



**GEOPHYSICAL SURVEY REPORT
MIDAS HIGH RESOLUTION MAGNETIC SURVEY
APOLLO AREA
PROJECT 14013
KAMINAK GOLD CORP.**

April 9, 2014

Passion for Geoscience
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Introduction

This report describes the logistics, data acquisition, processing and presentation of results of a MIDAS magnetic airborne geophysical survey carried out for Kaminak Gold Corp. over one property near Dawson City, Yukon. Total coverage of the survey block amounted to 121 km. The survey was flown between March 22 and March 24, 2014.

The purpose of the survey was to map the geology and structure of the area. Data were acquired using a MIDAS magnetic system with two high-sensitivity cesium magnetometers. The information from these sensors was processed to produce maps and images that display the magnetic properties of the survey area. A GPS electronic navigation system ensured accurate positioning of the geophysical data with respect to the base map coordinates.

The survey was performed by CGG Canada Services Ltd., Toronto office. Maps and data in digital format are provided with this report.

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Survey Area Description

Location of the Survey Area

One block near Dawson City, Yukon (Figure 1) was flown between March 22 and March 24, 2014, with Dawson City, Yukon as the base of operations. Survey coverage consisted of 110 km of traverse lines flown with a spacing of 100 m and 11 km of tie lines with a spacing of 1000 m for a total of 121 km.

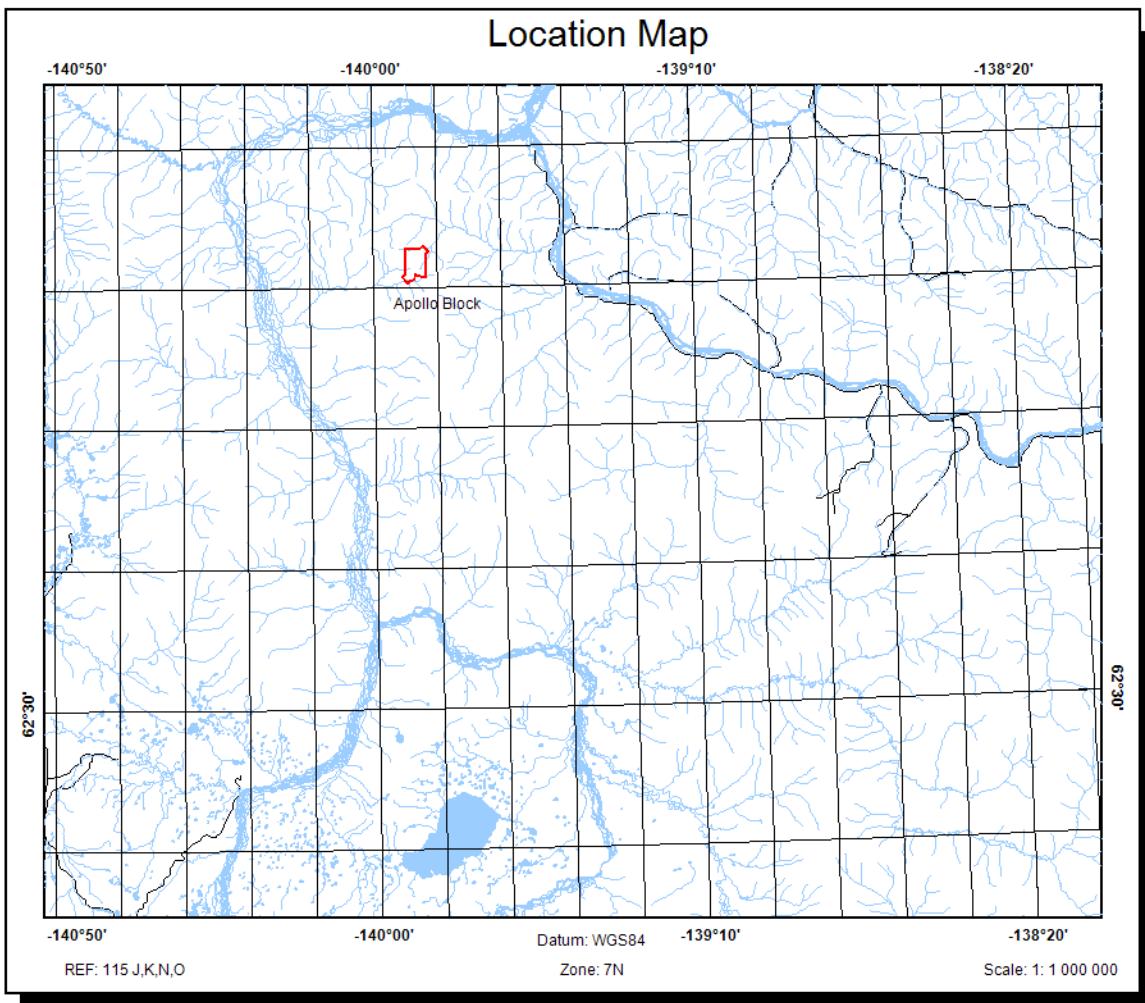


Figure 1 Apollo Area - Location Map

Table 1 contains the coordinates of the corner points of the survey blocks.

Block	Corners	X-UTM (E)	Y-UTM (N)
14013-1	1	555571	6987137
Apollo Area	2	555395	6987136
	3	555032	6986774
	4	554656	6987135
	5	554313	6987489
	6	554655	6987831
	7	554649	6991246
	8	556660	6991250
	9	557025	6991620
	10	557394	6991251
	11	557745	6990901
	12	557395	6990549
	13	557400	6987596
	14	556947	6987596
	15	556125	6987879
	16	555875	6987155

Table 1 Area Corners NAD83 UTM Zone 7N

Block	Line Numbers	Line direction	Line Spacing	Line km
1	10010 - 104900	135°/315°	100 m	110.6 km
Apollo Area	19010 - 19050	45°/225°	1000 m	11.9 km

Table 2 Planned line kilometre summary

During the survey GPS base stations were set up to collect data to allow post processing of the positional data for increased accuracy. The location of the GPS base stations are shown in Table 3.

Status	Location Name	WGS84 Longitude (deg-min-sec)	WGS84 Latitude (deg-min-sec)	Orthometric Height (m)
Primary	Dawson City, Yukon	139° 07' 12.84"W	64° 02' 49.46" N	385.2
Secondary	Coffee Camp	139° 05' 32.76" W	62° 54' 42.79" N	384.7

Table 3 GPS Base Station Location

The location of the Magnetic base stations are shown in Table 4.

Status	Location Name	WGS84 Longitude (deg-min-sec)	WGS84 Latitude (deg-min-sec)
Primary	Coffee Camp	139° 05' 32.76" W	62° 54' 42.79" N

Table 4 Magnetic Base Station Location

System Information



Figure 2 MIDAS System

The MIDAS system is composed of a horizontal boom fixed to the belly of a helicopter containing two magnetometers, a fluxgate magnetometer and a GPS antenna for flight path recovery. The helicopter has a tail boom mounted GPS antenna for in-flight navigation, radar, laser and barometric altimeters, video camera and data acquisition system.

Aircraft and Geophysical On-Board Equipment

Helicopter:	AS350 B2
Operator:	Great Slave Helicopters
Registration:	C-GDCV
Average Survey Speed:	94.97 km/h (26.38 m/s)
Digital Acquisition:	CGG HeliDAS.
Video:	Panasonic WVCD/32 Camera with Axis 241S Video Server. Camera is mounted to the exterior bottom of the helicopter between the forward skid tubes
Magnetometer:	2-Scintrex Cesium Vapour (CS-2 and CS-3), mounted on a transverse boom (13.3 m separation); Operating Range: 15,000 to 100,000 nT Operating Limit: -40°C to 50°C Accuracy: ±0.002 nT Measurement Precision: 0.001 nT Sampling rate: 10.0 Hz
Fluxgate:	Billingsley TMF100 Triaxial fluxgate, mounted on one of the booms; Axial alignment: < ±1 degree Sensitivity: 100 µV per nT Sampling rate: 10.0 Hz
Radar Altimeter:	Honeywell Sperry Altimeter System. Radar antennas are mounted to the exterior bottom of the helicopter between the forward skid tubes Operating Range: 0 – 2500ft Operating Limit: -55°C to 70°C 0 to 55,000 ft Accuracy: ± 3% (100 – 500ft above obstacle) ± 4% (500 – 2500ft above obstacle) Measurement Precision: 1 ft Sample Rate: 10.0 Hz
Laser Altimeter:	Optech G-150 mounted on the belly of the helicopter; Operating Range: 0.2 to 250 m

Operating Limit: -10°C to 45°C

Accuracy:

±5 cm (10°C to 30°C)

±10 cm (-10°C to 45°C)

Measurement Precision: 1 cm

Sample Rate: 10.0 Hz

Aircraft Navigation:

NovAtel OEM4 Card with an Aero antenna mounted on the tail of the helicopter;

Operating Limit: -40°C to 85°C

Real-Time Accuracy:

1.2m CEP (L1 WAAS)

Real-Time Measurement Precision: 6 cm RMS

Sample Rate: 2.0 Hz

Barometric Altimeter:

Motorola MPX4115AP analog pressure sensor mounted in the helicopter

Operating Range: 55 kPa to 108 kPa

Operating Limit: -40°C to 125°C

Accuracy:

± 1.5 kPa (0°C to 85°C)

± 3.0 kPa (-20°C to 0°C, 85°C to 105°C)

± 4.5 kPa (-40°C to -20°C, 105°C to 125°C)

Measurement Precision: 0.01 kPa

Sampling Rate = 10.0 Hz

Temperature:

Analog Devices 592 sensor mounted on the camera box

Operating Range: -40°C to + 75°C

Operating Limit: -40°C to + 75°C

Accuracy: ± 1.5°C

Measurement Precision: 0.03°C

Sampling Rate = 10.0 Hz

Base Station Equipment

Primary Magnetometer:

CGG CF1 using Scintrex cesium vapour sensor with Marconi GPS card and antenna for measurement synchronization to GPS. The base station also collects barometric pressure and outside temperature.

