



ETD

EXPLORATION **TRENDS** & DEVELOPMENTS

March 2020

Advances in **GEOPHYSICAL TECHNOLOGY**

THE NORTHERN MINER

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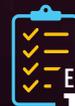
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Published in co-operation with
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Printed in Canada.

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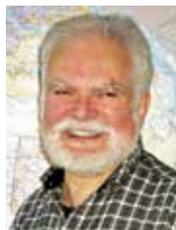


Cover photo: SHA Geophysics' Heli-GT system flying a low-level, high-resolution airborne magnetic gradient survey in Nevada.

Credit: SHA Geophysics

MINERAL EXPLORATION TRENDS & DEVELOPMENTS IN 2019

By Patrick G. Killeen Ph.D., geophysical consultant and retired research scientist, Geological Survey of Canada, Ottawa



This is the fourth year that Decennial Mineral Exploration Conferences (DMEC) has served as the patron for Exploration Trends & Developments. DMEC organized the very successful Exploration '17 conference, held in Toronto in 2017, the sixth in the series of conferences which began in 1967. This year DMEC support came from the sponsoring companies listed on page 23.

The ETD review originated with the Geological Survey of Canada (GSC), where for more than 50 years GSC scientists prepared an unbiased annual publication on trends and new developments in geophysical exploration for minerals. This marks the 28th year that Patrick Killeen has written the review, originally as a GSC research scientist.

The Canadian Exploration Geophysical Society (KEGS) was the patron of ETD between 2007 and 2016. DMEC and KEGS are committed to the promotion of geophysics, especially as it is applied to the exploration for minerals other than oil; to fostering the scientific interests of geophysicists; and to promoting high professional standards, fellowship and co-operation among persons interested in this industry.

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■ Flying-Cam's DISCOVERY UAV with RSI's Advanced Digital Spectrometer. Credit: Flying-Cam



EXPLORATION TECHNOLOGY IN 2019:

THE RISE OF THE MACHINES

2019 saw a slight upturn in exploration spending. New partnerships, collaborations and strategic alliances were reported. Airborne surveys for petroleum saw a slight decrease but surveys for mineral exploration picked up. New, upgraded and enhanced geophysical technology appeared for airborne, ground, borehole and physical rock property measurements. This included both hardware and software developments, particularly the latter. Data processing capabilities continued to increase along with the growing size of datasets including multiparameter survey results. Instrumentation saw a trend toward use of Android apps for control and transfer of data using smartphones or tablets. The use of artificial intelligence and machine learning appeared as a major influence in moving from raw survey data to interpretation and definition of drilling targets.

Airborne geophysical surveys were conducted by contractors worldwide for both mineral exploration and for large regional surveys in government projects. At least one contractor added a new aircraft to its fleet. An increase in the use of airborne gravity for mineral exploration was also reported. Several new developing airborne EM and MT technologies were flown over test sites. Airborne TDEM systems had numerous upgrades to increase power, reduce noise, and reduce the weight of transmitter loops using new materials, for surveying at higher elevations and speeds. Airborne EM is seeing a trend towards more use of natural EM fields. A new air-to-ground system was developed and tested using an airborne Tx with multiple Rx's on the ground.

Several large applied mineral exploration R&D projects have developed, ranging from an industry-led consortium to a university-led project, with government and industry collaborators, to examine geological and geophysical datasets. Notable new developments include a new wing tip vertical gradiometer mag system installation, a new combined EM/mag/gamma-ray system installation, a new high-power TDEM system, new data enhancement methods, more automatic procedures for classifying geologic units from geophysical datasets, more joint 3D inversions of airborne EM and mag data, 3D inversion of borehole EM data, 3D inversion of borehole and surface gravity data, AI-assisted targeting for mag and gamma-ray data and increased capability of data acquisition systems with multiple geophysical parameter measurements.

New for UAV's are an improved navigation system for flying near the earth's magnetic poles, an improved real-time collision avoidance system to fly slung-birds lower, an ultra-light towed-bird magnetometer and a new magnetic anomaly detection (MAD) functionality for magnetic compensation systems. A new gamma-ray spectrometer for a UAV platform was also developed and is now flying.

Two companies updated physical rock property measuring tools that can now link with Android devices from which data can be sent out on the internet. There is new software for processing ground EM data and one company integrated geologic and seismic data to image structure of mineralized systems to help explain geophysical survey results. In MT, more 3D MT inversion capabilities were developed as well as new joint 3D inversion of surface and downhole DCIP datasets.

Developments in borehole geophysics include an improved gravity logging system with increased rugosity, logging speed and lowered costs. DCIP methods were adapted to combine downhole and surface array measurements to trace the direction of intersected mineralization and BHEM probes were upgraded for longer operating times.

Ground geophysics saw at least four companies develop a method for connecting multiple Tx's for increased power output. A new TDEM Rx has increased recording speeds up to 1.4 million samples/second/channel. A new land gravity meter was introduced and a new distributed array IP method combines IP technology with 3D inversion to extend investigations to 1000m depth with electrodes on surface and in boreholes. There is a new broadband EM and IP Tx and advances in 3D IP equipment which can self-correct 3D station wiring errors. 3D IP and resistivity surveys now have survey capacity of over 900 channels and there are new communication modules for wireless synchronization of multiple receivers in 2D/3D distributed IP surveys. Improved MT sensors were introduced along with new broadband sensors and updated EM receivers. There is a new trend to use MT for monitoring volcanic activity and space weather (magnetic storms). A new networking feature can upload data in real time from remote monitors. There are increased capabilities for MT surveys, now with unlimited dipole configurations for deep surveys. A new DCIP technique injects current down boreholes below a surface array of 3D receivers. **ETD**

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■ Geotechnologies' EQUATOR airborne EM system lifting off in Siberia.
Credit: Geotechnologies

Corporate Highlights

Abitibi Geophysics of Val d'Or, Que., reported establishing several successful international partnerships and that business activity overseas increased steadily throughout 2019. The company attributes this to enhancements to its exclusive technologies which include the ARMIT TDEM B-field and dB/dt sensor achieving greater depth of investigation and resolution using InfiniTEM XL and OmniVision TDEM loop configurations. The company's IP methods expanded to include OreVision2D, OreVision3D and DasVision distributed-array surveys. Abitibi is the sole provider of borehole gravity services with in-house GraviLOG systems and GeoTk multiple borehole and surface gravity 3D inversion software.

Toronto-based **Advanced Geophysical Operations and Services (AGCOS)** reported increasing interest in surveys with its integrated natural and controlled-source EM technique (NCSEM). The company continued to develop and upgrade its broadband multifunction EM data acquisition systems GEPARD-8 and GEPARD-4, introducing new broadband magnetic sensors as well as new lightweight AMT sensors. It also completed development of a new broadband current source and new TDEM transmitters.

ClearView Geophysics of Brampton, Ont., has been applying conventional geophysical equipment in unconventional ways for mineral exploration since 1996. This core competency has been adapted for creative solutions in non-exploration applications. The company recently used radiodetection to trace a vertical crack in a concrete monolith structure (like a concrete dam) by inserting a transmitter tracing wire into the crack. A wheeled receiver was lowered down the monolith's side, with a mirror and binoculars used to view the display. GPR was deployed similarly at regular intervals to get a 3D presentation of the internal structure. In another application, GPR, EM31, cesium magnetics and RTK GPS were used to characterize a water-filled quarry. The EM31 ground conductivity data collected from a boat at 10 times per second were used for calibrating true water depths to 7 metres and the production of a high-resolution depth-to-bottom map where the higher the conductivity, the deeper the water. For depth-to-bedrock surveys along a planned pipeline route, ClearView outfitted a sleigh with a standard **Sensors & Software** Noggin 100 GPR with an AgGPS132 and counter wheels from a **Geonics** EM61HH hand-held metal detector.

In 2019, **Crone Geophysics & Exploration** of Mississauga, Ont. focused on manufacturing products and implementing improvements developed by R&D in 2018. It also continued to produce ground-based Crone TEM systems. In 2019, contract surveys kept Crone's field crews busy worldwide.

EON Geosciences of Montreal continued to provide airborne high-resolution magnetic, gamma-ray spectrometric, gravity and EM surveys. In 2019 the company added another Piper Navajo aircraft to its fleet of fixed-wing aircraft. EON also moved its offices to make its

operations more productive and efficient.

Geo Data Solutions GDS, of Laval, Que., continues to provide global services in the acquisition, processing, presentation and interpretation of aeromagnetic data using magnetometer sensors in fixed-wing aircraft or helicopters in a “stinger” configuration. GDS also offers combined high-resolution magnetic and gamma-ray spectrometric surveys using **RSI** detector packs. A **Canadian Micro Gravity (CMG) GT-2A** gravimeter with gyroscopic stabilization platform is used for the acquisition of total field gravimetric data. The company will soon offer magnetic and gravity 3D inversions and interpretation using software developed at **Memorial University** of Newfoundland. Exclusively in Quebec, GDS now offers the AirTEM helicopter TDEM system (HTEM) designed by **Triumph Instruments** of Georgetown, Ont., based on the concept of a rigid airframe to maximize signal-to-noise ratio. The latest generation Triumph HTEM system features versatile options including: in-flight base frequency and duty cycle adjustment; all-in-one 3-axis receiver coil, full waveform recording at a 10-micro-second sample rate; and on-time, off-time and B-field processing. It is the only HTEM system available that allows both resistive on-time profiling and conductive on-time profiling as well as dual-frequency mode processing, all available by reprocessing the flight data collected at a single base frequency. Both conductive and resistive targets can be processed without having to re-fly the survey lines.

Moscow-based **Geotechnologies** continued to improve the EQUATOR airborne EM system which is the only system that can perform Time Domain (TD) and Frequency Domain (FD) measurements simultaneously. In 2019, the company developed a 7.5 m diameter transmitter while keeping all the advantages of the 11.5 m diameter transmitter (100 Am² dipole moment for TD and wide frequency bandwidth from 77 Hz to 14 kHz for FD) resulting in increased survey productivity. The company also worked on a partnership with the **University of Cagliari**, Italy, to make their system (EM, mag, gamma-ray spec) more readily available in Europe.

