The 728.26 hectare FH property in NW BC, 50km S of Stewart, is underlain principally by a sequence of metavolcanic &
sedimentary rocks of the Lr-mid Jurassic Hazelton Group and Triassic Stuhini Group, intruded by a diorite intrusion interpreted to
be age equivalent to the Hazelton Group. Belt-wide, these host rocks often contain a variety of mineral deposits such as
molybdenum & copper-gold porphyry/skarn deposits, high grade precious metal veins/epithermal deposits, & VMS deposits rich in
gold & silver (eg: Homestake Ridge - nearby advanced stage exploration Au-Ag deposit).
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**TOTAL COST** $3,000
Airborne Geophysical Interpretation

of the

FH Property

Skeena Mining Division, British Columbia

NTS Map Sheet 103P/11

for

Homestake Resource Corporation

by

Christopher Campbell, P. Geo.
September 30, 2013
Summary

A helicopter-borne electromagnetic, magnetic and gamma-ray spectrometer survey was originally flown by Fugro Airborne Surveys in August–September 2011 over the Kinskuch Property of Bravo Gold Corporation. Bravo Gold changed its corporation name to Homestake Resource Corporation in April 2012, subsequently acquired the FH Property which lays inside the original Kinskuch survey, and which is completely covered by that dataset. The contents of this report detail the reinterpretation of the airborne data within the newly acquired claim group.

The properties lays immediately north of the village of Alice Arm, itself located on the east side of Observatory Inlet at the mouth of the Kitsault River, British Columbia; the FH Property is covered by ~81.1 line-kilometres of data acquired on a grid pattern of 100 m spaced traverses oriented east–west, controlled by 1,000 m spaced tie lines flown north–south. Products obtained from this survey include the total magnetic intensity, (magnetic) first vertical derivative, derived coplanar apparent resistivity grids at 900, 7200 and 56,000 Hz, and gamma-ray spectrometry grids of total counts, potassium, thorium and uranium. A geosoft and ascii database of the profile data, as well as the auto-pick airborne electromagnetic anomalies, was also provided by the contractor.

Enhanced derivative grids of the magnetics were generated and imaged as part of this interpretation; a texture and phase analysis of the magnetics was also undertaken in order to identify and map possible zones of structural complexity which may in turn indicate zones of favourable mineralization. A profile by profile review of all AEM anomalies was carried out preparatory to identifying high-priority areas of interest and zones for further investigation and ground follow-up.

The original objectives of this survey were two-fold:

- provide high resolution electromagnetic and magnetic data for the direct detection and delineation of sulphide-associated gold occurrences
- facilitate the mapping of bedrock lithologies and structure which in turn influence the emplacement or hosting of economic mineralization.

These objectives have been or are being met via this interpretation; the data has enabled both the mapping and delineation of controlling structures, and identification of anomalous conductivity suggesting sulphide mineralization.
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1. Introduction

An airborne electromagnetic, magnetic and gamma-ray spectrometry survey was originally conceived and designed to cover the regional area surrounding the FH claims.¹ This survey was then re-interpreted in more detail in order to aid in the design of subsequent exploration programs arising from the time that the FH property was acquired by Homestake Resource Corporation (HSR). Overarching objectives of this survey were two-fold:

- provide high resolution electromagnetic and magnetic data for the direct detection and delineation of sulphide-associated gold-silver occurrences,
- facilitate the mapping of bedrock alteration, lithologies and structure which in turn may suggest the emplacement or hosting of economic mineralization.

A helicopter-borne electromagnetic, magnetic and gamma-ray spectrometry survey (Dighem⁶) was carried out in August–September 2011; the interpretation of this survey within the area of the three newly acquired claims is the focus of this report.

1.1. Location and Access

The FH Property is located within the Skeena Mining District approximately 6 kilometres northeast of Alice Arm, British Columbia and is centered at Longitude 129°26’32.4” West, Latitude 55°31’59.1” North on NTS Sheet 103P/11.

Primary access to the property is by helicopter, with a short ride from the nearby towns of Alice Arm or Kitsault (Figure 1b.) A cat road constructed in 1966 to access the nearby Ajax molybdenum porphyry deposit crosses the property on the west side of the Dak River and could be upgraded for access to tidewater in Alice Arm².

Figure 1a. British Columbia Location Map

Figure 1b. FH Location Map
1.2. Claims

The centre of the FH Property (claim number 954209) is currently 100 percent owned by Clive Brookes, but under option to Homestake Resource Corp. The remainder of the property was staked by or on behalf of Homestake Resource Corp. The property consists of 3 mineral claims totalling 728.26 hectares (Table 1).

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Table 1. Mineral Claims comprising FH Property
1.3. Climate and Physiography (From Harris S., 2003)

The FH claims lies within the Boundary Ranges of the Coast Mountains. Topography on the property is steep with several areas of inaccessible cliffs. Elevations range from approximately 120 metres along the Dak River, a tributary of the Kitsault River that bisects the property, to 900 metres on the flanks of Wilauks Mountain in the southeast corner of the property. Slopes are covered with mature balsam and old growth stands of hemlock, and soils are well-developed in all areas of the property with the exception of talus slopes below cliffs. Summer and winter temperatures are moderated by the property’s proximity to the ocean, but annual rainfall can exceed 200 centimetres and snow accumulations can be heavy. Field exploration on the property can be carried out from May to October.
2. Geology

2.1. Regional Geology [modified from Parish et al\textsuperscript{3} and Harris\textsuperscript{4}]

The area of the FH property has been described in maps by McConnell\textsuperscript{5}, Turnbull\textsuperscript{6}, Hanson\textsuperscript{7,8,9,10,11}, Dawson and Alldrick\textsuperscript{12} and more recently by Greig et al\textsuperscript{13} and Evenchick et al\textsuperscript{14}. Figure 3 is a compilation of the most recent regional mapping by Greig et al and Evenchick et al.

The property is located along the western margin of the Intermontane Belt immediately east of the Coast Plutonic Complex (unit ETH on Figure 3). The Intermontane Belt rocks in this area are comprised of volcanic and sedimentary rocks that are correlative with the Middle Jurassic Salmon River Group (unit JHSRC), Lower to Middle Jurassic Hazelton Group (unit JHV) and the Late Triassic to Early Jurassic Stuhini Group (units PTs and PTcv). These volcanic and sedimentary rocks were deposited in an active metallogenic volcano-sedimentary environment, as the Stikinia terrane was approaching continental North America, and are known as the Stewart Complex (Grove\textsuperscript{15}; Alldrick\textsuperscript{16}). This productive belt is host to more than 200 major mineral occurrences including the


\textsuperscript{4} Harris S., 2003 op. cit. (Footnote 2 on Page 1)


\textsuperscript{8} Hanson, G., 1922a: Reconnaissance Between Kitsault River and Skeena River, British Columbia; in Geological Survey of Canada Summary Report, Part A, p. 35-50.

\textsuperscript{9} Hanson, G., 1922b: The Dolly Varden Mine; in Canadian Institute of Mining Bulletin, Volume 25, p. 212-220.

\textsuperscript{10} Hanson, G., 1923: Reconnaissance Between Skeena River and Stewart, British Columbia; in Geological Survey of Canada Summary Report, Part A, p. 29-45.

\textsuperscript{11} Hanson, G., 1928: Mineral Deposits of the Alice Arm District; in Geological Survey of Canada Summary Report, Part A, p. 27.


\textsuperscript{13} Greig, C.J. et al, 1994: Geology of the Cambria Icefield: Stewart (103P/13), Bear River (104A/4), and parts of Meziadin Lake (104A/3); Geological Survey of Canada, Open File 2931


historic gold mines Eskay Creek, Premier and SNIP, the Granduc, Dolly Varden-Torbit and Anyox, as well as major mineral deposits such as Galore Creek, KSM and Brucejack Lake.

Bounding the eastern and southern side of the Stewart Complex are the Mid to Late Jurassic rocks of the Bowser Lake Group (unit JBRA in Figure 3.) These consist mostly of deep marine flysch and turbidite sedimentation derived from the Cache Creek terrane as it was accreted onto Continental North America, which infilled the fore-arc basin as Stikinia was approaching the continent.

The volcano-sedimentary sequence is cut by four stages of intrusive activity. Each stage is discussed below in order from oldest to youngest:

The oldest of these is an intrusive rock that cuts through the centre of the FH property, (unit JKu) that has not been dated, although it is believed to be correlative with the early to middle Jurassic Hazelton Group volcanic package. Similar intrusive rocks are clearly associated with mineralization at the Homestake Ridge Project, located 25 km to the northwest and the Red Mountain project located 45 km to the northeast. The composition of this intrusive rock will be discussed in more detail in the Property Geology section.

Four small stocks on Mount McGuire, approximately 5 km northeast of the FH property have been dated by K/Ar at 55.1±3 Ma (Dawson and Alldrick, 1986). The stocks are variably porphyritic quartz monzonites and are directly related to the Ajax porphyry Mo deposit (unit ETA on Figure 3). A contact metamorphic aureole surrounds these stocks comprising calc-silicate skarns and biotite hornfels.

The most prominent intrusive suite in the area is the Coast Range Batholith approximately 4 km west of the property. The batholith is quartz monzonite to granodiorite in composition and has been K/Ar dated at 51–43 Ma (Dawson and Alldrick, 1986). The youngest intrusive rocks in the area are narrow microdiorite to lamprophyre dykes.
2.2. Property Geology

Geology on Figure 4 is based upon previous mapping by Savell\textsuperscript{17} and Kemp\textsuperscript{18}, with the following geologic summary is abridged from Savell (1992). Geological mapping carried out in 2003 was largely confined to the 1.0 by 0.5 km Cu-Au soil anomaly between Chanterelle and Pine Creeks (Harris S., 2003).

The oldest unit mapped on the property is an undivided assemblage of sedimentary rocks, interpreted by Grieg et al and Evenchick et al to be part of the Triassic Stuhini Group, including; finely laminated dark grey to black argilites and siltstones, dark grey massive greywackes, and grits and conglomerates (coloured beige in Figure 4 and


equivalent to unit PTcv in Figure 3) The greywackes locally include argillite clasts and the conglomerates contain felsic volcanic, argillite clasts and quartz pebbles.

These sediments are overlain and in fault contact with a series of massive, blocky weathering grey-green to blue-green andesite flows and tuffs. This unit (coloured green in Figure 4), which is correlative with both the Evenchick et al and Grieg et al unit JHv (undivided Jurassic Hazelton Group Volcanics), is locally porphyritic with hornblende and plagioclase phenocrysts.

The geologic unit most intimately associated with mineralization on the property is a massive, blocky and rusty weathering grey-green to pale blue-grey microdiorite to diorite unit (coloured light pink and pink on Figure 4, and unit JKu in Figure 3) that trends north-northwesterly through the centre of the 1992–2003 grid area. It is in fault and intrusive contact with the andesites and sediments and varies from fine- to medium-grained and equigranular to hornblende- and/or feldspar-porphyritic. Locally the contact zones of this intrusion, particularly along Chanterelle Creek, have a fine-grained texture. This intrusion may be a subvolcanic equivalent of the Jurassic andesitic volcanics. There are numerous subvolcanic Jurassic intrusions distributed throughout the Intermontane Belt in northwestern BC that are directly related to Cu-Au mineralization (Harris S., 2003).

The youngest unit on the property is comprised of a series of lamprophyre dykes that are dark brown to black and contain 5-7% euhedral biotite phenocrysts. A prominent lamprophyre dyke is parallel to, and probably related to, the northwest-trending fault located along Chanterelle Creek.

There are three prominent fracture orientations observed on the FH property; a subvertical northeast-striking set, a steeply south-dipping east-striking set, and a moderately to steeply northeast-dipping, northwest-striking set. The former two sets probably include a conjugate fracture set and all three of these sets are associated with faulting. Northwest- and northeast-striking faults commonly bound the diorite intrusion (Harris S., 2003).
Figure 4. Property Geology (modified from Harris S., 2003)
3. Airborne Geophysics

3.1. Exploration Criteria

The majority of mineralization in this region is not expected to provide particularly good conductive responses due to the relatively thin and discontinuous nature of the vein and stockwork systems as well as the perhaps dissemination of the associated sulphides. An exception would however occur in the event of VMS mineralization, which because of the significant sulphide content, should normally result in strong conductive responses.

As pointed out by Hodges and Amine\textsuperscript{19}, gold mineralization presents a challenge for geophysical surveys; First, because the gold mineralization itself does not provide a contrast with the host geology that is detectable by any of the geophysical parameters, and second, because economic deposits can be quite small, with complex geology and structure. Discovery of gold deposits requires geophysical surveys that can detect subtle structures which might control deposition, and directly detect the weak anomalies created by alteration and deposition processes. Exploration for gold is therefore commonly a mapping exercise. Magnetic and electromagnetic as well as gamma-ray spectrometer surveys can all be valuable mapping tools, depending on the terrain, the regolith and geomorphology, and the target.

Geophysical signatures may include all or some of the following:

- airborne and ground magnetic surveys to detect magnetite-rich zones and as an aid to mapping;
- induced polarization/resistivity surveys to outline disseminated sulphides;
- resistivity surveys to help map alteration zones;
- airborne and ground radiometric surveys to help delineate K-rich alteration zones;
- audio-frequency magnetotelluric surveys to define the limits of the porphyry systems; and
- short-wave infrared spectroscopy for clay alteration identification in the field.

The low mineral concentrations of shear-hosted and contact Au deposits generally do not provide direct-targeting for any EM system, unless there is significant supergene enrichment. Exploration for these deposits does benefit from using airborne geophysics, however, including electromagnetic, magnetic and radiometric applications for mapping geology, structure and alteration. Based on these characteristics and through extrapolations to the known and suspected mineralization on the Kinskuch Property, an airborne geophysical survey of combined electromagnetic (broadband, frequency-domain DIGHEM) and magnetics was chosen in 2011 by Bravo Gold as an optimum first pass method of mapping and hopefully delineating controlling structures as well as

\textsuperscript{19} Hodges, G. and Amine, D., 2010. Exploration for Gold Deposits with Airborne Geophysics. KEGS PDAC Symposium 2010
possible sulphide mineralization.

3.2. Helicopter Frequency-Domain EM Overview

Electromagnetic induction involves generating an electromagnetic field which induces current in the earth which in turn causes the subsurface to create a magnetic field. By measuring this magnetic field, subsurface properties and features can be deduced. This method measures the magnitude and phase of induced electromagnetic currents, which are related to the subsurface electrical conductivity. Electrical conductivity is a function of the soil and rock matrix, percentage of saturation, and the conductivity of the pore fluids. A transmitter (Tx) coil or loop is used to generate a time-varying magnetic field, the primary field, which induces an electromagnetic force in the neighboring regions of space. This electromagnetic force drives eddy currents in the earth, and other conductive elements, which in turn produce a new magnetic field, the secondary field, registered by one or more receiver (Rx) coils. The secondary magnetic field contains information on the resistivity distribution in the ground, which can then be converted into geological knowledge because of the different electric properties of earth materials. In HEM systems, the electromagnetic sensor equipment is placed in a cylindrical tube, the so-called bird, carried by a helicopter over the survey area (see schematic below). Data are collected along selected flight lines at predetermined sampling rates, and the associated system flight heights are registered simultaneously by the aid of radar and/or laser altimeters. Most modern HEM systems allow surveying at two to six different transmitter frequencies in a typical bandwidth from a few hundred Hertz to more than 100 MHz. Normally, a set of transmitter and receiver coils is used for each frequency of operation, and the separation between the rigidly mounted coils ranges between 5 and 10 m. The unit of measurement for both the in-phase I and the quadrature Q component is traditionally the dimensionless ratio of secondary to primary field intensity expressed in part-per-million, i.e., \(I/Q = H_s/H_p \times 10^6\) ppm where \(H_s\) and \(H_p\) denotes the secondary and the primary field at the receiver, respectively.
Modern frequency-domain airborne electromagnetic (AEM) systems utilize small transmitter and receiver coils having a diameter of about half a metre. The transmitter signal, the primary magnetic field, is generated by sinusoidal current flow through the transmitter coil at a discrete frequency. As the primary magnetic field is very close to a dipole field at some distance from the transmitter coil, it can be regarded as a field of a magnetic dipole sitting in the centre of the transmitter coil and having an axis perpendicular to the area of the coil. The oscillating primary magnetic field induces eddy currents in the subsurface. These currents, in turn, generate the secondary magnetic field which is dependent on the underground conductivity distribution. The secondary magnetic field is picked up by the receiver coil and related to the primary magnetic field expected at the centre of the receiver coil. As the secondary field is very small with respect to the primary field, the primary field is generally bucked out and the relative secondary field is measured in parts per million (ppm). Due to the induction process within the earth, there is a small phase shift between the primary and secondary field, i.e., the relative secondary magnetic field is a complex quantity. The orientation of the transmitter coil is horizontal (vertical magnetic dipole 'VMD') or vertical (horizontal magnetic dipole 'HMD'), and the receiver coil is oriented in a maximum coupled position, resulting in horizontal coplanar, vertical coplanar, or vertical coaxial coil.
systems.  

