U. S. DEPARTMENT OF THE INTERIOR

U.S. GEOLOGICAL SURVEY

Aeromagnetic Surveying in Wisconsin 1998-99: Digital Data Files

by

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Logistics Report

by

High-Sense Geophysics Limited[3]

Open-File Report 99-527

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ABSTRACT

This CD-ROM contains digital data, image files, and text files describing the data formats and survey procedures for aeromagnetic data collected in the southern one-third of Wisconsin during 1998-1999. The generous use of digital links among files within a digital directory structure promote rapid access to specific information units and data objects.

INTRODUCTION

Over the past 12 years the U.S. Geological Survey has conducted a series of aeromagnetic surveys in Wisconsin aimed at completing the coverage of high-quality, moderate-resolution aeromagnetic surveying in the State. The data from these surveys have proven to be an effective tool for delineating structures in the Precambrian basement in Wisconsin and have been useful in the study of the mineral resources in the region. Precambrian basement rocks rarely crop out in this region because of glacial deposits and Paleozoic sedimentary cover rocks. Surveys by the U.S. Geological Survey (USGS) in 1988 (Hittleman and others, 1992), 1996 (Snyder, 1998), and 1997 (Daniels and others, 1998) have closed gaps in the aeromagnetic coverage of the Midcontinent rift area, adjacent to Minnesota.

The most recent survey flown in 1998-99 is the focus of this report. It extends aeromagnetic coverage southwards to the bottom of the state. This report releases the digital data for that survey. Both digital flight-line and gridded data are included as well as images of the gridded magnetic data presented as one contiguous map. Facts about this survey and parameters for the digital files are given on this CD.

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DATA DESCRIPTION

Navigating on this CD

The data products have been placed on this disk in a digital directory structure that allows specific information and data objects to be found quickly. Beginning at the entry point (the main folder), choose among only three sub-folders and examine the contents of the folder you select. Keep following this procedure until you find the desired information or data object. This process is facilitated if you are using an IBM-style PC computer with a Windows operating system and Word or Adobe compatible reading software. In this case, you can navigate among the read_Nth. files via a system of hyper-links. Begin by opening the read_1st. file in the main folder. The rest should be self-explanatory.

The pdf_pgm\ folder contains a program for reading .pdf files. A pdf reader will allow you to take advantage of the hyper-linked system.

Survey Specifications

The flight lines were nominally spaced 800 meters apart and trended North-South with a flight altitude of 304 meters above ground level. Control-lines were spaced 12500 meters apart and trended East-West. However, in the southeast corner of the survey area surrounding Milwaukee, the flight lines were East-West and the control-lines North-South.

The magnetic data were sampled every 0.1 seconds using a Geometrics G-822a cesium sensor and a High-Sense frequency counter, with a resultant resolution of about 0.005 nT per sample. Data samples were effectively taken every 6 meters of ground distance.

Radar, Barometric, and GPS altitudes were recorded and are included in the line data set found elsewhere on this CD. Base magnetometer data were also collected and are supplied as an independent channel in the line data set. Surveying was disallowed during the relatively few periods of greater geomagnetic activity.

Navigation and position recovery were accomplished using a Global

Position System (GPS) and differential corrections. The expected horizontal accuracy is on the order of 3 meters.

Additional details may be found in the appendix, which contains the logistics report provided by the contractor, High-Sense Geophysics Limited.

Survey Time-frame, Location, and Extent

The survey was flown between September 15, 1998 and February 21, 1999. During this time 74,000 line kilometers of magnetic data were collected.

Excluding three previous survey areas, this survey filled the southern one-third of the state of Wisconsin being bounded on East by Lake Michigan, on the South and West by the Wisconsin state line, and on the North by the 44th parallel, but also included a substantial North-East extension over Green Bay. The index map shows a color map of the complete survey area superimposed on a black and white reference map.

Digital Data Products

The original digital data products included 14 line-data files sampled at 1/10 second intervals and 2 gridded data sets, one magnetic data and the other radar-altitude data. This CD contains those data products plus a 1-second winnowed line-data set and Images of a shaded shaded relief map made from the magnetics grid. Following are short descriptions of each:

Line Data, 1/10-second: An ASCII data set consisting of 14 files that have been compressed. The compressed data files, summaries of the contents of each file, and a channel and format description is given on this CD in the folder named cmpressd\. Additionally, programs and instructions for uncompressing the files (Bracken, 2000) on various computer types are included under cmpressd\cmprpgms\. The uncompressed data set will take about 2 Gb of disk space with each file averaging 150 Mb. The formatting of the ascii files is such that "free-form" reads with a fortran program are difficult; specific formats are necessary.

