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KEGS’ Fourth Year as Patron of Exploration Trends & Developments

By Patrick G. Killeen PhD, Geophysical Consultant and retired Research Scientist, Geological Survey of Canada, Ottawa, 2010

The “Trends” review originated with the Geological Survey of Canada (GSC) where for over 40 years scientists 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 18th 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 cooperation among persons interested in these problems.”

Contents

4 2009 — A YEAR OF SURVIVAL AND REBOUND
4 CORPORATE HIGHLIGHTS
6 AIRBORNE GEOPHYSICAL SURVEYING
12 Airborne Data Acquisition and Processing
14 Aeromagnetic Surveying
16 Airborne Electromagnetic Surveying
18 Airborne Gamma-ray Spectrometric Surveying
18 Airborne Gravity Surveying
19 GROUND SURVEY TECHNIQUES
19 Physical Rock Properties and Elemental Analysis
20 Data Processing and Positioning
21 Drillhole Methods
22 Ground Electromagnetic Methods
24 Gravity Surveying
24 Induced Polarization
25 Ground Magnetic Surveying
25 Ground Penetrating Radar (GPR)
25 Ground Radiometric Surveying
26 Companies and Websites
26 Abbreviations

Cover photo:
Geotech VTEM survey being carried out for the Government of Ghana.

Credit: Geotech
2009 — A YEAR OF SURVIVAL AND REBOUND

In 2009, mergers, joint ventures and partnerships continued as synergistic relationships between companies were sought. Airborne geophysical technology saw the development of new acquisition systems, magnetometers, gamma-ray spectrometers and improvements in electromagnetic systems. Several airborne geophysical survey contractors reported a decrease in the number of private sector surveys but an increase in public sector surveys. The result was a smaller number of larger surveys that helped companies ride out the downturn in the economy. Providers of airborne gravity survey services continued to increase in number. Combining magnetic and/or radiometric measurements with airborne gravity has not been unusual, but now a trend towards combining gravity and electromagnetic (EM) surveys is appearing. Today, any contractor can purchase an airborne gravimeter and offer that service for mineral exploration. Gravity anomalies in mineral exploration are relative “pimples” compared to structures that are the targets for oil. The “very high” spatial resolution required to find ore bodies using airborne geophysics has led to the use of small, light airborne platforms ranging from “crop dusters” to Very Light Aircraft (VLA) as well as development of a new Unmanned Airborne Vehicle (UAV). The latter, which seemed promising a few years ago has run into the stumbling block of “permission to fly” beyond the line-of-sight, which has so far hampered the widespread use of the UAV. For airborne EM (AEM), the dipole moment of the systems continues to increase, translating into increased depth of exploration for conductors.

For ground geophysics, 2009 saw the introduction of new borehole logging technology including spectral IP, and a borehole gravimeter. There were significant improvements in data processing software, in EM equipment, a new magnetometer, induced polarization (IP) and resistivity instrumentation and new developments related to ground probing radar (GPR). Elemental analyzers, usually based on x-ray fluorescence (XRF) technology, are becoming more powerful and easier to use. Several new versions were reported this year.

CORPORATE HIGHLIGHTS

For Val d’Or, Que.-based Abitibi Geophysics 2009 was a year of growth. The company established a partnership offering its services in the Maghreb region of North Africa and another in West Africa, opened an office in St. John’s, Nfld., and a business development office in Ottawa. On the technology side, Abitibi Geophysics enhanced its InfiniTEM system to generate a 40,000,000 Am² dipole moment and to measure on-time and off-time dB/dt and B-field. Two new services were introduced:

1. unique borehole logging technology brought to Canada through the Abitibi-Terratec (Germany) joint venture, and
2. mobile equipment that provides an elemental analysis of rock samples in the field (as Canadian agent for Innov-X Systems).

Abitibi Geophysics was a founding member of the Geopolis Geoscientific Centre in Val d’Or, which offers synergistic mining expertise under one roof. This 8,000-sq.-m facility is shared by 11 companies including, Abitibi Geophysics, and its sister companies TerraScope Instruments (also of Val d’Or) and Abitibi-Terratec. Abitibi uses the expanded facilities for equipment manufacture and maintenance as well as a stimulating work environment for the geophysical and operations teams.

Aerogeophysica of Moscow, reported being involved in an airborne gravity project in Brazil with Fugro Airborne Surveys, as part of a long-term cooperative agreement. The survey commenced in June 2009 and employed GT-1A airborne gravimeters.

Following acquisitions in 2008, Aeroquest saw further integration of the various operating units in 2009, including Aeroquest Surveys in Toronto, UTS Aerostream in Perth, Australia, and Geophex in Raleigh, N.C. In October, Optimal Geomatics joined the Aeroquest Group of Companies. With offices in Huntsville, Ala. and Vancouver, B.C., Optimal adds LiDAR and photogrammetry to the range of survey methods offered by Aeroquest. The company continues to offer the Spectrem 2000 fixed-wing airborne EM technology through a partnership with Spectrem Air, a division of Anglo American. Aeroquest reported a shift away from the previously strong mineral exploration markets towards oil and gas and government surveys. The company completed its first full year of airborne gravity survey acquisition using the TAGS (turnkey airborne gravity system) gravimeter. Two TAGS gravimeters are now in operation. They have flown successfully in southeast Asia, Africa and North America.

Aretech Exploration Services (Madrid) reported that its new subsidiary Xcalibur Airborne Geophysics (Johannesburg) continued to successfully acquire and process fixed-wing and helicopter airborne survey data throughout Africa in 2009, and subsidiary Prospectors Aerorelevamentos e Sistemas Ltda. (Rio de Janeiro) expanded its survey operation beyond Brazil to surveys in four other countries. In addition, Prospectors has acquired a new airborne gravity surveying capability.

Discovery International Geophysics, a ground geophysics services provider based in Saskatoon, Saskatchewan with affiliated companies in Guangzhou, China (Discovery China Geophysical Consulting) and St. John’s, Newfoundland (Discovery Atlantic Geophysics), began offering SQUID TEM (Superconducting Quantum Interference Device Transient EM) surveys in 2009 utilizing the Supracon AG high-temperature (liquid nitrogen) SQUID developed by Institute for Photonic Technology (IPHT) in
Jena, Germany. Discovery International has been in business for 12 years and recently concluded an agreement with Supercon AG to be the exclusive, worldwide provider of their Jessy Deep HTS SQUID TEM sensor.

EXIGE (EXpertise In GEophysics), a geophysical consulting company established in 2007 in Johannesburg, South Africa engaged primarily in geophysical data quality control and assessment, interpretation and modelling for natural resources exploration, civil engineering and precision farming. In 2009 the company moved into acquisition in ground potential field methods and direct current (DC) resistivity. A key achievement at EXIGE was the introduction of a unique small and stable multi-sensor aerial platform designed for highly flexible surveys flown at low operational cost in natural resources exploration. This development originated from an R&D program in which two potential carriers were identified; the UAV, and the VLA. EXIGE and its partner AirWatch (a joint venture between Wagtail Aviation and Alto Air, both of Potchestrom, South Africa) have developed GyroLAG (Gyrocopter Light Airborne Geophysics), the next generation of advanced and “smarter” airborne multi-sensor geophysical VLA platforms. GyroLAG bridges the gap between traditional airborne and ground surveys and offers the simultaneous collection of geophysical data from more than two sensors. Commercial launch of GyroLAG in its full capacity is planned for the first quarter of 2010. The platform in a magnetic, radiometric and/or still camera configuration is already available for surveys.

Fugro Airborne Surveys (Fugro), headquartered in Ottawa, offers airborne time-domain and frequency-domain electromagnetics, magnetics and magnetic gradiometry, gamma-ray spectrometry, gravity and gravity gradiometry. Survey services include data collection, data processing, interpretation and consulting from operational bases in North America, South America, Africa, Europe and Australia.

In 2009 Fugro introduced new services and significant enhancements to its airborne geophysical systems and processes including the following: FALCON gravity gradiometer technology acquired from BHP Billiton and offered world-wide by Fugro, was successfully test-flown in a combined EM-FALCON-Mag configuration in Australia; the Helicopter and the Atikokan Mineral Development Initiative compensated for reduced demand from the private sector. While GDS reported strong price-competition for surveys, large volumes of data from fewer surveys made for efficient acquisition and processing.

December 2009 marked the end of a challenging yet successful year for Geotech which celebrated its second full year at the new corporate headquarters in Aurora, Ontario where it continues to design, build, operate and repair its airborne fixed wing and helicopter geophysical survey systems. Although global economics caused a slowdown in exploration, new technical advances allowed the company to excel in this environment. The Versatile Transient EM (VTEM) helicopter-borne time-domain system continued to see improvements including the newly unveiled megaVTEM,
Exploration Trends & Developments in 2009

with over 1.5 Million NIA, which has now begun commercial production. The new ZTEM, (Z-axis Tipper Electromagnetic) is a helicopter-borne natural field electromagnetic system. The ZTEM is the implementation of airborne AFMAG, and provides the deepest penetration of any proven airborne EM system. ZTEM is applicable in many exploration applications from porphyry, sedex, uranium, epithermal gold and geothermal targets as well as nickel and volcanogenic massive sulphides (VMS), kimberlite and diamond targets. The company’s continued R&D efforts also led to the introduction of the AirMt (Airborne Magnetic Total Field) electromagnetic system to the market. AirMt has been designed for mapping deep geological formations as well as shallower features like kimberlite pipes.