3.3. Operations

Fugro Airborne Surveys was contracted to fly an airborne electromagnetic and magnetic survey for Bravo Gold Corp. over the Kinskuch (and FH) Property; operations were based out of the hamlet of Alice Arm. Data acquisition occurred during the period August 1 to September 14, 2011. Final survey coverage consisted of 3,281.8 line-kilometres, including tie lines acquired in 85 flights (multiple flights per day); of this total, some 81.116 line-kilometres covered the FH Property. Flight lines were flown east–west (000°–090°) with a nominal line separation of 100 m. Tie lines were flown perpendicular (000°–180°) to the traverse lines at intervals of 1,000 m.

The survey employed the DIGHEM\textsuperscript{V}-DSP electromagnetic system. Ancillary equipment consisted of a high-sensitivity cesium-vapour magnetometer and a 256-channel spectrometer, radar and barometric altimeters, a digital video camera, a digital recorder and an electronic navigation system. The instrumentation was installed in an AS350-B3 turbine helicopter (registration C-GHKM) owned and operated by Questral Helicopters Ltd. The helicopter flew at an average airspeed of 92.5 km/h (~25.7 m/s) or ~50.0 knots; although the nominal EM sensor height was 35 m, the actual achieved over the FH Property (varied terrain plus tree heights) was 52.1 metres, mean terrain clearance.

In many portions of the survey area, thick forest and extreme topography forced the pilot to exceed normal terrain clearance for reasons of safety; the standard deviation of bird height is 16.5 m, with a maximum of ~150 m. It is possible that some valid anomalous features may have escaped detection in areas where the bird height exceeded 100 m. In difficult areas, the forward speed of the helicopter was reduced to a level that permitted excessive bird swinging. This problem, combined with the severe stresses to which the bird was subjected, gave rise to aerodynamic noise levels that are slightly higher than normal on some lines. Where warranted, re-flights were carried out to minimize these adverse effects.

The survey was further hampered by very poor weather, even for this part of the north coast, British Columbia; only 12.75 days of production were achieved while 23 days were lost completely to unacceptable weather precluding airborne survey operations, and many if not most days were cut short due to fog, rain and high winds along the higher elevations and ridge tops. Average production was less than 75 line-kilometres per day, indicating the very poor conditions.

A complete description of the field program is provided by the contractor’s logistical 
report\textsuperscript{21}, attached to this report as Appendix B.

3.4. Data Presentation

Electromagnetics

The Dighem electromagnetic system utilizes a multi-coil coaxial/coplanar technique to 
energize conductors in different directions. The coaxial coils are vertical with their axes in 
the flight direction. The coplanar coils are horizontal. The secondary fields are sensed 
simultaneously by means of receiver coils that are maximum-coupled to their respective 
transmitter coils. The system yields an in-phase and a quadrature channel from each 
transmitter-receiver coil-pair. In HEM, the coplanar coils lie in the horizontal plane with 
their axes vertical, and parallel. These coils are most sensitive to massive conductive 
odies, horizontal layers, and the halfspace. 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 
conduakers perpendicular to the flight direction. Coaxial coils generally give the sharpest 
anomalies over localized conductors.

- in-phase: that 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.
- 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.

Apparent resistivity grids, which display the conductive properties of the survey area, 
were produced by the contractor from the 7200 Hz, and 56,000 Hz coplanar data; these 
images are also presented in the following figures.

\textsuperscript{21} Fugro Airborne Surveys, 2012, DIGHEM/Magnetic/Radiometric Survey, Alice Arm, British Columbia, 
Figure 7. Apparent Resistivity 56,000 Hz
(calculated from respective coplanar in-phase and quadrature channels)

Figure 8. Apparent Resistivity 7200 Hz

The image above is displayed using a histogram equalization using a reverse-colour lookup table, so that high resistivities (low conductivity) are shown as ‘cold’ colours (blues)

To reiterate, the apparent resistivity images above are expressed in units of ohm-m and are generated from the relative in-phase and quadrature EM components for each of the three coplanar frequencies using a pseudo-layer half-space model. The inputs to the resistivity algorithm are the in-phase and quadrature amplitudes of the secondary field.

As stated in Fugro (2011), both resistive and weakly conductive trends are evident on the apparent resistivity images. Although there are several areas where the more magnetic units correlate with resistive units there is no consistent resistivity/magnetic correlation. This suggests that in some cases, the magnetic and resistivity parameters are responding to different causative sources; i.e., the EM-derived resistivity is responding to changes in the overburden and near-surface layers, while the magnetic data are reflecting changes in the underlying deeper basement units.

If the target shears are highly silicified and non-porous, these should show as narrow resistive units. These non-magnetic, non-conductive linear trends may prove to be the
more attractive targets in the search for quartz-vein mineralization. Conversely, increased porosity, alteration, or an increase in sulphide content associated with some shears or faults, could show as more conductive trends. Any weak responses that are associated with the margins of inferred intrusive features will also be of exploration interest.

![Figure 9. Apparent Resistivity 900 Hz (calculated from in-phase and quadrature channels)](image)

There are other resistivity lows and highs in the area that might also be of interest. Some of these are quite extensive and might reflect "formational" conductors or layers that could be of minor interest as direct exploration targets. However, attention may be focused on areas where these zones appear to be faulted or folded or where anomaly characteristics differ along strike.

Some of resistive areas are due to resistive rock units, or might be attributed to magnetite suppression. Some anomalous magnetite-associated responses exhibit positive quadrature responses, denoting weak conductivity, but still show as resistive units because of the magnetite suppression.

Other resistive zones are quite subtle, and could be due to changes in overburden thickness, rather than changes in rock type. However, those are associated with linear
magnetic breaks, contacts, or decreases in magnetite, are considered to be of slightly higher priority.

In the search for auriferous mineralization, the value of EM conductors may be of little importance, unless the gold is known to be associated with conductive material such as sulphides, conductive shears or faults, alteration products, or magnetite-rich zones. As mentioned previously, resistive zones can often be of greater exploration interest, particularly if the host rocks are siliceous. The magnetic parameter appears to have been more effective than the resistivity, in delineating rock units and areas of structural deformation that may have influenced local mineral deposition.

Radiometrics

Radiometric or gamma-ray spectrometer (GRS) surveys detect and map natural radioactive emanations, called gamma rays, from rocks and soils. All detectable gamma radiation from earth materials come from the natural decay products of only three elements, i.e. uranium, thorium, and potassium. In parallel with the magnetic method, that is capable of detecting and mapping only magnetite (and occasionally pyrrhotite) in soils and rocks, so the radiometric method is capable of detecting only the presence of U, Th, and K at the surface of the ground. The use of the method for geological mapping is based on the assumption that absolute and relative concentrations of these radioelements vary measurably and significantly with lithology. The method provides estimates (once the full suite of corrections and processing is completed) of apparent surface concentrations of, the most common naturally occurring radioactive elements, potassium (K), equivalent uranium (eU), and equivalent thorium (eTh).

No other geophysical method, however, and probably no other remote sensing method, requires the consideration of so many variables in order to reduce the observational data to a form that is useful for geological interpretation. For example, in addition to the geometry and physical property contrasts of the radioactive sources, the measured gamma radiation is a function of the size, efficiency and speed of the detector. It is also dependent on environmental and other effects, such as soil moisture, rainfall, vegetation, non-radioactive overburden, and the movement of airborne sources of radiation in the lower atmosphere. Interpretation of gamma-ray spectrometry requires an understanding of the underlying physics of the method, and an insight into the data acquisition, system calibration and data processing and presentation procedures. An excellent and thorough review of AGRS is provided by Minty, 1997.

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As stated by Fugro (2011), ‘...although the results are attenuated by overburden cover the lower elevations in the south, there are a few local weak Potassium or Uranium zones that appear to be mapping distinct rock types or zones of alteration. Most of the higher background counts occur in the more resistive units and higher elevations, where the (thinner) overburden suppression of radioelement responses is expected to be less.

There are exceptions however, as evidenced by the coincident radioelement highs and the resistivity lows associated with the drainage patterns in the survey area. Although some of these features could be partially due to inaccurate altitude corrections in areas of steep topography or dense tree cover, they could indicate that some of the valleys are fault-controlled. Fault-controlled valleys can yield higher total counts that are coincident with linear magnetic lows. However, some silica-rich alluvial deposits can also yield (Thorium) highs. Younger sediments within these valleys will be more closely related to the rock types from which they were derived.

There is some correlation between the radiometric and magnetic trends, due to the very different depths of exploration. A general correlation exists between anomalous radiometric responses along the higher ridges and the more resistive rock units.
Another way to display radiometric data is to combine three datasets on the one image using a red-green-blue ternary ratio. Each of the datasets are displayed using a different basic colour, which when combined make a display with each shade representing different relative amounts of potassium, thorium and uranium. Usually the colours are displayed as follows:

- Red = potassium
- Green = thorium
- Blue = uranium

Using this colour scheme the following can be interpreted from the colours on the map:

- Red = high potassium with low uranium and thorium
- Blue = high uranium with low potassium and thorium
- Green = high thorium with low potassium and uranium
- Cyan = high thorium and uranium with low potassium
- Magenta = high potassium and uranium with low thorium
- Yellow = high potassium and thorium with low uranium
Black = low potassium, thorium and uranium
White = high potassium, thorium and uranium.

Figure 14. Ternary Image Explanation

The units of measurement of a radiometric survey are counts per second. The values can vary depending on the survey height, type of spectrometer used and background radiation. To ensure that the units have geological significance and that adjacent surveys can be directly compared, the measurement units are (or should be) converted to reflect mean-ground-level abundances of the radioelements.

<table>
<thead>
<tr>
<th>Radioelement</th>
<th>Counts (cps)</th>
<th>Equivalent (ppm)</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Potassium</td>
<td>0–450</td>
<td>0–5%</td>
<td>percent</td>
</tr>
<tr>
<td>Thorium</td>
<td>0–230</td>
<td>0–58</td>
<td>parts per million</td>
</tr>
<tr>
<td>Uranium</td>
<td>0–120</td>
<td>0–20</td>
<td>parts per million</td>
</tr>
<tr>
<td>Total count</td>
<td>0–4600</td>
<td>0–150</td>
<td>nanoGray per hour</td>
</tr>
</tbody>
</table>

Table 2. Radioelement conversions to effective ground concentrations
Magnetics:

Modern high-resolution aeromagnetic data provides a view of completely obscured rocks, allowing much finer divisions of provinces regionally, and units locally. As magnetic field compilations extend to greater scales, they may be used to tie existing isolated interpretations or maps together through continuous data coverage, provide continent-scale perspectives on geologic structure and evolution, and extend geological mapping of exposed (particularly Precambrian basement) regions into sediment-covered areas. A fundamental building block in these interpretations is the geophysical domain, distinguished on the basis of anomaly trend, texture, and amplitude. Where basement is exposed, these domains often coincide with lithotectonic domains, geologic provinces, or cratons, depending on the scale of investigation. Delineating areas of magnetic anomalies having similar characteristics is intended, therefore, to isolate areas of crust having similar lithological, metamorphic, and structural character, and possibly, history. Anomaly trends may indicate the type of deformation undergone: for example, sets of parallel, narrow curvilinear anomalies may attest to penetrative deformation whereas broad ovoid anomalies might suggest relatively undeformed plutons. The average anomaly amplitude within a domain reflects its bulk physical properties. For
example, calc-alkaline magmatic arcs generally are marked by belts of high-amplitude positive magnetic anomalies while greenstone terranes commonly are associated with subdued magnetic fields. Additionally, where anomaly trends show abrupt changes in direction at domain boundaries, the relative age of the adjacent domains may also be inferred.

This airborne geophysical interpretation is based on an integrated analysis using a combination of GEOSOFT’s integrated editors (spreadsheet and flight path), INTREPID’s advanced Fourier filtering and multiscale edge detection, ER MAPPER’s image enhancements and MAPINFO/DISCOVER’s GIS capability. All the final data is also presented as a series of digital maps and images generated at scale of 1:10,000. The airborne geophysical gridded data was analyzed using the following enhanced images:

- Residual Magnetic Intensity; pseudocolour and colourdrape images
- Calculated Vertical Derivative; greyscale shaded-relief and colourdrape images
- Total Horizontal Derivative; colourdrape images
- Analytic Signal (total gradient); colourdrape images
- Tilt derivative; colourdrape images
- ZS Filters; Edge and Area group derivatives, colourdrape images
- Apparent resistivities based on 7200 and 56,000 Hz coplanar coils; pseudocolour images
- Multilplots of magnetics and electromagnetics.

Projection Specifications:

- Map projection: NUTM15
- Datum: NAD83
- Central meridian: 129° West
- False Easting: 500000 m
- False Northing: 0 m
- Scale Factor: 0.9996 m

In addition, the analysis and interpretation included a methodical review of the underlying profile data via both the contractor-supplied multiplots and an interactive review via GEOSOFT’s integrated editors; example shown below in Figure 16.
The subsequent analysis depends in part at least on the processing, visualization, mapping, and integration capabilities provided by specialized geophysical software. Discrete features and trends are checked on a profile by profile basis, linked to a variety of images and GIS layers, before final decisions as to interpretation and recommendations for ground follow-up are made.
One of the by-products from the airborne geophysics program is a digital elevation model, derived from the GPS height and radar altimeter. Although not as accurate as a terrestrial geodetic survey, it remains a relatively inexpensive and accurate model of the topography of the study area. The errors contained in these sorts of DEMs are of the order of approximately 10 metres; the main contributions being from the radar altimeter data (1–2 metres) and the GPS height data (5–10 metres). When height comparisons are made in areas of flat terrain to elevations obtained during the course of third order gravity traverses and/or the elevations of geodetic stations, the errors are on the order of approximately 2 metres.

The DEM in this event reflects a very rugged topography, with ~650 m relief present in a relatively constrained area.
The final magnetic intensity (Figures 18 above) has been corrected for parallax and diurnal, and a spike-removal filter applied. Additionally, the data was edited for abrupt elevation shifts which did cause some associated jumps or spikes on the steeper slopes. The data was then tie-line levelled and gridded using a bi-directional grid technique using a 20 m cell size, one-fifth of the nominal traverse line spacing. A correction for the regional reference field (IGRF) was applied; hence the term ‘residual magnetic intensity.’
4. Data Interpretation

4.1. Overview — Electromagnetics/Magnetics/Radiometrics

Analogies to known mineralization within the immediate area of the present survey were established as part of this interpretation, and are tabulated below.

