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MINERAL EXPLORATION TRENDS AND DEVELOPMENTS IN 2015

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

The Canadian Exploration Geophysical Society (KEGS) has been the foremost sponsor of Exploration Trends & Developments since 2007, making this the organization’s tenth year as our primary patron.

The Trends review originated with the Geological Survey of Canada (GSC), where for over 50 years GSC scientists have prepared an unbiased annual publication on trends and new developments in geophysical exploration for minerals. This year, KEGS’ support came from the companies listed in the Sponsor’s Box below. This marks the 24th year it has been written by Patrick Killeen, originally as a research scientist at the GSC.

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

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Cover photo: Martin Dubois, senior geophysicist with Abitibi Geophysics, on an ARMIT TDEM survey in Quebec. Credit: Abitibi Geophysics
Mineral exploration activity in 2015 did not see a hoped-for recovery, but it was an innovative year in terms of technology development, new business relationships and international ventures, as well as new applications to increase productivity. Most companies experienced lower levels of activity, but a few reported increased activity and one saw near record work levels. More companies diversified from mineral exploration to other targets such as groundwater or geothermal power sources and there were more partnerships, consortia, and collaboration to share equipment and expertise. The year also saw a trend toward more international work, with companies opening more offices and subsidiaries around the globe. The sector also put more effort into re-processing legacy data using new interpretation and modelling techniques.

In spite of the ongoing commodities downturn, three companies moved to larger premises, two with significant R&D lab space, indicating a positive outlook. New advances were made in airborne, ground and drillhole technology, including data-processing techniques. Several advances in airborne TDEM were reported, at least three new airborne TDEM systems became available and a fourth was to be released in 2016. Companies improved existing TDEM systems, increasing dipole moments for greater depth penetration. A new airborne gravity gradiometer (AGG) was released. An airborne navigation and data recording system was installed on a tablet PC for use as a standalone system without cables connected to the aircraft. While UAVs were introduced for more applications, they are not yet mainstream, and development of UAV-friendly geophysical instrumentation continues.

Ground geophysical technology saw new instrumentation, (some with Wi-Fi connectivity) for magnetic susceptibility and conductivity measurements. New and improved resistivity/IP, ground VLF, TDEM, and UXO detection systems were released, as well as a backpack portable gamma-ray spectrometer. In drillhole geophysics, a new portable logging system was introduced, a new gamma-ray sensor was developed, and a new “Photo-electric” logging tool was released, based on the spectral gamma-gamma (SGG) method. A new data-acquisition system for both surface and borehole surveys was introduced, along with a new slim (32 mm) borehole EM, mag and IP logging tool. For MT work, one company developed a new capacitive “line-antenna” that permits effective operations on frozen, very dry, or very rocky ground. Test surveys in which mag and TDEM systems were deployed on sleighs towed by a snowmobile or an ATV achieved good production, even in poor ground conditions. Also, the first gravity survey in a horizontal borehole was conducted.

Everyone found 2015 difficult; however, the people in this industry continued to show their mettle, innovation, resourcefulness, resilience and imagination. In 2016, let’s take courage from others who persevered through difficult times. As Winston Churchill said: “If you’re going through hell, keep going.”

EXPLORATION TECHNOLOGY IN 2015: THE INNOVATIONS CONTINUE
In 2015, Abitibi Geophysics of Val d’Or, Que., focused on increasing the depth penetration of induced-polarization technology, especially through conductive cover. IPower-3D-IP has mapped mineralization to depths of 700 metres and OreVision, an inline 2-D array, has proven effective to depths of 400 metres. Abitibi also expanded its borehole EM capabilities with the acquisition of a digitlAtlantis B-field sensor. In addition, the company announced a partnership with GEM Systems to operate AeroVision, a horizontal gradient magnetometer system installed on a UAV. In May, Abitibi signed a partnership with the Société pour le développement minier de la Côte d’Ivoire (SODEMI) to supplement geological field knowledge with Abitibi’s interpretation expertise. SODEMI purchased the latest geophysical technology and Abitibi provided training for its geophysicists in Val-d’Or and in Côte d’Ivoire. SODEMI conducts the field operations with Abitibi supervising quality control and final data processing and interpretation. The company signed a similar agreement with Sagax Maghreb in Morocco.

The five consulting and contracting member companies of the Assegai Geophysics Alliance, based in Potchefstroom, South Africa, deliver integrated geophysical solutions in airborne, ground, marine, wireline and data-modelling applications. In 2015, Assegai member Exige did consulting work for the International Geoscience Services (IGS) in Nottingham, U.K., supervising a World Bank-funded airborne geophysical survey in Burkina Faso. Exige also carried out field tests in South Africa and Australia of its Inert Gas Mixture (IGM) technology for Acid Rock Drainage (ARD) control. In addition, the company signed an agreement with French aerospace company ECA Group to market the IT180 mini-UAV, in South Africa and Australia. The UAV is designed for mining and environmental studies using magnetic or thermal sensors, or video cameras. GyroLAG, also part of Assegai, has partnered with Canadian-based Triumph Instruments and Triumph Surveys to offer gyrocopter and helicopter-borne AirTEM time-domain EM survey services.

Paris-headquartered CGG merged its airborne and marine geophysics into CGG Multi-Physics, with offices in Toronto and...
globally. CGG developed a new high moment version of its TEMPEST EM system that also features other extensive upgrades, and released a new FALCON Plus Airborne Gravity Gradiometry (AGG) system.

Condor Consulting of Lakewood, Colo., established a branch office in Vancouver under the name Condor North Consulting and added staff in both offices in 2015.

Since the 1970s, the primary focus at Mississauga, Ont.-based Crone Geophysics & Exploration was the manufacture, development and deployment of its proprietary Pulse-EM, Time-Domain ground EM system. Last year, it acquired its 3D E-SCAN Resistivity and IP technology from Premier Geophysics. The technology has broadened the company’s ability to offer true 3-D resource detection and drill targeting for an expanded range of resources.

Dias Geophysical carries out 3-D and 2-D resistivity and induced polarization (DCIP) surveys using its proprietary DIAS32 system, which it continued to improve in 2015. In addition to its Toronto-area office, the company opened an office in Vancouver, and secured an office/warehouse facility in Saskatoon to base its operations and R&D centre.

Montreal-based EON Geosciences flew a range of high-resolution magnetic, gamma-ray spectrometric and gravity airborne surveys worldwide, using both fixed-wing aircraft and helicopters. The company reported a comparable level of work to the previous year, with about 25% of its activity outside of Canada. Flight tests confirmed that improvements and increased system power have made its ETHEM time-domain EM system more robust and increased data fidelity.

GEM Systems, in Markham, Ont., celebrated 35 years in business in 2015. Founded by Dr. Ivan Hrvoic, the company develops airborne, ground, and stationary magnetometers and gradiometers. In the early 1980s, GEM introduced Overhauser magnetometers, the first robust, cost-effective rapid-sampling magnetometers that provided sub nanoTesla measurements. Today, the magnetometer is used as a calibration standard in almost all magnetic field observatories in the world, as well as in exploration.

In 1995, GEM introduced Potassium alkali vapour technology, which became one of the most precise magnetometers in the world measuring the magnetic field at the sub picoTesla level. The high-sensitivity Potassium magnetometers were used to develop the Super Gradiometer, a system for measuring very subtle magnetic gradient changes at the femtoTesla level. Super Gradiometers are deployed globally to research earthquake and volcano precursors. Last year, three systems were installed 200 metres below ground in the Conrad Observatory in Trømfjord, Austria, where a 3-D gradient array with nine very large sensors will study the ionosphere and magnetoosphere and the Earth’s core.

Montreal-based Geosphair Aviation, which specializes in airborne survey methodology and survey-aircraft modifications, improved the stability at sea of its newly developed Seaplane Bathymetric System. In 2015, the company also developed a Belly Pod specially designed to house a Riegl LiDAR, IMU and Camera on its Super-Cub aircraft, which flew a total of 80 hours of LiDAR survey in Quebec. The Super-Cub platform has proven to be a low-maintenance, slow speed, versatile and economic platform.

Geotech, based in Aurora, Ont., has focused on emerging markets recently, forming new subsidiaries in several countries. In Russia, Moscow-based AeroGeotech Rosearo Group, formed in 2014, flew several thousand line-km last year. In Kazakhstan, it formed the joint venture KazGeotech in 2014 with Astana-based KazGeology. The joint-venture partners have agreed to establish a Centre of Excellence for airborne geophysical surveys in the country, with a regional focus that will encourage surrounding
nations to employ Kazakhstan’s exploration expertise.

Moscow-based Geotechnologies completed several surveys with its EQUATOR helicopter-borne EM system in the Norilsk and Yakutia regions for mineral exploration and groundwater studies. The company reported steady demand for its geophysical equipment for airborne magnetic and EM surveys.