While Geotech has offices in Canada, Geotech Airborne Limited offices are located in Perth Australia, St. Michael Barbados, Rio de Janeiro Brazil, Accra Ghana and Johannesburg South Africa.

For Pico Envirotec Inc (PEI) of Newmarket, Ont., 2009 was a very active year in spite of the global economic downturn. Orders for turnkey integrated airborne systems were received from clients in India, Hong Kong, USA, China, Pakistan and Egypt. Several large orders were received for PGIS (portable geophysical information system) portable gamma-ray spectrometers, which were shipped to Australia, South Africa, Mongolia, China, Libya and Nigeria. The company continued the development of the automated airborne survey systems introduced in 2008, namely AutoMAG, AutoSPEC and SmartDART. The AGRS-10 gamma-ray spectrometer was upgraded to the new AGRS-2010 advanced gamma-ray spectrometer; the AGIS-XP/MMS-4 was upgraded and improved to the new AGIS-2010 integrated airborne system; and finally, a partnership with T.H.E.M. Geophysics of Gatineau, Que. led to the introduction of the P.THEM Time-domain helicopter-borne EM system.

Pitney Bowes Map Info of Troy N.Y. had acquired Australian-based Encom Technology in December 2007 and in January 2009 the name officially became Pitney Bowes Business Insight (PBBI). With the addition of software for document and data management solutions, plus a range of products and services from Pitney Bowes, PBBI now offers more ways to integrate, manage and intelligently use data.

Radiation Solutions Inc. (RSI) based in Mississauga, Ont., reported that while 2009 was not as busy as the two previous years, it was a year of healthy sales for their airborne, carborne and handheld gamma-ray spectrometer products.

Founded in 1956, Sander Geophysics (SGL) of Ottawa, Ont. specializes in high-resolution airborne surveys for petroleum and mineral exploration, and environmental mapping. The company carries out airborne gravity, magnetic, electromagnetic and radiometric surveys worldwide using fixed-wing aircraft and helicopters. SGL completed testing of four new AIRGrav systems in 2009 and now has 12 AIRGrav systems operating worldwide. AIRGrav surveys were flown in combination with high-resolution magnetics using fixed-wing aircraft and helicopters. The company completed their first full year in SGL’s recently expanded head office and hangar facility in Ottawa. The three-storey addition provided SGL with a floor space of over 4,000 sq. m, and a work environment that accommodates data processing facilities, laboratories, workshops and offices, in addition to the adjoining hangar, which is used for maintenance and modification of SGL’s fleet of 15 aircraft.

Denmark-based SkyTEM ApS entered its sixth year providing helicopter-borne time-domain EM (TDEM) surveys. Beginning with one system in 2004 the company can now position five crews anywhere on the globe. Smooth field operations are supported by having a complete second unit at each site plus enough systems at the head office to replicate all five field operations should the need arise. All worldwide operations are coordinated and organized from the Danish head office except in Australia, where the survey operations are carried out in cooperation with Geoforce Pty Ltd based in Malaga, Western Australia. In addition, the company recently retained a representative in Eastern Europe and another in Canada with a focus on the Americas. The R&D group at SkyTEM developed the company’s unique patented dual transmitter moment. The group’s ongoing system development includes a new project to enhance the ability of the system to discern subtle changes in resistivity contrasts and improve resolution of near-surface horizons.

AIRBORNE GEOPHYSICAL SURVEYING

Aerogeophysica continued its survey activities for the Russian mining market and large-scale surveys for oil and gas exploration. Survey projects employed all geophysical parameters offered by the company’s equipment fleet. 2009 was the company’s last year of a large 4-year government oil survey project in East Siberia, covering 210,000 sq. km. The multi-parameter survey with 500 m flight-line spacing was carried out with two airborne gravimeters (the Graviton and the GT-1A), Aeromaster magnetometers and RSI spectrometers. In another large exploration project Aerogeophysica completed a survey in the region of Transbaikalia in eastern Russia. Combined EM-4H and spectrometer data confirmed the potential for uranium and gold. Regional gravity surveys, which commenced in 2007 in southern Russia employing GT-1A gravimeters and Aeromaster magnetometers, will continue in 2010, supplying the Russian Ministry of Natural Resources with a geophysical data base for estimating the oil and gas potential in this large territory.

The government of British Columbia selected Aeroquest for the Quest West project. Despite the challenges of difficult access and rugged topography the AeroTEM survey was completed successfully and on time. The AeroTEM system was also chosen for a project in western Ontario for the Ontario Geological Survey because of its broad applicability to a wide range of geologic targets. The UTS Aeroquest UHRAM (ultra-high (spatial) resolution aeromagnetics) system flew surveys for Geoscience Australia. The system provides very high detail in airborne magnetic and radiometric data acquisition with a
Exploration Trends & Developments in 2009

gradiometer configuration on a PAC-750 Crop-Duster, designed for safe, low (15 to 40 m altitude) and slow operation.

In its third year of operation, Montreal, Que.-based EON Geosciences continued its strong growth by conducting several large government aeromagnetic surveys throughout Canada. In 2009, the company flew over 300,000 line-km for the Geological Survey of Canada (Natural Resources Canada) and the Quebec Ministry of Natural Resources and expects to conduct some large airborne surveys at the international level in 2010. Increasing company staff, acquiring additional state-of-the-art geophysical equipment, and signing a long-term lease agreement to augment its fleet of Piper Navajo aircraft, expanded capacity. The company now has the capability to survey and process more than 40,000-line-km of airborne geophysical data per month. EON offers high-resolution fixed-wing and helicopter-borne magnetic and radiometric surveys to both the public and private sectors.

In 2009, EXIGE and its exclusive partner AirWatch performed trials and fine-tuned their GyroLAG VLA platform that evolved from six years of aviation development. The GyroLAG conforms to military specifications and commercial aviation certification. The VLA is a Kriek IIB, South African designed and built, operated under a Part 96 license (commercial operations of non-type certified aircraft). GyroLAG is a single-pilot operated ultra-high resolution airborne geophysical platform that combines dense data sampling (10 Hz or more), accurate position location (DGPS), low ground clearance (less than 50 m), slow speed (less than 100 km/hr on line), multiple parameter measurements and automatic data quality control. The aircraft is fitted with an integrated UHF and Bluetooth communications package; day and night glass cockpit; GPRS-based active tracker unit with built-in memory; and satellite tracking for extreme remote operations. GyroLAG accommodates up to seven distinct remote sensing technologies including a range of digital cameras covering the entire IR to UV spectrum, a 3-component fluxgate magnetometer, a gamma-ray spectrometer (16 to 32 litre detector) and gravity sensors (INS-DGPS data enhanced - average 3-4 mGal accuracy for 5 km half-wavelength resolution).
Agility and ruggedness have been proven during a sequence of separate surveys and tests in difficult conditions.

In 2009, Fugro successfully flew a test program involving a FALCON gravity unit combined with a time-domain EM system in the same aircraft. This follows the previously successful surveys combining Fugro’s frequency-domain RESOLVE EM with FALCON in a single helicopter. In 2010 any combination of electromagnetic, magnetic, FALCON gravity gradiometry and radiometric measurements from a single platform will be offered. The company’s four FALCON gravity gradiometry systems carried out numerous FALCON surveys in South America, Africa and Australia during 2009. The company is currently carrying out a large-scale multi-client FALCON survey in the Kimberley region of Western Australia to assist in differentiating the mafic units associated with nickel mineralisation. Besides gradiometry, a number of airborne gravimetry surveys were conducted in South America and Africa.

The high frequency capability and sensitivity to weakly conductive units of the DIGHEM and RESOLVE helicopter frequency-domain EM systems were used to advantage on gold and kimberlite exploration programs in northern and western Canada in 2009. The broadband GEOTEM system was flown in western Canada for Alberta’s Energy Resources and Conservation Board and surveys were flown in Saskatchewan and Manitoba targeting coal deposits. Fugro’s TEMPEST system was applied to both shallow and deep targets where good resolution of subtle conductivity differences was essential. In Australia, large-scale TEMPEST surveys were completed, targeting uranium as part of Geoscience Australia’s Onshore Energy Security Program in Western Australia and Northern Territory. The company reported excellent resolution of both shallow and deep targets associated with uranium mineralisation in paleochannels and along unconformity surfaces. The TEMPEST systems also assisted in locating new groundwater sources in the Pilbara region in Western Australia. The Heligeotem system was flown for the Geological Survey of Canada on projects in British Columbia, and was also used on mineral exploration projects where the transmitter power of 1.2 million Am2 provided a significant advantage in depth of exploration. Fugro’s GENESIS system completed the phase 1 follow-up in Nigeria, as part of a regional mapping program for the Nigerian Government. These data provided a complementary data set to the regional magnetic and radiometric data also collected by Fugro.

Fugro’s magnetic and gamma-ray spectrometry aircraft flew surveys in North and South America, Australia, Africa and New Zealand. In Canada, over 190,000 line-km in multiple surveys were flown for the Geological Survey of Canada in the Northwest Territories, Quebec and Saskatchewan. In Ontario, a 74,000 line-km survey was flown for Ontario’s Ministry of Northern Development and Mines. The Australian government awarded large-scale surveys, and Brazilian operations were very active as well.