Quebec City-based **Instrumentation GDD, (GDD)** continued development of new technology, as well as upgrades to existing equipment for IP and TDEM surveys. For portable tools used in prospecting and for measuring physical properties of rock samples, free Android applications were developed to run the software on any Android device.

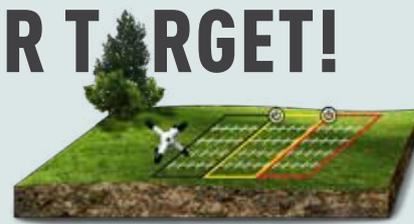
Metal Earth is a seven-year \$104 million applied research project led by the Mineral Exploration Research Centre (MERC), at Laurentian University in Sudbury, with a main goal to improve the understanding of the mineral endowment in Precambrian Rocks. Metal Earth uses new and existing geological, geochemical, geochronological and geophysical data. A major focus is defining crustal to mantle scale differences between transects that cross metal-endowed and lesser-endowed Archean greenstone belts. This will determine the key mechanisms responsible for the genesis of base and precious metal deposits. The new geophysical data includes physical rock property measurements on outcrop, hand-samples and in boreholes. Various types of seismic data have been collected along each transect and over some crustal scale structures associated with mineral deposits, including regional reflection, high-resolution reflection, large offset refraction and some experimental passive seismic data. Regional broadband magnetotelluric (MT) data have been collected on and around the transects and higher resolution Audio MT data has been collected over some crustal-scale structures. Finally, gravity data were acquired along the transects. All of these data are being analyzed and interpreted with inversion and imaging methods to meet

the main goal. Seismic surveys were able to image features in the top 10 km, including some crustal structures. The MT data shows large and primarily horizontal conductive features in the mid crust. The gravity and magnetic data can infer subsurface geometry in the upper crust when there are strong contrasts in density and magnetic susceptibility.

June 2019 marked **Mira Geoscience**'s 20th anniversary providing integrated interpretation for earth modelling, interpretation and data management. The company continued to expand its integrated interpretation software and consulting services for mineral exploration from its Montreal headquarters and Australian offices. The next generation of low-cost geophysical tools was launched through Geoscience ANALYST Pro version 3.0, which provides an easy-to-use interface for forward modelling and inversion of potential fields data. It is a geophysical interpretation environment for geological understanding without limitations on model size. Geoscience ANALYST Pro Geophysics was also released for advanced geophysical interpretation. Potential fields, resistivity, IP and EM modelling and inversion are all now available from the same interface. In October Mira started a new industry-led research consortium focused on delivering software and methods that make the use of advanced geophysics a day-to-day, practical reality for industry. In early 2020, gravity and magnetic modelling and inversion will be included in the basic GOCAD Mining Suite package. This software allows users to build plausible geological models, consistent with both geological and geophysical data. Its 3D interpretation and modelling environment allows testing of geological ideas with geophysical forward modelling.

Paterson, Grant & Watson Limited (PGW), a Toronto-based consulting firm, has extended its machine learning approach to geophysical

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interpretation. It was originally designed for automated interpretation of surficial geology and regolith from radiometric data, DEM and satellite imagery. It is now applied to mineral prospectivity, incorporating magnetic data, mapped and interpreted lithology and structure, to characterize known mineral deposits and locate terrains with similar signatures. The workflow incorporates a choice of several machine learning algorithms to optimize the results. PGW is currently interpreting a nationwide 546,000 line-km magnetic/radiometric survey of Sierra Leone in partnership with Xcalibur for the EITAP World Bank project. Through its **IDPeX** partnership in India, the company has completed an interpretation covering most of the state of Orissa and two blocks in southern India. It has also selected priority areas for follow-up TDEM surveys by the **Geological Survey of India**.

Toronto-based **Quantec Geoscience** reported several improvements to equipment and processes, including additional interpretation capabilities and procedures to enhance safety. TITAN 24 DCIP & MT, a multiparameter, distributed technology celebrated its 20th year in 2019. Launched in 2000 by Quantec, it pioneered the commercial application of distributed technology (and MT) which allowed deeper exploration with DCIP and resistivity than ever before. TITAN has now carried out over 500 surveys across the globe and has directly contributed to new discoveries. In 2019 the company initiated fatigue management programs for all vehicular mob/demob greater than 4 hours in duration and now has fatigue management processes in all field operations. This promotes safety by reducing the risk of driving incidents and driver fatigue.

Headquartered in Sudbury, Ont., **Ronacher McKenzie Geoscience** provides geological and geophysical consulting services for mineral exploration ranging from desktop project generation to in-field services and data interpretation. In 2018, the company began developing a machine learning tool applicable to exploration data and targeting, aimed at determining relationships between multiple datasets and decreasing the time required to target a potential area. In 2019, the company received an entrepreneurship grant from the Canadian government that advanced development of the machine learning tool, which launched in Q4. Through the integration of datasets in 3D, including geological, structural, geochemical and geophysical data, and machine learning, Ronacher McKenzie can interpret datasets, identify targets and increase the odds of discoveries.

Ottawa-based **Sander Geophysics Ltd. (SGL)** provides worldwide airborne geophysical surveys for petroleum and mineral exploration and geological and environmental mapping. In 2019, SGL flew airborne surveys in North America, South America, the Middle East, Europe and Australia. Highlights include the completion of a very large gravity-only survey in the Middle East, designed to improve geoid modelling, as well as a follow-on large gravity-only survey in Australia for regional mapping. In addition, several fixed-wing and helicopter gravity and magnetic surveys were flown in North America for mineral exploration. Magnetic-only surveys and combined magnetic and radiometric surveys, as well as a large combined magnetic, radiometric and EM survey, were flown in various countries. A fixed-wing methane mapping survey was flown in Canada.

Scintrex of Concord, Ont. reported that the CG-6 Autograv gravity meter introduced in December 2016 has been well-received in the market with strong sales. The company says the CG-6 has become the de facto world standard for land-based relative gravity meters.

SJ Geophysics, based in Vancouver, provides world-wide geophysical data acquisition and consulting services specializing in DCIP, EM (surface and borehole), MT, gravity and magnetic surveys. In 2019, surveys were completed in the U.S., Mexico, Australia and Papua New Guinea. Improvement and further development of the Volterra Acquisition System continued to be a key research focus for the company.

SkyTEM Surveys, headquartered in Denmark, established a new office in Santiago, Chile to expand and accommodate rapid growth throughout South America. It provides project management and full-service data processing and interpretation.

Southern Geoscience Consultants (SGC) moved to new premises in West Perth in 2019. The company has expanded into mine site environmental geophysical surveying (distribution of contaminant plumes, depth to bedrock, bedrock fracture mapping and visualization of confining layers and aquifer units) and are now sales agents for **J.A. Hallberg Mapping**.

In October, **Terraplus**, based in Richmond Hill, Ont., moved their offices to a larger facility to accommodate a greater inventory of equipment (for rent and sale) and to improve support capabilities. The company also upgraded and enhanced its physical rock property measuring equipment. **END**

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With headquarters in Paris, **CGG Multi-Physics** acquires, processes and interprets geophysical data acquired by airborne or marine platforms for resource exploration and geological mapping, from offices in Toronto and globally. During 2019 it deployed the Helitem2 and Tempest AEM technologies as well as the Falcon Plus and Full Spectrum Falcon AGG systems, on resource exploration, geothermal, water and government mapping projects.

EON Geosciences flew large aeromagnetic and gamma-ray spectrometric surveys in the Northwest Territories for the territorial government, the Canadian Prairies, several U.S. states, for the USGS and for private mining companies. The company is scheduled to fly an aeromagnetic survey in Europe in the spring of 2020.

Expert Geophysics, a Toronto, Ont.-based airborne geophysical survey company, completed several commercial helicopter-borne MobileMT surveys in 2019 in Ecuador, the U.S. (Utah), Kyrgyzstan and Canada (BC, Ontario, Saskatchewan). The surveys demonstrated that the MobileMT technology, based on natural EM fields, can successfully map resistivity from near surface to depths exceeding 1 km. Four MobileMT systems are now available for worldwide operations.

Geosphair Aviation, based in Montreal, specializes in airborne survey aircraft rental and operation. The company's Navajo spent the winter in the Yellowknife, N.W.T. area, flying an aeromagnetic survey for **EON** of Montreal. The rest of the season was spent flying small LiDAR grids in eastern Canada. The company is also working on the installa-

■ Main photo: Precision GeoSurveys' three-sensor magnetic gradient boom flying over Vancouver Island.

Inset top left: CGG Multi-Physics' Tempest airborne EM system with the bird docked.

Inset top right: NRG Exploration's Xcite TDEM system on the ground at the Bronkhorstspuit Dam in South Africa. Inset bottom: Wing tip mag pod of Terraquest's magnetic gradiometer system on survey in South Carolina for the USGS.

Credits: Erik Keyser, CGG Multi-Physics, NRG Exploration, Terraquest

tion of a complete wing tip vertical gradiometer mag system (WTG) on a customer's aircraft. The WTG design was developed in 2014 by Geosphair, which also holds the STC. The high-resolution, self-compensating system, yielding very low FOM numbers, is expected to be flying a survey in a few months.

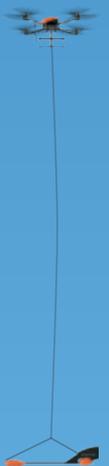
Geotech, based in Aurora, Ont., was awarded numerous airborne geophysical surveys for government agencies around the world in 2019 including: a 468,000 line-km fixed-wing magnetic and gamma-ray spectrometric survey awarded by PRECASEM (Projet de renforcement des capacites dans le secteur minier), currently ongoing in Cameroon; a 3,000 line-km VTEM ET survey and 3,000 line-km VTEM Plus surveys for groundwater were completed for the **North Dakota State Water Commission (NDSWC)**; VTEM, ZTEM and new GFEM

Drone geophysical survey

Geoscan Ltd. is an expert in the development of professional unmanned aerial vehicles and geophysical equipment. For geological exploration industry, Geoscan company has developed long-flying quadcopter, GeoShark quantum rubidium magnetometer, as well as the equipment and software for creating precise 3D terrain models. The total length of low-altitude magnetic survey profiles performed by the company in 2019 exceeds 20,000 linear kilometers.