Quebec-city based Instrumentation GDD celebrated its 40th anniversary in 2015. In its early days, GDD developed the first digital IP receiver, the SWP/1, in collaboration with Société Québécoise d’Exploration Minière (SOQUEM). It also developed an IP Transmitter (Tx II) that has now been improved to 10kW and 4800V capabilities. The latest IP Tx updates (model Tx4) allows 20A (at low voltage), GPS synchronization, real-time current recording via a Tx Controller and an improved user interface. In the late ‘90s, GDD introduced the Multi-Parameter Probe (MPP) for magnetic susceptibility and conductivity measurement and the Sulphides, Susceptibility, Waste system (SSW) for dilution control in base metal mining. Today, the MPP probe provides more accurate EM conductivity readings and can be used with any smart phone or tablet. GDD also developed the first 24-bit 3-D 32-channel IP Receiver, the Sample Core IP (SCIP) device for Resistivity and Chargeability core/sample measurement, and the powerful NordicEM TEM Receiver.

Lamontagne Geophysics moved to a new address in Kingston, Ont., with a special laboratory for testing and calibrating surface and down-hole EM systems. The new lab includes a zero-field room suitable for spectral measurements and tensor calibration of 3-axis EM systems and a 570 metre-deep test borehole.

Groningen, Netherlands-based Medusa Systems is now Medusa Sensing. The new name better describes its line of products. The company reported the first sales of its radiation-sensing AGRS systems in China and Brazil. It also teamed with Geoduster Technologies based in Knysna, South Africa, to develop a new series of optimized, low-weight detector systems aimed at UAV applications.

Mira Geoscience, headquartered in Montreal, continued to expand its integrated interpretation software and consulting services through its four offices in Canada and Australia. The company’s geophysical innovations focus on development and application of quantitative methods to integrate geology-geo-physics-geochemistry interpretation. Mira acquired several codes from Brisbane-based Fullagar Geophysics in 2015, including VPmg and VPem1D. These programs are a cornerstone of interpretation workflows for geologically-based forward modeling and inversion of potential field and time-domain EM data.

New Resolution Geophysics (NRG) of Cape Town, South Africa, specializes in the collection of ultra-high-resolution airborne gravity, magnetic, radiometric and electromagnetic data. Last year, the company introduced Xcite, a new helicopter-borne time-domain EM (HTDEM) system, which uses an innovative inflatable bird as a carrier for the loop and is now available for surveys.

Mississauga, Ont.-based Radiation Solu-
handheld and RS-330 portable gamma-ray spectrometers were used for follow up to RS-500 airborne anomalies over rugged territory at several former mine sites.

**Ronacher McKenzie Geoscience**, established in 2014 and based in Toronto and Sudbury, Ont., integrates and interprets geophysical and geological data in 3-D. This approach to data interpretation allows for efficient targeting to increase the odds of discovery. To maximize data quality, the company plans, manages and executes field programs, including ground and airborne geophysics, surface sampling, mapping and drilling programs. In addition, RMG offers land management services and workshops.

**RMS Instruments** of Mississauga, Ont., reported a surge of activity in the integration and engineering of complete airborne exploration systems, coupled with advanced training programs throughout the world. In 2015, the company provided comprehensive system engineering, integration, installation and training both in-house and at client-country locations. It also developed a new compensator system designed specifically for aeromagnetics on UAV platforms.

**Sander Geophysics (SGL)** of Ottawa celebrated 60 years in business in 2015. Founded in 1956, SGL specializes in high-resolution airborne surveys for petroleum and mineral exploration, and environmental mapping. From the earliest days flying helicopter magnetic systems and frequency domain EM systems designed and built in-house, the company now flies fixed-wing helicopter magnetic systems and frequency domain EM systems and workshops.

SGL reported 2015 was another busy year, with growing interest in multi-parameter surveys, which include simultaneous recording of gravity, magnetic, electromagnetic and radiometric data.

Early in 2015, Sander Geophysics and **SkyTEM** began to offer helicopter surveys combining SkyTEM’s deep-looking helicopter time-domain EM systems with SGL’s high-resolution AirGrav technology. Simultaneous recording of TEM, gravity and magnetic data reduces acquisition costs.

Through its sister company **Micro-g LaCoste** of Lafayette, Colo., **Scintrex** of Concord, Ont., offers full borehole gravity logging services with the Gravilog probe for mining applications and BlueCap for oil and gas applications. The survey department of Scintrex/Micro-g LaCoste has formed a consortium with Nevada-based **Magee Geophysical** and **Explorer Geophysical** of Riyadh, Saudi Arabia to establish the Saudi Arabia Gravity Network on behalf of the country’s **General Commission for Survey** (GCS). The network consists of a highly accurate gravity calibration line adjacent to the Red Sea Coast and several thousand CG-5 relative gravity stations based on a backbone grid of A10 absolute gravity measurements.

**SkyTEM Canada**, based near Kitchener, Ont., successfully mapped the Caber North deposit in Quebec with its recently developed SkyTEM516 system in early 2015. The system has a dipole moment of more than 1,000,000 NIA. The Caber North deposit is a challenging target – 1.3 million tonnes at 4% zinc and 1.7% copper buried under more than 300 metres of conductive overburden. The SkyTEM516 was able to map the deposit with a unique receiver design that reduced the noise level by a factor of 20.

**Terraquest** of Markham, Ont., provides high-resolution airborne geophysical surveys globally using advanced gravimetric, total field magnetic, horizontal gradient, radiometric and proprietary XDS VLF-EM methods. Last year Terraquest performed surveys in Canada, the U.S., and Suriname and was awarded a 75,000 line-km aeromagnetic and radiometric survey in northern Ontario for the **Ministry of Northern Development and Mines (MNDM)**. In 2015, **Triumph Instruments** develops and manufactures airborne, ground and borehole geophysical instrumentation and has deployed its innovative AirTEM helicopter time-domain EM system in Canada, China and Mexico. The company is a collaboration between the co-founder of Aerogeo International (now part of Geotech) and the founder of Brampton, Ont.-based instrument developer **IFG**. The companies recently consolidated their operations in Georgetown and are developing new sensor technologies to improve airborne EM detection of high-conductance targets, and in borehole instrumentation, an oriented temperature sensor array to determine the rate and direction of water flow within freshwater aquifers.

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**EXPLORATION TRENDS & DEVELOPMENTS**

Credit: Terraquest
Last year, CGG deployed FALCON systems on several regional projects, including regional basin mapping in east Africa and Papua New Guinea. FALCON was used on major oil and gas exploration projects in the U.S. and Greece, to survey for base metal and IOCG deposits, and for water mapping. HeliFALCON, the world’s only helicopter AGG system, provided high-resolution datasets in challenging, rugged terrain in Japan, where it was used to map geothermal systems, and in the southern Papuan Highlands, for oil and gas exploration. CGG’s TEMPEST EM systems were deployed for ground water, base metals and iron ore exploration, as well as regional geological mapping programs. In Western Australia, CGG conducted a 30,000-sq.-km TEMPEST survey in the Pilbara region’s West Canning Basin to investigate the groundwater resource potential of the Broome and Wallal Sandstone aquifers. CGG’s high-powered HELITEM airborne EM systems surveyed for copper, gold, and nickel in Australia and Africa.

EON Geosciences flew two separate projects for the United States Geological Survey (USGS) in Washington State and Iowa. It also flew two large regional surveys for the Ministère de l’Énergie et des Ressources Naturelles du Québec (MERN), in the Côte-Nord and Otish Mountain regions of northern Quebec, and helicopter-borne magnetic surveys in Spain and Eastern Canada.

Geophysics GPR of Longueuil, Que., flew an aeromagnetic survey in Alsace, France, in 2015 as part of a study to establish a geothermal power plant. A geological model, which was a key factor in determining the plant’s location, was developed using inversion of the aeromagnetic and other geophysical data, combined with geological data.

Geotech completed two large World Bank-sponsored fixed-wing magnetic-spectrometric surveys for Cameroon’s Ministry of Industry, Mines and Technological Development (550,000 line-km) and Burkina Faso’s Bureau des Mines et de la Geologie (145,000 line-km). It also flew a 37,000 line-km VTEM survey for India’s National Geophysical Research Institute (NGRI). Large
EXPLORATION TRENDS & DEVELOPMENTS

(more than 10,000 line-km) AEM and aeromagnetic surveys were completed for mineral exploration companies in Australia, Kazakhstan, Russia, Cameroon, Cote d’Ivoire and Gabon. In 2015, Geotech flew the second-highest number of VTEM line-km since 2010, which included its highest-altitude-ever survey averaging 4,882 metres.

In 2015, Saskatoon-based Goldak Airborne Surveys marked its 20th year as an airborne survey contractor flying combined radiometric and gradient magnetic surveys. The company’s two Piper Navajo aircraft flew regional magnetic surveys for Quebec’s MERN and Alaska’s Division of Geological and Geophysical Surveys (DGGS), in addition to private sector work in Saskatchewan’s Pikoo diamond district. Goldak also flew magnetic/radiometric surveys for the Geological Survey of Newfoundland and the USGS with its Cessna Caravan.

