Direktoratet for mineralforvaltning
med Bergmesteren for Svalbard
Postboks 3021, N-7441 Trondheim

Rapportarkivet 2001

Bergvesenet rapport nr	Intern Journal nr	Internt arkiv nr / rapp.nr	Rapport lokalisering	Gradering
BV **4626**	1364/98			**Åpen**
Kommer fra ..arkiv	**Ekstern rapport nr**	**Oversendt fra**	**Fortrolig pga**	**Fortrolig fra dato:**
	1319-1	Geologiske Tjenester a.s.		

Tittel
High sensitive magnetic and electromagnetic helicopter survey
Evje - Iveland, Ogna - Egersund and Flakstadøy Island Blocks, Part 1

Forfatter	Dato År	Bedrift
St-Hilaire, Camille	aug 1998	America Mineral Fields Inc SIAL Geocsiences Inc Geologiske Tienester AS

Kommune	Fylke	Scannet rapport	1: 50 000 kartblad	1: 250 000 kartblad
Evje Iveland Hå Flakstad	Rogaland Vest-Agder Nordland	☒ Ja Filene finnes på Nettprog (P)	12122 12123 15123 15124 10313	Mandal Stavanger Svolvær

Fagområde	Dokument type	Forekomster
Geofysikk		Evje Ogna Flakstad
Råstoffgruppe	**Råstofftype**	
Malm/metall	Cu Ni Ti	

Sammendrag / innholdsfortegnelse
BV 4626 inneholder tekstdelen med data-CD,
BV 4627 inneholder alle kartbilag.

BILAG TIL JR.NR. 1364/98

AMERICA MINERAL FIELDS INC.

HIGH SENSITIVITY MAGNETIC, AND ELECTROMAGNETIC SURVEY
Evje-Iveland, Ogna-Egersund, and Flakstadøy Island Blocks
NORWAY

FINAL REPORT

Project no.: 98-H03-04

By

SIAL GÉOSCIENCES Inc.

August 1998

SIAL

Table of Contents

Table of Contents (suite)

List of Tables

1.0 INTRODUCTION

This report describes the specifications and results of a high sensitivity magnetic, and multifrequency EM helicopter survey carried out for **AMERICA MINERAL FIELDS INC.** by **SIAL Géosciences Inc.** The field work began June 1, 1998 and was completed June 19, 1998. The final processed data and report were delivered at the end of July 1998.

The survey was located in Norway, and contained three mining blocks requiring a total of 1677.8 line-km of helicopter survey (figure 1). The survey area was outlined on topographic maps supplied to **SIAL** by **AMERICA MINERAL FIELDS INC.** The block-1 is located in the South Central Norway, in the Evje-Iveland area, block-2 is located in the Southwest Norway, in the Ogna-Egersund area, and finally, block-3 is located in the Northwest Norway, in the Flakstadøy Island area.

The purpose of the survey is twofold:

First, the survey must detect anomalous conductive and magnetic areas which may be caused by, or related to economic mineralization

Secondly, the survey must provides magnetic and EM results to assist geological mapping and to indicate structures potentially favourable to the presence of base-metal mineralization.

2.0 SURVEY SPECIFICATIONS

2.1 Lines and data

A total of 1677.8 line-km of helicopter survey was flown on three mining blocks at a nominal line spacing of 200 meters and helicopter ground clearance of 60 meters. The spacing between lines never varied by more than 50% from the nominal line spacing over a distance of more than 3 km. Tie-lines, located at near opposite edges of each block and crossing all traverse lines where also flown. Table 1 summarizes the specifications of each mining block.

Table 1: Blocks Surveyed

BLOCK	AREA	BEGINNING DATE	ENDING DATE	Line Spacing (meters)	LINES SURVEYED	
					LINE DIRECTION	Total Km
BLOCK-1	Evje-Iveland	05/06/98	10/06/98	200	90°	667.6
BLOCK-2	Ogna-Egersund	01/06/98	04/06/98	200	90°	766.3
BLOCK-3	Flakstadöy Island	18/06/98	19/06/98	200	90°	243.9

2.2 Helicopter

The survey was done using two Astar AS-350 helicopters, registration LN-DCF (type B2) and LN-ORJ (type B1), which carried the magnetometer and the EM system. Installation of the survey equipment in the helicopters was done by qualified **SIAL** personnel. The average survey-speed of the helicopters was 100 km/hr and the ground clearance was typically 60 meters. At this speed and with a recording rate of 10 times per second, the distance between samples along survey lines was typically 3 metres for magnetic and EM data.