Magnetometer Operating Range: 15,000 to 100,000 nT

Barometric Operating Range: 55kPa to 108 kPa

Temperature Operating Range: -40°C to 75°C

Sample Rate: 1.0 Hz

GPS Receiver:

NovAtel OEM4 Card with an Aero antenna

Real-Time Accuracy:

1.8m CEP (L1)

Sample Rate: 1.0 Hz

Secondary Magnetometer: GEM Systems GSM-19

Operating Range: 20,000 to 120,000 nT

Operating Limit: -40°C to 60°C

Accuracy: ± 0.2 nT

Measurement Precision: 0.01 nT

Sample Rate: 0.33 Hz

Quality Control and In-Field Processing

Digital data for each flight were transferred to the field workstation, in order to verify data quality and completeness. A database was created and updated using Geosoft Oasis Montaj and proprietary CGG Atlas software. This allowed the field personnel to calculate, display and verify both the positional (flight path) and geophysical data. The initial database was examined as a preliminary assessment of the data acquired for each flight.

In-field processing of CGG survey data consists of differential corrections to the airborne GPS data, filtering of all geophysical and ancillary data, verification of the digital video, and diurnal correction of magnetic data.

All data, including base station records, were checked on a daily basis to ensure compliance with the survey contract specifications. Re-flights were required if any of the following specifications were not met.

Navigation

A specialized GPS system provided in-flight navigation control. The system determined the absolute position of the helicopter by monitoring the range information of twelve channels (satellites). The Novatel OEM4 receiver was used for this application. In North America, the OEM4 receiver is WAAS-enabled (Wide Area Augmentation System) providing better real-time positioning.

A Novatel OEM4 GPS base station was used to record pseudo-range, carrier phase, ephemeris, and timing information of all available GPS satellites in view at a one second interval. These data are used to improve the conversion of aircraft raw ranges to differentially corrected aircraft position. The GPS antenna was set-up in a location that allowed for clear sight of the satellites above. The set-up of the antenna also considered surfaces that could cause signal reflection around the antenna that could be a source of error to the received data measurements.

Flight Path

Flight lines did not deviate from the intended flight path by more than 25% of the planned flight path over a distance of more than 1 kilometre. Flight specifications were based on GPS positional data recorded at the helicopter.

Clearance

The survey elevation is defined as the measurement of the helicopter radar altimeter to the tallest obstacle in the helicopter path. An obstacle is any structure or object which will impede the path of the helicopter to the ground and is not limited to and includes tree canopy, towers and power lines.

Survey elevations may vary based on the pilot's judgement of safe flying conditions around man-made structures or in rugged terrain.

The average survey elevation achieved for the helicopter and instrumentation during data collection was:

Helicopter	35 metres
Magnetometer	35 metres

Survey elevations did not deviate by more than 20% over a distance of 2 km from the contracted elevation.

Flying Speed

The average calculated ground speed was 95 km/h ranging between 50 to 130 km/h. This resulted in a ground sample interval of approximately 1.4 to 3.6 metres at a 10 Hz sampling rate.

Airborne High Sensitivity Magnetometer

To assess the noise quality of the collected airborne magnetic data, CGG monitors the 4th difference results during flight which is verified post flight by the processor. The contracted specification for the collected airborne magnetic data was that the non-normalized 4th difference would not exceed 1.6 nT over a continuous distance of 1 kilometre excluding areas where this specification was exceeded due to natural anomalies.

Magnetic Base Station

Ground magnetic base stations were set-up to measure the total intensity of the earth's magnetic field. The base stations were placed in a magnetically quiet area, away from power lines and moving metallic objects. The contracted specification for the collected ground magnetic data was the non-linear variations in the magnetic data were not to exceed 10 nT per minute. CGG's standard of setting up the base station within 50 km from the centre of the survey block allowed for successful removal of the active magnetic events on the collected airborne magnetic data.

Compensation System

The presence of the helicopter in close proximity to the sensors causes considerable interference on the readings. The orientation of the aircraft with respect to the sensors and the motion of the aircraft through the earth's magnetic field are contributing factors. A special calibration flight is flown to record the information necessary to remove these effects.

The manoeuvre consists of flying a series of calibration lines at high altitude to gain information in each of the required line directions. During this procedure, the pitch, roll and yaw of the aircraft are varied. Each variation is conducted in succession (first vary pitch, then roll, then yaw).

A three-axis fluxgate magnetometer measures the orientation and rates of change of the aircraft's magnetic field with respect to the earth's magnetic field. A compensation algorithm is applied to generate a set of coefficients for each line direction and for each magnetometer sensor to compensate for permanent, induced and eddy current magnetic noise generated by the aircraft.

Data Processing

Flight Path Recovery

To check the quality of the positional data the speed of the bird is calculated using the differentially corrected x, y and z data. Any sharp changes in the speed are used to flag possible problems with the positional data. Where speed jumps occur, the data are inspected to determine the source of the error. The erroneous data are deleted and splined if less than five seconds in length. If the error is greater than five seconds the raw data are examined and if acceptable, may be shifted and used to replace the bad data. The GPS-Z component is the most common source of error. When it shows problems that cannot be corrected by recalculating the differential correction, the barometric altimeter is used as a guide to assist in making the appropriate correction. The corrected WGS84 longitude and latitude coordinates were transformed to NAD83 using the following parameters.

Datum:	NAD83
Ellipsoid:	GRS80
Projection:	UTM Zone 7N
Central meridian:	141° West
False Easting:	500000 metres
False Northing:	0 metres
Scale factor:	0.9996
WGS84 to Local Conversion:	Molodensky
Dx,Dy,Dz:	0, 0, 0

Recorded video flight path may also be linked to the data and used for verification of the flight path. Fiducial numbers are recorded continuously and are displayed on the margin of each digital image. This procedure ensures accurate correlation of data with respect to visible features on the ground. The fiducials appearing on the video frames and the corresponding fiducials in the digital profile database originate from the data acquisition system and are based on incremental time from start-up. Along with the acquisition system time, UTC time is also recorded in parallel and displayed (Figure 3).

Altitude Data

Radar altimeter data are despiked by applying a 1.5 second median and smoothed using a 1.5 second Hanning filter. The radar altimeter data are then subtracted from the GPS elevation to create a digital elevation model that is gridded and used in conjunction with profiles of the radar altimeter and flight path video to detect any spurious values.

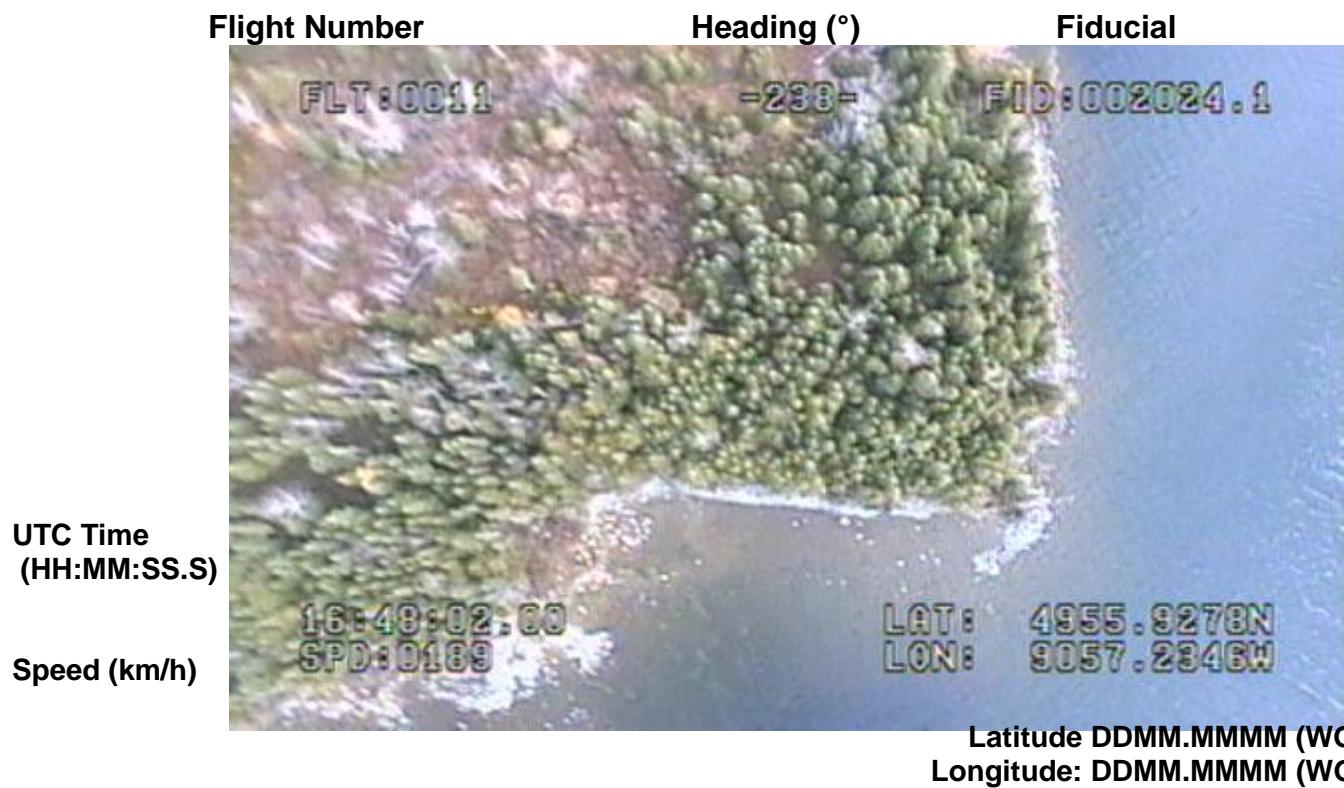


Figure 3 Flight path video

Magnetic Base Station Diurnal

The raw diurnal data are sampled at 1 Hz and imported into a database. The data are filtered with a 51 second median filter and then a 51 second Hanning filter to remove spikes and smooth short wavelength variations. A non-linear variation is then calculated and a flag channel is created to indicate where the variation exceeds the survey tolerance. Acceptable diurnal data are interpolated to a 10 Hz sample rate and the local regional field value of 56992.5, calculated from the average of the first day's diurnal data, was removed to leave the diurnal variation. This diurnal variation is then ready to be used in the processing of the airborne magnetic data.