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surveys were completed in Spain for the EU-funded INFACIT project coordinated by **Helmholtz-Zentrum Dresden-Rossendorf (HZDR)** (in cooperation with project partners including Anglo American, First Quantum Minerals, Atalaya Mining and SRK); 2,400 line-km of VTEM surveys were completed in the second VTEM survey for the **South African National Roads Agency (SANRAL)** to help identify geological risk areas for road planning and; VTEM and ZTEM surveys awarded by the Government of China for evaluation of geological hazards in a national railway project on the Tibetan Plateau.

Geotechnologies completed surveys for gold exploration and groundwater mapping in several areas of eastern Siberia in 2019. A Eurocopter AS350B3 was equipped with the EQUATOR TEM and mag system, as well as a 32 l NaI detector for gamma-ray spectrometry, to carry out the surveys.

New Resolution Geophysics (NRG) with headquarters in Cape Town, South Africa, continued to fly high-resolution helicopter and fixed-wing magnetics and radiometrics, fixed-wing gravity and magnetics and helicopter TDEM in Africa, the Middle East and Australasia. In 2019 an increased dipole moment was implemented on all five of the company's Xcite Helicopter TDEM systems and the year saw a significant increase in TDEM survey activities. One notable Xcite project was a large (more than 19,000 sq. km) airborne EM survey of New South Wales' Greater Cobar area flown for **Geoscience Australia** and the **Geological Survey of New South Wales**.

Precision GeoSurveys, based in Vancouver, specializes in low-level airborne geophysical surveys in remote and mountainous terrain. In 2019 the company flew EM, magnetic and radiometric surveys across Canada, the western U.S. and Europe. It also reported progress on innovative methods to reduce magnetic noise using a combination of new software and hardware as well as improvements to its EM technologies.

Sander Geophysics reported that 2019 was a busy year flying geophysical surveys, including combined gravity and magnetic surveys, combined radiometric and magnetic surveys, and combined EM, radiometric and magnetic surveys, as well as standalone gravity surveys and magnetic surveys. Survey projects included completion of: a large multi-year gravity survey in the Middle East to refine the geoid; large follow-on gravity surveys in Western Australia for regional mapping; another season of combined magnetic, radiometric and frequency domain EM surveying in Ireland with its SGFEM system; and a government-funded gradient magnetic, radiometric and VLF survey in Canada. The company also started a large government gradient magnetic survey and completed several gravity and magnetic surveys for mineral exploration in

Canada using its AIRGrav system in fixed-wing aircraft and helicopters. It flew a magnetic survey for research purposes for the US military and in South America, flew several gravity and magnetic surveys for petroleum exploration and completed a helicopter-borne magnetic gradient survey for mineral exploration. Also in 2019 SGL flew an extensive methane mapping survey using its unique SGMethane detection system over a producing gas field in Canada, to demonstrate how its advanced methane processing capabilities can provide accurate information about source locations and methane flux. SGL's interpretation group completed several integrated interpretation projects with 2D, 2.5D and 3D modelling of airborne data, using available seismic, geologic and drill-hole data as additional constraints. It also completed several forward modelling projects.

In 2019, the Heli-GT helicopter georeferenced 3 axis magnetic gradiometer system, developed by Toronto-based **SHA Geophysics**, carried out surveys across North America. A survey of Cantex Mine Development's high grade lead-zinc-manganese project at Rackla in the Yukon mapped a weak but distinct magnetic signature that extended the original strike length by over 4 km. The Heli-GT system also flew in Nevada in search of silver and later in Ontario's Ring of Fire area for base metal exploration. The Heli-GT's unique combination of four high-sensitivity cesium sensors and accurate pitch, roll and yaw determination allows the measurement of total field as well as magnetic gradients in the true east, north and vertical directions, fully independent of towed-bird orientation. The entire sensor package; magnetometers, radar altimeter and GPS system, are housed in a bird that is towed 25 m below the helicopter for greatly reduced magnetic interference.

In 2019, **SkyTEM's** helicopter transient EM (HTEM) systems were employed on mineral exploration, groundwater and geotechnical mapping projects globally. Large programs were flown in Brazil, Canada, Africa, several European countries, New Caledonia and Australia. In North America, SkyTEM312 was used for mineral exploration surveys in Ontario, Quebec, Alaska and B.C. as well as a geotechnical mine-site survey in New Mexico. SkyTEM312 technology was also employed for numerous water surveys in California, Nebraska, Florida and Wyoming. In Africa, the system was used by several mineral exploration companies in Botswana, the Democratic Republic of the Congo and South Africa. SkyTEM conducted extensive groundwater mapping surveys across Australia, New Zealand, New Caledonia and Malaysia with the high-power, low base frequency 12.5Hz SkyTEM312HP. The system was particularly useful for mapping in Patterson, Western Australia where it collected quality data in traditionally difficult-to-map

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conductive geological terranes. In Europe, geotechnical investigations were carried out with the SkyTEM304 and the new SkyTEM306HP systems for the **Swedish** and **Norwegian Geotechnical Institutes** and for the **LBEG** in Germany. These projects included pre-engineering studies for roadways and tunnels and analysis for potential landslides.

Terraquest of Markham Ont. provides high-resolution total field magnetic, horizontal gradient, gravimetric, radiometric and proprietary digital Matrix VLF-EM airborne geophysical surveys, using both fixed-wing and helicopter platforms. In 2019, improved inversion software was developed for the Matrix VLF data with the ability to show the VLF in 3D renderings. Flights over the Athabasca basin showed very good correlation with known IP mapping. Also post-processing options can now be selected to enhance Matrix data to focus on the specific geological signature of each project. In 2019, the company flew magnetic and radiometric fixed-wing and helicopter surveys in Canada, Mexico and Central and South America. It completed the largest airborne geophysical survey the USGS has ever awarded (68,548 line-km) in Missouri. Another regional magnetic and radiometric survey totalling 51,000 line-km was flown for the USGS in South Carolina.

Airborne Data Acquisition & Processing

After moving offices in 2018, Vancouver-based **Computational Geosciences Inc. (CGI)** now has a dedicated artificial intelligence and machine learning group with geoscience experience. The group works on a variety of datasets and problems in 2D and 3D using its V-NET deep convolutional neural network architecture. The work, which includes both supervised and semi-supervised learning, addresses problems in mineral exploration with few training examples and sparse, disparate datasets. Applications include:

- 1 Determination of probability of mineral occurrences (mineral prospectivity) to guide drilling; based on multiple data inputs (AEM data, geologic mapping, magnetic data, geochemistry).
- 2 Aquifer prospectivity mapping based on large-scale gravity, magnetic, topographic, and geologic datasets.
- 3 Automatic classification of geologic units from seismic data and detection and tracking of seismic horizons from few training examples.

- 4 Automatic classification from AEM data, of regions in a structural conductivity model that represent geologic units.
- 5 Airborne IP automated detection to predict which AEM decays have IP responses, and using 3D multi-parameter EM inversion, to recover the chargeability and produce a corrected conductivity model.
- 6 Real time well-log prediction of rock properties and mineralogy to interpret lithology from drilling data and to optimize drilling patterns.
- 7 3D structural geology interpretation from remote sensing directly predicted from magnetic, SRTM, and spectral satellite data.

CGI reported that 3D EM inversion work continued to grow, using its proprietary 3D EM codes to provide custom inversion solutions tailored to project needs.

Expert Geophysics provides advanced data processing and interpretation including inverted resistivity-depth MobileMT data. The MobileMT data inversion algorithm is based on the conjugate gradient method with adaptive regularization and weighting of the inverted parameters, eliminating artefacts and errors in depth inherent in methods without weighting functions.

GDS now offers EM interpretation services applicable to any AEM system, using methods that interface with a Geosoft Oasis Montaj database. Currently available are: parametric modelling and inversion of a layered-earth, 1D smooth inversion and modelling and inversion of plates or a sphere in a stratified earth.

In 2019 **Geotech** continued to provide advanced interpretation for its VTEM, ZTEM and aeromagnetic surveys, including 3D ZTEM inversion and 3D MVI magnetic inversion services. The company reported growing demand for 3D inversions of ZTEM natural field EM data, AIIP (airborne inductively induced polarization) mapping of VTEM time-domain EM data, and AI-assisted interpretation and targeting for fixed-wing magnetic and gamma-ray spectrometric data.

From 2012 to its completion in 2019, **UBC-GIF** ran a successful industry-sponsored R&D project to create GIFtools. This provided an extensive system of user interfaces to set up, execute, and interpret results of the advanced geophysical forward modelling and inversion codes developed at the **University of British Columbia**. This



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made advanced geophysics accessible to everyday practitioners. **Mira Geoscience** created a commercially-supported version of GIFtools that can be run from Geoscience ANALYST and is now incorporated into Geoscience ANALYST Pro Geophysics. The new Mira Geoscience industry-led, research consortium started in 2019 will continue the work inspired by the GIFtools project, broadening the scope beyond UBC-GIF codes. It will include VP Geophysics Suite and codes developed by other researchers, including open source geophysical codes. VP codes are complementary to UBC-GIF codes, offering geological model parameterization with direct inversion for 3D geological contact geometry in addition to conventional grid parameterization. MIRA will evaluate relevant open source geophysical codes such as SimPEG and, where useful, provide the ability to use them from the same interface. The consortium will deliver a platform that other researchers may use as a common set of tools for development of new methods so that the basics of data and model handling and visualization do not have to be re-invented. It will focus on interoperability with other software, including standard geological, geophysical and geochemical interpretation software. The primary deliverable of the consortium is corporate licences to software, along with workshops, training, technical support and annual meetings to share innovation. The founding members of the consortium are Anglo American, Barrick Gold, Glencore, Rio Tinto, Teck Resources and Vale.