<table>
<thead>
<tr>
<th>Minfile_No</th>
<th>Name</th>
<th>Status</th>
<th>Airborne Response</th>
</tr>
</thead>
<tbody>
<tr>
<td>103P 003</td>
<td>Devlin</td>
<td>Showing</td>
<td>Lays on flank NNW-trend dyke, weak Dighem CP response. Local K-anomaly.</td>
</tr>
<tr>
<td>103P 042</td>
<td>Dak</td>
<td>Showing</td>
<td>No direct geophysics; localized mag high ~120 m east but AEM due surficial only?</td>
</tr>
<tr>
<td>103P 155</td>
<td>San Diego</td>
<td>Prospect</td>
<td>No direct geophysics; lays on margin of NW-trend dyke, itself ‘kinked’ due to x-cutting structural offset? Elevated AGRS counts, but AEM due surficial response?</td>
</tr>
<tr>
<td>103P 161</td>
<td>Fox</td>
<td>Showing</td>
<td>Occurs on flank of NE-trend mag dyke; possible blo(?) apparent. No direct AEM.</td>
</tr>
</tbody>
</table>

Table 3. Comparison of airborne geophysics to known mineralization

The tabulated results above are based on the MINDEP published locations for the respective showings, etc.; uncertainties in these locations may therefore be affecting the comparison. For the most part, there is no direct, strong conductive correlation (exception suggested by the Devlin occurrence), although a combination of magnetics and gamma-ray spectrometry appear to suggest structure and/or lithology as being a component of the overall geophysical responses.

As stated earlier, the mineralization of this region is not expected to provide particularly strong conductive responses due to the relatively thin and discontinuous nature of the vein and stockwork systems as well as the (perhaps) dissemination of the associated sulphides. Fortunately, the magnetic intensity images and derived derivatives serve to delineate the contacts of both magnetic and non-magnetic units. The latter could reflect felsic intrusions or siliceous breccias that might host auriferous mineralization).

4.2. Magnetics

Overall, the magnetics suggests that this area has been subjected to significant deformation and/or alteration. Structural complexities are evident on the contour maps as variations in magnetic intensity, intercalated bands, irregular patterns, and as offsets or changes in strike direction. A strong correlation is shown between a previous structural analysis carried out by Coller\textsuperscript{23} and the current aeromagnetic survey.

Enhancement filters applied to the magnetic grid have highlighted a number of dominant structural orientations and trends. Interpretation of these data has identified regionally significant structures that define the gross structural architecture of the area.

Geological mapping taken from the available regional geology sheets has been incorporated with the structural interpretation for improved geological context. A sophisticated suite of filter enhancements were applied to the gridded magnetic data.

Figure 19. Structural analysis of Kinskuch (Hastings) Project area (Coller, 2008)

The initial (and standard) first vertical derivative or calculated vertical gradient is commonly used to isolate and map edges of magnetic bodies. Essentially, these types of derivatives work to suppress the longer wavelength anomalies allowing one to follow the traces of the (near) outcropping geological formations more closely. In addition to the first vertical derivative, (shown following), the tilt derivative (TILT) was found to be particularly informative, and is referenced further in the report.

A combination of the total horizontal and tilt derivative are highly suitable for mapping shallow basement structure and mineral exploration targets; they have distinct advantages over many conventional derivatives. The total horizontal derivative provides an effective alternative to the vertical derivative to map continuity of structures and enhance magnetic fabric. The advantages of the tilt derivative are its abilities to normalize a magnetic field image and to discriminate between signal and noise.
Fig. 22a. Tilt derivative  

Fig. 22b. Tilt Derivative (+ve phase only)
The analytic signal phase data can also be used to directly map the approximate position of the anomaly source bodies. Miller and Singh\textsuperscript{25} showed that the analytic signal phase is positive over source bodies and negative otherwise. A geographic information system (GIS) layer of the approximate source body positions can be produced by:

- Calculating the analytic signal phase of the gridded potential field
- Converting the resultant grid into a binary grid: +1 for positive phase values and -1 for negative phase values
- Using a raster-to-polygon utility to convert the positive areas to polygons

Where there are shallow sources, the polygons will tightly map the lateral extent of the source bodies. For deeper sources the source body polygons will be wider, and the deeper the source body the wider the polygon. The method is therefore dependent on the quality of the gridded data used. The advantage of this method is that it objectively determines the source positions from the magnetic anomaly data with more detail than can be manually interpreted.

Additionally, a suite of filters known as ‘ZS’ filters\textsuperscript{26} (after Zhiqun Shi, the primary author of this development) were employed and are shown in selected detail following.

Two types of filters have been developed for the purpose of enhancing weak magnetic anomalies from near-surface sources while simultaneously enhancing low-amplitude, long-wavelength magnetic anomalies from deep-seated or regional sources. The Edge filter group highlights edges surrounding both shallow and deeper magnetic sources. The results are used to infer the location of the boundaries of magnetized lithologies. The Block filter group has the effect of transforming the data into zones which, similar to image classification systems, segregate anomalous zones into apparent lithological categories. Both filter groups change the textural character of a dataset and thereby facilitate interpretation of geological structures.

Figures 24 to 27 above illustrate several advantages of the ZS filters; the 1vd, tilt and analytic signal derivatives will typically not provide easily interpreted edges when the sources are weakly magnetized or deeply buried, whereas the Edge and EdgeZone filter are designed to overcome that limitation. The two edge filters appear to provide a very sharp delineation of geologic units and at the same time, provide a relatively clear indication of structural breaks, such as along the Bowser Basin Transfer Zone which extends across the southern limits of the study area. The block filters (Area, Block and Plateau) appear to map the relatively non-magnetic Stuhini Group which borders the survey on the east and along the southern margins very well; these units additionally appear to extend northward through the central region.

4.2.1. Multiscale edge analysis

The analysis of lineaments is of fundamental importance to understanding geological structures and the stress regimes in which they are produced. Automatic analysis of lineaments has previously been done with information mapped from remotely sensed data, using either satellite- based imagery or aerial photographs. Potential field data may also be analyzed in terms of their lineament content. Edge detection and automatic trend analysis using gradients in such data are methods for producing unbiased
estimates of sharp lateral changes in physical properties of rocks. The assumption is made that the position of the maxima in the horizontal gradient of gravity or magnetic data represents the edges of the source bodies, although this should be used with caution. Such maxima can be detected and mapped as points, providing the interpreter with an unbiased estimate of their positions. The process of mapping maxima as points can be extended to many different levels of upward continuation, thus providing sets of points that can be displayed in three dimensions, using the height of upward continuation as the z-dimension. There have been recent developments and use of this method for interpretation of potential field data (e.g. Archibald et al, 1999 and Hornby et al, 1999).

Archibald (1999) refers to this process as multiscale edge analysis. Milligan more recently discusses the spatial and directional analysis of potential field gradients and in particular, new methods to help solve and display three-dimensional crustal architecture using a proprietary system of Euler deconvolution ‘worms.’

In multiscale edge analysis the assumption is made that lower levels of upward continuation map near-surface sources while higher levels of continuation map deeper sources. This assumption is generally true but must be treated with caution, due to the non-uniqueness of potential field solutions. The INTREPID software’s unique implementation of multiscale edge analysis includes the use of Euler worms’ which provide a view of structural geology obtained directly from potential field geophysical data. The method is based on Fourier techniques for continuation, reduction to pole and total horizontal derivatives coupled with automatic edge detection.

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27 Archibald, N., Gow, P. and Boschetti, F., 1999, Multiscale edge analysis of potential field data: Exploration Geophysics, 30, 38–44.


This fabric analysis determines the preferred orientation of basement or at least, magnetic linears within the FH Property. A number of statistical analytical methods of analyzing fabrics have been devised, with perhaps the simplest way of presenting and analyzing the data being diagrammatically via a rose diagram, shown following:
The rose diagram above is based on the computed strikes obtained through the multiscale edge detection. A preferential NE strike is evident, although a significant NNW cross-cutting fabric is also present and only marginally secondary. Further analysis and correlation to geology and the possible impact on economic mineralization is currently underway in conjunction with staff of Homestake Resource Corporation.

4.3. Electromagnetics

Although Fugro (2011) states, “... There are several low resistivity zones where values of less than 100 ohm-m are evident ... some of the more discrete responses might be attributed to increases in conductive sulphide content or clay-altered shears” no such zones lay within the FH Property. Nevertheless, one anomalously, albeit moderately conductive zone has been identified on the following image, conductive target A lays ~650 south-southwest of the Devlin occurrence along magnetic strike. This is a 2-line response and represents the single truly anomalous conductive target on the FH Property.

Further, the previously mapped QSP±Cpy alteration zone as mapped by Alldrick is herein modified on the basis of the apparent resistivity image, following. Further, anomalous Au and Cu in soils is mapped as occurring in this alteration zone (Harris S., 2003 and Smyth C., 2008) tying into the Devlin and San Diego mineral occurrences, but also extending significantly further northwest and southeast in that revised alteration zone, general zone of elevated resistivity.

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It is not expected that quartz-vein type auriferous mineralization would give rise to discrete AEM conductors, unless it was associated with semi-massive to massive sulphides (e.g., potential targets within the area could be associated with very weakly disseminated sulphides, which may be hosted by non-magnetic quartz-rich units, and which may in turn be overlain by conductive overburden. However, a single electromagnetic anomaly has been picked which may represent a possible conductive sulphide deposit. The bounding presence a fault or shear (i.e., magnetic linear) could conceivably serve as a conduit or host unit for auriferous mineralization. This single ‘high-priority’ AEM anomaly is therefore picked on the basis of favourable structure (magnetic association) as well as conductance.
<table>
<thead>
<tr>
<th>ID</th>
<th>Easting</th>
<th>Northing</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>472,115</td>
<td>6,152,830</td>
<td>2-line response, moderate strength tabular or flat-lying response on co-planar? Immediately flanking NE-trending magnetic dyke-type high.</td>
</tr>
</tbody>
</table>

Table 4. ‘high-priority’ AEM anomalies

4.4. Gamma-Ray Spectrometry

Attempts were made to establish a Th:K ratio for the FH Property area; however, bivariate statistics suggests that only a tenuous correlation exists, so that obtaining a statistically meaningful Th/K or anomalous K image is moot.

Regression analysis suggests that a $K_{predicted} = [23.933 + (1.6903 \times Th)]$ and that $K_{anomalous}$ (anomalous potassium) therefore becomes $K_{observed} - K_{predicted}$. The ‘anomalous’ potassium is shown on the following image. An elevated zone of potassium counts in shown along with inferred linears based on apparent gradients or patterns on the gamma-ray spectrometry (in particular, as evidenced on Figure 15 Ternary image). Essentially, the total counts are dominated by potassium (not unusual) with relatively very low thorium and uranium. The San Diego – Devlin ‘trend’ is seen as a generally elevated zone of potassium counts; whether or not this is due to increased potassic alteration or somewhat correlative to drainage and organics remains open to question. Radiometric linears correlative to magnetics and drainage are believed to reflect faulting; this applies especially to the NNW-SSE cross-linear.
Figure 32. Anomalous Potassium (cps)
5. Conclusions and Recommendations

A helicopter-borne electromagnetic and magnetic survey was flown by Fugro Airborne Surveys in August-September 2011 over the FH Property in the Skeena mining district of northwestern British Columbia; the survey is comprised of ~81.1 line-kilometres of data acquired on a grid pattern of 100 m spaced traverses oriented east–west, controlled by 1,000 m spaced tie lines oriented north–south. The survey was hampered by thick forest and extreme topography as well as by very poor weather, even for this part of the north coast. Average production was less than 75 line-kilometres per day, indicating the very poor conditions throughout.

The survey utilized Fugro’s DIGHEM®-DSP electromagnetic system. Ancillary equipment consisted of a high-sensitivity cesium-vapour magnetometer and a 256-channel spectrometer. The survey was completed without incident from a base of operations at Alice Arm at the southern margin of the survey block.

Products obtained from this survey include the total magnetic intensity, (magnetic) first vertical derivative, derived coplanar apparent resistivity grids at 900, 7200 and 56,000 Hz, and gamma-ray spectrometry grids of total counts, potassium, thorium and uranium. A geosoft and ascii database of the profile data, as well as the auto-pick airborne electromagnetic anomalies, was also provided by the contractor.

Additionally, as part of this interpretation, enhanced derivative grids of the magnetics were generated and imaged; a profile by profile review of all AEM anomalies was carried out preparatory to identifying high-priority areas of interest and zones for further investigation and ground follow-up.

Objectives of the airborne survey have been or are being met via this interpretation; the data has enabled both the mapping and delineation of controlling structures, and identification of anomalous conductivity suggesting sulphide mineralization. Enhancement filters applied to the magnetic grid have highlighted a number of dominant structural orientations and trends. The magnetics suggests that this area has been subjected to significant deformation and/or alteration. Structural complexities are evident on the contour maps as variations in magnetic intensity, intercalated bands, irregular patterns, and as offsets or changes in strike direction.

A single zone of anomalous conductivity is identified as occurring along magnetic strike from known mineralization. A program of geological prospecting, geochemical soil sampling and ground geophysics consisting of magnetics and 3D induced polarization / resistivity is recommended to further delineate the conductive zones and possibly identify disseminated sulphides which in turn could indicate anomalous Au mineralization. All targets and zones or areas of interest are supplied separately to Homestake Resource Corporation as Mapinfo *.tab files with accompanying annotation and geo-referencing.
6. Certificate of Professional Qualifications

I, Christopher J. Campbell, with business address of 4505 Cove Cliff Road, North Vancouver British Columbia V7G 1H7, hereby certify that:

- I am a graduate (1972) of the University of British Columbia, with a Bachelor of Science degree in Geophysics.
- I am a graduate (1986) of the University of Denver, with a Masters of Business Administration.
- I am a registered member in good standing of the Association of Professional Engineers and Geoscientists of British Columbia.
- I have practiced my profession for approximately forty years in Canada (British Columbia, Alberta, Saskatchewan, Manitoba, Ontario, Quebec, Newfoundland/Labrador, Yukon and Northwest Territories / Nunavut), United States of America, Australia, Russia, and Africa.
- I have no interest, direct or indirect, in the properties or securities of Homestake Resource Corporation, or in any of their related companies or joint venture partners anywhere in Canada.

Dated this day September 30, 2013 in North Vancouver, British Columbia.

Christopher J. Campbell, P. Geo.
## Appendix A

### Statement of Expenditures

<table>
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<th>Office Studies</th>
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</tr>
</tbody>
</table>
Appendix B.

Fugro Airborne Surveys

DIGHEM$^{V-DSP}$ Survey

for

Bravo Gold Corp.

Kinskuch Project

Alice Arm, British Columbia

Report #11047

January 5, 2012
DIGHEM/Magnetic/Radiometric Survey
Alice arm, British Columbia, Canada
Project 11047
Bravo Gold / Intrepid G.

NTS: 103 P/5,6,11,12
AIRBORNE DIGHEM/MAGNETIC/RADIOMETRIC SURVEY
Alice arm, British Columbia, Canada

PROJECT 11047

Client: BRAVO GOLD / INTREPID G.

Date of Report: January 5, 2011
FUGRO AIRBORNE SURVEYS

Fugro Airborne Surveys was formed in early 2000 through the global merger of leading airborne geophysical survey companies: Geoterrex-Dighem, High-Sense Geophysics, and Questor of Canada; World Geoscience of Australia; and Geodass and AOC of South Africa. Sial Geosciences of Canada joined the Fugro Airborne group in early 2001, and Spectra Exploration Geosciences followed thereafter. In mid 2001, Fugro acquired Tesla 10 and Kevron in Australia, and certain activities of Scintrex. Fugro also works with Lasa-Geomag located in Brazil for surveys in South America. With a staff of over 400, Fugro Airborne Surveys now operates from 12 offices worldwide.

