DEPARTMENT OF INTERIOR
US GEOLOGICAL SURVEY
BRANCH OF ACQUISITION & FEDERAL ASSISTANCE

AEROMAGNETIC SURVEY
ILIAMNA AND ANCHORAGE AREAS, SW ALASKA

Contract: 00CRCN0009

Project: 00A04-10

by

SIAL GEOSCIENCES Inc.

December 2000

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

1.0 INTRODUCTION

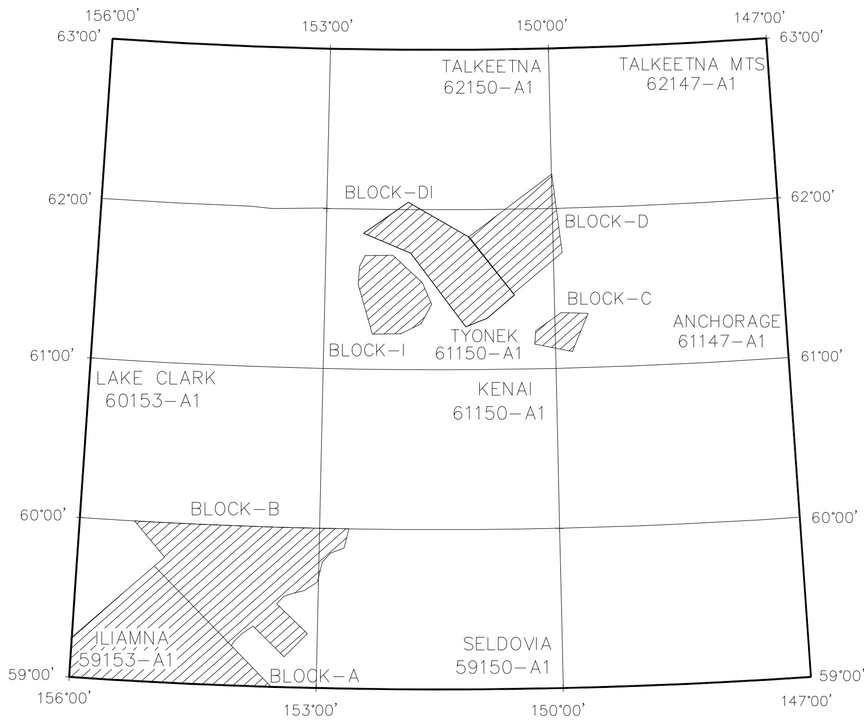
SIAL Geosciences Inc. (SIAL) was awarded U.S. Geological Survey contract no. 00CRCN0009, by the U.S. Department of Interior, Branch of Acquisition & Federal Assistance, on March 31st 2000. This contract required SIAL to carry out high-sensitivity fixed-wing aeromagnetic surveys in the Iliamna and Anchorage areas, Alaska. The survey area is divided in five blocks described in table 1 below. Figure 1 shows the block locations in latitude/longitude coordinates.

The primary goal of this project was to acquire and process digitally recorded aeromagnetic data. The survey was carried out between May 31st and July 27th, 2000. Preliminary archived digital data on CD-ROM were delivered one week later, i.e. August 3rd, 2000. Final products were delivered on October 27th, for block AB, and on November 13th, 2000, for blocks C, D, DI and I.

This report describes the data acquisition and processing procedures as well as parameters and delivery products for this survey.

Table 1: Bocks Surveyed

BLOCK	BEGINNING DATE	ENDING DATE	LINES SURVEYED				
			Terrain Clearance (meters)	Line Direction	Line Spacing (meters)	Tie-line Spacing (meters)	Total Km
AB	May 31st	July 25th	300	135°	1 600	20 000	10 700
C	June 22nd	July 27th	150	90°	800	10 000	1 080
D	June 15th	June 22nd	150	135°	800	10 000	4 300
I	June 23rd	July 26th	150	90°	800	10 000	3 120
DI	June 25th	July 1st	300	135°	1 600	20 000	2 900



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FIXED–WING AEROMAGNETIC SURVEY – ALASKA

FIGURE 1 – LOCATION MAP

SIAL Géosciences inc.

