Data Acquisition and Processing Report

Helicopter-borne **MobileMT**

Electromagnetic & Magnetic survey

Mt Read Project

in Tasmania, Australia
for Accelerate Resources Limited
by Expert Geophysics Limited

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'Expert Geophysics' Job #18014

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Executive Summary

Expert Geophysics Limited (EGL) conducted a helicopter-borne **MobileMT** electromagnetic and magnetic survey in Tasmania, Australia over one block (Mt Read Project) for Accelerate Resources Limited. Electromagnetic and magnetic geophysical data were acquired using EGL's airborne **MobileMT** system. Please refer to Appendix I for the Company Profile and Appendix II for the **MobileMT** technology description.

The purpose of the survey was mapping bedrock structure and lithology, including possible alteration and mineralization zones, using apparent conductivity corresponded to different depth levels and the magnetic properties of the bedrock units.

A total of 4 production flights were flown to complete 430 line kilometers of the survey over 104 sq.km area.

The survey was flown using helicopter AStar B2, registration VH-ZST, of Tasmanian Helicopters Pty Ltd. The survey production flights started on January, 11, 2019 and data acquisition was completed on January, 14, 2019. The survey operations were conducted from the Strahan town, 40 km north from the survey block.

The survey lines are oriented N 0°E at 200 and 400 m spacing, while six tie lines in the central part of the block are oriented in perpendicular direction to the survey lines and spaced at 500 m.

The geophysical survey results are presented in the form of digital databases, maps, sections and grids. The report describes the data acquisition procedures, equipment and digital data specifications, basic data analysis.

1 Introduction

The report describes the **MobileMT** airborne electromagnetic and magnetic survey that **Expert Geophysics Limited** (**EGL**, Appendix I) performed for **Accelerate Resources Limited** in the period of January 11-14, 2019 over the block of the Mt Read Project in SW Tasmania, Australia. Electromagnetic passive fields and magnetic data were gathered during this survey using **MobileMT** helicopter-borne system (Appendix II).

The Survey Area section of the report contains description of the survey area and flight paths. The Field Operation section includes information about the operation flow, the airport and base stations locations and flights dates. The Survey Equipment section describes the main and ancillary equipment used for the data acquisition. The Data Processing and Deliverables Specifications section consists of main data processing procedures and final products description. The Survey results discussion section includes basic data analysis and recommendations for further data analysis.

The following table includes a brief reference of the survey specifications (Table 1).

Table 1 - Summary Project Information

Client:	**Accelerate Resources Limited**
Client's contact:	• Mobile • Work Email:
Inspector/consultant:	Russell Mortimer Mobile: +61 (0) 400 225 280 e-mail: Russell@sgc.com.au
EGL Job Number	#18014
Survey area location:	Tasmania, Australia, Thomas Creek Prospect, SW from Birches Inlet
Crew and aircraft location:	Strahan town, 40 km N from the survey block
Mag Base station location:	Lat: - 42.562967 Long: 145.4119817
EM Ref station locations:	Lat: - 42.562967 Long: 145.4119817
Block:	Mt Read Project
Total line kms:	430 line-km
Total Survey Area:	104 sq.km
Traverse line direction/spacing:	0^0; 200m and 400 m
Tie lines direction/spacing:	90^0; 500m (6 lines)
Dates flown:	11-14 January, 2019
Helicopter:	AStar B2, VH-ZST, Tasmanian Helicopters Pty Ltd.
Average survey speed:	27 m/sec
Average helicopter terrain clearance:	183 m
Average magnetometer clearance:	110 m
Average EM sensor clearance:	93 m
Coordinates Datum:	WGS84
Coordinates Projection:	UTM, Zone 55S
MobileMT extracted frequencies, Hz:	56, 71, 89, 112, 141, 178, 224, 282, 355, 4511, 5683, 7160, 9022, 11366, 14321

2 Survey Area and Flight Specifications

The **MobileMT** survey area is located about 40 km south from Strahan town (Figure 1). The survey block is outlined by the coordinates listed in Table 2 in the WGS-84 datum, UTM zone 55S. Flight path over the survey block is presented in Figure 2.

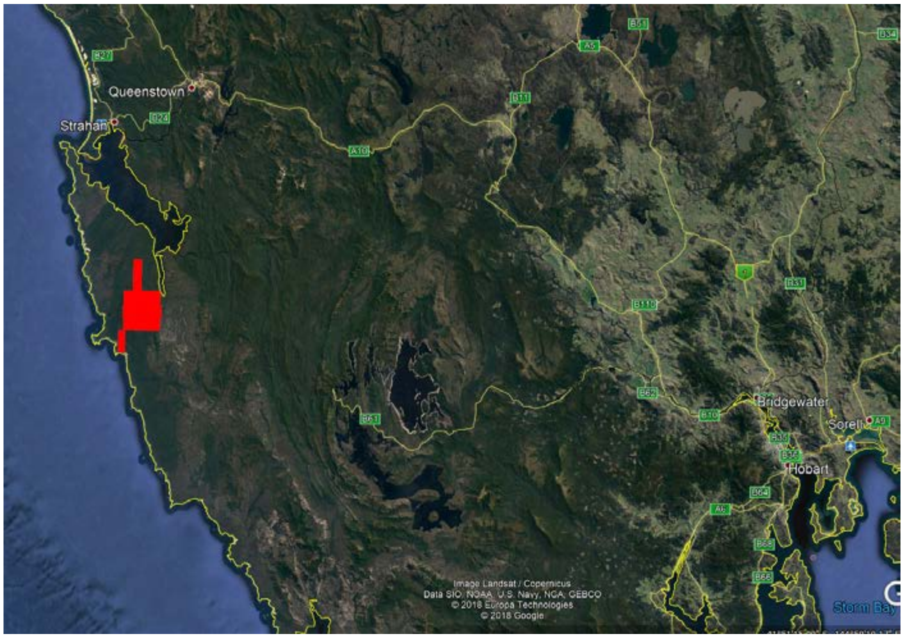

Figure 1 Survey blocks location

Table 2 - Coordinates of the survey blocks (WGS84, UTM zone 55S)

Mt Read Project block	
X	Y
363911	5276327
363872	5281741
365002	5281780
364924	5291400
367339	5291439
367339	5298878
369130	5298917
369091	5291439
373804	5291439
373843	5281663
365391	5281624
365391	5276366

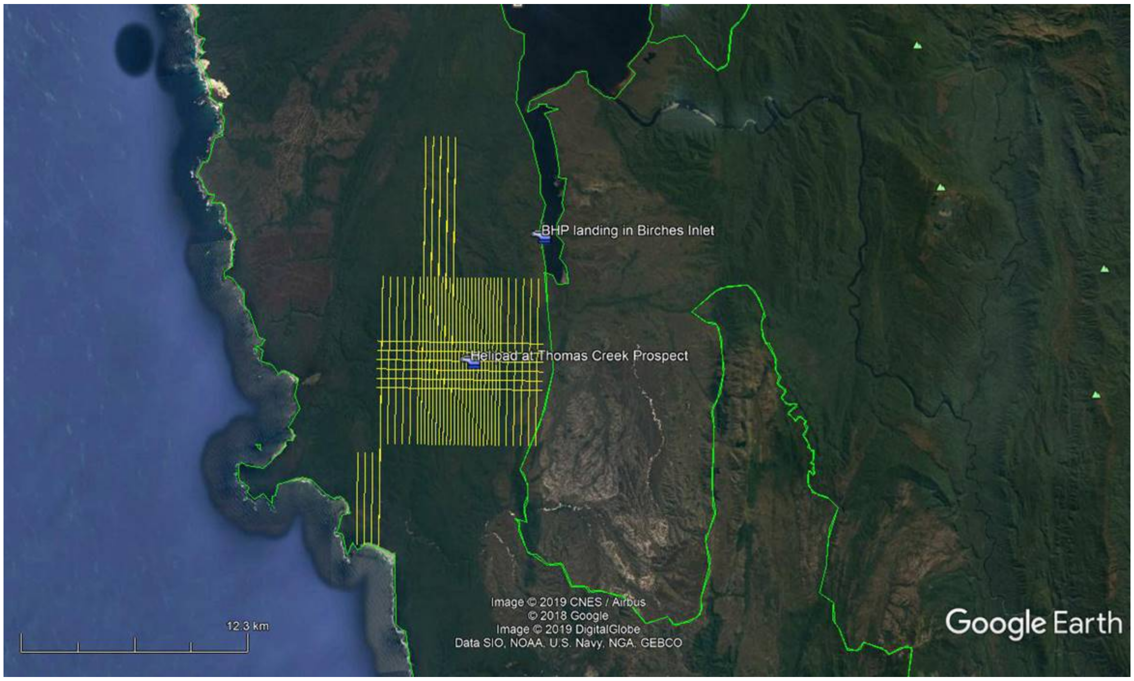

Figure 2 - Survey flight path

The survey flight lines specifications are in Table 3.

Table 3 - Flight lines specifications

Line spacing, m	Lines direction	Line numbers	# of lines	Line kms
200 and 400 m (traverse)	0^0	880-1840	36	373.35
500 (tie)	90^0	5050-5300	6	56.6
Total			**42**	**429.95**

The survey flown with an Airbus Helicopters SAS AStar B2, helicopter operated by Tasmanian Helicopters Pty Ltd., registration VH-ZST.

- Average terrain clearance of the helicopter during the survey was 183 m, at average speed 27 m/sec.
- Average terrain clearance of the magnetometer bird during the survey was 110 m,
- Average electromagnetic sensor terrain clearance 93 m.

3 Field Operations

3.1 Operation schedule

The survey operations were conducted from Strahan. The survey executed in 4 production flights from January 11, 2019 to January 14, 2019.

Table 4 - Operation schedule

Date	Operation	Comments
Jan., 7	arrived in Strahan	
Jan., 8-9	system assembly	
Jan., 10	the helicopter arrived in the morning (a AStar B2 provided by Tasmanian Helicopters Pty Ltd), the equipment installation on the helicopter was completed early in the afternoon. A reconnaissance flight to the survey area/Thomas Creek Camp was flown in the afternoon. The crew picked up the location for the MobileMT base station	
Jan., 11	-Test flight with the EM/mag bird in the middle of the day - Base station installation at the Thomas Creek Camp in the afternoon - Production started in late afternoon - flown 3 lines, 48 km	
Jan., 12	flown 162 km, the total flown is 210 km	
Jan., 13	the remaining lines are flown, the survey is complete.	
Jan., 14	the crew uninstalled the equipment from the helicopter, brought the base station from the site to Strahan and started packing.	The crew will be leaving Strahan, January 16th.

3.2 Aircraft parking and base stations locations

Locations of the aircraft parking, magnetic base station and MobileMT reference base station are specified in Table 5 and in Figure 1 and **Figure 2**.

Table 5 - Aircraft parking and base stations locations

	Latitude	Longitude
Aircraft parking	-42^{0}09'.2	145^{0}20'
Mag base station	- 42.562967	145.4119817
EM Ref base station N1	- 42.562967	145.4119817

3.3 Re-flights

Identified, during the survey quality control (QC), and re-flown flight-lines specified in Table 6

Table 6 - List of re-flown lines

Line Numbers	Length, km	Reason
1300, 1340, 1380	51 km	Noise from the helicopter engine air fan (the fan was turned off on the later flights)
5200	9 km	Interference from the cell phone

Only accepted by QC lines data are included into the final database.

