EXPLORATION

TRENDS & DEVELOPMENTS

March 2012

THE NORTHERN MINER
THE GLOBAL MINING NEWSPAPER

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EXPLORATION
TRENDS & DEVELOPMENTS

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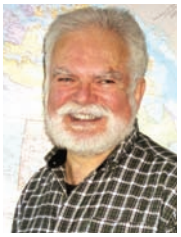
KEGS' sixth year as patron of Exploration Trends & Developments



By Patrick G. Killeen PhD, Geophysical Consultant and retired Research Scientist, Geological Survey of Canada, Ottawa 2011

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 20th 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 the 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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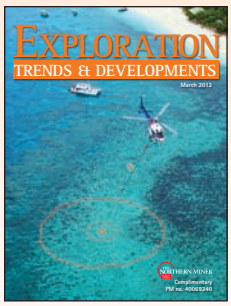


Cover photo: Geotech flying a VTEM and magnetic survey in Fiji

Credit: Geotech

MOVING RIGHT ALONG IN 2011

Much like the economy in general, airborne contract surveying started to come out of the doldrums in 2011. Additional aircraft were put into service, and in Canada, there was a fair amount of government survey work, both provincial and federal. There was robust gold exploration activity reported in Mexico, Canada, and West Africa, as well as diamond exploration activity in Canada. It has been called a healthy level of activity, not the unsustainable activity of a boom. Increased levels of exploration activity were also reported in Asia, Indonesia, Papua New Guinea, North and South America (notably Brazil), and Mongolia. The high level of activity in West Africa and the sub-Sahara area is partially a result of junior exploration companies finding more opportunities there. That, in turn, led to more small airborne contractors taking on international work in 2011. An increased number of ground and borehole surveys were also conducted at greenfield projects last year.

Radiometric surveying saw a resurgence in 2011, with steadily increasing sales of airborne and ground systems to replace aging systems, to supplement existing systems, and as a result of increased exploration budgets. In addition, some companies added gamma-ray detectors to the transmitter loops of their heli-borne EM systems. The trend of increasing the number of geophysical sensors on survey aircraft continued. Airborne gravimeters became lighter and smaller, with two new-generation versions developed in 2011.

The year also saw increasing use of airborne gravity and to a lesser extent, gravity gradiometer surveys for mineral exploration. However, the number of contracted gradiometer mineral surveys was limited by the number of systems available worldwide (10, including a new one in 2011) and because the surveys are very expensive. Although the new information from the gravity gradiometer tensors is attractive, only the tensor zz is widely used. The other tensors yield information in cases with simple geology, but are difficult to interpret in complex geology, and so are mainly used as input to inversions.

The number of companies flying heliborne time-domain EM (TDEM) systems increased and three completely new heli TDEM systems with novel features were introduced in 2011. Manufacturers increased the diameter of their transmitter loops yet again to penetrate even deeper. Natural field EM surveying saw even more attention and the AFMAG system is now available in fixed-wing and helicopter versions. There were signs that the UAV, in which interest seemed to peak about 2005, is not yet dead. Advances in processing EM and other data were reported by at least five companies, and included more 3-D solutions, modelling and inversions, plus a new radon background-removal process for gamma-ray spectrometry. To explore deeper with EM, higher sensitivity is needed and in 2011 there was increased demand for B-field EM surveys, and greater use of SQUID B-field sensors to obtain the required sensitivity. In a significant scientific breakthrough, a "room-temperature" B-field sensor with the sensitivity of a High Temperature SQUID was developed.

Ground geophysics saw the development of a new field-portable X-ray lab, new borehole logging tools for density and three-component EM, new logging services; three new ground TDEM systems, new resistivity/IP equipment, new magnetic susceptibility/conductivity meters, new Spectral IP equipment, (both surface and borehole) and a new generation GPR instrument for ice-thickness profiling on winter roads.

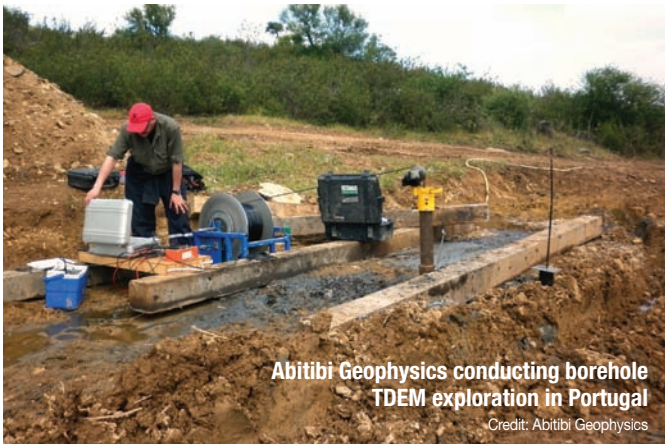
CORPORATE HIGHLIGHTS

Abitibi Geophysics of Val d'Or, Que., began several significant new projects in 2011, including borehole EM and sonic logging projects in Portugal and Ireland, a physical properties logging program on a potash development project in Eritrea, and borehole gravity field operations. On the R&D front, the company received a new EM sensor with noise levels and sensitivity better than High Temperature SQUID sensors in common geophysical use from RMIT University in Australia. Abitibi Geophysics also signed a co-founding agreement with the **Université du Québec en Abitibi-Témiscamingue (UQAT)** to create the **International Laboratory for Mining Geophysics (ILMG),** which started operations in 2011. Located in Val d'Or, ILMG will work on developing integrated geophysical solutions for the discovery and characterization of mineralized geological systems. Initial government funding of the lab was augmented by an ongoing financing campaign, with long-term funding to come from royalties and licences.

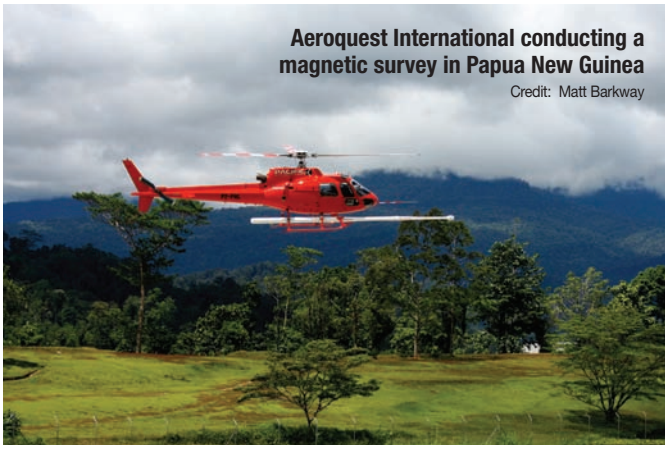
In 2011, Moscow-based **Aerogeophysica (AGP)** continued surveys that had been started in 2010 for government projects and for mineral exploration. In June, AGP won contracts for airborne gravity and combined EM-4H/spectrometry surveys on the Kamchatka Peninsula and in the Amur region of Russia. As the first stage of a large, two-year regional government project, the company completed an airborne gravity survey over a 160,000 sq. km area in northern Russia using a GT-2A. AGP also flew an interesting magnetometer test survey for a specialized application, and test flew the new version of the GT-2A gravimeter from **Gravimetric Technologies**, also based in Moscow.

Aeroquest International of Mississauga, Ont. merged its **Airborne Geophysics Division** (comprised of **Aeroquest Surveys** and **UTS Aeroquest**) into one entity called **Aeroquest Airborne** in December 2010. The group spent much of 2011 focusing on its growth model and streamlining processes for business development.

Saskatoon-based **Discovery International Geophysics** expanded operations with new business partnerships in Africa and South America. The company offers TEM surveys using the high-temperature (liquid nitrogen) SQUID manufactured by **Supracon AG** of Jena, Germany, and developed by the **Institute for Photonic Technology (IPHT),** also in Jena. Supracon believes its



Abitibi Geophysics conducting borehole TDEM exploration in Portugal
Credit: Abitibi Geophysics



Aeroquest International conducting a magnetic survey in Papua New Guinea
Credit: Matt Barkway

HT SQUID to be the most sensitive B-field detector commercially available in the world, ranking a close second to the ultimate sensitivity of the Supracon low-temperature (liquid helium) SQUID TEM sensor, which is proprietary to **Anglo American**.

In 2011, Montreal-based **EON Geosciences** flew surveys in the Northwest Territories for the territorial government, over Baffin Island in Nunavut for **Baffinland Iron Mines**, in northern Quebec for the **Ministère des Ressources Naturelles et de la Faune (MRNF)**, and in Colorado, for the **United States Geological Survey (USGS)**. EON also acquired two **THEM** time-domain electromagnetic systems, both of which are available for surveys worldwide, and continues to offer a full range of high-resolution fixed-wing and helicopter-borne magnetic, gamma-ray spectrometric, gravity, time-domain (THEM) and frequency domain (Hummingbird) electromagnetic surveys.

Last year, the company added a Piper Cheyenne II twin-turbine aircraft to its fleet and created a new company, **EON Airborne**, to control the operation and maintenance of the fleet. EON can now survey and process well over 50,000 line-km of airborne geophysical data per month. The company also signed several contracts for international surveys to be flown in 2012.

EXIGE (Expertise in Geophysics), based in Johannesburg, now offers airborne, ground, marine and wireline consulting and contracting globally, for geophysical applications to natural resource exploration. In 2011, the company launched WASP (Wingless Autonomous Survey Probe), a joint venture with France-based **Infotron**, a UAV manufacturer. This is EXIGE's second innovative airborne geo-survey platform, in addition to its GyroLAG (Gyrocopter Light Airborne Geophysics).

Fugro Airborne Surveys headquartered in Ottawa, offers a broad range of geophysical technologies globally, including airborne time-domain and frequency domain electromagnetics, magnetics and magnetic gradiometry, gamma-ray spectrometry, gravity and gravity gradiometry. Besides data collection and processing, the company offers interpretation and consulting services. In 2011, Fugro introduced new services and enhanced its airborne geophysical systems and processes. The company added another FALCON airborne gravity gradiometer, and now has five exclusive FALCON systems flying worldwide. HELI-FALCON also became available for exploration, increasing the ability to acquire the highest-resolution airborne gravity data.

Geophysics GPR of Longueuil, Que., continued to offer helicopter and fixed-wing magnetic, electromagnetic (EM-VLF and TDEM), radiometric and gravity surveys in 2011. As promised in 2010, in May 2011, GPR introduced a new helicopter TDEM system built in Longueuil called the GPRTEM. GPR has operational bases in Canada, Africa and South America.

Moscow-based **Geotechnologies**, founded in 2005, specializes in development of airborne geophysical survey technologies. To date, the company has developed EM-4H, a frequency domain airborne EM system in helicopter and fixed-wing configurations; Equator, a helicopter system for combined time-domain electromagnetic and magnetic surveys; GT-MAG, an

aeromagnetic system; and an infrared/aeromagnetic system. The company provides surveys employing these technologies and sells turnkey solutions that include all necessary software and hardware. All systems support the integration of additional geophysical equipment.

Aurora, Ont.-based **Geotech Ltd.** saw increasing demand last year for its VTEM helicopter-borne time-domain EM system, which kept its more than 30 systems busy around the globe. The company also offers true horizontal magnetic gradiometers (HGRAD) integrated into the VTEM PLUS platform. A new early-time VTEM system has been developed and a new yet-to-be-named VTEM system offering an extremely large transmitter loop is being tested. Geotech also flight-tested a new fixed-wing ZTEM system in 2011, and continued research and development on the new helicopter AirMt AFMAG system for mapping deep structures. In addition, the company also formed a new division that offers ground acquisition of high-quality tensor MT data.

JVX of Richmond Hill, Ont., introduced the Clarity3D Downhole Spectral IP/Resistivity (DSIP) system, which offers several advantages over conventional downhole IP technologies, including the ability to survey deeper holes, collect more information, and set up multiple arrays, all while maintaining high-quality data. The company offers Clarity3D surveys globally for exploration and for active mine operators to assist with ore zone mapping. JVX also advanced the development of its Surface Spectral IP Computation Technique, which allows identification of targets that may be missed using standard techniques. Finally, JVX grew significantly during 2011, hiring new field staff and administrators.

The **Advanced Geophysical Interpretation Centre (AGIC)** at **Mira Geoscience** has continued to grow since its inception in 2007, with an expanded Vancouver office and the opening of a Perth office. The **AGIC** has been at the forefront of development and implementation of constrained 3-D inversion methods, working collaboratively with clients on a broad range of technical solutions, including targeting services led by well-known principal consultants, and the GOCAD Mining Suite software based on the integration of VPmg and UBC inversion technologies with the GOCAD 3D earth modelling and 3D-GIS platform. Last year saw the release of the latest version of the GOCAD Mining Suite, including new development of workflow-based constrained gravity and magnetic inversions with VPmg and constrained 2-D and 3-D DC resistivity and IP inversions with UBC-GIF software.

MPX Geophysics (MPX) of Markham, Ont, completed its sixth year in operation, providing international airborne geophysical services. Last year, it established **MPX Geophysics Colombia SAS**, with offices in Medellin, for surveys in South America and Colombia — where the company has been successfully and safely operating since 2007. MPX's base in Veracruz, Mexico, has been handling Mexican and Central American projects since 2009. A new base in Bali, Indonesia, was recently established for projects in Southeast Asia. MPX flew surveys in many challenging environments during the year, including tropical rainforests, high-altitude Andes, the Arctic, and paramilitary controlled territories. Six airborne platforms are now positioned around the globe and the company plans further expansion. MPX offers high-resolution magnetic and radiometric surveys using both fixed-wing and helicopter platforms. Horizontal and vertical gradient magnetics, airborne gravity and LiDAR (Light Detection And Ranging) are also now offered.

Radiation Solutions Inc. (RSI), based in Mississauga, Ont., reported an active 2011, with first-time sales of its spectrometer products in Slovenia, Oman, Kyrgyzstan, Gabon and Taiwan. Its handheld and mobile spectrometer systems are now in over 80 countries. RSI's specialized hybrid RSX-3 system, which is a combination of the RS-500 and RS-700 series systems with 12 litres of detector, was flown in Japan on both fixed and rotary wing aircraft shortly after the accident at the Fukushima nuclear reactor last March. At the same time, RSI's airborne, carborne and stationary systems were active on the west coast of North America, monitoring the radiation fallout.

Triumph Surveys' time-domain EM and magnetic system
Credit: Triumph Surveys

Sander Geophysics (SGL) of Ottawa reported another successful year flying combined gravity and magnetic surveys, as well as combined magnetic, electromagnetic and radiometric surveys worldwide using fixed-wing aircraft and helicopters. The company specializes in high-resolution airborne surveys for petroleum and mineral exploration, and environmental mapping. SGL completed the refurbishment and outfitting of its de Havilland DHC-6 300 Twin Otter aircraft, which is now operating under Canadian registration and is capable of flying EM, magnetics, gravity and radiometrics. The fleet totals 16 company-owned and operated survey aircraft, all modified for airborne geophysical surveys. Last year, SGL started fixed-wing EM surveying with its frequency domain EM (SGFEM) system mounted on the Twin Otter. This system, which was originally developed and operated by the **Geological Survey of Finland,** and purchased by SGL in 2010, is currently flying a large survey in Europe.

Airborne gravity, provided by the company's unique AIRGrav system, was included in the majority of surveys SGL conducted last year. The company's 12

AIRGrav systems flew surveys in North America, South America, Europe, Greenland, Australasia, Asia and Antarctica. Airborne gravity for mineral exploration continued to be an important focus for the company and SGL completed and interpreted a helicopter gravity, magnetic and LiDAR survey for coal exploration.

Now in its eighth year of providing helicopter-borne TDEM surveys, Denmark-based **SkyTEM Surveys** continued to broaden its geographic reach and its TDEM technology. All operations are coordinated from the company's head office in Beder, with Australian activity carried out in co-operation with **GroundProbe,** based in Malaga, Western Australia. In North America, logistical and backup support and client relations are facilitated via the recently incorporated SkyTEM Canada, with contact points in Ottawa and Waterloo, Ont. It also has representatives in Eastern Europe and Asia.

TechnoImaging, based in Salt Lake City, Utah, was spun off from the University of Utah in 2009. The company now offers proprietary and non-exclusive 3-D inversion and R&D services for all airborne, land, borehole and marine electromagnetic and potential field methods for mineral, oil and gas exploration and production and environmental monitoring.