2.0 MANAGEMENT OF SURVEY

Coordination and general management of the project were carried out by Mr. Mouhamed Moussaoui, SIAL's Operation Manager. Mr. Moussaoui acted as liaison between the Project Manager for the U.S.G.S., Dr. Jon Doucette.

The survey and office crews consisted of the following permanent employees of SIAL :

Table 2: Field and Office Crew

POSITION	NAME
Project Manager	Mr. Mouhamed Moussaoui, P.Eng.
Field Geophysicist & Data Processing	Ms. Marie-Josée Bertrand
Field Operator & Electronic Technician	Mr. Marcus Watson
Pilot	Mr. Duane Colbers
Office Data Processing	Ms. Marie-Josée Bertrand, Geophysicist Mr. François Caty, Geologist Ms. Sylvie Robillard, Technician CAD Mr. Albert Sayegh, Technician CAD
Final Report	Camille St-Hilaire, M.Sc.A, Geophysicist

3.0 SURVEY AREA

The survey area, shown on Figure 1, covers portions of the Talkeetna, Talkeetna Mts, Tyonek, Anchorage, Iliamna and Seldovia Quadrangles in South West Alaska. A total of 23,100 line-km (14,366 miles) were flown. Cultural effects in the data are observed, particularly on block C, which is almost centered on Anchorage.

On Blocks AB, C, D, and DI, the observed relief is relatively flat to moderate and did not present significant difficulty in meeting altitude and line spacing specifications. On the other hand, on Block I, extreme topography was observed (steep mountains with incised drainage), which could not be safely flown by fixed-wing aircraft within the requested altitude specifications. Table 3 presents the elevation ranges calculated on each block from the difference between Z-GPS and Radar Altimeter data.

Table 3: Elevation Range

Block	Minimum (meters)	Maximum (meters)
AB	0	2,180
C	0	375
D	0	235
DI	0	1,991
I	38	3,385

4.0 SURVEY EQUIPMENT

All the instrumentation used during the survey met the contractual specifications.

4.1 Aircraft

A Cessna 421 (registration C-GEGH) equipped with a 10-foot stinger, owned and operated by SIAL was used. Average flying speed was 270 km/h.

4.2 Digital and Analog Acquisition System

A RMS DAS-8/DGR-33 data-acquisition system and a HDS60 graphic recorder were used. This system:

- accepted digital data from the magnetometer, radar and barometric altimeters, time and raw GPS positions
- produced a hard-copy graphic record (analog) of both coarse and fine scales data from the magnetometer, 4th difference X-track, radar and barometric altimeter data, fiducial date and time.
- produced a digital machine-readable record of raw data on an external hard-disk

The analog records were of sufficient resolution to enable visual checks to be made of system performance. The chart speed of the analog recorder was 12 mm/sec. One-second intervals were indicated on the analog by means of short tics and fiducial numbers printed at 10-seconds intervals.

The data acquisition system was synchronized to GPS time through a one-second GPS pulse. Synchronization was checked at the end of each day of survey.

4.3 Airborne Magnetometer

Airborne magnetometer:	Geometrics G-822A Cesium Vapor split beam in a tail stinger installation
Sensor static resolution:	better than 0.1 nT
In-flight sensibility:	± 0.001 nT
Dynamic range:	20,000 - 95,000 nT
In-flight noise envelope:	< 0.01 nT
Sampling rate:	ten (10) readings per second or approximately 7.5 meters (25 feet at average aircraft speed of 270 km/s)
Heading error:	< 1 nT
Recording interval:	0.1 sec

4.4 Compensator

The aircraft generated magnetic field was compensated with an Automatic Aeromagnetic Digital Compensator unit (AADCII) yielding digital signal correction of 18 to 30 terms based on the vector field components and their derivatives as measured by a 3-axis fluxgate sensor.

