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EXPLORATION TRENDS & DEVELOPMENTS

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MINERAL EXPLORATION TRENDS
AND DEVELOPMENTS IN 2012

By Patrick G. Killeen Ph.D., Geophysical Consultant and retired
Research Scientist, Geological Survey of Canada, Ottawa 2012

KEGS’ seventh year
as patron of Exploration
Trends & Developments

The Trends review
originated with the Geological Survey of
Canada (GSC), where for over 45 years, GSC scientists have
prepared an unbiased annual publication on trends and new
developments in geophysical exploration for minerals. The
Canadian Exploration Geophysical Society (KEGS) first
became the primary “patron” of the annual review of Mineral Exploration Trends &
Developments in 2007. This year, KEGS support came from the companies listed
in the Sponsor’s Box below. This marks the 21st year it has been written by Patrick
Killeen, originally as a research scientist at the GSC, and since 2007 through KEGS.

Founded in 1953, KEGS has the stated purpose according to its constitution: “... To promote the science of
geophysics especially as it is applied to the exploration for minerals other than oil; to foster the
common scientific interests of geophysicists; to maintain a high professional standing among its
members; and to promote fellowship and co-operation among persons interested in
these problems.”

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EXPLORATION TECHNOLOGY IN 2012:
THE INNOVATIONS CONTINUE

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Cover photo:
Precision GeoSurveys
flying an aeromag
survey near
Juneau, Alaska
Credit: Precision GeoSurveys

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EXPLORATION TECHNOLOGY IN 2012: THE INNOVATIONS CONTINUE

Exploration activity in 2012 seemed to flatten out after signs of a recovery in the previous year. Reduced exploration budgets affected the type and location of geophysical surveys around the globe. Airborne surveys saw an increase in magnetic and gamma-ray spectrometric surveys over other survey types. Companies continued to expand their territories, from domestic survey operations to international operations, or into new countries — often with the formation of partnerships with other companies or the establishment of a sister company. Thus, decreased activity in one part of the world was somewhat balanced by increased activity in other parts. Some companies even acquired new aircraft. Significant mergers and acquisitions took place in the airborne contract survey business in 2012. With continued stress in the marketplace in the future, there will likely be more pressure for consolidation within the industry.

Exploration technology continued to see refinements of earlier innovations, and to incorporate feedback from “ground truth” surveys into the processing and interpretation of airborne surveys. One example was the use of drill-hole gravity measurements to assist with airborne gravity. The development of any new technology often requires years of feedback from ground surveys to fully understand what it all means. In 2012, companies conducting airborne gravity surveys continued to broaden applications, including, for example, to iron ore exploration in Labrador. The number of contractors offering airborne gravity services increased. Several new helicopter-borne time-domain EM (TDEM) systems appeared, existing systems were updated or enhanced and a fundamentally different TDEM system was in the field-testing stage. The use of natural field (passive) EM surveys continued to increase, with new or improved systems becoming available for both airborne and ground surveys. The number of large airborne survey systems with combined EM, magnetic, gravimetric and gamma-ray spectrometric capabilities also increased. In data processing, new developments in 3-D inversion and 3-D modelling of EM, magnetic and gravimetric parameters were reported.

In other airborne-related developments, a new upgraded version of an airborne gravimeter came on the market. Several companies reported the use of airborne sniffing, i.e. methane detection sensors or seep detector surveys, some started offering infrared thermal imaging, and the UAV/UAS trend continued to evolve with the testing of a magnetic gradiometer system and the release of a magnetic compensator and new ultra-high sensitivity magnetometer, both tailored for UAV applications.

On the ground, geophysical developments included the use of more dB/dt (coil) and B-field sensors (SQUID, fluxgate). There were also advances and improvements in borehole geophysical equipment, including gravity and EM probes, and software improvements for gamma-ray spectral logging and televIEWers (both optical and acoustic), as well as a new borehole magnetometric resistivity (MMR) system. Other advances included:

- a new ground TDEM system; new IP and resistivity equipment with new software; a new magnetic susceptibility meter and upgraded versions of magnetic susceptibility/conductivity meters; a new magnetometer; a new 3-D resistivity/IP/MT system; software enhancements for GPR ice profiling; and new and improved ground radiometric systems, including vehicle-mounted.

An interesting and significant new development in IP surveying was made possible by the use of SQUIDs. Both MMR and magnetic IP (MIP) have been tried in the past, but the sensors available were not sensitive enough for them to work well. Now, SQUIDs have the sensitivity to make rapid measurements of the weak magnetic field of the decaying currents that are usually measured with the IP method. In MIP, the magnetic field is measured during the off time, i.e. during the current decay. In MMR, the magnetic field is measured during the on time to calculate the resistivity. So basically, the IP method determines chargeability and resistivity by measuring electrical components, while these are determined by measuring magnetic components in MIP and MMR.

CORPORATE HIGHLIGHTS

Abitibi Geophysics, based in Val d’Or, Que., reported an exceptional year with the successful field trial and subsequent production surveys using the ARMIT combined B-field and dB/dt three-component TDEM sensor. The IPower3D induced-polarization system has been modified to allow the use of 2,000-metre arrays and new processing and interpretation software has been successfully tested. The “iron rush” in the Labrador Trough has increased interest in the Gravilog borehole gravity system, which has been deployed to aid in iron ore resource estimates.

In May, 2012, Aurora, Ont.-based Aeroquest International was acquired by Geotech, also based in Aurora. The acquisition involved subsidiaries Aeroquest Airborne in Canada, UTS Geophysics in Australia, Aeroquest Mapcon in Canada and the U.S., and Geophex in the U.S. Aeroquest reports that it is benefiting from the stability and vast resources of its new parent company and that it is already seeing an increased demand for its broad range of airborne geophysical services. Within the Americas, Aeroquest Airborne (Aurora, Ont.) offers a full suite of airborne geophysical solutions, including both time-domain EM (Aero-TEM IV) and frequency-domain EM (Impulse), ultra-high resolution fixed-wing magnetics, helicopter-borne magnetics and gradiometry, and radiometrics to the mineral and petroleum industries. Perth-based UTS Geophysics, which specializes in...
ultra-high-resolution airborne geophysical surveys, continues to offer low-level, fixed-wing and helicopter-borne magnetics, gravimetrics, and radiometrics throughout Asia Pacific, Australia, the Middle East and Africa.

In 2012, Bell Geospace of Houston created a new look, including a logo based on actual survey data. The U.S. Department of Energy has provided funding to install Geotech’s fixed-wing ZTEM system onto one of Bell Geospace’s Basler BT-67’s, allowing FTG gravity and ZTEM to be acquired simultaneously. Although this combination will initially be applied to geothermal exploration, simultaneously acquiring ZTEM, FTG, and magnetometric data should provide a powerful structural mapping tool.

Mississauga, Ont.-based Crone Geophysics, which marked its 50th anniversary last year, reported that its equipment is employed on six continents, with Crone’s field crews conducting surveys on over 40 projects throughout Canada, the United States, South America, East Africa and Europe in 2012 alone. The year also saw the release of the new Crone borehole MMR system, which was used in Ontario and Ireland.

EON Geosciences of Montreal moved its main office to a larger facility to accommodate its geophysical equipment R&D division and more personnel. EON continues to offer a full range of high-resolution fixed-wing and helicopter-borne surveys worldwide, including magnetic, gamma-ray spectrometric, gravity and electromagnetic (time-domain [ETHEM] and frequency-domain [Hummingbird]).

Fugro NV and CGGVeritas announced in September that Fugro’s Geoscience Division, of which Fugro Airborne Surveys and Fugro Ground Geophysics are a part, will be acquired by
CCGVeritas. The deal was expected to be completed by January 2013. It is business as usual at both companies in serving their exploration clients.

Fugro Airborne Surveys, headquartered in Ottawa, introduced dedicated FALCON Airborne Gravity Gradiometry (AGG) systems into the Africa, Middle East and Europe and South America regions served by its Johannesburg and Rio de Janeiro offices, respectively. HeliFALCON, which was introduced into Australia, Brazil and Canada, saw high demand for iron ore, base metals and shale gas exploration. The GRYPHON Dash-7 multiparameter airborne platform (fixed-wing TDEM, FALCON AGG, magnetics and radiometrics) came online in 2012 with the first commercial GRYPHON survey flown for Argex Titanium over its Mouchalagane property in Quebec. Fugro reported subsequent strong demand for this exclusive technology, with the system operational in Chile at year-end and carrying out large regional exploration programs. Fugro also acquired a Basler BT-67, for deployment in early 2013, to expand its GRYPHON capability worldwide.

Geophysics GPR of Longueuil, Que., continued to offer helicopter and fixed-wing magnetic, electromagnetic (EM-VLF and TDEM), radiometric and gravity surveys in 2012. GPR made improvements to the helicopter GPRTEM system introduced in 2011, and three systems were available in 2012. GPR has operational bases in Canada, Africa and South America.

