,13,14	
Dec 06,2005	flts 15,16,17,18	
Dec07,2005	flts 19,20	
Dec 08,2005	Ferry to Questa	
	Flts 21,22	Questa
Dec 09,2005	flts 23,24,25	
Dec 10,2005	flts 26,27,28,29	
Dec 11,2005	flt 30,31,32,33	
Dec 12,2005	flt34,35,36,37,38	
Dec 13,2005	flt 39,40,41,42	
Dec 14,2005	flt 43,44,45,46	
Dec 15,2005	flt 47,, survey complete	

APPENDIX C - ARCHIVE DATA DESCRIPTION

Line-data archives :

Line data are archived in Geosoft ASCII xyz format, described as follows :

line	10.0	line number
fltdir	10.0	flight direction deg from north
LONGITUDE	13.6	wgs84
LATITUDE	13.6	wgs84
X	10.2	wgs84
Y	10.2	wgs84
nad27_x	10.2	
nad27_y	10.2	
fiducial	10.2	
date	10.1	
GPSTime	13.2	time
RALT	10.2	radar altitude in feet
BALT	10.2	baropressure in mbars
GALT	10.2	
bmagf	10.2	base station mag (diurnal nT)
AIRMAG	10.2	raw mag nT
magd	10.2	diurnal corrected mag nT
magdh	10.2	heading and level corrected mag nT
igrf	10.2	IGRF 2000
residmag	10.2	Residual mag nT

Gridded data:

The grids in this directory are in Geosoft format, in WGS84-UTM coordinate system. For each area, 4 grids are presented, described as follows:

1) resid_tr.grd --- residual mag grid in nT.
2) lresid..grd --- microlevelled grid of residual mag in nT.
   This grid was used to produce contour maps.
3) ralt.grd -- radar altimeter grid in feet
4) dtm.grd -- calculated digital terrain in meters