SGL continued to provide the processed x and y horizontal gravity components for gravity surveys, in addition to the traditional z component. This is a unique capability of its AIRGrav system. Progress was made with several R&D projects designed to further enhance the resolution and accuracy of gravity data from AIRGrav surveys, and to improve geoid measurements with it. Several integrated interpretation projects were completed in 2019 for resource exploration and geotechnical purposes, as well as forward modelling projects to assist with survey design.

The DAQNAV airborne data acquisition, navigation and magnetic compensation system, developed by **SHA Geophysics**, has been in operation since 2013. The acquisition module logs and displays data from all devices outputting data via major communication interfaces. The navigation module enables users to load and view in real-time, their own

flight plan, background map, DTM grid and drape surface grid. As of early 2019, the DAQNAV system offers out-of-the-box compatibility with **RSI** spectrometers and **GEM Systems** airborne magnetometers and gradiometers. In 2019, the company's GT-Grid mapping system, to process or re-process gradient data, was used in projects for companies in Canada, the U.S. and Africa. Although it is compatible with airborne horizontal gradient survey systems, the full benefit of GT-Grid is only realized when using the 3-axis Heli-GT system to accurately resolve magnetic gradients in the north, east and vertical directions.

Sydney-based **Tensor Research** has developed the QuickDepth magnetic depth interpretation tool for ModelVision. The tool uses AI to suggest the most appropriate geological model and to estimate the depth without the need to perform a geophysical inversion. It uses both the original line data for maximum spatial precision and the total magnetic intensity grid to obtain additional 3D information by FFT transformation of the grid. The magnetic tensor is used to derive parameters required to locate the centre of magnetization of the magnetic source, detect the geological model style and estimate the target orientation, depth and magnetic properties. QuickDepth also uses the Tensor, Euler 2D, Euler 3D, Werner deconvolution, Peter's Length and Tilt depth methods to estimate depths where there is an appropriate model style for the AI-selected model type. Model styles include thin, medium and thick formations/dykes; thin, medium and thick pipes; ellipsoids (skarn, IOCG), channels and edges. The interpreter can override the AI-selected model style and the depths will be immediately recomputed along with depth statistics for the different computation methods and a quality measure for the selected anomaly. The tensor provides a very useful measure of the level of interference between adjacent anomalies and if too high, will reject it from further analysis. The interpreter is always in control of the process by selecting the most appropriate geological model for each anomaly. The AI process assists and speeds the estimation of cover depth and magnetic properties. Solutions are posted on maps and sections for immediate geological evaluation. The statistics and quality measures are helpful to understand the precision of depth interpretation. Periodic gridding and contouring of the points provides quick feedback on the lateral consistency of the depth horizon.

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Solutions can be exported to Oasis montaj GDB files or ASCII CSV format files for use in other systems. RockMod is a new rock properties tool in ModelVision that allows comparison of magnetic and density properties derived from inversion, against standard rock-property charts. Although a range of standard charts are supplied, users' proprietary charts can be added. The charts can be single axis or double axis with log or linear scales. They are useful during interpretation discussions when chart sub-populations can be selected interactively to see where they occur in the magnetic map. Simple charts showing the range of magnetic susceptibility and density for different rock type classes and cross plots of density versus susceptibility also provide very useful information for segmentation of rock types.

Aeromagnetic Surveying

Gatineau, Que.-based **Devbriio Geophysics'** AIM LOW real time collision-avoidance technology was recently put to use in Quebec, Ontario, the Maritimes and Nunavut on high-resolution magnetic surveys using UAVs. New R&D developments were aimed at safely lowering the altitude of the magnetic sensor slung below the UAV down to 3 m clearance of obstacles, while flying at a speed of 12 m/s without prior knowledge of obstacles or terrain. A special navigation system was also developed to avoid the traditional navigation problems encountered when flying near or above the earth's magnetic poles using UAVs. Devbriio continues its long-time partnership with **SkyTEM Surveys** from Denmark, handling all of their surveys in Canada and the U.S.

In 2019, Markham, Ont.-based **GEM Systems** released the CARDINAL, an ultra-lightweight towed-bird magnetometer system designed specifically for UAVs. Operation is as simple as attaching the bird to the UAV using the supplied tow cable. The CARDINAL includes GEM Systems' designed GSMP-19 optically pumped Potassium magnetometer with sensor dimensions 115 mm x 40 mm, GPS, IMU and battery, all within a super-lightweight aerodynamic housing weighing a total of 1.5 kg. Data are stored in internal flash memory, where data from a 30 minute flight can be transferred in approximately 30 seconds or optionally, data can be transferred in real-time via RadioLink. Potassium-based magnetometers provide the highest sensitivity, absolute accuracy and gradient tolerance of all optically pumped magnetometers on the market.

In 2019, Mississauga, Ont.-based RMS Instruments conducted R&D into developing MAD functionality for their adaptive aeromagnetic compensation systems. This resulted in efficient detection algorithms which yield high detection sensitivity and location estimates in real-time, at a reasonable computational cost. The MAD capability works seamlessly with the system's real-time compensation function. This new technology has been implemented in prototype form in the AARC52, one of the RMS systems tailored to UAV platforms. The company reported that demand for all aeromagnetics products remained strong, particularly for the DAARC500 and AARC510, used on conventional (fixed-wing and helicopter) platforms, and the AARC51 and AARC52, used on UAVs. New enhancements include redundant real-time data recording on two different media, with the system's embedded real-time operating system maintaining the files on both recording devices with a high level of robustness and reliability. In addition, the firmware now supports user-defined gradient geometries, particularly relevant in installations with as many as 8 magnetometer inputs. Geometries can be tailored to the specific requirements of a project such as alternate forms of tri-axial configurations or multiple vertical gradients and facilitates the analysis of calibration flight data to provide insight into changes in the magnetic signature of an installation.

Airborne Electromagnetic Surveying

CGG Multi-Physics offers three airborne EM technologies: Helitem, Tempest and Resolve. The company updated its Helitem technology to create the Helitem2 system. Using a square transmitter wave enables early off-time measurement and effective energizing of deep conductive targets. Due to an upgraded receiver system, the Helitem2 is capable of base frequencies as low as 6.25 Hz, the lowest base frequency of any helicopter TDEM system operating commercially. The upgraded Tempest fixed-wing systems were used extensively during 2019 on groundwater, geological mapping, and mineral exploration projects in Australia and North America. Tempest continued to acquire data on **Geoscience Australia's (GA)** multi-year AusAEM survey project, which will cover more than 2 million sq. km of northern Australia. CGG's Resolve technology continued to be used for high precision conductivity measurements. It was applied in 2019 for diamond exploration in resistive regimes due to its extremely high resolution and sensitivity to small variations in resistivity.

Expert Geophysics is introducing an innovative airborne EM system called "μTEM" (MicroTEM), which uses a controlled-source field. The system, which has a super-early time range (0.3-40 microsec) and an almost absolute square waveform, is intended for precise, high-resolution near-surface mapping of structures, fractures and sediments.

Geotech completed the design and successful testing of a new generation TDEM transmitter, that features a more square-shaped transmitter pulse, with markedly faster turn-off time (<0.5 msec), higher power,

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larger dipole-moment (>1 M NIA) and extended 12.5/15 Hz, as well as standard 25/30Hz, transmitter base frequency. The new transmitter is planned for commercial launch in 2020. In cooperation with Vale and **Platform Geoscience** (Toronto, Ont.), Geotech ground-tested the new Groundfloor EM (GFEM) air-to-ground, 15/30 Hz TDEM method over a Vale nickel-copper deposit and test site in Sudbury and VMS copper deposit test sites in Spain. GFEM uses multi-component receiving equipment on the surface along with an airborne TDEM transmitter. With the large transmitter-receiver separation of GFEM, it is possible to compute the received primary field from the airborne loop with sufficient accuracy to allow non-decaying anomalies to be observed in the system on-time. This allows the detection and discrimination of the different kinds of extremely high conductivity targets. Field results will be presented in 2020. In 2019, ZTEM Lite was successfully flown for porphyry copper exploration at high elevations in Peru. The ZTEM Lite sensor, which is the fixed-wing receiver design in a towed-bird configuration, has lighter weight and improved aerodynamics so it can be flown at much higher elevations than either the standard ZTEM or VTEM helicopter EM systems.

NUVIA Dynamics of Mississauga, Ont. has upgraded and rebranded the PicoEnvirotec P-THEM system and is now offering it as NuTEM (Nuvia Time Domain EM) for commercial helicopterborne TDEM surveys with magnetics and radiometrics (optional). NuTEM is well suited for mineral and groundwater exploration, geological mapping and environmental applications. It features a powerful compact transmitter with a dipole moment of 300,000 NIA, 3-axis receiver, full waveform recording, small loop footprint for high target resolution and receiver removed from the transmitter eliminating bucking of primary field. In 2020, further improvements will include a new receiver, console and receiver suspension system.

Sander Geophysics continued to offer its unique four-frequency EM system (SGFEM) for high-resolution EM surveying. SGFEM does not require a towed bird since the transmitter and receiver are mounted on the wing tips of a fixed-wing aircraft, making it ideal for high-speed, high-resolution mapping. The SGFEM system can also be used in combination with any other sensors (e.g. gravity, magnetic, radiometric, methane) to provide a multiparameter geophysical survey system. In 2019, the company flew another large EM, magnetic and radiometric survey in Ireland with the SGFEM system. This marked the sixth year of involvement in the **Geological Survey of Ireland's** ongoing multi-disciplinary **Tellus** program, in which SGL has conducted airborne mapping of most of the island (Northern Ireland and the Republic of Ireland).

SkyTEM launched a new high-power system in 2019, SkyTEM306HP. The system is engineered to collect multi moment data and deliver high-resolution near-surface data concurrently with deep investigation capabilities. It has a fully digital multichannel receiver for continuously-sampled and streamed data with advanced and real-time signal gating and measured B-field. Enhanced features include extremely high accuracy due to a 5 MHz sample rate with 36-bit resolution in 3 channels and rejection of high-frequency noise. The re-engineered receiver coil system offers at least a five-fold reduction in late-time noise levels for greater resolution at depth. An aerodynamically engineered rigid and lightweight carbon fibre carrier frame permits take-off of the highest-powered systems (500,000 NIA or 1,000,000 NIA) with a full fuel tank. This maximizes production rates in hot climates and at high elevations. SkyTEM reports that the system can fly faster than any HTEM system reducing acquisition costs by flying at production speeds of up

to 150 km/h, unprecedented in HTEM history. As with all SkyTEM systems, preliminary data are available within 48 hours after collection. Quick review of the data creates the ability to rapidly reconfigure system parameters to maximize results in various geological settings. System customization can be achieved within a few hours. For example, the survey can begin in FAST configuration for economy and later be reconfigured to conventional set-up for highly detailed mapping.