Moscow-based Geotechnologies offers a wide range of airborne geophysical technologies, including frequency-domain and time-domain electromagnetics, magnetics and magnetic gradiometry and infrared thermal imaging. In 2012, the company completed several contracts for geophysical systems production, deployment and systems integration for Alrosa, Geoken Co., and the Norilsk Branch of Russian Geological Research Institute (NF VSEGEI).

MPX Geophysics (MPX) of Markham, Ont., reported a very successful 2012 providing international services. The company offers high-resolution magnetic and radiometric surveys using fixed-wing and helicopter platforms. It can also provide horizontal and vertical gradient magnetics, airborne gravity and LiDAR using seven airborne platforms positioned around the globe. MPX’s Colombian and Mexican offices flew numerous airborne geophysical surveys. Increased demand for services in South America saw the establishment of a new base of operations in Lima, Peru, where the company is currently flying helicopter-bornemagnetic, radiometric and LiDAR surveys. The year also saw the signing of partnership deals with local companies in Jakarta, Indonesia and Manila, Philippines, from which MPX now offers airborne geophysical services throughout Southeast Asia.

Pico Envirotec (PEI) of Concord, Ont., continued to develop, supply and support turnkey geophysical survey systems for airborne and ground applications. In 2012, PEI was awarded a significant project by the government of Venezuela. The integrated geophysical airborne system contains a high-sensitivity magnetometer (AirMag), a gamma-ray spectrometer (AirSpec) and a time-domain electromagnetic system (P-THEM). Delivery was scheduled for early 2013. The system also includes a large training component and software and computers for advanced data processing. A number of PEI’s Integrated Radiation Information Systems (IRIS) were supplied to China, Japan and Hong Kong during 2012 and successfully tested. Two fixed-wing combined gamma-ray spectrometer, magnetometer systems were delivered to McPhar International (Uxbridge, Ont.) for projects in Southeast Asia and India. PEI is currently customizing the IMPAC (integrated multiparameter airborne console) for several European clients. Those systems are designed to work with sophisticated scientific detectors.
and sensors in research applications. PEI expanded its association and co-operation with the Czech company ENVINET during 2012, Together, the companies improved PEI’s gamma-ray spectrometry and radiation-detection technologies, and increased its market for radiation-detection instrumentation in Europe and Asia.

Ottawa-based Sander Geophysics (SGL) reported flying airborne gravity surveys with the company's 12 AIRGrav systems in North America, South America, Greenland, Europe, Australasia, Asia, Antarctica and Africa in 2012. It bought a second Eurocopter AS-350 B3 Helicopter and performed extensive modifications over the summer to transform it into a magnetically quiet survey aircraft capable of flying gravity, magnetic and radiometric surveys. It completed testing in Ottawa and was being shipped overseas to complete a large helicopter-borne AIRGrav survey. SGL’s fleet now totals 17 company-owned and operated survey aircraft, all modified for airborne geophysical surveys. The company specializes in high-resolution airborne surveys for petroleum and mineral exploration, and environmental mapping. The company carries out airborne gravity, magnetic, electromagnetic, radiometric and LiDAR surveys worldwide using fixed-wing aircraft and helicopters. SGL also reported a busy year flying combined gravity and magnetic surveys, as well as combined magnetic, electromagnetic and radiometric surveys.

To serve the North American market, Denmark-based SkyTEM Surveys operates as SkyTEM Canada, based in Waterloo, Ont. In Australia, the company is represented by GroundProbe (Malaga, Western Australia). The company is also finalizing arrangements to establish an office and base of operations in Africa, as well as in the Far East. SkyTEM announced a strategic partnership agreement with SECON Aries Aerial Surveys Private (SAAS) in India. The partnership will offer a full-fledged program of airborne geophysical surveys and consulting services in India using SkyTEM’s airborne geophysical systems and SAAS’s capabilities. SAAS, which is a joint venture of SECON Private of India and Aries Aviation International of Canada is the first Indian-owned company specifically set up to target India’s growing airborne remote sensing market. Services offered by SAAS include airborne geophysical surveys, aerial photography, LiDAR and hyperspectral surveys.

Terraquest, of Markham, Ont., conducts airborne geophysical surveys for mineral, oil and gas exploration worldwide using fixed-wing and helicopter platforms. It had a busy 2012 carrying out high-resolution aeromagnetic horizontal gradiometry, gamma-ray spectrometry, gravity, electromagnetic and seep-detector surveys. The company saw increased interest in its proprietary XDS VLF-EM surveys for mapping low-conductivity and disseminated structures. Terraquest continued to upgrade and retrofit its fixed-wing airborne systems. The Cessna 206 was completely degaussed and outfitted with a new, longer tail stinger, and wing-tip pods and the twin turbine King Air C90 was outfitted with new wing-tip pods and a vertical tail stinger to increase its geophysical survey capabilities.

Thomson Aviation based in Griffith, Australia, continued to expand its territory of operations in 2012 by adding Laos and the Philippines to the Southeast Asian and South Pacific countries it serves. The company routinely flies helicopter magnetic surveys using Geometrics cesium vapour sensors, and radiometric surveys using Radiation Solutions’ RS-500 gamma-ray spectrometers in the region. Thomson strengthened its operations in Indonesia and neighbouring countries with the establishment of P. T. Thomson Aviation, with a regional office in Jakarta. Last year, Thomson increased the services it offers to include fixed-wing airborne gravity surveying using the CMG GT-2A system. Also, through a partnership with Outer Rim Developments of Perth, Thomson will soon provide surveys with a newly developed helicopter-towed time-domain electromagnetic system.
In 2012, **EON Geosciences** flew surveys in Quebec for the **Ministère des Ressources Naturelles et de la Faune** (MRNF), **Iamgold** and **Belmont Resources**; in California, for the **United States Geological Survey** (USGS); and in southeastern Greenland, for the **Geological Survey of Denmark and Greenland**. The Greenland survey marked EON’s first international survey, with a second planned for 2013. The company began flying its new ET-HEM time-domain electromagnetic system, which is now available for surveys worldwide. The system has a 50-sq.-metre octagonal transmitter loop with a dipole moment of 235,000 NIA, and a programmable base frequency of 30, 45, 75, or 90 Hz. Additionally, EON put its recently acquired Piper Cheyenne II twin-turbine aircraft into operation, increasing the company’s survey capacity.

**Sister company EON Airborne** is in the process of obtaining its air operator certification from Transport Canada, which will allow it to control and manage the operation and maintenance of the aircraft fleet.

**Fugro** deployed additional TEMPEST EM systems on Cessna Caravans in Africa, for a total of three systems. In 2012, the company introduced the 75 Hz TEMPEST with improved spatial resolution and lower noise levels in shallow or resistive terrain. R&D into the TEMPEST transmitter and receiver design led to significant transmitter power and signal-to-noise improvements which will be introduced into the Australian market in early 2013. The TEMPEST system, using a 225 Hz base frequency, branded as GENESIS, successfully completed a paleochannel mapping program in Africa, launching a new near-surface, high-resolution mapping capability. The Cessna Caravan-mounted TEMPEST system will receive a dipole moment upgrade in early 2013 with a doubling of transmitter power. HELITEM developments in 2012 pushed the envelope for difficult deposit detection with the detection of the Lalor Lake massive sulphides (600 metres wide and 550 metres deep) in the Snow Lake area of Manitoba. According to Fugro, Lalor Lake deposit, owned by **HudBay Minerals**, had not been detected previously by any active airborne EM system.

The company’s aeromagnetic fleet conducted a variety of surveys in 2012, ranging from large-scale mapping programs to high-resolution mineral and petroleum exploration programs across the globe. Fugro’s Canadian-based magnetic and gamma-ray spectrometric aircraft were busy flying surveys primarily in Eastern Canada. In addition to a number of surveys conducted for publicly traded companies, several government mapping surveys were started or completed including: a survey in northern Quebec for the MRNF; a survey near Pelly Lake, Nunavut, for **Natural Resources Canada** (NRCan); and a survey in northern Ontario for the Ministry of **Northern Development and Mines** (MDNM). Surveys were also carried out in the United States in Kansas and Colorado.

Fugro conducted numerous HELITEM surveys in Canada, West and East Africa, the Middle East, Brazil and Australia. Fugro’s broadband GEOTEM and TEMPEST time-domain electromagnetic systems were active in the Northwest Territories and
Nunavut, participating in large uranium and base metal exploration programs. The systems were used in surveys for ground water exploration and characterization in West Africa and in large mineral exploration programs in West Africa and Australia. Fugro also conducted surveys for water for the Western Australian Department of Water within the Perth metropolitan area, and for the Department of Agriculture in the Pilbara region of Western Australia.