In its 27th year, **Terraquest** of Markham Ont., reported another busy year flying high-resolution aeromagnetic gradiometry, gamma-ray spectrometry, gravity, electromagnetic and seep-detector surveys using fixed-wing and helicopter platforms in support of mineral and oil and gas exploration activities. Last spring, the company took delivery of a King Air C90. The aircraft is a twin turbine, ideal for offshore, long endurance, and extreme cold weather survey operations. The C90 was outfitted with a tail stinger and two extended wingtip pods to measure magnetic data, Blackhawk in-wing fuel lockers and a new interior. Throughout the installation, the company was able to maintain pressurization requirements, giving the aircraft an advantage on mobilizations and ferrying to and from remote survey blocks. All of Terraquest's aircraft are equipped with global tracking systems to enhance safety. The company also used several leased aircraft in 2011, including a second King Air, and a second Navajo.

Tundra Airborne Surveys flying Scott Hogg and Associates' Heli-GT tri-axial gradiometer system in Ontario
Credit: Tundra Airborne Surveys

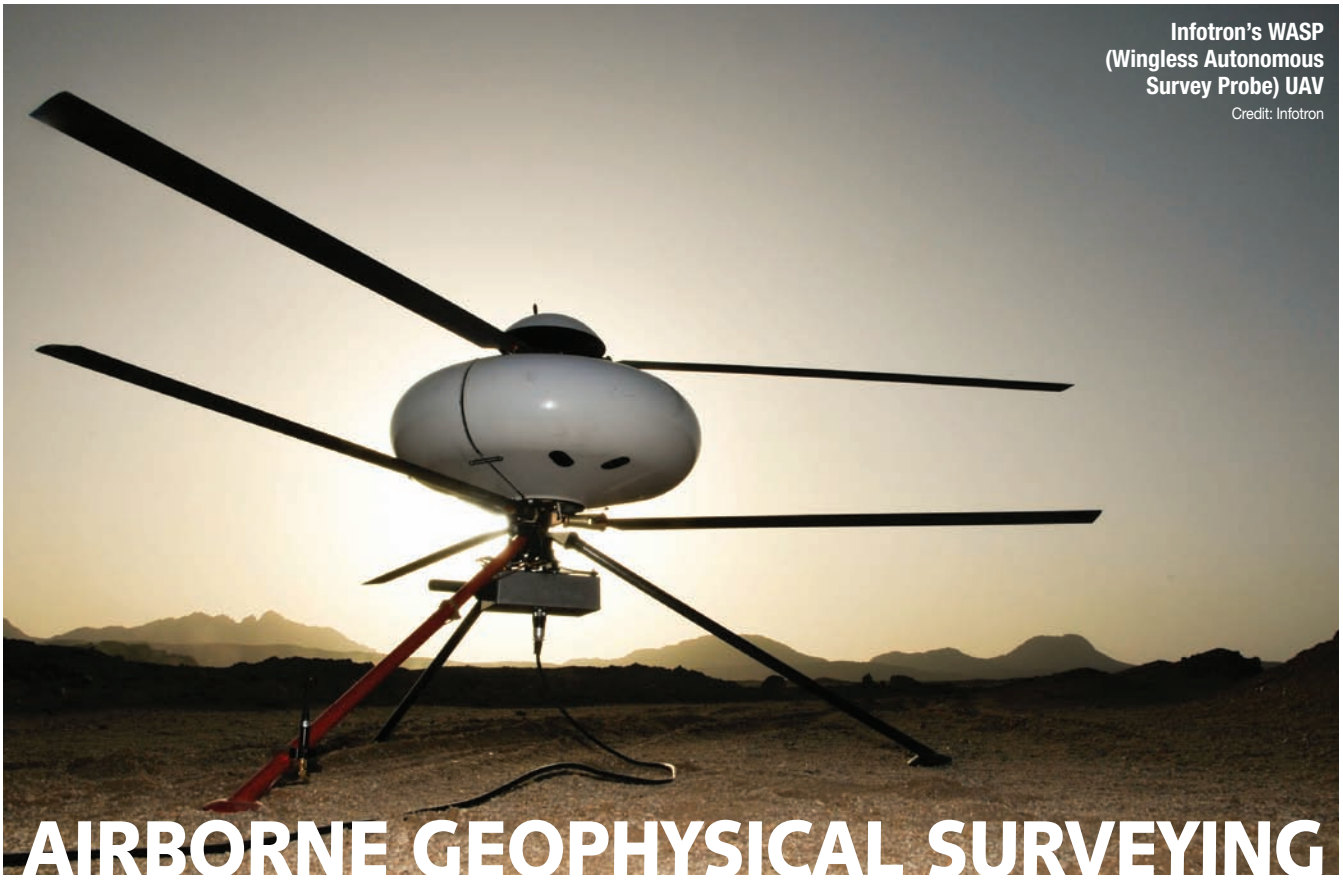
Thomson Aviation's base at the Griffith Airport, in New South Wales, Australia, is in the same area where the company started aerial crop spraying operations 18 years ago. In 2006, Thomson formed a geophysical division, employing the skills developed by the company's pilots for low-level and accurate GPS flying. State-of-the-art equipment for high-resolution magnetic, radiometric and digital terrain mapping was installed in appropriate aircraft.

The geophysics division specializes in high-resolution, high-quality magnetics and radiometrics, often flying as low as 25 metres a.g.l. in flat terrain and as close as 25 metres line spacing. To obtain a sub-2-metre sample interval for the magnetics, the Geometrics G823A cesium vapour magnetometers are sampled at 40 Hz and maximum gamma-ray count rates are obtained with the **Radiation Solutions** RS-500 spectrometers by employing up to 66 litres of detector. All data are processed in-house using Intrepid and Geosoft software for the magnetics and full-spectrum processing of the radiometrics incorporating NASVD noise-reduction techniques.

Rockwood, Ont.-based **Triumph Surveys** was formed in 2011 to offer heli-borne time domain electromagnetic and magnetic surveys throughout North America and Mexico. The company has developed an 8-metre-diameter time-domain EM system with a maximum dipole moment of 150,000 Am^2 and selectable base frequency from 25 Hz to 150 Hz. Triumph has installed the system on a dedicated AS350 B-3 helicopter in Mexico. The system also acquires total magnetic field, differential GPS, and radar altimeter data, with radiometrics optional.

Tundra Airborne Surveys (TAS), now based in St. Catharines, Ont., reported a busy 2011. Early in the year, TAS entered into a partnership with Toronto-based Scott Hogg and Associates (SHA), whereby TAS operates SHA's Heli-GT tri-axial helicopter gradiometer system and SHA continues to do the data processing and interpretation. The partnership flew a total of 36,000 line-km in northern Ontario, mostly for diamond and gold exploration.

TAS also flew its first commercial survey with its Diamond DA42 Twin Star horizontal magnetic gradient platform. The 20,000 line-km low-level survey was conducted in north-central Quebec for a diamond exploration company. The extremely fuel-efficient DA42 has a large wingspan, with the wing-tip magnetometers 16.2 metres apart. TAS continues to provide combined magnetic horizontal gradient, radiometric, and VLF-EM surveys using Navajo aircraft leased from KASI Aviation Services of Dorval, Que.



Infotron's WASP (Wingless Autonomous Survey Probe) UAV
Credit: Infotron

AIRBORNE GEOPHYSICAL SURVEYING

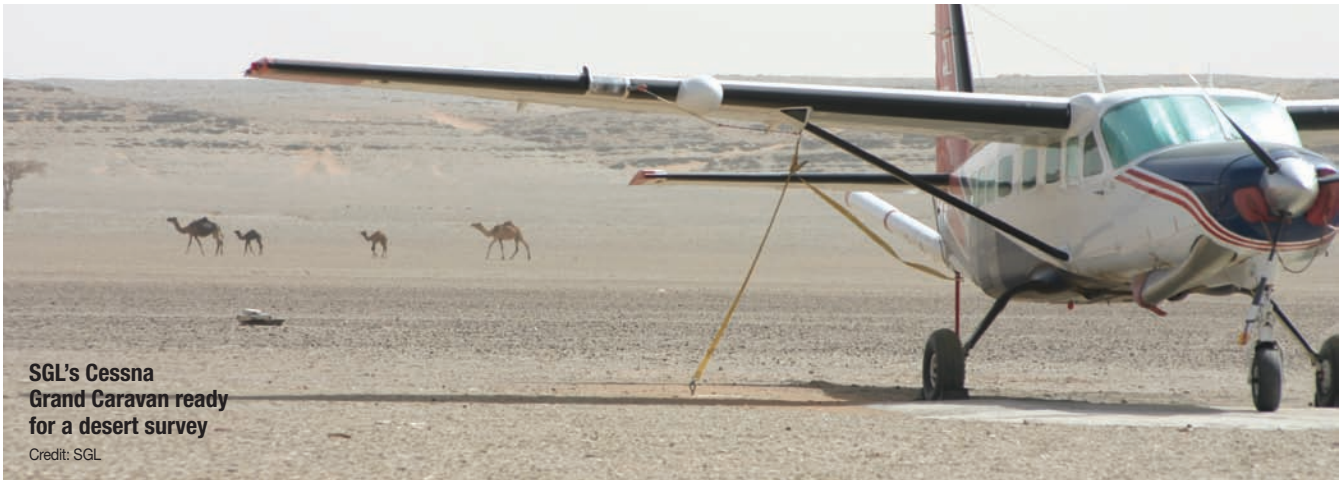
In April, **Aerogeophysica** (AGP) flew airborne magnetics at super-low flight altitudes to test a method for detecting unexploded shells remaining from the Second World War. The search targets were considered to be iron objects with a weight of 10 to 25 kg and equivalent iron dummies were used for the tests. The survey was flown along parallel lines with 50-metre line spacing. The test showed that reliable magnetic data on the targets could be obtained at flight altitudes of 15 metres above ground level. In a survey project for uranium and gold exploration in the Transbaikalia region, the company covered 34,000 sq. km with airborne magnetics, spectrometry and frequency domain EM surveys with line spacing of 500 metres, and 100 metres where more detail was required. AGP mapped Neogene paleo-valley sedimentary uranium deposits overlain by basaltic cover with a combination of EM-4H electromagnetic survey and a high-quality multi-channel gamma-ray spectrometric survey.

AGP also conducted test flights of the new GT-X airborne gravimetry system, developed by Gravimetric Technologies, in southern Russia, near Saratov. The GT-X was mounted on an AN-30 aircraft that had been used for airborne gravimetry with the GT-1A. The new model employs the same gravimetric sensor as in the GT-1A/2A gravimeters but uses a laser gyro-module instead of a mechanical inertial gyro system. This modification extends the geographic range of gravimetric surveys, avoiding problems that arise in the northernmost and southernmost latitudes. This modification also improves the reliability of the gravimetric system. Data obtained from test flights with the GT-X and the GT-1A are being used in tests of the data-processing software. A combined gravity/magnetics survey was also completed near the west coast of the Kamchatka Peninsula. It was the first gravity survey for hydrocarbon exploration under a **Gazprom** project in the shelf zone of the Sea of Okhotsk. AGP collected data with an accuracy approaching 0.32 mGal from an area of 15,000 sq. km at a survey altitude of 300 metres a.s.l., flying AN-26 and AN-30 aircraft.

Aeroquest Airborne flew more than 1 million line-km of fixed-wing and helicopter airborne geophysical surveys in 2011, in Australasia, Asia, North America, South America, Europe and Africa. Locations varied from off-shore to desert to mountainous terrain. The majority of the activity was for mineral exploration companies and government departments, but petroleum exploration was also a significant focus. The company completed a 27,000 line-km AeroTEM helicopter-borne EM survey for the Alberta government, in its ongoing efforts to define the framework for hydrogeologic investigations. In addition, Aeroquest completed a large AeroTEM HD survey for the **Geological Survey of Brazil** (CPRM), which is trying to stimulate mineral exploration. The project was the first modern EM survey the CPRM has contracted. Aeroquest's UHRAM magnetic systems were very active globally in 2011, and are now deployed full-time in North America.

The company now offers "full motion description" of its AeroTEM systems using laser altimetry and orientation data to describe the motion of the EM bird during flight, providing a more accurate interpretation of the data.

In 2011, **EXIGE**'s first GyroLAG (a



SGL's Cessna Grand Caravan ready for a desert survey
Credit: SGL

joint venture with **Airwatch** of Potchestrom, South Africa) was used in commercial aeromagnetic surveys. The unique gyrocopter, purpose-built for geo-surveys, flew a 6,100 line-km, low-level (less than 40 metres a.g.l.), ultra-high-resolution fluxgate magnetic survey in the Barberton mountain area of South Africa. A second aircraft was also produced to be deployed in early 2012 for magnetic and radiometric surveys in West Africa (Sierra Leone). The upgraded design should allow a gravimeter to be included. The recent association between EXIGE and Calgary-based **LiDAR Services International** will add high-quality LiDAR mapping and ortho-imagery in 2012.

AGP test flies the new GT-X gravimeter from Gravimetric Technologies
Credit: Aerogeophysica

EXIGE also teamed up with French UAV manufacturer **Infotron** in 2011 to use its WASP (Wingless Autonomous Survey Probe), a VTOL counter-rotating double-rotor (1.8-metre diameter) platform for geo-surveys. The UAV is propelled either by a 46cc two-stroke engine or a brushless electrical motor for a maximum payload of 5 kg (3 kg for the electrical version) with a maximum ground speed of 90 km/h, a maximum altitude of 3,000 metres, up to two hours endurance and real-time wireless data transfer up to 10 km. Geo-surveys to date include a 250 Hz fluxgate magnetic survey (30 km/hr with 10-metre line spacing) in northern Algeria and a radiometric environmental survey over a gold mine dump near Johannesburg.

Firefly Aviation, a Calgary-based airborne geophysical survey company that began operations in 2001, has completed high-resolution surveys throughout Canada, the United States, Africa, and

Thomson Aviation's new, turbo-powered PAC-750 for magnetic and radiometric surveying
Credit: Thomson Aviation

Goldak Airborne Surveys at Dakhla airport in Morocco for Western Sahara tri-axial magnetic gradient and radiometric survey
Credit: Goldak Airborne Surveys

Central and South America. The company, which owns and operates four dedicated survey aircraft, specializes in custom-designed fixed-wing High Resolution Aeromagnetic (HRAM) surveys. Firefly also provides expertise in difficult logistical challenges associated with remote or international projects and offers full data processing and interpretation services. During 2011, Firefly completed several equipment and technology additions and upgrades. Since 2008, the company has phased in the newest aeromagnetic compensators, the RMS DAARC500, which offer state-of-the-art magnetic compensation. During 2010 and 2011, the company began including radiometric surveys as part of the package using the **Radiation Solutions** RSX-5 system, the latest generation gamma-ray spectrometer, which provides data resolution and stability far superior to previous technology.

Fugro continued to offer the FALCON airborne gravity gradiometer technology to the mineral and petroleum exploration industries. FALCON was specifically designed for airborne surveys and measures the differential curvature gradients used to derive the full gravity tensor and vertical gravity. To meet the growing demand for high-resolution airborne gravity data in mineral exploration programs, a fifth FALCON system was deployed. In addition, the company began offering HELI-FALCON, the FALCON gravity gradiometer technology installed in a helicopter

platform, which results in better terrain-following capability, increased spatial resolution and signal, and superior signal-to-noise ratio for better anomaly detection.

Fugro reported that demand for the RESOLVE and DIGHEM frequency domain EM systems increased worldwide in 2011, but particularly in Western Canada and Alaska. The broadband GEOTEM time-domain system was active in coal exploration in central Canada and base metal exploration in the Northwest Territories. Fugro applied the TEMPEST system to both shallow and deep targets in North America and Australia. The MEGATEM system spent the year surveying in Africa, carrying out large-scale regional multi-parameter exploration programs. In 2011, HELITEM surveying saw the deployment of two systems in Africa, two new systems in Australia, one additional system in Brazil and two new systems in North America.