Total Magnetic Field

The Total Magnetic Field (TMF) data collected in flight were profiled on screen along with a fourth difference channel calculated from the TMF. Spikes were removed manually where indicated by the fourth difference. The despiked data were then corrected for lag by 2.0 seconds. The diurnal variation that was extracted from the filtered ground station data was then removed from the despiked and lagged TMF. Once, the diurnal was removed, a magnetic value for the centre of the measurement platform was calculated by taking the average of the lagged and diurnally corrected, port and starboard magnetic sensors. The results were then levelled using tie and traverse line intercepts. Manual adjustments were applied to any lines that required levelling, as indicated by shadowed images of the gridded magnetic data. The manually levelled data were then subjected to a microlevelling filter.

Transverse Magnetic Gradient

Transverse magnetic gradient data was calculated from the lag corrected port and starboard sensors of the MIDAS system. The gradient was calculated with respect to the flight line direction with the median removed on a line-by-line basis. The results were then subjected to a microlevelling filter to remove any short

wavelength residual line-to-line discrepancies.

Enhanced Total Magnetic Field

Bidirectional gridding with the transverse gradient should produce a surface that correctly renders both the measured data and the measured horizontal gradient at each survey line. This can be an advantage when gridding data that include features approaching the line-separation in size and also for rendering features that are not perpendicular to the line direction, particularly those which are sub-parallel to the line direction

Final transverse magnetic gradient data were used in conjunction with the Total Magnetic Field to create a Horizontal Gradient Enhanced grid of the Total Magnetic Field. This grid was created using the enhanced bi-directional gridding tool in proprietary CGG Atlas software.

Calculated Vertical Magnetic Gradient

The Enhanced Total Magnetic Field grid was subjected to a processing algorithm that enhances the response of magnetic bodies in the upper 500 metres and attenuates the response of deeper bodies. The resulting vertical gradient grid provides better definition and resolution of near-surface magnetic units. It also identifies weak magnetic features that may not be quite as evident in the TMF data. Regional magnetic variations and changes in lithology, however, may be better defined on the Total Magnetic Field.

Digital Elevation

The radar altimeter values are subtracted from the differentially corrected and de-spiked GPS-Z values to produce profiles of the height above mean sea level along the survey lines. These values are gridded to produce contour maps showing approximate elevations within the survey area. Any subtle line-to-line discrepancies are manually removed. After the manual corrections are applied, the digital terrain data are filtered with a microlevelling algorithm.

The accuracy of the elevation calculation is directly dependent on the accuracy of the two input parameters, laser altimeter and GPS-Z. The GPS-Z value is primarily dependent on the number of available satellites. Although post-processing of GPS data will yield X and Y accuracies in the order of 1-2 metres, the accuracy of the Z value is usually much less, sometimes in the ±5 metre range. Further inaccuracies may be introduced during the interpolation and gridding process.

Because of the inherent inaccuracies of this method, no guarantee is made or implied that the information displayed is a true representation of the height above sea level. Although this product may be of some use as a general reference, **THIS PRODUCT MUST NOT BE USED FOR NAVIGATION PURPOSES.**

Contour, Colour and Shadow Map Displays

The magnetic are interpolated onto a regular grid using a modified Akima spline technique. The resulting grid is suitable for image processing and generation of contour maps. The grid cell size is 20% of the line interval.

Colour maps are produced by interpolating the grid down to the pixel size. The parameter is then incremented with respect to specific amplitude ranges to provide colour "contour" maps.

CONCLUSIONS AND RECOMMENDATIONS

This report provides a very brief description of the survey results and describes the equipment, data processing procedures and logistics of the airborne survey over the Apollo Area, near Dawson City, Yukon. The various maps included with this report display the magnetic properties of the survey area.

It is recommended that the survey results be assessed and fully evaluated in conjunction with all other available geophysical, geological and geochemical information. In particular, structural analysis of the data should be undertaken and areas of interest should be selected. An attempt should be made to determine the geophysical "signatures" over any known zones of mineralization in the survey areas or their vicinity.

It is also recommended that image processing of existing geophysical data be considered, in order to extract the maximum amount of information from the survey results. Current software and imaging techniques often provide valuable information on structure and lithology, which may not be clearly evident on the contour and colour maps. These techniques can yield images that define subtle, but significant, structural details.

Respectfully submitted,

CGG

R14013

Appendix A List of Personnel

List of Personnel:

The following personnel were involved in the acquisition, processing, interpretation and presentation of data, relating to a MIDAS magnetic airborne geophysical survey carried out for Kaminak Gold Corp. over the Apollo Area near Dawson City, Yukon.

Duane Griffith	Manager, Geophysical Services
Brett Robinson	Project Manager
Chris Sawyer	Flight Planner
Aaron Rampersad	Electronics Technician
Glenn Charbonneau	Pilot (Great Slave Helicopters)
Amanda Heydorn	Data Processor
Patrice Marchesi	Data Processor

All personnel were employees of CGG, except where indicated.

Appendix B Data Archive Description

Data Archive Description:

Survey Details:

Survey Area Name: Apollo Area
 Project number: 14013
 Client: Kaminak Gold Corp.
 Survey Company Name: CGG
 Flown Dates: March 22 to March 24, 2014
 Archive Creation Date: April 9, 2014

Geodetic Information for map products:

Datum: NAD83
 Ellipsoid: GRS80
 Projection: UTM Zone 7N
 Central meridian: 141° West
 False Easting: 500000 metres
 False Northing: 0 metres
 Scale factor: 0.9996
 WGS84 to Local Conversion: Molodensky
 Dx,Dy,Dz: 0, 0, 0

Grid Archive:

Geosoft Grids:

File	Description	Units
mag	Horizontal Gradient Enhanced Total Magnetic Field	nT
cvg	Calculated Vertical Magnetic Gradient	nT/m
mhg	Measured Transverse Magnetic Gradient	nT/m

Linedata Archive:

Geosoft Database Layout:

Field	Variable	Description	Units
1	X	Easting NAD83	m
2	Y	Northing NAD83	m
3	fid	fiducial	-
4	longitude	Longitude WGS84	degrees
5	latitude	Latitude WGS84	degrees
6	flight	Flight number	-
7	date	Flight date	ddmmyy
8	altrad_heli	Helicopter height above surface from radar altimeter	m
9	altlas_heli	Helicopter height above surface from laser altimeter	m
10	gpsz	Helicopter height above geoid	m
11	dem	Digital elevation model (above geoid)	m
12	diurnal	Measured ground magnetic intensity	nT
13	diurnal_cor	Diurnal correction – base removed	nT
14	magport_raw	Total magnetic field, port sensor – spike rejected	nT
15	magstar_raw	Total magnetic field, starboard sensor – spike	nT

		rejected	
16	magport_comp	Total magnetic field, port sensor - compensated	nT
17	magstbd_comp	Total magnetic field, starboard sensor - compensated	nT
18	magport_lag	Total magnetic field, port sensor - corrected for lag	nT
19	magstar_lag	Total magnetic field, starboard sensor - corrected for lag	nT
20	mag_ave_diu	Total magnetic field, average of port and starboard sensors – diurnal variation removed	nT
21	mag_tmf	Total magnetic field	nT
22	transgrad	Measured transverse horizontal magnetic gradient	nT/m
23	fx	Fluxgate magnetometer, component 1	nT
24	Fluxgate magnetometer, component 2	nT	
25	fz	Fluxgate magnetometer, component 3	nT

Note – The null values in the GDB and XYZ archives are displayed as *.