Fugro Airborne Surveys is a professional services company specializing in low level remote sensing technologies that collects, processes, and interprets airborne geophysical data related to the subsurface of the earth and the sea bed. The data and map products produced have been an essential element of exploration programs for the mining and petroleum industries for over 50 years. Engineers, scientists and others with a need to map the earth’s subsurface geology use Fugro Airborne Surveys for environmental and engineering solutions. From mapping kimberlite pipes and oil and gas deposits to detecting water tables and unexploded ordnance, Fugro Airborne Surveys designs systems dedicated to specific targets and survey needs. State of the art geophysical systems and techniques ensure that clients receive the highest quality survey data and images.

Fugro Airborne Surveys acquires both time domain and frequency domain electromagnetic data as well as magnetic, radiometric and gravity data from a wide range of fixed wing (airplane) and helicopter platforms. Depending on the geophysical mapping needs of the client, Fugro Airborne Surveys can field airborne systems capable of collecting one or more of these types of data concurrently. The company offers all data acquisition, processing, interpretation and final reporting services for each survey.

Fugro Airborne Surveys is a founding member of IAGSA, the International Airborne Geophysics Safety Association. Our health, safety and environment management system has successfully achieved certification to the international standard OHSAS 18001 and our quality management system has also successfully achieved certification to the international standard ISO 9001:2000 Quality Management Systems – Requirements.
Summary

This assessment report describes the logistics, data acquisition, processing and presentation of results of a DIGHEM electromagnetic and magnetic airborne geophysical survey carried out for Bravo Gold / Intrepid G., over Alice arm, British Columbia, Canada. Total coverage of the survey block amounted to 3821.8 km. The survey was flown from August 2\textsuperscript{nd} to September 14\textsuperscript{th}, 2011.

The purpose of the survey was to map the geology and structure of the area. Data were acquired using a DIGHEM electromagnetic system, supplemented by a high-sensitivity cesium magnetometer and a 256-channel spectrometer. The information from these sensors was processed to produce maps and images that display the magnetic, conductive, and radioactive 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 data were processed and compiled in the Fugro Airborne Surveys Toronto office. Maps and data in digital format are provided with this report.
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   Base Station Equipment  
   Contract Specifications  
   Spectrometer  

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   Electromagnetic Data  
   Apparent Resistivity  
   Residual Magnetic Field  
   Calculated Vertical Magnetic Gradient (First Vertical Derivative)  
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   Contour, Colour and Shadow Map Displays  
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   Maps  
   Report  
   Flight Path Videos  

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Radiometric Data

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1. Survey Area Description

Location of the Survey Area
The survey block located between Alice arm and Kinskuch lake, British Columbia, Canada (Figure 1) was flown August 2\textsuperscript{nd} to September 14\textsuperscript{th}, 2011, with Alice Arm as the base of operations. A total of 3457.6 km of traverse lines were flown with a spacing of 100 m and 364.2 km of tie lines with a spacing of 1000 m for a total of 3821.8 km for the complete survey. Table 1 contains the coordinates of the corner points of the survey block.
Table 1 Area Corners NAD83 UTM Zone 9N

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<td>51</td>
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</table>
During the survey a base station GPS was set up to collect data to allow the post processing of the positional data for increased accuracy. The location of the GPS base station is recorded in Table 2. The location of the Magnetic base station is recorded in Table 3.

### Table 2 GPS Base Station Location

<table>
<thead>
<tr>
<th>Status</th>
<th>Location Name</th>
<th>WGS84 Latitude (deg-min-sec)</th>
<th>WGS84 Longitude (deg-min-sec)</th>
<th>Orthometric Height (m)</th>
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</thead>
<tbody>
<tr>
<td>Primary</td>
<td>Alice arm camp</td>
<td>N 55 28' 48.88186&quot;</td>
<td>W129 29' 24.11968&quot;</td>
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<td>Secondary</td>
<td>Alice arm camp</td>
<td>N 55 28' 48.86634&quot;</td>
<td>W129 29' 23.96640&quot;</td>
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</table>
Table 3 Magnetic Base Station Location

<table>
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<th>Status</th>
<th>Location Name</th>
<th>WGS84 Latitude (deg-min-sec)</th>
<th>WGS84 Longitude (deg-min-sec)</th>
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<tbody>
<tr>
<td>Primary</td>
<td>Alice arm Camp</td>
<td>N 55 28' 48.86634&quot;</td>
<td>W129 29' 23.96640&quot;</td>
</tr>
<tr>
<td>Secondary</td>
<td>Alice arm Camp</td>
<td>Close primary magnetic base station</td>
<td>Close primary magnetic base station</td>
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</tbody>
</table>

All the grids and maps have been produced with the following coordinate system:

- Projection: Universal Transverse Mercator (UTM Zone 9N)
- Datum: NAD83
- Central meridian: 129° West
- False Easting: 500000 metres
- False Northing: 0 metres
- Scale factor: 0.9996
- Dx, Dy, Dz: 0, 0, 0

The field crew for the survey were as follows:

- Pilot: Ed Ashie, Matt Ritchie, Sheridan King
- Electronics Operator: Burke Scieman, Gary Ellis
- Processor: Mikhail Maslennikov, Mihai SZENTESY, Mihai SZENTESY
- AME: Craig Elder, Collin Quinlan
2. System Information

Figure 2: The DIGHEM System
The DIGHEM system comprises a 30m cable which tows a 9m bird containing the EM transmitter and receiver coils,(three coplanar and two coaxial), a magnetometer, a laser altimeter and a GPS antenna for flight path recovery. The helicopter has a tail boom mounted GPS antenna for in-flight navigation, a radar altimeter, a barometric altimeter, a video camera, a 256-channel spectrometer, and a data acquisition system.

**Aircraft and Geophysical On-Board Equipment**

**Helicopter:** AS350 B2  
**Operator:** Questral Helicopter Ltd.  
**Registration:** C-GJIX  
**Average Survey Speed:** 55 knots / 110 kph / 30m/s  
**Magnetometer:** Scintrex CS-3 single cell cesium vapour, slung below the helicopter, sensitivity = 0.01 nT, sampling rate = 0.1 s, ambient range 20,000 to 100,000 nT.  
**Digital Acquisition:** Fugro Airborne Surveys HELIDAS.  
**Barometric Altimeter:** Motorola MPX4115AP analog pressure sensor with a pressure sensitivity of 150mV/kPa and a 10 Hz recording interval mounted in the helicopter.  
**Radar Altimeter:** Honeywell or Sperry, AA 330 or RT220 short pulse modulation 4.3 GHz, sensitivity 1 ft, range 0 to 2500 ft, 10 Hz recording interval mounted in the helicopter.  
**Laser Altimeter:** Optech G-150 fixed pulse repetition rate of 1 kHz with a sensitivity of ±5 cm from 10°C to 30°C and ±10 cm from -20°C to +50°C. The laser altimeter is housed in the EM bird and measures the distance from the EM bird to ground. The laser altimeter penetrates tree canopy better than the radar altimeter. This information is used in the processing algorithm that determines EM conductor depth.  
**Camera:** Panasonic WVCD/32 Camera with Axis 241S Video Server  
**Electronic Navigation:** NovAtel OEM4/V with a 1 sec recording interval, with an accuracy of ±0.6m using SBAS. Aero Antenna mounted on the tail of the helicopter.

**Base Station Equipment**

**Magnetometer:** Scintrex CS-2 single cell cesium vapour, mounted in a magnetically quiet area, measuring the total intensity of the earth's magnetic field in units of 0.01 nT at 1 Hz, within a noise envelope of 0.20 nT.
GPS Receiver: NovAtel OEM4/V, 1 sec recording interval, with an accuracy of ±0.6m using SBAS.

Data Logger: CF1, SBBS (single board base station).

Secondary Magnetometer: GEM Systems GSM-19T with a sensitivity of 0.10 nT, sampled at 3 second intervals.

**Contract Specifications**

The Survey Area is comprised of one block located near Alice arm, British Columbia, Canada. The Survey Area consisted of approximately 3855.7 line kilometres of coverage.

Table 3 Line kilometre summary

<table>
<thead>
<tr>
<th>Block</th>
<th>Line Numbers From</th>
<th>Line Numbers To</th>
<th>Line direction</th>
<th>Line km (@ 100 metres)</th>
</tr>
</thead>
<tbody>
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<td>12450</td>
<td>E-W (90°)</td>
<td>3491.5</td>
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<td>19010</td>
<td>19240</td>
<td>N-S (0°)</td>
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Optimum Survey Elevations for the helicopter and instrumentation during normal survey flying are:

<p>| | |</p>
<table>
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</thead>
<tbody>
<tr>
<td>Helicopter</td>
<td>60 metres</td>
</tr>
<tr>
<td>Magnetometer</td>
<td>35 metres</td>
</tr>
<tr>
<td>DIGHEM EM sensor</td>
<td>35 metres</td>
</tr>
<tr>
<td>Spectrometer</td>
<td>60 meters</td>
</tr>
</tbody>
</table>

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

Survey Elevations 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.

Electromagnetics

Spheric pulses may occur having strong peaks but narrow widths. The EM data area considered acceptable when their occurrence is less than 10 spheric events exceeding the
stated noise specification for a given frequency per 100 samples continuously over a distance of 2,000 metres.

<table>
<thead>
<tr>
<th>Frequency</th>
<th>Coil Orientation</th>
<th>Peak to Peak Noise Envelope (ppm)</th>
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</thead>
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<td>900 Hz</td>
<td>horizontal coplanar</td>
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<td>7,200 Hz</td>
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<td>56,000 Hz</td>
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<td>40.0</td>
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</table>

Airborne High Sensitivity Magnetometer

The non-normalized 4th difference will not exceed 1.6 nT over a continuous distance of 1 kilometre excluding areas where this specification is exceeded due to natural anomalies.

Ground Base Station Magnetometer

For acceptance of the magnetic data, non-linear variations in the magnetic diurnal should not exceed 10 nT per minute.

**Spectrometer**

Manufacturer: Radiation Solutions  
Model: RS 500 - Console ID#5522  
Type: 256 Multichannel, Potassium stabilized. NaI detector crystals  
Accuracy: 1 count/sec.  
Update: 1 integrated sample/sec.

The RS 500 Airborne Spectrometer employs four downward looking crystals (16.8 L or 1024 cu.in.) and one upward looking crystal (4.2 L or 256 cu.in.). The downward crystal records the radiometric spectrum from 410 KeV to 3 MeV over 256 discrete energy windows, as well as a cosmic ray channel that detects photons with energy levels above 3.0 MeV. From these 256 channels, the standard Total Count, Potassium, Uranium and Thorium channels are extracted. The upward crystal is used to measure and correct for Radon.

The shock-protected Sodium Iodide (Thallium) crystal package is unheated, and is automatically stabilized with respect to the Potassium peak. The RS 500 provides raw or Compton stripped data that has been automatically corrected for gain, base level, ADC offset, and dead time.

The system is calibrated on-site, using three accurately positioned hand-held sources. Additionally, fixed-site hover tests or repeat test lines are flown to determine if there are any differences in background. This procedure allows corrections to be applied to each survey flight, to eliminate any differences that might result from changes in temperature or humidity.
3. Data Processing

Appendix D depicts the data processing flow for the electromagnetic and magnetic datasets.

Field

All digital data were verified for validity and continuity. The data from the aircraft and base station were transferred to the field PC’s hard disk. Field data were then sent to the FAST office to be checked by a geophysicist for adherence to the survey specifications as outlined in the previous SYSTEM INFORMATION section. Any failure to meet the survey specifications resulted in a reflight of the line or portion of the line unless aircraft safety was at risk or the client’s on site representative approved the data.

Flight Path Recovery

The raw range data from at least four satellites are simultaneously recorded by both the base and mobile GPS units. The geographic positions of both units, relative to the model ellipsoid, are calculated from this information. Differential corrections, which are obtained from the base station, are applied to the mobile unit data to provide a post-flight track of the aircraft, accurate to within 1 metre. Speed checks of the flight path are also carried out to determine if there are any spikes or gaps in the data.

The corrected WGS84 latitude/longitude coordinates are transformed to the UTM coordinate system used on the final maps. Images or plots are then created to provide a visual check of the flight path.

Electromagnetic Data

EM data are processed at the recorded sample rate of 10 samples/second. Spheric rejection median and Hanning filters are then applied to reduce noise to acceptable levels. EM test profiles are then created to allow the interpreter to select the most appropriate EM anomaly picking controls for a given survey area. The EM picking parameters depend on several factors but are primarily based on the dynamic range of the resistivities within the survey area, and the types and expected geophysical responses of the targets being sought.

The interpretation geophysicist determines initial anomaly picking parameters and thresholds. Anomalous electromagnetic responses that meet the specific criteria are then automatically selected and analysed by computer to provide a preliminary electromagnetic anomaly map. The automatic selection algorithm is intentionally oversensitive to assure that no meaningful responses are missed. Using the preliminary maps in conjunction with the multi-parameter stacked profiles, the interpreter then classifies the anomalies according to their source and eliminates those that are not substantiated by the data. The final interpreted EM anomaly map will include bedrock, surficial and cultural conductors. A map containing only bedrock conductors can be generated, if desired.
**Apparent Resistivity**

The apparent resistivities in ohm-m are generated from the in-phase and quadrature EM components for all of the coplanar frequencies, using a pseudo-layer half-space model. The inputs to the resistivity algorithm are the in-phase and quadrature amplitudes of the secondary field. The algorithm calculates the apparent resistivity in ohm-m, and the apparent height of the bird above the conductive source. Any difference between the apparent height and the true height, as measured by the radar altimeter, is called the pseudo-layer and reflects the difference between the real geology and a homogeneous half space. This difference is often attributed to the presence of a highly resistive upper layer. Any errors in the altimeter reading, caused by heavy tree cover, are included in the pseudo-layer and do not affect the resistivity calculation. The apparent depth estimates, however, will reflect the altimeter errors. Apparent resistivities calculated in this manner may differ from those calculated using other models.

In areas where the effects of magnetic permeability or dielectric permittivity have suppressed the in-phase responses, the calculated resistivities will be erroneously high. Various algorithms and inversion techniques can be used to partially correct for the effects of permeability and permittivity. No corrections for permeability and permittivity were made to the data for this survey.

The apparent resistivity parameters portray all of the information for a given frequency over the entire survey area. This full coverage contrasts with the electromagnetic anomalies, which provide information only over interpreted conductors. The large dynamic range afforded by the multiple frequencies makes the apparent resistivity parameter an excellent mapping tool.

The preliminary apparent resistivity images are carefully inspected to identify any lines or line segments that might require base level adjustments. Subtle changes between in-flight calibrations of the system can result in line-to-line differences that are more recognizable in resistive (low signal amplitude) areas. If required, manual level adjustments are carried out to eliminate or minimize resistivity differences that can be attributed, in part, to changes in operating temperatures. These levelling adjustments are usually very subtle, and do not result in the degradation of discrete anomalies.

After the manual levelling process is complete, revised resistivity grids are created. The resulting grids can be subjected to a microlevelling technique in order to smooth the data for contouring. The coplanar resistivity parameter has a broad ‘footprint’ that requires very little filtering. Apparent resistivity maps, which display the conductive properties of the survey area, were produced from the 900 Hz, 7200 Hz and 56 000 Hz coplanar data. Maximum resistivity values are calculated for each frequency. These cutoffs eliminate the erratic higher resistivities that would result from unstable ratios of very small EM amplitudes.

**Residual Magnetic Field**

A Fugro CF-1 cesium vapour magnetometer was operated at the survey base to record diurnal variations of the earth's magnetic field. The clock of the base station was synchronized with that of the airborne system to permit subsequent removal of diurnal drift.