4.5 Radar altimeter

Two radar altimeter were simultaneously used:

Radar altimeter:	King KRA-10	Radar Radio
Range:	20-2500 ft	1-5000 ft
Resolution:	1.6 mV/foot	2 mV/foot
Accuracy:	1% over flat terrain	1% over flat terrain
Sensitivity:	better than 10 feet	better than 10 feet

4.6 Barometric altimeter

Barometric altimeter:	Rosemount 1241
Range:	sea-level to 10,000 ft
Resolution:	1 mV/foot
Accuracy:	± 7 feet
Electronic drift:	< 10 feet/hour

For each flight, the barometric altimeter was calibrated with the radar altimeter pre and post flight and the "drift" was determined by flying over an airstrip of known elevation at several altitudes. This drift and the GPS altitude were used to correct the barometric altitude of flight.

4.7 Navigation and Flight Path Recovery Systems

4.7.1 Video Camera

An ELMO TSN272 color video camera with audio capability recorded the flight path terrain beneath the aircraft. The video camera recorded alphanumerically the flight line number, fiducial, time and GPS generated X-Y UTM coordinates in the top portion of each frame.

4.7.2 GPS

In flight positioning was sampled at a rate of 1 hertz using a TRIMBLE-4000SE real-time differential GPS receiver system, in conjunction with a Land-Star satellite-link and a PICODAS PNAV-4001 navigation console. The system enables data to be positioned to an absolute accuracy better than 5 metres. At least, 4 satellites were monitored at all times during the survey.

4.7.3 Pilot Guidance

In conjunction with the GPS, a Picodas PNAV-4001 Navigation Console provided in-flight navigation control (XY guidance).

4.8 Base Stations

A digital record of the variation of the earth's magnetic field was continually recorded. A digital base station magnetometer was placed near the survey areas in a magnetically clean environment, away from sources of electromagnetic interference or excessive magnetic gradients. Table 4 presents the location of the base station magnetometer. The airborne and base station magnetometers were synchronized with an accuracy better than 1.0 second.

Base station magnetometer:	GEM GSM-19 Overhauser with internal memory (14 days self-sufficiency)

Sensor static resolution:	better than 0.1 nT
Sensitivity:	± 0.001 nT
Dynamic range:	20,000 - 95,000 nT
Noise envelope:	less than 0.1 nT
Sampling rate:	once per 3 seconds

Table 4: Base Station Magnetometer Location

AREA	BLOCKS	DATE	FLIGHT	BASE STATION MAGNETOMETER USED		
				Mean Value (nT)	**X UTM**	**Y UTM**
ILIAMNA	AB	June 15	3-4	56,217	669200	6789700
		June 16 to July 27	5 to 29	56,258	669200	6789400
		June 22	10	55,805	USGS Base Station at Eldeldorf Military Base	
ANCHORAGE	C, D, DI, I	May 31, June 1	2 to 5	53,745	398125	6624675
		June 9 to June 13	7 to 13*	53,420	398126	6624677
		July 10 to July 25	14 to 25	54,965	396500	6624625

* Flights 1, 6, 10 16 and 22 : Bad weather or Tests

On June 22nd, the base station magnetometer failed and SIAL used digital data registered by the USGS base station magnetometer located at Eldeldorf Military base.

4.9 Field Data Plotting and Verification System

4.9.1 Hardware

The field processing system consisted of a Pentium-PC with a high-resolution screen, a Zip tape drive, a Cannon BJ-4000 color bubble-jet printer and a video player.

4.9.2 Software

The computer was equipped with custom and commercial software capable of providing preliminary compilation through initial contours in addition to profile plots required to confirm the validity of data collected on each flight. The software package included Geosoft, Oasis and Nortech HPM differential processing software.