3.4 Field Personnel

The following personnel participated in the field operations:

Project Manager: Andrei Bagrianski

Crew Chief/DataQC, Processor: Andrei Bagrianski

Operator/Tech.support: Michael Kuzmin

Pilot: Andrew Kerr

4 Survey Equipment and Specifications

4.1 Equipment composition

The main instrumentation installed on the **MobileMT** tow-bird:

- Three orthogonal induction coils (1.4 m diameter each) to measure naturally occurring magnetic fields in the frequency range 25 Hz – 20,000 Hz
- Geometrics G822A Cesium Magnetometer, installed in a separate towed-bird, 20 m above the **MobileMT** bird, sensitivity of 0.001 nT/10 Hz sampling
- GPS antenna, installed on the towed-bird with the magnetometer.

The main instrumentation installed on the helicopter:

- EGL PC-104 based Data Acquisition System
- EGL Navigation system with Pilot Steering Indicator

- Smartmicro model UMRR-0A Radio Altimeter, 0 – 500 m range
- GPS antenna, installed on the helicopter tail

Base Stations and Ground Support instrumentation comprises:

- **MobileMT** Ground Base Station, 4-channel (2 channels for signal and 2 channels for reference signal), to measure variations of the electric field in two directions with 4 pairs of electrodes. Electrical line length – 50 m each line, direction X – 85 degrees, Y – 175 degrees (N1 base station); direction X – 40 degrees, Y – 130 degrees (at Dufferin base station)
- GEM Systems GSM-19 Base Station Magnetometer, 0.1 nT sensitivity, with data logger;
- A Field Data Processing Workstation and a full suite of software for the quality control and preliminary processing of the airborne geophysical data.

MobileMT EM system
MobileMT EM specifications:

- Airborne receiver: Three orthogonal induction coils (1.4 m diameter each)
- Airborne shell: Aerodynamic shaped capsule
- Digitizing rate: 73,728 Hz
- Tow cable length: 97 m
- Ground sensors 4 pairs of electrodes
- Electrode separation 50 m (typical)
- Frequency range: 25 Hz – 20,000 Hz
- Output computed parameters: Apparent conductivity for selected frequencies
- Output frequencies: Selectable from 25 Hz – 20,000 Hz depending on signal strength

Selected frequencies and corresponded frequency gates are in the Table 7

Table 7 - Frequency gates extracted from the data (Hz)

Start	End	Center	Start	End	Center
47.9	64.0	55.9	3859.4	5162.2	4510.8
60.3	80.7	70.5	4862.5	6503.9	5683.2
76.0	101.6	88.8	6126.4	8194.4	7160.4
95.7	128.0	111.9	7718.7	10324.3	9021.5
120.6	161.3	141.0	9725.0	13007.8	11366.4
152.0	203.2	177.6	12252.7	16388.8	14320.8
191.4	256.1	223.8			
241.2	322.6	281.9			
303.9	406.5	355.2			

4.2 The Airborne Magnetometer System

The airborne magnetometer system is a state-of-the-art system developed by EGL. It utilizes a Geometrics G822A cesium magnetometer sensor, installed in the towed-bird and the high accuracy Larmor frequency counter developed.

4.3 The Airborne GPS Navigation System

EGL uses a proprietary GPS navigation system utilizing the GPS Receiver with Linx RXM-GNSS-TM GPS Engines. The key features of the GPS Receiver are:

• L1 1575.42MHz, C/A code

• 33-channel satellite tracking

• Position accuracy: 2.5m

• 10 Hz update rate

• Constellation System Support:

- GPS
- GLONASS
- GALILEO
- QZSS

• DGPS support:

- (SBAS) Satellite-Based Augmentation System
- (RTCM) Radio Technical Commission for Maritime Services
- (WAAS) Wide-Area Augmentation System
- (EGNOS) European Geo-Stationary Navigation System
- (MSAS) MTSAT Satellite-Based Augmentation System
- (GAGAN) GPS-Aided Geo-Augmented Navigation

An EGL Computer/Pilot Steering Indicator is used to compute the flight path grids in real-time onboard the helicopter (Figure 3, Figure 4).

Figure 4. EGL Navigation Computer, Moving-map Display

Figure 3. Pilot Steering Indicator and Radio Altimeter Indicator

4.4 Data Acquisition System

The data acquisition system features an EGL PC-104-based data acquisition system. The EGL data acquisition system is an instrument developed by EGL for airborne geophysical data acquisition tasks. It features EGL proprietary technology and software. The EGL data acquisition system simultaneously records data on internal flash disk and displays it on a color LCD display, at a repetition rate of 0.33 sec, for post-flight computer processing. The five main functions fulfilled by the data acquisition system are: 1) system control and monitoring, 2) data acquisition, 3) real-time data processing, 4) navigation, and 5) data playback and analysis.

4.5 Radar-Altimeter

A Smartmicro model UMRR-0A radar altimeter system records the ground clearance to an accuracy of 3% over a range of 0 ft to 1,640 ft (0 to 500 m). The altimeter is interfaced to the navigation system and the data acquisition system with an output repetition rate of 10 Hz and digitally recorded.

4.6 MobileMT ground base station

The MMT Ground Base Station comprises:

• 4 pairs of electrodes, 50 m separation each;

• EGL PC-104 based Data Acquisition System with a GPS system to record the GPS time together with the electric data;

• A power supply unit.

4.7 MobileMT Magnetometer base station

The Magnetometer Base Station was a GSM-19 Overhauser magnetometer.

The base-station magnetometer, with digital recording, operated continuously throughout the airborne data acquisition, with a sampling interval of 0.2 seconds, and sensitivity of 0.1 nT. The ground and airborne system clocks synchronized using GPS time, to an accuracy of far better than 1 second. At the end of the day's work, the digital data transferred from the base station's data-logger to the FWS. This base station located in a place with low magnetic gradient (less than 2nT/m). The base station sited away from moving steel objects, vehicles or hydro transmission lines to ensure minimum interference and noise levels.

4.8 Field Computer Workstation

The Field Data Processing Workstation (FWS) is a dedicated computer system for use at the technical base in the field. The workstation to be used on this project is designed for use with Geosoft OASIS Data Processing Software. It is also capable of processing and imaging all the geophysical and navigation data acquired during the survey, producing semi-final, preliminary-levelled maps.

The main features of the FWS are:

- Portability;
- Digital Data Verification - flight data quality and completeness were assured by both statistical and graphical means;
- Flight Path Plots - flight path plots quickly generated from the GPS satellite data to verify the completeness and accuracy of a day's flying;
- Versatility - the FWS used in both the field and the office. Data pre-processed in the field up-loaded to the computers at the Data Processing Centre to speed up data turnaround;
- Preliminary Maps - the FWS software permitted creation preliminary maps of the electromagnetic and magnetic data during the survey;

- Quality Control – acquired data quickly and efficiently checked for quality in the field on daily basis.

5 Data Processing and Deliverables Specifications

5.1 EM Data Processing

The data recorded by the towed bird sensors (three mutually orthogonal dB/dt components of the EM field) is first merged with the recorded two mutually orthogonal electrical components of electric field on the stationary base station into one file. The program which is proprietary of EGL applied the FFT to the records of the merged file and calculates the matrices of the relation between the magnetic and electrical field signals on the different time bases and in the different frequency bands. The module of the determinant of each matrix is a rotation invariant parameter and it is used as an output parameter.

The frequencies for the data processing selected at the beginning of the survey based on the signal strength and the local noise interference. The selected 15 frequencies for the survey presented in the Table 7.

As an additional product, apparent conductivity data (EM final processed data), was transformed through apparent resistivity curve $\rho_A(\sqrt{T})$ (where T is period), into resistivity-depth profile $\rho(z)$ with Molochnov-Viet method (Berdichevsky, Dmitriev, 2002[1]):

$$\rho(\sqrt{T}) = \begin{cases} \rho_A(\sqrt{T})\left[1 + \dfrac{1}{2}\dfrac{d\log\rho_A(\sqrt{T})}{d\log\sqrt{T}}\right]^2 & \text{for } \dfrac{d\log\rho_A(\sqrt{T})}{d\log\sqrt{T}} \le 0 \\ \rho_A(\sqrt{T})\left[1 - \dfrac{1}{2}\dfrac{d\log\rho_A(\sqrt{T})}{d\log\sqrt{T}}\right]^{-2} & \text{for } \dfrac{d\log\rho_A(\sqrt{T})}{d\log\sqrt{T}} \ge 0 \end{cases}$$

$$z(\sqrt{T}) = h_{eff}(\sqrt{T}) = \sqrt{\frac{\rho_A(\sqrt{T})T}{2\pi\mu_o}} \;.$$

,where h_{eff} is effective penetration depth which is proportional to the skin-depth (δ) $\frac{1}{\sqrt{2}}\delta$.

The Molochnov-Viet transformation done for data visualization in the form of resistivity-depth sections and producing 3D resistivity-depth databases.

[1] Berdichevsky, M.N., and Dmitriev, V.I., 2002, *Magnetotellurics in the context of the theory of ill-posed problems*, Investigations in Geophysics **11**, SEG, Tulsa.

5.2 Magnetic Data Processing

Raw total magnetic field data are recorded at 0.1-second sampling intervals.

The Earth's magnetic field is known to vary as a function of time. Time varying magnetic events such as magnetic storm transients and more regular diurnal variations which occur during the acquisition of magnetic data may affect the accuracy of the survey data and distort magnetic anomalies. Separation of the time-dependent variations in the magnetic field from a real geomagnetic anomaly requires an independent estimate of the transient magnetic field events. Base station magnetometer data provides this independent estimate. The diurnal base station data was analyzed for spikes and spurious sections which were manually removed from the dataset. A 10 point low pass filter was then applied to the diurnal data.

The magnetic data was corrected for the diurnal variations, leveled and filtered. Raw magnetic data has initial pre processing only (spike removal, short gaps interpolated). On the next stage, all of the magnetic data processed by an adjustment procedure that statistically treats the line data. It is designed to recognize and remove systematic bias and small random errors in the data which can cause survey line mis-ties. Bias errors in the magnetic data arise from changes in the level of the total magnetic field.

To remove bias errors, each profile of a given data set in the survey was shifted up or down systematically by an amount such that the sum of the square of the mis-tie errors for that data set over the entire survey network is minimized. The systematic corrections are further constrained such that the sum of the systematic corrections is zero, effectively eliminating DC shifts to the network as a whole. After this systematic adjustment, the remaining intersection mis-ties studied and removed. The final statistical choice of the data values at each intersection is a function of the reliability weights of each line for each data set. The random error correction for each data set prorated between intersections. After editing the adjusted line data for line pulls and data quality, they were input to a minimum curvature gridding algorithm and a grid produced.

IGRF (International Geomagnetic Reference Field) was removed from the processed magnetic data for isolating the regional field background and better locating magnetic anomalies. Reduce to Pole transformation (RTP) was applied to both, to observed and to extracted IGRF magnetic field, to fix asymmetry of magnetic anomalies due to possible displacement of the magnetization vector from vertical direction.