The trend from project-scale helicopter-borne surveys to large-scale fixed-wing surveys that began in 2007 for Geo Data Solutions (GDS) continued through 2009. The fixed-wing surveys, totalling about 220,000 line-km, that accounted for most of GDS’s workload included; an aeromagnetic survey in Newfoundland, an aeromagnetic survey in Hall Peninsula (Baffin Island), a total magnetic field and transverse gradient survey in the Marmion Lake (Atikokan Ont.) area and an aeromagnetic/radiometric survey south of LG4 in Quebec. Smaller surveys were flown elsewhere in Canada, using both the fixed-wing systems and helicopter systems that can include transient electromagnetics.

With a 35-metre transmitter diameter Geotech’s new megaVTEM collects both dB/dt and B-field measurements for Z, X and optional Y axis. The receiver now offers five microsecond to 10 millisecond time gates. The new high-
powered megaVTEM with the industry's largest transmitter dipole moment (1,500,000 NIA) started commercial surveys in the fall of 2009. Other significant improvements included the development of a new VTEM acquisition system to permit simultaneous acquisition of X-Y-Z channel data and improved EM decay sampling from time gates as early as five microseconds to as late as 13.1 milliseconds across 50 channels. Geotech's flagship VTEM (Versatile Time-Domain Electromagnetics) and ZTEM AFMAG helicopter EM systems continued to fly commercially. Over 30 VTEM electromagnetic systems and its various configurations are operational globally with over 1,500,000 line-km of VTEM surveys flown in 40 countries since 2002. Geotech now offers eight ZTEM systems with over 100,000 line-km flown since 2007 in North America, South America and Australia. 2009 saw continued testing and limited commercial surveys with the newly developed AirMt (Airborne Magnetic Total Field) electromagnetic system, which is the newest generation total field (XYZ) AFMAG acquisition system. Geotech also offers airborne gravity, radiometrics and airborne magnetic gradiometer (fixed wing and helicopter) surveys. The company has carried out surveys worldwide combining the three airborne techniques.

**MPX Geophysics**, which was formed in 2006, is now based in Markham, Ont., having moved from Richmond Hill. The company reported a fairly busy year with the launch of a third airborne platform in 2009 and the opening of a new office in Mexico. MPX offers high-resolution magnetic and radiometric surveys from both fixed-wing and helicopter platforms with the use of both towed birds and fixed booms. Most of the year’s projects were in Latin America.

Formed in 2005, **New Resolution Geophysics** (NRG) of Pretoria, South Africa, is a specialized airborne contractor with a focus in Africa. Key technologies include the XPlo8er high-resolution helicopter magnetic gradient and radiometric system as well as a dedicated airborne gravity platform. NRG has completed over one million line-km of airborne surveys in over 30 countries in Africa and Australasia.

**New-Sense Geophysics Ltd.** (NSG) reported a successful year conducting a number of helicopter and fixed-wing magnetic and radiometric surveys in North, Central, and South America. NSG believes the company’s relatively small to moderate size is an advantage, making it possible to provide better service in the field of airborne magnetic and radiometric data acquisition. In 2009 the company refined its data acquisition procedures and protocols and will be releasing a “new generation” data acquisition unit in early 2010.

**Novatem** (Mont-Saint-Hilaire, Que.) carried out airborne and heliborne magnetic, radiometric and time-domain electromagnetic surveys mainly in Canada, Europe and Africa. Novatem reported flying fewer surveys in 2009 than previous years, but of greater scale. Several projects in Ecuador were stopped prematurely for political reasons and some other projects were deferred temporarily due to political instability. In a partnership with SkyTEM, the company carried out more TDEM surveys for water and environmental in-
vestigations than for mining exploration. Novatem continued the development of a new proprietary TDEM system in collaboration with several research organizations in North America. The system will be specially adapted for the extreme conditions of the Canadian north. By choosing different technologies than those used in currently available systems, ambitious objectives in terms of power and sensitivity are reportedly planned. A prototype of the system is expected to be ready by the end of 2010.

**Pico Envirotec Inc** received a very large order for an airborne system for the Airborne Mineral Survey Expedition (AMSE) Wing, Geological Survey of India, in addition to several orders for turnkey integrated airborne systems. These included a magnetometer and gamma-ray spectrometer system for ARCN, a Chinese government agency; an IRIS helicopter-borne radiation monitoring system for the Hong Kong Observatory; an airborne gravity, magnetic gradiometer and gamma-ray spectrometer system for the NMA, an Egyptian government agency, and a helicopter-borne magnetometer and gradiometer system for GRI, a government agency of Pakistan.

Delivery of the systems for AMSE commenced in September 2009 with an airborne gravity system, configured for use on multiple platforms, including AMSE's Dhruv helicopter and their de Havilland DHC-6 Twin Otter, as well as road vehicles. Delivery is to be completed in early 2010 with an integrated time-domain EM, spectro-radiometer (from **ASD Inc**, Boulder, Colo.), magnetometer and gamma-ray spectrometer system. The airborne gravity system delivered to AMSE comprised a GT-1A airborne gravimeter, dual-frequency GPS receivers, radar and barometric altimeters, a data acquisition system and spare parts. Software and computers for quality control of data, data processing, interpretation and mapping were also delivered. AMSE sent two groups of engineers and geoscientists to Toronto for training on system operation and maintenance and on quality control of data, data processing, interpretation and mapping. Prior to shipment to India, the airborne gravity system underwent extensive flight and acceptance testing in Newmarket, Ont. by installing the entire system in a Eurocopter AS350 B2 A-Star helicopter. An AMSE inspection team attended the testing, which took place over a period of one week.

The airborne system delivered to the NMA included a **Canadian Micro Gravity** GT-1A airborne gravimeter, a vertical magnetic gradiometer and a PEI AGRS-10 advanced airborne gamma-ray spectrometer system with 64 litres of sensor. This system was installed on NMA's Beech King Air 200 aircraft, which was modified in Toronto by PEI. Flight-testing of the aircraft was completed in late December 2009 with delivery to the NMA in Egypt at year's end. Software for data QC and data processing and interpretation were also delivered. System operation and maintenance training was undertaken by PEI personnel in both Toronto and in Egypt.

**Prospectors** continued to fly surveys in its home country Brazil, as well as expanding into other Latin American countries, recording and processing primarily potential field and radiometric data using both fixed-wing aircraft and helicopters. The company has also flown numerous helicopter EM surveys over the last few years. In 2009, Prospectors added the new GT-2A scalar gravity meter mounted in a magnetically clean Piper Chieftain. The GT-2A is a significantly improved model of the **Gravitometric Technologies/Canadian MicroGravity** GT-1A provided in cooperation with **Airborne Petroleum Geophysics** (APG). Field results demonstrated that the new gravity meter provides a wider dynamic range and deliv-
Exploration Trends & Developments in 2009

Sander Geophysics (SGL) reported another busy and successful year flying numerous gravity (AIRGrav) and magnetic surveys, as well as several large magnetic and radiometric surveys. Despite the worldwide economic slowdown, SGL acquired over 1.5 million line-km of survey data in 2009, including several large airborne gravity and magnetic surveys for petroleum exploration, and a very high-resolution airborne gravity survey for mineral exploration. SGL completed surveys in North America, Africa, Greenland, Australasia and the Middle East. In addition, the company completed its participation in the data-acquisition phase of Antarctica’s Gamburtsev Province Project (AGAP), and is currently participating in NASA’s ICE Bridge project in Antarctica.

In 2009 SkyTEM carried out combined TEM/magnetic surveys and magnetic surveys in terrain as diverse as the Australian outback, the tropical forests of Malaysia, densely populated Germany and the Netherlands, the low relief of Denmark, the rugged topography of Sweden, and the mountains of Greenland and Norway. Survey objectives varied from mineral exploration and hydrogeological evaluations to the study of landslide risks.

In its twenty-fifth year of operation, Terraquest of Markham Ont. reported that the company has now carried out fixed wing geophysical surveys in 21 countries on five continents. The company’s two King Airs, one Cessna Caravan 208, two Navajos, and one Cessna 206 are all equipped with horizontal magnetic gradiometers, radiometrics and the proprietary XDS-VLF-EM. Terraquest reported a busy year carrying out a large horizontal magnetic gradient, radiometric, XDS-VLF-EM survey in the Canadian Arctic for Natural Resources Canada, and a number of other projects in South America, Africa, Europe and Greenland. Terraquest added three DAARC 500 data acquisition systems by RMS Instruments as well as three new Radiation Solutions crystal packs for its survey operations.