Report:

A logistics and processing report for Project #14013 in PDF format:

R14013.pdf

Appendix C Map Product Grids

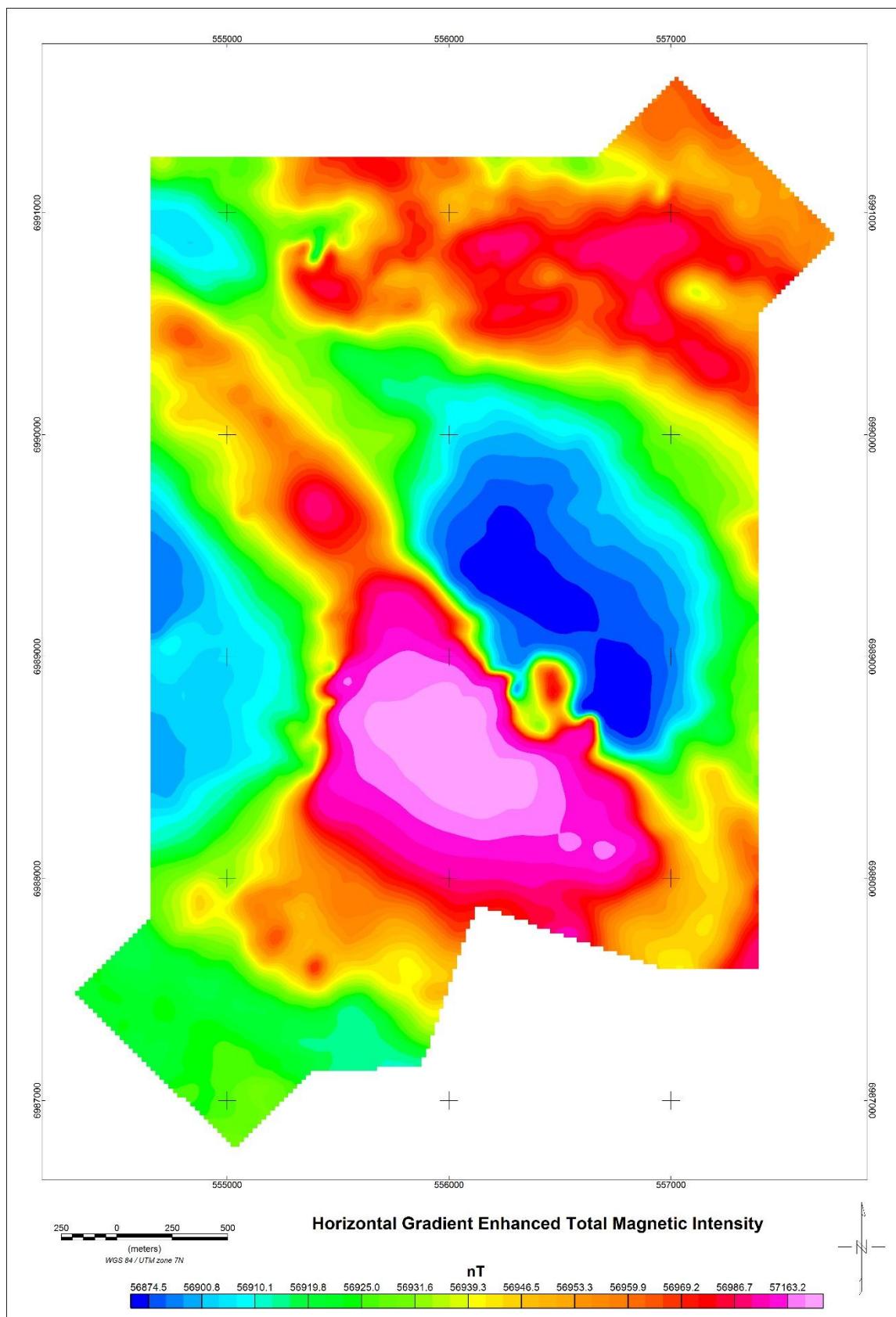


Figure 4 Horizontal Gradient Enhanced Total Magnetic Intensity

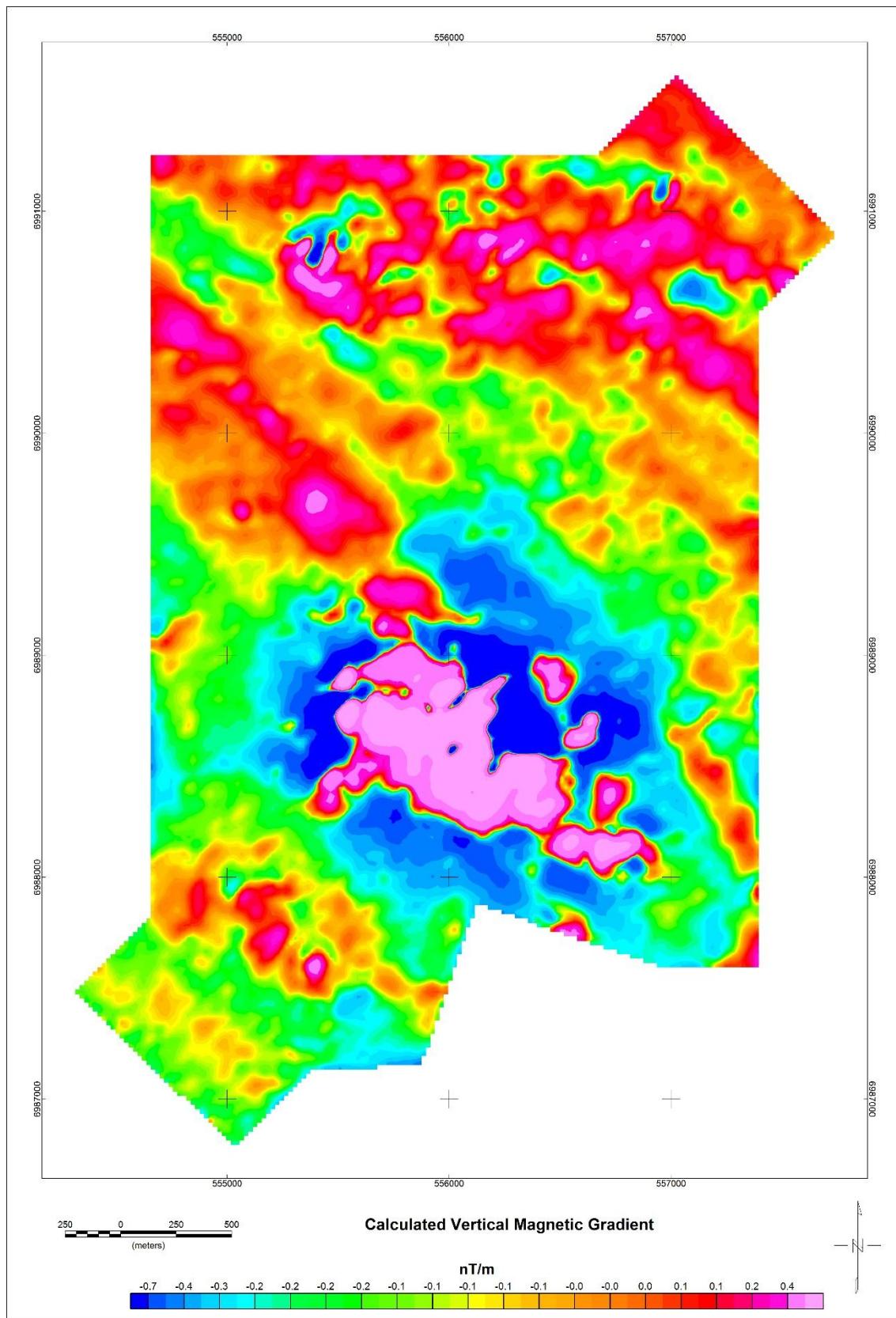


Figure 5 Calculated Vertical Magnetic Gradient

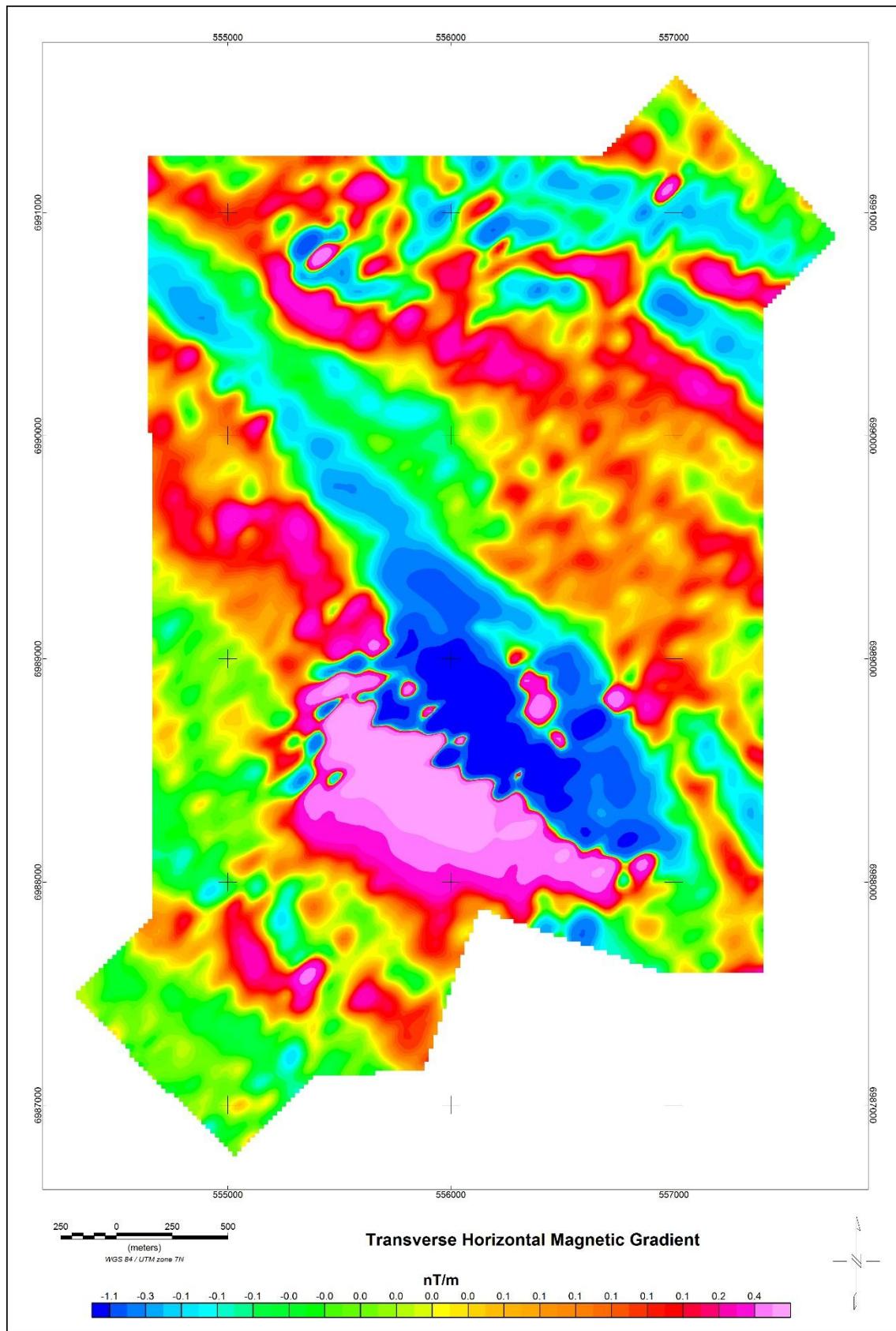


Figure 6 Transverse Horizontal Magnetic Gradient

Appendix D Background Information

Magnetic Responses

The measured total magnetic field provides information on the magnetic properties of the earth materials in the survey area. The information can be used to locate magnetic bodies of direct interest for exploration, and for structural and lithological mapping.

The total magnetic field response reflects the abundance of magnetic material in the source. Magnetite is the most common magnetic mineral. Other minerals such as ilmenite, pyrrhotite, franklinite, chromite, hematite, arsenopyrite, limonite and pyrite are also magnetic, but to a lesser extent than magnetite on average.

In some geological environments, an EM anomaly with magnetic correlation has a greater likelihood of being produced by sulphides than one which is non-magnetic. However, sulphide ore bodies may be non-magnetic (e.g., the Kidd Creek deposit near Timmins, Canada) as well as magnetic (e.g., the Mattabi deposit near Sturgeon Lake, Canada).

Iron ore deposits will be anomalously magnetic in comparison to surrounding rock due to the concentration of iron minerals such as magnetite, ilmenite and hematite.

Changes in magnetic susceptibility often allow rock units to be differentiated based on the total field magnetic response. Geophysical classifications may differ from geological classifications if various magnetite levels exist within one general geological classification. Geometric considerations of the source such as shape, dip and depth, inclination of the earth's field and remanent magnetization will complicate such an analysis.

In general, mafic lithologies contain more magnetite and are therefore more magnetic than many sediments which tend to be weakly magnetic. Metamorphism and alteration can also increase or decrease the magnetization of a rock unit.

Textural differences on a total field magnetic contour, colour or shadow map due to the frequency of activity of the magnetic parameter resulting from inhomogeneities in the distribution of magnetite within the rock, may define certain lithologies. For example, near surface volcanics may display highly complex contour patterns with little line-to-line correlation.

Rock units may be differentiated based on the plan shapes of their total field magnetic responses. Mafic intrusive plugs can appear as isolated "bulls-eye" anomalies. Granitic intrusives appear as sub-circular zones, and may have contrasting rings due to contact metamorphism. Generally, granitic terrain will lack a pronounced strike direction, although granite gneiss may display strike.

Linear north-south units are theoretically not well-defined on total field magnetic maps in equatorial regions due to the low inclination of the earth's magnetic field. However, most stratigraphic units will have variations in composition along strike that will cause the units to appear as a series of alternating magnetic highs and lows.

Faults and shear zones may be characterized by alteration that causes destruction of magnetite (e.g., weathering) that produces a contrast with surrounding rock. Structural breaks may be filled by magnetite-rich, fracture filling material as is the case with diabase dikes, or by non-magnetic felsic material.

Faulting can also be identified by patterns in the magnetic total field contours or colours. Faults and dikes tend to appear as lineaments and often have strike lengths of several kilometres. Offsets in narrow, magnetic, stratigraphic trends also delineate structure. Sharp contrasts in magnetic lithologies may arise due to large displacements along strike-slip or dip-slip faults.

Appendix E Glossary

CGG GLOSSARY OF AIRBORNE GEOPHYSICAL TERMS

accelerometer: an instrument that measures both acceleration (due to motion) and acceleration due to **gravity**.

altitude attenuation: the absorption of gamma rays by the atmosphere between the earth and the detector. The number of gamma rays detected by a system decreases as the altitude increases.

AGG: Airborne **gravity gradiometer**.

AGS: Airborne **gamma-ray spectrometry**.

amplitude: The strength of the total electromagnetic field. In **frequency domain** it is most often the sum of the squares of **in-phase** and **quadrature** components. In multi-component electromagnetic surveys it is generally the sum of the squares of all three directional components.