GyroLAG reported very good results from the world’s first Very Light Aircraft airborne scalar gravity survey with its tail dragging fixed-wing Maule M5-235C. The company flew magnetic and gamma-ray spectrometric gyrocopter soil-zoning surveys for the agriculture industry in Southern Africa. GyroLAG also completed an 11,000 line-km gyrocopter magnetic and radiometric survey for its Airborne Geophysics Observatory partnership with Nelson Mandela Metropolitan University (NMMU).

SGL flew airborne gravity and magnetic surveys for petroleum exploration and regional mapping, as well as several large magnetic gradient and radiometric surveys for government agencies. The company flew AIRGrav surveys in North America, South America, Asia and Antarctica, with its 12 AIRGrav systems in fixed-wing aircraft and helicopters. For most of the surveys, airborne magnetic data were recorded simultaneously and for several surveys, EM, radiometrics, methane sensing and scanning LiDAR were also flown. SGL completed large magnetic and radiometric projects in Canada for Ontario’s MNDM and for Quebec’s MERN, as well as in Uruguay and Chile. In North America, it conducted a magnetic survey for petroleum exploration where the 3-D geomagnetic reference models based on the magnetic data were used for real-time steering of directional wells with MWD techniques. SGL also flew a combined gravity and gradient magnetic survey to assist with a U.S. military research project, and completed several large interpretation projects. The company provides fully integrated interpretation with 2-D, 2.5-D and 3-D modelling of potential field data, using seismic, geology, and drillhole data as constraints.

For several years, SGL has flown airborne methane sensing surveys in support of petroleum exploration surveys and for environmental monitoring, including one of an oilsands facility in Canada. Ultra-sensitive high-resolution sensors record methane gas concentrations in the air which are then used to map ground level gas flux rates. The data provide a baseline measurement to assess future survey measurements and monitor methane changes.

Scott Hogg & Associates of Toronto carried out Heli-GT surveys in British Columbia, Saskatchewan and Ontario last year, and continued to work with Tundra Airborne Surveys of St. Catharines, Ont. The Heli-GT system measures total magnetic field plus three geo-referenced gradients that are automatically corrected to produce accurate north, east and vertical gradients.

SkyTEM was very busy in 2015 due primarily due to its two latest technology launches. An alternative to fixed-wing EM, the SkyTEM312FAST system is engineered for high sample rate data acquisition at helicopter speeds approaching 150 km per hour and a dipole moment of 510,000 NIA. The system was flown in 2015 for mineral exploration and groundwater mapping projects in Australia, and water/oil and gas exploration in B.C. and Alberta. SkyTEM516 records early time and late time data for both shallow and deep investigations. This new system was flown in mineral exploration projects in Nunavut, Sweden and Norway.

SkyTEM Canada teamed with SGL to acquire SkyTEM516 magnetic and gravity data at TMAC Resources’ Hope Bay and Elu gold exploration projects in Nunavut. Operating 24/7 to take advantage of long days in the Arctic summer, they acquired 10,000 line-km of data on the Greenstone belt. Preliminary data and 1-D EM inversions were delivered every 48 hours. Post processing of airborne IP signatures will also be completed and the company
is working to model the airborne IP effect from SkyTEM datasets. SkyTEM Canada flew 21,000 line-km for Geoscience BC’s Peace Project in northeast B.C., to map the region’s aquifers. All data acquisition, flown with SkyTEM312FAST and covering 8,000 sq. km, was completed in only 43 days. SkyTEM312 was also used to map aquifers in the near surface as well as to the top of the deeper oilsands resources in the Fort McMurray area of Alberta for a major Canadian oil and gas company. In the U.S., SkyTEM 508 was employed primarily for water surveys but also for base metal exploration in southern California. SkyTEM flew several surveys for governments, utilities, farms and a university in California’s drought-stricken Central Valley. In Nebraska, SkyTEM 508 was used to map aquifers for the Eastern Nebraska Water Resources Assessment (ENWRA). In Africa for the second year, SkyTEM and its partner, Xcalibur Airborne Geophysics (Wonderboom, South Africa), flew tens of thousands of line-km with SkyTEM304 for diamond exploration in Angola and for graphite exploration in Mozambique.

Four SkyTEM systems, the SkyTEM304, SkyTEM308 (a developmental system) and SkyTEM312 in both standard and Fast configurations, were deployed in Australia to fly large mineral exploration and groundwater surveys. The Department of Agriculture and Food WA (DAFWA) based in Perth, used SkyTEM’s airborne EM surveying to more than double the odds of finding water in the Gascoyne water wellfield. Previous drilling resulted in a one-in-five chance of finding water. Of 70 SkyTEM targets identified, DAFWA has already located more than 30 sites suitable for production bores. The company also flew mineral exploration, water mapping and geotechnical engineering surveys in Norway, Sweden and Germany.

Terravest has been carrying out HRAM, and gamma-ray spectrometer surveys globally since 1984. The company’s three fixed-wing aircraft fly magnetic, gradiometry and radiometric surveys and now include: GT-2A Gravimetric, proprietary XDS VLF-EM and Matrix VLF-EM and most recently, Poco Time Domain EM surveys. The GT-2A gravimeter provides enhanced total gravity field resolution at depth. The proprietary broadband XDS VLF-EM system provides detailed structural mapping, now in conjunction with the digital Matrix VLF-EM system developed by Magenta of Newmarket, Ont. The company’s proprietary “Structural Multi-View,” a helicopter VLF-EM system, continues to be used throughout South and Central America on small helicopters. The Structural Multi-View system is a 5-metre stinger consisting of a magnetometer, XDS VLF-EM, and a gamma-ray spectrometer with a 20.8-litre crystal pack flown at low speeds and low terrain clearance for high-quality detailed data.

Perth-based Thomson Aviation now routinely flies ultra-detailed to regional fixed-wing and heli-borne magnetic and radiometric surveys around the world. The company flew corporate surveys in Australia, Africa and Southeast Asia, completed a 100,000 line-km World Bank-funded regional magnetic and radiometric survey begun in 2014 in Mozambique for the Ministry of Mineral Resources, and a 100,000 line-km survey for Geo-science Australia in the Northern Territory. It was awarded the 2013-2017 airborne geophysical survey for New Zealand Petroleum & Minerals (NZPAM), which includes 100,000 line-km
EXPLORATION TRENDS & DEVELOPMENTS

A 3-D image produced by Mira’s new Geoscience ANALYST software.

of heli-borne and 70,000 line-km of fixed-wing flying. Expanding into Central America, the company was awarded a 35,000 line-km fixed-wing project in Nicaragua.

**Tundra Airborne Surveys** of St Catharines, Ont., provides combined magnetic horizontal gradient, radiometric, and VLF-EM surveys using its own Diamond DA-42 Twin Star and a leased Piper Navajo from KASI Aviation Services of Dorval, Que. The company reported a quiet year. Its partnership with **Scott Hogg & Associates** continued with a small Heli-GT/radiometric survey for Happy Creek Minerals over the Fox property in B.C., followed by a Heli-GT survey over two blocks in Saskatchewan’s Pikoo Diamond District for North Arrow Minerals. At the beginning of the year, in partnership with **Geophysics GPR International**, TAS completed over 10,000 line-km of fixed-wing magnetic survey with the DA-42 for the Quebec government over the Gaspé Peninsula.

**Airborne Data Acquisition and Processing**

Since 2012, **Aarhus Geophysics**, based in Denmark, has been heavily involved in research on modelling and inversion of the Airborne IP (AIP) effect. The AIP mode forward modelling and inversion is carried out using a multiparametric approach, including a full suite of Cole-Cole parameters. Aarhus claims a proven track record of AIP effect inversions on gold, uranium, massive sulphides, copper porphyry, BIF, kimberlite, VMS, permafrost and groundwater surveys. The company has produced a case study of AIP multiparametric inversion of VTEM data flown in 2008 over the Mt. Milligan copper-gold porphyry deposit in central B.C., as a part of **Geoscience BC**’s Quest initiative. The airborne VTEM survey displayed a strong IP effect over the mineralized zone, and was inverted to extract the Cole-Cole parameters. Results showed a positive correlation between the published near-surface chargeability from ground IP surveys and chargeability from VTEM airborne data. Aarhus operates internationally with partner companies in Canada (**Promiseland Exploration** of Vancouver) and Australia (**Newexcelco** of Perth).