All five FALCON airborne gravity gradiometry (AGG) systems (both fixed-wing and helicopter-borne) were fully occupied on projects in Australasia, Asia-Pacific, and across the Americas, targeting iron ore, uranium, base metals, iron oxide copper-gold and gold. The systems were also used on basin architecture mapping projects for both conventional and unconventional oil and gas targets. The FALCON technology continued to receive strong interest in North America with systems active in hydrocarbon exploration activities in Central and Western Canada. The FALCON systems also carried out a number of base metal surveys in Eastern Canada and iron ore surveys in Quebec and Labrador. The HeliFALCON AGG system was introduced into Australia in 2012 and surveys were completed for iron ore, uranium, base metals and shale gas. The largest HeliFALCON-MAG mineral exploration program to date was completed in Brazil, demonstrating the efficacy of the AGG technology as a mineral exploration tool.

Saskatoon, Sask.-based Goldak Airborne Surveys reported a busy 2012, with several large-scale projects completed. In January, the company completed its first overseas project: an 88,000 line-km three-axis magnetic/radiometric survey in Western Sahara for Metalex Ventures. In the first quarter, it also finished a 107,000 line-km magnetic survey over the South Rae Craton in the Northwest Territories for the Geological Survey of Canada. Goldak's three Piper Navajo aircraft spent the summer in western Newfoundland on a 116,000 line-km mag/horizontal gradient offshore survey, also for the GSC. The company conducted several smaller-scale magnetic, radiometric and VLF-EM surveys, including its first-ever Tri-axial gradiometer survey flown with its Cessna Caravan. The year end saw Goldak mobilizing two aircraft to northwest Ontario for a 127,000 line-km horizontal gradient survey for Ontario's MNDM.

Novatem, based in Mont-Saint-Hilaire, Que., reported its business in 2012 mainly consisted of large-scale, fixed-wing airborne magnetic and radiometric surveys in Europe, North America and Africa, and helicopter-borne magnetic, radiometric and TDEM surveys in Canada and Africa. Novatem Aviation added a new twin engine aircraft to its fleet, for a total of four aircraft now in service.

Precision GeoSurveys, based in Vancouver, specializes in low-level airborne geophysical surveys in mountainous terrain. The company operates a combination of its own and chartered helicopters, and has provided high-resolution geophysical data on over 200 mineral exploration projects in Africa, Europe, and across North America in a wide variety of geological and geophysical environments. Precision is now developing new passive EM and time-domain EM technologies, which will be optimized for low-noise data in mountainous terrain.

In the past, Sander Geophysics conducted several methane detection surveys for one client, but last year SGL made the service publicly available for petroleum exploration and environmental mapping. The methane detection system offers direct detection of hydrocarbon gases that naturally seep into the air. These gases can be related to active hydrocarbon systems, industrial activity, biogenic processes and landfills. Methane surveys conducted by SGL have shown that methane concentrations related to hydrocarbon systems are well above background levels, even in jungle environments. The company uses ultra-sensitive, high-resolution sensors on survey aircraft to record methane gas concentrations in the air. These airborne data can then be used to map ground-level gas flux rates, matching measured data to known methane sources and potential hydro-
carbon seeps. Other geophysical information, such as gravity or magnetic data, can be collected simultaneously using fixed-wing or helicopter platforms.

Petroleum exploration and regional mapping in 2012 saw SGL’s unique AIR-Grav technology flown in several large combined airborne gravity and magnetic surveys. SGL also flew many smaller gravity and magnetic surveys, including surveys for mineral exploration and prospect mapping, and a large fixed-wing magnetic gradient and radiometric survey for mineral exploration. Several magnetic surveys were flown in Canada, and large fixed-wing magnetic and radiometric surveys for regional mapping were completed in South America. In addition, a very large combined gravity, magnetic and radiometric survey was started in Africa in 2012. The company also completed a large survey in Ireland that it had begun in 2011 using its Twin Otter equipped with a frequency-domain electromagnetic system (SGFEM), stinger mounted magnetometers, and a radiometric system. Formerly operated by the Geological Survey of Finland (GTK) and the British Geological Survey (BGS), the SGFEM system has been used extensively in Europe and Africa to produce high-resolution geophysical data.

A combined gravity, magnetic and radiometric survey was completed in Virginia to help the USGS study the faults that caused the region’s earthquake in August 2011. This earthquake was among the largest in history along the U.S. Eastern Seaboard and caused extensive damage. The USGS says the survey, which was conducted using SGL’s AIRGrav system, marks the first time that airborne gravity has been used to map seismic hazards in the U.S. The company was again selected to supply an AIRGrav system and participate in NASA’s IceBridge project in Antarctica and Greenland. It will also participate in a similar multi-year project designed by the University of California at Irvine to study glaciers in Greenland and Chile, by flying an AIRGrav system mounted in a helicopter.

SGL flew a number of magnetic surveys using single-sensor and gradient configurations (horizontal gradient or tri-axial) in 2012, mostly in combination with other techniques, including gravity, radiometrics, methane sensing and scanning LiDAR. It also completed radiometric surveys, including a helicopter magnetic and radiometric survey in Canada; a fixed-wing radiometric, magnetic, gravity and methane sensing survey for petroleum exploration in Australasia; a large fixed-wing magnetic gradient and radiometric survey in Europe; and a re-
gional fixed-wing EM, magnetic and radiometric survey in Europe. A very large fixed-wing radiometric, magnetic and gravity survey is also well under way in Africa.

In 2012, SkyTEM Surveys reported flying numerous TDEM/magnetic surveys in Canada, the U.S., Brazil, Africa, Australia, Europe and Thailand with objectives ranging from mineral exploration to groundwater studies. In an interesting project, SkyTEM technology was flown in Antarctica for a National Science Foundation-funded research team to map the hidden distribution of groundwater in Antarctica. The survey allowed researchers to look beneath the surface to locate and study microbial ecosystems in sub-glacial environments. In November, the National Geophysical Research Institute of India (NGRI), in collaboration with Denmark’s Aarhus University subcontracted SkyTEM Surveys to map aquifers in six areas in India beginning in March 2013. The objective of the Aquifer India Mapping Project (AQUIM) is to acquire 13,800 line-km of airborne geophysical data and apply advanced data processing techniques to assess the use of helicopter-borne EM for aquifer mapping. The study is being managed under a collaborative research program between NGRI in India, the HydroGeophysics Group, Aarhus University in Denmark and India’s Ministry of Water Resources. The airborne data are being collected to locate, map, and assess the status of the aquifers and their vulnerability to contamination by human activities.

In 2012, Terraquest completed several surveys using combinations of HRAM, gravity, seep detector technology and electric field sensors in support of oil and gas exploration in Central Africa. The company also flew an offshore mapping project in western Newfoundland for NRCan and numerous gradient magnetic, gamma-ray spectrometry and XDS VLF-EM surveys in Europe and the Americas. The company reported an increase in demand in the Americas for its two identically equipped helicopter fixed-boom stinger systems using Terraquest’s proprietary “Structural Multi-View” technology. Both systems are certified for installation on Bell 206 and AStar series helicopters. The system, with a 5-metre stinger, consists of a magnetometer, XDS VLF-EM, and gamma-ray spectrometer with a 20.98-litre crystal pack mounted in the luggage compartment. It is suited for low-speed, low-altitude surveys, resulting in high-quality detailed data.

Tundra Airborne Surveys (TAS) of St. Catharines, Ont., provides combined magnetic horizontal gradient, radiometric, and VLF-EM surveys using a leased Navajo aircraft from KASI Aviation Services of Dorval, Que. The company reported that 2012 was quieter than the previous year. Tundra’s partnership with Toronto-based Scott Hogg & Associates continued, with several Heli-GT tri-axial gradiometer/radiometric surveys flown in British Columbia and Heli-GT surveys flown in the eastern Arctic and northern Ontario. TAS was busy in June with its Diamond DA42 Twin Star horizontal magnetic gradient platform, flying 15,000 line-km of low-level, 50- and 75-metre spaced lines for several companies in Saskatchewan’s La Ronge Gold Belt. Later in the summer, a short-nose stinger built by Lake Central Air Services of Muskoka, Ont., was added to the aircraft to accommodate a Herz Totem-2A VLF antenna.
Airborne Data Acquisition and Processing

Condor Consulting of Lakewood, Colo., continued to develop an extensive suite of ZTEM (Z-axis Tipper Electro Magnetic) case studies. It plans to release its ZTEM Primer Rev 4, which includes a recently expanded section of ZTEM applied to porphyry copper-gold targets, at the 2013 Prospectors and Developers Association of Canada (PDAC) convention. The Primer also has Condor’s first case study between the ZTEM and its sister AFMAG technology, the ground-based ELF system. Condor expanded its professional services to include regional assessments using geological, geophysical and remote sensing inputs. The company continues to carry the Pitney Bowes Business Insight (PBBI) Encom line of geophysical software.

Fugro Airborne Surveys’ Interpretation Services has now adopted the full suite of Fugro LCT gravity and magnetic processing and modelling software into its exploration toolbox and offers the solutions-based services globally. During 2012, the interpretation group developed and introduced advanced processing and interpretation techniques to provide 3-D modelling and inversion, and the integration of geophysics, geology, seismic, well log and satellite data into fully integrated 3-D earth models. Numerous projects kept the group busy all year, including interpretation for water, gold, iron ore, base metals, graphite, uranium, manganese, and oil and gas exploration. Integrated basin architecture interpretations were completed for coal, coal seam methane and unconventional and conventional oil and gas targets using FALCON AGG and magnetic data, along with other available datasets.