Fugro carried out FALCON airborne gravity gradiometry surveys in North America, South America, Europe, Africa and Australia during 2011. FALCON surveys were flown for a number of companies, as well as government agencies that included **Natural Resources Canada** (NRCan), Ontario's **Ministry of Northern Development and Mines** (MNDM), the **Geological Survey of Finland** and the **USGS**. Applications included water, coal, diamonds, VMS and iron exploration projects. Multiple FALCON surveys targeting iron ore formations were also carried out in the Labrador Trough in western Labrador. Fugro also conducted a number of airborne gravimetry surveys in South America and Africa, and the fleet of magnetic and gamma-ray spectrometry aircraft flew surveys in Europe, Australia, Africa, South America and North America, including acquisition of 76,000 line-km of magnetic data for Ontario's MNDM.

Goldak Airborne Surveys of Saskatoon was very busy in the early part of the year completing an airborne magnetic survey of over 190,000 line-km using four aircraft, for the **Ministère des Ressources Naturelles et de la Faune** (MRNF) of Quebec. This was the largest single survey in the company's history and pushed its total flying to over 3 million line-km in only 10 years. In 2011, the company saw major interest in its triaxial gradient magnetic system coupled with VLF and/or radiometrics. A large magnetic gradient and radiometric survey for **Metalex Ventures**, in Western Sahara, marked the company's first international project.

In 2010 and 2011, **Novatem** of Mont-Saint-Hilaire, Que., flew large-scale fixed-wing airborne magnetic and radiometric surveys in Europe, North America and Africa. Mainly in Canada and Africa, the company flew helicopter-borne magnetics, radiometrics and TDEM surveys. During this period, Novatem added two twin-engine aircraft to its fleet. The magnetic signature of these aircraft was considerably improved using specially designed titanium and stainless steel parts. The magnetic compensation uses Novatem software developed over more than 15 years. All components of the magnetic field are measured in real time and integrated into the compensation calculation to provide accurate magnetic measurements. All data obtained from low-terrain clearance surveys are fully preserved.

SGL flew several large airborne gravity and magnetic surveys for petroleum exploration in 2011 using AIRGrav. It also flew many smaller surveys, including fixed-wing and helicopter-borne gravity and magnetic surveys for mineral exploration. It completed a number of radiometric surveys, including a helicopter magnetic and radiometric survey for mineral exploration in Canada, and a large fixed-wing magnetic gradient and radiometric survey in Europe. It started a large survey in Ireland using its Twin Otter equipped with a frequency domain electromagnetic system, stinger-mounted magnetometers, and a radiometric system. The survey is part of the Tellus Border project, a regional mapping project that will collect scientific data on soils, water and rocks across several counties of Ireland.

SGL continues to offer scanning LiDAR in conjunction with other surveys and it flew several such surveys with fixed-wing aircraft and helicopters in 2011. The LiDAR system produces extremely high-

Terraquest's Heli Stinger system mounted on an AStar helicopter in Honduras
Credit: Terraquest

resolution digital terrain models that can be used for gravity terrain corrections and other mapping applications.

SkyTEM Surveys was contracted in 2011 to fly TDEM/Magnetic surveys, sometimes including radiometrics, in challenging environments ranging from the rugged terrain in the Yukon to tropical conditions in Thailand, and from the deserts of Australia to frigid, remote landscapes of Greenland. It also flew surveys in Antarctica, Brazil, Denmark, Finland, Germany, Italy, Netherlands, Norway, Spain, Sweden and the U.S. Survey objectives included mineral exploration (nickel, copper, gold, diamonds, uranium, coal), salt water intrusion and a variety of groundwater and engineering studies (planning for a pipeline corridor and CO_2 sequestration).

Surveys in North America ranged from locating water, to fracture shale in British Columbia, for a group of major gas producers, to mapping water resources for the USGS, to flying several gold exploration projects in the Yukon and B.C. One of the more challenging projects was surveying the slopes of still-moving Mount St. Helens as part of a slope-stability study by the USGS. Exploration for base and precious metals kept the SkyTEM system busy all year in Scandinavia. The first surveys with the recently launched high-powered SkyTEM 508 system were flown there throughout the summer and fall. The system was used for a wide variety of precious and base metal mapping projects in Australia, including a survey for coal that produced data which improved the client's drilling program and its coal resource model. A pipeline pre-engineering study in Australia employed the SkyTEM system to characterize the pipeline route in advance of construction.

In 2011, **Terraquest** completed four significant surveys using HRAM, gravity, seep detector technology and electric field sensors in support of oil and gas exploration, both offshore in the North Atlantic and onshore mapping the Marcellus shales in the northeastern U.S. For the third consecutive year, the company worked with France's **BRGM**, based in Orleans, carrying out a HRAM and gamma-ray spectrometer mapping project. Terraquest completed many gradient magnetic, gamma-ray spectrometric and XDS VLF-EM surveys in Africa, North America, Central America and South America. The company's helicopter fixed boom or stinger system saw more heli-borne surveys flying its proprietary Structural Multi-View throughout North and Central America. The system can be mounted on Bell 206 Jet Rangers or AStar AS350 platforms. The Structural Multi-View system is a 5-metre stinger with a magnetometer and XDS VLF-EM, plus a spectrometer with a 20.8-litre crystal pack typically mounted in the luggage compartment. The system is ideal for operating at low speeds and low altitude, resulting in detailed, high-quality data.

Now in its fifth year of operation, **Thomson Aviation** has completed over 1.2 million line-km of regional surveying in three states of Australia for **Geoscience**

Australia and over 750,000 line-km for more than 80 private companies using its four fixed-wing aircraft. Using leased helicopters, it has also conducted surveys in New Zealand, Papua New Guinea and Indonesia. The company is now marketing its services in other countries and investigating other data acquisition methods to combine with magnetics and radiometrics. In 2011, Thomson added a turbo-powered PAC-750 aircraft manufactured in New Zealand to its fleet of fixed-wing aircraft. Its PT6-34 turbine engine gives improved performance and reliability over comparable piston-engine aircraft. In particular, it has superior climb performance, which enables it to follow the terrain closely and its high power-to-weight ratio allows a heavy payload (up to 66 litres of radiometric detector, for example). Its special features provide for high safety standards, and its size and payload allows the addition of other geophysical hardware. The PAC-750, which was chosen specifically for geophysical operations, has already proven itself by flying over 100,000 line-km, providing excellent quality data.

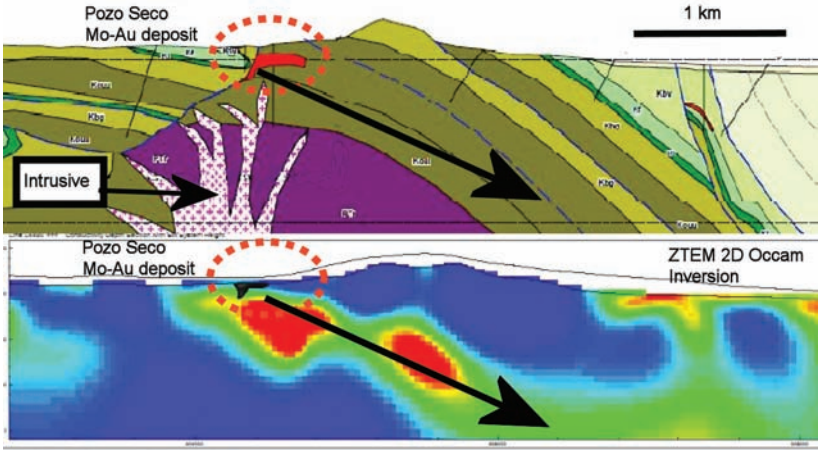
Airborne Data Acquisition and Processing

In 2011, **Condor Consulting** of Lakewood, Colo., continued to develop case studies and tutorial materials for its commercial processing and interpretation services. The company's new-business development priority is the processing and interpretation of ZTEM, AFMAG and Falcon airborne gravity gradiometer surveys. Condor upgraded its website to communicate these materials to existing clients and the exploration community at large. The company has now been a re-seller for the **Pitney Bowes Business Insight** (PBBI) Encom line of geophysical software for 10 years.

EXIGE has added CVI (Compact Volume Inversion) software to its core interpretation services. CVI offers unconstrained 3-D inversion of magnetic and gravity data sets. The company used CVI in several commercial projects in 2011, notably a regional 3-D modelling of iron ore deposits in the northern parts of South Africa.

The **Geotechnologies** data control and navigation system, NavDat, is a complete solution for navigation, integration of different geophysical equipment, data recording, visualization, and quality control. NavDat is widely used as a part of airborne geophysical systems, including system modifications developed for EM and magnetic systems, gamma-ray spectrometers and infrared scanners. The Linux-based NavDat software is installed in an on-board computer (laptop), with a guidance unit and LCD-screen mounted in the cockpit to provide navigation and other essential information to the pilot. The system allows very accurate navigation for surveys to a scale of 1:5,000 or less.

Geotech has been working on new methods to interpret integrated multi-parameter geophysical data. The company started a new innovative ground geophysical group, CORE Geoscience, to develop integrated resistivity models that can incorporate geological and geophysical signatures. CORE is an amalgamation of two EM-specialized exploration groups that offers ground acquisition of high-quality tensor MT data and new developments



Interpretation of a ZTEM survey by Condor Consulting
Credit: Condor Consulting

Geotechnologies' GT-MAG airborne magnetic system on an AN-2 in Kazakhstan
Credit: Geotechnologies

in interpretation using the integration of both ground and airborne EM. In 2011, the company continued to advance in-house interpretation services, which now include a complete suite of data processing and interpretation products to support its VTEM, ZTEM and AirMt AFMAG, as well as its aeromagnetic-gradiometric and spectrometric surveys. Standard services now include full 1-D/2-D/3-D forward modelling and inversion for VTEM and ZTEM data in addition to EM anomaly picking, time-constant (Tau) calculations, apparent-conductivity calculation, conductivity depth slices, and Maxwell 2.5D Conductive Plate Modelling.

Advanced VTEM post-processing includes EMflow conductivity-depth and RDI resistivity-depth-imaging, 3-D conductivity image voxels and depth-slices and AirBeo 1-D conductivity-depth inversion. Advanced ZTEM post-processing includes Karous-Hjelt current density-depth imaging, 3-D resistivity voxels & depth-slices, Geotools 2D & Emigma 3D forward modelling, and its Avert2D inversion with topographic and receiver clearance correction for AirMt and ZTEM data, which was introduced in 2011.

Geotech partnered with industry-leading inversion experts **Mira Geoscience** and **TechnoImaging** in 2011 to offer more advanced 3-D EM inversion capability. With its new CORE Geoscience division, Geotech sees additional advancements in joint-inversion of ZTEM and ground MT in 2012. Advanced magnetic post-processing for Geotech's new VTEM HGRAD and Heligrad systems includes advanced derivatives, such as the total horizontal gradient and tilt-angle derivative, that can be derived from the measured cross-line and calculated in-line and vertical gradients. The company also offers 3-D magnetic modelling and inversion using the UBC 3-D magnetic inversion code, as well as full-suite derivative potential field analyses in Oasis Montaj Magmap.

Keeping the development of the Common Earth Model central to Mira Geoscience's **AGIC**, airborne data are inverted in tight integration with geological and physical property data, and from multiple survey types. The results are physical property and geological earth models that provide more consistent results than inverting the data in isolation. Last year saw the completion of: constrained 3-D ZTEM inversions that accounted for nearby conductors that distort the fields; joint 3-D ZTEM inversions with ground MT data; constrained and joint inversion of airborne, ground, and three-component down-hole magnetic data; constrained inversions of frequency domain and time-domain airborne data; constraining of lakes to reveal basement signature in airborne gravity gradiometry data; and combined inversion of airborne gravity gradiometry data and ground gravity data.

SGL continued to refine and improve its GPS processing software, as well as increasing use of the horizontal components of the gravity field measured by AIRGrav. This has led to higher resolution and better accuracy gravity data from AIRGrav surveys, which has helped SGL perform geoid measurements using AIRGrav. Mapping the geoid is important for determining the effects of changing sea levels on low-elevation coastal areas.

SkyTEM's TDEM system was developed to match the results of the Geonics Protem 47 ground EM system and to provide highly detailed images of the subsurface. It can deliver inversions within two days of acquisition and it maximizes productive flying time by eliminating high-altitude calibration flights, particularly valuable on days with low cloud cover. Extremely high signal-to-noise ratios and the latest-time gates available contribute to the high quality of SkyTEM data.

In addition to the EM data, the system collects total field magnetic data at the lowest altitude available from a helicopter TDEM platform with the magnetometer (and all instruments) mounted on the transmitter loop frame. In 2011, a spectrometer was also mounted on the carrier frame. This brought the receivers of all three parameters (EM, mag, gamma-spec) close to the ground, resulting in the highest lateral and horizontal resolution obtainable.

During 2010, **TechnoImaging** announced the availability of the only practical 3-D airborne electromagnetic (AEM) inversion service for entire AEM surveys, based on the concept of a moving AEM system footprint. 3-D conductivity models are delivered in industry-standard formats. In 2011, 3-D AEM inversions were completed for every existing AEM system from surveys in Australia, Canada, Finland, Ghana, Tanzania, the U.S., and Zambia. In a non-exclusive project near the mining area of Kamiskotia, Ont., TechnoImaging inverted 3,800 line-km of MEGATEM data in less than two days, for a 3-D conductivity model discretized to over 15 million cells. The company is continually expanding its 3-D AEM inversion capabilities.

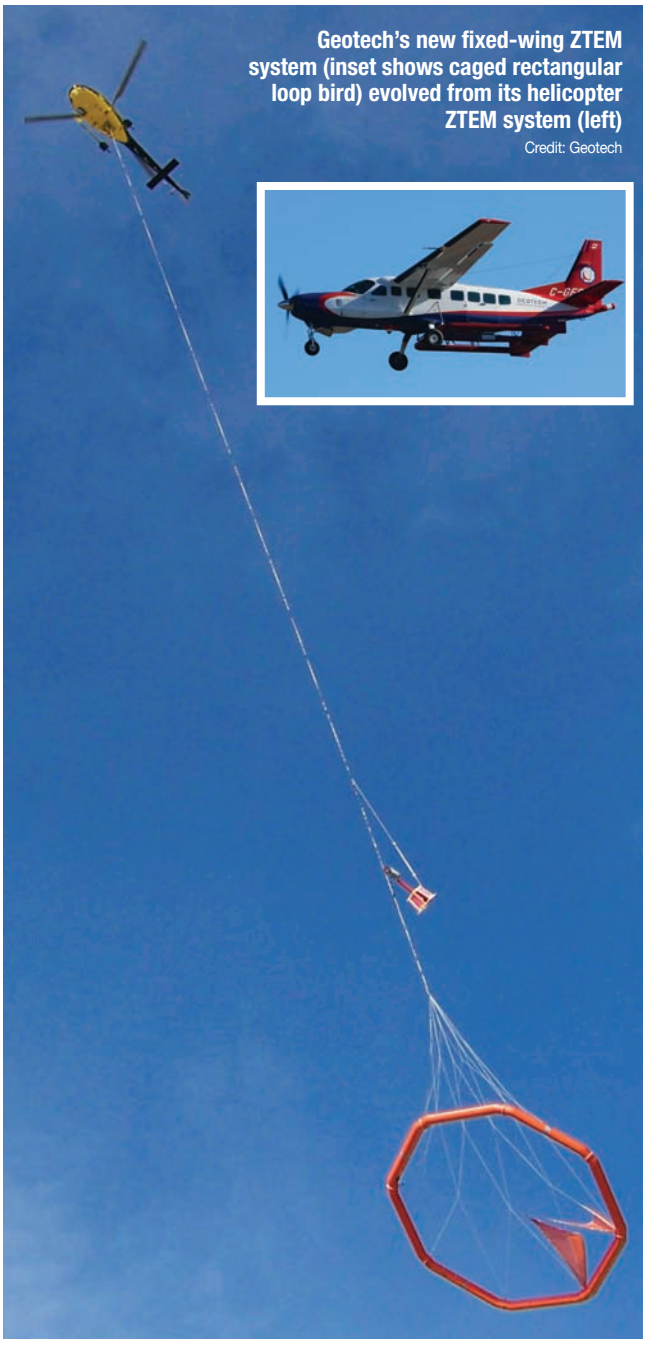
TechnoImaging also broke the 1 billion cell barrier in 2011 with the 3-D inversion of all USGS gravity data from Alaska to a suite of 3-D density models. This was achieved using the company's 3-D gigacell gravity and magnetic inversion service, for which entire surveys of gravity or magnetic data can be inverted for deposit-scale model resolution. In a non-exclusive project from the Bathurst mining camp in New Brunswick, the company inverted all 15,500 line-km of **Bell Geospace**'s 2010 reprocessed Air-FTG full tensor gravity gradiometry data to a 3-D density model with over 80 million cells.