5.3 Ancillary data processing

Positions and altitudes of the magnetic sensor and EM receiver are derived from data of two GPS antennas (A – on the helicopter, B- on the magnetic sensor bird) and radar-altimeter positioned on the helicopter. A digital elevation model (DEM) channel has been calculated by subtracting the filtered radar-altimeter data from the GPS-A elevation.

5.4 Data Deliverables

The following products are available from the survey data.

Databases:

Electromagnetic and Magnetic data are presented in two separate databases in Geosoft DGB format:

- 18014_AccelRes_EM.gdb with EM data
- 18014_AccelRes_MAG.gdb with magnetic data

The databases channels description is in the Table 8 and Table 9.

Table 8 - Geosoft 18014_AccelRes_EM.gdbData Format

Channel Name	Units	Description
xe:	metres	EM bird UTM Easting WGS84 Zone 55 South
ye:	metres	EM bird UTM Northing WGS84 Zone 55 South
ze:	meters	EM bird elevation above geoid
gtime:	Sec of the day	GPS time
RdAlt:	metres	helicopter terrain clearance from radar altimeter
alt_e:	Metres	EM bird terrain clearance
DTM:	metres	Digital Elevation Model
PLM:	Units	Powerline monitor
ac_56:	mS/m	Apparent Conductivity for freq 55.9 Hz
ac_71:	mS/m	Apparent Conductivity for freq 70.5 Hz
ac_89:	mS/m	Apparent Conductivity for freq 88.8 Hz
ac_112:	mS/m	Apparent Conductivity for freq 111.9 Hz
ac_141:	mS/m	Apparent Conductivity for freq 141.0 Hz
ac_178:	mS/m	Apparent Conductivity for freq 177.6 Hz
ac_224:	mS/m	Apparent Conductivity for freq 223.8 Hz
ac_282:	mS/m	Apparent Conductivity for freq 281.9 Hz
ac_355:	mS/m	Apparent Conductivity for freq 355.2 Hz
ac_4511:	mS/m	Apparent Conductivity for freq 4510.8 Hz
ac_5683:	mS/m	Apparent Conductivity for freq 5683.2 Hz
ac_7160:	mS/m	Apparent Conductivity for freq 7160.4.2 Hz
ac_9022:	mS/m	Apparent Conductivity for freq 9021.5 Hz
ac_11366:	mS/m	Apparent Conductivity for freq 11366.4 Hz
ac_14321:	mS/m	Apparent Conductivity for freq 14320.8 Hz

Table 9 – Geosoft 18014_AccelRes_MAG.gdb Database Format

Channel Name	Units	Description
xm:	metres	mag bird UTM Easting WGS84 Zone 55 South
ym:	metres	mag bird UTM Northing WGS84 Zone 55 South
zm:	meters	mag bird elevation above geoid
gtime:	Sec of the day	GPS time
RdAlt:	metres	helicopter terrain clearance from radar altimeter
alt_m:	Metres	mag bird terrain clearance
DTM:	metres	Digital Elevation Model
GPS_A_ALT:	Meters, ASL	helicopter GPS altitude
GPS_B_LAT:	Decimal degrees	Mag bird longitude, WGS84
GPS_B-LON:	Decimal degrees	Mag bird latitude, WGS84
basemag:	nT	Magnetic base station data
Mag_raw:	nT	Measured magnetic field
Mag_cor:	nT	Corrected for diurnal magnetic field
IGRF:	nT	Residual, IGRF removed magnetic field
Mg_RTP:	nT	Mag_cor, redused to pole magnetic field
Igrf_RTP:	nT	Residual, IGRF removed magnetic field, reduced to pole

The databases can be synchronized based on *gtime* channel.

Resistivity-Depth transformed data is presented in resistivity-depth sections (in pdf format) and in gdb database format.

Table 10 – Geosoft 18014_RDS.gdb Database Format (Resistivity-Depth Sections)

Channel Name	Units	Description
xm:	meters	mag bird UTM Easting WGS84 Zone 55 South
ym:	meters	mag bird UTM Northing WGS84 Zone 55 South
DTM:	meters	Digital Elevation Model
Depth:	meters	Depth from surface (array channel)
Res:	Ohm-m	Resistivity (array channel)

Resistivity-Depth Sections in visual, raster format are presented in the pdf files:
18014_ResSec_CentralPart.pdf Sections for central part of the block
18014_ResSec_NPart.pdf Sections for north part of the block
18014_ResSec_SPart.pdf Sections for south part of the block

Refer to Table 11 for summary of the grids and maps (Appendix III) which accompany this report.

Table 11 – Lists of grids (in Geosoft format) and maps (in Geosoft and PDF formats).

Grids	Maps	Description
DTM	18014_AccelRes_DTM	Digital Terrain Model
PLM	18014_AccelRes_PLM	Powerline Monitor
Mag_cor		Total Magnetic Intensity (observed and processed)
Mag_rtp		Mag_cor reduced to pole
IGRF_RTP	18014_AccelRes_mag-IGRF-	Mag_cor IGRF removed, reduced to pole
ac_56	18014_AccelRes_ac56Hz	Apparent Conductivity for 55.9 Hz
ac_71		Apparent Conductivity for 70.5 Hz
ac_89		Apparent Conductivity for 88.8 Hz
ac_112	18014_AccelRes_ac112Hz	Apparent Conductivity for 111.9 Hz
ac_141		Apparent Conductivity for 141.0 Hz
ac_178	18014_AccelRes_ac178Hz	Apparent Conductivity for 177.6 Hz.
ac_224		Apparent Conductivity for 223.8 Hz
ac_282	18014_AccelRes_ac282Hz	Apparent Conductivity for 281.9 Hz
ac_355		Apparent Conductivity for 355.2 Hz
ac_4511	18014_AccelRes_ac4511Hz	Apparent Conductivity for 4510.8 Hz
ac_5683		Apparent Conductivity for 5683.2 Hz
ac_7160	18014_AccelRes_ac7160Hz	Apparent Conductivity for 7160.4 Hz
ac_9022		Apparent Conductivity for 9021.5 Hz
ac_11366		Apparent Conductivity for 11366.4 Hz
ac_14321	18014_AccelRes_ac14321Hz	Apparent Conductivity for 14320.8 Hz

6 Survey results discussion and recommendations

The purpose of the survey was mapping bedrock structure and lithology, including possible alteration and mineralization zones, using apparent conductivity corresponded to different depths and the magnetic properties of the bedrock units.

The total natural field data for 15 frequencies, depending on natural signal, in the range 56-14,321 Hz, were used to produce apparent conductivity grids and maps and resistivity sections along surveyed lines (Table 11, Figure 5, Figure 6, Appendix III, and followed the report files and databases).

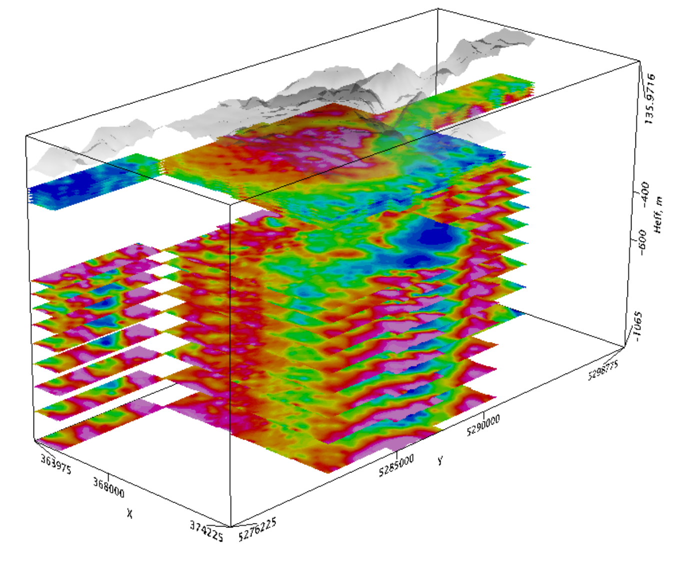

Figure 5 Apparent conductivity grids located with frequencies effective-depth 56-14321 Hz

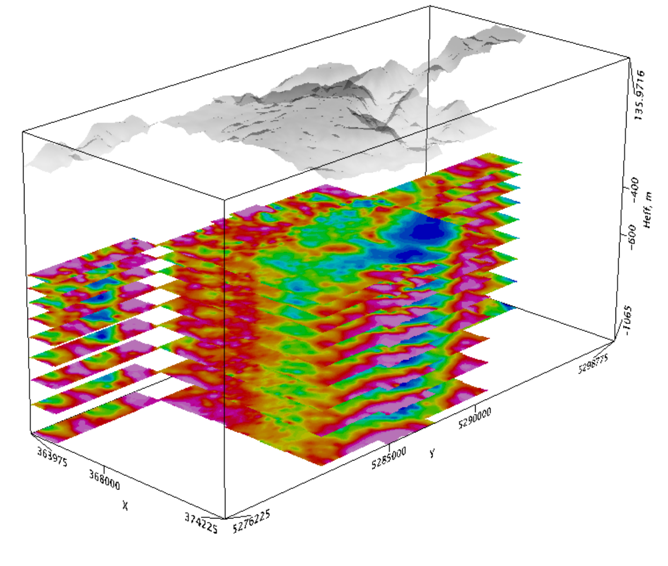

Figure 6 Apparent conductivity grids located with frequencies effective-depth 56-355 Hz

Conductivity distribution on the surveyed block doesn't show very high contrasts and differentiation in average. Apparent conductivity range for all frequencies is in 1-3.5 mS limit (~300-1000 Ohm-m resistivity). Frequencies in the whole range reflect structural and isometric conductive zones. Relation between conductive zones and magnetic field distribution on the block is shown on the combined maps in the Appendix III. As shown in Figure 5 and Figure 6, depth of investigation changes with frequencies – in the area's geoelectrical conditions, the lowest 56 Hz reflects the depth close to 1000 m, and the highest, 14321 Hz corresponds to approximately 50 m depth. Depth of investigation change over the area can be seen on the resistivity section along the central line (L1300) crossing the area from S to N (Figure 7).