**Condor Consulting** reported a strong shift in activity away from basic targeting programs traditionally supported by juniors, to more integrated geophysical and geological assessments, often involving complex legacy data. The company’s Geointerp service saw several major projects in and around Saskatchewan’s Athabasca Basin. Gravity has grown in popularity as a technique being applied around the margins of the basin to map alteration systems that could be associated with uranium mineralization. Ground gravity data provided by Forum Uranium from its Maurice Point property was used to model the equivalent airborne gravity gradient response. Condor’s assessment is that the gravity lows typical of the Maurice Point area could be mapped below about 200-300 metres of sandstone cover. Condor also collaborated with Terry Hoschke, a geophysical consultant in Perth, in a **CAMIRO** project to compile aeromagnetic responses over porphyry copper-gold deposits. The last time such a project was undertaken was 45 years ago. Condor continues to be a re-seller for the **Pitney Bowes Business Insight** (PBBI) Encom line of geophysical software and is now a re-seller for the Model Vision Pro software being marketed by Sydney-based **Tensor Research**.

In 2015, Toronto-based **Geosoft** made it easier to share files and data by providing support for Leapfrog models, ASEG-ESF, LCT, and SEG-Y files. Geosoft 2-D maps can also be exported as Adobe PDF files that include georeferencing and map layers. A new 3-D drillhole planning tool enables proposed holes to be drawn directly in 3-D within the context of other geological, geophysical, and geochemical data and new isovalue options provide more control over how surfaces are created. The voxel math tool now supports open and closed surface operations. In addition, several new database channel math functions have been added, including concatenation of string values and access to data on offset rows. The Voxi Earth Modelling constraint builder now supports vector voxels and the ability to build complex constraint models containing multiple surfaces. The company has also updated the airborne survey planning tools. An approximation of a draped flight path can be created to determine if the exploration target body can be detected with the proposed survey specifications. The detection map enables quick identification of areas where the survey may not detect the potential target.

**Geotech** improved its proprietary Airborne Induced Polarization (AIIP) mapping algorithm, which allows it to extract Cole-Cole chargeability parameters routinely from its VTEM time-domain EM survey data. AIIP mapping is now offered as a commercial product for all of its VTEM system surveys, past and present. The company has also implemented AIIP removal for deleterious IP effects in its helicopter time-domain EM data, for example in permafrost terrains. Geotech’s proprietary superparamagnetic (SPM) extraction algorithm has also been applied for identifying and differentiating SPM-contaminated EM decays from true nickel-copper-platinum group element target responses for its recent VTEM surveys in Greenland. The proprietary Av2Dtopo ZTEM inversion for converting tipper responses to resistivity-depth sections is now provided for free for all its ZTEM natural field EM surveys. The quality and efficiency of its 3-D ZTEM inversions has also been improved by adopting a cloud-based, parallel-processing computing approach using the UBC MT3d code. Software changes to its ZTEM core-processing allow the company to extract tipper data at lower frequencies (22.5 and 15 Hz) than previously possible.

In collaboration with **TerraSurvey** of Pretoria, South Africa, **GyroLAG** has validated the integration of a new LiDAR camera on both gyrocopters and UAV. It continued in partnership with Fraunhofer FHR and Hochschule Koblenz University in Germa-
ny to develop the geomatics toolbox, now comprising a complete suite of innovative airborne sensors for gyrocopters. It includes the PanX (multi-spectral 3-5 channels 450-950 nm and VIS camera), PanTIR (8-14 um thermal infra-red camera and VIS), PanHYPER (hyper-spectral camera 450-950 nm) and high-resolution RGB camera (36 Mp) systems. GyroLAG also continues work on worldwide distribution of its “plug and fly” franchise of gyrocopter airborne FLAG (Fly Light Airborne Geophysics) and FLAReS (Fly Light Airborne Remote Sensing) configurations.

In 2015, Medusa upgraded its Gamman processing software to include a “non-negative least squares” algorithm to process full spectral data. The new approach avoids “negative” nuclide concentrations, which are a mathematically sound outcome of previous Gamman versions. The company has developed a new, sensor-embedded gamma-ray data-acquisition and processing system to be released in early 2016. The system, which has a small-footprint, low-power processing board connected to a micro-MCA board and a separate HV/preamp unit, was developed with Geoduster. Medusa also plans to release a new series of 3.5-inch diameter cylindrical CsI airborne radiation detectors, which are about 20%-25% more efficient than the classic 4x4x16 inch square NaI detectors (for the same detector volume).

Mira Geoscience launched Geoscience INTEGRATOR for mine site data and model management. It is currently under development for mineral exploration, to be commercially available in 2016. The company also released Geoscience ANALYST, a free 3-D visualization and collaboration software for integrated, multi-disciplinary data and earth models. GOCAD Mining Suite, a fully integrated, multi-disciplinary earth-modelling solution, was updated to version 14.1, offering significant interface changes for improved data organization. Finally, a new inversion algorithm from Fullagar Geophysics was released: VPem3D, for fast approximate 3-D modelling and inversion for airborne, downhole, and ground dB/dt or B-field data.

Concord, Ont.-based Pico Envirotec made hardware and software changes to IMPAC, its data-acquisition system, and to its AGRS family of spectrometers, greatly increasing their functionality, reliability and robustness. The newly developed digital environmental sensor (P-DES) also provides a compact integrated solution to replace various auxiliary sensors such as pressure, temperature and humidity.

SGL continues to research ways to enhance the resolution and accuracy of gravity data from AIRGrav surveys, and to improve geoid measurements using AIRGrav. Central to these projects is refining and improving GPS processing software and further utilizing the horizontal components of the gravity field measured by AIRGrav. The company also refined its EM processing.

In 2013, Scott Hogg & Associates introduced its DAQNAV airborne navigation and data recording system which logs data to an SD Card from all devices outputting data. In 2015, SHA installed the DAQNAV system on a Panasonic FZ-G1 10-inch tablet that can run up to 18 hours on its internal battery and displays real-time aeromagnetic compensation in addition to instrument diagnostics. This tablet system, coupled with a Ublox, USB-powered GPS system, was installed in an Astar B2 helicopter as a standalone system without cabling or power connections to the aircraft. SHA’s data-processing and interpretive services were in demand last year for ground and aeromagnetic re-processing using the company’s specialized GT-Grid and SI-Grid software. It also carried out projects in South Africa, Ivory Coast, Botswana, Kazakhstan, Canada and the U.S.

Starting in 2016, Perth-based Tensor Research assumes full responsibility for the ongoing development, technical support and sales of the ModelVision magnetic and gravity interpretation system following its transfer from Pitney Bowes (pbEncom). ModelVision has undergone 30 years of continuous R&D for 3-D interactive geological modelling, inversion, processing and display of potential field data. It was the first commercial product to provide full-tensor gravity modelling for the Falcon gravity gradiometer and it has been extended to include the new generation of SQUID full-tensor magnetic gradiometers along with 6-channel joint inversion. A new suite of tools for modelling and process-
Aeromagnetic Surveying

In 2015, GEM announced the official launch of the Monarch UAV magnetic gradiometer drone. After rigorous flight testing last year, it was expected to be commercially deployed for survey work in early 2016. The Monarch contains two specially designed, highly sensitive lightweight potassium magnetometers, GPS, and autopilot for autonomous flights at a cruise speed of 70 km/hr and a range of around 1.5 hours. The UAV was developed by partner UAS USA in Longmont, Colo., and has been used for tornado and hurricane monitoring. GEM has already received orders for the Monarch from North America, Africa, and Australia. New trial applications are also underway with the lightweight potassium sensors on a rotary wing VTOL UAV.

GEOtech has expanded the use of its heli-stinger magnetic and towed magnetic-gradiometer surveys for mineral exploration applications. The company continues to fly hundreds of thousands of line-km of fixed-wing magnetic and mag-gradiometric surveys in combination with spectrometries, aboard its fleet of Cessna Grand Caravan and Pacific Aerospace PAC 750XL aircraft. The PAC750’s relatively high power-to-weight ratio enables it to safely conduct contour flying of magnetic surveys at low levels.

In the first half of 2015, RMS Instruments completed its AARC51 Adaptive Aeromagnetic Real-Time Compensator, designed specifically for aeromagnetics on UAV platforms. It includes the magnetometer interface (counter) and real-time compensation for a high-sensitivity magnetometer, together with general-purpose data acquisition and recording capabilities. It is lightweight (under 1.8 kg), compact (133mm by 133 mm by 216 mm), uses low power and is rugged and reliable. While based on its predecessors in the AARC500-family of instruments, the AARC51 includes UAV-specific features. It has a redesigned magnetometer interface, reducing instrumental noise levels by 30%, and excellent temperature stability (±5 ppb). AARC51 should be available by early 2016.

RMS reported that new clients in remote areas of Siberia and Kazakhstan have benefited from its comprehensive on-site services. The company installed aeromagnetic gradiometers, a gamma-ray spectrometer, GPS with navigation and associated ancillary equipment on board several fixed-wing Cessna Caravan 208B aircraft. RMS also provided operator and pilot training, AME (Aircraft Maintenance Engineering) guidance and installation assistance, installation testing, test flight data analysis, aircraft control surface and fixed signature assessment, and identified interferences. RMS offers On-Board Electronic (OBE) Compensation, Magnetometer Gating and Adaptive Compensation for extended capabilities and robust aeromagnetic installations. It also offers power spectrum analysis of magnetic data, a vital tool to identify disturbances during the installation testing.