A fourth difference editing routine was applied to the magnetic data to remove any spikes.
The aeromagnetic data were corrected for measured system lag, and then adjusted for regional variations (or IGRF gradient, 2010, updated to the date of data acquisition and adjusted for altimeter variations). The data were then corrected for diurnal variations by subtraction of the digitally recorded base station magnetic data. 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. The gridded data show the magnetic properties of the rock units underlying the survey area.

If a specific magnetic intensity can be assigned to the rock type that is believed to host the target mineralization, it may be possible to select areas of higher priority on the basis of the total field magnetic data. This is based on the assumption that the magnetite content of the host rocks will give rise to a limited range of contour values that will permit differentiation of various lithological units. Structural complexities are evident on the images as variations in magnetic intensity, irregular patterns, and as offsets or changes in strike direction.

The magnetic results, in conjunction with the other geophysical parameters, have provided valuable information that can be used to effectively map the geology and structure in the survey area.

**Calculated Vertical Magnetic Gradient (First Vertical Derivative)**

The diurnally-corrected, IGRF-corrected magnetic data were 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 total field data. Regional magnetic variations and changes in lithology, however, may be better defined on the total magnetic field parameter.

**Digital Elevation**

The laser altimeter values (ALTLAS_BIRD – EM bird to ground clearance) are subtracted from the differentially corrected and de-spiked GPS-Z values to produce profiles of the height above the ellipsoid along the survey lines. These values are gridded to produce contour maps showing approximate elevations within the survey area. The calculated digital terrain data are then tie-line levelled and adjusted to mean sea level. Any remaining 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, ALTLAS_BIRD and GPS-Z. The ALTLAS_BIRD value may be erroneous in areas of heavy tree cover, where the altimeter reflects the distance to the tree canopy rather than the ground. 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 ±10 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 and resistivity data 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.

**Radiometric Data**

All radiometric data reductions performed by Fugro rigorously follow the procedures described in the IAEA Technical Report 323

All processing of radiometric data was undertaken at the natural sampling rate of the spectrometer, i.e., one second. The data were not interpolated to match the fundamental 0.1 second interval of the EM and magnetic data.

The following sections describe each step in the process.

**Dead Time Correction**

After the raw data have been checked and edited to remove any spikes or gaps, the first step in the reduction sequence for AGS data is dead-time correction. This is carried out using electronically measured dead-time data. Dead-time correction is made to each window using the expression:

\[ N = \frac{n}{1 - Tr} \]  \hspace{1cm} (3.1)

Where:
- \( n \) is the corrected count in each second
- \( Tr \) is the recorded dead-time, the time taken to process all pulses reaching the detector in one second.

Dead-time correction is applied to each window in the downward-looking detector, (including the

---

cosmic and total count windows), but not to the upward-looking data, as these are processed by different circuits.

Intermediate Filtering for Background Corrections

Digital filters are applied to radar altimeter data to smooth sudden jumps that can arise when flying over steep terrain which cause problems when height correcting the data. A 5 point filter is used. The spectrometer cosmic channel is also filtered to reduce statistical noise. In this case, an 11 to 21 point filter would be used. To calculate radon background from the upward-looking detector data, heavily filtered uranium upward, uranium downward, and thorium downward data are needed as described below. Original data will also be preserved.

- Radar altimeter is smoothed with a 5-point Hanning filter
- The Cosmic window is smoothed with a 21-point Hanning filter

Aircraft and Cosmic Background

The determination of the cosmic and aircraft background expressions for each spectral window has been described in chapter 4 of IAEA Technical Report 323. These expressions are of the form:

\[ N = a + bC \]  

(3.2)

Where:
- \( n \) is the combined cosmic and aircraft background in each spectral window,
- \( a \) is the aircraft background in the window,
- \( C \) is the cosmic channel count and
- \( b \) is the cosmic stripping factor for the window.

The expressions are evaluated for each window at each data point using the filtered cosmic channel data and the results subtracted from the data.

Radon Background

Determination of the constants necessary for the correction of background due to radon using upward detectors requires several steps. The procedure outlined in IAEA 323 is generally correct, but more recent studies have refined the process. The first step, determining the contributions of atmospheric radon to the various spectrometry windows is best achieved through a series of test flights, usually over water. The method of least squares allows the constants in equations 4.9 to 4.12 (IAEA 323) to be determined. The next step is to determine the response of the upward looking detector to radiation from the ground (equation 4.13 IAEA 323). The procedure recommended by Grasty and Hovgaard (1996) summarized below, is more reliable than that in IAEA 323.
In view of the high correlation between radiation in the uranium and thorium windows, it is better to assume that the upward response originating from the ground can be correlated to either counts in the thorium window or to counts in the uranium window. This is equivalent to assuming that either $a_1$ or $a_2$ is equal to 0. Solving for $a_1$ or $a_2$ is accomplished by subtracting measurements for the upward channel and the uranium channel (or thorium channel) at approximately 30s intervals to find a set of differences. The total count channel will be used to determine whether the radioactivity is increasing or decreasing. It is necessary to first subtract the counts in the uranium channel (or thorium channel) from the total count, to reduce bias of the final result. If the total count channel indicates that the radioactivity is decreasing, the sign of both the upward and downward differences must be reversed. The value of the constant is then simply the ratio of the sum of the adjusted differences in the upward channel divided by the sum of the adjusted differences in the downward channel.

The expression for the radon component in the downward uranium window is given by:

$$Ur = \frac{u - a_1 U - a_2 T + a_2 bT - bu}{3au - a_1 - a_2 aT}$$  \hspace{1cm} (3.3)

where: $Ur$ is the radon background detected in the downward U window  
$u$ is the measured count in the upward uranium window  
$U$ is the measured count in the downward uranium window  
$T$ is the measured count in the downward thorium window  
$a_1$, $a_2$, $au$ and $aT$ are proportionality factors and  
$bu$ and $bT$ are constants determined experimentally.

Using the values for $a_1$ or $a_2$ determined above in this equation will result in a reasonable estimate of $Ur$, which will permit the other channels to be corrected for radon. The measured count rates $u$, $U$ and $T$ used in equation (4.6) must first be corrected for cosmic and aircraft background. The radon counts in the total count, potassium, and thorium windows, can be calculated from $Ur$ using equations (4.10), (4.11) and (4.12) from IAEA Report 323.

Because of the low count rate in the upward uranium window, this window must be filtered considerably to reduce statistical noise. For a system with two upward-looking detectors of volume 8.4 L, a 200 point running average should be suitable. In areas of unusually high radioactivity pulse pile-up can occur and errors will arise in the calculated value of $Ur$. In these areas the radon background component should not be calculated but interpolated from adjacent sections of line. A test line was established in the survey area. Tests were carried out at the start and end of each day, and at the end of each flight. Data were acquired over a four-minute period at the nominal survey altitude (68 m). The data were then corrected for dead-time, aircraft background and cosmic activity.

The survey altitude test data were used to monitor atmospheric background and to calibrate the upward and downward looking detector systems. Variations in the uranium window can be partly due to radon but also due to soil moisture variations, or small changes in the flying height or flight path. Variations due to soil moisture and flight path errors can largely be overcome by a simple normalization procedure based on the count in the thorium window. The procedure assumes a given percentage change in thorium count from the ground will correspond to the same percentage change in the uranium counts from the ground. First, the average thorium count rate for the tests during the entire survey period is found. Then, for each test, the uranium count rate is multiplied by the average thorium count, divided by the thorium count for that flight. Changes from flight to flight
in the resulting normalized uranium count are then due to variations in radon and corrections can be
determined for each flight. This procedure is described more fully in IAEA Technical Report 323.

Calculation of Effective Height AGL

The filtered radar altimeter data will be used in adjusting the stripping ratios for altitude and to carry
out attenuation corrections. They are then converted to effective height (he) at STP by the
expression: (3.4)

\[
he = h \times \frac{273.15 \times P}{T + 273.15} \frac{1013}{T + 273.15}
\]  

(3.4)

where: h is the observed radar altitude
T is the measured air temperature in degrees C
P is the barometric pressure in millibars

If necessary, the pressure can be estimated from the barometric (or GPS) altitude using the
expression: (3.5)

\[
P = Poe^{H/8581}
\]  

(3.5)

Where: H is the barometric (or gps) altitude in meters
Po is the barometric pressure (at sea level) in millibars

Stripping

The stripping ratios \(\alpha, \beta, \gamma, a, b\) and \(g\) are determined over calibration pads as described in Chapter
4 of Report 323. The principal ratios \(a, \beta\) and \(g\) vary with STP altitude above the ground and should
be adjusted before stripping is carried out. Using the six stripping ratios, the background corrected
count rates in the three windows can be stripped to give the counts in the potassium, uranium and
thorium windows that originate solely from potassium, uranium and thorium. These stripped count
rates are given by equations (4.44) to (4.47) in the Report.
Attenuation Correction

The background corrected total count and stripped count rates vary exponentially with aircraft altitude. Consequently, the measured count rate is related to the count rate at the nominal survey altitude by the equation: (3.6)
\[ N_s = N_m e^{(h_o-h)} \]  
(3.6)

Where: \( N_s \) is the count rate normalized to the nominal survey altitude, \( h_o \),  
\( N_m \) is the background corrected, stripped count rate at STP equivalent height \( h \),  
m is the attenuation coefficient for that window.

Conversion to Apparent Radioelement Concentrations

The fully corrected count rate data is used to estimate the concentrations in the ground of each of the three radioelements, potassium, uranium and thorium. The procedure determines the concentrations that would give the observed count rates, if uniformly distributed in an infinite horizontal slab source. Because the U and Th windows actually measure \(^{214}\text{Bi}\) and \(^{208}\text{Tl}\) respectively, the calculation implicitly assumes radioactive equilibrium in the U and Th decay series. The U and Th concentrations are therefore expressed as equivalent concentrations, \( eU \) and \( eTh \). The calculated potassium, uranium and thorium concentrations are determined using the expression:
\[ C = \frac{N}{S} \]  
(3.7)

where: \( C \) is the concentration of element (K%, eU ppm or eTh ppm)  
\( S \) is the broad source sensitivity for the window, and  
\( N \) is the count rate for each window, after dead-time, background, stripping and attenuation correction.

An estimate of the air absorbed dose rate from geological sources will be made from the apparent concentrations, K%, eU ppm and eTh ppm, using the expression:
\[ E = 13.1 * K + 5.67 * eU + 2.49 * eTh \]  
expressed as nGyh\(^{-1}\) (nanoGray/hour)  
(3.8)

Calculation of Radioelement Ratios (Optional)

The ratios of the three radioelements (eU/eTh, eU/K and eTh/K) are frequently plotted as profiles. Due to statistical uncertainties in the individual radioelement measurements, some care must be taken in the calculation of these ratios. A common method of determining ratios is as follows:

1. Neglect any data points where the potassium concentration is less than 0.25% as these measurements are likely to be over water.
2. Progressively sum the element concentrations of adjacent points on either side of the data point until the total accumulated concentration exceeds a threshold value. This threshold is normally set to be equivalent to at least 100 counts for both the numerator and denominator.

3. Calculate the ratios using the accumulated sums. With this method, the errors associated with the calculated ratios will be similar for all data points. For contouring, the ratios can be produced directly from the gridded concentration data by ring searching to ensure both numerator and denominator exceeds the 100 count threshold as above.

**Gridding**

Most map products require the data to be interpolated onto a regular grid. Many of the standard gridding algorithms are unsuited to AGS data, because of the inherent statistical variations. A suitable gridding algorithm was used; one that takes the average of all data points lying within a circular or elliptical area, inversely weighted for distance from the grid point.
4. Final Products

Digital Archives
Line and grid data in the form of a Geosoft database (*.gdb) and XYZ file and Geosoft grids (*.grd) have been written to a DVD. The formats and layouts of these archives are further described in Appendix E (Data Archive Description). Hardcopies of all maps have been created as outlined below.

Maps
Scale: 1:20,000
Parameters: Residual Magnetic Intensity (RMI)
First Vertical Derivative of the Residual Magnetic Intensity
Resistivity maps (2 horizontal coplanar frequencies)
Dighem EM anomaly / interpretation maps
U, Th, K, and TC maps

Media/Copies: 2 Paper plus PDF and Geosoft MAP

Report
Media/Copies: 2 Paper plus PDF

Flight Path Videos
Media/Copies: DVD; 1 copy of each. BIN/BDX format

All maps, grids and sections have been produced with the following coordinate system:

Projection: Universal Transverse Mercator (UTM Zone 9N)
Datum: NAD83
Central meridian: 129° West
False Easting: 500000 metres
False Northing: 0 metres
Scale factor: 0.9996
Dx,Dy,Dz: 0, 0, 0
5. Survey Results

Magnetic Data

A Fugro CF-1 cesium vapour magnetometer was operated at the survey base to record diurnal variations of the earth’s magnetic field. The clock of the base station was synchronized with that of the airborne system to permit subsequent removal of diurnal drift. (A GEM Systems GSM-19T proton precession magnetometer was also operated as a backup unit.)

The diurnally corrected enhanced total magnetic field data, using the measured horizontal gradient, have been presented as contours on the base maps using a contour interval of 5nT where gradients permit. The maps show the magnetic properties of the rock units underlying the survey areas.

The corrected enhanced total magnetic field data have been subjected to a processing algorithm to produce maps of the calculated vertical gradient. This procedure enhances near-surface magnetic units and suppresses regional gradients. It also provides better definition and resolution of magnetic units and displays weak magnetic features that may not be clearly evident on the total field maps.

The data contained on the digital archive show the magnetic and conductive properties of the rock units underlying the survey areas.

The magnetic images show that the survey areas have been subjected to deformation and/or alteration. These structural complexities are evident on the colour maps as variations in magnetic intensity, irregular patterns, and as offsets or changes in strike direction.

If a specific magnetic intensity can be assigned to the rock type that is believed to host the target mineralization, it may be possible to select areas of higher priority on the basis of the magnetic data. This is based on the assumption that the magnetite content of the host rocks will give rise to a limited range of contour values that will permit differentiation of the various lithological units.

The magnetic results have provided valuable information that can be used in conjunction with the other geophysical parameters, to help map the geology and structure in the survey areas.

Apparent Resistivity

Apparent resistivity grids, which display the conductive properties of the survey area, were produced from the 900, 7200 Hz, and 56000 Hz coplanar data. The maximum resistivity values, which are calculated for each frequency, are 1060, 8,000 and 30,000 ohm-m respectively. These cut-offs eliminate the erratic higher resistivities that could result from unstable ratios of very small EM amplitudes. All coplanar resistivity data will be included on the final data archive.

Both resistive and weakly conductive trends are evident on the near-surface 56 kHz maps. Although there are several areas where the more magnetic units correlate with resistive units there is no consistent resistivity/magnetic correlation. This suggests that in some cases, the magnetic and resistivity parameters are responding to different causative sources; i.e., the EM-derived resistivity is
responding to changes in the overburden and near-surface layers, while the magnetic data are reflecting changes in the underlying deeper basement units.

If the target shears are highly silicified and non-porous, these should show as narrow resistive units. These non-magnetic, non-conductive linear trends may prove to be the more attractive targets in the search for quartz-vein mineralization. Conversely, increased porosity, alteration, or an increase in sulphide content associated with some shears or faults, could show as more conductive trends. Any weak responses that are associated with the margins of inferred intrusive features will also be of exploration interest.

There are other resistivity lows and highs in the area that might also be of interest. Some of these are quite extensive and might reflect "formational" conductors or layers that could be of minor interest as direct exploration targets. However, attention may be focused on areas where these zones appear to be faulted or folded or where anomaly characteristics differ along strike.