Winnowed Line Data, 1-second: The original 1/10-second data was winnowed by a factor of 10 to a 1-second interval. These files are included in the winnowed\ folder, taking about 200 Mb. They may be viewed immediately with a good ascii editor. A description of the winnowing process is included in the folder. Their summaries, and channel and format description are the same as the original data.

Gridded Data: Two large gridded data sets were provide by the contractor, one is the final leveled magnetic data, the other of radar altimeter data. Both grids are provided in Grid Exchange format and the magnetics grid has been translated to various

other formats as well. They may found in the grid\ folder along with descriptions of the more common formats. Additionally, A usgs standard file (grid) has been included. This file format may be used directly in the USGS potential-field geophysical-processing software (Phillips, 1997) also included on this CD in the procpgms\ folder.

Imaged Map: A map was produced from the magnetics grid, and images are provided in various formats for 800, 400, and 200 meter pixel sizes. These may be found in the reports\images\ folder. The light source for shading is from the South-East.

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Logistics
Report

for a

High Resolution Fixed Wing Magnetic Survey

of

Portions of the States of Wisconsin, Minnesota, Michigan and Iowa

carried out on behalf of

U.S. Geological Survey
Denver, Colorado

by

High-Sense Geophysics Limited

Toronto, Canada
July 1999
(980825-1)

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1. INTRODUCTION

In September 1998, High-Sense Geophysics Limited was contracted by the United States Geological Survey to provide a fixed wing magnetic survey over an area of interest located primarily in the southern half of Wisconsin, and portions of Minnesota, Michigan and Iowa.

The survey was flown between September 15, 1998 and February 21, 1999. A total of 74015 line-kilometers of total field magnetic data, flown at a nominal line spacing of 800 metres, was collected, processed and plotted on-site.

The technical objective of the survey was to provide high resolution magnetic maps, suited for anomaly delineation, detailed structural evaluation and identification of lithologic trends. Fully corrected magnetic maps were prepared by High-Sense's Toronto office after completion of survey activities.

2. LOCATION

Latitude and longitude coordinates, central meridian and zone used to define the blocks are listed below - see accompanying map for relative locations.

Central meridian: 87° W, UTM Zone: 16

Area 1

Corner No.	Latitude	Longitude
1	43° 30' 00" N	91° 20' 00" W
2	43° 48' 00" N	91° 22' 30" W
3	44° 00' 00" N	91° 33' 30" W
4	44° 02' 30" N	91° 39' 00" W
5	44° 02' 30" N	90° 51' 00" W
6	44° 15' 00" N	90° 51' 00" W
7	44° 15' 00" N	90° 18' 00" W
8	44° 26' 00" N	90° 18' 00" W
9	44° 26' 00" N	90° 02' 30" W
10	44° 00' 00" N	90° 02' 30" W
11	44° 00' 00" N	90° 00' 00" W
12	43° 30' 00" N	90° 00' 00" W

Area 2

Corner No.	Latitude	Longitude
1	43° 00' 00" N	91° 12' 30" W
2	43° 17' 30" N	91° 13' 30" W

3	43° 30’ 00” N	91° 20’ 00” W
4	43° 30’ 00” N	90° 00’ 00” W
5	43° 00’ 00” N	90° 00’ 00” W

Area 3

Corner No.	Latitude	Longitude
1	43° 30’ 00” N	90° 00’ 00” W
2	44° 02’ 30” N	90° 00’ 00” W
3	44° 02’ 30” N	88° 47’ 30” W
4	44° 00’ 00” N	88° 47’ 30” W
5	44° 00’ 00” N	88° 15’ 00” W
6	43° 45’ 00” N	88° 15’ 00” W
7	43° 45’ 00” N	88° 45’ 00” W
8	43° 30’ 00” N	88° 45’ 00” W

Area 4

Corner No.	Latitude	Longitude
1	44° 00’ 00” N	88° 47’ 30” W
2	44° 32’ 30” N	88° 47’ 30” W
3	44° 32’ 30” N	87° 22’ 30” W
4	44° 00’ 00” N	87° 22’ 30” W

Area 5

Corner No.	Latitude	Longitude
1	44° 32’ 30” N	87° 40’ 00” W
2	45° 09’ 00” N	87° 40’ 00” W
3	45° 52’ 30” N	87° 05’ 00” W
4	45° 52’ 30” N	86° 45’ 00” W
5	45° 15’ 00” N	86° 45’ 00” W
6	44° 32’ 30” N	87° 22’ 30” W