Airborne Electromagnetic Surveying

CGG’s new High Moment TEMPEST is a high-powered version of the proven broad bandwidth square wave time-domain EM system. It provides higher power via a multi-turn Tx loop, and a fourfold improvement in signal-to-noise ratio for greater depth of exploration. The system was deployed with great success in the Pilbara region of Western Australia on a joint water and minerals exploration project. In 2015, the TEMPEST fixed-wing AEM system was upgraded and outfitted on a Cessna 208 Grand Caravan aircraft.

Geophysics GPR is upgrading its TDEM system, GPRTEM. The GPRTEM2 system will have a new receiver, amplifier and platform developed to improve stability of the receiver in flight. A modification to the transmitter geometry will also reduce power output. Flight tests are planned to determine the overall improvement of the signal-to-noise ratio.

GEOtech completed its first commercial surveys using the VTEM XTREM, a system designed for deep exploration featuring a dipole-moment of greater than 2 million NIA. The greater power was achieved by using a heavier gauge 35-metre-diameter transmitter loop, a redesigned transmitter system and a new externally-mounted motor generator system. The company also developed VTEM ET, an early-time response HTDEM system for hydrogeological and engineering applications. The VTEM ET system features a lighter, redesigned transmitter loop system and a new induction coil receiver sensor that allow it to precisely measure EM fields as early as 3-5 micro-seconds after the turn-off for more precise, near-surface resistivity characterization for groundwater. The company has also developed a VTEM gradiometer-receiver system that features dual time-domain EM measurements from two, vertically spaced EM sensors for improved SPM (superparamagnetic) monitoring. The first field test of a high power ground-to-air, controlled-source ZTEM survey was also completed in North America.

New Resolution Geophysics’ next generation HTDEM system, Xcite, is the result of three years of R&D. A patented inflatable bird has been developed as a carrier for the system. The transmitter loop diameter is roughly 20 metres, resulting in a programmable output power (dipole moment) of up to 372,000 NIA. The inflatable structure supports different loop sizes, thereby providing variable system output powers, is light weight (450 kg), and ultra-compact size when deflated (three 2 by 2 by 1-metre boxes) which is optimal for shipping, and set up time is around 2 hours. All raw, streaming data are recorded and time
The Poco EM system is a low-weight, mid-sized helicopter system designed by Dr. Petr Kuzmin, who also designed the VTEM and ZTEM systems. Terraquest (Toronto), aboard its Cessna Grand Caravans. The company is currently flying tests in South Africa with the GT-2A gravimeter on an Astar B3 helicopter platform, combining airborne gravimetry with its fixed-wing ZTEM natural field EM sensor for deep mineral exploration and oil and gas applications.

Precision GeoSurveys, based in Vancouver, specializes in low-level airborne geophysical surveys in remote and mountainous terrain. In 2015, Precision flew 1TEM time-domain EM, magnetic, and radiometric surveys across Western Canada and the Western U.S. 1TEM is a TDEM system with a single wrap transmitter loop with fast ramp-off time capable of measuring early time responses. It maps shallow as well as deep conductive features using later time gates.

SGL currently flies EM surveys using the company’s fixed-wing frequency domain EM system (SGFEM). The four-frequency system is ideal for high-resolution mapping of shallow-to-moderate-depth targets. For deep targets, the company also offers gravity data in conjunction with SkyTEM’s helicopter time-domain EM surveys. SGL completed the first phase of a three-year EM, magnetic, and radiometric survey in Ireland using the SGFEM system, and flew a combined SkyTEM and AIRGrav helicopter survey in northern Canada for mineral exploration.

Terrquest announced that it is now the exclusive operator of a new advanced helicopter time-domain EM system designed by Dr. Petr Kuzmin, who also designed the VTEM and ZTEM systems. The Poco EM system is a low-weight, mid-sized helicopter system adaptable for safe operation in all terrain and environmental conditions. The system operates in the kHz to MHz hand, and therefore has improved sensitivity to highly resistive lithology and alteration systems that may be poorly resolved by conventional TDEM systems. The system is designed to map geological targets in the top 70 metres with resistivities in the range of 100 to 1000 Ohm-m, and has been shown to detect kimberlites on at least two surveys. Because of its light weight and relatively compact size, Poco is well adapted for inaccessible Cordilleran and Andean targets, such as porphyry systems. Poco may be used detecting kimberlite pipes, hydrogeology, geological mapping of relatively resistive rock formations and for measuring alteration systems associated with porphyry, gold or uranium mineralization.

Airborne Gravity Surveying

In 2015, Houston-based Bell Geospace acquired full-tensor gravity data for petroleum and mineral exploration projects worldwide, but found most work overseas — especially in Asia and Africa. Bell continued to develop innovative methods that incorporate the full-tensor data for signal processing and signal enhancement. The Contact Lineament Processing (CLP) method uses unique properties of the full tensor to define a self-steering filter to enhance linear features. Applied iteratively, it reduces high-frequency chatter in gradient data. Bell improved interpretation tools such as full-tensor migration, a fast inversion method, and full-tensor gridding, which uses the properties of the tensor-to-image features between survey lines.

FALCON Plus, the newest release in CGG’s FALCON AGG technology, features improvements in hardware, software, processing workflows and data-acquisition technology that reduced the noise by half. In addition, FALCON Plus provides 20 times better spatial resolution (150 metre vs. 3,000 metre) and up to 10 times higher accuracy (0.1 mGal vs. 1.0 mGal). FALCON Plus exhibits a minimum sensitivity to air turbulence. As with CGG’s unique FALCON technology, FALCON Plus incorporates two separate gravity gradiometer instruments onboard the aircraft for immediate assessment of system noise, assuring high-data quality.

Geotech operates two GT-2A gravity systems, manufactured by Canadian Micro Gravity (Toronto), with the GT-2A gradiometer and a fixed-wing ZTEM natural field EM sensor for deep mineral exploration and oil and gas applications.

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Tel.: +1 418-877-4249
In 2015 Kazzinc of Kazakhstan used Toronto-based Advanced Geophysical Operations and Services' (AGCOS) AMT-MVP technique in northern Kazakhstan to extend two different gold fields. State-owned KazGeology successfully applied the technology for polymetal exploration in central Kazakhstan. The AMT-MVP technology also led to a significant new gold discovery by Kinross Gold.

Toronto-based Quantec Geoscience reported a modest rebound in work levels in 2015. The company completed surveys around the globe, with increased activity in the Southwestern U.S. Mining projects made up the majority of the work, along with an increase in geothermal projects. There continued to be an emphasis on deep imaging, mainly through combined DCIP and MT surveys, both 2-D and 3-D. All three of Quantec’s proprietary system technologies: SPARTAN MT, TITAN 24 and ORION 3D, were in demand.

Scintrex introduced an upgraded gPhoneX with much lower drift and noise levels. This instrument is used for monitoring gravity and vertical acceleration seismic activity over long periods. Applications include groundwater monitoring and ocean-loading effects on high-accuracy gravity surveys.

Physical Rock Properties and Elemental Analysis
In 2015, GF Instruments of Brno, Czech Republic, developed the Multi Kappa 3L, a new magnetic susceptibility probe. The probe provides three simultaneous depth soundings with 0.12, 0.25 and 0.5-metre axial depth ranges, which measure the magnetic susceptibility gradient and reduces the influence of uneven ground surfaces. Typical temperature drift of sensors is 2 x 10^-6 SI units per 1° Celsius. The probe is suitable for both spot measurements and continuous profiling of magnetic susceptibility for geological surveys, archaeology and prospecting.

In 2016, Instrumentation GDD will release a new MPP probe (MPP3wifi) for use with any Wi-Fi connected device. The probe is accessible through a built-in wireless access point and provides a web application to display and collect data. The MPP probe simultaneously measures the magnetic susceptibility (10^-3 SI) and the relative and absolute EM conductivity (mhos/metre) of drill core or field samples. Absolute EM conductivity measurements were improved and owners of previous MPP software can get the latest enhanced version from GDD. Also in early 2016, GDD’s SCIP device will be able to measure and export the fullwave signal (Vp and I), similar to the GDD IP Rx. The user will be able to visualize and reprocess datasets using IP Post-Processing software.