Airborne Gamma-ray Spectrometric Surveying

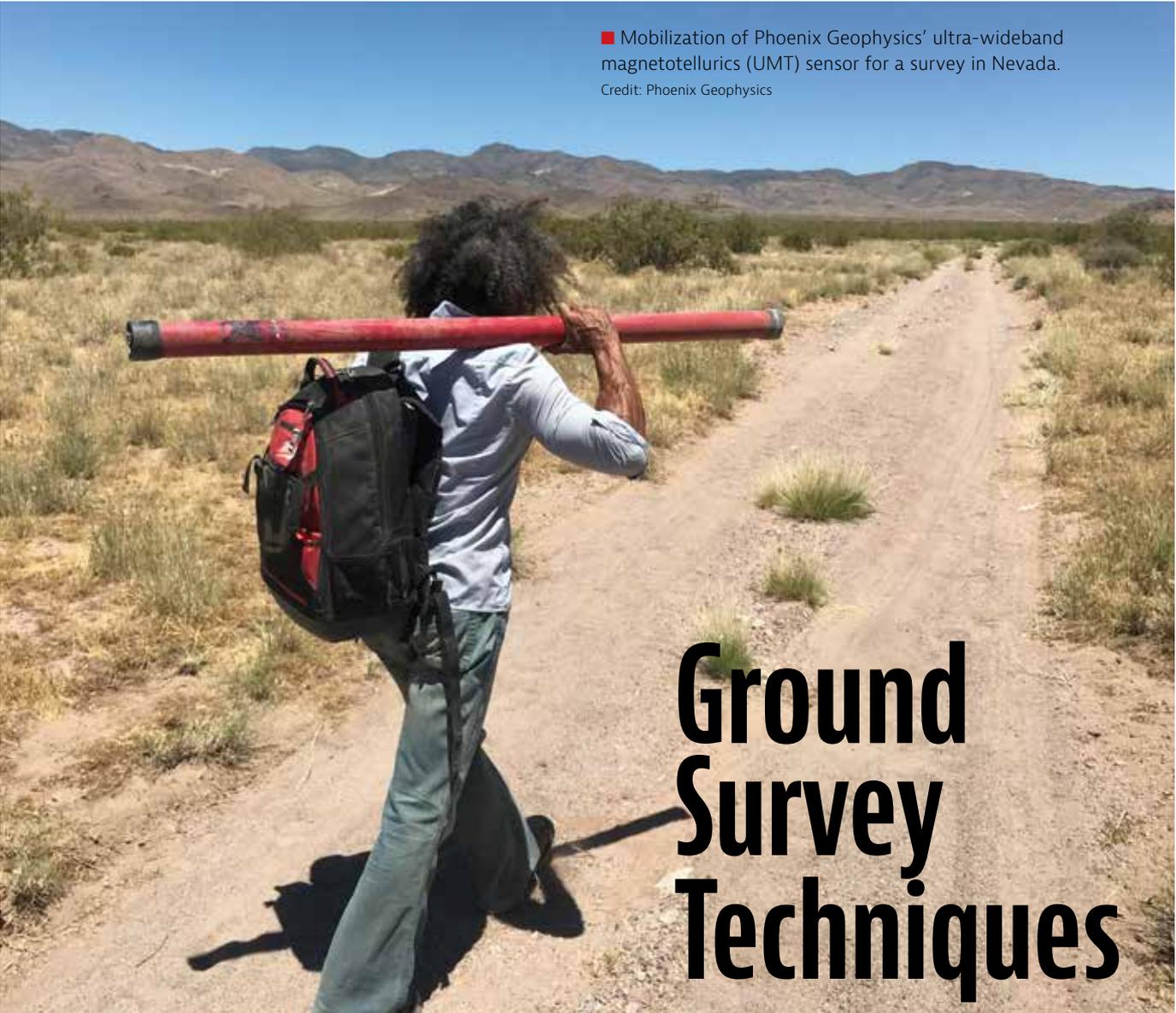
After developing the first SARA 4.0 (Special Aerial Response Automatic Helicopter) unmanned airborne magnetic detection system, **Flying-Cam**, with R&D offices in Belgium, is now providing gamma-ray spectrometry with its latest unmanned helicopter, DISCOVERY. It offers a 2.5 hour flight time with up to 100 km range. The spectrometer uses full spectral data and RSI's Advanced Digital Spectrometer. It includes mapping displays with navigation position and definable radiation overlays. The system is equipped with the unique Flying-Cam auto-pilot and high-precision dual antenna RTK GPS system. This latest generation of the auto-pilot has been in service since 2003 with the well-proven SARA system. The airborne gamma-ray spectrometry system is only one of the multiple payload capabilities of DISCOVERY that includes MAD, hyperspectral, laser scanning and ISR (intelligence, surveillance and reconnaissance).

Radiation Solutions Inc. (RSI) of Mississauga, Ont., reported that high-quality radiometric data were successfully collected in 2019 from a medium-lift UAV platform using a system comprised of a gamma-ray spectrometer and console. The RSI system incorporates an RS-602 console with an RSX-0.5 (2 l) NaI(Tl) detector. Extensive analysis and evaluation of data quality, aircraft payload and flight characteristics verified that an NaI(Tl) crystal volume of 2 l is optimal for geological investigation when using low-flying, mid-range UAV platforms. For smaller UAVs with payload restrictions, a 3x3 (0.39 l) NaI(Tl) detector with proprietary RSI electronics provides a compact, lightweight and economical alternative that is ideal for mapping near-surface mineralization or uranium occurrences. Both UAV configurations are equipped with Wi-Fi, Bluetooth, GPS and onboard spectral analysis and both have sufficient sensitivity for mineral exploration. They can also be combined with a magnetometer and/or other detection technologies.

Airborne Gravity Surveying

The Falcon family of airborne gravity gradiometer systems were designed by **CGG Multi-Physics** specifically for use in light aircraft and helicopters and the company claims it offers the highest resolution airborne gravity data. In 2019, Falcon surveys were flown across the globe including a number of high-resolution surveys targeting gold. Falcon Plus is the company's newest development in the Falcon family of airborne gravity gradiometer (AGG) systems, which provides the lowest noise gravity gradient data. The Falcon system, in a helicopter platform, HeliFalcon, is often used in rugged areas and where ultra-high-resolution gravity data are required. In 2019, the HeliFalcon was deployed in Japan, Canada and South America. CGG's Full Spectrum Falcon technology offers the highest resolution, broadest bandwidth airborne gravity data as it simultaneously acquires both Falcon airborne gravity gradient data, and sGrav airborne gravity data. These data streams are integrated to obtain a high-accuracy gravity signal over a broad bandwidth, improving imaging at depth and increasing spatial resolution for near-surface geology. Full Spectrum Falcon was deployed in Australia, Indonesia and North America. **ETD**

■ Mobilization of Phoenix Geophysics' ultra-wideband magnetotellurics (UMT) sensor for a survey in Nevada.
Credit: Phoenix Geophysics



Ground Survey Techniques

Physical Rock Properties & Elemental Analysis

Both new and older versions of the **GDD** Multi Parameter Probe (MPP), model MPP-EM2S+ can now link the probe with any Android device by installing the free GDD MPP application and pairing it with the probe via Bluetooth or communication cable. This unique and useful feature for this portable tool is considerably more efficient and less expensive than a PDA which can be completely replaced by the app. It is also more user friendly allowing simple data transfer in multiple formats that can be sent by email. The same concept, to be employed in the Sample Core IP (SCIP) tester is undergoing final testing. It will be introduced in 2020 providing ease of operation for determination of electrical properties of rock and borehole samples for planning geophysical surveys and understanding results of borehole measurements.

Terraplus announced several updates to the KT-20 physical rock property measuring system, introducing curved magnetic susceptibility calibration pads and conductivity reference pads to be used with the KT-20 curved sensors. Four magnetic susceptibility calibration pads in BQ, NQ, HQ and PQ diameters can be used to recalibrate or confirm the readings from a KT-20 10 kHz curved sensor. Four conduc-

tivity reference pads, in the same diameters, can be used to confirm the KT-20's 100 kHz curved sensor conductivity measurements. A large sample holder was also introduced for the KT-20's IP/resistivity module to supplement the small sample holder previously available. The large sample holder enables measurement of chargeability and resistivity of core samples ranging from 5 cm to 39 cm in length.