Aeromagnetic Surveying

In 2011, **Geotechnologies** launched its turnkey airborne magnetic system, GT-MAG. The extremely high sample rate (1,000 samples per second), accuracy of 0.2 pT/(Hz1/2), and precise navigation tools allow high-precision, high-detail (to a scale of 1:5,000) magnetic surveys, even when GT-MAG is integrated with an electromagnetic system. It is highly automated and allows unmanned operation for magnetic surveying. The system includes a data acquisition unit with embedded GPS-receiver, a navigation and data control system (NavDat), real-time automatic magnetic compensator (ReinMag) and post-processing tools. The system, which is easily integrated with a wide range of geophysical equipment, has connections for up to four cesium vapour sensors, a three-component fluxgate sensor, radar-altimeter, barometric altimeter and a thermometer.

The sophistication of the technology and ease of use ensures its reliability and effectiveness. In September, two fixed-

SGL's Twin Otter on survey in Ireland
Credit: Alison McCleary



Geotech's new fixed-wing ZTEM system (inset shows caged rectangular loop bird) evolved from its helicopter ZTEM system (left)
Credit: Geotech

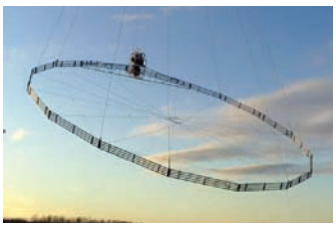
wing aircraft (AN-2) of **Geoken Co.,** based in Kazakhstan, were equipped with GT-MAG systems. Although Geoken has many years of experience in geophysical exploration, the company had never used airborne methods. The complete process of installation, launching and personnel training took only 20 days and Geoken surveyed about 90,000 line-km in two months using these systems.

Geotech now offers the latest in true horizontal magnetic gradiometers (HGRAD) integrated onto the VTEM PLUS platform. The gradiometer uses two **Geometrics** total field magnetic sensors with a sampling interval of 0.1 seconds and a horizontal separation of 12.5 metres, located 10 metres above the transmitter loop. A second GPS antenna and an inclinometer are also positioned 10 metres above the transmitter loop. The nominal terrain clearance for the magnetic sensors is 40 metres, 22 metres less than in previous VTEM systems.

Mississauga, Ont.-based **RMS Instruments** won several major contracts for instrumentation, systems integration and deployment last year. It introduced the second-generation AARC500 and DAARC500 systems for real-time aeromagnetic compensation and data acquisition, with significant improvements in performance, functionality and reliability, and full compatibility with first-generation instruments. Updates are added regularly, with firmware releases for first and second-generation systems.

The AARC510 Adaptive Aeromagnetic Real-time Compensator is in full production. Its compact form factor (21.6 cm by 13.3 cm by 30.5 cm) and light weight (4.5 kg) facilitate strap-down installations in small fixed-wing aircraft and helicopters. In addition to real-time compensation for up to four sensors (and three gradients), and an embedded (single or dual-frequency) GPS receiver, the AARC510 also supports four differential analog inputs, and data acquisition through an Ethernet interface, which allows seamless interfacing to **Radiation Solutions**' spectrometers. The remote control capabilities of the AARC510 allow a single Windows-based device to control and operate the AARC510 and other instruments (such as the spectrometer). This package provides the core of a data-acquisition system for airborne magnetics and radiometrics. Optional embedded GPS receivers supported by all of RMS Instruments' products in the ARC500-family (AARC500, AARC510, DAARC500 and DAS500) now includes the new OEM6-series of **NovAtel**'s next-generation GNSS receivers.

Airborne Electromagnetic Surveying



Geophysics GPR's new GPRTEM helicopter time-domain EM system
Credit: Geophysics GPR

In 2011, **Geophysics GPR** introduced the new GPRTEM helicopter time-domain EM system, which has a 13-metre transmitter loop with a dipole moment of 600,000 NIA, is easily transported and has service available worldwide. The system collects dB/dt for both "off-time" and "on-time" measurements and the acquisition rate is 30 or 90 Hz for detection of both shallow and deep targets. The motor generator located on the transmitter loop is electrically isolated from the helicopter.

Geotech has developed a new early-time VTEM system for shallow mapping, such as for hydrogeologic surveys and kimberlite exploration. The system features an improved frequency bandwidth that allows earlier-time decay measurements and also a newly implemented system response calibration design that uses transmitter waveform streaming. It includes new software that improves the rejection of the primary field for better early-time data. The tests and surveys flown with the new system have produced excellent results, to be published in 2012. Another new VTEM system which in-house is called VTEM-EXTREME is being tested. Offering an extremely large loop (43 metres diameter) and

over 2.5 million NIA, this VTEM, which is the largest-dipole airborne TDEM system commercially available, arguably has the best signal-to-noise ratio in the industry.

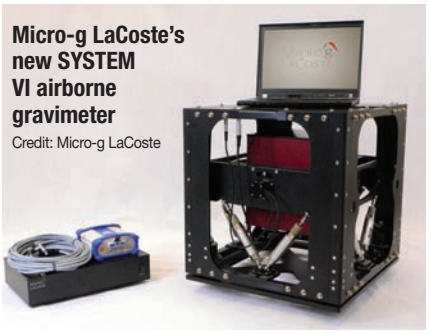
Geotech's ZTEM (Z Tipper Electro Magnetic), a helicopter-borne natural field electromagnetic AFMAG system, provides the deepest penetration of any proven airborne EM system. The continued success of the helicopter ZTEM system has led to the development of a new fixed-wing ZTEM system for regional exploration. The FW-ZTEM system, which features a newly redesigned, retractable airborne sensor, was fitted onto a Cessna Caravan and successfully flight-tested in 2011. The new system, designed to be deployed with multi-parameter sensors (including magnetics, gravity/gravity-gradiometry, spectrometric) will be available for surveys in North America in 2012.

During the year, Geotech continued with system design testing and conducted limited commercial surveys with its newly developed helicopter AirMt (Airborne Magnetic Tensor) AFMAG EM system, which uses the newest generation total field (XYZ) EM measurement sensor. AirMt measures the magnetic field Amplitude Parameter (AP) that is rotationally invariant, featuring even higher signal-to-noise than the standard tipper measurement measured in ZTEM. AirMt is the next step in the company's AFMAG technology for higher-resolution mapping of deep geological formations.

After three years of research and development, the **Novatem** TDEM system is now operational. The receiver loops of the Novatem system are configured so that they are only slightly influenced by the primary field, if at all. It is therefore possible to obtain measurements during the on-time and off-time of the pulse without using a bucking coil. These measurements and the B-field are recorded to improve the response to ultra-high-conductance bodies. As the conductance of geological bodies increases, the EM response tends to zero, so that ultra-high-conductance bodies are undetectable if the response is only measured during the off-time. However, these bodies have a strong response during the on-time. Thus the B-field response is stronger in high-conductance bodies than its time variation (dB/dt) and the signal-to-noise level is significantly higher.

The SkyTEM time domain EM system
Credit: SkyTEM

Bell Geospace flys an Air FTG survey
Credit: Bell Geospace



Micro-g LaCoste's new SYSTEM VI airborne gravimeter
Credit: Micro-g LaCoste

The Novatem system is configured to minimize any alteration of the measurement sensitivity of the system during the surveys. The configuration of the receiver loops assures very good rigidity between the transmitter loop and receiver loops. This strongly reduces any noise induced by geometric deformation of the entire transmitter-receiver set. Three receiver coils are employed so that both vertical (Z) and horizontal (X and Y) components are recorded. Being insensitive to the primary field, the system does not have to correct measurement errors of these components caused by any residual transmitter current. In conventional systems, to make the induced voltage in the receiver during the on-time of the transmitter insignificant so that the system can start the acquisition as soon as possible after the end of the impulse, it is necessary to use a receiver loop with a diameter about 10 times smaller than the transmitter loop. In the Novatem system, each receiver loop has a surface area of about 0.62 sq. metres. The measurement of the vertical (Z) component (the most important) of the magnetic field is obtained using eight receiver loops. This gives a measurement surface of about 5 sq. metres. To obtain an equal sensitivity with other systems, the receiver loops of the Novatem system require five times fewer turns on the receiver coils, which reduces the inductance value by a factor of 25, increasing the resonance frequency of the system's receivers and hence the bandwidth. It is thus possible to attenuate the signal from the primary loop (transmitter) in the receiver loop by a factor of 60 dB (which is a factor of 1,000 in voltage).

Novatem can now conduct higher-resolution surveys for TDEM sounding and TDEM prospecting. Main applications include delineation of conductivity contrasts associated with lithology or hydrothermal alteration, oil and groundwater investigations and prospecting to locate massive sulphide deposits at great depths.

Sander Geophysics started conducting fixed-wing frequency domain electromagnetic surveys last year using its SGFEM system. The system, which is mounted on SGL's Twin Otter, allows frequency domain EM surveys to be flown in combination with magnetics, radiometrics and gravity.

SkyTEM's R&D group made several improvements to its time-domain electromagnetic system during 2011 and three

configurations are now available based on the area of the transmitter loop: 100, 300 or 500 sq. metres. The first system, launched in 2004, is the SkyTEM 304 with a transmitter area of 314 sq. metres. The system has always been unique due to the placement of all receiver sensors on the carrier frame, which minimizes the distance to the ground and ensures all data are accurately positioned. The system is based on a dual-moment transmitter, a null-position receiver coil configuration and a transmitter able to turn off current in the coil within a few microseconds. These unique features allow the TDEM system to provide bias-free data from about 10 microseconds to 10 milliseconds, outperforming many other systems on the market.

The newly developed SkyTEM 508, which was employed in Scandinavia last year, has a transmitter moment of roughly 500,000 NIA with eight turns on a 500-sq.-metre loop. The system was developed to achieve a very high signal-to-noise ratio at the late TDEM gate-centre times with no loss in ability to measure bias-free data as early as 10 microseconds (from the beginning of turn off). The dual-moment transmitter allows recording data at late decay times: 15, 35 or even 60 milliseconds. The SkyTEM 101 was designed to map from the very near surface to a depth of about 150 metres with high resolution. A new, more aerodynamic carrier frame was introduced last year, resulting in reduced vibration and lower noise. Bias-free data are recorded at very early times (10 microseconds) from the beginning of turn-off, delivering the highest resolution of near-surface geology with an airborne system.

Airborne Gamma-ray Spectrometric Surveying

Medusa Systems BV, based in Groningen, Netherlands, released a new version of its GAMMAN software intended to process gamma-ray spectra from geophysical surveys. The new version has an integrated approach to the correction of airborne gamma-ray data for attenuation due to altitude effects and cosmic and radon backgrounds. This approach is based on a combination of full spectrum analysis (FSA) and Monte Carlo-based modelling of the detector's response to air attenuation and radon effects. The company says one of the advantages of the new method is that it makes an upward-looking detector for radon estimation obsolete. The algorithm uses a large database of detector spectra for each altitude between 0 and 160 metres. It also contains detector response spectra for radon in air. The origin of the gamma radiation from radon in the air is similar to that from radon in the ground below the detector. However, the different geometries of the "air-bound" radon source and the "soil-bound" radon source produces spectra that are very different in shape. This allows separation of the ground-source and air-source radon contribution in the measured spectra.

In boreholes, a similar approach is used to separate radon contributions to measured spectra of the air or fluid inside boreholes, from the radon contributions of the borehole wall-rock matrix surrounding the sensor. Tests of the method were reportedly promising and results will be published soon.

Airborne Gravity Surveying

In 2011, **Bell Geospace** of Houston continued acquisition, processing and interpretation of full tensor gravity gradiometry data for natural resource exploration worldwide. The company developed full tensor gridding methods to provide better resolution between survey lines and updated full tensor noise-reduction methods. Bell has also been working with specialists in industry and academia to improve inversion of full tensor gravity data.

SGL flew an AIRGrav survey in Australia for the **Victorian Department of Primary Industries**' CarbonNet Project. The project is investigating the potential of capturing CO_2 from electricity generation and new coal-based industries in Gippsland and moving it to Victoria's geological basins. The survey is designed to provide a better understanding of the geology of the region, and the geological structure of the onshore, near-shore and immediate offshore area.

SGL is again participating in **NASA**'s IceBridge project in Antarctica and Greenland, having supplied an AIRGrav airborne gravimeter for the past two seasons. The surveys are designed to provide vital information about the ice sheet at the poles using a DC-8 aircraft mounted with sensor equipment from multiple agencies.

Lafayette, Colo.-based **Micro-g LaCoste** introduced a new airborne gravimeter, called SYSTEM VI, which is less than half the size and weight of its TAGS airborne gravimeter, and has improved performance in turbulence. SYSTEM VI is designed to withstand 20 g shocks for STC requirements.

An SGL Caravan starts a gravity survey for a carbon capture and storage project in Australia
Credit: Sander Geophysics

Thermo Fisher Scientific's FXL field X-ray lab
Credit: Thermo Fisher Scientific

GROUND SURVEY TECHNIQUES

Abitibi Geophysics entered an agreement with Australia's **RMIT University** to fund the development of the ARMIT B-field and dB/dt sensor for ground and borehole geophysical data acquisition. The RMIT team delivered a three-component sensor which was in field testing at presstime. A field test on an early prototype conducted in Utah last August showed that the ARMIT sensor is quieter than published noise figures for high temperature SQUID sensors and spheric noise. The ARMIT three-component compact sensor weighs only 3 kg and is rugged and low to the ground. It can be firmly placed on the ground without the need for levelling. It operates at ambient temperatures from -40 degrees C to 50 degrees C without the need for cooling with liquid nitrogen or helium.

The most challenging survey Abitibi Geophysics conducted in 2011 was an IPower3D IP survey on Baffin Island. The survey successfully identified drill targets despite the short season, the lakes intersecting the zone of interest and the depth to the sulphides. The company also reported that the new TerraScope 18kW TDEM transmitter with selectable base frequency was particularly useful on nickel projects in Ontario and Ungava.

EXIGE announced a partnership with South African ground geophysics company **Global Geophysical**, which performs magnetic, gravity and electrical resistivity surveys in southern Africa. Integrated ground/air geophysics from data acquisition to interpretation are now routinely offered in gold, iron ore, manganese and uranium exploration. EXIGE's latest alliance with **Land & Marine Surveys (LMS)** of South Africa adds geophysics (fluxgate magnetic and gravimetry) to its surveying capability. LMS conducts bathymetry with single or multi-beam echo sounders,

Abitibi Geophysics conducting a borehole Gravilog survey in the Yukon
Credit: Abitibi Geophysics & Scintrex

sub-bottom profiling, side-Scan sonar surveys and ROV surveys.

Monex GeoScope P/L, based in Melbourne, has been working in the industry for over 10 years. It initially offered consulting on geophysical surveys, specializing in non-standard applications, but over the last five years, as demand grew for its terraTEM suite of products, Monex has widened its focus to include equipment design and manufacturing.

Physical Rock Properties and Elemental Analysis

Last January, **Thermo Fisher Scientific** of Billerica, Mass., introduced its all new Thermo Scientific Niton FXL field X-ray lab for mining and exploration. These portable analyzers can determine the elemental composition of any sample at all stages of exploration, mining, production, and refining processes in minutes. The Niton FXL analyzer is suited to industrial minerals, precious and base metals, and oil and gas applications. It delivers nondestructive, XRF-based elemental analysis with lab-quality testing performance and low levels of detection for up to 40 elements. Housed in a compact, portable package that can be operated virtually anywhere onsite, the lab is built from durable, dust and water-resistant Lexan plastic. Weighing less than 14 kg, the Niton FXL lab is easy to transport and operate from the back of a truck, mounted on a portable tripod, or in an onsite lab. It includes advanced batteries that support continuous operation on a single charge. With its closed-beam design, which requires minimal licensing in most countries, the Niton FXL lab is available with 1-mm, 3-mm and 8-mm spot sizes; a sample spinner for reducing sample heterogeneity issues due to particle size; and a 9-inch LCD touchscreen display. In addition, the Thermo Scientific TestAll Geo software automatically determines the correct analytical test mode for rapid analysis of major and minor elements in geological samples.