Area A

Corner No.	Latitude	Longitude
1	42° 29’ 30” N	90° 29’ 00” W
2	42° 29’ 30” N	90° 39’ 30” W
3	42° 37’ 30” N	90° 43’ 30” W
4	42° 40’ 30” N	91° 00’ 00” W
5	42° 45’ 00” N	91° 06’ 00” W
6	42° 52’ 30” N	91° 07’ 30” W
7	42° 55’ 00” N	91° 10’ 15 W
8	43° 00’ 00” N	91° 12’ 30” W
9	43° 00’ 00” N	90° 29’ 00” W

Area B

Corner No.	Latitude	Longitude
1	44° 00’ 00” N	87° 52’ 30” W
2	44° 00’ 00” N	87° 35’ 19” W
3	43° 45’ 00” N	87° 36’ 16” W
4	43° 22’ 30” N	87° 46’ 19” W
5	43° 09’ 34” N	87° 47’ 28” W
6	43° 09’ 34” N	88° 11’ 23” W
7	43° 22’ 30” N	88° 11’ 23” W
8	43° 29’ 02” N	88° 40’ 49” W
9	43° 36’ 53” N	88° 40’ 49” W
10	43° 36’ 53” N	88° 19’ 56” W

Area C

Corner No.	Latitude	Longitude
1	43° 09’ 38” N	88° 11’ 23” W
2	43° 09’ 38” N	87° 47’ 28” W
3	42° 54’ 30” N	87° 46’ 07” W
4	42° 47’ 12” N	87° 41’ 40” W
5	42° 40’ 52” N	87° 41’ 40” W
6	42° 37’ 30” N	87° 43’ 00” W
7	42° 29’ 18” N	87° 43’ 00” W
8	42° 29’ 18” N	88° 27’ 47” W
9	42° 32’ 45” N	88° 27’ 47” W
10	42° 32’ 45” N	87° 55’ 22” W
11	42° 43’ 45” N	87° 55’ 22” W
12	42° 43’ 45” N	88° 27’ 47” W
13	42° 50’ 05” N	88° 27’ 47” W
14	42° 50’ 05” N	88° 15’ 08” W