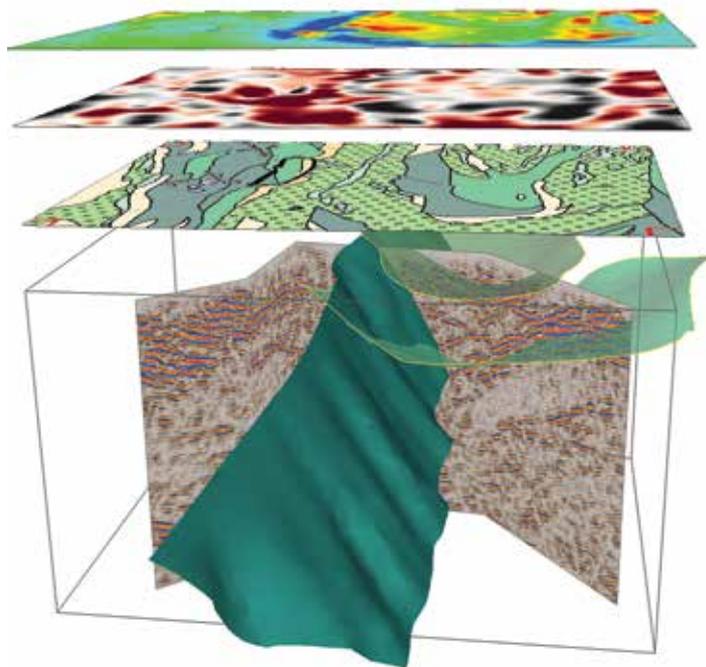
Ground Data Acquisition & Processing

Lakewood, Colo.-based **Condor Consulting** continued its technology initiatives related to the processing of 3D IP surveys as well as the processing and analysis of geophysical data, primarily acquired in exploration for porphyry copper deposits (PCDs). It completed its formal collaboration on 3D IP modelling with **Seequent** (formerly **Geosoft**), developing and testing an innovative method to effectively process large 3D surveys using a sensitivity-based data reduction approach. The collaborative results were presented in 2019 at the **KEGS-PDAC** workshop in Toronto and the **AEGC** conference in Perth. The PCD study consisted of two parts: examination of PCDs which show strongly conductive features that lack an accepted origin, and; the building

of a case study inventory of AFMAG/MT survey data over PCDs. Results from the first part were published by the **Society of Economic Geologists** and presented at the AEGC 2019 conference. For the second part, a compilation was prepared of AFMAG data obtained using the commercial ZTEM system. This work is complementary to an earlier industry-supported project (CAMIRO 205) that Condor undertook to compile aeromag data over PCDs, with results published in 2017. Finally, at the beginning of 2019, Condor and Sudbury-based **Ronacher McKenzie Geoscience** announced the formation of a strategic alliance to better serve their clients.

In 2019, the main research emphasis at Kingston, Ont.-based **Lamontagne Geophysics** was on developing new software for processing multi-fold step loop EM data, aimed at imaging both conductive and magnetic discrete targets in an environment with a complex background structure. The first development concentrated on conductive targets. The processing software has two parts. The first part uses a 2D matched filter approach for the detection, location and characterization of massive sulphide targets of a particular shape, orientation, size, depth and lateral position. To date, only targets of ellipsoidal shapes have been used. The process is applied for a multiplicity of targets of varying parameters, resulting in density functions that locate the specific targets along the profiles and as a function of log conductivity. The second part parses the output of the first process into sections that display confidence levels along vertical sections for a number of conductivity classes. Colour synthesis software is used to display conductivity classes on sections where the colour intensity is modulated by the confidence level for every pixel so that the colour tends to be light where confidence level is low and dark where it is high. The new processing methods are presently being applied to UTEM 5 step loop EM data.

In 2019 **Mira Geoscience** continued to foster an integrated approach to geological and geophysical modelling techniques. An ongoing technical collaboration between Mira, Red5 and HiSeis implemented an integrated geological, petrophysical, seismic, and non-seismic geophysical program at the Darlot gold mine in Australia, for brownfields targeting in hardrock environments. Results showed that the capability of modern 3D seismic surveys to image formational contacts and structures in hardrock environments can be very effective in such exploration programs because the geometry of mineralized systems can be directly imaged over large volumes of ground. The formational and structural geometry revealed by 3D seismic shows the primary control on the physical property variations to which magnetic, gravity, and electrical or EM methods respond. Along with seismic interpretation, this can provide constraints and guidance on the interpretation of other geophysical



■ An integrated visualization of the Darlot gold mine, from collaborators Mira Geoscience, Red5 and HiSeis. From top: magnetic data, seismic depth slice, bedrock geology map and seismic section showing the El Dorado Shear Zone in green, and interpreted sills of the Mt Pickering Dolerite in light green. Viewed in GOCAD Mining Suite. Credit: Mira Geoscience

data. In another integrated geological-geophysical case study from the Curaca Valley copper region in Bahia, Brazil, the company used a large geophysical dataset including airborne gravity, magnetic and EM, and combined it with existing 2D regional geology from different sources to produce a 3D integrated model. Results showed that regional scale geophysical datasets can be used in areas of extensive cover and limited outcrop to quickly develop 3D geological models that can serve different purposes such as targeting or hypothesis-testing via forward modelling.

Quantec Geoscience has added more 3D MT inversion capabilities to its interpretation solutions. Three 3D inversion codes are now available to help with overall turnaround and to reduce ambiguities which often arise in complex environments. To support the ORION PLUS survey dataset, the company now inverts the surface and downhole DCIP datasets in a joint 3D inversion which allows increased depth of investigation and enhanced resolution at depth. It has also improved its survey planning software Q-SDPLAN for comprehensive planning of large surveys and documenting information for field crews after surveys are deployed.

Drillhole Methods

Abitibi Geophysics has reintroduced the GraviLOG borehole gravity system, with improved efficiency and lower cost. Inversion of gravity data acquired in multiple boreholes and on surface, with and without constraints, is now available using its proprietary GeoTk inversion software. The company has also been continually improving its ARMIT TDEM B-field and dB/dt sensor, and a borehole ARMIT sensor will be field tested for commercial use in early 2020.

The Multipole Resistivity Imaging or MRI-32 DCIP resistivity method developed by Saskatoon, Sask.-based **Discovery International**

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■ GF Instruments' CMD-1 conductivity meter in the field.

Credit: GF Instruments

Geophysics, has been adapted to survey drill holes. When combined with surface array measurements, a complete 3D resistivity and IP image can be obtained in the vicinity of the hole. This borehole IP provides a method for IP/resistivity surveying of drill holes where some sulphide mineralization has been intersected, but not enough to form a conductor detectable with borehole TDEM. It can still provide information for follow-up drilling in the direction of additional and greater sulphide concentrations. The technique will be useful in exploration where the sulphide mineralization or alteration is not strong enough to form a conductor, but is still indicative of economic mineralization such as porphyry copper-gold deposits and orogenic mesothermal gold deposits.

SJ Geophysics reported a strong demand for its Volterra-BH system, with a large increase in the number of boreholes surveyed. The system's ability to survey below drill rods has been very successful in areas of poor

ground conditions, allowing boreholes at risk of collapse to be surveyed safely and efficiently. In 2019, multiple horizontal and up-hole oriented boreholes drilled into a mountain face were surveyed with the Volterra-BHEM system. The Volterra-BH 32 mm and 38 mm probes have been upgraded to increase battery capacity to provide 10 hours of operation.

Ground Electromagnetic Methods

Abitibi Geophysics reported completion of several OmniVision TDEM surveys in North America and overseas during 2019. The OmniVision loop configuration and ARMIT sensor detects both poor and good conductors at any dip angle, all in one survey.

Crone Geophysics introduced a new portable 20kW TEM transmitter in 2019 which uses a patented power-connection design allowing multiple local portable power sources to be connected. This makes it possible to provide high power while still maintaining portability or to provide high power with one large power source. The new design also minimizes cable connections for a more robust system. Other improvements include new connecting cable materials and construction to improve its 3D surface B-Field sensors (LANDTEM SQUID and Fluxgates). This allows the cables to remain flexible and reliable over greater temperature variations. Crone now incorporates automatic orientation devices to process precise azimuth, dip and roll in all of its surface sensors to decrease reading and in-field deployment times. Its LANDTEM PEM-SQUID sensors are made with fibreglass dewars for longevity and durability. The company's CDR3/4 line of simultaneous PEM receivers have improved features such as higher memory storage, faster data transfer times, real time borehole probe monitoring, custom channel configurations for 50Hz or 60Hz power line rejection and automatic synchronization. Crone is now offering MMR surveys using their standard CDR3/4 PEM receiver, providing a more flexible and adaptable system for surface or borehole applications or their combination.

GF Instruments (Brno, Czech Republic), has outfitted its CMD electromagnetic conductivity meters with a new control unit. The large family of 1-, 3-, and 6-receiver probes (with depth ranges from 0.15 to 60 m) can now be driven from either a new, fully compatible control unit (B/W or colour display, real-time clock, two Bluetooth channels, detachable GPS) or from a free smartphone app. The company expects that this new development will provide significant advantages for all CMD users.

GDD's new second-generation TDEM receiver NordicEM24, developed for mineral and groundwater exploration and geotechnical investigations now has the ability to increase the data recording speed up to 1.4 million samples/second/channel, providing a maximum of

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11.2 million samples per reading for the 8-channel model. GDD is also working on new features for the second generation TDEM receiver to make it compatible with other systems and increase its applications in exploration and geotechnical investigations.

SJ Geophysics continued to carry out surface TEM surveys using very high sensitivity induction magnetometers and/or three-component fluxgate magnetometers. The company's EM Transmitter (EMTX) saw a number of upgrades in 2019 including a more reliable and stable power supply. There is also a new capability to connect multiple transmitters together in series and/or parallel to increase output voltage and current for higher power output and flexibility in loop design. The EMTX is controlled via Bluetooth from Android tablets.

Gravity Surveying

In 2019 **GF Instruments** introduced the LG-1 Galileo, a new land gravity meter equipped with a lightweight, rugged sensor with a fully quartz core. The instrument is operated from a detachable control unit with graphical colour display that allows the operator to adjust the levelling and to observe and store data during measurement. MicroGal sensitivity (with precise tide, tilt, drift and temperature compen-



■ GF Instruments' Galileo land gravity meter.
Credit: GF Instruments

sation), worldwide measuring range, and high mechanical resistance, which are all features developed with user consultations, make Galileo suitable for all types of land gravity surveys.

Induced Polarization

Abitibi Geophysics has added DasVision to its suite of IP methods. DasVision is a distributed array method that combines the **IRIS FullWaver** technology with 3D inversion to increase the depth of investigation of IP

to 1000 m or more over large areas, at a reasonable cost. Electrodes are positioned in optimal locations over the surface and inside boreholes. The company also introduced the 3D version of its OreVision IP solution, further increasing DOI and resolution.