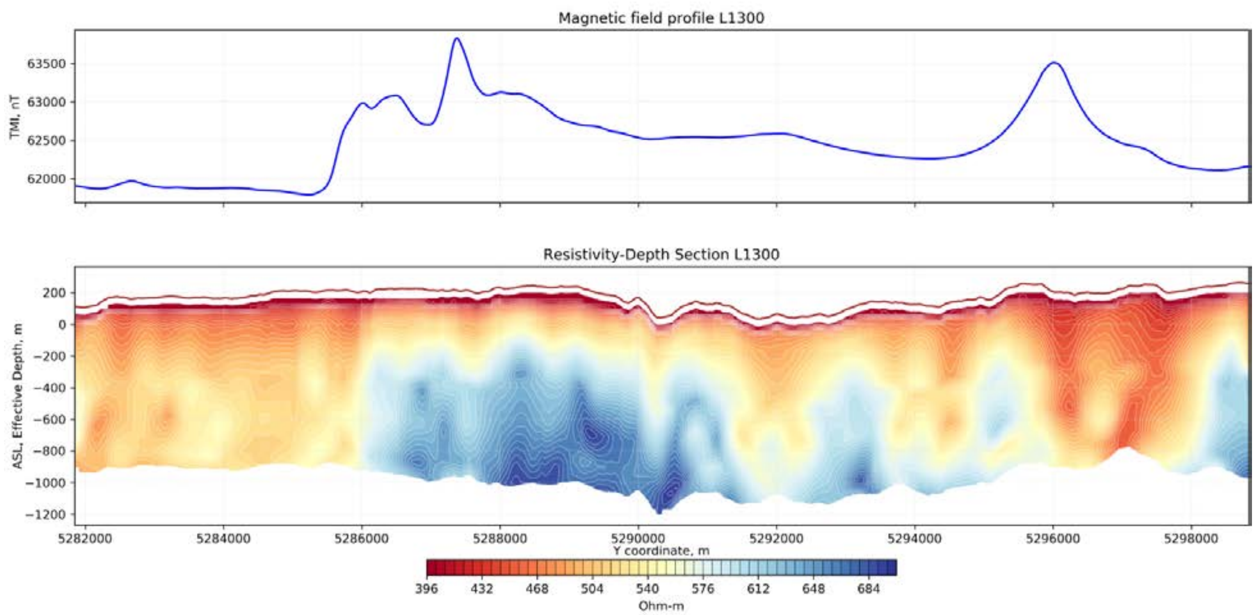

Figure 7. Resistivity-Depth section with magnetic field profile along the line L1300.

According to the conductivity maps and resistivity sections there is a comparatively conductive overburden layer covers the whole block, but most conductive near surface area on the block is over the central intrusion reflected in the magnetic field (see apparent conductivity maps on high frequencies in Appendix III).

There are three discrete isometric magnetic anomalies on the block – in the central, southern and northern survey lines parts (see magnetic field map in App.III).

In general, there are three conductive zones associated with the central magnetic source (intrusive) (Figure 8). A – on the west contact a long SN conductive structure; B – discrete conductive zone inside of the 'intrusive'; and C – stretched conductive zone along the northern contact. According to the L1540 resistivity section, the B and C zones are subvertical going to the depth several hundred meters (Figure 8).

The magnetic anomaly on the south end of the block is open to west and the magnetic source is conductive in comparison with host rocks. Shape of the conductor in the resistivity section is similar to 'kimberlite pipe type' (Figure 9).

Two conductive zones relate to a discrete magnetic anomaly on the northern end of the block (Figure 10).

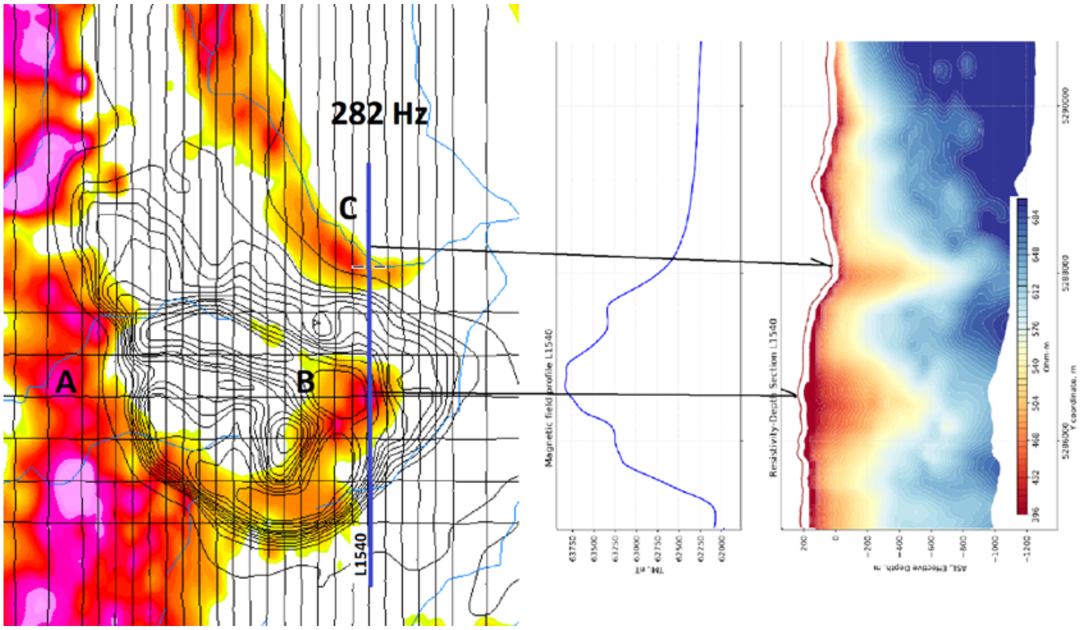

Figure 8. Central magnetic anomaly and related conductive zones. Contours of the magnetic anomaly over apparent conductivity grid (282 Hz) (left); fragment of resistivity section with magnetic field profile (right).

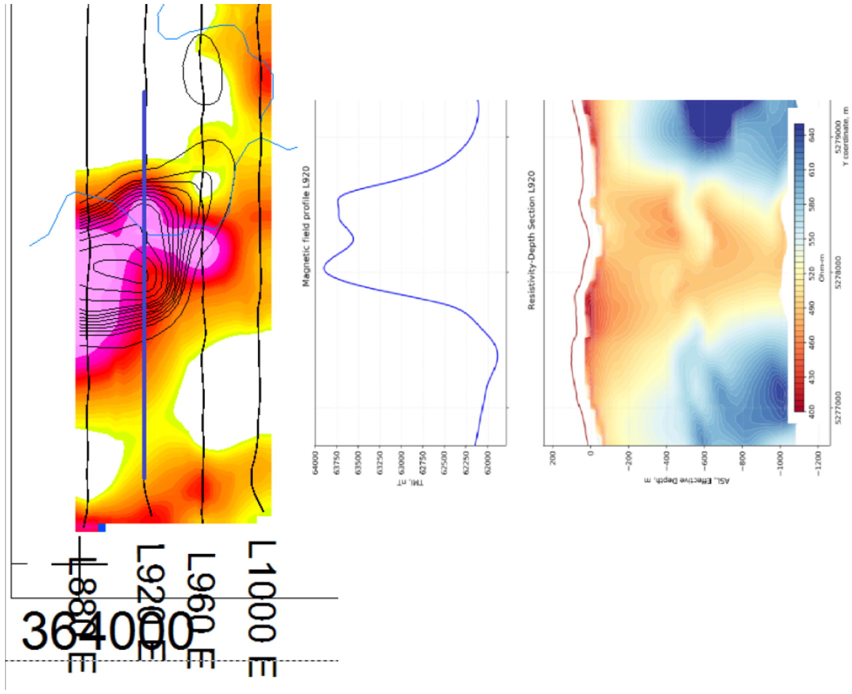

Figure 9. South magnetic anomaly. Contours of the magnetic anomaly over apparent conductivity grid (282 Hz) (left); fragment of resistivity section with magnetic field profile (right).

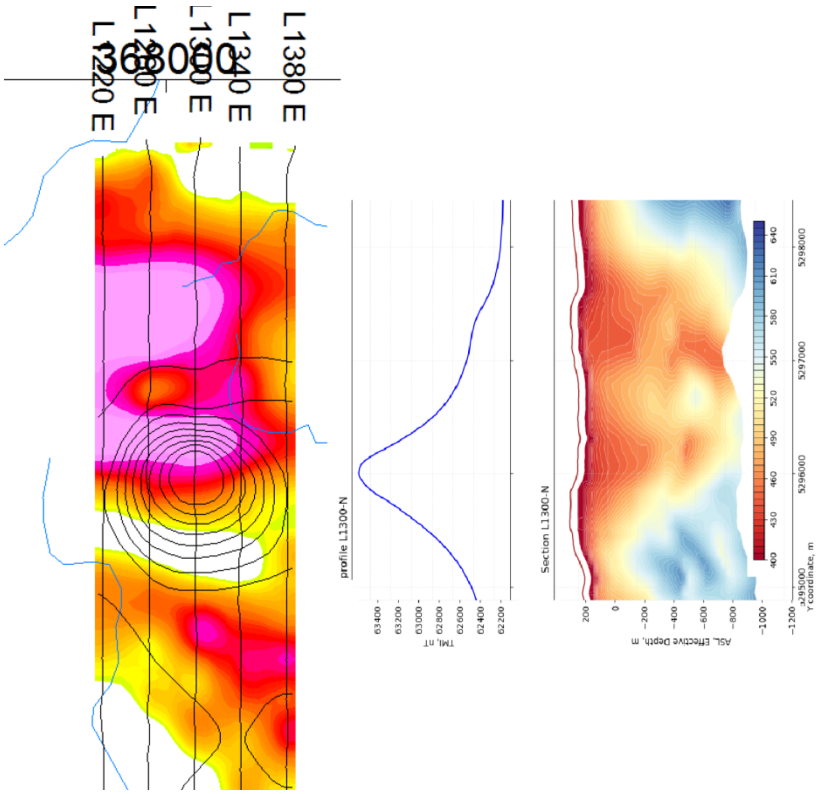

Figure 10. North magnetic anomaly. Contours of the magnetic anomaly over apparent conductivity grid (282 Hz) (left); fragment of resistivity section with magnetic field profile (right).

It is recommended to make complex analysis with known geological and geochemical information before test drilling planning.

Andrei Bagrianski, Ph.D., P.Geo

February, 12, 2019

MobileMT Job#18010 for Canadian Energy Materials Inc

PROFESSIONAL GEOSCIENTIST
ANDREI BAGRIANSKI
PRACTISING MEMBER
1530
ONTARIO

Appendix I Company Profile

About us

Expert Geophysics Limited is based in Toronto, Canada.

President and founder, **Andrei Bagrianski** Ph.D., P.Geo., has over 35 years of professional experience in the acquisition, processing, and interpretation of airborne and ground geophysical data for a wide range of applications. From 2002 to 2016, he was Chief Operating Officer and General Manager at Geotech Ltd. Andrei has been directly involved in contracting, organizing, and supervising hundreds of airborne geophysical surveys on all continents except Antarctica. Andrei has extensive international field work experience that includes projects in Brazil, Bolivia, Colombia, Ecuador, Peru, Botswana, Malawi, South Africa, Libya, USA, Canada, Russia, Kazakhstan, and India.

Petr Kuzmin, Ph.D., the designer of the **MobileMT** system, has over 40 years of experience in the development of ground and airborne TDEM, MT, and IP methods, equipment, and software. Working for Geotech Ltd., Canada, from 2000 until 2009, Dr. Kuzmin was the principal designer of the award winning systems VTEM, ZTEM, and AirMt. Since 2009, Dr. Kuzmin has completed a number of successful developments: ground AFMAG, ultra-fast airborne TD (HiRes), airborne VLF system, an airborne navigation system, a high accuracy magnetometer counter, and the MobileMT. Dr. Kuzmin holds a doctorate in Geophysics, has authored nearly 20 patents, and published over 40 technical papers.

Services

Expert Geophysics Limited specializes in airborne geophysical surveys with advanced electromagnetic systems. **EGL** offers surveying with **Mobile MagnetoTellurics** (**MobileMT**), the most advanced generation of airborne AFMAG technologies. The patent pending **MobileMT** technology utilizes naturally occurring electromagnetic fields in the frequency range of 25 Hz – 30 000 Hz. The **MobileMT** technology is the product of extensive experience in developing equipment and signal/data processing algorithms for natural electromagnetic fields measurement. **MobileMT** combines the latest advances in electronics, airborne system design, and sophisticated signal processing techniques.