5.0 OPERATIONS - FIELD PROCESSING - VERIFICATIONS

5.1 Summary

The survey base of operation was established at Anchorage or Iliamna.

Bourget calibrations were carried before mobilization to Alaska and after demobilization. The FOM tests were carried at the Merrill Field Airport, Alaska. One FOM test (July 3rd, 2000) is tabulated in Appendix A along with the compilation of all the altimeter calibrations.

Lag-tests, to determine the time difference between the magnetometer and positioning devices, were performed by flying in two directions, at the normal survey height, over a large steel tank that provided an anomaly sufficient to determine the system lag in relation to the GPS positioning data.

Mobilization to Anchorage started on May 25th, 2000. All pre-survey tests and base installations were completed by May 29th. Survey flying commenced on May 31st, and ended on July 27th. Demobilization was completed by August 6th, 2000. All the digital flight logs are presented in Appendix B.

5.2 Quality control

All flight records, the differentially corrected GPS and the base station magnetometer records were merged into a single GEOSOFT-OASIS database on a flight by flight basis. Profiles were examined in detail, on the analog records and mainly using OASIS scrolling and zooming capabilities. The main concerns were the speed check of GPS data, diurnal activity, and altimeter data (mainly radar and GPS Z jumps).

5.2.1 Lag

RMS/GPS synchronization was achieved by the RMS acquisition software. This software uses the 1-pps transmission from the GPS-TRIMBLE console that contains the GPS time. Upon reception of the GPS signal, the corresponding RMS system time was logged. GPS and RMS were recorded as data fields in the raw RMS file at the rate of 1 per second.

5.2.2 Flight Path

Flight path was recovered from the differential GPS X and Y data. It was verified daily to enable reflight to be called where needed.

5.2.3 Magnetic

Field quality control procedures were:

1) application of lag (see section 5.2.1).
2) application of a de-spiking filter. This filter only affects discrete spikes, leaving most of the data untouched.
3) monitoring of compensation quality, especially for flights made over topographic highs
4) visual inspection of magnetic profiles
5) preliminary color maps

Before demobilization, to be sure that data were of good quality, a final check was carried out. Control line magnetic data were gridded separately and the result compared to the survey line grid.

5.2.4 Altimeters

No field processing was applied on the radar altimeter data. Field barometric correction was based on pre- and post-flight barometric measurements made on the airstrip. Corrections were calculated using the known elevation of the airstrip, and were linearly interpolated over the flight data. The barometric data were then compared to the more stable GPS altitude.

The topographic profile was calculated from the difference between the barometric and radar altimeters, and used to detect and correct discontinuities in radar values.

5.2.5 Magnetic base data

After having been merged in the main OASIS database, the base magnetometer data were carefully inspected in order to remove any cultural noise and spikes. A 30 second low-pass filter was then applied to remove small amplitude noise.

OASIS profiles and SIAL software were then used to compare the degree of diurnal activity with contract tolerance. Periods of activity close to or above this tolerance were listed and re-flights done.

5.3 Gridding and color plotting

GEOSOFT line gridding (minimum curvature) software was used in the field. Color maps of the total field, as well as of its derivatives and shadow, were regularly produced in the field, with flight path overlay, in order to evaluate data quality.

6.0 OFFICE COMPILATION

Final compilation was completed in **SIAL**'s head office, Ville St-Laurent, under the supervision of Mr. Mouhamed Moussaoui, P.Eng. Other personnel assigned to this project were Mr. François Caty, Geologist and Computer Scientist (Processing Support), Ms. Sylvie Robillard and Mr. Albert Sayegh, Technicians (AutoCad/Drafting). All field processing steps were exhaustively verified and updated before proceeding further.

6.1 Total field leveling and gridding

For the magnetic survey the steps to be completed at this stage were:

- Complete visual verification of the magnetic profile (de-spike)
- Diurnal correction
- Lag removed
- International Geomagnetic Reference Field (IGRF; Geosoft 1995) computed along each flight line at the appropriate altitude above sea level and removed
- Intersection leveling of the residual field
- Decorrugation
- Production of the deliverable items (maps and archive files).