2.3 Magnetometer System

A GEOMETRICS G822A Cesium split-beam total field magnetic sensor was used, with an inflight sensitivity of 0.001 nT and a sampling interval of 0.1 second. The heading error was ± 0.25 nT and the sensor tolerated gradients up to 10 000 nT/m. The operating range of the sensor was 20 000 to 100 000 nT and the aerodynamic noise envelope was less than 0.5 nT. The magnetometer sensor was towed 12 meters under the helicopter with a nominal terrain clearance of 48 meters.

A GEM GSM-19 Overhausser magnetometer was used as a base station to measure diurnal variation. It operated at a sample interval of 2 seconds. It was located at the survey operation base, in a region of low magnetic gradient and cultural interference. It was used to monitor the fluctuations in the earth's magnetic field. No fluctuation exceeding 10 nT over a one minute period was observed during the survey.

2.4 Electromagnetic system

The electromagnetic system used for this survey has 5 frequencies and was mounted in a rigid kevlar bird of 8 meters length. Its specifications were:

Model:	SIGHEM-5
Manufacturer:	SIAL Géosciences Inc./GEOTECH
Frequencies:	919 Hz, vertical coaxial coils (sensitivity 0.1 ppm) 845 Hz, horizontal copl. coils (sensitivity 0.1 ppm) 4496 Hz, vertical coaxial coils (sensitivity 0.1 ppm) 4162 Hz, horizontal copl. coils (sensitivity 0.1 ppm) 32460 Hz, horizontal copl. coils (sensitivity 1 ppm)
Tx-Rx Separation:	6.45 meters
Noise envelope:	1 ppm
Sampling rate:	10 per second
Time-constant:	0.1 second

The SIGHEM-5 has been developed by electronic engineers at **SIAL** and incorporates state-of-the-art electronics for unequalled stability and sensitivity. The system was calibrated at the start and at the end of the survey, using an external coil. An internal coil was also used about 2 to 3 times per hour during survey flights for instrumental drift corrections. Finally, an external ferrite rod was used to calibrate the phase components of the system at the start of the survey.

Ten (10) EM-channels of In-Phase and Quadrature values, along with monitors for atmospheric and power-line noise, were sampled ten times per second. The EM bird was towed 30 meters below the helicopter with a terrain clearance of 30 meters.

2.5 Positioning System

In-flight positioning was sampled at a rate of 10 per second using an ASHTECH GG 24 channels real-time differential GPS receiver in conjunction with a PICODAS PNAV-2100 navigation console. At least 6 satellites were monitored at all times. The system enables data to be positioned to an absolute accuracy better than 5 meters. The system used a mobile receiver in the helicopter and a reference receiver, located at the base station.

Terrain clearance was sampled twice per second, using a KING KRA10 radar altimeter located in the helicopter. The radar altimeter recorded the ground clearance to an accuracy of about 1 meter. The recording was done in both digital and analog form.

2.6 Ancillary Equipment

- Digital data were acquired using the RMS DGR-33-A recording system in conjunction with an HDS60 thermal graphic printer to obtain analog chart presentation of geophysical data. Data were simultaneously recorded on cartridge-style magnetic tape every 0.1 second for post-flight computer processing.

- A Panasonic colour video camera and cassette recorder operating in NTSC format recorded the flight-path terrain passing beneath the helicopter. Time and fiducial numbers were superimposed on the video recording.

3.0 PERSONNEL

The survey crew consisted of:

Olivier Ayotte:	An experienced electronic technician who operated the geophysical instruments and assisted with helicopter navigation.
Weizhong Shen:	An experienced geophysicist who compiled and checked the data with the in-field work-station, assisted the operations and supervised the field crew
Neils Werring and Bjφrn Steien:	Two professional pilots who flew the geophysical instrumentation safely and within survey specifications.

4.0 DATA PROCESSING

4.1 Flight Path

Flight path was recovered from GPS X- and Y- data recorded on the helicopter and at the base station. It was verified daily in the field to enable reflights to be done when required. For this survey no reflights were necessary and real-time differential GPS navigation was accomplished for all the survey.

4.2 Magnetic Data

The magnetic data were quality controlled using the fourth difference and edited as necessary. All magnetic field measurements were successfully completed and no reflights were required.