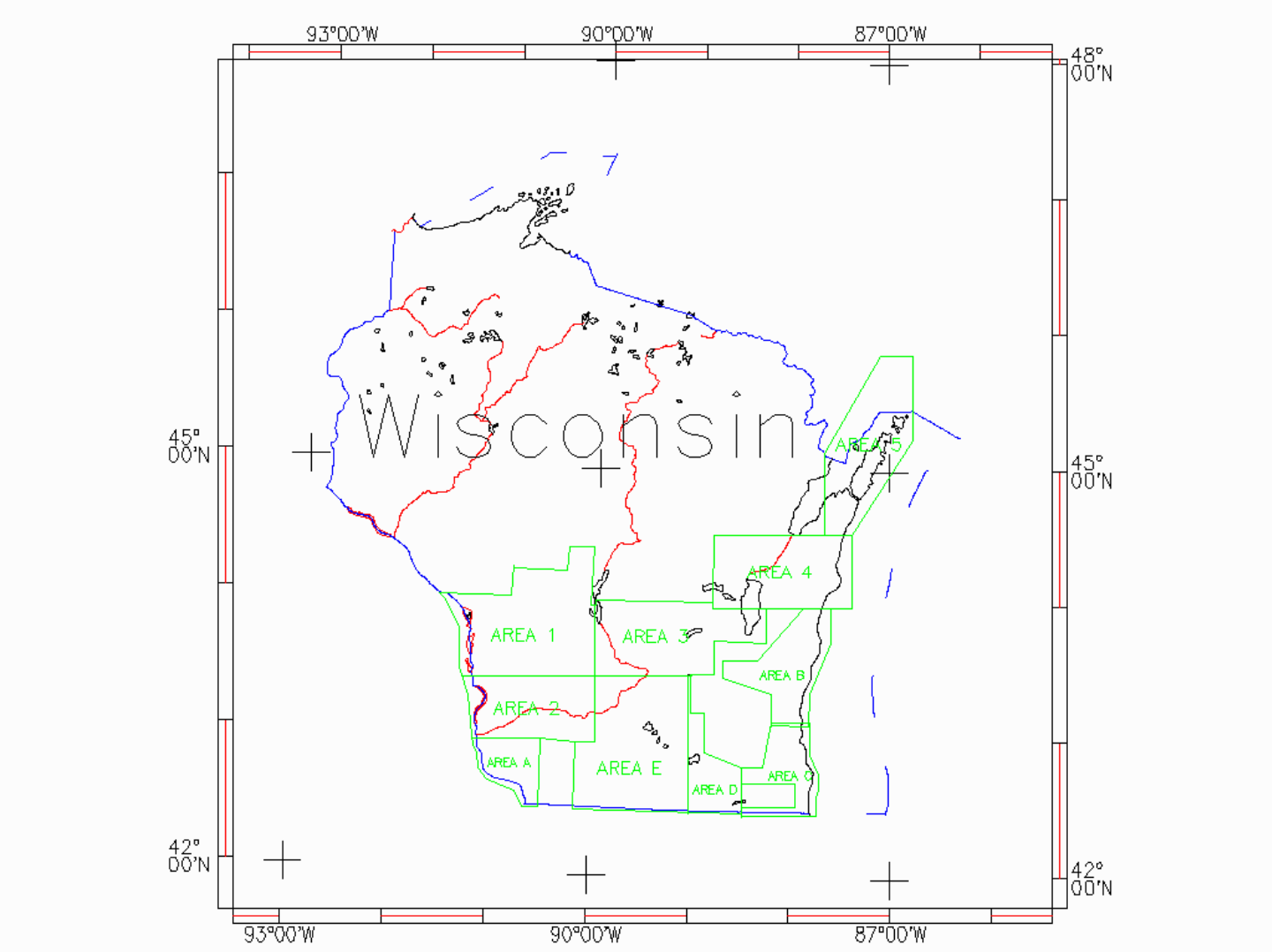
Area D

Corner No.	Latitude	Longitude
1	43° 30’ 00” N	88° 58’ 42” W
2	43° 13’ 29” N	88° 58’ 42” W
3	43° 13’ 29” N	88° 50’ 26” W
4	42° 55’ 36” N	88° 50’ 26” W
5	42° 50’ 05” N	88° 27’ 47” W
6	42° 29’ 30” N	88° 27’ 47” W
7	42° 29’ 30” N	89° 02’ 30” W
8	43° 30’ 00” N	89° 02’ 30” W

Area E

Corner No.	Latitude	Longitude
1	42° 29’ 30” N	90° 08’ 30” W
2	43° 00’ 00” N	90° 08’ 30” W
3	43° 00’ 00” N	90° 00’ 00” W
4	43° 30’ 00” N	90° 00’ 00” W
5	43° 30’ 00” N	89° 02’ 30” W
6	42° 29’ 30” N	89° 02’ 30” W

Location Map: Wisconsin Project Area



3. AIRCRAFT AND EQUIPMENT

3.1 Aircraft

The aircraft used was a Cessna 206 fixed wing (C-GNNN) owned and operated by Bruceland Air of Wiarton, Ontario.

3.2 Airborne Geophysical System

3.2.1 Magnetometer

One Geometrics G-8 22A Optically Pumped Cesium Split Beam Sensor was mounted in a fixed wing pod at the end of the wind. The Larmor frequency output was processed by a High-Sense magnetometer counter that provides a resolution of 10 ppb (in a magnetic field of 50,000 nT this resolution is equivalent to 0.005 nT) ten times per second.

3.2.2 Magnetic Compensation

A Billingsley Magnetics TFM100-1E three axis fluxgate magnetometer measured the orientation and rates of change of the aircraft's magnetic field with respect to the Earth's magnetic field. Correction factors were then generated to compensate for permanent, induced and eddy current magnetic anomalies generated by the aircraft.

3.2.3 GPS Navigation

A Novatel 951 twelve channel GPS receiver, which is an integral component of the HS-GFCS-II flight control system, provided precise positioning.

3.2.4 Altimeter

A Terra TRA 3000 radar altimeter was mounted on the aircraft. This instrument operates with a linear performance over the range of 20 to 1500 metres, and records the terrain clearance of the magnetic sensor.

A Rosemount barometric altimeter was also mounted on the aircraft. This instrument operates with a linear performance over the range of -1000 to 15000 feet.

3.2.5 Geophysical Flight Control System

The High-Sense MiniMag Data Acquisition flight control system monitored and recorded magnetometer, altimeter and GPS equipment. Input from the various sensors was monitored every 0.005 seconds for precise coordination of geophysical and positional measurements. GPS positional coordinates and terrain clearance were presented to the pilot by means of an LCD touch screen display. The magnetometer response, 4th difference, and altimeter profile were also shown on the LCD touch screen display for real time monitoring of equipment performance.

3.2.6 Digital Recording

The output of the magnetometer, compensation equipment and altimeter as well as uncorrected GPS coordinates were recorded digitally on disk at a sample rate of ten times per second by the HSG MiniMag Data Acquisition system. Line number, GPS time and system time were also recorded for use during subsequent differential GPS correction.

3.3 Ground Monitoring System

3.3.1 Magnetometer

A Scintrex H-8 magnetometer was operated as a base station to record diurnal variations of the Earth's magnetic field. Readings with a resolution of 0.1 nT were recorded digitally every second, and synchronized with GPS time for accurate correction of the airborne data.