Some of resistive areas are due to resistive rock units, or might be attributed to magnetite suppression. Some anomalous magnetite-associated responses exhibit positive quadrature responses, denoting weak conductivity, but still show as resistive units because of the magnetite suppression.

Other resistive zones are quite subtle, and could be due to changes in overburden thickness, rather than changes in rock type. However, those are associated with linear magnetic breaks, contacts, or decreases in magnetite, are considered to be of slightly higher priority.

In the search for auriferous mineralization, the value of EM conductors may be of little importance, unless the gold is known to be associated with conductive material such as sulphides, conductive shears or faults, alteration products, or magnetite-rich zones. As mentioned previously, resistive zones can often be of greater exploration interest, particularly if the host rocks are siliceous. The magnetic parameter appears to have been more effective than the resistivity, in delineating rock units and areas of structural deformation that may have influenced local mineral deposition.

Radiometric Data

The radiometric data are self-explanatory. Although the results are attenuated by overburden cover the lower elevations in the south, there are a few local weak Potassium or Uranium zones that appear to be mapping distinct rock types or zones of alteration. Most of the higher background counts occur in the more resistive units and higher elevations, where the (thinner) overburden suppression of radioelement responses is expected to be less.

There are exceptions, however, as evidenced by the coincident radioelement highs and the resistivity lows associated with the drainage patterns in the survey area. Although some of these features could be partially due to inaccurate altitude corrections in areas of steep topography or dense tree cover, they could indicate that some of the valleys are fault-controlled. Fault-controlled valleys can yield higher total counts that are coincident with linear magnetic lows. However, some silica-rich alluvial deposits can also yield (thorium) highs. Younger sediments within these valleys will be more closely related to the rock types from which they were derived.
There is some correlation between the radiometric and magnetic trends, due to the very different depths of exploration. A general correlation exists between anomalous radiometric responses along the higher ridges and the more resistive rock units.

The creation of radiometric ratio maps or images should be considered, in order to minimize anomalous responses that could be partially due to changes in survey height, and to highlight zones that exhibit higher concentrations of one radioelement relative to the others.
6. 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 Kinskuch near Alice arm, British Columbia.

The magnetic results have provided valuable structural information that can be used to help locate the more favourable areas for mineral deposition on the block. In addition to locating numerous linear faults and shears, the magnetic data have outlined the contacts of both magnetic and non-magnetic units.

There are several low resistivity zones where values of less than 100 ohm-m are evident. Some of these broader zones are likely due to conductive clays or graphitic shales, while some of the more discrete responses might be attributed to increases in conductive sulphide content or clay-altered shears. Although the former “formational” zones may be of little economic interest, those in the latter category might warrant additional work.

Other anomalous responses coincide with magnetic linears that could reflect contacts, faults, or shears. These inferred contacts and structural breaks are also considered to be of particular interest as they may have influenced or controlled mineral deposition within the survey areas.

The anomalous targets (both resistive and conductive) and some of the bedrock conductors defined by the survey should be subjected to further investigation, using appropriate surface exploration techniques. Anomalies that are currently considered to be of moderately low priority may require upgrading if follow-up results are favourable.

It is also suggested that additional 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 can often provide valuable information on structure and lithology, which may not be clearly evident on the images provided with this report. These techniques can yield images that define subtle, but significant, structural details.

Respectfully submitted,

FUGRO AIRBORNE SURVEYS CORP.
Appendix A

Data Archive Description
Data Archive Description:

Survey Details
Survey Area Name: Kinskuch project, Alice arm, British Columbia
Job number: 11047
Client: Bravo Gold / Intrepid G.
Survey Company Name: Fugro Airborne Surveys
Flown Dates: August 2nd to September 14th, 2011
Archive Creation Date: January 5, 2012

Geodetic Information for map products
Projection: Universal Transverse Mercator (Zone 9N)
Datum: NAD83
Central meridian: 129° West
False Easting: 500000 metres
False Northing: 0 metres
Scale factor: 0.9996

Grid Archive:

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Linedata Archive:

Geosoft Database and Line Archive File Layout (Kinskuch.xyz & Kinskuch.gdb):

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<td>CXQ1000_FILT</td>
<td>coaxial quadrature 1000 Hz - unlevelled</td>
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<td></td>
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<td>apparent resistivity - 7200 Hz</td>
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<td>41</td>
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<td>apparent resistivity - 56 kHz</td>
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<tr>
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<td>DEP900</td>
<td>apparent depth - 900 Hz</td>
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<td>CPPL</td>
<td>coplanar powerline monitor</td>
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<td>48</td>
<td>CXSP</td>
<td>coaxial spherics monitor</td>
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<tr>
<td>49</td>
<td>CPSP</td>
<td>coplanar spherics monitor</td>
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Maps:
PDF files of delivered maps at a scale of 1:20,000. One map set consists of one sheet.

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<td>nT/m</td>
</tr>
<tr>
<td>MAG.pdf</td>
<td>Residual Magnetic Intensity Sheet*</td>
<td>nT</td>
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<td>Apparent Resistivity 7200 Hz Sheet*</td>
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<td>RES56K.pdf</td>
<td>Apparent Resistivity 56k Hz Sheet*</td>
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<td>U.pdf</td>
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Report:
*R11047_A.pdf*: A assessment report in PDF format
Appendix B

List of personnel
The following personnel were involved in the acquisition, processing, interpretation and presentation of data, relating to a DIGHEM airborne geophysical survey carried out over the Kinskuch area, Alice arm, British Columbia for Bravo Gold Corp.

Lesley Minty Project Manager
Don Ellis Senior Electronics Technician
Mihai Szentesy Field Data Processor / Crew leader
Mikhail Maslennikov Field Data Processor / Crew leader
Kambiz Yazdani Field Data Processor / Crew leader
Gray Ellis Equipment Operator
Burke Schieman Equipment Operator
Tayebe Hamzeh Data Processor
Tai-chyi Shei Geophysicist- Interpretation
Lyn Vanderstarren Drafting Supervisor
Ed Ashie Pilot (Questral Helicopters)
Matt Ritchie Pilot (Questral Helicopters)
Sheridan King Pilot (Questral Helicopters)
Craig Elder AME (Questral Helicopters)
Collin Quinlan AME (Questral Helicopters)

All personnel are employees of Fugro Airborne Surveys, except for the pilot and AME who are employees of Questral Helicopters.
Appendix C

Background Information
Electromagnetics

Fugro electromagnetic responses fall into two general classes, discrete and broad. The discrete class consists of sharp, well-defined anomalies from discrete conductors such as sulphide lenses and steeply dipping sheets of graphite and sulphides. The broad class consists of wide anomalies from conductors having a large horizontal surface such as flatly dipping graphite or sulphide sheets, saline water-saturated sedimentary formations, conductive overburden and rock, kimberlite pipes and geothermal zones. A vertical conductive slab with a width of 200 m would straddle these two classes.

The vertical sheet (half plane) is the most common model used for the analysis of discrete conductors. All anomalies plotted on the geophysical maps are analyzed according to this model. The following section entitled Discrete Conductor Analysis describes this model in detail, including the effect of using it on anomalies caused by broad conductors such as conductive overburden.

The conductive earth (half-space) model is suitable for broad conductors. Resistivity contour maps result from the use of this model. A later section entitled Resistivity Mapping describes the method further, including the effect of using it on anomalies caused by discrete conductors such as sulphide bodies.

Geometric Interpretation

The geophysical interpreter attempts to determine the geometric shape and dip of the conductor. Figure B-1 shows typical HEM anomaly shapes which are used to guide the geometric interpretation.

Discrete Conductor Analysis

The EM anomalies appearing on the electromagnetic map are analyzed by computer to give the conductance (i.e., conductivity-thickness product) in siemens (mhos) of a vertical sheet model. This is done regardless of the interpreted geometric shape of the conductor. This is not an unreasonable procedure, because the computed conductance increases as the electrical quality of the conductor increases, regardless of its true shape. DIGHEM anomalies are divided into seven grades of conductance, as shown in Table 4. The conductance in siemens (mhos) is the reciprocal of resistance in ohms.
Figure B-1 Typical HEM anomaly shape
The conductance value is a geological parameter because it is a characteristic of the conductor alone. It generally is independent of frequency, flying height or depth of burial, apart from the averaging over a greater portion of the conductor as height increases. Small anomalies from deeply buried strong conductors are not confused with small anomalies from shallow weak conductors because the former will have larger conductance values.

<table>
<thead>
<tr>
<th>Anomaly Grade</th>
<th>Siemens</th>
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<tr>
<td>7</td>
<td>&gt; 100</td>
</tr>
<tr>
<td>6</td>
<td>50 – 100</td>
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<td>5</td>
<td>20 – 50</td>
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<td>4</td>
<td>10 – 20</td>
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<td>2</td>
<td>1 – 5</td>
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<tr>
<td>1</td>
<td>&lt; 1</td>
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</table>

Table 4 EM Anomaly Grades

Conductive overburden generally produces broad EM responses which may not be shown as anomalies on the geophysical maps. However, patchy conductive overburden in otherwise resistive areas can yield discrete anomalies with a conductance grade (cf. Table B-1) of 1, 2 or even 3 for conducting clays which have resistivities as low as 50 ohm-m. In areas where ground resistivities are below 10 ohm-m, anomalies caused by weathering variations and similar causes can have any conductance grade. The anomaly shapes from the multiple coils often allow such conductors to be recognized, and these are indicated by the letters S, H, and sometimes E on the geophysical maps (see EM legend on maps).

For bedrock conductors, the higher anomaly grades indicate increasingly higher conductances. Examples: the New Inso copper discovery (Noranda, Canada) yielded a grade 5 anomaly, as did the neighbouring copper-zinc Magusi River ore body; Mattabi (copper-zinc, Sturgeon Lake, Canada) and Whistle (nickel, Sudbury, Canada) gave grade 6; and the Montcalm nickel-copper discovery (Timmins, Canada) yielded a grade 7 anomaly.

Strong conductors (i.e., grades 6 and 7) are characteristic of massive sulphides or graphite. Moderate conductors (grades 4 and 5) typically reflect graphite or sulphides of a less massive character, while weak bedrock conductors (grades 1 to 3) can signify poorly connected graphite or heavily disseminated sulphides. Grades 1 and 2 conductors may not respond to ground EM equipment using frequencies less than 2000 Hz.

The presence of sphalerite or gangue can result in ore deposits having weak to moderate conductances. As an example, the three million ton lead-zinc deposit of Restigouche Mining Corporation near Bathurst, Canada, yielded a well-defined grade 2 conductor. The 10 percent by volume of sphalerite occurs as a coating around the fine grained massive pyrite, thereby inhibiting electrical conduction. Faults, fractures and shear zones may
produce anomalies that typically have low conductances (e.g., grades 1 to 3). Conductive rock formations can yield anomalies of any conductance grade. The conductive materials in such rock formations can be salt water, weathered products such as clays, original depositional clays, and carbonaceous material.

For each interpreted electromagnetic anomaly on the geophysical maps, a letter identifier and an interpretive symbol are plotted beside the EM grade symbol. The horizontal rows of dots, under the interpretive symbol, indicate the anomaly amplitude on the flight record. The vertical column of dots, under the anomaly letter, gives the estimated depth. In areas where anomalies are crowded, the letter identifiers, interpretive symbols and dots may be obliterated. The EM grade symbols, however, will always be discernible, and the obliterated information can be obtained from the anomaly listing appended to this report.

The purpose of indicating the anomaly amplitude by dots is to provide an estimate of the reliability of the conductance calculation. Thus, a conductance value obtained from a large ppm anomaly (3 or 4 dots) will tend to be accurate whereas one obtained from a small ppm anomaly (no dots) could be quite inaccurate. The absence of amplitude dots indicates that the anomaly from the coaxial coil-pair is 5 ppm or less on both the in-phase and quadrature channels. Such small anomalies could reflect a weak conductor at the surface or a stronger conductor at depth. The conductance grade and depth estimate illustrates which of these possibilities fits the recorded data best.

The conductance measurement is considered more reliable than the depth estimate. There are a number of factors that can produce an error in the depth estimate, including the averaging of topographic variations by the altimeter, overlying conductive overburden, and the location and attitude of the conductor relative to the flight line. Conductor location and attitude can provide an erroneous depth estimate because the stronger part of the conductor may be deeper or to one side of the flight line, or because it has a shallow dip. A heavy tree cover can also produce errors in depth estimates. This is because the depth estimate is computed as the distance of bird from conductor, minus the altimeter reading. The altimeter can lock onto the top of a dense forest canopy. This situation yields an erroneously large depth estimate but does not affect the conductance estimate.

Dip symbols are used to indicate the direction of dip of conductors. These symbols are used only when the anomaly shapes are unambiguous, which usually requires a fairly resistive environment.

A further interpretation is presented on the EM map by means of the line-to-line correlation of bedrock anomalies, which is based on a comparison of anomaly shapes on adjacent lines. This provides conductor axes that may define the geological structure over portions of the survey area. The absence of conductor axes in an area implies that anomalies could not be correlated from line to line with reasonable confidence.

The electromagnetic anomalies are designed to provide a correct impression of conductor quality by means of the conductance grade symbols. The symbols can stand alone with geology when planning a follow-up program. The actual conductance values are printed in the attached anomaly list for those who wish quantitative data. The anomaly ppm and depth are indicated by inconspicuous dots which should not distract from the conductor
patterns, while being helpful to those who wish this information. The map provides an interpretation of conductors in terms of length, strike and dip, geometric shape, conductance, depth, and thickness. The accuracy is comparable to an interpretation from a high quality ground EM survey having the same line spacing.

The appended EM anomaly list provides a tabulation of anomalies in ppm, conductance, and depth for the vertical sheet model. No conductance or depth estimates are shown for weak anomalous responses that are not of sufficient amplitude to yield reliable calculations.

Since discrete bodies normally are the targets of EM surveys, local base (or zero) levels are used to compute local anomaly amplitudes. This contrasts with the use of true zero levels which are used to compute true EM amplitudes. Local anomaly amplitudes are shown in the EM anomaly list and these are used to compute the vertical sheet parameters of conductance and depth.

**Questionable Anomalies**

The EM maps may contain anomalous responses that are displayed as asterisks (*). These responses denote weak anomalies of indeterminate conductance, which may reflect one of the following: a weak conductor near the surface, a strong conductor at depth (e.g., 100 to 120 m below surface) or to one side of the flight line, or aerodynamic noise. Those responses that have the appearance of valid bedrock anomalies on the flight profiles are indicated by appropriate interpretive symbols (see EM legend on maps). The others probably do not warrant further investigation unless their locations are of considerable geological interest.

**The Thickness Parameter**

A comparison of coaxial and coplanar shapes can provide an indication of the thickness of a steeply dipping conductor. The amplitude of the coplanar anomaly (e.g., CPI channel) increases relative to the coaxial anomaly (e.g., CXI) as the apparent thickness increases, i.e., the thickness in the horizontal plane. (The thickness is equal to the conductor width if the conductor dips at 90 degrees and strikes at right angles to the flight line.) This report refers to a conductor as thin when the thickness is likely to be less than 3 m, and thick when in excess of 10 m. Thick conductors are indicated on the EM map by parentheses "( )". For base metal exploration in steeply dipping geology, thick conductors can be high priority targets because many massive sulphide ore bodies are thick. The system cannot sense the thickness when the strike of the conductor is subparallel to the flight line, when the conductor has a shallow dip, when the anomaly amplitudes are small, or when the resistivity of the environment is below 100 ohm-m.

**Resistivity Mapping**

Resistivity mapping is useful in areas where broad or flat lying conductive units are of
interest. One example of this is the clay alteration which is associated with Carlin-type deposits in the south west United States. The resistivity parameter was able to identify the clay alteration zone over the Cove deposit. The alteration zone appeared as a strong resistivity low on the 900 Hz resistivity parameter. The 7,200 Hz and 56,000 Hz resistivities showed more detail in the covering sediments, and delineated a range front fault. This is typical in many areas of the south west United States, where conductive near surface sediments, which may sometimes be alkaline, attenuate the higher frequencies.