Appendix II MobileMT electromagnetic technology

MobileMT (Mobile MagnetoTellurics) is a newly developed approach to electromagnetic data acquisition from synchronized a towed three component inductive magnetic sensor and grounded two orthogonal electric lines. The system is designed and implemented in order to overcome existing limitations of airborne techniques based on passive electromagnetic fields principles and, ultimately, for improving exploration efficiency.

MobileMTis a passive airborne electromagnetic technique that records magnetic (in the air) and electric (on the ground) fields generated by natural sources in the audio frequency range. The natural electromagnetic primary field sources for MobileMT are considered with frequencies ranging from 25 Hz to 30 kHz (ELF+VLF). The exploration system includes two pairs of grounded electric wire lines, one of them is for reference signal, and moving three-component inductive coil system softly suspended and with low-noise signal amplifiers for magnetic field measurements (dB/dt) in three orthogonal directions. A crucial element of the technology is the capability of aerial acquisition magnetotelluric data in four decades frequency band. Field data are acquired using stationary orthogonal pairs of electrical field sensors (grounded wire dipoles) and towed magnetic field detectors (three orthogonal induction coils).

In order to continue evolution of the airborne electromagnetic passive fields technology and in comparison with the last AFMAG development (Bob Lo, 2009) the current development is focused on:

- Expanding measured frequencies range into high end to complement deep exploration with near surface, shallow and medium depth of investigation;
- Increasing sensitivity and reducing system noise level to provide with data at low natural electromagnetic fields signal conditions especially in the range of the last hundred – first thousands Hz frequencies band where the field spectral density is lowest (dead-band);
- Providing ability to recover electrical properties differences between geological boundaries of any direction, including and between horizontal and vertical boundaries;
- Increasing spatial and frequency data resolution;
- Measuring of elements of admittance-type transfer functions of the magnetotelluric field.

Theory and Method

Some part of the thunderstorm energy is converted into electromagnetic fields that are propagated in the ionosphere-Earth interspace. These electromagnetic fields and the currents induced by these fields in the subsurface are used in audiomagnetetotelluric prospecting to measure the electrical resistivity of geological environment.

Measuring telluric currents induced by the natural electromagnetic fields in the subsurface on the ground synchronised with measuring the magnetic components of the natural audio frequency electromagnetic fields in the air and mutual processing both airborne and ground data (Figure 1) is a way to improve the quality and increase informative of the measured airborne data. In practice the reference fields may be measured by inductive coils or grounded electric lines (Labson et al., 1985). To obtain accurate signal of the natural field spectrum and eliminate noise spectra of sensors we use electrical field measurements at the base station. One of the reasons of choosing electrical components for reference is capacity to control the natural signal strength in the wire lines. Each electrical field component on the base station is registered independently from two sensors, signal and reference, which is utilized to eliminate the data bias distortions (Labson et al., 1985). This technical solution is critically helpful in periods of weak natural field signals in some frequency bands.

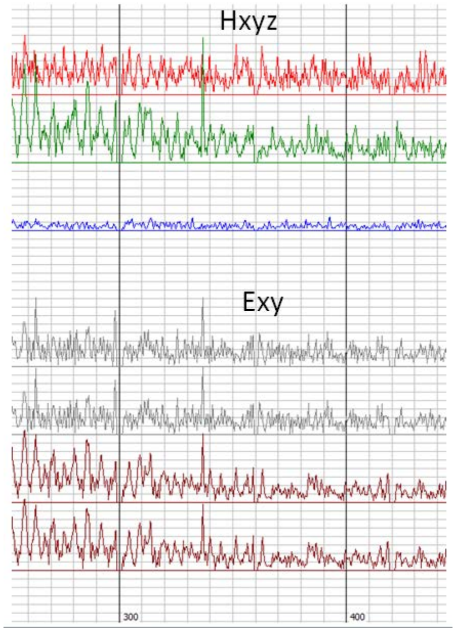

Figure 1. A section of time series of *E*xy and *H*xyz data

Exploiting signals of two horizontal electric components along with three magnetic components we can process them with the magnetotellurics response functions based on linear relations between components of the electric and magnetic fields. In general, processing of the field data is based on the Larsen and Chave robust remote-reference method (Chave et al., 1987; Larsen, 1989). The data processing program merges the stationary measured electrical two horizontal components and the moving orientation irrelevant receiver of three magnetic field components into one file. The program applies FFT technique to the recordings and calculates the matrixes of the relations between the electric and magnetic signals (six admittances) on the different time bases and in different frequency bands. In the result of modular computation of the matrixes determinants, as rotation invariant parameters, we calculate apparent conductivity in mS/m as a parameter of EM mapping. The rotation invariant parameters are free from the receiver motion distortions. The admittances (***Y***) are represented as the electric field horizontal vectors projection into the space of the magnetic field three components. In other words, the combined system measures combination of tensor and scalar (rotational invariant) components as the transfer function of a total magnetic field, through the three orthogonal directions measurements of an airborne receiver, to the two orthogonal horizontal directions of electric field measured at a ground base location. Generalizing the Weiss-Parkinson relationship (Berdichevsky and Zhdanov, 1984), such as that measured three orthogonal magnetic field components (***H***xyz) are linearly related to the horizontal electric fields measured on the ground (***E***xy, reference), with adoption it to the admittances domain (***Y***):

$$\begin{bmatrix} Hx \\ Hy \\ Hz \end{bmatrix} = \begin{bmatrix} Yxx & Yxy \\ Yyx & Yyy \\ Yzx & Yzy \end{bmatrix} \begin{bmatrix} Ex \\ Ey \end{bmatrix} \qquad (1)$$

Solutions of the equations are obtained by averaging over a number of closely spaced frequencies **Error! Reference source not found.**(Table below).

An example of frequency windows used for harmonics averaging. Base 15 Hz, Gates ratio 2.

	Window, Hz		
N	start	end	mid
1	15	30	23
2	30	68	49
3	68	135	101
4	135	270	203
5	270	540	405
6	540	1080	810
7	1080	2160	1620
8	2160	4320	3240
9	4320	8640	6480
10	8640	17280	12960
11	17280	28800	23040

The windowing way is flexible and can be optimized depending on signals, cultural noise and an exploration task.

H (magnetic) and ***E*** (electric) components time series data, fully synchronized, digitized and recorded at 73,728 Hz frequency, is converted from time to frequency domain using FFT technique. The complex data spectrums (field examples in 2 and 3) is expressed in apparent conductivity (σ) equivalent to its real part:

$$\sigma = \mu\omega|Y^2| \qquad (2)$$

where ***Y*** is the determinant of the corresponded matrix in (1); Y^2 = im(Y^2)/re(Y^2); μ is the magnetic permeability of free air and ω is the angular frequency.

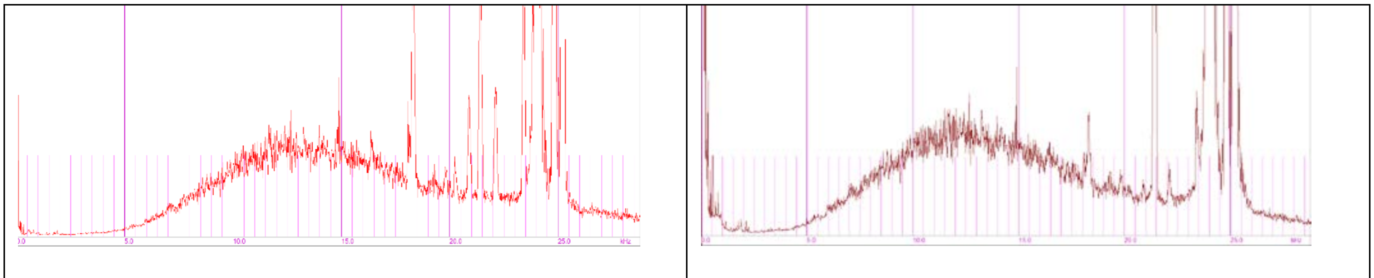

Figure 2 Airborne magnetic X-coil spectrum up to 30,000 Hz range (left) with the corresponding electric X-line 1 spectrum (right)

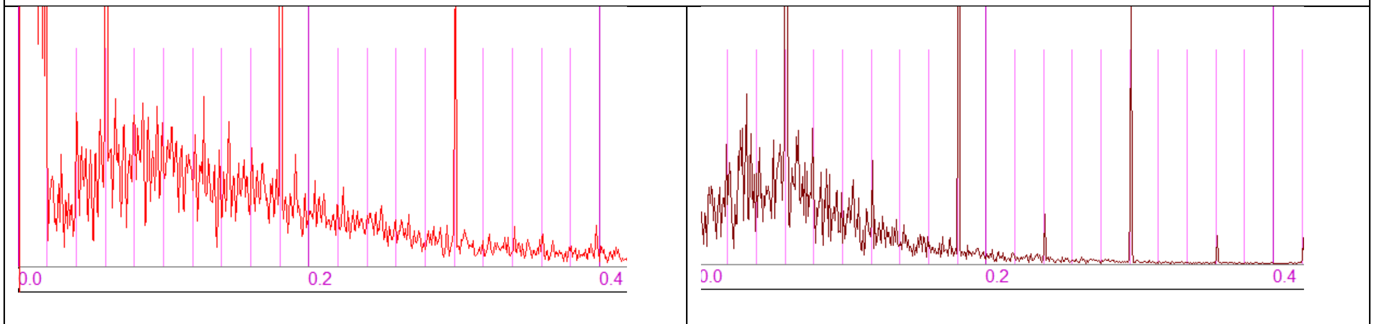

Figure 3 Airborne magnetic X-coil spectrum up to 400 Hz range (left) with the corresponding electric X-line 1 spectrum (right)

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Berdichevsky, M.N., and M.S. Zhdanov (1984), Advansed theory of deep geomagnetic sounding: Elseiver.

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Larsen, J. C. (1989), Transfer functions: smooth robust estimates by least-squares and remote reference methods: Geophysical Journal International, **99**, 645-663.