3.3.2 GPS Monitor

A Magnavox 9200 twelve channel receiver with a fixed antenna was also active at the base of operations. Raw satellite data was digitally recorded to enable differential correction of the corresponding airborne data.

3.3.3 Recording

The output of the magnetic and GPS monitors was recorded digitally on a dedicated PC. A visual record of the last four hours of activity is graphically maintained on the computer screen to provide an up to date appraisal of magnetic activity. At the conclusion of each production flight raw GPS and magnetic data were transferred to the main compilation computer.

3.4 Field Compilation System

A Pentium PC computer and a Hewlett Packard Design Jet 350C colour plotter were used for field data processing and presentation. Processing software and procedures were developed by High-Sense Geophysics Limited, and include the Geopak RTICAD imaging system.

4. PERSONNEL

4.1 Field Operations

USGS Representative	: Robert E. Bracken
High-Sense data processors	: Amir Soltanzadeh
	Steven Green
	Darrick Wagg
Bruceland pilots	: Will Plageman, Tom Martindale
Bruceland Engineer	: Tom Elmes

4.2 Project Management

USGS, Denver office	: Robert E. Bracken
High-Sense, Toronto office	: Ted Urquhart

5. SURVEY PARAMETERS

Traverse Line spacing	: 800 metres
Control Line spacing	: 12,500 metres
Nominal Terrain clearance	: 1000 feet
Navigation	: Global Positioning System
Traverse Line direction	: North-South, (East West for Area C)
Control Line direction	: East-West, (North-South for Area C)
Measurement interval	: 0.1 sec
Airspeed (nominal)	: 210 km/hr
Measurement spacing (nominal)	: 6.0 meters
Airborne Digital Record	: Radar Altimeter
	Barometric Altimeter
	Total Field Magnetics
	Time (Local and GPS)
	Raw Global Positioning System (GPS) data
	Magnetic compensation parameters
Base Station Record	: Ambient Total Field Magnetics
	Raw Global Positioning System (GPS) data
	Time (Local and GPS)

6. OPERATIONS AND PROCEDURES

6.1 Flight Planning

Survey block outlines were specified by USGS (section 2.0), and the coordinates used to generate pre-calculated navigation files. These, in turn, were used by the airborne data acquisition system to plan flights at the designated line spacing of 800 metres.

6.2 Base Station

The GPS and magnetic base station site was established at various locations close to the base of operations for each particular area. A total of four locations were used during the course of the survey. A description and exact position of the locations is listed below:

1. *Green Bay Wisconsin:* The base station was set up in a remote section of the airport.

   44º 29’ 41.98” N **174.6 m asl**
   88º 07’ 50.12” W **(Clarke 1866 spheroid)**

2. *Manitouwoc Wisconsin:* The base station was set up in a remote section of the airport.

   44º 07’ 19.6176” N **168.4 m asl**
   87º 41’ 03.1164” W **(Clarke 1866 spheroid)**

3. *Platteville Wisconsin:* The base station was set up in a remote section of the airport.

   42º 41’ 30.5797” N **278.5 m asl**
   90º 26’ 24.8613” W **(Clarke 1866 spheroid)**

4. *Janesville Wisconsin:* The base station was set up in a remote section of the airport.

   42º 36’ 40.1443” N **203.38 m asl**
   89º 02’ 44.1223” W **(Clarke 1866 spheroid)**

The GPS antenna should be located at an accurately surveyed position point, since positional errors are carried through to the differentially corrected data. Because no suitable control point was available, the location of the GPS antenna was determined by recording 24 hours of GPS data and averaging the resultant antenna coordinates (the assumption being that the deliberate errors introduced by military

selective availability satellite signal distortion will average to zero over an extended period of time).

6.3 Data Compilation

Data recorded by the airborne and base station systems was transferred to the field compilation system. As each flight was completed, the following compilation operations were carried out.

6.3.1 Flight Path Correction

The GPS data was differentially corrected to remove errors introduced by 'selective availability', an intentional accuracy degradation method used by the military. The correction process uses the known fixed location of the base station to calculate the error associated with each satellite. These errors are then removed from the survey GPS data enabling a position to be calculated with an accuracy in the order of three metres, with four or more satellites in view. Satellite visibility and coverage were good throughout field operations. Both GPS receivers were generally tracking a minimum of seven satellites.