Vancouver, B.C.-based Universal Wing Geophysics continued with its development of a UAV platform to carry geophysical payloads. There continues to be challenges, primarily related
to the lack of a reliable low-cost aircraft in the market and to “permission to fly”. In response to these challenges Universal, in partnership with a sister company Stratus Aeronautics Corp. of Vancouver, has developed its own purpose-built aircraft over the last two years. The aircraft, named Venturer, is now available as a production model. A Venturer UAV, equipped for magnetic field detection by horizontal gradiometer with a cesium sensor in each wing tip is currently being fitted and will soon be undergoing trials. Expected availability for this system to do commercial surveys is the third quarter of 2010. The company has also fitted a Venturer aircraft with a digital still camera, together with a MEMS accelerometer, fluxgate magnetometer and DGPS systems. The system has proven its capability to acquire orthophotograph-quality images to make highly accurate digital terrain maps. In concert with a development partner, near real-time web delivery of ortho-rectified images via a web portal has been achieved by fitting the aircraft with an IP radio modem to provide the bandwidth for downloading images while the aircraft is airborne. This was a research project with various BC emergency services to study the application of the camera payload UAV for real-time emergency response coordination. This platform provides a strong base for applications where the aircraft can be used within line-of-sight of the operator, (making permission to fly easier to obtain) Applications include forestry, engineering projects and mine operation monitoring and mapping. In the meantime Universal has been working with Transport Canada regarding beyond-line-of-sight use of a UAV. The company now believes it has the protocols in place to get permission to fly at low level, in remote areas beyond line-of-sight. An aircraft is currently being fitted to these specifications and will be undergoing endurance and beyond line-of-sight trials in early 2010.

The Skydart total field cesium magnetometer, a helicopter towed-bird system, was put into commercial survey service. The system, based on the payload in the company’s first (now discontinued) UAV, is self-contained and simply hooks on the external load hook of any helicopter for immediate use. The navigation aids are the only equipment to be installed in the helicopter. This system completed 10,000 line-km of survey work in Northern Ontario in 2009 and 7,000 line-km of surveys in Nunavut in 2008.

**Xcalibur** is a South African airborne geophysical company that specializes in ultra-high resolution airborne gradient magnetic and radiometric surveys. Their fleet of aircraft comprises turbine Air Tractors, turbine Islanders (BN-2T), leased Jet Rangers and Eurocopters. This enables the company to collect data at lower ground clearance, (typically 10 m to 40 m) than commonly used in the airborne survey industry. Because spatial resolution improves when flight altitude is reduced, low-level data provides significantly more detailed information for Kimberlite detection, base and precious metal exploration, structural and lithological/contact mapping and mine planning. The survey height is generally only limited by the height of the vegetation and the presence of man-made features such as power lines, buildings and antennae. Xcalibur has operated for seven years with an excellent safety record collecting approximately 2 million line-km of low-level data. The company has conducted surveys throughout Africa (Mali, Republic of Congo, South Africa, Botswana, DRC, Angola, Tanzania, Mozambique, Madagascar) and Canada, and is now preparing to expand to other continents. In addition to high-resolution magnetics and radiometrics, Xcalibur uses the twin turbine Islander aircraft to provide regional gravity, magnetic and radiometric surveys. These aircraft have the capability of operating at low speeds (80 knots) and are ideal for high-resolution gravity surveys for hydrocarbon exploration over water. The company also provides survey design, data enhancement and quantitative and qualitative interpretation.

**Airborne Data Acquisition and Processing**

Bell Geospace of Houston, Texas, continued to improve its acquisition, processing and interpretation techniques for gravity gradiometry data for mineral exploration. Recent advances in acquisition include improvement of flight drapes and terrain correction. For areas with rugged terrain, a proprietary line-by-line drape was used to minimize the flight clearance. A new drape design algorithm takes into account all three primary drape constraints (acceleration, slope and clearance) more effectively. The previous drape design programs did little to account for minimizing acceleration over peaks and valleys. For areas where the surface density is not well known, the company has developed and refined a variable density terrain correction technique based on wavelet decomposition to better fit the terrain response to FTG (Full Tensor
Exploration Trends & Developments in 2009

Gradient) output. The technique is most appropriate for large areas that have varying lithologies. Bell Geospace also refined techniques that use computed rotational invariants to resolve target geometries, enhance contact information, and better define lithological units.

Condor Consulting of Lakewood, Colo., which marked its 10th anniversary in 2009, continued to expand its professional resources of full-time employees and consultants under contract. With overall work levels declining in 2009 after a rapid rise through the previous four years, Condor examined ways to enhance its core business activities in the processing and analysis of airborne geophysical data. The review showed a major opportunity developing with the emergence of airborne gravity gradiometry for mineral exploration. As part of this strategic assessment, Condor undertook the evaluation of a number of FALCON gravity gradiometer data sets acquired in the Athabasca Basin several years ago to aid explorers in finding new high-grade uranium resources. The company reported that combined with airborne EM information, the FALCON data are providing new insights into the geological structure of the Basin.

Geotech reported that the ZTEM acquisition system has been improved and can now extract In-Phase and Quadrature, at six or more frequencies, from 30 to 720 Hz, which is now standard. Geotech has also expanded its in-house data processing, consulting and interpretation capability to provide post-survey support. Services include 1D-2D-3D forward modelling and inversion of VTEM, ZTEM, magnetic and radiometric data for precise drill targeting. Interpretation reporting suitable for mineral assessment filing is available as an option to standard deliverables. Advanced VTEM post-processing includes EM anomaly picking, Time-Constant (Tau) calculations, apparent conductivity, EM flow conductivity-depth and resistivity-depth-imaging (RDI), and Maxwell three-dimensional conductive plate modelling. Advanced ZTEM post-processing includes EM picking, Karous-Hjelt current density-depth imaging, Geotools 2D and Emigma 3D forward modelling and Zvert2D inversion. The newly implemented ZTEM Apparent-Resistivity transform will be available in 2010. Development of proprietary Zvert2D inversion for ZTEM and AFMAG data has expanded the applicability and usefulness of geologic mapping tools, with penetration capability to a depth of several kilome-
trects. The VTEM systems have included Z-X component measurements with its standard survey configuration since the fall of 2008. A full XYZ-component sensor has now been developed and has been in use since the fall of 2009. Geotech’s new 3-axis magnetic gradiometer now employs four cesium sensors and three GPS sensors.

During the latter part of 2009 PEI developed an integrated “single console” airborne system, which combines all of the features of PEI’s AGIS-XP, MMS-4, and PDS-3 into a single 19-inch rack-mountable console. The new AGIS-2010 integrated airborne system features eight differential analog input channels; interfaces for four magnetometers; an advanced gamma-ray spectrometer; an airborne gravimeter, radar, laser and barometric altimeter; a GPS receiver, and a tri-axial fluxgate magnetometer measuring roll, pitch and yaw data. The AGIS-2010 records data directly to a solid-state memory card, and is then backed-up to a removable USB memory stick. The AGIS-2010 also includes an imbedded GPS Navigation Module providing steering guidance to the pilots, and a digital camera system to record flight path images.

In 2010 PEI will release advanced magnetic compensation software providing compensation coefficients in real time to run on the AGIS-2010 console. It will be compatible with the AGIS-XP or later systems.

Sander Geophysics (SGL) made significant improvements to the processing of GPS data and developed a new processing technique for gravity data. Both of these developments resulted in higher resolution and better accuracy gravity data from AIRGrav (Airborne Inertially Referenced Gravimeter) surveys. The company performed numerous interpretation projects, and in 2009 commenced two large integrated interpretation projects, including a combined gravity/magnetic survey, and a combined magnetic/radiometric survey, both of which were previously acquired by SGL. Data interpretation was performed using in-house SGL software, as well as commercial 2D, 2.5D and 3D modelling software.

SkyTEM reported that several clients took advantage of their pre-survey modeling service to optimize the data acquisition parameters for their surveys.

Aeromagnetic Surveying

GEM Systems of Markham, Ont. has completely redesigned the company’s airborne system from the data acquisition software and hardware to the bird with tri-axial magnetic sensor array. The new bird has maximized sensitivity of the sensor location, redesigned electronics and dismountable elements for easy transportation. The new system builds on the original multi-sensor configuration, radar altimeter, 20 Hz DGPS and GEM’s data acquisition software with real-time data and altitude display. New developments include: reduced electronics box size and weight (to ⅓), memory back-up in every magnetometer, integration of VLF-EM, a new multiplexor mounted in the bird with memory to integrate data from all magnetometers, GPS and VLF-EM, and to back-up all data in a solid-state memory which can store over 50 hours of data. There is also new data acquisition system software with real-time display, sensor signal strength, altitude alarm, flight information log and flight tracking of previous flights.

The new tri-axial bird uses larger volume (70 mm diameter cell) potassium sensors designed for low-gradient applications to map geologic structures that are weakly magnetic such as in exploration for diamonds, gold, silver, platinum and palladium. A high gradient option is also available. High sensitivity (0.0007 nT) together with high sampling rates (20 readings per second) allows for very detailed mapping. The new system had successfully flown 35,000 line-km by December 2009.

Four new products were introduced by San Jose, California-based Geometrics:

- A new bird with integrated GPS antenna has been deployed in Chile with Anglo Gold Ashanti. The bird incorporates a flat profile GPS antenna mounted on the ring tail with an integral 25-metre antenna coaxial cable leading to the GPS receiver in the helicopter.
The longer heavier bird provides lower noise and greater stability in all terrain conditions. Multiple-sensor arrays are available.

- A combined airborne-marine towed seabird system for both airborne and marine survey applications was recently flight-tested. The G-882 Marine Cesium fish was deployed as a test from a helicopter off Moffett Field in Mountain View Calif. This combined bird and fish is based on the G-882 Marine magnetometer which is a pressure vessel rated for 2,700 metres of water-depth. The fish-bird is for surveillance applications where a first pass would be in airborne mode and then a second slower traverse would be in "dip" mode where the bird dives into the water for more precise location of the target. This technique has primary application in military reconnaissance.