Data Processing and Positioning

Lamontagne Geophysics Ltd. (LGL) of Kingston, Ont., continued to develop a time-stepping, multigrid, finite-difference 3-D EM solution suitable for use in both forward modelling and in EM inversion. The inversion software using this solution will be initially designed for ISR imaging. The code is aimed at large-scale fixed-loop EM geometries. In a typical application with the current code, a model can be rendered at 25-metre resolution within a 5-km cube and the regional structure extended over a cube more than 20 km in size. Optimization of the code for use in a High Performance Computing cluster is ongoing.

AGIC saw increased demand for lithologic-based, constrained and combined inversion of ground gravity, airborne gravity gradient, and magnetic data for iron ore. Using the new release of VPmg, the inversion allows the introduction of geologic and physical property constraints as well as high magnetic susceptibilities to be accurately modelled. Other developments saw the increased application of constrained ground 3-D MT, 3-D EM, and 3-D DC resistivity and IP inversions with UBC-GIF codes.

In 2011, **AMIRA International** of Melbourne, and **TechnoImaging** launched the three-year AMIRA project P1058 Spectral induced polarization for 3D mineral discrimination, sponsored by **Abitibi Geophysics**, **Barrick Gold**, **BHP Billiton**, **First Quantum Minerals**, **Geophysical Resources and Services**, **Khumsup**, **Teck Resources**, **Quantec Geoscience**, and **Zonge International**. Central to AMIRA P1058 is the use of the Generalized Effective Medium Theory of Induced Polarization (GEMTIP) that directly relates bulk complex resistivity spectra with mineral properties. AMIRA P1058's research activities include petrophysical and GEMTIP analysis of world-class mineral deposits, the development of 3-D inversion and mineral discrimination software, workflows, and field trials.

Drill-hole Methods

Abitibi Geophysics carried out borehole EM and sonic logging projects in Portugal and Ireland; hole-to-hole 3-D IP projects in Mexico, Honduras and Ghana; and an extensive physical properties logging project on a potash development property in Eritrea last year. In Ontario and Quebec, hole-to-hole 3-D IP surveying continued, following early successes that demonstrated to gold exploration companies a good correlation of sulphides with gold.

Caracle Creek International Consultants (CCIC), based in Toronto, continued to deploy and develop the EarthProbe high-resolution resistivity/IP surface and borehole system in collaboration with **Geoserve Logging and Tomography** (Markham, Ont.). EarthProbe operates in four configurations to allow rapid and accurate imaging of the subsurface: surface DCIP, borehole profiling, borehole-to-borehole tomography, and surface-to-borehole tomography. Building on previous R&D test work, EarthProbe expanded its surface survey capabilities to include longer electrode arrays (up to 1.2 km in length providing theoretical depth of investigation between 300 metres and 400 metres), winter surveys over frozen ground and lakes, and boat-towed arrays over open water. With the assistance of IRAP funding provided by **NRCan**, EarthProbe's borehole system was used in increasingly wider-spaced holes, proving its borehole-to-borehole imaging capability for holes with 350 metres separation and ability to resolve mineralized gold zones less than 4 metres thick under a variety of host-rock conditions. CCIC also worked extensively with commercial software developers to ensure that the high-resolution surface and borehole data collected by the EarthProbe system could be presented and inverted to industry standards and be easily incorporated into a variety of 3-D earth modelling programs.

During 2011, **Delta Epsilon Instruments** of Grand Junction, Colo., developed a new Micro-Density Tool, the GMD-1004. This borehole logging tool uses a small 10 micro-Curie Cs-137 source that does not require a radioactive materials licence in most markets. The company conducted MCNP modelling to derive an optimal source-to-detector spacing and source-holder characteristics for the tool. Delta also incorporated into the GMD-1004 a natural gamma detector with identical measuring geometry for the purposes of subtracting the natural gamma radiation from the apparent density reading. These procedures are done automatically in the DELogger software, permitting a displayed output in engineering units or g/cm^3. The company also began to incorporate both memory and GPS data in the Delta Epsilon SC-133 portable scintillometer as an option for 2012.

Toronto-based **DGI Geoscience** reported significant growth in both acquisition and interpretation services in 2011. Acquisition projects in North America saw DGI field crews operating from coast to coast, and into the Far North. One area of growth was the DGI expertise in Optical (OTV) and Acoustic (ATV) Televiewer surveying. The televiewers provide oriented core/borehole features *in-situ*, under naturally occurring pressure, temperature and stress. This is important information for resource, structural and geotechnical applications. Data are now being acquired at earlier stages of projects for use in multiple stages of project development.

Based on 15 years of borehole logging for quantitative *in-situ* physical rock properties, DGI has developed a new 2-4C process: a statistically robust methodology to assess, interpret and define relationships between physical rock properties and other quantitative data sets, like geochemical, geotechnical, geophysical and assays. Rigorous calibration and standard operating procedures provide true multi-disciplinary integration with accuracy and repeatability, as well as 3-D representation. Two years in development, the launch of the 2-4C ("to foresee") process greatly expands DGI's processing and interpretation services. DGI has also used 2-4C to assess QA/QC. The process bridges the gap between geophysics and other geosciences for true integration of traditionally disparate data sets.

JVX introduced the Clarity3D Downhole Spectral IP/Resistivity (DSIP) System. The result of a multi-year R&D

Time-domain EM equipment (left to right): Geonics' PROTEM CM system; Monex GeoScope's terraTX-50 external transmitter; and Geonics' G-TEM system
Credit: Geonics and Monex GeoScope

program, Clarity3D is a major advancement in downhole IP technology. It is used to map orebodies and mineralization intersected by drill holes, and can detect anomalies up to 200 metres off-hole. The system can survey drill holes to a depth of 3 km, collared from surface or from underground workings. Clarity3D can acquire large volumes of data compared to conventional downhole IP systems because it uses up to 10 potential electrodes, with all cables inside one shielded sheath. Thus, each measurement records up to 10 times the data of a conventional IP system. The system reduces EM coupling through the use of custom-designed cables, and collects high-resolution data with a high signal-to-noise ratio. Clarity3D allows flexible setup with different electrode arrays, including gradient, cross-hole, pole-dipole, and mise-à-la-masse, and fast, efficient data collection. The data are used to compute 2-D and 3-D conductivity and chargeability inverse models, to help direct further drilling.

Scintrex has built a borehole gravity training facility in Concord, Ont., where it it based. The company, which commercialized its Gravilog borehole gravity meter in Canada in co-operation with **Abitibi Geophysics,** will make the Gravilog systems available internationally this year for applications including mining, petroleum, geotechnical and research.

Discovery International Geophysics conducting a SQUID TEM survey in Kazakhstan
Credit: Discovery International Geophysics

Ground Electromagnetic Methods

Discovery International is now using the Jessy Deep SQUID sensor with SMARTemV and SMARTem24 receivers from **Electromagnetic Imaging Technology (EMIT)** of Perth, and high-powered transmitters from **Phoenix Geophysics** (Toronto) and **Zonge International** (Tucson, Ariz.), in deep exploration for highly conductive targets. Survey work has expanded from the original base of operations in the Athabasca basin of northern Saskatchewan to the rest of Canada and overseas to Kazakhstan and Portugal. A test survey in 2010 over **HudBay Minerals**' Lalor zinc-gold deposit, in Manitoba, obtained the highest signal-to-noise TEM data ever obtained over this kilometre-deep orebody.

GEM Systems of Markham, Ont., based its new "Walking VLF" ground system on a new proprietary tilt system first implemented in its airborne version and then migrated to the ground. The new tilt sensor replaces a previous fluid-filled sensor with a solid state chip, significantly improving accuracy.

The Walking VLF system can be combined with GEM's Walking Magnetometer. Sample rates between 1 and 10 Hz are used for walking or mobile surveys, respectively. Data include in-phase, out-of-phase, horizontal component (x), vertical component (y), and field strength in pT.

In 2011, Mississauga, Ont.-based **Geonics** developed two new time-domain systems: PROTEM CM and G-TEM. The PROTEM CM system, which is based on the well known PROTEM technology, combines the PROTEM receiver and TEM47 battery-operated transmitter in a single unit, smaller in size and about half the weight of the individual receiver and transmitter components. An internal lithium-ion battery powers both the receiver and transmitter section, providing up to eight hours of operation and 24 volts power. The receiver section is compatible with all other Geonics transmitters in the reference-cable mode of operation.

Geonics has developed a new time-domain EM system, G-TEM, aiming to reduce cost while maintaining the core performance of the more advanced PROTEM systems, and adding several new features. The G-TEM's features include: an integrated Panasonic Toughbook computer with 10-inch colour display, user programmable receiver gate positions, single, multiple or continuous records, multiple data presentation formats, data inversion software, built-in GPS and 320 GB of data storage. The modular design allows receiver and transmitter sections to operate as a single console, or individually, to accommodate different layout requirements. The total console weight, including a set of batteries for the transmitter and a

set for the receiver section, is only 13 kg.

GroundMetrics Inc. (GMI) of San Diego, is developing a new type of electric field (E-field) sensor for applications involving measurements of E-fields on land, through subsurface resistivity imaging, that employs a chemically inert electrode and couples to the E-field via capacitive coupling. The GMI sensor, based on work of sister company **QUASAR Federal Systems** (also in San Diego) for defence and homeland security applications, provides accurate measurements of the electric field. The device contacts the ground via a proprietary metal surface that is ruggedized and weather-proofed to last for several years, even in extreme conditions. The electrodes connect to a 24-bit data-acquisition unit that records electric field data from 0.03Hz to over 1kHz. The signal source can be any artificial EM source, or natural (e.g. MT or AMT) source. GroundMetrics is working with **Technoimaging** to provide an acquisition, processing and 3-D inversion service.

Mineral, oil and geothermal exploration and production will be a company focus, particularly in places where galvanic systems don't work well, like dry desert and frozen tundra. The electrodes can be used in mineral exploration surveys with IP, MT and CSEM. The key performance characteristic of the GMI sensor is that the sensor output to a constant signal does not vary with the ground resistance.

In 2011, **Lamontagne Geophysics** reported two new hardware developments with inductive source resistivity (ISR), and with UTEM 5. The main development in ISR technology was the use of capacitive electrodes designed for measurement in very arid areas. The new system was used for ISR imaging surveys at 2 Hz base frequency.

Lamontagne field-tested its new UTEM 5 surface EM system, which demonstrated very high sensitivity, particularly in low-frequency measurements. The main features tested were: three-component data reduction, making use of accelerometer measurements for orientation, and simultaneous measurements of the response with up to three transmitter loop locations. The system includes a new sensor, receiver and reduction software.

Monex GeoScope, the developer,

GEM Systems "Walking VLF" ground EM system
Credit: GEM Systems

manufacturer and distributor of terraTEM, continued to improve its range of transient EM products. First introduced in 2010, the fully integrated, high-powered 5 kW terraTX-50 external transmitter was designed for use with the terraTEM. Maximum loop voltage was increased to 250 V from 100 V. In 2012, the company plans to implement significant increases in output power and a new graphical touchscreen interface that will provide information on the transmitter performance status, and key information from the internal GPS and crystal synchronization, as well as controlling the transmitter waveform.

In other developments, the VECTEM 5, a three-component downhole receiver probe for use with the surface terraTEM, is now available in 42-mm or 31-mm OD, and the magPI, a 32-mm B-field probe, was introduced. Monex is working to integrate its terraTEM products with third-party software and hardware. Customization of external housing and GUI are now also possible. For example, a simultaneous 200 kHz 32-channel system multiplexed to 96 channels was developed for an application requiring high-resolution sampling.

Gravity Surveying

Micro-g LaCoste continued to expand its 4-D gravity survey business, using its A10 absolute gravimeters. The absolute-gravity meter is preferred for 4-D applications where the drift of relative-gravity meters will interfere with the long-period, low-amplitude gravity signal. The company also completed a major upgrade of the FG-5 absolute gravimeter dropper, now called the FG-5X, which eliminates rebound and greatly extends the useful drop length.

Induced Polarization

Discovery International has developed an innovative IP and resistivity survey procedure called MRI-32 (Multipole Resistivity Imaging: 32 channels), which obtains pole-dipole, pole-pole and reverse pole-dipole (dipole-pole) array data in one pass along a survey line. The combination of data from three different electrode arrays enhances resolution in a common inversion using Geotomo RES2DINV. The reversed pole-dipole data eliminates the bias from a single pole-dipole data set, and the pole-pole data adds information at increased depth. The company developed survey procedures to obtain continuous data over land, swamp and open water more productively and economically than distributed-array IP/resistivity systems, which produce similar data.

In 2011, **GF Instruments** of Brno, Czech Republic, introduced a new model of the standard version of the ARES instrument for resistivity and IP tomography, equipped with a powerful (850 W) transmitter (2000 Vp-p, 5 A). The unit can be powered from a 12 V battery or from a generator (via AC/DC convertor) while maintaining full transmitter performance for multi-electrode cable measurement and for VES. The new, easily portable ARES system in its compact waterproof

Micro-g LaCoste's FG-5X absolute gravimeter dropper
Credit: Micro-g LaCoste

left: Instrumentation GDD's 32 channel IP receiver
Credit: Instrumentation GDD

right: GF Instruments' ARES instrument for resistivity and IP tomography
Credit: GF Instruments

casing, can be used in surveys with very high or low ground resistivity and achieve a much better depth of investigation.

Last year, Quebec City-based **Instrumentation GDD** developed new options to install an internal GPS inside all GDD IP receivers (from 2 to 32 channels) to record precise time with full-wave data for post-processing. With the new, small, inexpensive and lightweight GDD IP 2-channel IP receiver and the GPS option, the telluric/noise can be recorded and removed from resistivity/IP data for better readings. With GDD IP receivers, small chargeability variations can be detected even in noisy environments. New external connectors are now installed on the Pelican box to connect the electrodes to the receiver and to connect the battery pack, which enables the box to be kept closed in the field. The IP receivers also have new internal lithium-ion batteries with longer life and operating time. In 2012, all GDD receivers will have these features and older models can be upgraded.

JVX made major advances in developing proprietary spectral IP computation software and has used it with several IP/Resistivity data sets collected in Canada and elsewhere. The company's Surface Spectral IP Computation Technique has aided discovery of significant gold mineralization in follow-up drilling programs. In conventional IP/Resistivity surveys, the chargeability is measured as an average of the decaying secondary voltage after shut-off. In spectral IP, the receiver samples the decaying voltage many times, defining the shape of the decay curve. The curve characteristics are then analyzed using the Cole-Cole model. This model is defined by four independent parameters which represent physical properties of the subsurface, namely resistivity (R), chargeability (M), time constant (Tau) and the dimensionless exponent (C). JVX's software performs spectral IP (MIP) computation on all measured decays from any IP receiver and outputs the most important parameters: MIP, Tau and C. The parameters MIP (related to the volume percent metallic sulphides) and Tau (related to grain size) are the most useful to characterize anomalies that have similar resistivity and chargeability. In gold exploration, these parameters provide information for picking and prioritizing drill targets. The software also has potential for identifying new targets by reprocessing older data sets.

right: The Terraplus KT-10 S/C magnetic susceptibility/conductivity meter
Credit: Terraplus

Scintrex's ENVI Cs cesium vapour magnetometer
Credit: Scintrex

Ground Magnetic Surveying

The **GDD** MPP-EM2S+ probes measure the magnetic susceptibility (10^{-6} SI) and the relative and absolute conductivity (Mhos/m) of objects such as drill core and field samples. The magnetic susceptibility and conductivity information is used for planning magnetic and EM geophysical surveys. Typically, the MPP probe can be used in a core-shack environment with a Somo 650-M handheld PDA, or in the field with the more robust Juniper Archer handheld PDA. The software has been updated to add a geometric factor that automatically corrects magnetic susceptibility values for core diameters or flat surface. A new single-reading mode freezes the display after a reading and new circuitry protects the MPP probe against use of the wrong power supply.

Scintrex upgraded its magnetometers with the introduction of the ENVI p+ to replace the ENVI and ENVI PRO proton magnetometer and the ENVI Cs to replace the NavMag cesium magnetometer while retaining the features of the original magnetometers. The ENVI p+ and the ENVI Cs use the same console, so the sensors are interchangeable with minimal effort.