AGCOS introduced the AT-4000 (4kW), a new portable mid-power broadband multifunction transmitter for IP and controlled-source EM methods. The transmitter can be powered by motor-generator or battery pack and is rated up to 40 A regulated current output. It can generate 200 frequencies in the 50,000 - 0.01 Hz frequency range, has very fast turn-off times (<10 µsec) and a regulated duty cycle. It also has GPS, cable synchronization with receivers and a controller with full current waveform recording operated through intuitive GUI. The AT-100 and AT-4000 broadband transmitters, when used in combination with the GEPARD-8 and GEPARD-4 broadband multifunction EM receivers, can provide cost effective and quality EM data acquisition over a wide depth interval. This applies to most ground EM techniques such as BBMT, MVP, CSAMT, FDEMS, IP, resistivity, TDEM and SP.

Crone Geophysics has made several improvements in 3D IP equipment. The capability of the Mark 7 E-SCAN for virtually unlimited expansion of the total number of addressable electrode stations provides greater flexibility in deployment of its 3D IP/Resistivity system on a very large scale. The unique QA/QC system for 3D ESCAN data points allows inversion models to be built and reviewed daily. Also, new advances in field station electronic modules now make it possible to detect and self correct for any 3D station wiring errors.

Dias Geophysical, based in Saskatoon,

Sask., carried out surveys in Australia, Canada, Chile, China, the Dominican Republic and the U.S. It now has offices in Canada, the U.S. and Chile, and strategic partnerships in Asia and Australia. Dias completed over 35 3D IP and resistivity surveys worldwide with its proprietary DIAS32 system, and has now expanded its survey capacity to over 900 channels. The GS5000 transmitter, which was introduced to DIAS32 surveys in 2019, delivers up to 20 A using up to 5,000 V and 25 kW of power, weighs 32 kg and offers high-speed waveform control, internal timing control and current monitoring. The company also implemented a 3D inversion capability using the SimPEG 3D DCIP codes, both regular and Octree versions.

GDD has developed the RTE03, a new communication module that allows wireless synchronization of multiple GDD receivers of any model and year of manufacture. This enables 2D/3D distributed IP surveys by controlling them all in real time in a network, from one single operating point. This provides a significant increase in investigation depth by avoiding noise in long cables (>800 metres), and enhances quality control and electrode contact resistance along with the ability to view real time pseudosections. In addition, with GDD post-process software, it is possible to merge the data from several IP receivers into a single file to facilitate processing and interpretation. The RTE03 communication module was successfully tested by placing four, 8 channel GDD IP receivers (model GRx8mini) in a wireless synchronized 2D configuration in an IP distributed data acquisition, achieving a maximum investigation depth of about 500 m with good data quality. Another feature provided by the communication module is the ability to visualize and record the current and power transmitted in real time, on the PDA at the receiver, by connecting a RTE03 to the transmitter. It can record all current measurements for every reading, or the average, to reduce calculation errors that can affect the subsequent 2D/3D inversions. It is now also possible to configure a high-voltage transmitter of 4800V by connecting two to six transmitters in Multi-Tx mode (up to 30,000 W-4800 V-20 A), providing a high-power output for all conditions, especially valuable in dry terrains. The GDD IP system provides full waveform data and GDD post-process software allows better definition of anomalies with its stacking and noise rejection features as well as the reprocessing of data. In 2020, the new IP Tx current recorder will be available to record the full waveform of the cur-

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■ Instrumentation GDD's IP Tx current recorder. Credit: Instrumentation GDD

rent generated by any current source up to 20A at 1000 SPS. It can replace the current recording functions of the EM-IP Tx controller at a fraction of its cost.

Magnetotelluric

AGCOS has improved frequency response and noise characteristics of its AMS-15 (AMT) and AMS-37 (MT) magnetic sensors to 50,000 - 0.1 Hz and 3,000 - 0.00001 Hz respectively. It also introduced two new broadband sensors, the AMS-27 (30,000 - 0.0003 Hz) and AMS-47 (24,000 - 0.00001 Hz), as well as new lightweight HAMT sensors (AMS-11, AMS-12 and AMC-14). The broadband multifunction EM receivers, GEPARD-8 (8 channels) and GEPARD-4 (4 channels), were updated with an improved GUI interface and 6 recording bands. This allows simultaneous broadband MT data acquisition in the 40,000 - 0.00001 Hz frequency range with flexible configurations of electrical sensors, magnetic sensors and fluxgate magnetometers. The flexibility of the GEPARD system for MT applications can provide data acquisition for a wide range of survey tasks, from large-scale deep regional surveys to mapping of low-contrast near-surface anomalies.

Toronto-based **Phoenix Geophysics** continued to improve and supply the latest generation of ultra-wideband magnetotellurics (UMT). Over 50 new generation systems were delivered and commissioned in 2019 and the company's MTU-5C receiver was used on all continents, including Antarctica. Applications ranged from research projects, such as the **Metal Earth**, to exploration for minerals, hydrocarbons and geothermal resources. New applications for 2020 appear to be trending to volcanic monitoring and space weather (monitoring for magnetic storms that affect power grids). The company also participated in

research projects in 2019 with the **University of Saskatchewan** in Canada and **Prague University** in the Czech Republic. Equipment was deployed and data collected in a short five-day research survey, providing processed EDI data within minutes after acquisition using the EMpower processing software. New developments in instrument features at Phoenix were aimed at QC. Data are now downloaded and processed within seconds, allowing critical decisions to be made immediately in the field. The company also introduced its new "straight out of the box" networking feature so that any user can upload data in real time with a simple cellular modem and a subscription to a remote server. This dramatically reduces costs for making remote reference measurements allowing researchers to monitor variations of natural EM signals such as in zones with active volcanics and tectonics. There are now stations in Japan, the U.S. and other countries that are live and accessible through the internet. Another development included a new electrode amplifier for measurements in areas where the contact resistance is higher than 20 kOhm. The amplifier provides flat response up to 1kHz and a calibrated response up to 10 kHz, which is important for magnetotellurics observations in areas with permafrost, or glacial cover. Other advances relate to the 30kW TXU-30 transmitter. Laboratory tests with a high-power combination of multiple TXU-30s were successfully completed. The combiner adds the TXU-30s in series allowing power and current output up to 150 kVA / 150 A. Any previous generation TXU-30 can be added to the combiner, assuming sufficient generator power is used.

TITAN 130 IP and TITAN 160 multi-parameter surveys have been added to **Quantec Geoscience's** survey capability. The TITAN 130 provides unlimited dipole configuration options for deep surveys. A recent survey in the U.S. was deployed over 7 km in length, achieving n=1 to 70 quality data. The use of the RT 160 data loggers allow similar deployment but can also capture full frequency MT data. The array-based MT data provides relatively rapid, high-quality deep resistivity imaging, which in the AMT frequency band, surpasses resistivity information collected by CSAMT and provides more comprehensive information at a small premium in cost. The SPARTAN MT system provides AMT capability, low-frequency (MT) acquisition and Quantec's full frequency application. In 2019 broadband coil technology was introduced into the company's

solution set. It still provides separate high- and low-frequency coils for unique and robust MT solutions with more sensitivity and flexibility than the single broadband coil approach. A multifunction quality assurance tool, the QALIGN/QSIM, was developed for field crews that ensures greater accuracy for MT coil deployment and makes it easy to confirm that coils are aligned and/or orthogonal, which is critical for accurate surveys. The QSIM aspect of the device, allows the operator to test up to six coils at the site prior to deployment, for faults that may have occurred in local transit. It also checks each dipole setup for contact impedance and all information is transmitted by Wi-Fi to the local computer for inclusion in processing routines. Accurate testing can be done in high-noise environments which is not possible with standard voltmeters. ORION PLUS was first introduced at the Lac des Isles palladium mine north of Thunder Bay, Ont. The technique enhances the ORION 3D DCIP survey results by injecting current down selected holes below the deployed array of 3D receivers on the surface. The encouraging results indicate that subsurface injections should be added to 3D surveys where possible. This is particularly useful where surveys are near mine sites and drill holes are available.

SJ Geophysics completed multiple combined DCIP/MT surveys in 2019. The Volterra-MT system can acquire MT data in a variety of configurations, from scalar MT to tensor MT. Data acquisition can be integrated with 2D and 3D IP surveys using the same electric field dipoles with the addition of sensitive induction magnetometers. Significant enhancements were made to the MT signal-processing software to improve the signal-to-noise ratio and decrease processing time for faster data turnaround. Inversion capabilities have also been improved with 2D inversion modelling now being offered using the **Scripps MARE2DEM** inversion software.

Seismic

SGC reported that it is now working with **Echo Group** of Calgary to offer Landstreamer seismic (S and P-wave) for near-surface high-resolution definition surveys, supplemented by EM and electrical methods. Landstreamer seismic is based on the marine streamer concept. The company has also become agents in Australia and Canada for the **SARA Geobox** passive seismic equipment and now offer that capability with their Niche Acquisition group. **E.D.**