Resistivity mapping has proven successful for locating diatremes in diamond exploration. Weathering products from relatively soft kimberlite pipes produce a resistivity contrast with the unaltered host rock. In many cases weathered kimberlite pipes were associated with thick conductive layers that contrasted with overlying or adjacent relatively thin layers of lake bottom sediments or overburden.

Areas of widespread conductivity are commonly encountered during surveys. These conductive zones may reflect alteration zones, shallow-dipping sulphide or graphite-rich units, saline ground water, or conductive overburden. In such areas, EM amplitude changes can be generated by decreases of only 5 m in survey altitude, as well as by increases in conductivity. The typical flight record in conductive areas is characterized by in-phase and quadrature channels that are continuously active. Local EM peaks reflect either increases in conductivity of the earth or decreases in survey altitude. For such conductive areas, apparent resistivity profiles and contour maps are necessary for the correct interpretation of the airborne data. The advantage of the resistivity parameter is that anomalies caused by altitude changes are virtually eliminated, so the resistivity data reflect only those anomalies caused by conductivity changes. The resistivity analysis also helps the interpreter to differentiate between conductive bedrock and conductive overburden. For example, discrete conductors will generally appear as narrow lows on the contour map and broad conductors (e.g., overburden) will appear as wide lows.

The apparent resistivity is calculated using the pseudo-layer (or buried) half-space model defined by Fraser (1978)\(^2\). This model consists of a resistive layer overlying a conductive half-space. The depth channels give the apparent depth below surface of the conductive material. The apparent depth is simply the apparent thickness of the overlying resistive layer. The apparent depth (or thickness) parameter will be positive when the upper layer is more resistive than the underlying material, in which case the apparent depth may be quite close to the true depth.

The apparent depth will be negative when the upper layer is more conductive than the underlying material, and will be zero when a homogeneous half-space exists. The apparent depth parameter must be interpreted cautiously because it will contain any errors that might exist in the measured altitude of the EM bird (e.g., as caused by a dense tree cover). The inputs to the resistivity algorithm are the in-phase and quadrature components of the co planar coil-pair. The outputs are the apparent resistivity of the conductive half-space (the source) and the sensor-source distance. The flying height is not an input.
variable, and the output resistivity and sensor-source distance are independent of the flying height when the conductivity of the measured material is sufficient to yield significant in-phase as well as quadrature responses. The apparent depth, discussed above, is simply the sensor-source distance minus the measured altitude or flying height. Consequently, errors in the measured altitude will affect the apparent depth parameter but not the apparent resistivity parameter.

The apparent depth parameter is a useful indicator of simple layering in areas lacking a heavy tree cover. Depth information has been used for permafrost mapping, where positive apparent depths were used as a measure of permafrost thickness. However, little quantitative use has been made of negative apparent depths because the absolute value of the negative depth is not a measure of the thickness of the conductive upper layer and, therefore, is not meaningful physically. Qualitatively, a negative apparent depth estimate usually shows that the EM anomaly is caused by conductive overburden. Consequently, the apparent depth channel can be of significant help in distinguishing between overburden and bedrock conductors.

Interpretation in Conductive Environments

Environments having low background resistivities (e.g., below 30 ohm-m for a 900 Hz system) yield very large responses from the conductive ground. This usually prohibits the recognition of discrete bedrock conductors. However, Fugro data processing techniques produce three parameters that contribute significantly to the recognition of bedrock conductors in conductive environments. These are the in-phase and quadrature difference channels (DIFI and DIFQ, which are available only on systems with “common” frequencies on orthogonal coil pairs), and the resistivity and depth channels (RES and DEP) for each coplanar frequency.

The EM difference channels (DIFI and DIFQ) eliminate most of the responses from conductive ground, leaving responses from bedrock conductors, cultural features (e.g., telephone lines, fences, etc.) and edge effects. Edge effects often occur near the perimeter of broad conductive zones. This can be a source of geologic noise. While edge effects yield anomalies on the EM difference channels, they do not produce resistivity anomalies. Consequently, the resistivity channel aids in eliminating anomalies due to edge effects. On the other hand, resistivity anomalies will coincide with the most highly conductive sections of conductive ground, and this is another source of geologic noise. The recognition of a bedrock conductor in a conductive environment therefore is based on the anomalous responses of the two difference channels (DIFI and DIFQ) and the resistivity channels (RES). The most favourable situation is where anomalies coincide on all channels.

The DEP channels, which give the apparent depth to the conductive material, also help to determine whether a conductive response arises from surficial material or from a conductive zone in the bedrock. When these channels ride above the zero level on the depth profiles (i.e., depth is negative), it implies that the EM and resistivity profiles are responding primarily to a conductive upper layer, i.e., conductive overburden. If the DEP channels are below the zero level, it indicates that a resistive upper layer exists, and this usually implies the existence of a bedrock conductor. If the low frequency DEP channel is
below the zero level and the high frequency DEP is above, this suggests that a bedrock conductor occurs beneath conductive cover.

**Reduction of Geologic Noise**

Geologic noise refers to unwanted geophysical responses. For purposes of airborne EM surveying, geologic noise refers to EM responses caused by conductive overburden and magnetic permeability. It was mentioned previously that the EM difference channels (i.e., channel DIFI for in-phase and DIFQ for quadrature) tend to eliminate the response of conductive overburden.

Magnetite produces a form of geological noise on the in-phase channels. Rocks containing less than 1% magnetite can yield negative in-phase anomalies caused by magnetic permeability. When magnetite is widely distributed throughout a survey area, the in-phase EM channels may continuously rise and fall, reflecting variations in the magnetite percentage, flying height, and overburden thickness. This can lead to difficulties in recognizing deeply buried bedrock conductors, particularly if conductive overburden also exists. However, the response of broadly distributed magnetite generally vanishes on the in-phase difference channel DIFI. This feature can be a significant aid in the recognition of conductors that occur in rocks containing accessory magnetite.

**EM Magnetite Mapping**

The information content of HEM data consists of a combination of conductive eddy current responses and magnetic permeability responses. The secondary field resulting from conductive eddy current flow is frequency-dependent and consists of both in-phase and quadrature components, which are positive in sign. On the other hand, the secondary field resulting from magnetic permeability is independent of frequency and consists of only an in-phase component which is negative in sign. When magnetic permeability manifests itself by decreasing the measured amount of positive in-phase, its presence may be difficult to recognize. However, when it manifests itself by yielding a negative in-phase anomaly (e.g., in the absence of eddy current flow), its presence is assured. In this latter case, the negative component can be used to estimate the percent magnetite content.

A magnetite mapping technique, based on the low frequency coplanar data, can be complementary to magnetometer mapping in certain cases. Compared to magnetometry, it is far less sensitive but is more able to DIGHEM closely spaced magnetite zones, as well as providing an estimate of the amount of magnetite in the rock. The method is sensitive to 1/4% magnetite by weight when the EM sensor is at a height of 30 m above a magnetitic half-space. It can individually DIGHEM steep dipping narrow magnetite-rich bands which are separated by 60 m. Unlike magnetometry, the EM magnetite method is unaffected by remanent magnetism or magnetic latitude.

The EM magnetite mapping technique provides estimates of magnetite content which are usually correct within a factor of 2 when the magnetite is fairly uniformly distributed. EM magnetite maps can be generated when magnetic permeability is evident as negative in-
phase responses on the data profiles.

Like magnetometry, the EM magnetite method maps only bedrock features, provided that the overburden is characterized by a general lack of magnetite. This contrasts with resistivity mapping which portrays the combined effect of bedrock and overburden.

The Susceptibility Effect

When the host rock is conductive, the positive conductivity response will usually dominate the secondary field, and the susceptibility effect will appear as a reduction in the in-phase, rather than as a negative value. The in-phase response will be lower than would be predicted by a model using zero susceptibility. At higher frequencies the in-phase conductivity response also gets larger, so a negative magnetite effect observed on the low frequency might not be observable on the higher frequencies, over the same body. The susceptibility effect is most obvious over discrete magnetite-rich zones, but also occurs over uniform geology such as a homogeneous half-space.

High magnetic susceptibility will affect the calculated apparent resistivity, if only conductivity is considered. Standard apparent resistivity algorithms use a homogeneous half-space model, with zero susceptibility. For these algorithms, the reduced in-phase response will, in most cases, make the apparent resistivity higher than it should be. It is important to note that there is nothing wrong with the data, nor is there anything wrong with the processing algorithms. The apparent difference results from the fact that the simple geological model used in processing does not match the complex geology.

Measuring and Correcting the Magnetite Effect

Theoretically, it is possible to calculate (forward model) the combined effect of electrical conductivity and magnetic susceptibility on an EM response in all environments. The difficulty lies, however, in separating out the susceptibility effect from other geological effects when deriving resistivity and susceptibility from EM data.

Over a homogeneous half-space, there is a precise relationship between in-phase, quadrature, and altitude. These are often DIGHEMd as phase angle, amplitude, and altitude. Within a reasonable range, any two of these three parameters can be used to calculate the half space resistivity. If the rock has a positive magnetic susceptibility, the in-phase component will be reduced and this departure can be recognized by comparison to the other parameters.

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3 Magnetic susceptibility and permeability are two measures of the same physical property. Permeability is generally given as relative permeability, $\mu_r$, which is the permeability of the substance divided by the permeability of free space ($4\pi \times 10^{-7}$). Magnetic susceptibility $k$ is related to permeability by $k = \mu - 1$. Susceptibility is a unitless measurement, and is usually reported in units of $10^6$. The typical range of susceptibilities is $-1$ for quartz, $130$ for pyrite, and up to $5 \times 10^5$ for magnetite, in $10^6$ units (Telford et al, 1986).
The algorithm used to calculate apparent susceptibility and apparent resistivity from HEM data, uses a homogeneous half-space geological model. Non half-space geology, such as horizontal layers or dipping sources, can also distort the perfect half-space relationship of the three data parameters. While it may be possible to use more complex models to calculate both rock parameters, this procedure becomes very complex and time-consuming. For basic HEM data processing, it is most practical to stick to the simplest geological model.

Magnetite reversals (reversed in-phase anomalies) have been used for many years to calculate an “FeO” or magnetite response from HEM data (Fraser, 1981). However, this technique could only be applied to data where the in-phase was observed to be negative, which happens when susceptibility is high and conductivity is low.

**Applying Susceptibility Corrections**

Resistivity calculations done with susceptibility correction may change the apparent resistivity. High-susceptibility conductors, that were previously masked by the susceptibility effect in standard resistivity algorithms, may become evident. In this case the susceptibility corrected apparent resistivity is a better measure of the actual resistivity of the earth. However, other geological variations, such as a deep resistive layer, can also reduce the in-phase by the same amount. In this case, susceptibility correction would not be the best method. Different geological models can apply in different areas of the same data set. The effects of susceptibility, and other effects that can create a similar response, must be considered when selecting the resistivity algorithm.

**Susceptibility from EM vs Magnetic Field Data**

The response of the EM system to magnetite may not match that from a magnetometer survey. First, HEM-derived susceptibility is a rock property measurement, like resistivity. Magnetic data show the total magnetic field, a measure of the potential field, not the rock property. Secondly, the shape of an anomaly depends on the shape and direction of the source magnetic field. The electromagnetic field of HEM is much different in shape from the earth’s magnetic field. Total field magnetic anomalies are different at different magnetic latitudes; HEM susceptibility anomalies have the same shape regardless of their location on the earth.

In far northern latitudes, where the magnetic field is nearly vertical, the total magnetic field measurement over a thin vertical dike is very similar in shape to the anomaly from the HEM-derived susceptibility (a sharp peak over the body). The same vertical dike at the magnetic equator would yield a negative magnetic anomaly, but the HEM susceptibility anomaly would show a positive susceptibility peak.

**Effects of Permeability and Dielectric Permittivity**
Resistivity algorithms that assume free-space magnetic permeability and dielectric permittivity, do not yield reliable values in highly magnetic or highly resistive areas. Both magnetic polarization and displacement currents cause a decrease in the in-phase component, often resulting in negative values that yield erroneously high apparent resistivities. The effects of magnetite occur at all frequencies, but are most evident at the lowest frequency. Conversely, the negative effects of dielectric permittivity are most evident at the higher frequencies, in resistive areas.

The table below shows the effects of varying permittivity over a resistive (10,000 ohm-m) half space, at frequencies of 56,000 Hz (DIGHEM) and 102,000 Hz (DIGHEM).

**Apparent Resistivity Calculations**

**Table 5 Effects of Permittivity on In-phase/Quadrature/Resistivity**

<table>
<thead>
<tr>
<th>Freq (Hz)</th>
<th>Coil</th>
<th>Sep (m)</th>
<th>Thres (ppm)</th>
<th>Alt (m)</th>
<th>In Phas e</th>
<th>Quad Phase</th>
<th>App Res</th>
<th>App Depth (m)</th>
<th>Permittivity</th>
</tr>
</thead>
<tbody>
<tr>
<td>56,000 CP</td>
<td>6.3</td>
<td>0.1</td>
<td>30</td>
<td>7.3</td>
<td>35.3</td>
<td>10118</td>
<td>-1.0</td>
<td>1 Air</td>
<td></td>
</tr>
<tr>
<td>56,000 CP</td>
<td>6.3</td>
<td>0.1</td>
<td>30</td>
<td>3.6</td>
<td>36.6</td>
<td>19838</td>
<td>-13.2</td>
<td>5 Quartz</td>
<td></td>
</tr>
<tr>
<td>56,000 CP</td>
<td>6.3</td>
<td>0.1</td>
<td>30</td>
<td>-10.4</td>
<td>42.3</td>
<td>76620</td>
<td>-25.8</td>
<td>20 Granite</td>
<td></td>
</tr>
<tr>
<td>56,000 CP</td>
<td>6.3</td>
<td>0.1</td>
<td>30</td>
<td>-19.7</td>
<td>46.9</td>
<td>71550</td>
<td>-26.0</td>
<td>30 Diabase</td>
<td></td>
</tr>
<tr>
<td>56,000 CP</td>
<td>6.3</td>
<td>0.1</td>
<td>30</td>
<td>-28.7</td>
<td>52.0</td>
<td>66787</td>
<td>-26.1</td>
<td>40 Gabbro</td>
<td></td>
</tr>
<tr>
<td>102,000 CP</td>
<td>7.86</td>
<td>0.1</td>
<td>30</td>
<td>32.5</td>
<td>117.2</td>
<td>9409</td>
<td>-0.3</td>
<td>1 Air</td>
<td></td>
</tr>
<tr>
<td>102,000 CP</td>
<td>7.86</td>
<td>0.1</td>
<td>30</td>
<td>11.7</td>
<td>127.2</td>
<td>25956</td>
<td>-16.8</td>
<td>5 Quartz</td>
<td></td>
</tr>
<tr>
<td>102,000 CP</td>
<td>7.86</td>
<td>0.1</td>
<td>30</td>
<td>-14.0</td>
<td>141.6</td>
<td>97064</td>
<td>-26.5</td>
<td>10 Epidote</td>
<td></td>
</tr>
<tr>
<td>102,000 CP</td>
<td>7.86</td>
<td>0.1</td>
<td>30</td>
<td>-62.9</td>
<td>176.0</td>
<td>83995</td>
<td>-26.8</td>
<td>20 Granite</td>
<td></td>
</tr>
<tr>
<td>102,000 CP</td>
<td>7.86</td>
<td>0.1</td>
<td>30</td>
<td>-107.5</td>
<td>215.8</td>
<td>73320</td>
<td>-27.0</td>
<td>30 Diabase</td>
<td></td>
</tr>
<tr>
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<td>7.86</td>
<td>0.1</td>
<td>30</td>
<td>-147.1</td>
<td>259.2</td>
<td>64875</td>
<td>-27.2</td>
<td>40 Gabbro</td>
<td></td>
</tr>
</tbody>
</table>

Methods have been developed (Huang and Fraser, 2000, 2001) to correct apparent resistivities for the effects of permittivity and permeability. The corrected resistivities yield more credible values than if the effects of permittivity and permeability are disregarded.