Terraplus of Richmond Hill, Ont., introduced the KT-10 S/C magnetic susceptibility/conductivity meter for measurements on rock samples or drill core. The KT-10 S/C can simultaneously measure magnetic susceptibility and conductivity or measure magnetic susceptibility or conductivity independently. The instrument comes with an Android application

Sensors & Software's new version of the IceMap GPR system
Credit: Sensors & Software

(compatible with Android-operated smart phones or tablets) for real-time profiling when measuring magnetic susceptibility and conductivity simultaneously. The measurement range for conductivity is 1 to 10,000 S/m, extendable to 100,000 S/m. Its sensitivity for magnetic susceptibility is 1 x 10^{-6} SI units, the same as the KT-10 magnetic susceptibility meter. Other KT-10 features maintained in the KT-10 S/C include Bluetooth wireless communication, large memory, graphical display and GeoView; a data visualization and post-processing software.

Ground Penetrating Radar (GPR)

EXIGE and partner **Open Ground Resources** offer GPR for high-resolution mapping of the shallow subsurface. Projects in 2011 included mapping of shallow voids, mining and mineral exploration, with antennas ranging from 40 to 1000 MHz for applications with various depths and resolutions.

Last year, Mississauga, Ont.-based **Sensors & Software** introduced a new generation of IceMap, a GPR system designed specifically for rapid profiling of ice thickness on winter roads. The new IceMap system includes: a wireless, fully integrated tow sled including GPS, automatic picking of ice thickness with continuous graphical and numerical display, thin ice warning indicator, data sampling tied to driving speed, simplified ice coring calibration, easy review of recorded data to find all locations thinner than a user-defined threshold, coincident display of real-time survey path on Google Earth, IcePicker PC software with data export in a variety of formats for health and safety reports, GIS platforms and overlays on Google Earth.

Seismic

Micro-g LaCoste introduced a new long-period seismometer in 2011, the LPS-1, which is smaller and more affordable than its successful gPhone gravity monitoring meter.

Micro-g-LaCoste's new long period seismometer
Credit: Micro-g-LaCoste

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Companies and Websites

Abitibi Geophysics Inc.: www.ageophysics.com
Aerogeophysica Inc.: www.aerogeo.ru
Aeroquest Airborne: www.aeroquest.ca
AirWatch: www.alto-air.com
AMIRA International: www.amira.com.au
Bell Geospace Inc.: www.BellGeo.com
BRGM: www.BRGM.fr
Canadian Exploration Geophysical Society: www.KEGSonline.org
Caracle Creek International Consulting Inc.: www.caraclecreek.com
Condor Consulting Inc.: www.CondorConsult.com
Delta Epsilon Instruments: www.DeltaEpsilon.com
DGI Geoscience Inc.: www.dgigeoscience.com
Discovery International Geophysics: www.discogeo.com
Electromagnetic Imaging Technology: www.electromag.com.au
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Firefly Aviation Ltd.: www.FireflyAviation.com
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Geotechnologies: www.gtcomp.ru
GF Instruments: www.GFinstruments.cz
Global Geophysical: see www.openground.co.za
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Gravimetric Technologies: www.CanadianMicro-Gravity.com
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LiDAR Services International Inc.: www.Li-DARServices.com
Medusa Systems BV: www.medusa-online.com
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Ministère des Ressources Naturelle et de la Faune: www.mrn.gouv.qc.ca
Ministry of Northern Development and Mines: www.mndm.gov.on.ca
Mira Geoscience: www.MiraGeoscience.com
Monex GeoScope: www.MonexGeoScope.com.au
MPX Geophysics Ltd.: www.MPXgeophysics.com
NASA's ICE Bridge project: www.espo.nasa.gov/oib
Natural Resources Canada: www.nrcan.gc.ca
Novatem Inc.: www.novatem.com
Open Ground Resources: www.openground.co.za
Phoenix Geophysics: www.Phoenix-Geophysics.com
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Triumph Surveys Inc.: info@triumphsurveys.com
Tundra Airborne Surveys Ltd.: www.tundraair.com
United States Geological Survey: www.usgs.gov
UQAT: www.UQAT.ca
Victoria Department of Primary Industries: www.dpi.vic.gov.au
Zonge International: www.Zonge.com

Abbreviations (for acronyms used in the text)

A	Ampere
AC	Alternating Current
AEM	Airborne EM
AFMAG	Audio Frequency Magnetotellurics
a.g.l.	above ground level
AMT	Audiofrequency MT
a.s.l.	above sea level
B	Magnetic Field
dB/dt	rate of change of B with time
CSEM	Controlled Source EM
DC	Direct Current
EM	Electromagnetic
GB	GigaByte
GIS	Geographic Information Systems
GPR	Ground Probing Radar
GPS	Global Positioning System
HRAM	High Resolution Air Mag
HT	High Temperature
Hz	Hertz = cycles per second
IP	Induced Polarization
IRAP	Industrial Research Assistance Program
ISR	Inductive Source Resistivity
kW	kiloWatt
LiDAR	Light Detection And Ranging
MCNP	Monte Carlo N-Particle
MT	MagnetoTelluric
NASA	National Aeronautic and Space Administration
NIA	Dipole Moment of EM loop (N= Number of turns, I= current, A= area)
OD	Outside Diameter
PDA	Personal Data Assistant
pT	pico Tesla
QC/QA	Quality Control / Quality Assurance
RMIT	Royal Melbourne Institute of Technology
ROV	Remotely Operated Vehicle
STC	Supplementary Type Certificate
SQUID	Superconducting Quantum Interference Device
TDEM	Time Domain EM
TEM	Transient EM (= TDEM)
UAV	Unmanned Airborne Vehicle
UBC	University of British Columbia
UTEM	University of Toronto EM
V	Volt
VES	Vertical Electric Sounding
Vp-p	Volts peak-to-peak
VMS	Volcanogenic Massive Sulphide
VLF	Very Low Frequency
VTOL	Vertical Take-Off and Landing
W	Watt
XRF	X-Ray Fluorescence

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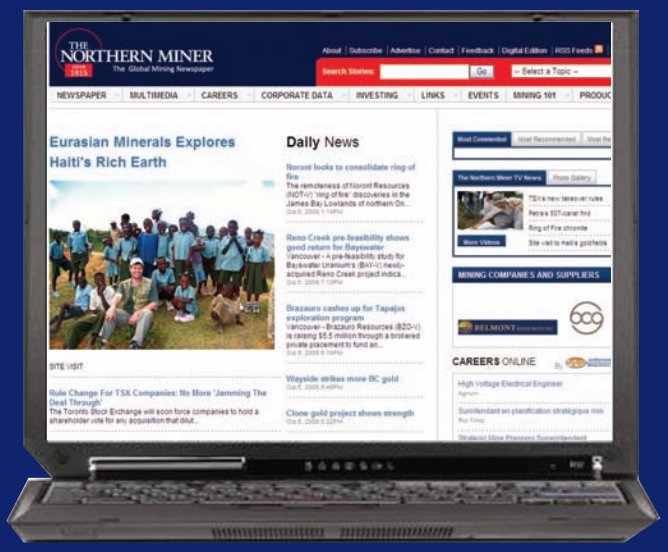

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AS A CONTRACT SERVICE 2012 **(1/April/2012)**
Compiled by P.G. Killeen, R.R. #1, Ompah, ON K0H 2J0 **(Sheet 1 of 3)**

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Aeroquest Airborne (Bob Motz)	7687 Bath Road Mississauga ON L4T 3T1	Tel: 905-672-9129 Fax: 905-672-7083 sales@aeroquest.ca www.aeroquest.ca	H: AeroTEM, Impulse (FEM), Triaxial Magnetic Gradiometry, CAR/FEM, CAR/TEM, CAR/AM FW: AM, AR, AG,TEM
EON Geosciences Inc. (Khaled Moussaoui)	6500 Trans-Canada St 120 Ville St-Laurent QC H4T 1X4	Tel: 514-341-3366 Fax: 514-341-5366 info@eongeosciences.com www.eongeosciences.com	FW: AM, AG, CAM/AR, VLFEM CAM/AEM Horizontal Gradiometer H: AM, AG, FEM, TEM, CAM/AR, VLFEM CAM/AEM/AR
Firefly Aviation Ltd. (Bruce Evans)	Springbank Airport Unit #4 550 Hurricane Dr. Calgary AB T3Z 3S8	Tel: 403-246-8083 Fax: 403-202-1493 Bruce.Evans@fireflyaviation.com	FW: AM
Fugro Airborne Surveys (OTTAWA) (Terry McConnell)	2191 Thurston Drive Ottawa ON K1G 6C9	Tel: 613-731-9575 Fax: 613-731-0453 Ottawa@fugroairborne.com www.fugroairborne.com	FW: AM, CAM/AEM, CAM/AEM/AR, CAM/AR, AG (FALCON Gravity Gradiometer) (AEM as TEM) (AM as Total field and Horizontal gradient)
Fugro Airborne Surveys (TORONTO) (Gregory Paleolog)	2505 Meadowvale Blvd. Mississauga ON L5N 5S2	Tel: 905-812-0212 Fax: 905-812-1504 Toronto@fugroairborne.com www.fugroairborne.com	H: AM, AEM, CAM/AEM, CAM/AR, CAM/AEM/AR, AG (FALCON Gravity Gradiometer) (AEM as TEM and FEM) (AM as Total Field, Horizontal, Vertical & Triaxial Gradiometer)
Geodata Solutions Inc. (Mouhamed Moussaoui)	1054 des Pervenches Laval QC H7Y 2C7	Tel: 514-867-9990 Fax: 450-689-1013 mmoussaoui@geodatasolutions.ca www.geodatasolutions.ca	FW: AM, CAM/AR H: AM, CAM/AR

***NOTATION:** AM - Aeromagnetic; CAM/AEM - Combined Aeromagnetic/Airborne EM; CAM/AR - Combined Aeromagnetic/Airborne Radiometric etc.; VLFEM - Very Low Frequency EM, AG - Airborne Gravity, FEM - Frequency Domain, Helicopter-H, FW-Fixed Wing, TEM - Time Domain, UAV - Unmanned Airborne Vehicle

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Geotech Ltd. (Ed Morrison)	245 Industrial Parkway N Aurora ON L4G 4C4	Tel: 905-841-5004 Fax: 905-841-0611 info@geotech.ca www.geotech.ca	H-TEM: VTEM Natural Field EM (AFMAG): ZTEM Hummingbird FEM CAM/EM, CAM/AR FW: CAM/AG Transverse & Longitudinal Magnetic Gradiometer
Goldak Airborne Surveys (Ben Goldak)	#2 Hangar Road Saskatoon SK S7L 5X4	Tel: 306-249-4474 Fax: 306-249-4475 info@goldak.ca www.goldak.ca	Fixed Wing: AM, CAM/AR, Transverse & Longitudinal, Vertical Gradiometer, VLFEM
MPX Geophysics Ltd. (Daniel McKinnon)	25 Valleywood Drive Unit 14 Markham ON M2N 7C4	Tel: 905-947-1782 Fax: 905-947-1784 Info@ MPXGeophysics.com www.MPXGeophysics.com	FW: AM, Transverse, Longitudinal, Vertical, AR, CAM/AR H: AM, Transverse, Longitudinal, Vertical Gradiometer, CAM/AR
New-Sense Geophysics Ltd. (Andrei Yakovenko)	195 Clayton Drive Unit 11 Markham ON L3R 7P3	Tel: 905-480-1107 Fax: 905-480-1207 info@new-sense.com www.new-sense.com	FW: Horizontal AM, CAM/AR H: CAM/AR
Novatem Inc. (Pascal Mouge)	1087, Chemin de la Montagne Mont-Saint-Hilaire QC J3G 4S6	Tel: 450-464-1655 Cell: 514-966-8000 Mouge@NOVATEM.com www.NOVATEM.com	H: COLIBRI AM, CAM/AEM, CAM/AR, CAM/AEM/AR; NOVATEM TDEM & Resistivity F: CAM/AR

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COMPANY (President or Senior Officer)	ADDRESS OF MAIN OFFICE	TELEPHONE NO.,/FAX NO., E-MAIL/WEBSITE	TYPES OF SURVEY OFFERED*
Oracle Geoscience International (Peter Moore)	2639 McCallum Avenue Regina SK S4S 0P6	Tel: 705-849-8224 info@oraclegeoscience.com www.OracleGeoscience.com	FW: AM, CAM/AR Transverse Longitudinal, Vertical & Triaxial Gradiometer
Precision Geosurveys Inc. (Harmen Keyser)	520-355 Burrard St. Vancouver BC V6C 2G8	Tel: 604 484 9402 Fax: 604 669 5715 info@precisiongeosurveys.com www.precisiongeosurveys.com	H: AM, CAM/AR Triaxial Gradiometer, VLFEM LiDAR
Sander Geophysics Ltd. (Stephan Sander & Luise Sander)	260 Hunt Club Road Ottawa ON K1V 1C1	Tel: 613-521-9626 Fax: 613-521-0215 info@sgl.com www.sgl.com	FW: AM, CAM/AR/VLFEM, AG, Scanning LiDAR Transverse & Longitudinal, Vertical Gradiometer/VLFEM H: CAM/AR/VLFEM, AG, Vertical Gradiometer/VLFEM, LiDAR
Scott Hogg & Assoc. Ltd. (Scott Hogg)	85 Curlew Drive, #104 Toronto ON M3A 2P8	Tel: 416-444-8245 Fax: 416-444-4409 scott@shageophysics.com www.shageophysics.com	H: Triaxial Magnetic Gradiometer
Terraquest Ltd. (Howard A. Barrie)	2-2800 John Street Markham ON L3R 0E2	Tel: 905-477-2800 Fax: 905-477-2820 info@terraquest.ca www.terraquest.ca	FW: AM, Transverse & Longitudinal, Gradiometer/VLFEM/AR, XTerra EM H: CAM/VLFEM/ AR, AEM Resistivity
Tundra Airborne Surveys Ltd. (John Charlton)	65 Dorchester Blvd. Unit 48, St Catharines ON L2M 7T7	Tel/Fax: 289-362-1609 Mobile: 416-432-9657 Info@ TundraAir.com www.TundraAir.com	FW: AM, CAM/AR/VLFEM, Transverse & Longitudinal Gradiometer

***NOTATION: AM - Aeromagnetic; CAM/AEM - Combined Aeromagnetic/Airborne EM; CAM/AR - Combined Aeromagnetic/Airborne Radiometric etc.; VLFEM - Very Low Frequency EM, AG - Airborne Gravity, FEM - Frequency Domain, Helicopter-H, FW-Fixed Wing, TEM - Time Domain, UAV - Unmanned Airborne Vehicle**

Manufacturers and Principal Distributors of Mining Geophysical and Geochemical Equipment & Software in Canada 2012; Compiled by P.G. Killeen, R.R. #1, Ompah, ON K0H 2J0 (1/April/2012)