- Custom-built helicopter booms are now offered for transverse or vertical gradiometer operations from small one-man or remotely controlled rotor craft platforms. The new mini-boom design was part of a U.S. Government-funded project to automate flight controls and do UAV UXO work. Geometrics teamed with UAV and neural network aircraft control system manufacturers to provide alpha-test units for low altitude autonomous flight used in UXO-type reconnaissance surveys.

- The G-824 Suprema-C Cesium Va-pour magnetometer was introduced with 300 femtoTesla sensitivity and sample rates up to 1,000 Hz. This technology incorporates new ultra-low noise sensor driver electronics and the CM321 SuperCounter. Four years in development, the system offers a three-fold increase in performance over any of the company's previous airborne magnetometers. More DAARC500 (Data acquisition & Adaptive Aeromagnetic Real-time Compensation) systems were delivered by Mississauga, Ont.-based RMS In-
struments during 2009 to customers in Canada and internationally for new installations as well as for upgrading older systems. The DAARC500 now supports data acquisition and recording through an ethernet (100/1000 Mbps) interface. The DAARC500 acts as a client in a client-server architecture implemented under TCP/IP, acquiring and recording streaming data blocks transmitted by the server. The system allows monitoring in real-time (in graphical form) of variable fields embedded within the data packets. This is very useful to monitor the status of the external device and ensures compatibility with the ethernet data output formats of Radiation Solutions’ spectrometers. The AARC510 Adaptive Aeromagnetic Real-time Compensator will be introduced in early 2010. This latest member of the family of advanced, adaptive real-time compensation systems, is a compact (22 by 13 by 30 cm), low-cost version of the AARC500, ideally suited for strap-down installations in small fixed-wing aircraft or helicopters. It has the same performance of the AARC500, but is limited to a maximum of four magnetometer inputs. All models in the RMS aeromagnetic compensation and data acquisition family of products are now available with an optional embedded GPS receiver. Magnetic data are directly tagged with GPS time and position. The option can be retrofitted into AARC500 and DAARC500 units in the field. RMS has made available a new software package of data-exporting utilities to DAARC500 users. This Windows-based application greatly simplifies the exporting of data to any processing/analysis software.

A number of magnetic surveys were flown by Sanders Geophysics in 2009, mostly in combination with other techniques, including gravity, radiometrics, and scanning LiDAR. SGL claims to have the industry’s most magnetically quiet triaxial magnetic gradiometer aircraft, with wingtip sensors that exhibit low magnetic noise levels, similar to those of the sensors in the tail stinger.

**Airborne Electromagnetic Surveying**

In a project started two years ago, the modernization of the EM-4H helicopter frequency-domain EM system and the improvement of EM data processing software was completed by Aerogeophysica in 2009. This resulted in the ability to obtain more quantitative information on the mineral potential of project areas. The company reported that a three-year EM survey covering about 100,000 sq. km along the eastern slope of the Ural Ridge was completed. The primary objective was iron ore exploration, but the data obtained during the EM-4H survey demonstrated the excellent potential for copper, gold and other minerals in the region.

During the recent global financial crisis, Aeroquest increased its efforts to improve its survey systems. In 2010, all of the AeroTEM helicopter time-domain electromagnetic systems will become fully programmable with full flexibility in the selection of base frequency, pulse width and sampling. Building on this digital system, the company intends to introduce an AeroTEM system with a peak moment over 1,000,000 NIA in 2010.

Fugro’s GENESIS is a broadband fixed-wing time-domain electromagnetic system designed as a regional mapping and reconnaissance tool. GENESIS produces high-resolution information as a 3D conductivity distribution that is able to show subtle variations in geology due to its broadband nature. For ease of mobility, logistics and commercial advantages, GENESIS is installed on a Cessna 208 Caravan that allows for survey operations from rough airstrips at relatively low cost. Applications range from large scale mapping to regolith and paleochannel mapping of conductive targets of moderate and shallow depth. Currently GENESIS is available in Fugro’s Central (Europe, Africa and Middle East) region. In 2009 the HeligEOTEM helicopter time-domain system was upgraded to a dipole moment of 1.2 million Am². The system offers a 3-axis multi-coil broadband receiver and provides dB/dt and B-Field data for both on-time and off-time measurements.

In 2009, Pico Envirotec Inc and T.H.E.M. Geophysics collaborated to develop the P-THEM helicopter-borne time-domain electromagnetic system, which is now marketed worldwide by PEI. P-THEM is a versatile state-of-the-art, button-on, time-domain helicopter-borne electromagnetic system. Weighing about 250 kg, it features a powerful transmitter, a state-of-the-art PC-based receiver and an advanced digital signal processing software package. Two versions of P-THEM are now available; P-THEM-II is powered by a motor generator mounted on the transmitter assembly, whereas P-THEM-I derives its power from the helicopter itself. Both EM systems comprise an eight-metre diameter (50 sq m) four-turn loop-transmitter assembly (larger diameters are possible), a digital receiver and a 3-axis receiver (suspended on the towable mid-way between the transmitter assembly and the helicopter), and a receiver coil mounted at the rear of the transmitter assembly (for dB/dt measurements). P-THEM transmits a half sine wave pulse with a peak moment of over 250k NIA. It is easily transportable and rapidly deployed, typically in less than one day. Data acquisition and recording are achieved using PEI’s AGIS-XP data acquisition system. A complete survey system also includes a high-sensitivity cesium magnetometer, a real-time OmniSTAR DGPS differential navigation system, a radar altimeter and an optional gamma-ray spectrometer. A helicopter-powered P-THEM-I system, with two transmitter assemblies, has been ordered by AMSE, Geological Survey of India, and will be delivered in early 2010.

In 2009 several SkyTEM clients chose the company’s patented dual moment op-
This unique feature has the ability to simultaneously transmit in two modes: high moment; which enables great depth penetration, and low moment; which ensures good discrimination of the more resistive horizons and/or near-surface anomalies. Combined with GPS and tilt sensors mounted on the carrying frame this overall combination ensures accurate inversions of the collected EM data.

Terraquest reported that its proprietary XDS-VLF-EM technology flew over 100,000 line-km in 2009 and is now routinely being flown in Africa, Europe, South and North America. The XDS-VLF-EM System is a proprietary airborne electromagnetic measurement system developed by Terraquest that redefines existing VLF-EM technology. A VLF system typically responds to conductivity variations in overburden, large faults or shear zones, and to graphitic formational conductors. Because of these characteristics, VLF-EM can be useful as a mapping tool particularly when combined with magnetics. Standard VLF measurements typically tune the receiver to a particular transmitter. Provided the transmitter is on, and provided the strike of the conductivity variation is in line with the direction to the transmitter, useful data can be acquired. Unfortunately, these conditions are not always met, and VLF data must often be discarded. The XDS-VLF system has been designed by Terraquest to overcome these challenges. The XDS has a 3-axis VLF sensor system mounted in the tail stinger of a fixed wing aircraft. While it can acquire data in the standard mode, tuned to a particular VLF transmitter, it is generally used in a “defined bandwidth” mode, receiving signals simultaneously from stations spanning from 22 kHz to 26 kHz. This includes the Cutler, Seattle and North Dakota transmitters (and anything else that falls in this bandwidth) and therefore the XDS can obtain useful information from a wide variety of geological strike orientations. This increases the reliability and utilization of the XDS measurement in comparison to the standard method.

The 3-axis VLF sensor consists of three coils mounted orthogonally to each other in the tail stinger, (or towed bird/stinger for helicopter installations) which independently measure the absolute magnitude of the signals in the X, Y and Z directions of the aircraft. In processing, these aircraft axes are assumed to be aligned along the flight direction (X), perpendicular to the flight direction (Y) and vertically (Z). In practice however, the aircraft axes will not be parallel to the flight line direction, and an upgrade to earth-based geographical coordinates is underway at Terraquest.
Airborne Gamma-ray Spectrometric Surveying

In 2009 Pico Envirotecc completed the development of its AGRS-2010 Advanced Gamma-ray Spectrometer based on the first, fully digital AGRS-10 gamma-ray spectrometer, which has been operational in a variety of aircraft for the last 10 years. The AGRS-2010 features: fast sampling (0.1sec), practically an unlimited number of connected detectors, substantially improved linearity corrections, high throughput, pileup and automatic baseline restoration, and most importantly, field replacement of detectors and automatic calibration based on natural radioactive elements.

One of the achievements Sander Geophysics reported in 2009 was the completion of a government funded combined magnetic and radiometric survey in Canada. (Several other companies that flew gamma-ray spectrometric surveys as a combined survey, are reported elsewhere in this review.)

Airborne Gravity Surveying

Fugro continued to fly successful FALCON gravity gradiometry surveys for the petroleum industry, particularly in terrain difficult for seismic exploration. FALCON was specifically designed for airborne surveys and measures the differential curvature gradients that are used to derive the full gravity tensor and vertical gravity. Measurements of the gravity field are at a sensitivity and spatial resolution considered to be greater than conventional airborne gravimetry. FALCON is offered from both fixed-wing and helicopter platforms but when used in a helicopter, achieves the highest spatial resolution. High spatial resolution is critical for mineral exploration with airborne gravity. Under the terms of its purchase from BHP Billiton, Fugro will be able to offer FALCON to the mineral exploration industry from April 1 2010.