**Recognition of Culture**

Cultural responses include all EM anomalies caused by man-made metallic objects. Such anomalies may be caused by inductive coupling or current gathering. The concern of the interpreter is to recognize when an EM response is due to culture. Points of consideration used by the interpreter, when coaxial and coplanar coil-pairs are operated at a common frequency, are as follows:

1. Channels CXPL and CPPL monitor 60 Hz radiation. An anomaly on these
channels shows that the conductor is radiating power. Such an indication is normally a guarantee that the conductor is cultural. However, care must be taken to ensure that the conductor is not a geologic body that strikes across a power line, carrying leakage currents.

2. A flight that crosses a "line" (e.g., fence, telephone line, etc.) yields a centre-peaked coaxial anomaly and an m-shaped coplanar anomaly. When the flight crosses the cultural line at a high angle of intersection, the amplitude ratio of coaxial/coplanar response is 2. Such an EM anomaly can only be caused by a line. The geologic body that yields anomalies most closely resembling a line is the vertically dipping thin dike. Such a body, however, yields an amplitude ratio of 1 rather than 2. Consequently, an m-shaped coplanar anomaly with a CXI/CPI amplitude ratio of 2 is virtually a guarantee that the source is a cultural line.

3. A flight that crosses a sphere or horizontal disk yields centre-peaked coaxial and coplanar anomalies with a CXI/CPI amplitude ratio (i.e., coaxial/coplanar) of 1/8. In the absence of geologic bodies of this geometry, the most likely conductor is a metal roof or small fenced yard. Anomalies of this type are virtually certain to be cultural if they occur in an area of culture.

4. A flight that crosses a horizontal rectangular body or wide ribbon yields an m-shaped coaxial anomaly and a centre-peaked coplanar anomaly. In the absence of geologic bodies of this geometry, the most likely conductor is a large fenced area. Anomalies of this type are virtually certain to be cultural if they occur in an area of culture.

5. EM anomalies that coincide with culture, as seen on the camera film or video display, are usually caused by culture. However, care is taken with such coincidences because a geologic conductor could occur beneath a fence, for example. In this example, the fence would be expected to yield an m-shaped coplanar anomaly as in case #2 above. If, instead, a centre-peaked coplanar anomaly occurred, there would be concern that a thick geologic conductor coincided with the cultural line.

6. The above description of anomaly shapes is valid when the culture is not conductively coupled to the environment. In this case, the anomalies arise from inductive coupling to the EM transmitter. However, when the environment is quite conductive (e.g., less than 100 ohm-m at 900 Hz), the cultural conductor may be conductively coupled to the environment. In this latter case, the anomaly shapes tend to be governed by current gathering. Current gathering can completely distort the anomaly shapes, thereby complicating the identification of cultural anomalies. In such circumstances, the interpreter can only rely on the radiation channels and on the camera film or video records.

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4 See Figure B-1 presented earlier.
5 It is a characteristic of EM that geometrically similar anomalies are obtained from: (1) a planar conductor, and (2) a wire which forms a loop having dimensions identical to the perimeter of the equivalent planar conductor.
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.

**Gamma Ray Spectrometry**

Radioelement concentrations are measures of the abundance of radioactive elements in the rock. The original abundance of the radioelements in any rock can be altered by the subsequent processes of metamorphism and weathering.

Gamma radiation in the range that is measured in the thorium, potassium, uranium and total count windows is strongly attenuated by rock, overburden and water. Almost all of the total radiation measured from rock and overburden originates in the upper .5 metres. Moisture in soil and bodies of water will mask the radioactivity from underlying rock. Weathered rock materials that have been displaced by glacial, water or wind action will not reflect the general composition of the underlying bedrock. Where residual soils exist, they may reflect the composition of underlying rock except where equilibrium does not exist between the original radioelement and the products in its decay series.

Radioelement counts (expressed as counts per second) are the rates of detection of the gamma radiation from specific decaying particles corresponding to products in each radioelements decay series. The radiation source for uranium is bismuth (Bi-214), for thorium it is thallium (Tl-208) and for potassium it is potassium (K-40).

The uranium and thorium radioelement concentrations are dependent on a state of equilibrium between the parent and daughter products in the decay series. Some daughter products in the uranium decay are long lived and could be removed by processes such as leaching. One product in the series, radon (Rn-222), is a gas which can easily escape. Both of these factors can affect the degree to which the calculated uranium concentrations reflect the actual composition of the source rock. Because the daughter products of thorium are relatively short lived, there is more likelihood that the thorium decay series is in equilibrium.

Lithological discrimination can be based on the measured relative concentrations and total, combined, radioactivity of the radioelements. Feldspar and mica contain potassium. Zircon, sphene and apatite are accessory minerals in igneous rocks that are sources of uranium and thorium. Monazite, thorianite, thorite, uraninite and uranothorite are also sources of uranium and thorium which are found in granites and pegmatites.

In general, the abundance of uranium, thorium and potassium in igneous rock increases with acidity. Pegmatites commonly have elevated concentrations of uranium relative to
Thorium. Sedimentary rocks derived from igneous rocks may have characteristic signatures that are influenced by their parent rocks, but these will have been altered by subsequent weathering and alteration.

Metamorphism and alteration will cause variations in the abundance of certain radioelements relative to each other. For example, alternative processes may cause uranium enrichment to the extent that a rock will be of economic interest. Uranium anomalies are more likely to be economically significant if they consist of an increase in the uranium relative to thorium and potassium, rather than a sympathetic increase in all three radioelements.

Faults can exhibit radioactive highs due to increased permeability which allows radon migration, or as lows due to structural control of drainage and fluvial sediments which attenuate gamma radiation from the underlying rocks. Faults can also be recognized by sharp contrasts in radiometric lithologies due to large strike-slip or dip-slip displacements. Changes in relative radioelement concentrations due to alteration will also define faults.

Similar to magnetics, certain rock types can be identified by their plan shapes if they also produce a radiometric contrast with surrounding rock. For example, granite intrusions will appear as sub-circular bodies, and may display concentric zonations. They will tend to lack a prominent strike direction. Offsets of narrow, continuous, stratigraphic units with contrasting radiometric signatures can identify faulting, and folding of stratigraphic trends will also be apparent.
Appendix D
Data Processing
Processing Flow Chart - Electromagnetic Data

Fugro Airborne Surveys
Electromagnetic Data Processing Flow

- EM System Lag Test Data
- EM System
- EM Airborne Flight Data
- Apply base level corrections
- EM Base Level Picks From Flights to Height
- Apply lag correction
- Edit EM data: manual spike removal, spheric removal filter
- Calculate Resistivity, Level EM and do Quality Control:
  - manual level adjustments
  - check phase and gain
  - microlevelling routines (optional)
- Geophysicist selects, interprets, and classifies EM anomalies
- Grids, Colour Maps, Contour Maps

Processing Flow Chart - Magnetic Data

Fugro Airborne Surveys
Magnetic Data Processing Flow

- Magnetic System Lag Test Data
- Magnetic System
- Magnetic Airborne Flight Data
- Load into Oasis database
- Magnetic Base Level Picks From Flights to Height
- Apply lag correction
- Edit airborne magnetic data: manual spike removal, fourth difference spike removal
- Edit base station data: spike removal, low pass filter, base station data
- Level magnetic data: base station subtraction magnetic leveling network/line intersections manual level adjustments microlevelling routines
- IGRF or local trend removal Derivatives
- Grids, Colour Maps, Contour Maps
Appendix E
Radiometric Processing Control File
CONTROL_BEGIN

PROGRAM = AGSCorrection
VERSION = 1.4.0

### Process or Calibration? ###
WhatToDo = Process Survey Line

### Corrections to apply ###
CorrectionType = Yes Filtering
CorrectionType = Yes LiveTimeCorrection
CorrectionType = Yes CosmicAircraftBGRemove
CorrectionType = Yes CalcEffectiveHeight
CorrectionType = No RadonBGRemove
CorrectionType = Yes ComptonStripping
CorrectionType = Yes HeightCorrection
CorrectionType = No ConvertToConcentration

### Main I/O settings ###
MainChannelIO|TC       = TC_Recal --> TC_Recal_Cor
MainChannelIO|K        = K_Recal --> K_Recal_Cor
MainChannelIO|U        = U_Recal --> U_Recal_Cor
MainChannelIO|Th       = TH_Recal --> TH_Recal_Cor
MainChannelIO|UpU      = U_UP --> U_UP_Cor
MainChannelIO|Cosmic   = COSMIC --> COSMIC_Cor
MainChannelIO|Spectrum = -->

### Control Channel I/O settings ###
ControlChannel|RadarAltimeter = ALTRAD_M [metres]
ControlChannel|Pressure/Barometer = KPA [kPa]
ControlChannel|Temperature = TEMP_EXT

### Input for correction ###
InputForCorrection = ROIs

### Negative count handling ###
NegativeCountHandlingROI = 0  // -1: Allow negative  0:Replace with zero  1:Replace with dummy
NegativeCountHandlingFullSpectrum = 0  // -1: Allow negative  0:Replace with zero
### Pre-filtering settings ###
Filtering|TC      = 0  
Filtering|K       = 0  
Filtering|U       = 0  
Filtering|Th      = 0  
Filtering|UpU     = 0  
Filtering|Cosmic  = 9  
Filtering|RadarAltimeter     = 3  
Filtering|Pressure/Barometer = 3  
Filtering|Temperature        = 3

### Live-time correction settings ###
LiveTimeChannel             = LIVE_TIME  
LiveTimeUnits               = milli-seconds  
ApplyLiveTimeCorrToUpU      = Yes

### Cosmic correction settings ###
CosmicCorrParam|TC      = 1.174925, 34.567198  
CosmicCorrParam|K       = 0.082062, 4.112891  
CosmicCorrParam|U       = 0.053759, 1.017845  
CosmicCorrParam|Th      = 0.063595, 0.080704  
CosmicCorrParam|UpU     = 0.013233, 0.859841  
CosmicCorrParam|SpectrumBackgroundFile    = YES

### Effective-Height settings ###
EffectiveHeightOutputChannel = EffectiveHeight  
EffectiveHeightOutputUnits   = metres

### Special Stripping (Compton Stripping) ###
ComptonCorrParam_Stripping_Alpha     = 0.276000  
ComptonCorrParam_Stripping_Beta      = 0.417000  
ComptonCorrParam_Stripping_Gamma     = 0.754000  
ComptonCorrParam_AlphaPerMetre       = 0.000490  
ComptonCorrParam_BetaPerMetre        = 0.000650  
ComptonCorrParam_GammaPerMetre       = 0.000690  
ComptonCorrParam_GrastyBackscatter_a = 0.043000  
ComptonCorrParam_GrastyBackscatter_b = 0.000000  
ComptonCorrParam_GrastyBackscatter_g = 0.000000

### Height Correction settings ###
SurveyHeightDatum     = 60.000000  
AttenuationCorrControl = 1  
AttenuationForNegROIs  = Yes  
HeightCorrParam|TC      = -0.006930, 300.000000  
HeightCorrParam|K       = -0.007889, 300.000000  
HeightCorrParam|U       = -0.008676, 300.000000  
HeightCorrParam|Th      = -0.003215, 300.000000

### Concentration settings ###
ConcentrationParam[K] = Concentration_K, 0.000000
ConcentrationParam[U] = Concentration_U, 0.000000
ConcentrationParam[Th] = Concentration_Th, 0.000000
AirAbsorbedDoseRateParam = DoseRate, 0.000000
NaturalAirAbsorbedDoseRateParam = NaturalDoseRate, 13.078000, 5.675000, 2.494000

CONTROL_END
GLOSSARY OF AIRBORNE GEOPHYSICAL TERMS

Note: The definitions given in this glossary refer to the common terminology as used in airborne geophysics.

**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.

**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.

**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.

**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 \(\frac{dB}{dt}\), 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.

**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 coil**: A wire coil of known size and dipole moment, which is used to generate a field of known *amplitude* and *phase* 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.

**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, or one of 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: [$\varepsilon$] The capacity of a material to store electrical charge, this is most often measured as the relative permittivity [$\varepsilon_r$], 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.

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. 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.

**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 *primary field* that oscillates smoothly over time (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.

**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 is often 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*.

**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).

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 \( \mu \omega h^2 \) and for a large, flat, conductor it is \( \mu \omega t \), where \( \mu \) is the magnetic permeability, \( \omega \) is the angular frequency, \( \sigma \) 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.

magnetic permeability: $\mu$ This is defined as the ratio of magnetic induction to the inducing magnetic field. The relative magnetic permeability $[\mu_r]$ 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.

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 \( \tan^{-1}(\text{in-phase} / \text{quadrature}) \).

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.

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: [p] 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 x √(resistivity/frequency). Note that depth of penetration is greater at higher resistivity and/or lower frequency.

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.

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 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.

*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*.

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Common Symbols and Acronyms

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\begin{align*}
\kappa & \quad \text{Magnetic susceptibility} \\
\varepsilon & \quad \text{Dielectric permittivity} \\
\mu, \mu_r & \quad \text{Magnetic permeability, relative permeability} \\
\rho, \rho_a & \quad \text{Resistivity, apparent resistivity} \\
\sigma, \sigma_a & \quad \text{Conductivity, apparent conductivity} \\
\sigma_t & \quad \text{Conductivity thickness} \\
\tau & \quad \text{Tau, or time constant} \\
\Omega m & \quad \text{ohm-metres, units of resistivity} \\
\text{AGS} & \quad \text{Airborne gamma ray spectrometry.} \\
\text{CDT} & \quad \text{Conductivity-depth transform, conductivity-depth imaging (Macnae and Lamontagne, 1987; Wolfgram and Karlik, 1995)} \\
\text{CPI, CPQ} & \quad \text{Coplanar in-phase, quadrature} \\
\text{CPS} & \quad \text{Counts per second} \\
\text{CTP} & \quad \text{Conductivity thickness product} \\
\text{CXI, CXQ} & \quad \text{Coaxial, in-phase, quadrature} \\
\text{FOM} & \quad \text{Figure of Merit} \\
\text{ft} & \quad \text{femtoelectr}\text{ons, normal unit for measurement of B-Field} \\
\text{EM} & \quad \text{Electromagnetic} \\
\text{keV} & \quad \text{kilo electron volts – a measure of gamma-ray energy} \\
\text{MeV} & \quad \text{mega electron volts – a measure of gamma-ray energy 1MeV = 1000keV} \\
\text{NIA} & \quad \text{dipole moment: turns \times current \times Area} \\
\text{nT} & \quad \text{nanotesla, a measure of the strength of a magnetic field} \\
\text{nG/h} & \quad \text{nanoGreys/hour \text{– gamma ray dose rate at ground level}} \\
\text{ppm} & \quad \text{parts per million \text{– a measure of secondary field or noise relative to the primary or radioelement concentration.}} \\
\text{pT/s} & \quad \text{picoteslas per second: Units of decay of secondary field, dB/dt} \\
\text{S} & \quad \text{siemens \text{– a unit of conductance}} \\
\text{x} & \quad \text{the horizontal component of an EM field parallel to the direction of flight.} \\
\text{y} & \quad \text{the horizontal component of an EM field perpendicular to the direction of flight.} \\
\text{z} & \quad \text{the vertical component of an EM field.}
\end{align*}
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