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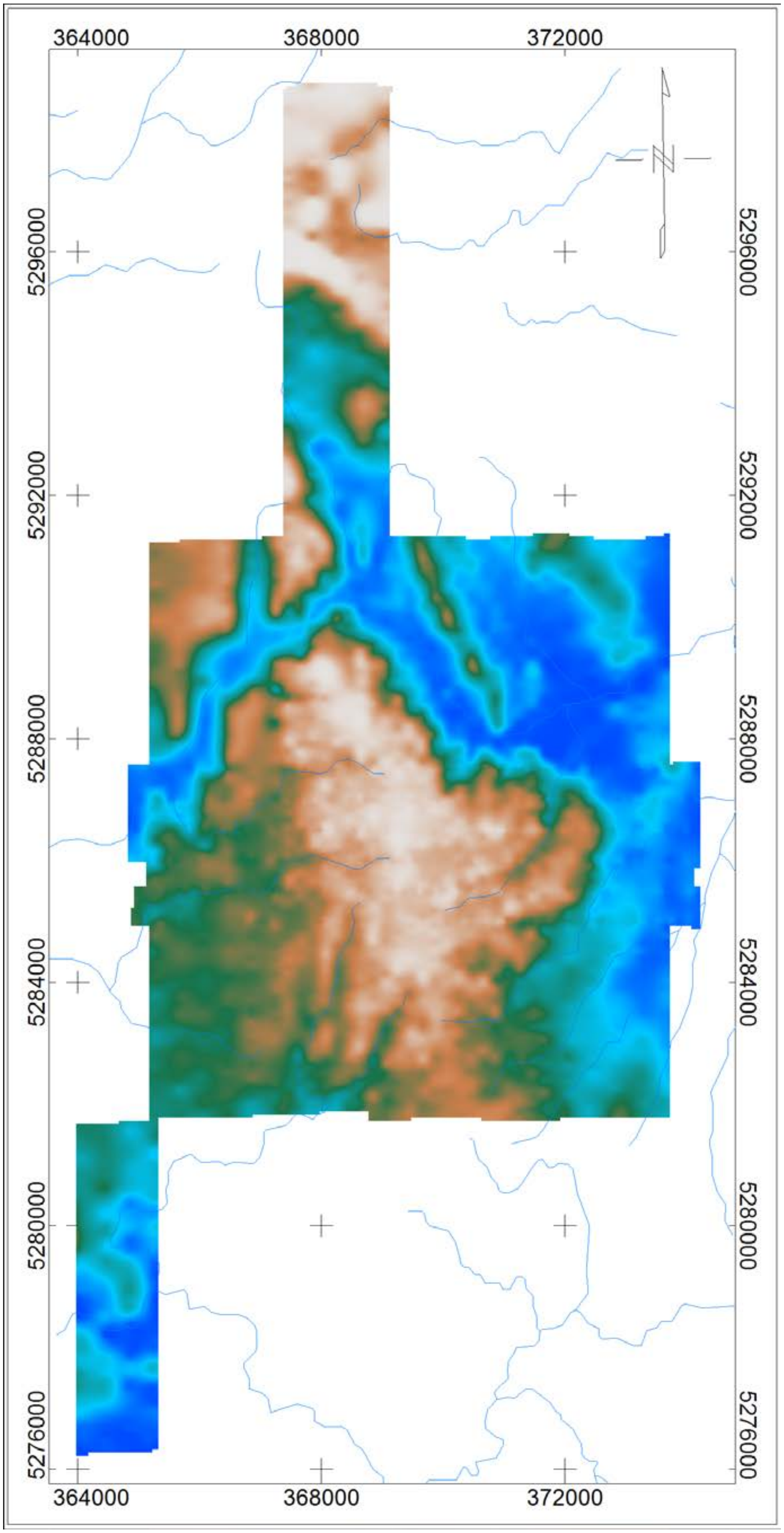
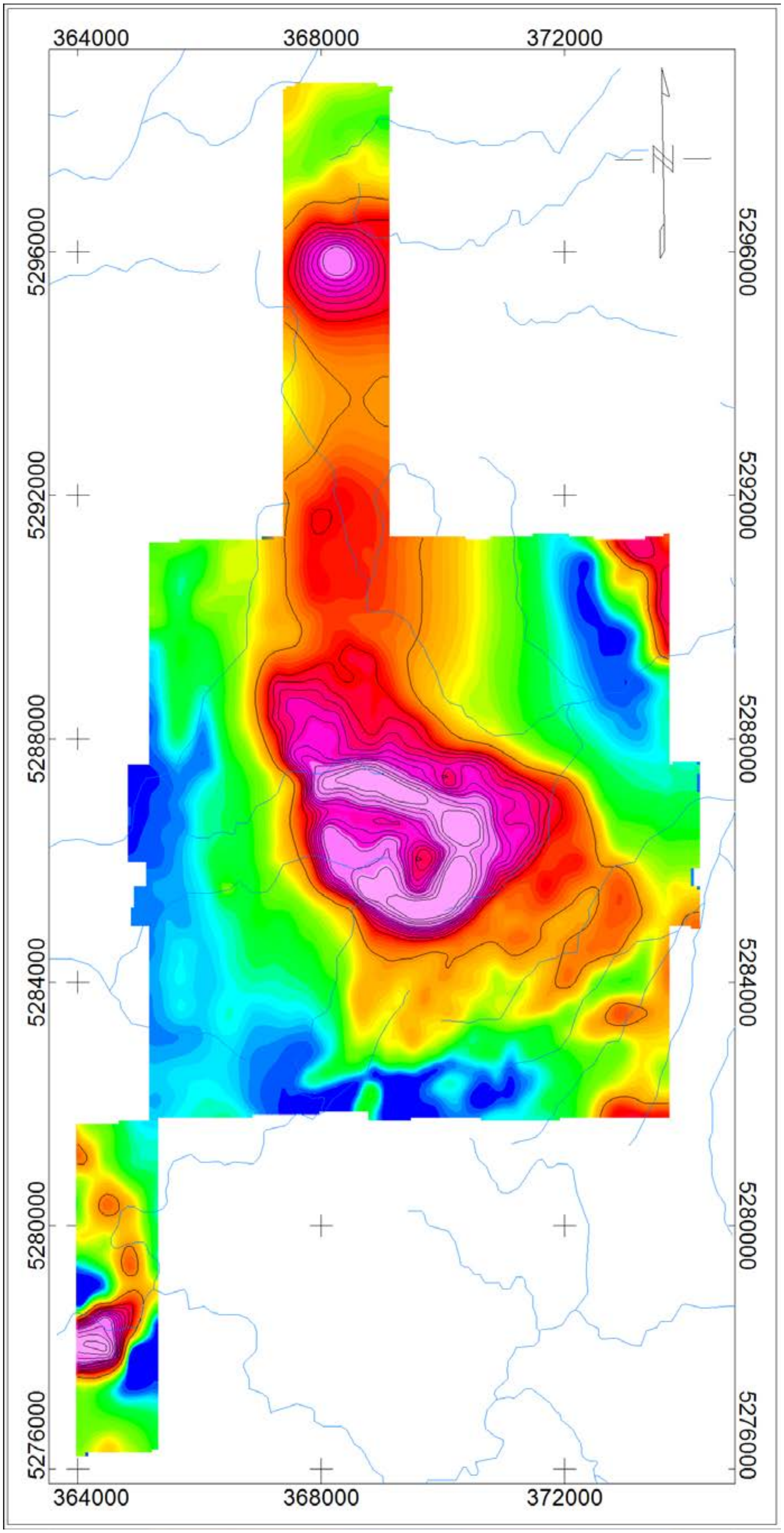
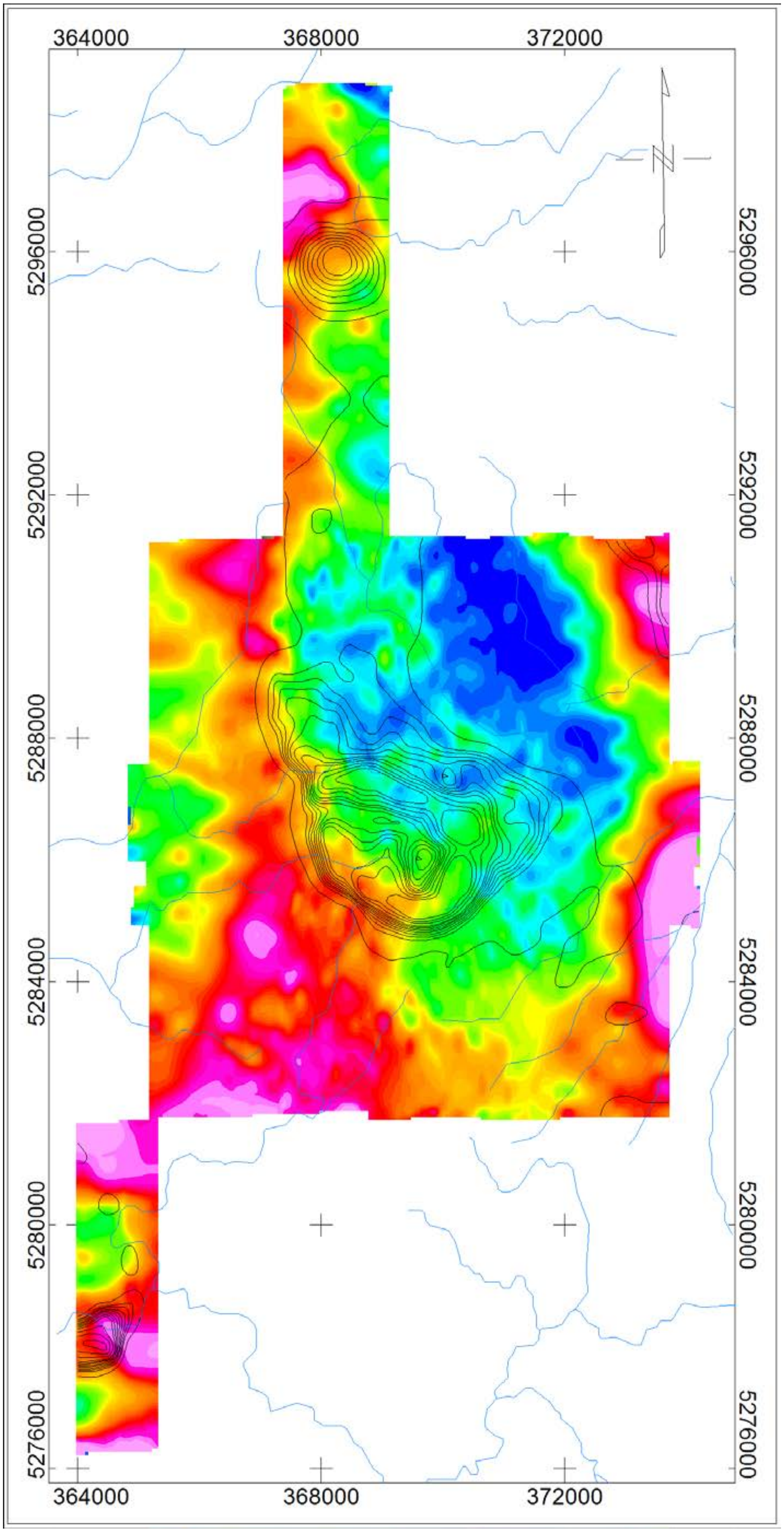
Appendix III MobileMT simplified maps images