analytic signal: The total amplitude of all the directions of magnetic **gradient**. Calculated as the sum of the squares.

anisotropy: Having different **physical parameters** in different directions. This can be caused by layering or fabric in the geology. Note that a unit can be anisotropic, but still **homogeneous**.

anomaly: A localized change in the geophysical data characteristic of a discrete source, such as a conductive or magnetic body: something locally different from the **background**.

apparent- : the **physical parameters** of the earth measured by a geophysical system are normally expressed as apparent, as in “apparent **resistivity**”. This means that the measurement is limited by assumptions made about the geology in calculating the response measured by the geophysical system. Apparent resistivity calculated with **HEM**, for example, generally assumes that the earth is a **homogeneous half-space** – not layered.

attitude: the orientation of a geophysical system relative to the earth. Some surveys assume the instrument attitudes are constant, and other surveys measure the attitude and correct the data for the changes in response because of attitude.

B-field: In time-domain **electromagnetic** surveys, the magnetic field component of the (electromagnetic) **field**. This can be measured directly, although more commonly it is calculated by integrating the time rate of change of the magnetic field **dB/dt**, as measured with a receiver coil.

background: The “normal” response in the geophysical data – that response observed over most of the survey area. **Anomalies** are usually measured relative to the background. In airborne gamma-ray spectrometric surveys the term defines the **cosmic**, radon, and aircraft responses in the absence of a signal from the ground.

base-level: The measured values in a geophysical system in the absence of any outside signal. All geophysical data are measured relative to the system base level.

base frequency: The frequency of the pulse repetition for a **time-domain electromagnetic** system. Measured between subsequent positive pulses.

base magnetometer: A stationary magnetometer used to record the **diurnal** variations in the earth’s magnetic field; to be used to correct the survey magnetic data.

bird: A common name for the pod towed beneath or behind an aircraft, carrying the geophysical sensor array.

bucking: The process of removing the strong **signal** from the **primary field** at the **receiver** from the data, to measure the **secondary field**. It can be done electronically or mathematically. This is done in **frequency-domain EM**, and to measure **on-time** in **time-domain EM**.

calibration: a procedure to ensure a geophysical instrument is measuring accurately and repeatably. Most often applied in **EM** and **gamma-ray spectrometry**.

calibration coil: A wire coil of known size and dipole moment, which is used to generate a field of known **amplitude** and **phase** or **decay constant** in the receiver, for system calibration. Calibration coils can be external, or internal to the system. Internal coils may be called Q-coils.

coaxial coils: [CX] Coaxial coils in an HEM system are in the vertical plane, with their axes horizontal and collinear in the flight direction. These are most sensitive to vertical conductive objects in the ground, such as thin, steeply dipping conductors perpendicular to the flight direction. Coaxial coils generally give the sharpest anomalies over localized conductors. (See also **coplanar coils**)

coil: A multi-turn wire loop used to transmit or detect electromagnetic fields. Time varying **electromagnetic** fields through a coil induce a voltage proportional to the strength of the field and the rate of change over time.

compensation: Correction of airborne geophysical data for the changing effect of the aircraft. This process is generally used to correct data in **fixed-wing time-domain electromagnetic** surveys (where the transmitter is on the aircraft and the receiver is moving), and magnetic surveys (where the sensor is on the aircraft, turning in the earth's magnetic field).

component: In **frequency domain electromagnetic** surveys this is one of the two **phase** measurements – **in-phase or quadrature**. In “multi-component” electromagnetic surveys it is also used to define the measurement in one geometric direction (vertical, horizontal in-line and horizontal transverse – the Z, X and Y components).