COMPANY	TELEPHONE (FAX)	E-MAIL/WEBSITE	SENIOR OFFICER
APEX PARAMETRICS LTD. P.O. Box 818 Uxbridge ON L9P 1N2	905-852-5875	apex_parametrics@on.aibn.com	Tapio Vaarre
CRONE GEOPHYSICS & EXPLORATION LTD. 3607 Wolfedale Rd Mississauga ON L5C 1V8	905-270-0096 (905-270-3472)	bravenhurst@cronegeophysics.com www.cronegeophysics.com	William (Bill) Ravenhurst
DUALEM INC. 540 Churchill Ave Milton ON L9T 3A2	905-876-0201 (905-876-2753)	inbox@dualem.com www.dualem.com	Rick Taylor
EXPLORANIUM 60 Queen St, Suite 1516 Ottawa ON K1P 5Y7	613-563-7242 (613-563-3399)	bryan.d.rockwood@saic.com www.saic.com/products/security	Bryan Rockwood
FUGRO AIRBORNE SURVEYS 2191 Thurston Dr Ottawa ON K1G 6C9	613-731-9575 (613-731-0453)	Ottawa@fugroairborne.com www.fugroairborne.com	Terry McConnell
GEM SYSTEMS INC. 135 Spy Court Markham ON L3R 5H6	905-752-2202 (905-752-2205)	info@gemsys.ca www.gemsys.ca	Dr. I. Hrvoic
GEONICS LTD. Unit 8, 1745 Meyerside Dr Mississauga ON L5T 1C6	905-670-9580 (905-670-9204)	geonics@geonics.com www.geonics.com	Miro Bosnar
GEOSENSORS INC. 66 Mann Ave Toronto ON M4S 2Y3	416-483-4691 (416-483-9909)	scott.holladay@geosensors.com	Scott Holladay
GEOSOFT INC. 207 Queens Quay West-Suite 810 Toronto ON M5J 1A7	416-369-0111 (416-369-9599) 1-800-363-6277	info@geosoft.com www.geosoft.com	Tim Dobush
GEOTECH LTD. 245 Industrial Parkway North Aurora ON L4G 4C4	905-841-5004 (905-841-0611)	info@geotech.ca www.geotech.ca	Ed Morrison
ICEFIELD TOOLS CORP. P.O. Box 30085 #300-116 Galena R Whitehorse YK Y1A 5M2	867-633-4264 (867-633-4217) 1-877-423-3435	info@icefieldtools.com www.icefieldtools.com	Erik Blake
IFG CORPORATION 26 Bramsteele Rd, Unit 2 Brampton ON L6W 1B3	905-451-5228 (905-451-2877)	info@ifgcorp.com www.ifgcorp.com	Detlef Blohm
INSTRUMENTATION GDD INC. 860 Boulevard de la Chaudière, St. 200 Québec QC G1X 4B7	418-877-4249 (418-877-4054)	gdd@gdd.ca www.gdd.ca	Pierre Gaucher
KROUM VS INSTRUMENTS LTD. 2206-701 Don Mills R Toronto ON M3C 1R9	416-421-6313	kstamenkov@kroumvsinstruments.com www.kroumvsinstruments.com	Kroum Stamenkov

Manufacturers and Principal Distributors of Mining Geophysical and Geochemical Equipment & Software in Canada 2012; Compiled by P.G. Killeen, R.R. #1, Ompah, ON K0H 2J0 (1/April/2012)

COMPANY	TELEPHONE (FAX)	E-MAIL/WEBSITE	SENIOR OFFICER
LAMONTAGNE GEOPHYSICS LTD. 115 Grant Timmins Dr Kingston ON K7L 4V4	613-531-9950 (613-531-8987)	lamont@kos.net www.lamontagnegeophysics.com	Dr. Yves Lamontagne
MARINE MAGNETICS 135 Spy Court Markham ON L3R 5H6	905-709-3135 (905-479-9484)	info@marinemagnetics.com www.marinemagnetics.com	Melissa Marlowe
PATERSON, GRANT & WATSON LTD. 155 University Ave, St. 1710 Toronto ON M5H 3B7	416-368-2888 (416-368-2887)	pgw@pgw.on.ca www.pgw.on.ca	Dr. D. James Misener
PHOENIX GEOPHYSICS LTD. Unit 3, 3781 Victoria Park Ave Scarborough ON M1W 3K5	416-491-7340 (416-491-7378)	mail@phoenix-geophysics.com www.phoenix-geophysics.com	Leo Fox
PICODAS GROUP CORP. Suite 308, Unit 24, 155 E Beaver Creek Rd Richmond Hill ON L4B 2N1	905-305-0515 (905-305-0525)	picodas@bellnet.ca www.picodas.com	Frank Bottos
PICO ENVIROTEC INC. 222 Snidercroft Rd Concord ON L4K 2K1	905-760-9512 (905-760-9513)	pei@picoenvirotec.com www.picoenvirotec.com	Keith Hall
RADIATION SOLUTIONS INC. 386 Watline Ave Mississauga ON L4Z 1X2	905-890-1111 (905-890-1964)	sales@radiationsolutions.ca www.radiationsolutions.ca	Jens Hovgaard
RMS INSTRUMENTS LTD. 6877-1 Goreway Dr Mississauga ON L4V 1L9	905-677-5533 (905-677-5030)	rms@rmsinst.com www.rmsinst.com	Onorio Rocca
SCINTREX LTD. 222 Snidercroft Rd Concord ON L4K 2K1	905-669-2280 (905-669-6403)	Scintrex@scintrexltd.com www.scintrexltd.com	Chris Nind
SCOTT HOGG & ASSOC. 85 Curlew Drive, #104 Toronto ON M3A 2P8	416-444-8245 (416-444-4409)	scott@shageophysics.com www.shageophysics.com	Scott Hogg
SENSORS & SOFTWARE INC. 1040 Stacey Court Mississauga ON L4W 2X8	905-624-8909 (905-624-9365)	sales@sensoft.ca www.sensoft.ca	Dr. Peter Annan
W. SODIN (GRAVITY) LTD. Unit 18, 95 West Beaver Creek Rd Richmond Hill ON L4B 1H2	905-886-8632 (905-886-4477)		Wolf Sodin
TERRAPLUS INC. Unit 12, 52 West Beaver Creek Rd Richmond Hill ON L4B 1L9	905-764-5505 (905-764-8093)	sales@terraplus.ca www.terraplus.ca	Claude B. Meunier

COMMERCIALLY-AVAILABLE INDUCED POLARIZATION (IP) EQUIPMENT 2012
Compiled by P.G. Killeen, R.R. #1, Ompah, ON K0H 2J0

(1/April/2012)

Manufacturer (Country)	(TD=Time Domain FD=Freq.Domain ϕ =Phase S=Spectral)	Transmitter Model No.	Cycling Time or Frequency	Transmitted Power	Transmitter Power Source (MG=Motor Generator)	Transmitter Weight	Receiver Model No.	Sensitivityor Accuracy	VoltageRange	MicroprocessorControlled/Data Memory	Receiver Weight
IRIS Instruments (France)	TD & FD	VIP 3000		3000 W	45 - 450 Hz 1 phase	16 kg					
	TD & FD	VIP 4000	.0625 - 4 Hz	4000 W	45 - 450 Hz 1 phase	16 kg	ELREC 6	0.01 mV/V0.6% typ. accuracy	10 µV to 10 V	Yes/2500stations	8 kg
	TD & FD	VIP 5000		5000 W	45 - 800 Hz 1 or 3 phases	23 kg	ELREC 10	0.01 mV/V0.6% typ. accuracy	10 µV to 15 V	Yes/3200stations	9 kg
	TD & FD	VIP 10000		10000 W	45 - 800 Hz 1 or 3 phases	35 kg					
Instrumentation GDD Inc. (Canada)	TD	Tx 1800W 2400V		1800 W	120 V, 60 Hz optional 240 V, 50-60 Hz	20 kg	GR x 8-32 8 channels	.005 mV/V0.5% typ.	5 µV to 16 V	PDA 128 MB/RAM 4GB/HD	7.1 kg
	TD	DM 3600W4800V	2 seconds	3600 W Dual Mode	120 V, 60 Hz optional 240 V, 50-60 Hz	2 x 20 kg	GR x 8-32 16 channels	.005 mV/V0.5% typ.	5 µV to 16 V	PDA 128 MB/RAM 4GB/HD	7.6 kg
	TD	Tx 3600W 2400V	with Optional 0.5,1, 2, 4, 8, DC	3600 W	240V, 50-60 Hz	32 kg	GR x 8-32 24 channels	.005 mV/V0.5% typ.	5 µV to 16 V	PDA 128 MB/RAM 4GB/HD	8.1 kg
	TD	DM 7200W - 4800V		7200 W Dual Mode	240V, 50-60 Hz	2 x 32 kg	GR x 8-32 32 channels	.005 mV/V0.5% typ.	5 µV to 16 V	PDA 128 MB/RAM 4GB/HD	8.6 kg
	TD	Tx 5000W 2400V		5000 W	240V, 50-60 Hz	45 kg					
	TD	DM 10000W - 4800V		10000 W Dual Mode	240V, 50-60 Hz	2 x 45 kg					
Phoenix Geophysics (Canada)	TD & FD, & phase IP	IPT-1 AC3000 or AC3006	FD:DC-5 Hz TD:1/64 to 4 Hz 25%/50%/75% duty cycle	300 W to 3 Kw	Battery or 1/2/3 Kw MG 400 or 50/60 Hz	17 kg	IPV-1	10 µV 1%	30 µV to 10 V, 5 ranges	No	1 kg

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Phoenix Geophysics (Canada) (cont'd)	TD, FD, ϕ IP & SIP	IPT-1 AC3004 or AC3007	FD &TD: DC-8 KHz 50% duty cycle or external Tx drive	300 W to 3 Kw	Battery or 1/2/3 Kw MG 400 or 50/60 Hz	17 kg	V-2 (ϕ IP)2 ch.	10µV 1%	10 µV to 10 V AGC	Yes internal precision clock	13 kg
	TD, FD, ϕ IP & SIP	T15/T30	FD &TD: DC-8 KHz 50% duty cycle or external Tx drive	15 Kw or 30 Kw	MG-15 or MG-30 400 Hz	T15 : 95 kgT30 : 120 kg	V-4 TD IP ϕ IP SIP 8 ch.	10µV 1%	10 µV to 10 V AGC	Yes, up to 576 Kb RAM	14 kg
	TD, FD & ϕ IP	IPT-2	FD: DC 4 Hz TD: 1/8 Hz	10 Kw	MG-15 400 Hz	39 kg	V-5 TD IP ϕ IP SIP 16 ch.	1µV 1%	1 µV to 10 V AGC	Yes, up to 24Mb (2 Mb standard)	14 kg
	TD, FD & SIP	IPT-6	FD &TD: DC-128 Hz 50% duty cycle	Up to 100 Kw	MG-65 or MG-100 400 Hz	470 kg					
Scintrex (Canada)	TD & FD						IPR-12 8 dipole	Better than 1%	50 µV to 14 V	Yes, 400 readings 8 dipoles	5.8 kg
Zonge (USA)	TD & FD ϕ IP & SIP	GGT-3	DC to 8 kHz	3 KVA	3 Kw MG 400 Hz	30 kg					
	TD & FD ϕ IP & SIP	GGT-10	DC to 8 kHz	10 KVA	5, 7.5 & 10 Kw MG 400 Hz	51 kg					
	TD & FD ϕ IP & SIP	GGT-30	DC to 8 kHz	30 KVA	32 KVA MG 400 Hz	93 kg	GDP-32ii 6 channel	0.03 µV	0.1 µV to 32 V AGC	Yes/32 MB/RAM 4 GB/HD	13.2 kg incl. batt.
	TD & FD	NT-20	DC to 512 kHz	480 W	Batteries	5 kg	GDP-32ii 16 channel	0.03 µV	0.1µ V to 32 V AGC	Yes/32 MB/RAM 4GB HD	19 kg incl. batt.
	TD & FD	ZT-30	DC to 512 Hz	3.6 Kw	Batteries	8 kg					

CAPABILITIES OF AIRBORNE GEOPHYSICAL SURVEY CONTRACTORS 2012
Compiled by P.G. Killeen, R.R. #1, Ompah, ON K0H 2J0 **(1/April/2012)**

COMPANY (Country) Telephone No. Web site	AIRCRAFT Fixed Wing = FW Helicopter = H (Positioning)	AEROMAGNETIC T=Total Field, G=Gradient L, TT, V=Longitudinal, Transverse & Vertical	AIRBORNE ELECTROMAGNETIC (Time domain = TD) (Frequency domain = FD)	AIRBORNE RADIOMETRIC (R), GRAVITY (G) & GRAVITY GRADIENT (GG)
Aerogeophysica Inc. (Russia) T: 7-495-641-1230 www.aerogeo.ru	Antonov-An-26,An-2 FW Ilyushin-Il14 Kamov-KA25,26 H (Ashtec GPS/Glonass)	Scintrex & Geometrics Cs Vapour (T, VG, LG)	6 Freq. Coax/coplanar FW AGP AEM H Towed Bird 4 Freq. Explorer HEM	Picodas PGAM 1000 R (50L) Picodas/PEI GRS 410 (33.6L) AGP G
Aerophysics (Mexico) T: 52-555-590-9928	Cessna 206, Piper Navajo FW Leased H (PNAV-GPS + Video)	Cs Vapour Helimag PMAG 3000 (T)	Explorer HEM H Towed Bird 5 Freq. Coaxial/coplanar	Picodas PGAM 1000 R 256 chan (16L or 33L down + 4L up)
Aeroquest Airborne (Canada) T: 905-672-9129 www.aeroquest.ca	Fletcher FU24 x 2 FW Cessna 206 x 2 PAC750-XL x 4 Cresco 750 x 1 Cessna 406 x 1 Leased H (GPS and Glonass + Video)	Triaxial G (4 sensors) H Scintrex & Geometrics Cs Vapour (T, LG, TTG) FW	AeroTEM IV TD H AeroTEM HD TD Impulse HEM FD	RSI RS-500 R 256-512 chan (16L down + 4L up) Exploranium GR-820 256 chan (16, 32 or 48L) TAGS G GT-1A & 2A
Airmag Surveys (USA) T: 215-673-2012 www.airmag.com	Cessna 320 x 4 FW Cessna 441 (Diff. GPS + Video)	Scintrex & Geometrics Cs Vapour (T)	Totem II VLFEM FW	Geoscience R (49L)
Bell Geospace, Inc. (USA) T: 281-591-6900 www.bellgeo.com	Basler BT-67 FW Cessna 208B Grand Caravan	Geometrics G822A Cs Vapour (T)	NA	Lockheed Martin FTG GG Full Tensor Gravity
Carson Services Inc./Aerogravity Division (USA) T: 215-249-3535 www.aerogravity.com	Twin Otter x 3 FW Sikorsky S-61 H (DGPS, Video Camera)	Geometrics G833 Cs Sensor & Scintrex Cs Vapour (T)	NA	Lacoste & Romberg G Sea/Air 3 axis

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EDCON-PRJ Inc. (USA) T: 303-980-6556 www.edcon-prj.com	Dragon Fly Ultralight FW Leased H	Geometrics Cs Vapour (T)	NA	NA
EON Geosciences Inc. (Canada) T: 514-341-3366 www.eongeosciences.com	Piper Navajo; King Air A90 FW Cessna 206 Piper Cheyenne II Leased H (DGPS, RT-DGPS, Digital Video)	Scintrex & Geometrics Cs Vapour (T, TTG)	THEM TD H Hummingbird FD Herz Totem-2A VLFEM	RSI RSX-5 256 chan R (32L down & 8L up) CMG GT-1A/GT-2A G
EXIGE (South Africa) T: 27-12-259-0651 www.exigesa.com	Kriek IIB x 2 H H (Modified gyrocopter) (GPS, DGPS, Digital colour video camera, digital flight path)	Fluxgate (T, Vectors, TTG optional)	'SP' type experimental device	TBD R 16L and 32 L down 256/512 chan INS-DGPS data G enhancement
Firefly Aviation Ltd. (Canada) T: 403-246-8083/F: 403-202-1493	PA31 Piper Navajo x 3 FW Cessna C206 (RT-DGPS)	Scintrex & Geometrics Cs Vapour (T)	NA	Radiation Solutions R RSX-5Spectrometer