Terraplus of Richmond Hill, Ont., introduced two new sensors for the KT-20 Physical Property Measuring System: the KT-20 IP and the 3F-32. The KT-20 IP is a galvanic induced-polarization/resistivity sensor that employs four contacts, allowing users to configure a wide range of electrical arrays. IP decay curves are shown in real-time on the KT-20’s transflective colour display. The standard KT-20 IP is available with 20 chargeability windows, while full waveform time-domain IP measurements with 300 chargeability windows is an option. The 3F-32 is a large-diameter sensor that measures the subsurface for agricultural, archaeological and environmental investigations. The 3F-32 sensor features three frequencies (1, 10 and 100 kHz) and is equipped with a telescopic pole and arm support for taking measurements while standing or walking. A new version of the GeoView software is also available for the KT-20 that includes an improved user control and graphical interface, a database browser, and the ability to generate daily reports.

Ground Data Acquisition and Processing
AGCOS improved its multifunction data-acquisition systems for AMT, MT, MVP, CSAMT, TDEM, TDIP, SIP, and Resistivity and added the controlled-source Frequency Domain EM Sounding (FDEMS) method. It is based on the measurement of 5-components of the EM field for calculation of apparent resistivity and phase, on the basis of geometrical factors. New versions of the multifunction EM receivers GEPARD-4 and GEPARD-8, and the multifunction current source AF-100, were also developed. The new systems support all earlier-developed functions as well as the newly implemented FDEMS technology. The FDEMS method
has a greater sensitivity to earth structures than CSAMT, AMT and MT methods. The new EM system consisting of multifunction EM receivers GEPARD-4B, GEPARD-8B and the multifunction transmitter AT-100, has an effective investigation depth of 3 to 300 metres. With a more powerful transmitter (50-100 kW) the depth of investigation can be increased to 5-6 km.

Lisbon-based EMTOMO developed VLF2DMF, a dedicated VLF inversion software based on the 2-D Occam technique. It provides basic Fraser Filtering for conductor maps and Karousis-Hjelt Filters for current-density pseudosections. The software also allows the creation of 2-D resistivity sections, resistivity depth plan slices as well as forward modelling. In 2015, GEM Systems became the global reseller of VLF2DMF software.

Lamontagne Geophysics first introduced its HTML5 software tools MultiLoops X and 3C Plotter in 2014. The suite of compatible tools now includes Vectorplot and Gridplot. Vectorplot is an interactive tool that makes it possible to display sections of primary field orientations and amplitudes for transmitter loops defined as UTEM loop files or entered by the user. The primary field coupling with target zones of varying strike and dip directions can be studied. Gridplot is used to locate transmitter loops, survey grids and boreholes on a Google map or photograph of any selected area. These free Javascript applications can be run online or offline.

On the consulting side, Mira Geoscience continued with its integrated approach to geological and geophysical modelling techniques. At the Mutooroo iron exploration project in Australia, for example, the company developed a geologically-based magnetic model using a variety of interpretation, modelling and inversion techniques. Using the limited constraint data on the magnetic units, a geologically plausible 3-D magnetic domain model that explains the measured magnetic response was developed and verified by the sparse geological and magnetic susceptibility data. Forward modelling was followed by a final stage of inversion. The result is a geologically-based model, consistent with geological constraints and geophysical...
survey data that provides a basis for confident decision-making and is able to accommodate new information as it becomes available.

Quantec is focusing its R&D efforts on the software side, trying to extract more information from recorded data and improve efficiencies through data integration with software vendors. For example, TITAN 24 IP data can now be imported directly into Geosoft. SPARTAN MT technology continues to evolve, with a trend towards more full frequency projects that deliver both deep and shallow information. Quantec reported exciting results from the effort to extract more geological information from the ORION 3D data sets. Rather than creating one final model that attempts to image all aspects of a survey area, Quantec is moving towards multiple final models that offer different perspectives for interpretation.

**Drillhole Methods**

A borehole EM (BHEM) survey conducted by Abitibi Geophysics on Osisko Gold Royalties’ Coulon project, located in an unexplored Archean volcanic belt in northern Quebec, resulted in the discovery of Lens 257. Osisko decided to drill an off-hole BHEM anomaly in spite of an absence of outcrop or anomalous data on surface. The best hole yielded 5.57% zinc, 1.87% copper and 69.93 grams silver per tonne over 20.3 metres.

During 2015, Delta Epsilon Instruments of Grand Junction, Colo. introduced the GVX4 borehole logger to its line of portable borehole logging systems. The GVX 4 may be fitted with up to 500 metres of standard 3/16 inch, four-conductor steel armoured logging cable ready to conduct comprehensive borehole geophysical surveys or high-resolution video surveys using a DE/BCM-01 Borehole Camera.

A new 3-axis down-hole EM sensor, BHUTEM5, is under development at Lamontagne Geophysics’ new facilities. A first working prototype of the BHUTEM5 showed a noise performance three times better than the BHUTEM4 sensor in the 2 Hz to 30 Hz base-frequency range and an even greater improvement below 1 Hz. The objective is to obtain five times higher sensitivity than BHUTEM4 at 4 Hz and to measure to frequencies as low as 0.25 Hz with a precision comparable to the UTEmS5 surface sensor. As with the BHUTEM4 system, the new down-hole system will be linked to the UTEm 5 receiver using a fibre optic cable/winch system with a 3,300-metre depth capability suitable for measurements in boreholes of NQ size or greater.

In 2015, Medusa developed a new borehole correction algorithm to properly quantify spectral gamma logging data. The company also developed its first prototype “OEM” spectral gamma-ray borehole sensor, which comprises a 1 by 1-inch CeBr3 crystal connected to a tiny multichannel analyzer board that fits inside a 1-inch inside-diameter logging tool. The system has excellent energy resolution of less than 4%. Medusa also partnered in an EU-funded R&D program, SoiMon, aimed at developing an actively compensated measurement while drilling (MWD) tool for soil research. The company’s Soimon tool was successfully tested and is now available for testing by drilling companies.

Denver-based Mount Sopris Instrument Co. has developed a fully digital, slimhole side-wall, 256-channel, spectral gamma-gamma density logging tool that records low-energy gamma-ray absorption in adjacent formations. This photoelectric (Pe) log is recorded in barns per electron and is output simultaneously with the tool’s other logs, including near and far raw counts/sec, near and far gamma-gamma density and real-time calibrated compensated density (g/cm3). The photoelectric effect, which is related to the equivalent atomic number (Z) of the elements in the formation, is a sensitive indicator of mineralogy. The 50-mm diameter tool, which is designed to withstand 200 Bar pressure and temperatures up to 70° Celsius, will work in boreholes up to 300-mm diameter. Experiments with cesium-137 and cobalt-60 gamma-ray sources with strengths ranging from 100 to 500 millicuries will be conducted in 2016. The tool is compatible with existing geophysical logging systems.
The world’s first borehole gravity survey in a horizontal well was completed in Alaska using the Scintrex/Micro-g Lacoste Bluecap tool. The tool is expected to be used primarily in highly deviated and horizontal wells for reservoir monitoring, but could be used to extend the effective investigation volume of highly deviated mine exploration and development drill holes. The tool is also being used in CO2 enhanced recovery and sequestration logging. In 2015, the first Gravilog mining surveys in Brazil were run by GeoRadar of Belo Horizonte.

**Ground Electromagnetic Methods**

Abitibi Geophysics completed three ARMIT-TDEM surveys in Saskatchewan’s Athabasca Basin during the winter. The excellent signal-to-noise ratio and the simultaneous measurement and recording of both B-field and dB/dt provided important definition of the deep conductors in the basin, which is not possible with conventional sensors.

In a proof-of-concept pioneering survey, Brampton, Ont.-based ClearView Geophysics completed snowmobile-mode cesium magnetometer and TDEM surveys on a large-scale gold exploration project in Nunavut with Cantley, Que.-based Devbrio Géophysique. The magnetometer was mounted on ClearView’s customized sleigh. Devbrio’s high-resolution, single platform-mounted Tx/Rx, high-current and full-waveform IMAGEM system was mounted on a separate, customized lightweight sleigh far enough apart and away from the snowmobile to avoid interference with each other. The survey was achieved at minimal cost by using one snowmobile and operator. In spite of rugged terrain with sparse patchy snow conditions the high-data quality far exceeded expectations. ClearView also carried out tests in ATV-mode using an Instrumentation GDD NordicEM24 receiver attached to a Geonics 3-D TDEM coil and a Geonics TEM47 battery-operated transmitter with the transmitter loop wound around a sleigh-mounted wooden frame. Readings were recorded automatically at regular intervals and showed that it is possible to use off-the-shelf equipment with a few modifications to carry out snowmobile or ATV-mode TDEM surveys.