Compton scattering: gamma ray photons will bounce off electrons as they pass through the earth and atmosphere, reducing their energy and then being detected by **radiometric** sensors at lower energy levels. See also **stripping**.

conductance: See **conductivity thickness**

conductivity: [σ] The facility with which the earth or a geological formation conducts electricity. Conductivity is usually measured in milli-Siemens per metre (mS/m). It is the reciprocal of **resistivity**.

conductivity-depth imaging: see **conductivity-depth transform**.

conductivity-depth transform: A process for converting electromagnetic measurements to an approximation of the conductivity distribution vertically in the earth, assuming a **layered earth**. (Macnae and Lamontagne, 1987; Wolfgram and Karlik, 1995)

conductivity thickness: [σt] The product of the **conductivity**, and thickness of a large, tabular body. (It is also called the “conductivity-thickness product”) In electromagnetic geophysics, the response of a thin plate-like conductor is proportional to the conductivity multiplied by thickness. For example a 10 metre thickness of 20 Siemens/m mineralization will be equivalent to 5 metres of 40 S/m; both have 200 S conductivity thickness. Sometimes referred to as conductance.

conductor: Used to describe anything in the ground more conductive than the surrounding geology. Conductors are most often clays or graphite, or hopefully some type of mineralization, but may also be man-

made objects, such as fences or pipelines.

continuation: mathematical procedure applied to **potential field** geophysical data to approximate data collected at a different altitude. Data can be continued upward to a higher altitude or downward to a lower altitude.

coplanar coils: [CP] In HEM, the coplanar coils lie in the horizontal plane with their axes vertical, and parallel. These coils are most sensitive to massive conductive bodies, horizontal layers, and the **halfspace**.

cosmic ray: High energy sub-atomic particles from outer space that collide with the earth's atmosphere to produce a shower of gamma rays (and other particles) at high energies.

counts (per second): The number of **gamma-rays** detected by a gamma-ray **spectrometer**. The rate depends on the geology, but also on the size and sensitivity of the detector.

culture: A term commonly used to denote any man-made object that creates a geophysical anomaly. Includes, but not limited to, power lines, pipelines, fences, and buildings.

current channelling: See current gathering.

current gathering: The tendency of electrical currents in the ground to channel into a conductive formation. This is particularly noticeable at higher frequencies or early time channels when the formation is long and parallel to the direction of current flow. This tends to enhance anomalies relative to inductive currents (see also **induction**). Also known as current channelling.

daughter products: The radioactive natural sources of gamma-rays decay from the original "parent" element (commonly potassium, uranium, and thorium) to one or more lower-energy "daughter" elements. Some of these lower energy elements are also radioactive and decay further. **Gamma-ray spectrometry** surveys may measure the gamma rays given off by the original element or by the decay of the daughter products.

dB/dt: As the **secondary electromagnetic field** changes with time, the magnetic field [**B**] component induces a voltage in the receiving **coil**, which is proportional to the rate of change of the magnetic field over time.

decay: In **time-domain electromagnetic** theory, the weakening over time of the **eddy currents** in the ground, and hence the **secondary field** after the **primary field** electromagnetic pulse is turned off. In **gamma-ray spectrometry**, the radioactive breakdown of an element, generally potassium, uranium, thorium, into their **daughter** products.

decay constant: see time constant.

decay series: In **gamma-ray spectrometry**, a series of progressively lower energy **daughter products** produced by the radioactive breakdown of uranium or thorium.

depth of exploration: The maximum depth at which the geophysical system can detect the target. The depth of exploration depends very strongly on the type and size of the target, the contrast of the target with the surrounding geology, the homogeneity of the surrounding geology, and the type of geophysical system. One measure of the maximum depth of exploration for an electromagnetic system is the depth at which it can detect the strongest conductive target – generally a highly conductive horizontal layer.

differential resistivity: A process of transforming **apparent resistivity** to an approximation of layer resistivity at each depth. The method uses multi-frequency HEM data and approximates the effect of shallow layer **conductance** determined from higher frequencies to estimate the deeper conductivities (Huang and

Fraser, 1996)

dipole moment: [NIA] For a transmitter, the product of the area of a **coil**, the number of turns of wire, and the current flowing in the coil. At a distance significantly larger than the size of the coil, the magnetic field from a coil will be the same if the dipole moment product is the same. For a receiver coil, this is the product of the area and the number of turns. The sensitivity to a magnetic field (assuming the source is far away) will be the same if the dipole moment is the same.

diurnal: The daily variation in a natural field, normally used to describe the natural fluctuations (over hours and days) of the earth's magnetic field.

dielectric permittivity: [ϵ] The capacity of a material to store electrical charge, this is most often measured as the relative permittivity [ϵ_r], or ratio of the material dielectric to that of free space. The effect of high permittivity may be seen in HEM data at high frequencies over highly resistive geology as a reduced or negative ***in-phase***, and higher ***quadrature*** data.

dose rate: see **exposure rate**.

drape: To fly a survey following the terrain contours, maintaining a constant altitude above the local ground surface. Also applied to re-processing data collected at varying altitudes above ground to simulate a survey flown at constant altitude.

drift: Long-time variations in the base-level or calibration of an instrument.

eddy currents: The electrical currents induced in the ground, or other conductors, by a time-varying **electromagnetic field** (usually the **primary field**). Eddy currents are also induced in the aircraft's metal frame and skin; a source of **noise** in EM surveys.

electromagnetic: [EM] Comprised of a time-varying electrical and magnetic field. Radio waves are common electromagnetic fields. In geophysics, an electromagnetic system is one which transmits a time-varying **primary field** to induce **eddy currents** in the ground, and then measures the **secondary field** emitted by those eddy currents.

energy window: A broad spectrum of **gamma-ray** energies measured by a spectrometric survey. The energy of each gamma-ray is measured and divided up into numerous discrete energy levels, called windows.

equivalent (thorium or uranium): The amount of radioelement calculated to be present, based on the gamma-rays measured from a **daughter** element. This assumes that the **decay series** is in equilibrium – progressing normally.

exposure rate: in radiometric surveys, a calculation of the total exposure rate due to gamma rays at the ground surface. It is used as a measurement of the concentration of all the **radioelements** at the surface. Sometimes called "dose rate". See also: **natural exposure rate**.

fiducial, or fid: Timing mark on a survey record. Originally these were timing marks on a profile or film; now the term is generally used to describe 1-second interval timing records in digital data, and on maps or profiles.

Figure of Merit: (FOM) A sum of the 12 distinct magnetic noise variations measured by each of four flight directions, and executing three aircraft attitude variations (yaw, pitch, and roll) for each direction. The flight directions are generally parallel and perpendicular to planned survey flight directions. The FOM is used as a measure of the **manoeuvre noise** before and after **compensation**.

fixed-wing: Aircraft with wings, as opposed to “rotary wing” helicopters.

flight: a continuous interval of survey data collection, generally between stops at base to refuel.

flight-line: a single line of data across the survey area. Surveys are generally comprised of many parallel flight lines to cover the survey area, with wider-spaced **tie lines** perpendicular. Flight lines are generally separated by **turn-arounds** when the aircraft is outside the survey area.

footprint: This is a measure of the area of sensitivity under the aircraft of an airborne geophysical system. The footprint of an **electromagnetic** system is dependent on the altitude of the system, the orientation of the transmitter and receiver and the separation between the receiver and transmitter, and the conductivity of the ground. The footprint of a **gamma-ray spectrometer** depends mostly on the altitude. For all geophysical systems, the footprint also depends on the strength of the contrasting **anomaly**.

frequency domain: An **electromagnetic** system which transmits a harmonic **primary field** that oscillates over time (e.g. sinusoidal), inducing a similarly varying electrical current in the ground. These systems generally measure the changes in the **amplitude** and **phase** of the **secondary field** from the ground at different frequencies by measuring the **in-phase** and **quadrature** phase components. See also **time-domain**.

full-stream data: Data collected and recorded continuously at the highest possible sampling rate. Normal data are stacked (see **stacking**) over some time interval before recording.

gamma-ray: A very high-energy photon, emitted from the nucleus of an atom as it undergoes a change in energy levels.

gamma-ray spectrometry: Measurement of the number and energy of natural (and sometimes man-made) gamma-rays across a range of photon energies.

GGI: gravity gradiometer instrument. An airborne gravity gradiometer (AGG) consists of a GGI mounted in an inertial platform together with a temperature control system.

gradient: In magnetic surveys, the gradient is the change of the magnetic field over a distance, either vertically or horizontally in either of two directions. Gradient data can be measured, or calculated from the total magnetic field data because it changes more quickly over distance than the **total magnetic field**, and so may provide a more precise measure of the location of a source. See also **analytic signal**.

gradiometer, gradiometry: instrument and measurement of the gradient, or change in a field with location usually for **gravity** or **magnetic** surveys. Used to provide higher resolution of **targets**, better **interpretation** of **target** geometry, independence from drift and absolute field and, for **gravity**, accelerations of the aircraft.

gravity: Survey collecting measurements of the earth’s gravitational field strength. Denser objects in the earth create stronger gravitational pull above them.

ground effect: The response from the earth. A common **calibration** procedure in many geophysical surveys is to fly to altitude high enough to be beyond any measurable response from the ground, and there establish **base levels** or **backgrounds**.

half-space: A mathematical model used to describe the earth – as infinite in width, length, and depth below the surface. The most common halfspace models are **homogeneous** and **layered earth**.

heading error: A slight change in the magnetic field measured when flying in opposite directions.

HEM: Helicopter ElectroMagnetic, This designation is most commonly used for helicopter-borne, **frequency-**

domain electromagnetic systems. At present, the transmitter and receivers are normally mounted in a **bird** carried on a sling line beneath the helicopter.

herringbone pattern: A pattern created in geophysical data by an asymmetric system, where the **anomaly** may be extended to either side of the source, in the direction of flight. Appears like fish bones, or like the teeth of a comb, extending either side of centre, each tooth an alternate flight line.

homogeneous: This is a geological unit that has the same **physical parameters** throughout its volume. This unit will create the same response to an HEM system anywhere, and the HEM system will measure the same apparent **resistivity** anywhere. The response may change with system direction (see **anisotropy**).

HFEM: Helicopter Frequency-domain ElectroMagnetic, This designation is used for helicopter-borne, **frequency-domain** electromagnetic systems. Formerly most often called HEM.