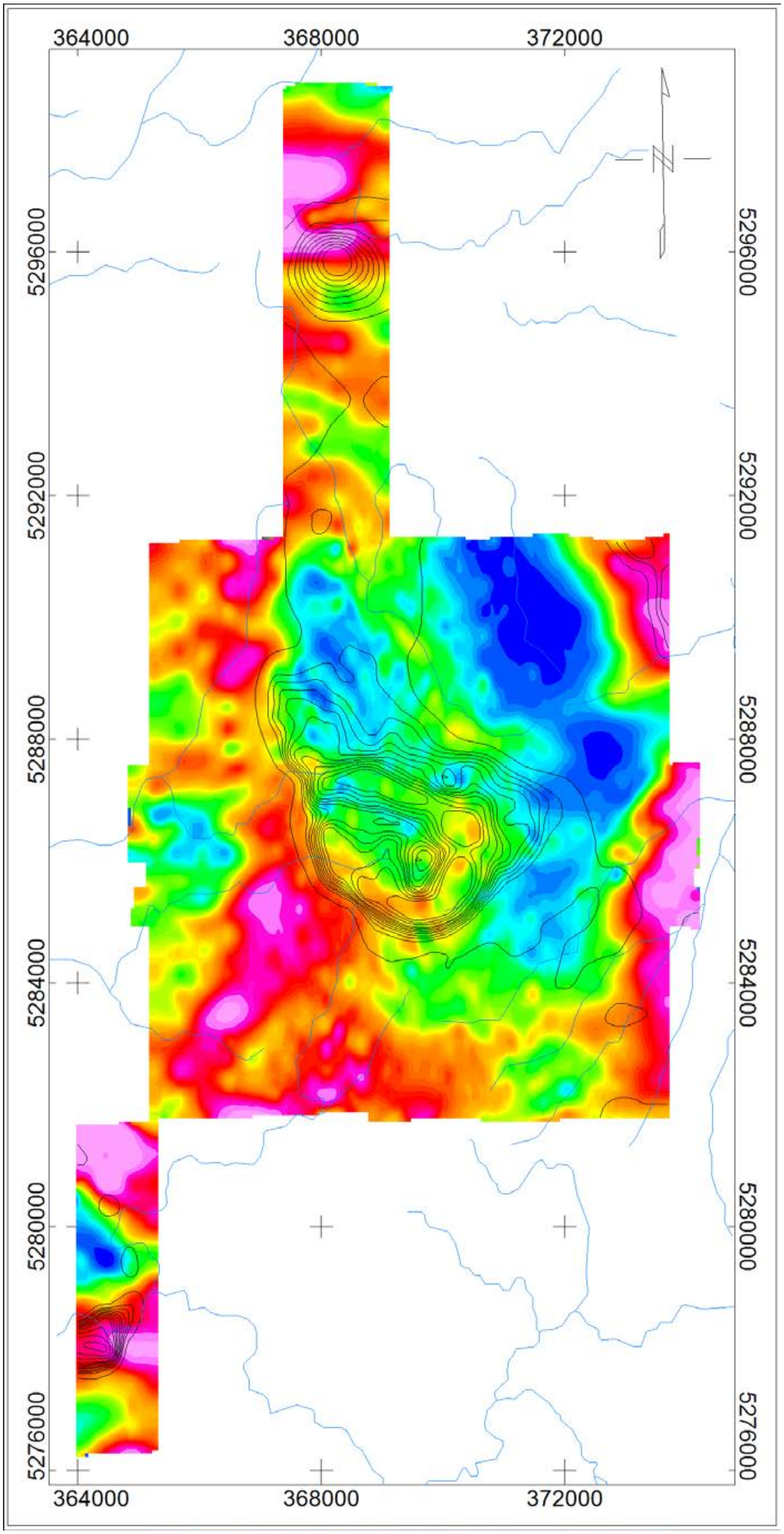
Digital terrain model



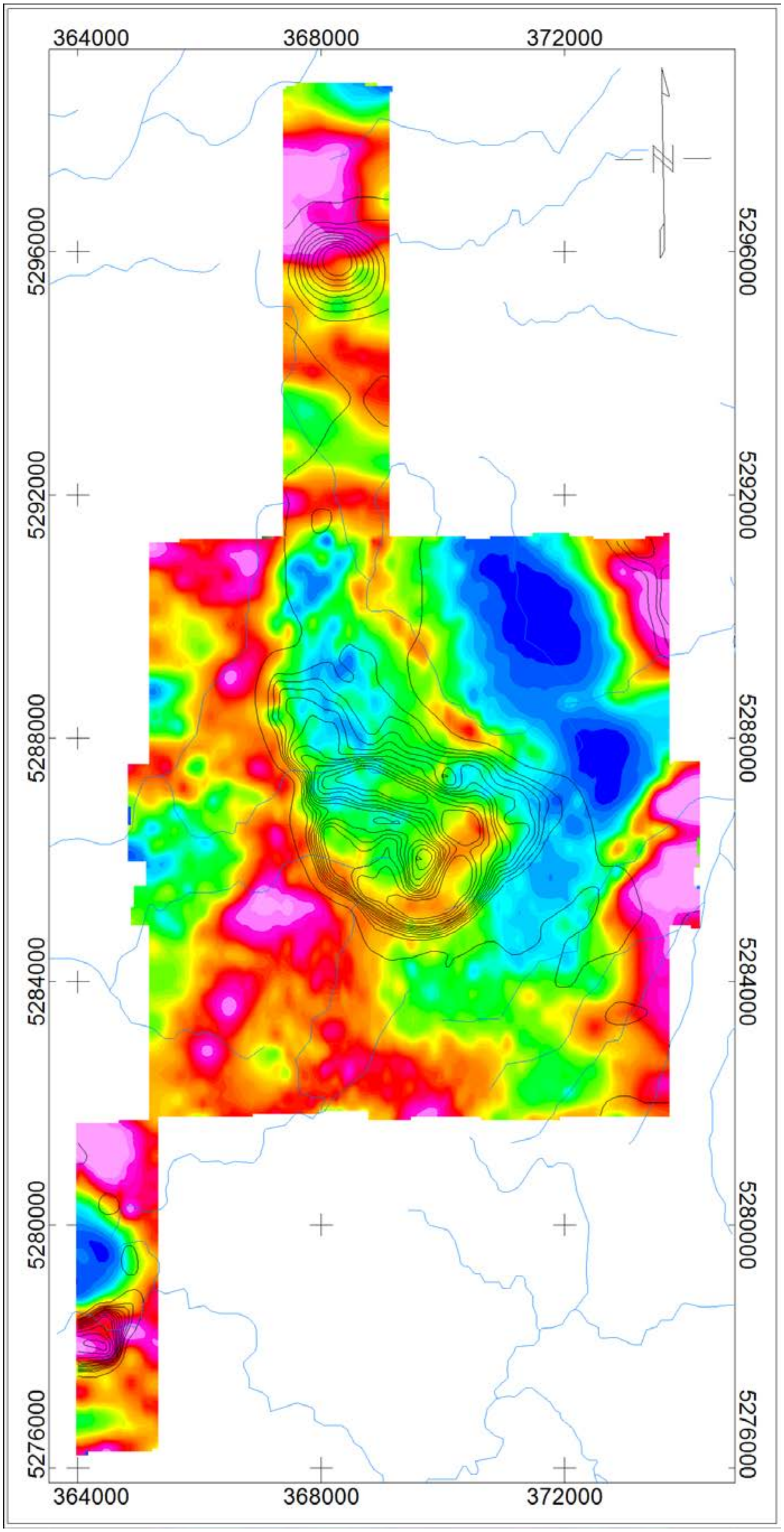
Total Magnetic Intensity Map (IGRF removed, RTP)



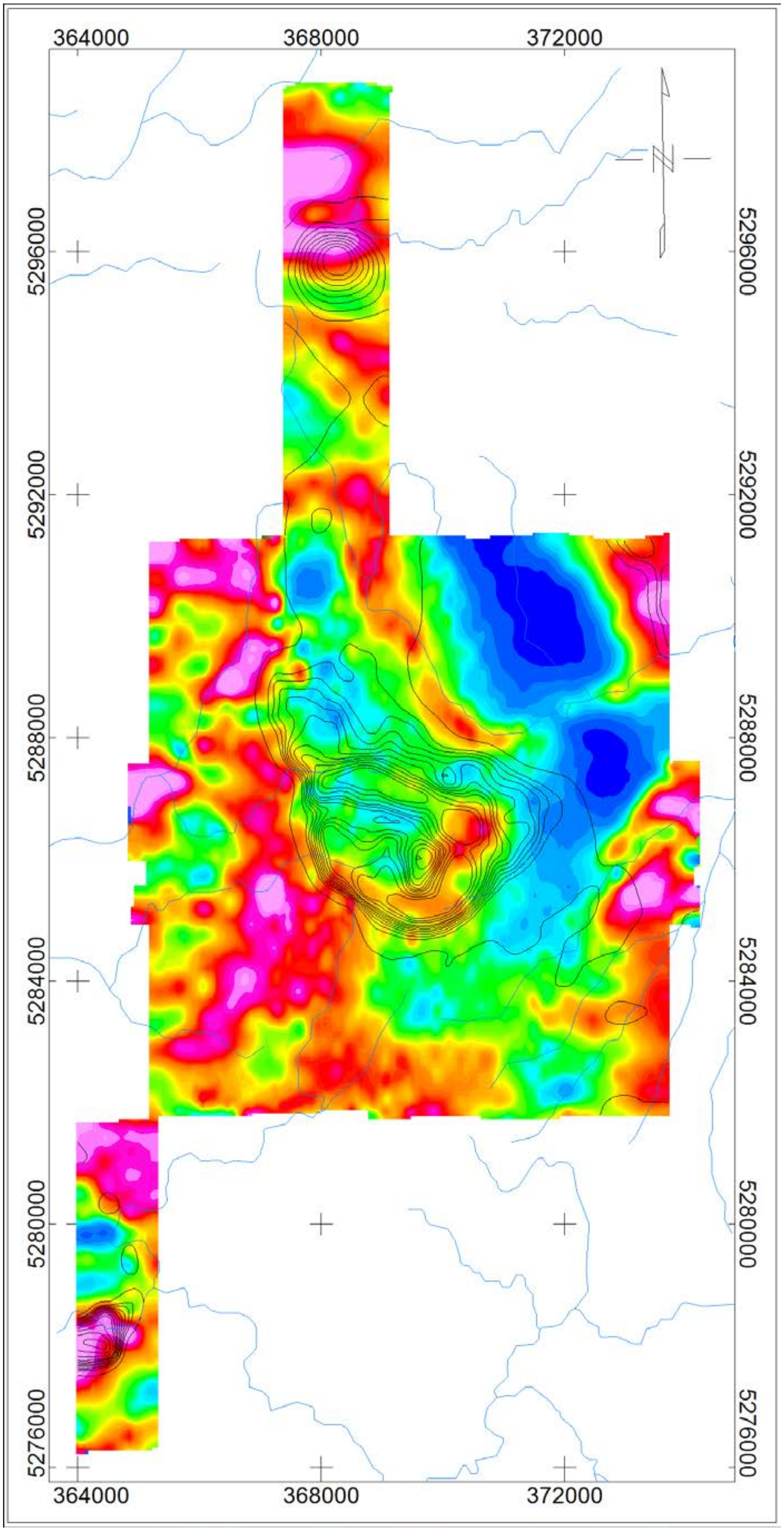
Apparent Conductivity 56 Hz with mag anomalies contours