New Resolution Geophysics (NRG) introduced a dedicated airborne gravity system using an industry standard GT-1A instrument mounted on a Pilatus PC6 aircraft. The PC6 is well known for its reliability, suitability for operation from remote airstrips (STOL aircraft) and most importantly, its ability to fly slowly. A key factor in any airborne gravity system is aircraft speed, which is inversely related to spatial resolution. Coupled with long-range tanks the company reported the system is capable of high production rates with improved resolution compared with other fixed-wing airborne gravity platforms. To date NRG has completed over 200,000 line-km of airborne gravity surveys in a variety of environments across Africa.

Sander Geophysics completed the first gravity survey using one of its three new Diamond Aircraft DA-42 fixed-wing aircraft, and completed certification and testing of the magnetic installation on the other two DA-42 aircraft. The DA-42 is an all-new twin diesel engine aircraft, with an advanced all-composite design and the latest in avionics and engine technology. The reliable and efficient diesel engines are designed to use jet fuel, which is more readily available than traditional piston engine aviation gasoline in many countries. In addition the aircraft’s composite construction gives the aircraft a low magnetic signature, ideal for high-resolution magnetic surveys.

The company successfully completed its participation in the data acquisition phase of Antarctica’s Gamburtsev Province Project (AGAP) that is part of the International Polar Year. Over 50,000 line-km of airborne gravity data were collected by the AIRGrav system mounted in the Twin Otter survey aircraft. The gravity map revealed the peaks and valleys of the Gamburtsev mountains hidden beneath the featureless surface of the ice sheet. Scientists at Columbia University’s Lamont-Doherty Earth Observatory are analyzing the data further. The company is also participating in NASA’s ICE Bridge project in Antarctica. Having previously supplied an AIRGrav airborne gravimeter for last year’s successful AGAP survey in Antarctica, SGL was chosen to supply a high resolution, gravity system in support of NASA’s current project. The ICE Bridge project is designed to provide vital information about the ice sheet at the poles, and will bridge the gap between the retirement of ICESat I (expected in 2009) and the launch of ICESat II (expected in 2014-15). During this period, NASA plans to acquire data using a DC-8 aircraft outfitted with various equipment from multiple agencies, including the AIRGrav system, which is being provided through an agreement with Lamont-Doherty Earth Observatory. Successful missions were flown over Antarctica from a base in southern Chile starting in October 2009, with over 40,000 line-km of data acquired.
GROUND SURVEY TECHNIQUES

ClearView Geophysics of Brampton, Ont. now offers EM surveys using the SQUID sensor. This B-field sensor is more sensitive to highly conductive targets and provides overall cleaner responses compared to traditional receiver sensors. Also ClearView can now provide Subsurface Utility Engineering (SUE) data compliant with CI/ASCE 38-02 standards. This standard formalizes the benefit of using professional engineers and geophysical techniques over traditional pipe and cable locators, to detect pipes and utilities.

Mississauga, Ont.-based Crone Geophysics & Exploration reported a steady year of contract time-domain EM surveys worldwide, split evenly between borehole and surface work, and with a significant increase in the use of B-field fluxgate and SQUID magnetic sensors. Nine years of conducting high sensitivity PEM-SQUID surveys for very deep or high conductance targets has made it possible for the company to offer this in 2009 as a routine, trouble-free survey with multiple 3-component sensors. The 3-component surface and borehole fluxgate magnetic sensors for the Pulse EM system also saw increased usage, especially for high conductance targets such as nickel sulphides, and to clarify multiple conductors in boreholes. This year, increased resolution (to 26 bits) was added to the Pulse EM receiver as well as full time-series measurements.

Geopros Oy of Finland reported the company has been concentrating on the operation and further development of a large borehole logging system, which is used to measure hydraulic properties of rock. The measured data are used for modelling the movement of groundwater in bedrock in the vicinity of the spent nuclear fuel repository currently under construction in Finland. This has kept Geopros busy for a long time, but the need for new data is expected to decrease in the coming years. The company may begin looking to apply their technology at new nuclear waste disposal projects in other countries.

Physical Rock Properties and Elemental Analysis

Abitibi Geophysics has established a laboratory to measure physical properties of rock samples including magnetic susceptibility, EM conductivity, galvanic resistivity, chargeability and specific gravity.

The company is now the Canadian agent for the Innov-X mobile elemental analysis equipment. This full suite of mobile and on-site products from Vancouver-based Innov-X Canada can provide immediate results to geologists even in remote sites. For established camps, the X-50 Mobile XRF is a bench-top analyzer with a closed beam configuration with up to 10 times the power of a handheld XRF analyzer. This makes the X-50 ideal for ores, tailings, concentrates, borings, cores, fragments, slurries, filters and films. The X-50 is capable of analyzing many transition metals, such as Cd, Ag, Sn, Sb, precious metals and rare earths.

The Innov-X Omega is a battery-powered handheld device providing elemental analysis in the field on outcrops, in trenches, on drill core, boulders, soils, or liquids without disturbing the sample. The Omega produces instant elemental analysis using a patent pending “light elements” LZ package, to directly detect many elements including Mg, Si, Al, P, and to determine Al/Si ratios. The LZ option extends the element range without the need for burdensome helium gas tanks or pumps.

In December 2009 Instrumentation GDD (GDD) of Quebec City, introduced a new computerized, battery-powered portable instrument developed in collaboration with several Canadian geophysicists, to measure the IP response of a sample. The GDD SCIP Tester (Sample Core IP Tester) is based on two of GDD’s successful field instruments (the GRx8-32 IP Receiver and the TxII line of IP Transmitters). The SCIP unit combines a stable, digitally controlled, low power transmitter (choice of voltage or constant current) with a single channel, programmable, twenty-window time-domain receiver that is fully capable of spectral analysis of the decay curve. It also provides DC resistivity data and calculates geometrically corrected resistivity in ohm-m over a wide dynamic range. Measurement of the IP response of a sample can aid exploration for a particular ore type by facilitating the choice of field techniques. The SCIP Tester will operate from -30°C to +55°C. Beta-testing clients have reported that the SCIP is efficient, convenient to operate and reliable, as well as fast. The SCIP
Exploration Trends & Developments in 2009

Geosoft displaying tortuously crooked sections.

Credit: Geosoft

In October 2009, Billerica, Mass.-based Thermo Fisher Scientific introduced its new Thermo Scientific Niton XL2 Series X-Ray fluorescence (XRF) analyzer for mining and exploration. The Niton XL2 is engineered to operate in harsh mining environments, reduce laboratory costs, and improve efficiency. The lightweight (1.53 kg) 45 kV instrument is ergonomically designed, features daylight-readable icons and a standard analysis range of more than 25 elements from sulphur to uranium. It is particularly suitable for development drilling, grade control, and mine mapping where repeatable elemental analyses are required for large numbers of mineralized samples. A new field mapping option is also available that when combined with the Niton XL3 GOLDD, allows real-time geochemical mapping while simultaneously identifying elemental anomalies. All Thermo Scientific Niton XRF analyzers store results matched to GPS coordinates and allow users to download the results to existing GIS and data analysis packages. Elemental Controls of Mississauga, Ont. is the Canadian distributor.

**Data Processing and Positioning**

In 2009, Toronto-based Geosoft released a new product, Geochemistry for ArcGIS (GfA), which provides a geochemical data analysis workflow within the ArcGIS environment and complements Geosoft’s subsurface Target for ArcGIS (TfA) extension. GfA allows explorers to simplify their geochemistry quality control process using standards and duplicates. Explorers can select and subset data interactively from maps based on lithology and regions, to enhance data display and create advanced geochemical maps within the ESRI ArcGIS Desktop environment. They can also complete multi-element geochemical data analysis using a variety of tools including: interactive multiple histogram plots, Pearson’s correlation reports, scatter plots, probability plots, ternary plots and box plots. The company continued to enhance its 3D subsurface capabilities adding data format support for Gemcom, Minessight and 3D DXF isosurfaces. For working with 2D inversion data, support was added for handling sections, especially tortuously crooked sections. These sections are fully geo-referenced for easy use in both 2D and 3D environments. A series of advances were made in the area of exploration information management in 2009. A full release of the DAP Server and Metadata Management Technology was completed. New features were based on leveraging ArcGIS Server technology for greater support for ESRI Geographical Information, beyond traditional integration with Shape files. The company also made general enhancements to the DAP Cataloguing Process and DAP Administration. A milestone for 2009 was the release of a new technology to help manage “personal stores” of exploration data. Geosoft Desktop Cataloger is an easy-to-use tool that catalogues spatial data on a personal computer and provides the ability to spatially search and find this data through the use of keywords. Spatial cataloguing, combined with Geosoft search and viewer technologies, enables easy access and integration of new data as soon as it is available. The company also planned to release in February 2010, a new tool set, Seeker, for finding, reviewing and delivery of data to the user. This intuitive map-based search tool incorporates new capabilities to search both internal and external data sources through graphical as well as keyword searches.