HTEM: Helicopter Time-domain ElectroMagnetic, This designation is used for the new generation of helicopter-borne, **time-domain** electromagnetic systems.

in-phase: the component of the measured **secondary field** that has the same phase as the transmitter and the **primary field**. The in-phase component is stronger than the **quadrature** phase over relatively higher **conductivity**.

induction: Any time-varying electromagnetic field will induce (cause) electrical currents to flow in any object with non-zero **conductivity**. (see **eddy currents**)

induction number: also called the “response parameter”, this number combines many of the most significant parameters affecting the **EM** response into one parameter against which to compare responses. For a **layered earth** the response parameter is $\mu\omega\sigma h^2$ and for a large, flat, **conductor** it is $\mu\omega\sigma t$, where μ is the **magnetic permeability**, ω is the angular **frequency**, σ is the **conductivity**, t is the thickness (for the flat conductor) and h is the height of the system above the conductor.

inductive limit: When the frequency of an EM system is very high, or the **conductivity** of the target is very high, the response measured will be entirely **in-phase** with no **quadrature (phase angle =0)**. The in-phase response will remain constant with further increase in conductivity or frequency. The system can no longer detect changes in conductivity of the target.

infinite: In geophysical terms, an “infinite” dimension is one much greater than the **footprint** of the system, so that the system does not detect changes at the edges of the object.

International Geomagnetic Reference Field: [IGRF] An approximation of the smooth magnetic field of the earth, in the absence of variations due to local geology. Once the IGRF is subtracted from the measured magnetic total field data, any remaining variations are assumed to be due to local geology. The IGRF also predicts the slow changes of the field up to five years in the future.

inversion, or inverse modeling: A process of converting geophysical data to an earth model, which compares theoretical models of the response of the earth to the data measured, and refines the model until the response closely fits the measured data (Huang and Palacky, 1991)

layered earth: A common geophysical model which assumes that the earth is horizontally layered – the **physical parameters** are constant to **infinite** distance horizontally, but change vertically.

lead-in: approach to a **flight line** outside of survey area to establish proper track and stabilize instrumentations. The lead-in for a helicopter survey is generally shorter than required for fixed-wing.

line source, or line current: a long narrow object that creates an **anomaly** on an **EM** survey. Generally man-made objects like fences, power lines, and pipelines (**culture**).

mag: common abbreviation for **magnetic**.

magnetic: (“**mag**”) a survey measuring the strength of the earth’s magnetic field, to identify geology and targets by their effect on the field.

magnetic permeability: [μ] This is defined as the ratio of magnetic induction to the inducing magnetic field. The relative magnetic permeability [μ_r] is often quoted, which is the ratio of the rock permeability to the permeability of free space. In geology and geophysics, the **magnetic susceptibility** is more commonly used to describe rocks.

magnetic susceptibility: [k] A measure of the degree to which a body is magnetized. In SI units this is related to relative **magnetic permeability** by $k=\mu_r-1$, and is a dimensionless unit. For most geological material, susceptibility is influenced primarily by the percentage of magnetite. It is most often quoted in units of 10^{-6} . In HEM data this is most often apparent as a negative **in-phase** component over high susceptibility, high **resistivity** geology such as diabase dikes.

manoeuvre noise: variations in the magnetic field measured caused by changes in the relative positions of the magnetic sensor and magnetic objects or electrical currents in the aircraft. This type of noise is generally corrected by magnetic **compensation**.

model: Geophysical theory and applications generally have to assume that the geology of the earth has a form that can be easily defined mathematically, called the model. For example steeply dipping **conductors** are generally modeled as being **infinite** in horizontal and depth extent, and very thin. The earth is generally modeled as horizontally layered, each layer infinite in extent and uniform in characteristic. These models make the mathematics to describe the response of the (normally very complex) earth practical. As theory advances, and computers become more powerful, the useful models can become more complex.

natural exposure rate: in radiometric surveys, a calculation of the total exposure rate due to natural-source gamma rays at the ground surface. It is used as a measurement of the concentration of all the natural **radioelements** at the surface. See also: **exposure rate**.

natural source: any geophysical technique for which the source of the energy is from nature, not from a man-made object. Most commonly applied to natural source **electromagnetic** surveys.

noise: That part of a geophysical measurement that the user does not want. Typically this includes electronic interference from the system, the atmosphere (**sferics**), and man-made sources. This can be a subjective judgment, as it may include the response from geology other than the target of interest. Commonly the term is used to refer to high frequency (short period) interference. See also **drift**.

Occam’s inversion: an **inversion** process that matches the measured **electromagnetic** data to a theoretical model of many, thin layers with constant thickness and varying resistivity (Constable et al, 1987).

off-time: In a **time-domain electromagnetic** survey, the time after the end of the **primary field pulse**, and before the start of the next pulse.

on-time: In a **time-domain electromagnetic** survey, the time during the **primary field pulse**.

overburden: In engineering and mineral exploration terms, this most often means the soil on top of the unweathered bedrock. It may be sand, glacial till, or weathered rock.

Phase, phase angle: The angular difference in time between a measured sinusoidal electromagnetic field

and a reference – normally the primary field. The phase is calculated from \tan^{-1} (**in-phase / quadrature**).

physical parameters: These are the characteristics of a geological unit. For electromagnetic surveys, the important parameters are **conductivity**, **magnetic permeability** (or **susceptibility**) and **dielectric permittivity**; for magnetic surveys the parameter is magnetic susceptibility, and for gamma ray spectrometric surveys it is the concentration of the major radioactive elements: potassium, uranium, and thorium.

permittivity: see **dielectric permittivity**.

permeability: see **magnetic permeability**.

potential field: A field that obeys Laplace's Equation. Most commonly used to describe **gravity** and **magnetic** measurements.

primary field: the EM field emitted by a transmitter. This field induces **eddy currents** in (energizes) the conductors in the ground, which then create their own **secondary fields**.

pulse: In time-domain EM surveys, the short period of intense **primary** field transmission. Most measurements (the **off-time**) are measured after the pulse. **On-time** measurements may be made during the pulse.

quadrature: that component of the measured **secondary field** that is phase-shifted 90° from the **primary field**. The quadrature component tends to be stronger than the **in-phase** over relatively weaker **conductivity**.

Q-coils: see **calibration coil**.

radioelements: This normally refers to the common, naturally-occurring radioactive elements: potassium (K), uranium (U), and thorium (Th). It can also refer to man-made radioelements, most often cobalt (Co) and cesium (Cs)

radiometric: Commonly used to refer to **gamma ray** spectrometry.

radon: A radioactive daughter product of uranium and thorium, radon is a gas which can leak into the atmosphere, adding to the non-geological background of a gamma-ray spectrometric survey.

receiver: the **signal** detector of a geophysical system. This term is most often used in active geophysical systems – systems that transmit some kind of signal. In airborne **electromagnetic** surveys it is most often a **coil**. (see also, **transmitter**)

resistivity: [ρ] The strength with which the earth or a geological formation resists the flow of electricity, typically the flow induced by the **primary field** of the electromagnetic transmitter. Normally expressed in ohm-metres, it is the reciprocal of **conductivity**.

resistivity-depth transforms: similar to **conductivity depth transforms**, but the calculated **conductivity** has been converted to **resistivity**.

resistivity section: an approximate vertical section of the resistivity of the layers in the earth. The resistivities can be derived from the **apparent resistivity**, the **differential resistivities**, **resistivity-depth transforms**, or **inversions**.

response parameter: another name for the **induction number**.

secondary field: The field created by conductors in the ground, as a result of electrical currents induced by the **primary field** from the **electromagnetic** transmitter. Airborne **electromagnetic** systems are designed to

create and measure a secondary field.

Sengpiel section: a **resistivity section** derived using the **apparent resistivity** and an approximation of the depth of maximum sensitivity for each frequency.

sferic: Lightning, or the **electromagnetic** signal from lightning, it is an abbreviation of “atmospheric discharge”. These appear to magnetic and electromagnetic sensors as sharp “spikes” in the data. Under some conditions lightning storms can be detected from hundreds of kilometres away. (see **noise**)

signal: That component of a measurement that the user wants to see – the response from the targets, from the earth, etc. (See also **noise**)

skin depth: A measure of the depth of penetration of an electromagnetic field into a material. It is defined as the depth at which the primary field decreases to 1/e of the field at the surface. It is calculated by approximately $503 \times \sqrt{(\text{resistivity}/\text{frequency})}$. Note that depth of penetration is greater at higher **resistivity** and/or lower **frequency**.

spec: common abbreviation for *gamma-ray spectrometry*.

spectrometry: Measurement across a range of energies, where **amplitude** and energy are defined for each measurement. In gamma-ray spectrometry, the number of gamma rays are measured for each energy **window**, to define the **spectrum**.

spectrum: In **gamma ray spectrometry**, the continuous range of energy over which gamma rays are measured. In **time-domain electromagnetic** surveys, the spectrum is the energy of the **pulse** distributed across an equivalent, continuous range of frequencies.

spheric: see **sferic**.

stacking: Summing repeat measurements over time to enhance the repeating **signal**, and minimize the random **noise**.

stinger: A boom mounted on an aircraft to carry a geophysical sensor (usually **magnetic**). The boom moves the sensor farther from the aircraft, which might otherwise be a source of **noise** in the survey data.

stripping: Estimation and correction for the gamma ray photons of higher and lower energy that are observed in a particular **energy window**. See also **Compton scattering**.

susceptibility: See **magnetic susceptibility**.

tau: [τ] Often used as a name for the **decay time constant**.