After long wavelength diurnal and lag corrections were applied and IGRF datum were removed, the final leveling of the total magnetic field was done by intersection analysis. First, all the intersection differences were calculated and examined. A small number of intersections were eliminated because of excessive altitude differences. A statistical leveling was done on each control line by subtracting a second order curve. Secondly, any residual difference between control line/traverse-line was applied on each traverse-line to produce identical values for the intersections.

The magnetic values were then reduced to a regular X-Y grid, using GEOSOFT MONTAJ random gridding (minimum curvature) software and the final grid was contoured. Hierarchies of contour intervals were defined, each with its own dropout density, pen weight, and periodic annotation. The cell size used for gridding was one half the line spacing.

6.2 Altimeters

The corrections to the GPS, barometric and radar altimeter data were done post-survey at the head office. All corrections were directed to the production of a non-corrugated topographic (ZGPS-radar) grid with a zero-level corresponding to sea level.

7.0 DELIVERIES

All maps and final archived digital data on CD-ROM (2 copies) required by the technical specifications of the contract were delivered on October 27th, for Block AB, and November 13th, 2000 (for Blocks C, D, DI and I). Appendix C contains a full description of the digital data archive format. Video tapes and analog charts, along with this project report (2 copies), were delivered in the middle of December, 2000.

7.1 Maps

For Blocks AB and ID, two Mylar copies of residual (IGRF removed) total magnetic field contours were delivered at a scale of 1:250,000. For Blocks C, D and I, the same maps were delivered at a scale of 1:100,000. Universal Transverse Mercador (UTM) projection was used with the following parameters:

-	Datum	WGS 1984 (NAD83)
-	Projection	UTM
-	Central Meridian	153^{o}W
-	Zone	5
-	False Northing	0 meters
-	False Easting	500,000 meter

7.2 Digital Data Recording

Digital data were supplied on CD-ROMS readable by standard common CD-ROM readers, including Mitsumi, Panasonic and Sun. The CD-ROMS contain flight number, line number, fiducial information, as well as latitude-longitude x-y UTM coordinates. Appendix C gives a description of the material CD-ROM's contents.

7.3 Miscellaneous Items

The following miscellaneous items were finally produced:

- Analogue records
- Video tapes
- This technical project report
- Flight log (Appendix B)
- Records of the FOM and Heading tests (appendix A)
- Records of the altimeter calibrations (appendix A)

8.0 CONCLUSIONS

All airborne and ground-based records were of excellent quality. Radar altitude tolerance was well respected with few exceptions in very rugged terrain (Block I).

Data acquisition was generally done in easy diurnal conditions. Although beneficial, diurnal corrections were not by itself effective enough to produce acceptable final maps. The remaining diurnal leveling error, that does not affect map and calculated gradient quality, is however estimated to be in the 1-3 nT range.

GPS results proved to be of high quality and very few intersection displacements were required. Most re-flights were caused by diurnal and bad GPS. The main causes of down-time were the weather, diurnal activity and aircraft maintenance.

It is hoped that the information presented in this report and on the accompanying products will be useful both in planning subsequent exploration efforts and in the interpretation of related exploration data.

Respectfully Submitted,

Camille St-Hilaire, M.Sc.A..
Senior Geophysicist

APPENDIX A

FOM TEST AND HEADING TESTS AND RADAR ALTIMETER CALIBRATIONS

AIRBORNE GEOPHYSICAL SURVEY
ANCHORAGE, ALASKA
Merrill Field Airport
F.O.M. TEST – July 3rd, 2000

- MAG1 = RAW MAG CMA1 = COMPENSATED MAG
- VALUES DETERMINED USING 60 (6 SECONDS) FIDUCIAL HIGH-PASS FILTER.
- VALUES DETERMINED USING THE MAXIMUM PEAK TO PEAK MANOEUVRES.