The base station magnetometer variations were removed from aeromagnetic data (International Geomagnetic Reference Field (IGRF) was not removed). The resulting data were further levelled using tie lines and gridded at grid cell spacing of 15 meters.

The second derivative of the total-magnetic-field was computed from the total field data by transforming the data set into the frequency domain, applying a transform function to calculate the second derivative, and then transforming it back into the spatial domain.

4.3 EM data

The EM data were levelled using the calibration data. Anomalies were then identified and their conductances were calculated using a vertical dike model.

5.0 SURVEY PRODUCTS

Final maps were produced at a scale of 1:20 000 and display a geophysical parameter, EM anomalies, the flight path, topographic features and UTM registration.

Transparent masters, on a screened topographic base, and three paper-prints of the following final maps were produced and delivered to **AMERICA MINERAL FIELDS INC.** at the end of July 1998:

- Total-Magnetic-Field Contours
- Computed Vertical-Magnetic-Gradient Contours
- EM-Apparent-Resistivity Contours (845 Hz)
- EM-Apparent-Resistivity Contours (4162 Hz)
- EM-Apparent-Resistivity Contours (32 460 Hz)

Two paper-copies of the following final maps were also produced in full color:

- Total-Magnetic-Field Contours
- Computed Vertical-Magnetic-Gradient Contours
- EM Profiles and Anomalies at 919 Hz (Cx) and 845 Hz (Cp)
- EM Profiles and Anomalies at 4496 Hz (Cx) and 4162 Hz (Cp)
- EM Profiles and Anomalies at 32460 Hz (Cp)
- EM-Apparent-Resistivity Contours (845 Hz)
- EM-Apparent-Resistivity Contours (4162 Hz)
- EM-Apparent-Resistivity Contours (32 460 Hz)

The following miscellaneous items were produced:

- Six copies of the digital profile archives in Geosoft format on CD-ROM
- Analogue records and video tapes
- Survey Report (6 copies)
- Digital tabular format of EM anomaly picks (appendix A)

The digital archives include the gridded data, the XYZ data, and vector files of flight lines. All digital data were georeferenced to the standard UTM-system for the area.

6.0 RESULTS

6.1 Magnetic Features

In this section, the magnetic data were essentially interpreted through a qualitative review of the magnetic total-field and computed vertical-magnetic-gradient maps which formed the basic interpretation tools used. A significant amount of information can be obtained from a qualitative this review. The magnetic maps, when interpreted, gives basic information about the geophysical properties of the rocks, which can enhance the geologic interpretation. Interpreted maps show magnetic and non-magnetic units, folds and faults which affect certain igneous, sedimentary and metamorphic rocks and intrusions. The value of the survey does not end with the first interpretation, but rather increases as more is discovered about the geology.

The vertical-magnetic-gradient is obtained with a mathematical algorithm applied to the total-magnetic field grid. This calculation allows the reduction of magnetic components coming from deeper geological units and therefore, the enhancement of magnetic elements located nearer to the ground surface.

The range of the total-magnetic-field observed on the three surveyed blocks are presented in table 2.

Table 2 : Variation Range of the Total-Magnetic-Field

BLOCK	AREA	UTM Map Sheets	Minimum (nT)	Maximum (nT)	Range (nT)
BLOCK-1	Evje-Iveland	1511 IV and 1512 III	47915	52900	4985
BLOCK-2	Ogna-Egersund	1211-I, 1212-II and 1212-III	44686	51009	6323
BLOCK-3	Flakstadøy Island	12	50166	58711	7702

BLOCK 1

On the Evje-Iveland block, the magnetic pattern is quite straightforward. A strong magnetic high is observed at both the Northern and Southern limits of the survey area.

BLOCK 2

On the Ogna-Egersund block, the airborne magnetic survey shows that the block is divided in two areas which show different magnetic backgrounds: a lower one located to the north, and a higher one located to the south. Many important features are also observed:

- The north-central part of the surveyed area is occupy by a large oval-shaped magnetic low. This low magnetic unit represent a huge massif of anorthosite and norite.
- Inside this oval-shaped magnetic pattern, an elongated magnetic high, trending east-west, is present on the western part
- All the southern half part of the survey area is probably occupy by mafic rocks. The vertical-magnetic-gradient map shows clearly that two magnetic dikes cross this area.

BLOCK 3

On the Flakstadöy Island block, the magnetic map shows an elongated magnetic high located in the central part, and crossing all the survey area with a N15°E trend.