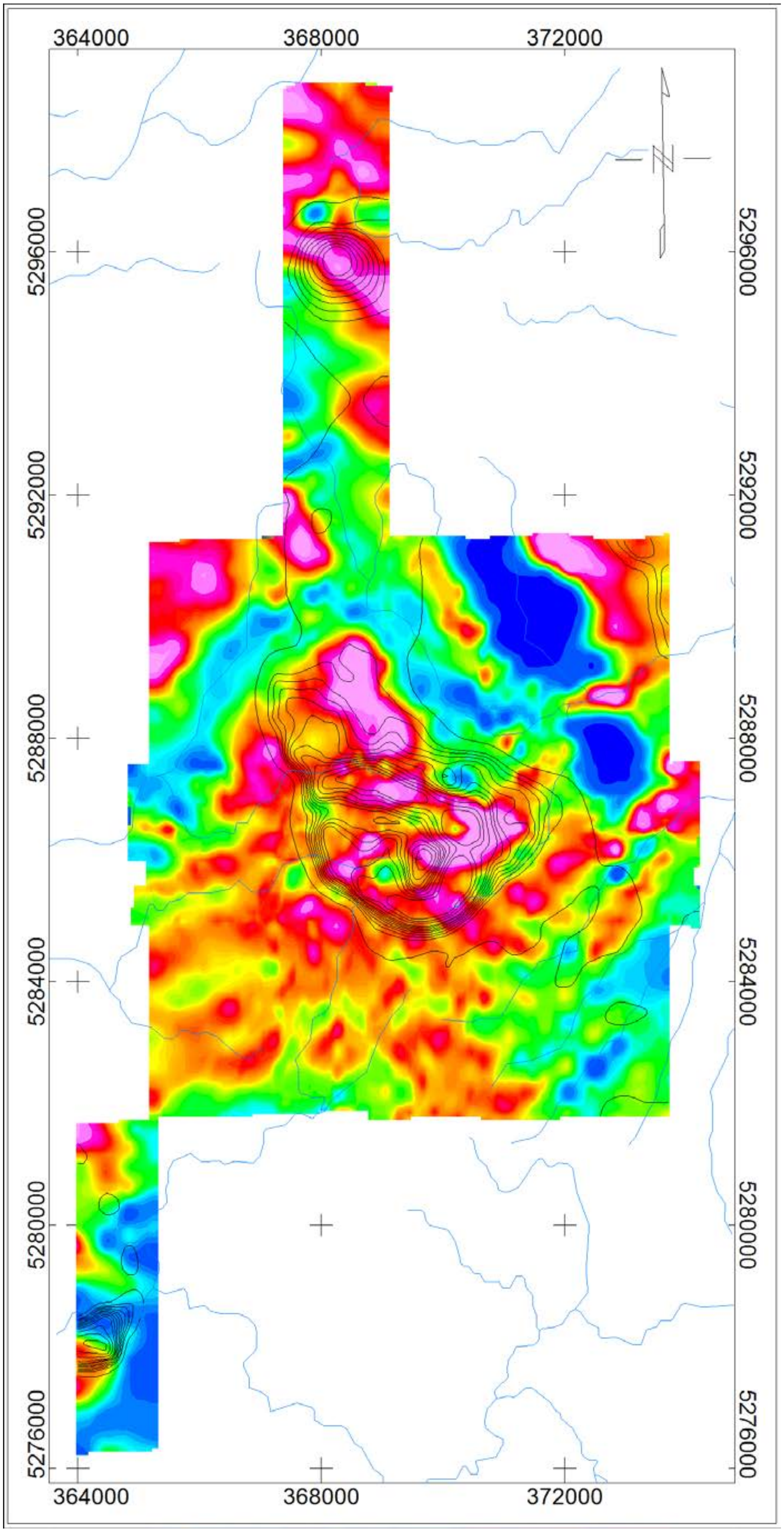
Apparent Conductivity 112 Hz with mag anomalies contours



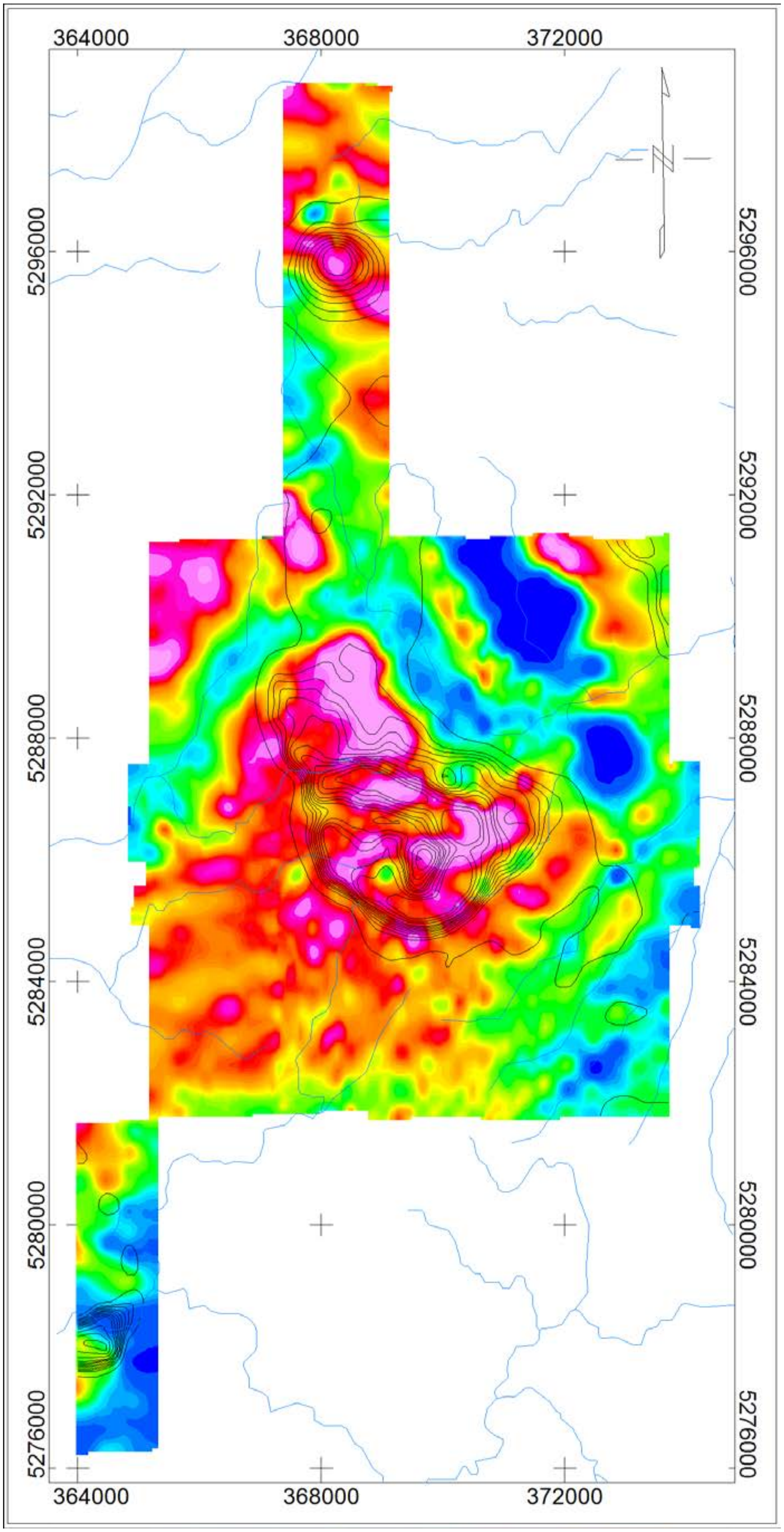
Apparent Conductivity 178 Hz with mag anomalies contours



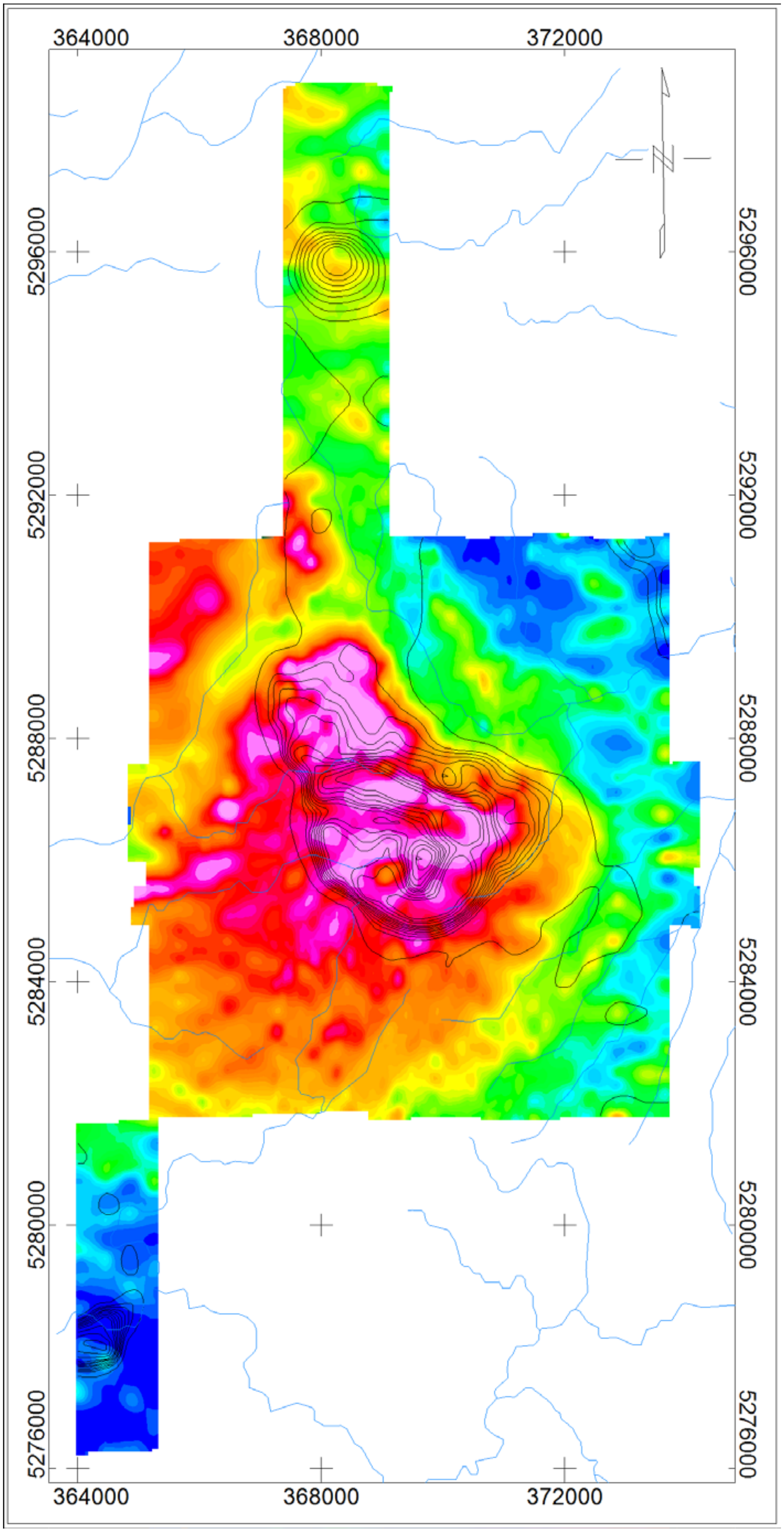
Apparent Conductivity 282 Hz with mag anomalies contours



Apparent Conductivity 4511 Hz with mag anomalies contours



Apparent Conductivity 7160 Hz with mag anomalies contours



Apparent Conductivity 14321 Hz with mag anomalies contours

Appendix IV. Resistivity-Depth Sections

(see accompanied 18014_ResSec_xxxPart.pdf files and 18014_RDS-xxxPart.gdb databases)