The main software development work at Kingston, Ont.-based Lamontagne Geophysics in 2009 was on the processing of H and E field UTEM measurements into conductivity or resistivity sections. CRCDI (Curved Reflector Conductivity Depth Imaging) is a conductivity imaging technique in which the first step is fitting the data in terms of equivalent “curved reflectors”, i.e. the response of perfectly conductive continuous surfaces that are allowed to become curved, to fit the response of individual channel data from any given transmitter loop. The data acquired from different loops are then combined into stacked diffusion-time horizons that are then converted into a conductivity estimate on a section that can extend to several kilometres in depth. The second step uses a 2D conductivity estimator similar to that used in CDI. As in CDI the data requires overlapping coverage such that each station is measured from three or more loops at differing relative locations to each receiver station.

Inductive Source Resistivity (ISR) is a technique where the electric (E) field response (from one or more large ungrounded inductive loops) is measured directly with electric dipoles. ISR resistivity imaging uses the CDI method applied to E field measurements as a first step to estimate the depth of diffusion of the electric field in an X-Z section. The fields inferred from this process penetrate to different depths depending on sampling time and distance/size of the transmitter loop. These different excitations are then used as source fields in an inversion of the electric field data into a resistivity section using a 2D integral equation approach with diffusion-time constraints. ISR imaging can image resistivity contrasts even in...
situations where the resistivity is such that there is too little induced current flowing to produce significant \(H\) field responses.

**Drillhole Methods**

_Abitibi Geophysics_ is upgrading its TDEM borehole logging system to the InfiniTEM II configuration to be available for service in the first quarter of 2010. It will improve exploration efficiency by increasing radial exploration in excess of 500 metres and by providing B-field measurements. The company reported use of borehole-to-borehole IP has proven to be much more efficient than the conventional in-hole arrays with respect to depth and radius of investigation. Targets 400 metres from the borehole have been located and successfully explained. Data are inverted in 3D using proprietary 3D imaging software. Abitibi has formed _Abitibi-Terratec_, a joint venture with _Terratec Geophysical Services_ of Germany, to bring its borehole logging technology to Canada. In addition to the TDEM and resistivity/IP logging, the new borehole system obtains information on well construction, rock lithology, fractures, porosity, permeability and water quality. Abitibi-Terratec also offers continuous, detailed, and scaled 360° true-colour images of the borehole walls for documentation and interpretation. The results can be displayed as a projection of features onto an imaginary core that can be rotated and viewed. Feature analysis includes dip, strike and fracture frequency and width. Additional data collected are: borehole deviation log (dip and dip direction of the borehole) to calculate the true borehole coordinates \(X, Y, Z\); total magnetic field strength and magnetic field vector; and natural gamma-ray intensity.

_Delta Epsilon Instruments_ (Grand Junction, Colo.) had a productive 2009 with the development of a new portable 2009 with the development of a new portable logger, refinement and market expansion of existing products and the issuance of a Canadian patent on a proprietary radio-metric device. Significant development work was carried out on the soon-to-be introduced 300-1H portable logger. The 300-1H is a completely self-contained, truly portable, digital state-of-the-art, manually cranked logger capable of logging holes to 300 metres in depth. The 300-1H is powered by an integral and readily available rechargeable power tool battery and is the world’s only “cordless” borehole logger. A version of the company’s 600 DL portable logger which is equipped with a four-conductor cable permitting both geophysical logs as well as borehole video to depths of 400 metres will become available during 2010.

_Geoserve Logging & Tomography_ based in Markham, Ont. uses new technology and software for advanced imaging between boreholes. Originally developed at the University of Toronto with initial funding by _CAMIRO_ (Canadian Mining Industry Research Organization), the company reported the technology has been proven in several difficult mining camps, including Sudbury, Red Lake and Bathurst. Geoserve provides borehole resistivity/chargeability logging and tomography for mineral exploration and geotechnical applications. Geoserve’s experi-
ence has shown that the technology can provide rapid and accurate imaging of ore zones between boreholes up to 400 metres apart and can detect conductive/chargeable bodies in the vicinity of a borehole at distances up to 100 metres. Bulk resistivity/chargeability measurements for calibration and interpretation of surface EM data are also provided. The methodology is applicable to both weak and strong resistivity contrasts.

Icefield Tools Corporation (Whitehorse, Yukon) has been continuously making improvements to their very successful Gyro Shot gyroscopically-oriented survey tool first introduced in 2007. The company reported that its ruggedness has been a key feature. As a testament to that, the instrument is now being used as a drop gyro in oilfield applications.

JVX Ltd. of Richmond Hill, Ont. has been researching and developing a Spectral IP/Resistivity surveying method in boreholes since 1999. As of 2009 this borehole surveying method is able to collect up to five times more data than conventional methods from surface and underground boreholes using specialized hardware and software developed by JVX. The system, which is typically used to map orebodies, has the capacity to survey boreholes to a depth of 1.5 km and the ability to detect off-hole anomalies at up to 200 metres distance. Another advantage of this system is that it is capable of surveying boreholes collared in underground workings, unlike standard EM methods. Conductivity and chargeability models computed from data are used to target areas more precisely for mine development and/or drilling. Models are presented in 3D and 2D to visualize subsurface geology. The method is currently being applied at mine sites in northern Ontario and Australia.

Scintrex Limited of Concord, Ont. has successfully commercialized Gravilog, a borehole gravity logging system, specifically designed for mining applications including detection of an off-hole orebody; determination of the excess mass of bodies, both remote and intersected by the hole; 3D modelling; the follow-up of surface and airborne gravity anomalies; and bulk density measurement of the intersected formations. In 2008 the first test carried out for Vale Inco at the Norman Township test site in Sudbury was reported. The second field test was conducted in March 2009 for Areva in a newly drilled, vertical borehole at Shea Creek in northern Saskatchewan. The company reported that results clearly show the unconformity, and the bulk density calculations show an indication of a low-density zone at the base of the Athabasca sandstone. The data are undergoing further analysis. The third and fourth field tests for Schlumberger and BHP Billiton respectively have been delayed until mid-2010 by request of these companies. The Gravilog system is now commercially available. Some of the key specifications of the system include a sensitivity better than 5 microGal with a one-minute reading time and an operating range of 7,000 mGal. The 3-metre-long, 48-mm-diameter sonde can operate in water-filled NQ (57.2 mm) holes to a depth of 3,000 metres. Measurements are made with the sonde stationary with vertical position determination in the borehole of ± 5 cm between successive stations (depth determined with a combination of pressure sensor, winch encoder and inclinometer). When the station spacing is 10 metres in a borehole, the Gravilog production rate averages one station every seven minutes. In a water-filled borehole, the depth of each station is accurately measured using a pressure sensor. Scintrex built two Gravilog systems in 2009 and planned to build several more systems during the first half of 2010. The first commercial surveys were carried out with promising results in Idaho for a junior mining company.

Ground Electromagnetic Methods

Since the introduction of the InfiniTEM configuration by Abitibi Geophysics in 2004 the company reported that a number of discoveries have been attributed to it. To double the depth of exploration for a typical VMS body, the company commissioned TerraScope Instruments to build an 18 kW TDEM power supply. This new transmitter can generate
Exploration Trends & Developments in 2009

a 40,000,000 Am² dipole moment in an InfiniTEM II loop, provide a stable on-time pulse, achieve a 99.7% linear ramp, and can be used for both on-time and off-time measurements. To further improve the detection of deep targets, weakly conductive targets or highly conductive targets, the EMIT (Electromagnetic Imaging Technology) SMARTem receiver was introduced which may be combined with an air coil, a fluxgate or a SQUID sensor and enables the measurement of on-time and off-time dB/dt and B-field. The culmination of these improvements is InfiniTEM II with a ten-fold improvement in signal to noise ratio that the company claims enables exploration for VMS targets to depths of 1,000 metres.

Discovery International Geophysics reported having used the Supracon Jessy Deep HTS sensor with the Geonics Protem receivers and transmitters, EMIT SMARTem receivers and Phoenix Geophysics transmitters in a wide range of TEM survey modes including fixed-loop, centre moving-loop, and slingram moving-loop. The SQUID TEM surveys are principally aimed at exploration for high conductivity targets at great depth (i.e. greater than 700 metres) because of its greater sensitivity and lower noise. There are also advantages for detecting basement conductors under conductive cover because SQUID measures the B-field rather than dB/dt.

EMpulse Geophysics of Dalmeny, Sask. expanded their 3D inversion cluster in 2009 to 24 nodes and 96 GB of RAM. As many as 400 stations can now be inverted in a reasonable time, fitting all six complex impedance and tipper elements. Further refinements have been made to the Adaptive Polarization Stacking data processing algorithm, the most notable of which is the inclusion of the vertical electric field. Initial attempts at using the vertical electric field for simple stack alignment has resulted in a significant increase in curve quality in the range 500 Hz to 1 kHz and 3 kHz to 5 kHz, i.e., the upper and lower edges of the dead band. It is hoped that this initial effort at using vertical E field will be greatly improved by hardware enhancements to improve the vertical E SNR (Signal to Noise Ratio) roughly three-fold and software improvements to make better use of the vertical E data through adaptive noise cancellation of the horizontal magnetic field data. As well, work is progressing on the construction of the new SFERIC III receiver featuring 24-bit resolution and expanded bandwidth of .001 Hz to 50 kHz. Initial field testing is expected to be underway by summer 2010 with commercial surveys by the winter of 2011.