6.2 EM Results

The EM anomalies maps represent a compilation and an interpretation (location and conductance, i.e. conductivity-thickness product) of all the EM anomalies detected.

Appendix A summarizes, in a tabular format, the results of this compilation.

An EM survey allows to detect three types of electric conductors. Each type is described hereafter:

6.2.1 TYPE 1 (Bedrock conductors)

Most of the time, the EM anomalies line up from line to line to draw the conductor axis. When a conductor is made up of EM anomalies characterized by well defined and narrow negative In-Phase and quadrature components, this type of conductor is often related to massive sulphide and/or graphite mineralized beds. Under such circumstances, the quantitative interpretation (conductance) of each anomaly is done by assuming a semi-infinite and vertical tabular model. This choice is justified because this model is the best one to represent narrow conductors, typical of sulphur and graphical mineralization.

BLOCK 1

On the Evje-Iveland block, only weak EM anomalies have been outlined and most of them seem to be located along rivers or over lakes.

BLOCK 2

On the Ogna-Egersund block, the strongest EM anomaly (conductance of 9.2 Siemens) has been observed on the flight line 1902, at UTM coordinates 315591 E and 6498623 N. This anomaly is located along a road and even if the associated conductance is quite high, the anomaly must be checked first for cultural effect before to attempt any further work.

BLOCK 3

On the Flakstadøy Island block, many strong type 1 EM anomalies have been outlined along the shore, on the eastern and southern limits of the block. All these anomalies are caused by the conductive seawater.

6.2.2 TYPE 2 (Superficial conductors)

This type of conductor is characterized by a series of wide and flared EM anomalies, more or lest aligned from line to line and with low In-Phase and quadrature components. The calculated conductances are generally weak (limited to a few siemens). This type of anomaly results from horizontal and superficial conductors, as alluvial and lake deposits, glacial cover, some lithological units and conductive overburden. In this case, the interpretation is done with a homogeneous half-space model. Since these conductors are horizontal, the maximum EM coupling is obtained with the horizontal coplanar configurations (945, 4212 and 36 360 Hz), which give the best representation of this type of conductors.

The EM survey shows that, on the three surveyed blocks, many wide and flared type 2 EM anomalies have been outlined. These anomalies are located along river layouts or over lakes and their calculated conductances are so low that they represent probably conductive alluvial and lake deposits.

6.2.3 TYPE 3 (Positive In-Phase conductors)

This third type of conductor consists in a positive In-Phase component without quadrature response. These EM anomalies are associated with highly magnetic lithologies and mineralization with a magnetic susceptibility so high that it affects the In-Phase component. This type of anomalies cannot be considered as "true" conductors but, when they can be, a negative response on the quadrature component is obtained and the conductor is classified as type 1.

On the surveyed blocks, many EM anomalies associated with magnetic highs (positive In-Phase) have been mapped. These anomalies are essentially attributed to zones with higher magnetic susceptibility containing magnetite.

6.3 EM-Apparent-Resistivity Results

The apparent resistivity maps were done with the horizontal coplanar coil configuration at the frequency 36 360 Hz. As mentioned in section 6.2.2, this is the best configuration for mapping horizontal conductors, which may represent conductive overburden, lake and alluvial deposits and some lithological units. Generally, the conductor signature corresponds to a wide area of low apparent resistivity and is interpreted with a half-space model.

Many small conductive areas are outlined on the apparent resistivity maps. Almost all of these areas are located along small river layouts or over lakes and represent probably conductive surface deposits.

On the other hand, the strong conductive areas observed on the Flakstadøy Island block (Block 3), correspond perfectly with the type 1 EM conductors previously mapped with the coaxial coil configurations (section 6.2.1). These conductive areas are due to seawater response.

7.0 CONCLUSIONS

A high resolution helicopter magnetic and electromagnetic survey was flown for **AMERICA MINERAL FIELDS INC.**, by **SIAL Géosciences Inc.**, on three mining blocks located in Nórway.

The magnetic survey provided results which assist the geological and structural mapping of the blocks.

On the other hand, the EM survey shows that:

- On the Evje-Iveland block, only week EM anomalies have been outlined and most of them seem to be located along rivers or over lakes
- On the Ogna-Egersund block, the strongest EM anomaly (conductance of 9.2 Siemens) is located along a road and even if the associated conductance is quite high, the anomaly must be checked first for cultural effect before to attempt any further work
- On the Flakstadøy Island block, many strong EM anomalies due to seawater have been outlined.

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

Respectfully Submitted,

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