Geotechnologies reported that its data control and navigation system, NavDat, now supports NovAtel’s GPS receivers and Radiation Solutions’ spectrometers. The new NavDat version was already implemented in airborne geophysical systems produced by Geotechnologies in 2012.

Several large integrated interpretation projects, as well as several smaller prospect-scale projects, were completed by Sander...
Geophysics last year. The primary datasets were previously acquired gravity and magnetic surveys, while other available data were used to constrain the interpretations, including seismic data, borehole data and available geological and geophysical information. Data interpretation was performed using in-house SGL software, and commercial 2-D, 2.5-D and 3-D modelling software.

Toronto-based Geosoft saw strong demand last year for its cloud-powered VOXI Earth Modelling technology, which has reduced the time and effort required to generate 3-D models using geophysical inversion techniques. The 2012 release of VOXI included the Geosoft Magnetization Vector Inversion (MVI) modelling technique. MVI allows the magnetization direction to vary within the model and thus take into account the combined effects of remanence, demagnetization, anisotropy and induced magnetization. The result is a more realistic representation of rock magnetization. The next release of VOXI will support gravity gradiometry data, including full tensor systems and vertical gravity gradiometry. Geosoft will also introduce Iterative Reweighting Inversion (IRI), a powerful technique that can be used to sharpen smooth inversion results and improve the geometry of the result and the amplitudes of the recovered physical properties. In 2012, Geosoft expanded its 3-D gridding methods to include Inverse Distance Weighting (IDW) and direct gridding. These new methods provide better support for the 3-D gridding of a broad range of data types. Angled clipping of objects in 3-D views provides the ability to clip parallel or perpendicular to dataset orientation or geological strike. A new geological modelling extension is being developed to create 3-D wireframe or geological models from 2-D interpretations. Improved 2-D digitization tools will make it easier to manage interpretation files and share or collaborate on models. Geosoft is also adding the wireframing tools to Oasis montaj, Target and ESRI extensions. Fully integrated within the Geosoft and ESRI platform, the 3-D Geosurface files can be shared with other users and brought into VOXI to constrain inversions.

TechnoImaging of Salt Lake City reported advances with new methods of 3-D airborne geophysical inversion, resulting in mega-cell 3-D airborne electromagnetic (AEM) inversion and giga-cell 3-D potential field inversions. The company introduced an innovative, unified approach to the 3-D joint inversion of multiple geophysical datasets using Gramian spaces of model parameters and Gramian constraints. The ability to jointly invert multiple geophysical datasets for 3-D earth models with different physical properties has always been a problem. TechnoImaging developed a novel approach to joint inversion by introducing Gramian constraints, which are based on the minimization of the determinant of the Gram matrix (i.e., a Gramian) of a system of the different model parameters. The principle of this approach is that the Gramian provides a measure of correlation between the different model parameters. By imposing the additional requirement of the minimum of the Gramian in regularized inversion, multi-modal inverse solutions are obtained with enhanced correlations between the different model parameters. This is a general approach, while methods based on petrophysical correlations or cross-gradient minimization are special case reductions.

In a test, the company produced a 3-D inversion of 90 line-km of vertical and inline MEGATEM II dB/dt data from the Reid-Mahaffy test site in Ontario. The model had 20-metre horizontal resolution, and was able to recover both the conductive overburden and sub-vertical basement conductors in a couple of hours. The methodology was also demonstrated with an example from the FALCON airborne gravity gradiometry (AGG) survey of 4,800 line-km over the Vredefort dome in South Africa, acquired by Fugro Airborne Surveys. TechnoImaging inverted all AGG survey data to a 3-D density model with over 358 million cells of 25 by 25 by 25-metres resolution.
Aeromagnetic Surveying

GEM Systems of Markham, Ont., has developed a Potassium optically pumped magnetometer sensor specifically for making ultra-high sensitivity magnetic measurements with Unmanned Airborne Vehicles. GEM’s UAV sensor is the most sensitive airborne system available globally and is easily installed in UAV platforms. Data can be stored onboard in an electronics box or transmitted during flight. Data from multiple days may be stored in the large-format memory. The sensitivity of the Potassium vapour sensor is 0.0005 nT @ 1 Hz, and can be configured as a single unit or multiple units for gradiometers.

Geotechnologies developed a second generation of its Rein-Mag magnetic compensation software in 2012. The concept that temporal and spatial variations of the earth’s magnetic field during calibration will affect calibration results was implemented in the ReinMag algorithm to improve compensation quality. Rein-Mag is used as a part of Geotechnologies’ GT-MAG aeromagnetic system. Initial surveys with the new ReinMag version were conducted last summer in Kazakhstan by Geoken Co., using AN-2 and L-410 fixed-wing aircraft.

Goldak’s Triaxial magnetic gradient system coupled with attitude determination and correction was a popular choice for airborne magnetic surveys. Attitude determination allows the measured gradients to be “rotated” to the line direction, removing the effects of crab, roll and pitch that cannot otherwise be corrected. In 2012, the company also began to employ a Novatel SPAN-CPT GPS receiver to provide accurate pitch, roll and yaw information in its Caravan.

Mississauga, Ont.-based RMS Instruments has expertise in magnetics, compensation, aircraft magnetic signature analysis and modification, radiometrics, gravity, navigation, ancillary equipment, field operations and complete system integration. The company has delivered technically advanced turnkey systems, including training, to clients globally. RMS reported that the second-generation of AARC500 and DAARC500 systems for real-time aeromagnetic compensation and data acquisition saw high demand in its first full year on the market. The new technology offers improvements in performance, functionality and reliability, and full compatibility with first-generation instruments. New updates are added periodically through firmware updates, such as the upcoming support for dynamic compensation of on-board electronic systems. The AARC510 Adaptive Aeromagnetic Real-Time Compensator which saw its first year in full production in 2011, now includes new built-in features tailored to UAV applications. The system is compact and cost-effective, yet powerful and comprehensive and is ideally suited to strap-down installations in small, fixed-wing aircraft and helicopters.
In an interesting ongoing R&D project, Carleton University in Ottawa, and Sander Geophysics are collaborating to design, build, and test an Unmanned Air System (UAS) for aeromagnetic surveying, the GeoSurv II. The latest GeoSurv II prototype weighs 90 kg, has a wingspan of 4.9 metres and is powered by a 30 HP 2-stroke engine. While its first flight is planned for spring 2013, a simulated version of the UAS was built to execute preliminary tests of its future performance. The simulated UAS was slung 33 metres below a helicopter as a T-shaped structure configured with a horizontal gradiometer with two magnetometers spaced 4.67 metres apart, to replicate the wingspan and sensor geometry of the UAS. A test survey was conducted using the simulated UAS in the Plevna area of Ontario, in the Grenville Province. The total magnetic intensity data recorded by the simulated UAS could then be compared to data from a conventional regional fixed-wing survey and a ground magnetic survey.

During 2012, Scott Hogg & Associates (SHA) carried out Heli-GT surveys in Ontario, British Columbia and Nunavut. The company developed the Heli-GT system to measure total magnetic field plus three geo-referenced magnetic gradients. Unlike most gradiometers, the system measures the pitch, roll and yaw of the bird in order to automatically resolve accurate gradients in the north, east and vertical directions, no matter the heading or attitude of the helicopter or magnetometer array. These geo-referenced gradients are then used by SHA’s GT-Grid software to produce high-resolution maps of the magnetic field in even the most complex geological settings. In 2012, a second Heli-GT was built and VLF-EM and gamma-ray spectrometer systems have been optionally included. SHA continued to work with Tundra Airborne Surveys, which brings years of field experience to the operations.

Airborne Electromagnetic Surveying

Fugro developed and tested an advanced broadband helicopter time-domain EM system that uses a novel dual-pulse waveform. The new system design provides HELITEM-like power for deep detection while offering a second unique pulse that effectively characterizes near-surface geology with high resolution.

Geophysics GPR continued to improve the helicopter GPR-TEM system (600,000 NIA) first introduced in 2011. The company has updated the receiver coils and electronics, increasing the signal-to-noise ratio and improved the data processing to optimize accuracy of the extracted data.

Geotech continued to survey across the globe with its fleet of over 30 VTEM helicopter-borne time-domain electromagnetic (EM) systems in 2012. A new full-waveform VTEM system with improved early-time data was developed and is currently being flown for surveys requiring very shallow mapping capability, i.e. for near-surface, hydrogeologic and kimberlite exploration, without any loss to its deep penetration characteristics. The system features both an improved system frequency bandwidth that allows for earlier time-decay measurements and a newly implemented system response calibration design. The new VTEM design uses the streamed half-cycle recording of transmitter and receiver waveforms to obtain a complete system response correction throughout the entire survey flight that helps to precisely eliminate the effect of the data acquisition system response on the recorded signals. The full-waveform technology can be added to the standard VTEM system without diminishing its patented low noise and deep penetration characteristics. In addition to improving the system bandwidth and the complete system response calibration, new digital signal processing techniques have been applied to reduce the effect of the input transmitter waveform and time-varying injected current using both a parasitic loop capacitance correction and a transmitter drift correction, as well as ideal waveform deconvolution.