The 3D E-SCAN technology that Crone Geophysics acquired in 2015 evolved to address the demand for a resistivity survey tool capable of mapping the deep core of entire mountain complexes, in search of geothermal energy sources. To develop such a tool, Premier Geophysics of Aurora, Ont. carried out a five-year R&D program with co-funding and support from the GSC, B.C.’s Department of Energy, Mines and Petroleum Resources and the BC Hydro and Power Authority. The resulting E-SCAN field data-acquisition technology produced the required true 3-D resistivity field datasets several years ahead of the initial...
breakthroughs in 3-D inversion algorithms that were achieved at the UBC-GIF (Geophysical Inversion Facility). Crone intends to offer true 3-D IP/resistivity mapping capability to resolve a broad spectrum of exploration challenges at an affordable cost at three levels of detail ranging from reconnaissance to high resolution. Recon3D E-SCAN provides single-line IP/resistivity traverses or multi-line lower-density 3-D coverage intended for initial property assessment; Target3D E-SCAN expands upon Recon3D’s defined areas of interest; and HiRes3D E-SCAN is the highest-density, highest objectivity true-3D mapping level. Crone’s program of overnight 3-D field data QC and progressive inversion modeling provides day-to-day survey guidance and improves project targeting. The 3D E-SCAN technology was first used in a HiRes3D IP and resistivity survey along the Comstock Trend, near Gold Hill, Nev. The 3-D IP and Resistivity imaging results were presented at the 2015 Symposium of the Geological Society of Nevada in Reno.

Crone also advanced its existing Pulse-EM system based on feedback from field crews. The multi-channel CDRx Receiver now has improved data-quality control software for the field, as well as new survey techniques that reduce data noise and improve data repeatability. The company upgraded its CSIRO LANDTEM High Temperature SQUID units with fibreglass dewars by initiating and supporting this development at CSIRO in Australia. The new dewars are larger and more rugged than the original glass dewars, which facilitates transport in challenging terrain. These units are used in ground time-domain EM surveys with the Pulse EM system (PEM-SQUID surveys).

GEM has seen a rebirth of VLF sales following the launch of its new ground VLF system. The system allows three VLF stations to be automatically measured simultaneously. The data are processed with VLF2DMF software to provide resistivity-depth sections for the top 100 metres, depending on ground conditions. GEM is now able to distribute EMTOMO’s VLF2DMF software with its VLF systems.

Geonics developed two new UXO detectors last year, the EM61BLU Array-MK2 and the EM61-LX2. They are based on the experience gained during the UXO LAO-sponsored trial in Sepon (Lao PDR) in 2014 in a “blind test” to detect BLU-26 bomblets in highly mineralized soil. All three Geonics-designed and manufactured instruments achieved best-overall performance among the 13 different instruments from Germany, Australia, the U.S. and Canada. Each UXO detector consists of two 1 by 0.5-metre transmitter coils with four receiver sensors for the EM61BLU Array-MK2 and two receiver sensors for the EM61-LX2 (located inside the transmitter coils), as well as an acquisition and processing console. Both instruments respond to a target based on amplitude and time-based windows in the form of audio and video indicators for real-time target registration.

GF Instruments introduced a high-resolution EM conductivity meter, the CMD Mini Explorer 6L for multi-depth surveys in the depth range 0.15 to 2.3 metres. Simultaneous readings of conductivity and inphase values (sampling at up to 10 Hz) at six depths with 1-D, 2-D and 3-D inversion can support detailed archaeological, agricultural and geological surveys, as well as road inspections. Measurements can be performed in manual or continuous measuring modes using GPS positioning and Bluetooth communication.

After the successful field test of new power electronics in the form of two medium-power UTEM 5 transmitter prototypes, Lamontagne Geophysics resumed development of the new compact design UTEM 5 transmitter to improve power efficiency by 35%, and be usable over a range of output levels from portable low-power to high-power applications. It will be able to operate with motor generators varying in power from 2,000W to 11,000W and voltage between 120 and 240V AC. The high voltage-regulated current waveform output will be optimized for use with light gauge wire loops.

Melbourne-based Monex GeoScope released three new geophysical survey instruments in 2013: the terraTEM24, Voltage Rectifier and TR_B Field sensor. In addition, Monex enhanced most of its standard products.

The terraTEM24 is a versatile TEM system that delivers excellent results in the traditional stationary TEM sounding mode, and can be deployed in mobile platforms such as a helicopter, UAV or a towed cart. For moving applications, full raw data can be streamed to internal SSD and registered with GPS and timing stamps. As with all terraTEM models, an internal transmitter is included, but with the output increased to a maximum current of 50 Amps at 12V through to 120 V, a maximum of 6 kW output power. This component (weighing less than 0.5 kg) is optional if only the receiver is required, but is a must for operators wanting a genuinely versatile instrument for all scenarios.

To support the terraTEM24 internal transmitter as well as the terraTX-50 standalone transmitter, a Voltage Rectifier was added to the terraTEM suite of products. The voltage output is controlled from a front panel dial or via a serial connection with the terraTEM24 or terraTX-50 transmitters. The Voltage Rectifier can be connected in series to provide 12 kW or 240 V at 50 Amps.

The TR_B Field sensor which is just 38 cm long and weighs 1.5 kg, has been fully integrated to work seamlessly as an accessory with the terraTEM24. Recording three components of the Earth’s magnetic field simultaneously, solid state rotation elements are used in conjunction with the terraTEM24 rotation software. The sensor also contains automatic nulling of the ambient B-field.

**Induced Polarization**

Previous exploration success boosted the popularity of Abitibi’s OreVision, a large spaced dipole-dipole array, in 2015. The system successfully delineated deep mineralization, confirmed by drilling, at Cartier Resources’ Cadillac Extension project, in Quebec, Cartier used OreVision to define the...
geometry and position of the favourable horizon containing massive sulphides. At its MacCormack project, in the Porcupine-Destor deformation corridor in Quebec, Cartier tested OreVision over a drilled InfiniTTEM anomaly and detected a deep extension of the gold zone.

**Dias Geophysical**’s DIAS32 system comprises as many single-channel receivers as is necessary for efficient survey operation, but in 2015, its capacity was expanded to over 100 receivers from 26, and the size of the receivers was reduced. Each receiver is part of a wireless network that transmits data, quality control, and system status information to the operational base. Dias emphasizes safety using its DIAS-LS proprietary lightning shunts. In addition, a current lockout system mitigates the risk of electrocution from the high-voltage transmitter wires. In 2015, the company carried out surveys in gradient, pole-dipole, dipole-pole-dipole (distributed multipole), and full 3-D modes. The single-channel system architecture allows for any survey mode at any scale. Dias acquired time series data on all surveys with the current waveform measured at two key locations for each survey. The company completed commercial surveys in Chile, the U.S., and Canada, mostly for mineral exploration. One 3-D survey was for an engineering application, the results of which are being interpreted with 3-D seismic data.

In 2015, **Instrumentation GDD** introduced a new versatile EM-IP Tx Controller compatible with both GDD IP and EM instruments. For IP surveys specifically, the GPS time stamp real-time current recorder (up to 40A) is compatible with any IP Transmitter on the market. When paired with a GDD IP receiver, accurate apparent resistivity values can now be recalculated from their real-time current measurements using the company’s IP post-processing software. A new, compact, inexpensive and lightweight GDD 8-channel Resistivity/IP Receiver was also released in 2015. The 3.5-kW IP Rx allows 3-D, multi-line configurations (1/8, 2/4). Like all GDD IP Rx models, the GRx8mini has GPS synchronization and enables display of real-time colour pseudo-sections.

GDD’s new IP Tx 10kW-4800V-20A (master-slave) will be released in early 2016. The new model Tx4 will allow 20A capabilities (at low voltage), GPS synchronization and real-time current recording (via a Tx Controller) and will have an improved user interface for better daily production. The IP Tx (current model TxII) can be upgraded to 15A capabilities (at low voltage).

**Iris Instruments** of Orleans, France, improved its FULL-WAVER distributed resistivity and IP system for 3-D surveys. The system consists of the V-Full Waver two-channel receiver module (signal recording) and I-Full Waver module (current recording). Both modules now include more memory to ensure autonomous data acquisition for several weeks, a graphical display to check the quality of the recorded signal, and the ability to transfer raw data to a USB stick at high speeds. In addition, cancellation algorithms for noise (rejection spikes and SP jumps) have been implemented in the PC processing software which filters the GPS time-stamped samples.

Vancouver-based **SJ Geophysics** released a new version of its digital Volterra Acquisition System. The unit now integrates temperature compensation to improve clock rate, and improves the input impedance from 20 M-ohm to 100 M-ohm, has an onboard memory of 32 GB and includes a modified battery tube to increase recording time. A single charge can power the unit for 10-12 hours and adding battery tubes in parallel can increase running time for larger surveys. SJ Geophysics also added a 32-mm diameter borehole probe to fit inside BQ drill rods, to complement the 38-mm probe and acquire IP, mag and EM data. In addition, the company improved the system’s signal-to-noise ratio from time series data by addressing natural field noise. Telluric cancellation (TC) methods were developed using robust filtering techniques and additional data from a remote reference site. Initial studies show that the TC methods improve the signal-to-noise ratio an average of two to three times in the RMS error of an individual measurement. This equates to the recovery of one or two dipoles (1-2 N values) at the noise threshold, which provides additional far-offset data to the inversion stage. SJ Geophysics used the system on surface and borehole EM, as well as on a variety of IP projects ranging from simple 2-D IP programs to complex 3-D IP programs.