The navigational correction process yields a flight path expressed in WGS 84 Latitude-Longitude coordinates. Transformation to local Clarke 1866 (NAD 27) UTM coordinates used the following projection parameters :

	Semi-major axis (a)	Flattening (f)
WGS 84	6378137.0	298.2572201
Clarke 1866 (NAD 27)	6378206.4	294.9786982

Local datum shift applied :

Delta X	:	9
Delta Y	:	-160
Delta Z	:	-176

UTM central meridian = 87º W (Zone 16)

False Easting	:	500,000
False Northing	:	0

6.3.2 Magnetic Corrections

Diurnal variations recorded by the base station were subtracted directly from the aeromagnetic measurements to provide a first order diurnal correction. Aeromagnetic data was compensated for permanent, induced and eddy current magnetic noise generated by the aircraft. Figure of Merit tests were conducted at the beginning of the survey and after each time the orientation of the magnetometer was adjusted (See Appendix A for details).

Control lines flown perpendicular to the traverse lines were used to provide level correction. Residual differences between control and traverse lines were used to carry out a further refinement of diurnal and heading errors. Micro leveling technique was also used to correct any problems not removed by tie line leveling. Any apparent cultural effects noted in the magnetic maps were not removed from either preliminary or final map products.

6.3.3 Map Products and Digital Data

Interim digital data for the blocks were supplied to USGS as the survey progressed. Following processing in the High-Sense Toronto office, copies of the final map products (see below), plus three (2) copies of the digital data (CD-ROM), video cassettes used to assist in tracking the aircraft, and this logistics report were delivered to USGS.