A new VTEM max system has been engineered to offer excellent shallow and deep mapping capabilities. It has an extremely large loop 35 metres in diameter, over 1.3 million NIA, and an improvement in the signal-to-noise ratio by a factor of 190 compared to the 2009 version of VTEM. The continuous improvement in the VTEM’s signal-to-noise levels and increase in dipole moment al-
The success of the helicopter ZTEM natural field electromagnetic system has led Geotech to deploy its new fixed-wing ZTEM system for regional geologic exploration programs in 2012-13. ZTEM systems have an advantage over other airborne EM techniques for deep resistivity mapping of geology in exploration. This is because the plane wave natural source fields used in ZTEM typically provide deeper penetration than controlled-source airborne transmitters. The new FW-ZTEM system outfitted onto a Cessna Caravan, features a redesigned, retractable airborne sensor. Its magnetometer has also been moved from the tail stinger directly onto the EM sensor for improved sensitivity. The FW-ZTEM system is designed to be deployed with multi-parameter sensors (including magnetic, gravity/gravity-gradient, and spectrometric). The system was successfully flight-tested and received its STC rating in 2011, and began commercial surveying in 2012. FW-ZTEM will be available for surveys in North America in 2013.

A result of R&D in sensor design for its natural field EM systems, Geotech has developed a new, lighter, more portable compact ZTEM base-station sensor. Weighing less than 25 kg each and designed to be hand carried by one person, the ferromagnetic-cored compact sensors are a significant improvement over the larger, heavier (more than 300 kg) air-core sensor design used previously for ZTEM surveys. Featuring low-noise design, the compact sensors are fully calibrated with existing air-core sensor technology. Being lighter and thus more easily deployed, the new compact ZTEM base station sensor reduces the cost of surveys by eliminating the need for helicopter support. Originally designed for FW-ZTEM, the compact sensors will eventually replace existing bi-axial (Hx-Hy) and Tri-axial (AirMt) air-cored sensors in future ZTEM surveys. Geotech is also redesigning its innovative AirMt sensor to improve performance and ease of use.

Geotechnologies refined its EM-4H frequency-domain EM system in 2012, developing a new EM-receiver and redesigning the electronics of the system to significantly increase the signal-to-noise ratio. In August 2012, an Alrosa fixed-wing aircraft (AN-2) was equipped with the refined EM-4H system. Deployment time was only one week, and in September, Alrosa completed a 10,000 line-km survey in Yakutia, Russia, with the system.

Pico Envirotec reported progress in development of three-dimensional time-domain EM data handling. Flight tests for an upgraded P-THEM helicopter-borne EM system were expected to be completed by the end of 2012.

Now in its ninth year of providing helicopter-borne TDEM surveys, SkyTEM Surveys continued to broaden its geographic reach and its TDEM technology. SkyTEM introduced a new system to the Canadian market in 2012, the SkyTEM508, its most powerful system yet. This latest development from SkyTEM is focused on mineral mapping and has an increased transmitter moment of approximately 500,000 NIA with eight turns on a 500-sq.-metre loop. The SkyTEM508 was flown on several surveys in Scandinavia and Australia and will be available in Africa and North America in early 2013. The system has the ability to deliver both dB/dt and B data, which has proven to be an advantage in quantitative 3-D inversion of the data. It’s also the only system capable of operating concurrently in dual transmitter modes: the Low Moment (LM) and fast turn off provide early-time data for shallow imaging and the High Moment (HM) for late-time data and deep imaging. SkyTEM now offers the exploration sector three configurations of its technology: the SkyTEM101, SkyTEM304 and SkyTEM508, based on the area of the transmitter loop (100, 300 and 500 sq. metres).

In 2012, Thomson Aviation evaluated the in-flight characteristics of an entirely new airborne TDEM system designed by Outer Rim Developments, for which Thomson will provide the platform. Each component of the system has been developed with the very latest technology available, including the powerful transmitter and the ARMIT-style receiver. Highly sensitive B-field and dB/dt data are streamed in real time to the new acquisition system for three orthogonal components and full on-time measurements using 32+bits of dynamic range. Special hardware and digital techniques have been developed to reduce the noise. The TDEM system was being tested flown over known sites at pretesting.

Triumph Surveys of Rockwood, Ont., was formed in 2010 to offer helicopter time-domain EM system surveys and sales to the mining industry. In 2012, the company completed the design and construction of a new rigid and lightweight electromagnetic system (the TS-150), which has a dipole moment of 125,000 - 150,000 NIA and weighs less than 500 kg. A complete system was sold to the Mexican Geological Survey and is now available for contract surveys in that country. Features of the system include variable base frequency, full-waveform recording and X and Z coil receivers.

Airborne Gamma-ray Spectrometric Surveying
Goldak reported radiometric surveying coupled with gradient magnetics was an effective combination in the past year. As a result, the company increased its radiometric capabilities and can now field three 32-litre gamma-ray spectrometric systems with eight litres of upward-looking detectors.
South Africa-based EXIGE installed a Medusa lightweight MS4000 gamma-ray spectrometer system from Medusa Systems, based in Groningen, the Netherlands, on its Gyrocopter, to conduct high-precision gamma-ray surveys. The gyrocopter was designed for use in rough terrain, where survey equipment must be both lightweight and rugged. The MS4000 was especially designed for rough conditions using the virtually unbreakable CsI as a detector material instead of commonly used NaI crystals.

Mississauga, Ont.-based Radiation Solutions Inc. (RSI) reported another busy year for all its spectrometer products. The NASVD program, which is being integrated into the RadAssist software package (for the RS-500 and RS-700 series of systems), is expected to be available later in 2013. RSI’s specialized hybrid RSX-3 system continues to be used in Japan as part of the follow-up to the Fukushima nuclear accident. In the U.S., the RS-500 airborne system was part of a chemical and radiological detection platform that was flown along heavily damaged areas of the East Coast after Hurricane Sandy, to assist emergency efforts on the ground.

### Airborne Gravity Surveying

Bell Geospace continued to develop data processing and interpretation methods that take advantage of the full gravity tensor. Using both the horizontal and vertical tensor components to grid the data provides higher-resolution images of the density structure of the geology between survey lines. Bell Geospace has also developed a special filter that uses the horizontal tensor components to emphasize the strike direction of geologic features.

Fugro Airborne Surveys reported that it has reduced noise levels in its FALCON AGG system by improving acquisition and processing in the system. The new digital FALCON systems have proven recorded noise levels of less than 1.3 Eötvös, approaching the elusive target of 1 Eötvös. A FALCON AGG survey was flown over Geoscience Australia’s Kauring Gravity Test Range east of Perth, to allow comparison with ground gravity, airborne gravity and other airborne gravity gradiometry systems. Data from the survey can be downloaded for free, from Geoscience Australia’s website. Besides AGG surveys, Fugro Airborne conducted total field airborne gravity operations globally for both mapping and petroleum exploration using the GT-2 sensor.

Micro-g LaCoste of Lafayette, Colo., introduced its TAGS-6 gravity meter, an upgrade to its Air-Sea System II, designed specifically for airborne operations. The system incorporates a time-tested, low-drift, zero-length-spring gravity sensor mounted on a gyro-stabilized platform. The sensor has a worldwide gravity measuring range of 20,000 mGals. Some of the new features of the TAGS-6 include: smaller and lighter sensor/gimbal, new slip ring technology as well as 20 Hz GPS and gravity data and a larger range of aircraft pitch and roll. In comparison with the original system, the TAGS-6 has 100 times the dynamic acceleration range, larger pitch and roll ranges, improved static repeatability, reduced power requirements and is much smaller and lighter.

Sander Geophysics completed a fixed-wing AIRGrav survey over the Kauring Gravity Test Site in Western Australia, and the data has been submitted to Geoscience Australia for public release. The AIRGrav survey clearly shows the high resolution and accuracy of the AIRGrav system. Geoscience Australia is expected to release the AIRGrav data as well as gravity data from other systems for comparison.