**Ground Magnetic Surveying**

To improve the quality and timeliness of ground magnetic surveys, **Abitibi Geophysics** intends to collect data with a UAV flying at low altitude and outfitted with AeroVision, a high-resolution magnetic gradiometer from **GEM Systems**. The rapid sampling rate of the data acquisition combined with the low UAV air speed results in a higher spatial resolution than a continuously recorded ground magnetometer survey. Test flights have yielded excellent quality data.

**GEM** has developed a multi-sensor towed ground rover for near-surface detailed searches. The system can be deployed with four high-sensitivity potassium magnetometers in gradiometer mode for both UXO and archeological investigations and can be adjusted to hold more sensors. Five systems were deployed in 2015.

**Magnetotelluric**

**EMpulse Geophysics** of Dalmeny, Sask., has developed a new capacitive “line-antenna” for measurement of the horizontal electric field in magnetotelluric surveys to combat “static shift” distortion of the horizontal electric field by near-surface 3-D bodies. The new antenna returns a potential that is integrated (averaged) down the entire length of each antenna leg. As opposed to point measurements of voltage with porous pot electrodes, the volume-averaged potential returned with the capacitive line-antenna is less susceptible to the effects of near-surface 3-D bodies and returns a potential more consistent with inductive scale length. Since the capacitive line-antenna is non-contacting, distortion-free apparent resistivity/phase curves are obtainable up to the highest measurement frequency of 31.5 kHz. This allows maximal use of the high frequency impedance data and therefore maximal fidelity in 3-D inverted models within the upper 225 to 710 metres, (which is skin depth at 5 kHz for a 1000 ohm-metre and 10,000 ohm-metre environment respectively). The new antenna permits effective operations on frozen, very dry, or very rocky ground, where traditional MT measurements are difficult to impossible. Measurement with the capacitive line-antenna is however, very sensitive to motion noise. With light stainless-steel cored IP wire, it is possible to get good earth response curves down to 30 to 100 Hz and with heavier twin-ax cable, good curves were obtained down to the 5 to 10 Hz range in normal field operations.
EXPLORATION TRENDS & DEVELOPMENTS

COMPANIES AND WEBSITES

Aarhus Geophysics: www.aarhusgeo.com
Abitibi Geophysics: www.ageophysics.com
AeroGeotech Rosearo Group: www.geotech.ca
AGCOS: www.AGCOS.ca
Assegai Geophysics: www.assegaigeophysics.com
Bell Geospace Inc: www.BellGeo.com
Bureau des Mines et de la Geologie du Burkina: www.bimagf.be
CAMIRO: www.camiro.org
Canadian Exploration Geophysical Society: www.KEGOnline.org
Canadian Micro Gravity: www.canadianmicrogravity.com
CGG Multi-Physics: www.cgg.com/Multi-Physics
ClearView Geophysics: www.geophysics.ca
Condor Consulting: www.CondorConsult.com
CSIRO: www.CSIRO.au
DAFWA: https://www.agric.wa.gov.au
Delta Epsilon Instruments
Delta Epsilon: www.deltaepsilon.com
Dia Geophysical: www.diageo.com
ECA Group: www.ecagroup.com
EMpulse Geophysics: www.EMpulse.ca
EMTOMO: www.emtomo.com
ENWRAL: www.lpsrnr.org/Programs/gwaem.htm
EON Geosciences Inc: www.EONgeosciences.com
EXIGE: www.exigesa.com
Explorer Geophysical: www.explorer-sa.com
Fullagar Geophysics: www.fullagargeophysics.com
GammaX: www.gammax.com
GCS: www.gcs.gov.sa
GEM Systems: www.gemsys.ca
GeoDuster Technologies: www.geoduster.com
Geological Survey of Newfoundland: gis.geosurv.gov.nl.ca
Geonics: www.geonics.com
Geophysics GPR International: www.geophysicsgpr.com
GeoRadart: www.georadar.com.br
Geoscience Australia: www.ga.gov.au
GeoscienceBC Peace project: www.geosciencebc.ca/s/PeaceProject.asp
Geosoft: www.geosoft.com
Geosphair Aviation: www.geosphair.com
Geotech Ltd: www.geotech.ca
Geotechnologies: www.geotechnologies-rus.com
GF Instruments: www.GFInstruments.cz
Goldak Airborne Surveys: www.goldak.ca
Gyrolog: www.gyrolog.com
IRF: www.irfgyro.com
IGS: www.igsint.com
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IRIS Instruments: www.iris-instruments.com
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Lamontagne Geophysics Ltd: www.LamontagneGeophysics.com
Magee Geophysical: www.gravityandmag.com
Magenta: www.magentageo.com
Medusa Systems BV: www.medusa-sensing.com
Micro-g LaCoste Inc: www.microlacoste.com
MIERN: www.miern.gouv.qc.ca
Ministry of Mineral Resources of Mozambique: www.miern.gov.mz
Ministry of Industry, Mines and Technological Development (Canada)
MNDM (Ontario): www.mndm.gov.on.ca
Mira Geosciences: www.mirageosciences.com
Mount Sopris Instruments: www.mountsopris.com
Newexco: www.newexco.com
NRG: www.airbornegeophysics.com
NMMU: www.nmmu.ac.za
NZPAM: www.nzpam.govt.nz
PicoEnvirotec: www.picoenvirotec.com
Pitney Bowes Business Insight:
www.pitneybowes.com/pbcencom
Precision GeoSurveys: www.precisiongeosurveys.com
Premier Geophysics Inc: www.premiergeophysics.com
Promiseland Exploration: www.promiselandexploration.com
Quantec Geoscience: www.quantecgeoscience.com
Radiation Solutions Inc: www.RadiationSolutions.ca
RMG: www.rmgeoscience.com
RMS Instruments: www.RMSInst.com
Sageag: www.sageag.com
Sander Geophysics: www.sgl.com
Scintrex Ltd: www.scintrexltd.com
Scott Hogg & Associates: www.shageoscience.com
SJ Geophysics: www.sigeophysics.com
SkyTEM Surveys: www.SkyTEM.com
SODEMI: www.sodemi.ci
SoiMon: www.soimon.eu
SOQUEM: www.soquem.qc.ca/en/home
Tensor Research: www.tensor-research.com.au
Terraplus Inc: www.terraplus.ca
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TerraSurvey: www.terrasurvey.ca.com
Triumph Instruments: www.triumph.ca
Triumph Surveys: www.triumph.ca
Tundra Airborne Surveys Ltd: www.tundraair.com
University of British Columbia: www.ubc.ca
USGS: www.usgs.gov
UASUSA: www.uasusa.com
Xcailbur: www.xagpa.com

ABBREVIATIONS (for acronyms used in the text)

A Ampere
AC Alternating Current
ADC Analog to Digital Converter
AEM Airborne EM
AGRS Airborne Gamma-Ray Spectrometer
AMT Audifrequency MT
B Magnetic Field
BGO Bismuth Germanate
BIF Banded Iron Formation
HRAM High Resolution Airborne Magnetic
BLU Bomb Live Unit
CAMIRO Canadian Mining Industry Research Organization
CDI Conductivity Depth Images
CeBr3 Cerium Bromide
CSAMT Controlled Source AMT
Csi Cesium Iodide
CSIRO Commonwealth Scientific and Industrial Research Organization
dB/dt rate of change of B with time
DC Direct Current
DCIP Direct Current Induced Polarization
DTM Digital Terrain Model
EM Electromagnetic
GIF Geophysical Inversion Facility
GPS Global Positioning System
HTDE Helicopter TDEM
HV High Voltage
Hz Hertz ~ cycles per second
IMU Inertial Measurement Unit
IOCG Iron Oxide Copper Gold
kHertz kiloHertz
kHz kiloHertz
kW kiloWatt
LaBr Lanthanum Bromide
LiDAR Light Detection And Ranging
MCA Multi Channel Analyzer
MT Magnetotelluric
MWD Measurement While Drilling
Na Sodium Iodide
NIA Dipole Moment of EM loop
QC Quality Control
RMS Root Mean Square
SD Secure Digital
SIP Spectral IP
SSD Solid State Drive
SQUID Superconducting Quantum Interference Device
TDEM Time Domain EM
TEM Transient EM (~ TDEM)
Tx/Rx Transmitter/Receiver
UAV Unmanned Airborne Vehicle
UBC University of British Columbia
USB Universal Serial Bus
UTEM University of Toronto EM
UXO Unexploded Ordnance
V Volt
VLF Very Low Frequency
VMS Volcanogenic Massive Sulphide
VTOL Vertical Take Off & Landing
W Watt

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