DIRECTION : 135^0	FID	MAG1	CMA1
PITCH	66874.2-66876.1	2.70	0.05
ROLL	66893.2-66895.0	2.39	0.04
YAW	66914.6-66912.3	1.46	0.07
TOTAL		**6.55**	**0.16**

DIRECTION : 225^O	FID	MAG1	CMA1
PITCH	66998.6-67000.8	3.03	0.06
ROLL	67022.0-67024.1	4.02	0.08
YAW	67038.8-67040.1	0.45	0.06
TOTAL		**7.50**	**0.20**

DIRECTION : 45^O	FID	MAG1	CMA1
PITCH	67110.6-67112.5	3.10	0.02
ROLL	67131.2-67133.1	4.29	0.02
YAW	67149.3-67151.7	2.12	0.05
TOTAL		**9.51**	**0.09**

DIRECTION : 315^O	FID	MAG1	CMA1
PITCH	67227.3-67229.0	2.66	0.05
ROLL	67243.6-67245.2	1.93	0.06
YAW	67264.4-67266.1	1.40	0.05
TOTAL		**5.99**	**0.16**

TOTAL VALUES	MAG1 (UP)	CMA1
	29.55	**0.61**

FOM = 0.61

APPENDIX B

FLIGHT LOGS

For Flight Logs refer to “flight_logs.pdf”

APPENDIX C

CD-ROM ARCHIVE FORMAT

LINE ARCHIVE FILE : BLOCK AB

TITLE	FORMAT	UNITS	DESCRIPTION
LINE	I7		Flight line ID (see note)
X83	F9.1	m	Easting (NAD83, UTM, zone 5)
Y83	F10.1	m	Northing (NAD83, UTM, zone 5)
LON83	F12.6	dec deg.	Longitude coordinate (NAD83)
LAT83	F10.6	dec deg.	Latitude coordinate (NAD83)
FID	F8.1		Fiducial
JDATE	I8		Year and julian date (yyyyddd)
TIME	F8.1	sec	Time UTC (seconds after midnight)
RALT	F7.1	m	Height above ground (radar altimeter)
BALT	F7.1	m	Barometric altitude
ZGPS	F7.1	m	GPS altitude (height above MSL)
DRIFT	F7.2	nT	Diurnal correction applied
MAGO	F9.2	nT	Raw compensated total magnetic field
MAGCB	F9.2	nT	Total magnetic field corrected for diurnal
MAGIGRF	F9.2	nT	Residual Total Magnetic Field, IGRF corrected
MAGLVL	F9.2	nT	Residual TMF, after Tie line leveling
MAGFIN	F9.2	nT	Final Residual TMF, after FFT decorrugation

LINE ARCHIVE FILE : BLOCK C

TITLE	FORMAT	UNITS	DESCRIPTION
LINE	I8		Flight line ID (see note)
X83	F9.1	m	Easting (NAD83, UTM, zone 5)
Y83	F10.1	m	Northing (NAD83, UTM, zone 5)
LON83	F12.6	dec deg.	Longitude coordinate (NAD83)
LAT83	F10.6	dec deg.	Latitude coordinate (NAD83)
FID	F8.1		Fiducial
JDATE	I8		Year and julian date (yyyyddd)
TIME	F8.1	sec	Time UTC (seconds after midnight)
RALT	F7.1	m	Height above ground (radar altimeter)
BALT	F7.1	m	Barometric altitude
ZGPS	F7.1	m	GPS altitude (height above MSL)
DRIFT	F7.2	nT	Diurnal correction applied
MAGO	F9.2	nT	Raw compensated total magnetic field
MAGCB	F9.2	nT	Total magnetic field corrected for diurnal
MAGIGRF	F8.2	nT	Residual Total Magnetic Field, IGRF corrected
MAGLVL	F8.2	nT	Residual TMF, after Tie line leveling
MAGFIN	F8.2	nT	Final Residual TMF, after FFT decorrugation