In mid-2012, Thomson Aviation completed its first airborne gravity survey for a petroleum company in the Fitzroy Trough of Western Australia using the GT-2A gravity meter manufactured by Canadian Micro Gravity. The Thomson-owned turbine-powered PAC 750, has proven to be the ideal aircraft for obtaining high-quality survey results. In addition to flying numerous surveys for private companies, the company was again selected by Geoscience Australia to conduct regional surveying in the states of Queensland and Western Australia totalling 150,000 line-km.
The collaboration of Abitibi Geophysics with the Royal Melbourne Institute of Technology (RMIT), Australia, on ARMIT, the first and only combined B-field and dB/dt sensor, continued in 2012 with successful field trials conducted. Results have exceeded expectations with tests confirming the femtotesla sensitivity of the ARMIT TDEM sensor and its extremely low noise envelope, significantly less than that published for HT SQUIDs and fluxgate sensors at frequencies between 0.2 Hz and 10 kHz. The sensors, which are capable of detecting a wide range of conductivities, are used on production surveys with any TDEM loop configuration, including InfiniTEM. These 3-kg, robust sensors have a battery life exceeding 24 hours, are compatible with the EMIT SMARTem 24 receiver and do not require cryogenic liquids, levelling, tuning or bucking out of the magnetic field. Abitibi has now manufactured 25 production units. The success of the sensor has led the company to sign a contract for the development of a borehole probe using ARMIT technology. Testing of the first prototype B-field & dB/dt borehole probe is planned for mid-2013. Abitibi reported considerable interest in ARMIT from clients working on nickel projects because the low frequency B-field capabilities allow the detection of deeply buried, highly conductive bodies, without the logistical challenges of SQUID.

Pico Envirotec delivered new portable gamma-ray spectrometers (PGIS-2), Dosemeters (PDOSE-3), and magnetometer base stations (PBM) to clients in Europe and Asia last year. PEI has invested strongly in R&D to improve ground instrumentation based on Android technology (for smart phones, tablets etc.). The Android-based portable/mobile data-acquisition system allows real-time processing and display of acquired data, as well as full ground GPS navigation. The survey data can also be exported to Google Earth for quick observation and presentation of results on a map.

Saskatoon-based Discovery International carried out standard DCIP resistivity surveys in Saskatchewan, B.C., Manitoba and Mexico. This included surveys with the new MRI-32 system (Multipole Resistivity Imaging: 32 channels), which was introduced in 2011.

Toronto-based Quantec Geoscience reported a record year in 2011/12 with DCIP and MT survey activity across the globe. Activity included the continued introduction of the ORION 3D system with surveys in Africa, and the Americas. Significant Quantec surveys included a four-month TITAN 24 program in Kazakhstan, several SPARTAN MT projects in Turkey for geothermal energy, and a large TITAN 24 program in Peru. The company was very active in Chile, Argentina and Peru with both conventional and proprietary technologies.

Physical Rock Properties
Toronto-based DGI Geoscience (DGI) specializes in quantitative
in-situ physical rock properties acquisition and interpretation services. In 2012, DGI significantly expanded capability on its new 2-4C (to foresee) process. Some of the developments and applications for the 2-4C process went beyond advanced exploration into active mining. Ore and waste rock characterization can be done better, earlier and faster with substantial cost benefits. DGI has been involved in innovative pilot projects to improve this characterization and hopes to have developed more conclusive methodology by summer 2013.

Thermo Fisher Scientific of Tewksbury, Mass., introduced its latest Thermo Scientific Niton XL3t series X-ray fluorescence (XRF) analyzers with embedded GPS functionality in September. Now, the portable XRF analyzers can quickly determine elemental composition of any sample type, and simultaneously record the GPS co-ordinates (latitude/longitude or UTM co-ordinates) of each assayed sample. Although in the past, portable XRF analyzers could be tethered by Bluetooth or wireless connectivity to third-party GPS devices, the wireless connection could get lost while operating in the field. This new capability makes it easier to capture the exact position of a sample at the same time the geochemical analysis is performed, ensuring data integrity and saving time. The analytical results and GPS co-ordinates are exported through the Thermo Scientific NDT Translator directly to a variety of commercially available GIS software packages allowing users to geospatially position elemental results and create geochemical maps.

**Data Processing and Positioning**

In 2012 software developments, Kingston, Ont.-based Lamontagne Geophysics (LGL) continued work on an improved Inductive Source Resistivity (ISR) imaging method which iteratively combines a new fine grid 3-D finite difference forward solution and an approximate 2-D inverse method.

**Drill-hole Methods**

Gravilog is a slim borehole gravity probe developed by Scintrex of Concord, Ont., and operated by Abitibi Geophysics. Gravilog is based on CG5 technology, miniaturized and packed into a probe that is only 48 mm in diameter. Gravilog can be used in holes as small as BQ, with drill rods removed, and in NQ holes with or without rods. In 2012, Scintrex developed an ATV-portable Gravilog borehole gravity system that is capable of logging to a depth of 2,300 metres. The maximum depth can be extended with the aid of a wireline truck. Borehole gravity provides quantitative definition of massive sulphides, iron ore, non-metallic deposits and verification of surface and airborne gravity anomalies. In particular, there has been considerable interest in borehole gravity for calculating resource estimates of iron ore deposits, nickel orebodies, VMS deposits and for detecting off-hole deposits. Borehole gravity provides an apparent density (bulk density) estimate of the formations surrounding the borehole. These apparent densities are used to aid in deposit evaluation, grade control and in estimation of local rock competency. In-situ density calculations provide confirmation of core sample density measurements, and can provide density estimates for sections with poor core recovery, which are important in planning open-pit and underground mining operations.
Caracle Creek International Consultants, based in Toronto, integrates geophysical and geological services for effective exploration programs. The company, which has offices in Canada, South Africa and the Dominican Republic can manage exploration programs or execute surveys. Geophysical services include planning and monitoring geophysical surveys and carrying out advanced inversions, integrated 3-D interpretation and targeting. The company continued to deploy and develop the EarthProbe high-resolution resistivity/IP surface and borehole system in collaboration with Geoserve Logging and Tomography of Markham, Ont. In 2012, the companies made significant progress in several areas.

In the area of hardware and data acquisition, EarthProbe surface cables can now be rolled onto a spool with relay switching units housed inside the spool, reducing the work to deploy the surface cables in the field and making the system more robust. Injection voltage booster units powered by batteries can now be placed anywhere on the surface line to compensate for voltage loss due to resistance of long wires.

In data processing and interpretation, the company worked with commercial software developers to ensure that the high-resolution surface and borehole data collected by the EarthProbe system can be presented and inverted to industry standard, and be easily incorporated into a variety of 3-D earth modelling programs. The company is working to extend the depth capability of its borehole system to 2 km from 400 metres for acquisition of high-resolution images between very deep boreholes, making deeper exploration more cost-effective.

Crone Geophysics’ new borehole MMR system can detect relatively low-conductivity targets, including conductors that may give a weak, or even zero response to standard TDEM technologies. A survey with MMR uses grounded wire configurations and the principle of electrical conduction in the form of current channelling to reveal conductive minerals potentially invisible to EM induction techniques. MMR, combined with a Crone Pulse-EM survey can significantly increase the range of mineralization detectable in each hole surveyed. MMR can detect weak or disseminated conductors, and Pulse-EM detects better conductors that support induced eddy currents. The Crone borehole and surface Pulse-EM Systems, which are designed and manufactured at the company’s Mississauga headquarters, saw numerous upgrades in 2012 which will be available in 2013. Upgrades to the transmitter allow for up to 30 A peak current (up from 20 A) from a single transmitter with current controlled, highly accurate linear ramps for continued high-accuracy step-response transformations. Crone has developed a method of connecting multiple transmitters that allows connections either in series (to use in larger loop configurations to maintain high current), or in parallel (to effectively double power to a peak current of 60 A). The dual transmitter configuration maintains the system portability for difficult access locations.

The CDR2 EM system was upgraded with an improved smart-stacking algorithm, and through extensive R&D, Crone has reduced noise in the CDR2 receiver, which now has 26-bit resolution. This very low-noise receiver and smart stacking have resulted in much-improved quality of B and dB/dt data. The company has also developed a new receiver to display full-waveform TDEM data in four channels simultaneously, which means all three components, Z, X and Y, can be read simultaneously from the sensors. The Crone EM surface fluxgate sensor prototype went into production in 2012 and is now available for surveys. Extensive research to reduce noise in this sensor resulted in sub pT resolution in all three components, which can be read simultaneously with the new receiver. Directly measuring the B-Field with this sensor or with SQUID-based sensors as part of a TDEM system, is a very effective way to search for high-conductance targets such as nickel sulphides. The Pulse-EM borehole probes saw upgrades in the X and Y components, which increased the gain by a factor of three, allowing for a much larger detection radius and improved data quality. The overall length of the probe was reduced and now includes a built-in orientation device with higher baud-rates.

Another new service developed in 2012 by DGI Geoscience is an improved method for analysis of televiewer data. In recent years, mining and engineering firms have been using borehole visualization through optical and acoustic televiewers increasingly for structural and geotechnical purposes, as well as for supplementing poor core recovery. DGI developed improved measurement and level of detail and new ways to visualize the televiewer data from a macro (project) to a micro (20 cm of a borehole) level. Legacy and new televiewer data can
now be processed much more effectively than as a standalone hole-by-hole visualization, especially when combined with other data acquired in-situ.