1. Maps at 1:100,000 of the Total Magnetic Field with contours, flight path in triplicate on clear mylar.

2. Maps at 1:100,000 of the radar altimeter with contours, flight path on clear overlay (mylar) in single copy.

Respectfully submitted,

Steven Green, E.I.T.
High-Sense Geophysics Limited
August 25, 1998

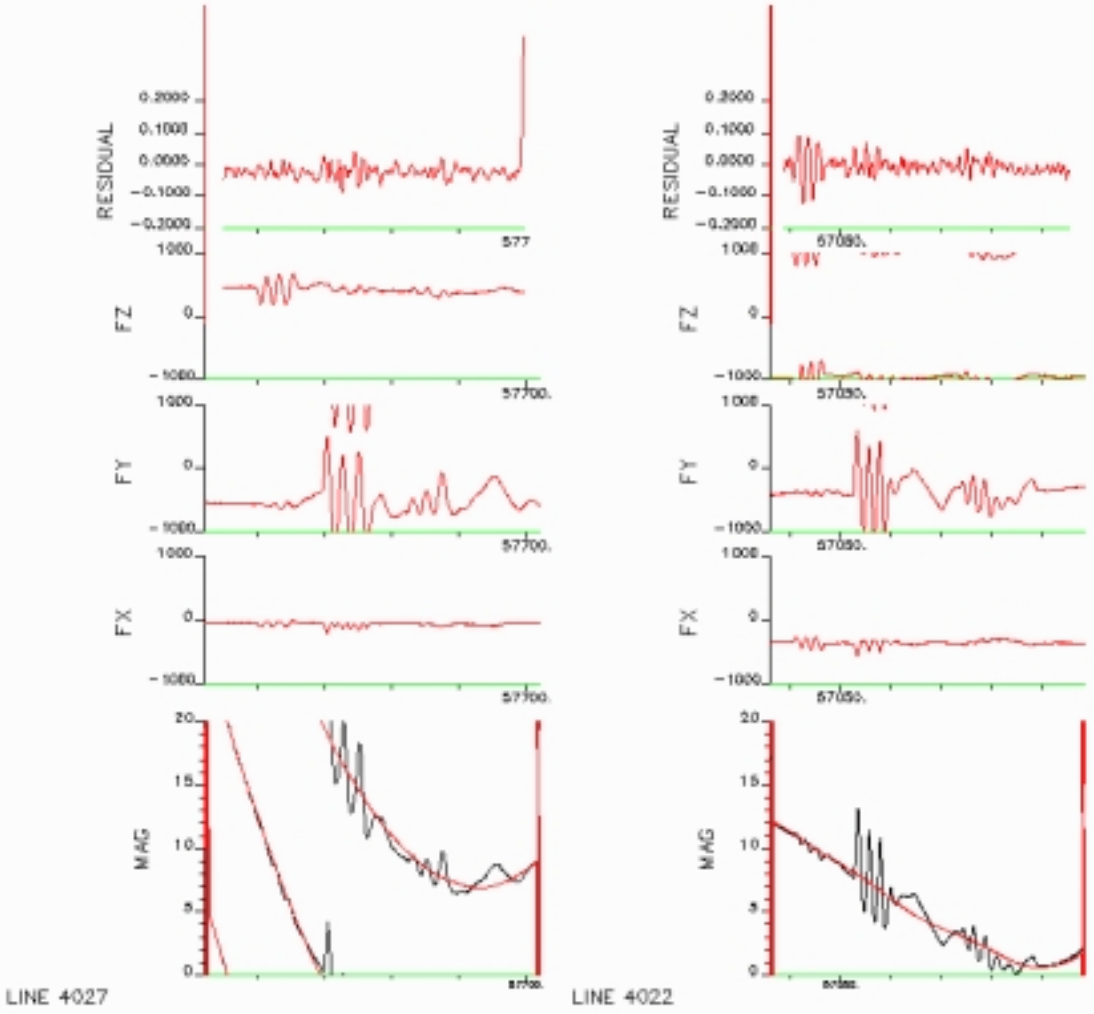
APPENDIX A: Figure-of-Merit

Magnetic Figure-Of-Merit Tests

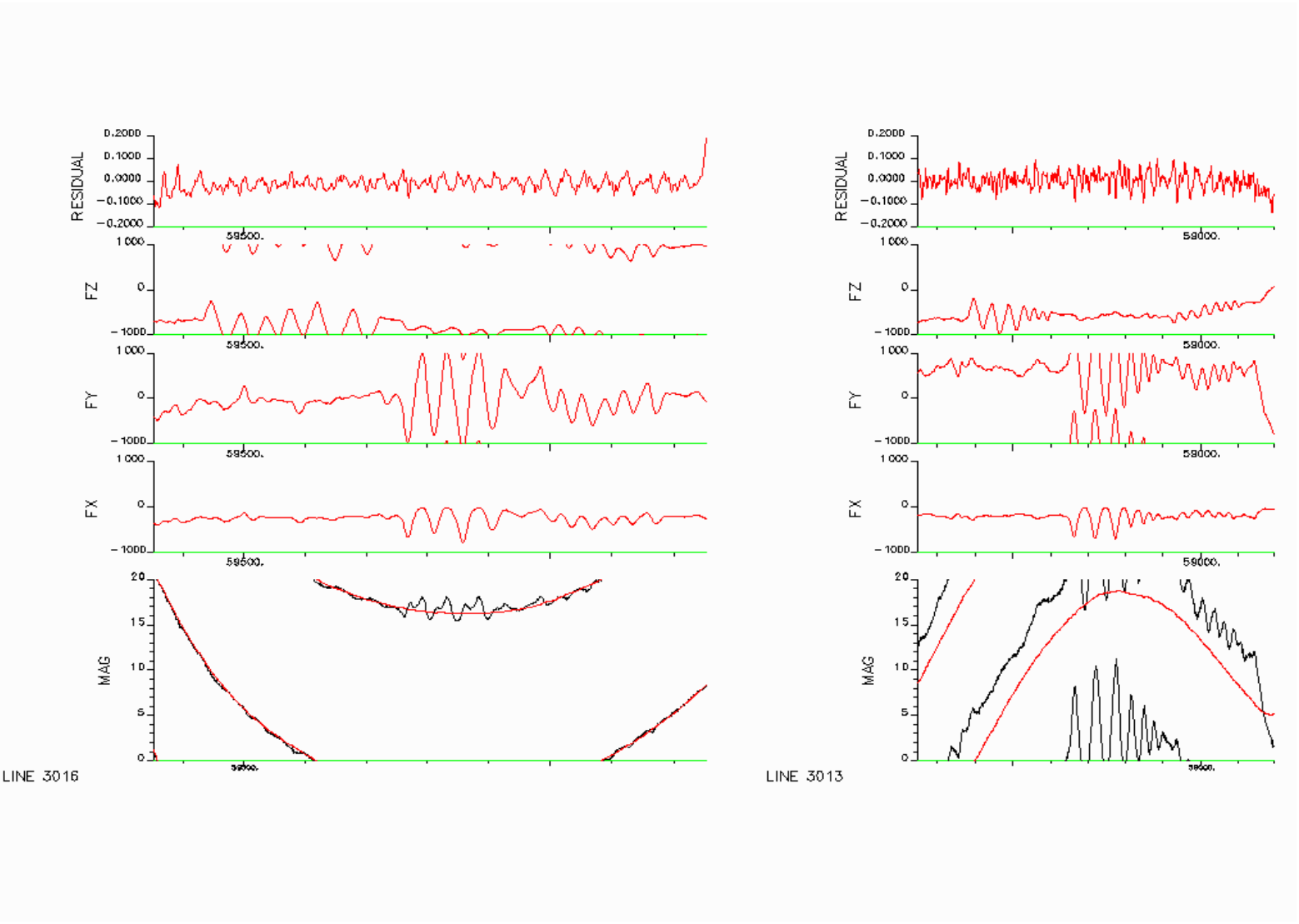
The airborne magnetic record is corrected using an 18 term post-flight digital compensation system that uses magnetic data from the Barrington 3-axis fluxgate magnetometer to determine the aircraft's attitude and rate of change with respect to the earth's magnetic field. The compensation system identifies the permanent, induced and eddy current magnetic contributions of the aircraft and provides a correction to be applied to the raw magnetic data to remove maneuver noise.