LINE ARCHIVE FILE : BLOCK D

TITLE	FORMAT	UNITS	DESCRIPTION
LINE	I8		Flight line ID (see note)
X83	F9.1	m	Easting (NAD83, UTM, zone 5)
Y83	F10.1	m	Northing (NAD83, UTM, zone 5)
LON83	F12.6	dec deg.	Longitude coordinate (NAD83)
LAT83	F10.6	dec deg.	Latitude coordinate (NAD83)
FID	F8.1		Fiducial
JDATE	I8		Year and julian date (yyyyddd)
TIME	F8.1	sec	Time UTC (seconds after midnight)
RALT	F7.1	m	Height above ground (radar altimeter)
BALT	F7.1	m	Barometric altitude
ZGPS	F7.1	m	GPS altitude (height above MSL)
DRIFT	F7.2	nT	Diurnal correction applied
MAGO	F9.2	nT	Raw compensated total magnetic field
MAGCB	F9.2	nT	Total magnetic field corrected for diurnal
MAGIGRF	F9.2	nT	Residual Total Magnetic Field, IGRF corrected
MAGLVL	F8.2	nT	Residual TMF, after Tie line leveling
MAGFIN	F8.2	nT	Final Residual TMF, after FFT decorrugation

LINE ARCHIVE FILE : BLOCK DI

TITLE	FORMAT	UNITS	DESCRIPTION
LINE	I8		Flight line ID (see note)
X83	F9.1	m	Easting (NAD83, UTM, zone 5)
Y83	F10.1	m	Northing (NAD83, UTM, zone 5)
LON83	F12.6	dec deg.	Longitude coordinate (NAD83)
LAT83	F10.6	dec deg.	Latitude coordinate (NAD83)
FID	F9.1		Fiducial
JDATE	I8		Year and julian date (yyyyddd)
TIME	F8.1	sec	Time UTC (seconds after midnight)
RALT	F7.1	m	Height above ground (radar altimeter)
BALT	F7.1	m	Barometric altitude
ZGPS	F7.1	m	GPS altitude (height above MSL)
DRIFT	F7.2	nT	Diurnal correction applied
MAGO	F9.2	nT	Raw compensated total magnetic field
MAGCB	F9.2	nT	Total magnetic field corrected for diurnal
MAGIGRF	F9.2	nT	Residual Total Magnetic Field, IGRF corrected
MAGLVL	F9.2	nT	Residual TMF, after Tie line leveling
MAGFIN	F9.2	nT	Final Residual TMF, after FFT decorrugation

LINE ARCHIVE FILE : BLOCK I

TITLE	FORMAT	UNITS	DESCRIPTION
LINE	I8		Flight line ID (see note)
X83	F9.1	m	Easting (NAD83, UTM, zone 5)
Y83	F10.1	m	Northing (NAD83, UTM, zone 5)
LON83	F12.6	dec deg.	Longitude coordinate (NAD83)
LAT83	F10.6	dec deg.	Latitude coordinate (NAD83)
FID	F8.1		Fiducial
JDATE	I8		Year and julian date (yyyyddd)
TIME	F8.1	sec	Time UTC (seconds after midnight)
RALT	F7.1	m	Height above ground (radar altimeter)
BALT	F7.1	m	Barometric altitude
ZGPS	F7.1	m	GPS altitude (height above MSL)
DRIFT	F8.2	nT	Diurnal correction applied
MAGO	F9.2	nT	Raw compensated total magnetic field
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MAGLVL	F8.2	nT	Residual TMF, after Tie line leveling
MAGFIN	F8.2	nT	Final Residual TMF, after FFT decorrugation

Note: The flight line ID is made as shown below:

```
xxxxx---: Line number
-----x--: Line segment
------xx: Direction code  1) north  2) east  3) south  4) west
                          5) NE     6) SE    7) SW     8) NW
```