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Fugro Airborne Surveys (Canada) T: 613-731-9575 T: 613-731-0453 www.fugroairborne.com	CASA 212 x 3 FW Cessna 208 Caravan x 2 Cessna 208B Grand Caravan x 12 Cessna 210 x 2 Cessna 404 x 1 Cessna 406 x 4 Piper Navajo x 2 de Havilland Dash 7 x 1 Shorts Skyvan x 1 Commander Shrike x 2 Diamond Twin Star x 4 Chartered Helicopters H (DGPS, RT-DGPS, Digital Video)	Fugro FASDAS FW Scintrex & Geometrics Cs Vapour (T, LG, TTG, VG, Triax) Helimag H (T, LG, TTG, VG, LTTVG, Triax)	MEGATEM ,GEOTEM FW TEMPEST, VLFEM HELITEM (TD, 2M H Am^2 Dipole, Multicoil X-Y-Z Rx) DIGHEM Digital (5 Freq. 900 Hz - 56000 Hz, 2 Coaxial & 3 coplanar coil sets) RESOLVE (6 Frequency, 330 Hz - 138,000 Hz, 1 Coaxial & 5 coplanar coil sets) HEM + MAGTTG + HRAD	Exploranium GR 820 FW R (256/512 chan) (49L down & 8.4L up) RSI RSX-5 H Exploranium GR 820, RSI RS-500 (256/512 chan) (16.8L down 4.2L up) FALCON FW-H GG TAGS FW G CMG GT-1A
Geo Data Solutions Inc. (Canada) T: 514-867-9990 www.geodatasolutions.ca	Piper Navajo FW ASTAR 350, Bell 206 H Robinson R44 (RT-DGPS)	Geometrics & Scintrex Cs Vapour (T, TTG)	Totem-2A VLFEM	RSI RSX-5 (16L down & 4L up) R
Geophysics GPR International Inc. (Canada) T: 450-679-2400 www.GeophysicsGPR.com	Hughes 300 H R44 Bell 206B/L ASTAR BA, B2, B3, Lama	Geometrics Cs Vapour (T, LG, TTG, VG)	GEOPHEX HEM H GEM-2A Towed Bird Multi Freq. Coaxial/Coplanar VLFEM GPRTEM	Pico Envirotec R (16L)
Geotech Ltd. (Canada) T: 905-841-5004 www.geotech.ca	Cessna 208B FW Grand Caravan x 2 Eurocopter AS350-B3 x 2 H	Geometrics G823A Cs Vapour (T, LG, TTG)	Geotech VTEM TD H AFMAG ZTEM FW/H Hummingbird FEM H	RSI RS-500 R CMG GT-1A G

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Goldak Airborne Surveys (Canada) T: 306-249-4474 www.goldak.ca	Piper Navajo x 3, FW Amphibious Cessna Caravan 208 Piper Cheyenne IIXL (DGPS, RT-DGPS, Digital Flight Path Camera)	Geometrics Cs Vapour (T, LG, TTG, VG, Triaxial)	Totem-2A VLFEM	RSI RSX-500 1024 R chan spectrometer (3 systems of 50.4L down & 8.4L up)
Microsurvey Aerogeofísica e Consultoria Científica Ltda (Brazil) T: 55-21-2445-1773 www.microsurvey.net	Cessna 208B FW EMB 820C x2 Piper Navajo PA 31	Scintrex Cs Vapour (T, G)	Ms Relief VLFEM SP-4 MT with 3 Coils	Picodas/PEI GRS 410 R (33.6L) RSI RS-500 256-512 chan (16L down & 4L up) Exploranium GR-820 256 chan (16, 32 or 48L) Lockheed Martin FTG GG Full Tensor Gravity
MPX Geophysics Ltd. (Canada) T: 905-947-1782 www.mpxgeophysics.com	Leased FW Leased H (DGPS RT-DGPS, Video)	Scintrex & Geometrics Cs Vapour (T, TTG)	NA	Pico Envirotec R GRS-10 Spectrometer 256-512 chan (50.4L down & 12.6L up) RSI 500
New-Sense Geophysics (Canada) T: 905-480-1107 www.new-sense.com	Leased: Navajo PA 31, FW Cessna 206 Leased Bell 206 (stinger) H ASTAR (stinger)	Scintrex CS-3 (T, LG)	NA	RSI RSX-500 R
Novatem Inc. (Canada) T: 450-464-1655/C: 514-966-8000 www.NOVATEM.com	Cessna 185, 208 FW Piper Navajo PA 31 Bell 206 H Eurocopter ASTAR D, BA, B2, B3, Lama	GEM Systems K-Vapour (T, LG, TTG, VG) Geometrics Cs-Vapour (T, LG, VG)	NOVATEM TD H	RSI RSX-5 (16L down & 4L up) R

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Oracle Geoscience International (Canada) T: 705-849-8224 www.oraclegeosceince.com	Piper Navajo FW (DGPS, RT-DGPS, Digital Video)	Geometrics Cs Vapour (T, LG, TTG, VG, Triaxial)	NA	RSI R 256-512 chan (16L down & 4L up)
Precision Geosurveys Inc. (Canada) T: 604 484 9402 www.precisiongeosurveys.com	Bell 206, ASTAR AS350 H (GPS, DGPS)	Scintrex Cs Vapor (T, G) (stinger & bird)	Totem 2A VLFEM H	Pico Envirotec GRS-10 R 256/512 chan Up to 16.8L down, 4.2L up Scintrex HeliGrav G
Prospectors A. S. Ltda. (Brazil) T.: 55-21-2502-2526 www.prospectorsbr.com	Piper Chieftain x 2 FW Cessna Grand Caravan x 2 Leased H	Geometrics Cs vapour (T, LG, TTG)	AeroTEM TD H	RSI RS-500 R (40L down, 8L up) X3 CMG GT-2A G
Sander Geophysics Ltd. (Canada) T: 613-521-9626 www.sgl.com	DIAMOND DA-42 x 3 FW Cessna 404 Cessna 208B Grand Caravan x 8 BN Islander x 2 Eurocopter AS-350B3 H (DGPS, RTDGPS + Video Digital Colour Camera)	Scintrex & Geometrics Cs Vapour Sander SMAG (T, LG, TTG, VG)	SGFEM FW Herz Totem-2A VLFEM	Exploranium GR820 R (256 chan) (60L) Sander AIR Grav G
Scott Hogg & Assoc. Ltd. (Canada) T: 416-444-8245 www.shageophysics.com	Leased H (GPS)	Scintrex CS-3 sensors (T, TG, LG, TTG, VG, Triaxial)	NA	NA
SkyTEM Surveys (Denmark) T: 45-8620-2050 www.skytem.dk	Leased Eurocopter B2 or B3 H (GPS)	Geometrics Cs vapour sensors, Kroum counter (T)	SkyTEM TD H	Radiation Solutions R Medusa

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COMPANY (Country) Telephone No. Web site	AIRCRAFT Fixed Wing = FW Helicopter = H (Positioning)	AEROMAGNETIC T=Total Field, G=Gradient L, TT, V=Longitudinal, Transverse & Vertical	AIRBORNE ELECTROMAGNETIC (Time domain = TD) (Frequency domain = FD)	AIRBORNE RADIOMETRIC (R), GRAVITY (G) & GRAVITY GRADIENT (GG)
Spectrem Air (South Africa) T: 27-11-659-1518 www.spectrem.co.za	Basler BT-67 FW (DGPS + video tracking)	Scintrex Cs vapour (T)	Spectrem2000 FW	Exploranium GR820 R (32L)
Terraquest (Canada) T: 905-477-2800 www.terraquest.ca	King Air 90 Turboprop FW Cessna 206 Navajo 325 Leased H (DGPS + Digital Video)	Scintrex Cs Vapour (T, LG, TTG) (T, VG)	XterraEM FW 10-100,000 Hz - 3 coils VLFEM FW/H	Picodas PGAM 1000 R 256 chan (4L, 8L down + 1 up)
Thomson Aviation (Australia) T: +61 2 6964 9487 www.thomsonaviation.com.au	PAC 750XL FW Cessna 210L x 3 Leased H (NovAtel OEMV-1VBS)	Geometrics G822A Cs Vapour (T)	NA	RSI RS-500 R (66L)
Tundra Airborne Surveys (Canada) T: 289-362-1609 www.TundraAir.com	Diamond DA-42 Twin Star FW Piper Navajo x 2 Leased H (DGPS + RT-DGPS + Digital Video)	Scintrex & Geometrics Cs Vp (T, LG, TTG) (T,TG,LG,TTG,VG,TRIAXIAL)	Totem 2A VLFEM	Pico Envirotec R 256 chan (32L down & 4L up)
UTS Geophysics (Australia) T: 61-8-9479-4232 www.uts.com.au	Fletcher FU24 x 2 FW Cessna 206 x 2 PAC750-XL x 4 Cresco 750 x 1 Cessna 406 x 1 Leased H (GPS and Glonass + Video)	Scintrex & Geometrics Cs Vapour (T, LG, TTG)	AeroTEM TD H Impulse HEM FD GEM-2A FD	RSI RS-500 R 256-512 chan (32L down & 4L up) Exploranium GR-820 256 chan (16, 32, 48L) TAGS G CMG GT-1A
Xcalibur Airborne Geophysics (PTY) Ltd. (South Africa) T: 27-12-543-2540 www.xagsa.com	Turbo Islander x 3 FW Airtractor x 2	Geometrics Cs vapour (T, LG, TTG)	NA	Exploranium GR-820 R RSI RS-5OO

MINING GEOPHYSICAL EQUIPMENT AND SOFTWARE COMMERCIALLY AVAILABLE IN CANADA 2012

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AIRBORNE EQUIPMENT						ELECTROMAGNETIC			GROUND EQUIPMENT						
COMPANY	Data Acquisition	Magnetometers	EM	Scint. Spectro-meters	Drillhole	Horl. Loop EM	VLF EM	Other EM	Scint. Spectro-meters	IP	Magnetometers	Resistivity	Gravi-meters	Suscepti-bility Meters	Other & Software
APEX PARAMETRICS						MAX-MIN 1									
CRONE GEOPHYSICS					3D-PEM-500W 3D-PEM-2.4 kW 3D-PEM-4.8kW	CEM	RADEM	Pulse (PEM) 500 w, 2.4 kW, 4.8 kW SHOOT-BACK CEM, VEM		IP-250		PEM Sounding			S
DUALEM								DUALEM-1 DUALEM-2 DUALEM-21 DUALEM-4 DUALEM-42 DUALEM-421 DUALEM-642							
EXPLORANIUM				GR-660 GR-820					GR-135						
FUGRO AIRBORNE SURVEYS															S Custom Solutions
GEM SYSTEMS	DAS (Real time data display & Acquisition) (Software)	Magnetometer GSMP-35A Complete Birds GSMP-35A(B) (Mag) GSMP-35GA(B) (Vertical Gradiometer) GSMP-35GA3(B)	GSM-90AV Airborne VLFEM				GSM-19V (Overhauser w VLF) GSM-19GV (Overhauser Grad w VLF) GSM-19TV (Proton with VLF) GSM-19TGV				<u>Potassium</u> GSMP-35 (Walking) GSMP-35G (Walking Gradiometer) <u>Overhauser</u> GSM-19 GSM-19W (Walking) GSM-19G (Gradiometer) GSM-19GW				

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COMPANY	Data Acquisition	Magnetometers	EM	Scint. Spectro-meters	Drillhole	Horl. Loop EM	VLF EM	Other EM	Scint. Spectro-meters	IP	Magnetometers	Resistivity	Gravi-meters	Suscepti-bility Meters	Other & Software
GEM SYSTEMS (CONT)		(Tri-Axial Gradiometer)					(Proton Grad w VLF) GSMP-35V (Potassium w VLF) GSMP-35GV (Potassium grad w VLF)				(Walking Gradiometer) Proton GSM-8 GSM-19T GSM-19TW (Walking) GSM-19TG (Gradiometer) GSM-19TGW (Walking Gradiometer)				
GEONICS					BH 43 BH 43-3D EM 39 EM 39S MAG 43-3D		EM-16 Tx27	Protem 67,47,57-MK2, CM, 67-Plus EM 42 EM 61-MK2 EM61-MK2-HP EM 61-HH-MK2 EM 63-3DMK2 EM 61-MK2A GTEM				EM 16R EM31-MK-2 EM31-3 EM34-3 EM38 EM31-S EM38DD EM38B EM-38-MK2			DL720 Logger DL600 Logger DAS 70 DAS 70ML Logger S
GEOSENSORS	Custom	Multi-channel High Rate Processors	Custom FDEM, TEM Helicopter Towed Bird & Fixed Mount					EM Sensors							
GEOSOFT															S

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COMPANY	Data Acquisition	Magnet-ometers	EM	Scint. Spectro-meters	Drillhole	Horl. Loop EM	VLF EM	Other EM	Scint. Spectro-meters	IP	Magnetometers	Resistivity	Gravi-meters	Suscepti-bility Meters	Other & Software
GEOTECH LTD.	Hummingbird H-DAS		Humming-Bird FEM VTEM Time Domain ZTEM AFMAG								M200				S
ICEFIELD					MI-03 MI-03N Borehole Surveying & Magnetics										S
IFG					Resistivity Conductivity IP Magnetic Temperature Gamma Density Caliper Tilt Orientation										S
Instrumentation GDD Inc.					SSW Probe Conductivity Susceptibility Nickel Grade			Pulse (PEM) TRM 3600W 10AA - 2400V		TX1800DM 7200W TX3600W RX8-32	MAG-GPS + EM BM7+	MPP-EM2S+ Probe Beep Mat BM8 with GPS		MPP-EM2S+ Probe Beep Mat BM8 with GPS	Chain + Level Density Meter LST
KROUM VS INSTRUMENTS	KANA8 SDAS1-PPC	KMAG4													

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LAMONTAGNE					BHUTEM-4 System	Large Loop EM UTEM3E ISR/UTEM system		Borehole & Surface Tx. UTEM3E Tx. UTEM3E Master/ Slave Tx. UTEM4 & UTEM4B Tx. (11kW)							S
MARINE MAGNETICS					Magnum Magnetometer						Sentinel Base Stn. Mag.				
PATERSON, GRANT & WATSON LTD.															S
PHOENIX	V5-PDAS		V5-TEM		Resistivity & Mag Probe	V5-FDEM	VLF-2	V5 AMT CSAMT MT		IPT-1/2/6 IPV-1 T-15/30 V-2/4/5		RV-1/2 RT-1			CT-2 IP Core Tester S
PICODAS	PDAS P101 AGIS II	HELIMAG II AIRMAG I	Explorer/ C/C 6 Freq.	PGAM 1000, GRS 400 Series											S Mag. Comp.
PICO ENVIROTEC	AGIS-XP IRIS-XP PGIS GEOIMAGE Digital Video Smart Dart	MMS-4 GMAG AUTO-MAG		GRS-10 GRS-16 Autospec Heli-pack Smart Dart					PGIS-S		PGIS-M				PEIcal. Praga 3 (Spectrom. Processing) PEIconv. PEIview

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RADIATION SOLUTIONS INC. (RSI)				RS-500 series RSX-4 (16L) RSX-5 (16L + 4L) RS-501 I/F Console RS-700 series RSX-1 (4L) RS-701 I/F Console RS-705 I/F Console					Handheld: RS-111, 111T NaI RS-120, 120T NaI RS-121, 121T NaI, RS-125, 125T NaI RS-230 BGO Vehicle Mount: RS-700 Series RSX-1 (4L) RS-701 I/F Console RS-705 I/F Console						
RMS INSTRUMENTS	GP 300 DAARC 500 DAS 500	DAARC 500 AARC 500 AARC510 Compensator Geometrics Mags.	Herz Totem 2A				Herz Totem 2A				Base Stn. Mag. Geometrics Portable CS & Proton Mags.				S Windows GP 300 Graph Printer Chart Recorder
SCINTREX		CS-3 CS-3SL					ENVI VLF			IPR-12 Rx GGT Series Tx	NAVMAG ENVIMAG CS-3 ENVI-CS	SARIS	CG-5		Training Custom Design-Consulting S
SCOTT HOGG & ASSOC.															S

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SENSORS & SOFTWARE								PulseEKKO & NOGGIN GPR							S
SODIN													100 100T 200 200T		
TERRAPLUS		GSMP-30A GSMP-30GS GSMP-30G3 GSMP-30G4	GSM-90 AV VLF	RS-500	GyroTracer QL40-ABI QL40-OBI QL40-FWS QL40-MAGSUS QL40-GAMMA QL40-ELOGIP QL40-SGR QL40-CALIPER MagCruiser RCAM-1000	Promis	GSM-19V GSM-19GV T-VLF	GDP-3224 GGT-3 GGT-10 GGT-30 ProeEx -GPR X3M GPR Stratagem Numis Lite Numis Plus Numis Poly GEM-2	RS-111 RS-120 RS-121 RS-125 RS-230 RS-700 Pima SP RT-50	Elrec Pro Elrec 6 Elrec 2 VIP-3000 VIP-4000 VIP-5000 VIP-10000 IP/L QL-ELOGIP	GSM-8 GSM-19 GSM-19G GSM-19W GSM-19T GSMP-35 GSM-90	Syscal kid Syscal R1 Plus Syscal Junior Syscal Pro Ohm-Mapper	Burris	KT-9 KT-10 KT-10 S/C MS-2 QL-MAGSUS	ES-3000 Geode Smartseis Seimographs Borehole Seismic System StrataVisor Viibsit-20 Vibsit-50 Vibsist-3000 WellCadReflex