During 2009 Mississauga, Ont.-based Geonics Limited made several improvements to its borehole and surface fluxgate sensors for TDEM applications, which includes removal of primary field effects as well as shortening of the time required for sensor stabilization. Additions introduced to the PROTEM Time-Domain system include: a) high power transmitter TEM67 PLUS with continuously variable output voltage from 20 to 240 V, maximum current of ± 28 A, and total power of 6,800 W; b) a USB port in addition to a RS 232 port for the PROTEM receiver to make interfacing to a new generation of computers more flexible; c) a direct interface for the PROTEM receiver to the SQUID sensor manufactured by Supracon from Jena, Germany. A new generation of high power metal detector, the EM63-3D-MK2 with three orthogonal transmitter coils and three orthogonal receiver coils was also introduced in 2009. The instrument is
specially designed for UXO (Unexploded Ordnance) detection and discrimination.

**GF Instruments** (Brno, Czech Republic) announced that their electromagnetic conductivity meter (CMD) now has a much wider range of completely new probes that can be used with its control unit. Continuous development and the latest redesign of traditional CM systems resulted in single/multi-depth probes with a unique reading stability better than 1 mS/m per 10°C over all working temperature ranges. In 2009 the wide selection of available probes was completed with the addition of: CMD Explorer (simultaneous 2.5, 4.5, 7.5 metre depth range), CMD Tiny (0.7 metre depth range) and CMD-4/6 (combined 6 or 9 metre depth range). Thus CMD systems enable production of layered conductivity and in-phase maps as well as accurate in situ EM inversion (like two-layer models). CMD features include fast response and high sampling rate (up to 10 Hz for moving applications), ultra-light weight, long battery life, Bluetooth communication and data transfer using a flash drive.

The UTEM 5 surface system development by **Lamontagne Geophysics** is now complete and field trials are being conducted with the first production systems. The company reported the new system shows a five-fold improvement in measurement precision over UTEM3 and UTEM4 in the normal frequency range of 2 Hz to 31 Hz and even greater improvement for measurements at lower frequencies extending well below 1 Hz. Field efficiency can be greatly improved by simultaneous 3-axis measurements from up to three transmitter loops. Development work has started on a new borehole system with similar characteristics.

Based on their extensive worldwide experiences in the application of both low temperature and high temperature SQUID sensors for ground time-domain electromagnetic surveys, **Supracon** and **Institute for Photonic Technology** developed innovative modifications to their existing single-channel High Temperature SQUID (HTS) system, called JESSY DEEP HTS. After three years of very successful application of their single-channel receiver measuring the vertical component of the magnetic field, the system is now equipped with three orthogonal SQUID magnetometers providing a noise-limited resolution of better than 50 fT/sq rt (Hz). Such high resolution instruments are particularly useful in the search for deep-seated ore bodies or marker horizons, and in areas of deep weathering. The new generation sensor, cooled with liquid nitrogen, permits operation with smaller sized transmitter loops. All components of the system have been tested and approved for rugged field operations. The receiver is now operational over a wide temperature range from -40°C to +50°C and was deployed in northern Canada during the last winter season by **Discovery International Geophysics**

**Gravity Surveying**

During 2009 **Abitibi Geophysics** expanded their gravity services by adding another Scintrex CG-5 gravity meter to its equipment inventory. This was complemented with two new Trimble dual frequency R7 RTK Glonass-equipped differential GPS systems, capable of centimetre-level accuracy, enabling the company to meet the highest standards for geographic positioning.

**Induced Polarization**

A comprehensive analysis of the Re-

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**Abitibi Geophysics operator with Scintrex CG-5 gravity meter**

Credit: Abitibi Geophysics

**GF Instruments Explorer conductivity meter.**

Credit: GF Instruments
sitivity/IP inversion math has allowed the Abitibi Geophysics research team to identify a possible way to maximize the sensitivity of the technique. The company reported that field testing and synthetic modelling proved that Resistivity/IP sensitivity could effectively be increased by a factor of ten or more. Development of a field implementation technique and of data processing tools related to this new approach named IPower3D will continue in 2010 and it is hoped the service will become available for exploration before the end of the year.

Instrumentation GDD reported improvements for the GDD 3D 32 channel IP Receiver in 2009. A few of the enhancements now delivered include: increased precision, multi-language support (English, Spanish, Portuguese and Chinese) and programmable windows of 10 milliseconds compared to the standard 20 milliseconds.

In 2009 GF Instruments introduced a new redesigned version of the Geoelectric Power Sounder, GEPS-2000 system for IP measurements and deep resistivity soundings. The new version of the engine-powered GEPS-2000 has a 2500 V, 10 A 3500 W transmitter for investigation of deep structures. Full data acquisition and processing support for both vertical electrical sounding and simultaneous 8-channel profiling for one-pass measurement of sections allows for fast and economic surveys. Individual parts of the device (including power engines) are one-man portable. The system is equipped with a detachable radio/cable-operated 8-channel receiver.

Ground Penetrating Radar (GPR)

In 2009 Mississauga, Ont.-based Sensors & Software announced two major innovations in Ground Penetrating Radar hardware: SPIDAR and IceMap. SPIDAR, is a complete family of products that enables networking of any number of Noggin or pulseEKKO PRO GPR systems. The SPIDAR addresses applications such as continuous mapping in real time or extraction of complex target geometry, which require simultaneous data acquisition from spatially distributed arrays, multiple frequency arrays, multiple polarization arrays and remote controlled, OEM and robotic applications. Using a Panasonic Toughbook PC and ethernet links, GPR units can be configured and triggered to deliver data concurrently at high rates. Data flow and storage along with positioning are all integrated using the SpiView for SPIDAR control software. Data storage in traditional dt1, accompanied by GFP files, provides real time data analysis. By simply touching the screen EKKO_View enables section review while EKKO_Mapper will create depth slice images.

IceMap is a new Noggin GPR system designed specifically for rapid profiling of ice thickness. Building on the traditional Noggin GPR family and years of practical operation for ice applications, the new IceMap system features a minimum ice thickness indicator, continuous display of current GPS position and cumulative distance travelled, simplified ice property calibration process, integration of IcePicker and Google Earth displays, simple recall and replay of recorded data and freshwater and sea-ice settings.

Ground Radiometric Surveying

Delta Epsilon Instruments reported sales of the SC-133 scintillometer continued to customers in North America, Australia, Africa and Europe. A number of units delivered to the USDOE for environmental monitoring and remediation work were equipped with (EX-133) crutch-mounted external detectors, facilitating the placement of the detector in close proximity to the intended target. Additionally, the company was issued a Canadian patent covering its unique neutron and gamma-ray survey meter with directional response.

In the summer of 2009, Pico Envirotec Inc introduced the PDOSE-2 Gamma-ray Dose Meter, a state-of-the-art portable survey meter. PDOSE-2 is a hand-held battery operated instrument designed for use in both rugged and normal environments. The PDOSE-2 can be equipped with several peripheral units providing the operator with a flexible instrument for in-situ or moving applications. In a stationary mode, PDOSE-2 is equipped with a remote power supply, communicating via RS-232 or Bluetooth with a remote computer. For moving operations the unit is equipped with a GPS receiver and a PC Hand Held computer. Features of the PDOSE-2 Gamma-ray Dose Meter include: two Geiger tubes for monitoring low-range and high-range, from natural background to 400mGy/h, embedded GPS receiver, and a rugged windows mobile PC Handheld with Bluetooth communication. Data recording includes GPS position, time and date, total counts on each tube, dose level and record number.
Companies and Websites

Abitibi Geophysics: www.ageophysics.com
Aerogeophysics: www.aerogeophysics.com
Aeroquest Surveys: www.aeroquest.ca
Airborne Petroleum Geophysics (APG): www.APGeophysics.com
AltoAir: www.alto-air.com
Antarctica's Gamburtsev Province Project (AGAP): www.ideal.columbia.edu/res/pi/gambit/
Aretech Exploration Services: www.AretechSolutions.com
ASD: www.ASDL.com
Bell Geospace: www.BellGeo.com
BHP Billiton: www.bhpbilliton.com
CAMIRO: www.camiro.org
Canadian Exploration Geophysical Society: www.KEGSonline.org
Canadian Micro Gravity: www.canadianmicrogravity.com
ClearView Geophysics: www.clearviewgeophysics.ca
Condor Consulting: www.CondorConsult.com
Delta Epsilon Instruments: www.DeltaEpsilon.com
Discovery International Geophysics: www.discgeo.com
Elemental Controls: www.ElementalControls.com
EMpulse Geophysics: www.EMpulse.ca
EON Geosciences: www.EONgeosciences.com
EXIGE: www.exigesa.com
Fugro Airborne Surveys: www.FugroAirborne.com

Abbreviations

(for acronyms used in the text)


ANNOUNCING...

The Northern Miner’s new and improved website...faster, easier to search, brighter graphics, more investor tools, new “hot sectors” and much more.


You’ll be glad you did!
BGAN
BGAN gives you high quality voice and broadband data connectivity worldwide through a single, small, lightweight terminal that fits easily alongside your laptop in a backpack.

inmarsat.com/mining/ca

It’s what you get, big time, with BGAN in your backpack. Send survey data to the lab and get results back. Rapidly, in real time. From anywhere to anywhere. Easily and reliably. Enhance decision-making. Reduce time in the field. Giving you more exploreability than ever before. Contact your local service provider by visiting us online.