TDEM: *time domain electromagnetic*.

thin sheet: A standard model for electromagnetic geophysical theory. It is usually defined as a thin, flat-lying conductive sheet, **infinite** in both horizontal directions. (see also **vertical plate**)

tie-line: A survey line flown across most of the **traverse lines**, generally perpendicular to them, to assist in measuring **drift** and **diurnal** variation. In the short time required to fly a tie-line it is assumed that the drift and/or diurnal will be minimal, or at least changing at a constant rate.

time constant: The time required for an **electromagnetic** field to decay to a value of 1/e of the original value. In **time-domain** electromagnetic data, the time constant is proportional to the size and **conductance** of a tabular conductive body. Also called the decay constant.

Time channel: In **time-domain electromagnetic** surveys the decaying **secondary field** is measured over a period of time, and the divided up into a series of consecutive discrete measurements over that time.

time-domain: **Electromagnetic** system which transmits a pulsed, or stepped **electromagnetic** field. These systems induce an electrical current (**eddy current**) in the ground that persists after the **primary field** is turned off, and measure the change over time of the **secondary field** created as the currents **decay**. See also **frequency-domain**.

total energy envelope: The sum of the squares of the three **components** of the **time-domain electromagnetic secondary field**. Equivalent to the **amplitude** of the secondary field.

transient: Time-varying. Usually used to describe a very short period pulse of **electromagnetic** field.

transmitter: The source of the **signal** to be measured in a geophysical survey. In airborne **EM** it is most often a **coil** carrying a time-varying electrical current, transmitting the **primary field**. (see also **receiver**)

traverse line: A normal geophysical survey line. Normally parallel traverse lines are flown across the property in spacing of 50 m to 500 m, and generally perpendicular to the target geology. Also called a **flight line**.

turn-arounds: The time the aircraft is turning between one **traverse** or **tie line** and the next. Turn-arounds are generally outside the survey area, and the data collected during this time generally are not useable, because of aircraft **manoeuvre noise**.

vertical plate: A standard model for electromagnetic geophysical theory. It is usually defined as thin conductive sheet, **infinite** in horizontal dimension and depth extent. (see also **thin sheet**)

waveform: The shape of the **electromagnetic pulse** from a **time-domain** electromagnetic transmitter.

window: A discrete portion of a **gamma-ray spectrum** or **time-domain electromagnetic decay**. The continuous energy spectrum or **full-stream** data are grouped into windows to reduce the number of samples, and reduce **noise**.

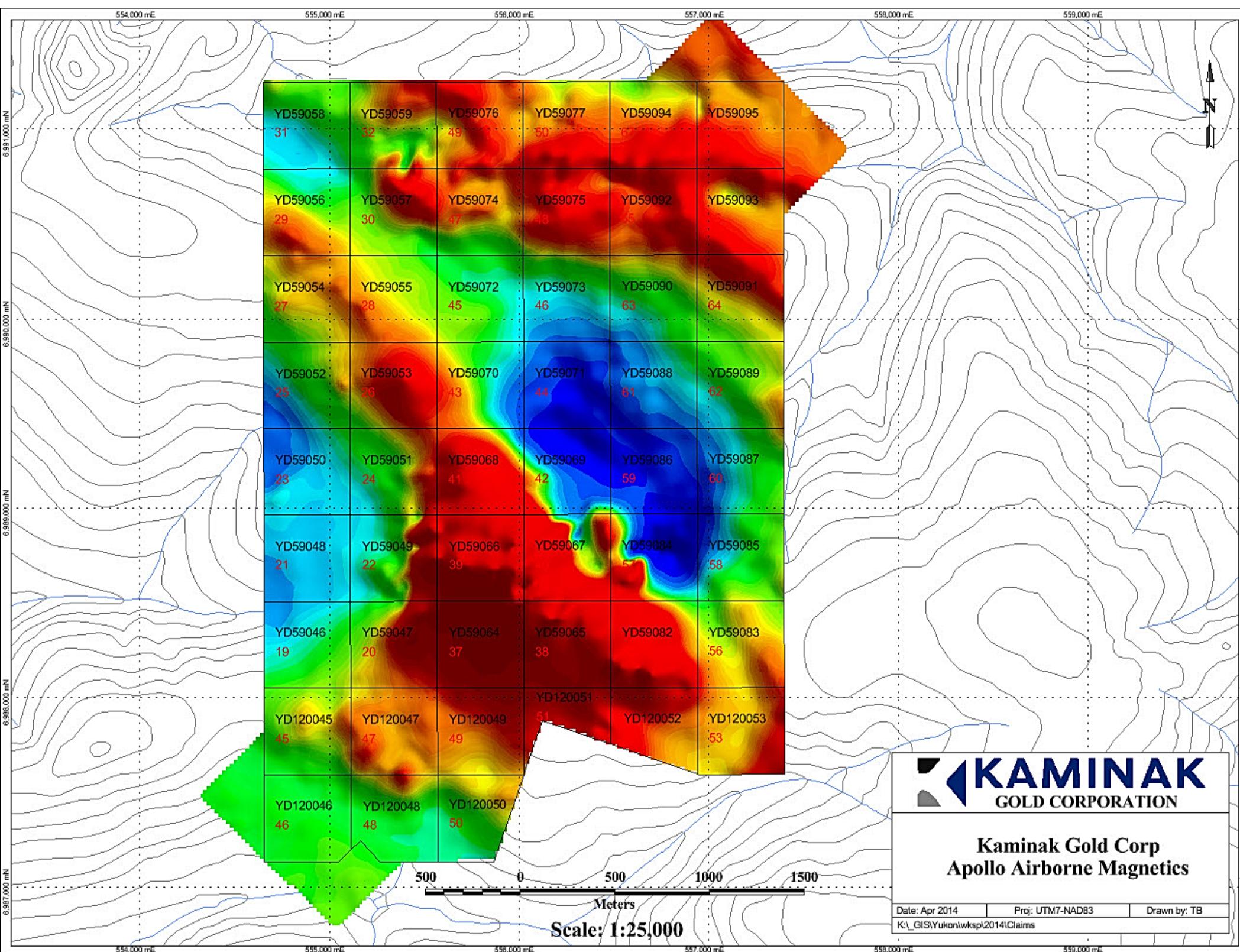
zero, or zero level: The **base level** of an instrument, with no **ground effect** or **drift**. Also, the act of measuring and setting the zero level.

Common Symbols and Acronyms

k	Magnetic susceptibility
ϵ	Dielectric permittivity
μ, μ_r	Magnetic permeability, relative permeability
ρ, ρ_a	Resistivity, apparent resistivity
σ, σ_a	Conductivity, apparent conductivity
σt	Conductivity thickness
τ	Tau, or time constant
Ωm	ohm-metres, units of resistivity
AGS	Airborne gamma ray spectrometry.
CDT	Conductivity-depth transform, conductivity-depth imaging (Macnae and Lamontagne, 1987; Wolfgram and Karlik, 1995)
CPI, CPQ	Coplanar in-phase, quadrature
CPS	Counts per second
CTP	Conductivity thickness product
CXI, CXQ	Coaxial, in-phase, quadrature
FOM	Figure of Merit
fT	femtoteslas, common unit for measurement of B-Field in time-domain EM
EM	Electromagnetic
keV	kilo electron volts – a measure of gamma-ray energy
MeV	mega electron volts – a measure of gamma-ray energy 1MeV = 1000keV
NIA	dipole moment: turns x current x Area
nT	nanotesla, a measure of the strength of a magnetic field
nT/s	nanoteslas/second; standard unit of measurement of secondary field dB/dt in time domain EM.
nG/h	nanoGreys/hour – gamma ray dose rate at ground level
ppm	parts per million – a measure of secondary field or noise relative to the primary or radioelement concentration.
pT	picoteslas: standard unit of measurement of B-Field in time-domain EM
pT/s	picoteslas per second: Units of decay of secondary field, dB/dt
S	siemens – a unit of conductance
x:	the horizontal component of an EM field parallel to the direction of flight.
y:	the horizontal component of an EM field perpendicular to the direction of flight.
z:	the vertical component of an EM field.

References:

- Constable, S.C., Parker, R.L., And Constable, C.G., 1987, Occam's inversion: a practical algorithm for generating smooth models from electromagnetic sounding data: *Geophysics*, 52, 289-300
- Huang, H. and Fraser, D.C, 1996. The differential parameter method for multifrequency airborne resistivity mapping. *Geophysics*, 55, 1327-1337
- Huang, H. and Palacky, G.J., 1991, Damped least-squares inversion of time-domain airborne EM data based on singular value decomposition: *Geophysical Prospecting*, v.39, 827-844
- Macnae, J. and Lamontagne, Y., 1987, Imaging quasi-layered conductive structures by simple processing of transient electromagnetic data: *Geophysics*, v52, 4, 545-554.
- Sengpiel, K-P. 1988, Approximate inversion of airborne EM data from a multi-layered ground. *Geophysical Prospecting*, 36, 446-459
- Wolfgram, P. and Karlik, G., 1995, Conductivity-depth transform of GEOTEM data: *Exploration Geophysics*, 26, 179-185.
- Yin, C. and Fraser, D.C. (2002), The effect of the electrical anisotropy on the responses of helicopter-borne frequency domain electromagnetic systems, Submitted to *Geophysical Prospecting*



Apollo Property 2014 Airborne Magnetics Survey Expenditures

CGG Airborne Geophysical and Great Slave Helicopters

March 3, 2014

Work performed	Contractor	Rate	Cost
110.6 line km (100m spacing)	CGG Airborne Geophysical	\$38/line km	\$4,202.80
11.9 line km (1000m spacing)	CGG Airborne Geophysical	\$38/line km	\$452.20
Mob/demob (4.7 hours)	Great Slave Helicopters	\$1650/hr	\$7,755.00
Total			\$12,410.00