In order to calibrate the compensation system, tests are flown at high altitude to determine the effects of aircraft pitch, roll and yaw. The aircraft flies each of the headings aligned with the direction of the survey flight lines and control lines, performing three sets of pitch roll and yaw maneuvers over periods of approximately six, ten and fourteen seconds. The data is subsequently used to calibrate the compensation system.

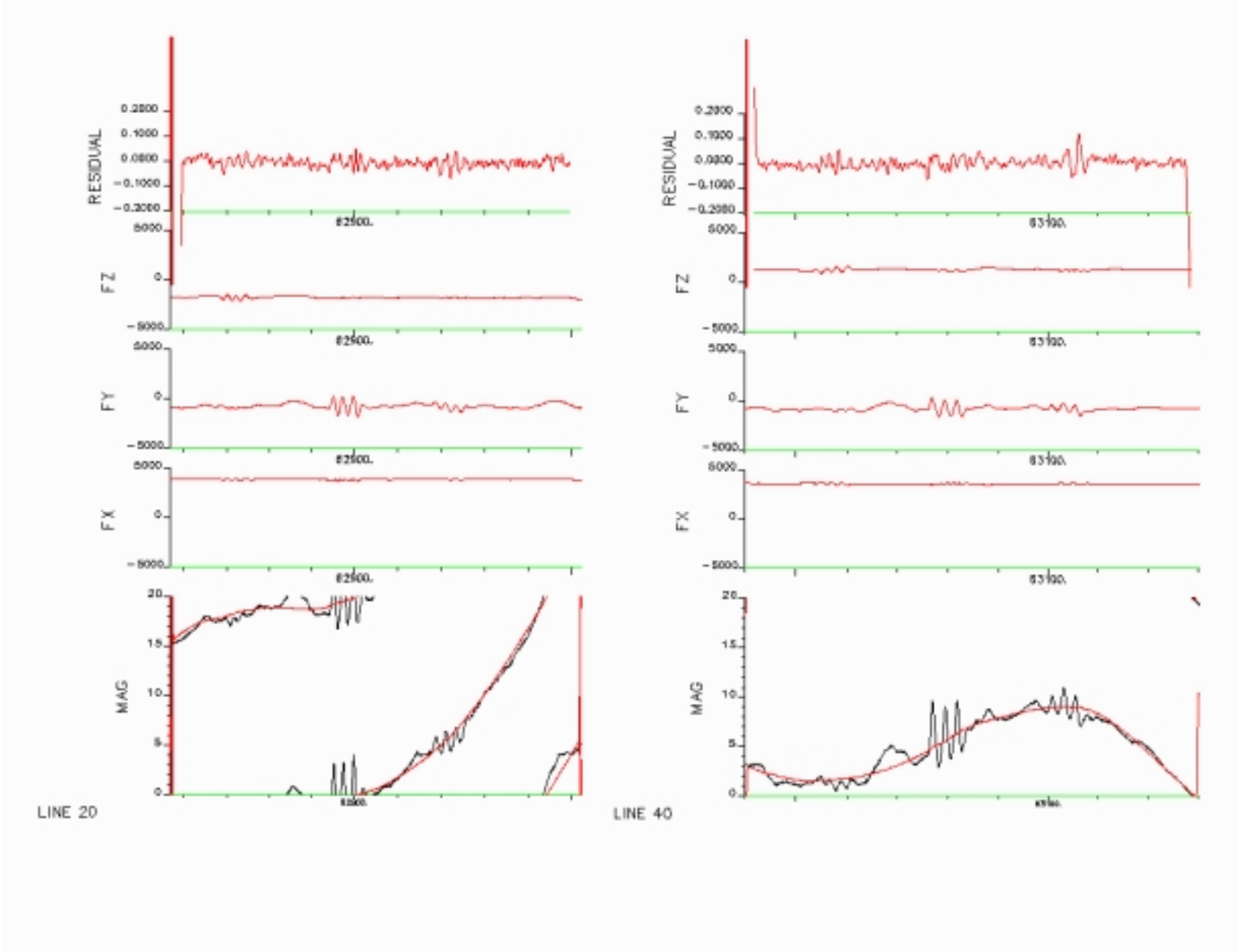
The following figures show the results (raw and compensated magnetic signature) of three Figure-Of-Merit tests: September 20 – 1.18
December 18 – 1.37
February 20 – 1.22



September 20 FOM Results (North: 4027, South: 40)



December 18 FOM Results (East: 3016, West: 3013)



February 20 FOM Results (North: 20, South: 40)

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