Medusa Systems reported a busy 2012, both in equipment sales and in joint developments. Medusa teamed with ALT (Luxemburg), to integrate the core of GAMMAN, Medusa’s spectral processing software, into ALT’s borehole data processing software, WellCAD. This gives users access to full gamma-ray spectrum processing technology, yielding improved processing of gamma-ray logging data. Medusa Systems also teamed with Terratec (Germany) to develop a low-power, small-footprint, multi-channel analyzer (MCA) for use in slim borehole logging tools. The objective is to produce spectrometric systems with better gamma-ray energy resolution, which allows separation of radon from uranium in borehole gamma-ray spectral logging measurements.

Scintrex continued to offer full borehole gravity logging services with its Gravilog probe in 2012. The gravilog surveys have reported accuracies of better than five microGals. The company plans to expand into Russia, Brazil and Australia. For 2013, Scintrex is working on a dual-sensor probe that will measure gravity and also obtain a direct bulk-density measurement unaffected by positional uncertainties of the probe.

Ground Electromagnetic Methods
Peakhurst, Australia-based Alpha Geoscience introduced the FASTSNAP, a state-of-the-art transient electromagnetic (TEM) survey system for near-surface investigations (4–1,000 metres depth). The FASTSNAP offers high productivity and versatility in the field due to the option of using two mobile receivers syn-
chronized to the transmitter by internal GPS. This allows data from multiple receiver configurations to be collected simultaneously without cables between transmitter and receiver units. The system is lightweight, with transmitter and receiver weighing 3 kg and 2 kg, respectively. Fast shut-off time of 2 microseconds for a 25-metre loop and 10 microseconds for a 100-metre loop is standard on the FASTSNAP, ensuring that minimal early-time data are lost in the ramp. The system-specific software package has options for fully integrated software packages covering acquisition, display of data in a variety of forms, GIS functionality, processing, interpretation and full inversion of data. Express processing can be achieved in real time, allowing presentation of data as conductivity-depth or resistivity-time sections. Full-waveform data collection means that measurements are no longer restricted to predefined time gates and the full characteristics of the analog signal are preserved. While stacking can be used in the field for quality control, each individual stack is recorded separately, allowing the user to remove noisy measurements from the dataset in post processing before stacking, therefore decreasing noise and statistical errors for more accurate modelling.

Yellowknife-based Aurora Geosciences provides geological and geophysical services to companies conducting mineral exploration in the north. In 2012, the company purchased and deployed the new ELF/AFMAG (extremely low frequency/audio frequency magnetics) survey system manufactured by Arrawac Associates, (Caledon, Ont.). The new electromagnetic system, which is in a beta testing phase, has been successfully tested by Aurora across several known deposits and the company is developing software to provide 3-D inversions of the data. The ELF/AFMAG system is designed to image electrical resistivity to depths of up to 2 km in regions of moderate conductivity. The system can image deep conductors not detectable by traditional EM methods and is also sensitive to weak conductivity contrasts, which is useful for mapping large-scale geological features.

This passive method measures vertical and horizontal components of the natural time-varying geomagnetic fields from telluric currents in the ground, which originate primarily from distant lightning strikes. The system calculates the tilt angle or Tipper Vector of the magnetic field at frequencies ranging from 11 to 1440 Hz, which can then be used to map and quantify conductivity contrasts in 2-D or 3-D, depending upon the survey layout. Because it measures natural fields, transmitter loops or power generators are not required, making the unit very portable, a particular advantage for surveys in rugged terrain. It can be operated by one or two people navigating by GPS, using reading times of about three to five minutes per station, with production typically between 2 and 4 line-km per day, depending upon station spacing and geomagnetic conditions.

Discovery International Geophysics carries out TEM surveys using the Supracon AG high-temperature (liquid nitrogen) SQUID developed by the Institute for Photonic Technology (IPHT) in Jena, Germany. The Supracon HT SQUID is touted as the most sensitive B-field detector commercially available. Discovery International conducted surveys last year in Saskatchewan, B.C., Manitoba, Quebec, and Minnesota for uranium, copper, zinc and nickel deposits.

Geonics, based in Mississauga, Ont., developed PROTEM CMX in 2012, a new time-domain EM system, designed to be used in hazardous environments with possible explosive gases, such as coal mines. The instrument includes a receiver and transmitter enclosed in a heavy gauge aluminum watertight housing, as well as a compact set of receiver and transmitter coils. The
EXPLORATION TRENDS & DEVELOPMENTS

were also built to meet specific requirements. and co-ordinate editing. Customized versions of the terraTEM to include contouring, pseudosections, profile and decay plots struction. Software available in the terraTEM has been expanded also improved the terraTEM receiver coil (TRC) induction sensor, which now includes a lower bandwidth, improved late-time self-levelling and auto-nulling capabilities. Monex GeoScope has products released in 2012 include a surface B-field sensor with operating temperature ranges. This transmitter model will have the same +/- 525 V output voltage limit as the 10 kW UTEM 4 transmitter but in a lighter package requiring a smaller motor generator. An early prototype of the power stage was field tested in 2012, in conjunction with the UTEM 5 surface sensor.

Melbourne-based Monex GeoScope, the developer, manufacturer and distributor of the terraTEM suite of electromagnetic products, continued to expand the instruments’ performance and capabilities. The new 50-amp, 250-Volt, terraTX-50 Version 2.0 with a touchscreen controller allows operators to increase the ramp time to record the primary field. In addition, the op- erator can automatically tune the transmitter to the particular loop. The GPS synchronization modules for the terraTEM and terraTX-50 are now built into both systems, greatly improving field mobilization. Crystal synchronization is also available with drift rates of less than 2.5 microseconds per day achievable. New products released in 2012 include a surface B-field sensor with self-leveling and auto-nulling capabilities. Monex GeoScope has also improved the terraTEM receiver coil (TRC) induction sensor, which now includes a lower bandwidth, improved late-time signal-to-noise ratio option, a smaller footprint and lighter construction. Software available in the terraTEM has been expanded to include contouring, pseudosections, profile and decay plots and co-ordinate editing. Customized versions of the terraTEM were also built to meet specific requirements.

Gravity Surveying

Micro-g LaCoste introduced the gPhoneX, a major upgrade of the gPhone. The gPhoneX gravity meter has low drift so that it can be used to integrate periodic signals (like earth tides) for very long time periods (e.g. years). The gPhoneX also has excellent high-frequency response which can be used to monitor higher-frequency non-periodic events such as earthquakes. The gPhoneX can be coarse-ranged over 7000 mGals (worldwide) with a +/-50 mGal dynamic range during measurements. For remote operation, the gPhoneX can be monitored and controlled via the Internet.

Induced Polarization (IP)

Abitibi Geophysics’ IPower3D induced-polarization system has been proven successful in resolving chargeable and resistive bedrock features below thick, conductive overburden from Baffin Island to northern Ontario. IPower3D is a truly three-dimensional IP survey with readings taken at many angles, sweeping through the subsurface. The 3-D inversions clearly show chargeable and resistive volumes, however, Abitibi clients expressed an interest in viewing more traditional two-dimensional depth sections. During 2012, the company developed a GX written for Geo-soft’s Oasis montaj that allows the production and interpreta- tion of two-dimensional depth sections taken from the 3-D data. This allows the new data to be visually compared to previous IP surveys conducted on the same grid. Once Abitibi was satisfied IPower3D works under thick, conductive overburden, it began to work on an extended array version. Originally, the array length was limited to 1,000 metres and was not readily scalable because each channel used a separate strand of wire. The new system uses cables analogous to those used in seismic surveys, each capable of carrying 20 channels, allowing lines of up to 2,000 metres to be surveyed from one set-up, increasing survey efficiency and depth of investigation.

Discovery International has developed an MMR/MIP sys- tem with support from Anglo American, using Supracon HT SQUIDs and SMARTem24 receivers to record complete time-series magnetic data at 0.25 or 0.125 Hz. Data are recorded with a measurement “rover” SQUID and a stationary “base” SQUID to facilitate remote reference noise reduction of the time-series data. The system is currently in final testing stages, with test sur- veys having been carried out over Denison Mines’ Phoenix un-
conformity uranium deposit in Saskatchewan; Teck Resources’ Highland Valley porphyry copper deposit in B.C.; and Anglo American’s Aislada porphyry copper prospect in Chile.

**GF Instruments** of Brno, Czech Republic, introduced a new 10-channel ARES II instrument for resistivity and IP tomography. The equipment is designed for rapid measurement on ground, in boreholes and for continuous marine surveys using standard (Schlumberger, dipole-dipole, pole-dipole, pole-pole, MGM) and user-defined arrays. It is powered from a 2,000 Vp-p, 5A, 850W transmitter. The unit with its graphical screen allows continuous acquisition of complex information about data quality (with signal curves) supported by several programmable levels of checking. The IP measuring procedure has sophisticated built-in noise cancellation technology (from self-polarization, industrial sources and telluric currents), which meets today’s demand for high resolution at low IP signal levels.

In 2013, **Instrumentation GDD** will introduce a new IP accessory that can be used with any IP equipment on the market to record the real current injected into the ground with a GPS timestamp. With post-processing software, geophysicists will be able to recalculate accurate resistivity values. The new accessory will also allow GPS synchronization between the transmitter and the receiver when the signal is too weak to do otherwise. In 2012, the company released new software for the IP receiver that allows gradient and pole-pole 3-D/multi-line configurations. A new time base has also been included in both GDD IP instruments: the IP 1,800W/3,600W/5,000W/10,000W – 4,800V IP transmitters and the 2/8/10/16/24/32 IP receivers. For safety reasons, a new optimized on/off switch system with an emergency switch will be added to every new GDD IP Transmitter in 2013.

**Ground Magnetic Surveying**

After two years of research and development, **Fugro Instruments** of Sydney launched its new handheld RT-1 magnetic susceptibility meter. The RT-1 replaces the GMS-2 magnetic susceptibility meter, about 2,000 of which were produced during its 15-year run. The RT-1 has numerous innovative features including: large memory capacity, ease of use, reversible screen, environmentally sealed custom-made injection moulded case, easily replaceable snap-in sensor and wireless communication device. Even the colour was researched during the development phase, with fluorescent pink chosen because it is easy to spot in any environment, from desert sands to arctic snow.

**Geometrics** of San Jose, Calif., recently upgraded its G-859 AP Mining Magnetometer to include a comfortable and ergonomic backpack based on military design. Improved wiring provides better power/signal distribution using rugged military grade connectors, all designed for the lowest magnetic self-signature. The specially compensated battery is designed to reduce the magnetic signature from electrical currents to less than 1 nT at 30 cm. Included with the G-859AP is the Novatel Smart-V1TM GPS, which is WAAS/EGNOS/MSAS ready for 1- to 2-metre positioning throughout North and South America. The G-859AP can also be upgraded to Novatel 10 Hz PVT or Oministar VBS with optional Raven Lightbar steering capabilities for precision mapping.

**Terraplus** of Richmond Hill, Ont., released the KT-10 v2 and KT-10 Plus v2 magnetic susceptibility meters in 2012. The instruments feature a number of improvements over previous versions, such as the ability to input depth information to correlate every core measurement with its depth. They can also be upgraded via the Internet to the KT-10 S/C or KT-10 Plus S/C to include conductivity measurements. The company also introduced the KT-10 Plus S/C and KT-10 C. The KT-10 Plus S/C is
similar to the KT-10 S/C except it has an extended measurement range for magnetic susceptibility and can provide a concentration estimate for iron ore in real time. The KT-10 C is a dedicated absolute conductivity meter that has all of the standard benefits offered by the KT-10 v2. In addition, three conductivity reference pads are now available for the KT-10 C, KT-10 S/C and KT-10 Plus S/C, in either the low, medium or high-conductivity ranges.

Magnetotelluric

The ORION 3D system is the only commercially available true 3-D Resistivity/IP/MT system, according to Quantec Geoscience. ORION 3D is a distributed acquisition system, which allows complete flexibility in adapting to the required survey shape, size and resolution. The system offers true 3-D exploration to depths of 750 metres for IP chargeability and DC resistivity, and 1,500 metres for MT resistivity. The receiver system is distributed across the entire project area much like a 3-D seismic survey. The high resolution is achieved through super-sampling of the survey area — a typical survey block of 2 by 2 km yields 135,000 streamed data records. The omni-directional sampling removes any line-direction bias in the final results. To date, ORION 3D surveys have been used successfully in the search for copper, gold and nickel. The company added a sixth TITAN 24 system in 2012. All systems are being updated with new features to increase efficiency in the field. The firmware and electronics have been modified for a wider operational temperature range from -50°C to +50°C. Telluric cancellation software has been developed and is now easily used with both ORION 3D and TITAN 24 to improve the signal-to-noise ratio in the IP data, and to allow for data collection through periods of high telluric activity.

New full frequency (10,000+ Hz to 1000+ s) MT loggers have been developed for the SPARTAN MT systems. These are being used worldwide in mining, geothermal and hydrocarbon applications. Quantec uses two sets of tuned coils at each site to facilitate simultaneous acquisition of high- and low-frequency data without interruption of the low frequency. This provides full coverage of both the high-frequency and low-frequency dead bands. The coils are calibrated in the Toronto office in a calibration chamber, one of only two such facilities in the world. The calibration procedure ensures high accuracy, seamless integration, and consistency of the data sets from survey to survey. Quantec also introduced new environmentally responsible electrode technologies. Testing and initial use of these stable-alloy electrodes confirmed the acquisition of high-quality data comparable to, or better than, the traditional chemical potential electrodes. The new electrodes provide more efficient field operation, stable results, and ease of permitting.

Ground Penetrating Radar (GPR)

Sensors & Software, based in Mississauga Ont., continued to develop and advance its line of GPR products. Innovations for 2012 of greatest interest to the mining and exploration communities are the extension of IceMap and the release of EKKO_Project. Winter roads are vital to mining and exploration in northern regions with roads frequently traversing long stretches of frozen lakes and rivers. Knowing the extent of the load-bearing capacity of these ice covered areas is extremely important to health and safety and operational scheduling. Sensors & Software has developed the “One Page Report” that summarizes long IceMap Surveys. As soon as a section of ice road has been mapped, IceMap can generate a one-page summary report that can be immediately reviewed by planners and inspectors. EKKO_Project, the company’s new GPR data management software features advanced GPR data editing and enhanced attribute viewing, while allowing all information to be stored in a single GPR project file. EKKO_Project’s optional Interpretation Module can be used to select targets or layers, add labels and identifiers on GPR lines, and compile tabulated reports of interpretations. To enhance understanding of GPR signals, EKKO_Project’s new Processing Module contains processing and analysis tools such as migration, time and spatial filtering, and attribute creation.

Ground Radiometric Surveying

RSI reported that handheld scintillometers and spectrometers continued to have healthy sales worldwide. In 2012, a map display capability for plotting acquired data on imported maps was added to RSAnalyst, the support software package for the RS-121/125/220/230 handheld models.

Sander Geophysics performed numerous specialized radiometric surveys designed to address various client requirements for assessing radiation due to manmade and natural sources. Surveys included baseline radiation surveys of nuclear plants, the surrounding urban areas, military establishments and other industrial sites. Besides baseline surveys, other surveys to locate and identify radioactive particles at nuclear sites were carried out. In conjunction with Gamma-Bob of Ottawa, SGL conducted a ground-based survey to search for possible sources of contamination due to plant operations at a nuclear facility in 2012. The survey was carried out using large-volume sodium iodide detector packs (as used in airborne surveys) mounted on a platform carried on the front lift of a small tractor. Gamma-ray data from each detector in the packs were recorded independently once per second to maximize system sensitivity.
Companies and Websites

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Triumph Surveys: sbalch@triumphsurveys.com
Tundra Airborne Surveys Ltd.: www.tundraair.com
University of California: www.ess.ucla.edu
UTS Geophysics: www.uts.com.au

Abbreviations (for acronyms used in the text)

| A         | Ampere          |
| AEM       | Airborne EM     |
| AFMAG     | Audio Frequency |
| ATV       | All Terrain Vehicle |
| B         | Magnetic Field |
| Csl       | Cesium Iodide  |
| dB/dt     | rate of change of |
| DC        | Direct Current  |
| ELF       | Extremely Low Frequency |
| EM        | Electromagnetic |
| ESRI      | Environmental Systems Research Institute |
| GIS       | Geographic Information Systems |
| GPS       | Global Positioning System |
| HRAM      | High Resolution Air Mag |
| HT        | High Temperature |
| Hertz     | Hertz = cycles per second |
| ISR       | Inductive Source Resistivity |
| kW        | Kilowatt |
| LidAR     | Light Detection And Ranging |
| LT        | Low Temperature |
| MIM       | Multiple Gradient Method |
| MIP       | Magnetic IP |
| MMR       | Magnetometric Resistivity |
| MT        | Magnetotelluric |
| NaI       | Sodium Iodide  |
| NASA      | National Aeronautic and Space Administration |
| NASVD     | Noise Adjusted Singular |
| NIA       | Dipole Moment of EM loop |
| (N= Number of turns, l= current, A= area) |
| pT        | pico Tesla |
| STC       | Supplementary Type Certificate |
| SQUID     | Superconducting Quantum Interference Device |
| TDEM      | Time Domain EM |
| TEM       | Transient EM (= TDEM) |
| UAS       | Unmanned Air System |
| UAV       | Unmanned Airborne Vehicle |
| UTEM      | University of Toronto EM |
| UTM       | Universal Transverse |
| V         | Volt |
| Vp-p      | Volts peak-to-peak |
| VMS       | Volcanogenic Massive Sulphide |
| VLF       | Very Low Frequency |
| W         | Watt |
| XRF       | X-Ray Fluorescence |

| GPS:     | Wide Area Augmentation System; U.S. |
| WAAS     | European Geostationary Navigation Overlay System |
| EGNOS    | Multifunctional Satellite Augmentation System; Japan |
| MSAS     | |
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