Companies & Websites

- Abitibi Geophysics:** www.ageophysics.com
AEGC: www.aegc.com.au
AGCOS: www.agcos.ca
CAMIRO: www.camiro.org
Canadian Exploration Geophysical Society: www.kegsonline.org
Canadian Micro Gravity: www.canadianmicrogravity.com
CGG Multi-Physics: www.cgg.com/multi-physics
ClearView Geophysics: www.geophysics.ca
Computational Geosciences: www.compgeoinc.com
Condor Consulting: www.condorconsult.com
Crone Geophysics & Exploration: www.cronegeophysics.com
Devbriio Geophysics: www.devbriio.com
Dias Geophysical: www.diasgeo.com
Discovery Int'l Geophysics: www.discogeo.com
DMEC: www.dmec.ca
Echo Group: www.echo-group.net
EON Geosciences: www.eongeosciences.com
Expert Geophysics: www.expertgeophysics.com
Flying-Cam: www.flying-cam.com
Garmin: www.garmin.com
GDS: www.geodatasolutions.ca
GEM Systems: www.gemsys.ca
Geological Survey of Canada: www.nrcan.gc.ca/earth-sciences
Geological Survey of India: www.gsi.gov.in
Geological Survey of Ireland: www.gsi.ie
Geological Survey of New South Wales: www.resourcesandgeoscience.nsw.gov.au
Geonics: www.geonics.com
Geoscience Australia: www.ga.gov.au
Geosoft: www.geosoft.com
Geosphair Aviation: www.geosphair.com
Geotech: www.geotech.ca
Geotechnologies: www.geotechnologies-rus.com
GF Instruments: www.gfstruments.cz
HZDR: www.hzdr.de
Instrumentation GDD: www.gddinstrumentation.com
IRIS Instruments: www.iris-instruments.com
J.A. Hallberg Mapping: www.sgc.com.au
KEGS: www.kegsonline.org
Lamontagne Geophysics: www.lamontagnegeophysics.com
LBEG: www.lbeg.niedersachsen.de/startseite/
Memorial University: www.mun.ca
Metal Earth: www.merc.laurentian.ca/research/metal-earth
Mira Geoscience: www.mirageosience.com
NDSWC: www.swc.nd.gov
Norwegian Geotechnical Institute: www.ngi.no
NRG: www.airbornegeophysics.com
NUVIA Dynamics: www.nuvia-dynamics.com
Paterson, Grant & Watson: www.pgw.ca
PDAC: www.pdac.ca
Phoenix Geophysics: www.phoenix-geophysics.com
Platform Geoscience: www.platformgeoscience.com
Prague (Charles) University: www.cuni.cz/uken-1.html
Precision GeoSurveys: www.precisiongeosurveys.com
Quantec Geoscience: www.quantecgeoscience.com
Radiation Solutions: www.radiationsolutions.ca
RMS Instruments: www.rmsinst.com
Ronacher McKenzie Geoscience: www.rmgeoscience.com
Sander Geophysics: www.sgl.com
SARA: www.sara.pg.it
Scintrex: www.scintrexltd.com
Scripps: www.scripps.ucsd.edu
Seequent: www.seequent.com
Sensors & Software: www.sensoft.ca
SHA Geophysics: www.shageophysics.com
SJ Geophysics: www.sjgeophysics.com
SkyTEM Surveys: www.skytem.com
Society of Economic Geologists: www.segweb.org
Southern Geoscience Consultants: www.sgc.com.au
Swedish Geotechnical Institute: www.swedgeo.se/en/
Tellus: www.tellus.ie
Tensor Research: www.tensor-research.com.au
Terraplus: www.terraplus.ca
Terraquest: www.terraquest.ca
Triumph Instruments: www.itriumph.ca
University of British Columbia: www.ubc.ca
University of Cagliari: www.unica.it
University of Saskatchewan: www.usask.ca
US Geological Survey: www.usgs.gov
Xcalibur: www.xagsa.com

Abbreviations & Acronyms

A	Ampere	DOI	Depth of Investigation	kW	kiloWatt		Estimation in Geophysics
AEGC	Australian Exploration Geoscience Conference	DTM	Digital Terrain Model	LBEG	Landesamt für Bergbau, Energie und Geology	SP	Self Potential
AEM	Airborne EM	EDI	Electronic Data Interchange	LiDAR	Light Detection and Ranging	SPS	Samples per Second
AFMAG	AMT	EITAP	Extractive Industries Technical Assistance Project	MAD	Magnetic Anomaly Detection	SQUID	Superconducting Quantum Interference Device
AI	Artificial Intelligence	EM	Electromagnetic	MHz	Mega Hertz	SRTM	Shuttle Radar Topography Mission
AMT	Audiofrequency MT	FFT	Fast Fourier Transform	MMR	Magnetometric Resistivity	STC	Supplementary Type Certificate
B	Magnetic Field	FOM	Figure of Merit	MT	MagnetoTelluric	TDEM	Time Domain EM
BBMT	Broadband MT	GIF	Geophysical Inversion Facility	MVP	Magnetovariational Profiling	TEM	Transient EM (= TDEM)
BH	BoreHole	GPR	Ground Probing Radar	NaI	Sodium Iodide	Tx/Rx	Transmitter/Receiver
CAMIRO	Canadian Mining Industry Organization	GPS	Global Positioning System	NIA	Dipole Moment of EM loop	UAV	Unmanned Airborne Vehicle (Drone)
CSAMT	Controlled Source AMT	HTEM	Helicopter TEM	PDA	Personal Data Assistant	UBC	University of British Columbia
dB/dt	Rate of change of B with time	GUI	Graphical User Interface	PDAC	Prospectors and Developers Association of Canada	USB	Universal Serial Bus
DC	Direct Current	Hz	Hertz = cycles per second	QA	Quality Assurance	UTEM	University of Toronto EM
DEM	Digital Elevation Model	HZDR	Helmholtz-Zentrum Dresden-Rossendorf	QC	Quality Control	V	Volt
DMEC	Decennial Mineral Exploration Conferences	IMU	Inertial Measurement Unit	R	Resistivity	VLF	Very Low Frequency
DNRME	Department of Natural Resources, Mines and Energy, Queensland Government	IOCG	Iron Oxide Copper Gold	RTK	Real-Time Kinematic	VMS	Volcanogenic Massive Sulphide
		IP	Induced Polarization	SANRAL	South African National Roads Agency	W	Watt
		kHz	kiloHertz	SimPEG	Simulation and Parameter		
		kOhm	kiloOhm				

PATRON



DMEC
Decennial Mineral Exploration
CONFERENCES



CANADIAN
EXPLORATION
GEOPHYSICAL
SOCIETY

GOLD



ABITIBI
G E O P H Y S I C S



CRONE G E O P H Y S I C S



DIAS
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AIRBORNE GEOPHYSICAL SURVEYS

Manufacturer (Country)	(TD=Time Domain FD=Freq. Domain ϕ =Phase S=Spectral)	Transmitter Model No.	Cycling Time or Frequency	Transmitted Power	Transmitter Power Source (MG=Motor Generator)	Transmitter Weight	Receiver Model No.	Sensitivity or Accuracy	Voltage Range	Microprocessor Controlled/Data Memory	Receiver Weight
Advanced Geophysical Operations and Services Inc. (Canada)	TD, FD, ϕ IP & SIP	AT-100	DC - 50kHz, 50% & 100% duty	100 W	12V battery	4 kg	GEPARD-4 (4ch) GEPARD-8 (8ch)	0.1 μ V / 1% typical	0.1 μ V to 10V	Intuitive GUI/SD Card up to 128Gb	7 kg with internal battery
	TD, FD, ϕ IP & SIP	KR-10	DC - 50kHz, 50% & 100% duty	500 W	12V-60V battery	5 kg	GEPARD-4 (4ch) GEPARD-8 (8ch)	0.1 μ V / 1% typical	0.1 μ V to 10V	Intuitive GUI/SD Card up to 128Gb	7 kg with internal battery
	TD	AT-3000	DC-30Hz, 50% duty	3 kW	12V-150V battery	12 kg	GEPARD-4 (4ch) GEPARD-8 (8ch)	0.1 μ V / 1% typical	0.1 μ V to 10V	Intuitive GUI/SD Card up to 128Gb	7 kg with internal battery
	TD	AT-3000R	DC-30Hz, 50% duty	3 kW	12V-150V battery, MG	28 kg	GEPARD-4 (4ch) GEPARD-8 (8ch)	0.1 μ V / 1% typical	0.1 μ V to 10V	Intuitive GUI/SD Card up to 128Gb	7 kg with internal battery
	TD, FD, ϕ IP & SIP	AT-4000	DC - 50kHz, 50% & 100% duty	4 kW	12V-150V battery, MG	28 kg	GEPARD-4 (4ch) GEPARD-8 (8ch)	0.1 μ V / 1% typical	0.1 μ V to 10V	Intuitive GUI/SD Card up to 128Gb	7 kg with internal battery
	TD, FD, ϕ IP & SIP	KR-30	DC - 50kHz, 50% & 100% duty	37 kW	3-phase MG	35 kg	GEPARD-4 (4ch) GEPARD-8 (8ch)	0.1 μ V / 1% typical	0.1 μ V to 10V	Intuitive GUI/SD Card up to 128Gb	7 kg with internal battery
	TD, FD, ϕ IP & SIP	KR-75	DC - 50kHz, 50% & 100% duty	75 kW	3-phase MG	55 kg	GEPARD-4 (4ch) GEPARD-8 (8ch)	0.1 μ V / 1% typical	0.1 μ V to 10V	Intuitive GUI/SD Card up to 128Gb	7 kg with internal battery
	TD, FD, ϕ IP & SIP	KR-175	DC - 50kHz, 50% & 100% duty	175 kW	3-phase MG	205 kg	GEPARD-4 (4ch) GEPARD-8 (8ch)	0.1 μ V / 1% typical	0.1 μ V to 10V	Intuitive GUI/SD Card up to 128Gb	7 kg with internal battery

Manufacturer (Country)	(TD=Time Domain FD=Freq. Domain ϕ =Phase S=Spectral)	Transmitter Model No.	Cycling Time or Frequency	Transmitted Power	Transmitter Power Source (MG=Motor Generator)	Transmitter Weight	Receiver Model No.	Sensitivity or Accuracy	Voltage Range	Microprocessor Controlled/Data Memory	Receiver Weight
IRIS Instruments (France)	TD & FD	VIP 3000		3000 W	45 - 450 Hz 1 phase	16 kg					
	TD & FD	VIP 4000	0.0625 - 4 Hz	4000 W	45 - 450 Hz 1 phase	16 kg	ELREC 6	0.01 mV/V0.6% typ. accuracy	10 μ V to 10V	Yes/2500stations	8 kg
	TD & FD	VIP 5000		5000 W	45 - 800 Hz 1 or 3 phases	23 kg	ELREC 10	0.01 mV/V0.6% typ. accuracy	10 μ V to 15V	Yes/3200stations	9 kg
	TD & FD	VIP 10000		10000 W	45 - 800 Hz 1 or 3 phases	35 kg					
Instrumentation GDD Inc. (Canada)	TD	Tx III-4800V-10A	DC 1,2,4,8 and 16 seconds	1800 W	120 V, 50-60 Hz	27 kg	GRx2-2 channels	Voltage: Resolution 1 μ V, Accuracy \leq 0.15%	\pm 10 μ V to \pm 15V for any channel	Archer 2 PDA-512Mb RAM Allegro 2 PDA-512Mb RAM	1.6 kg
	TD	Tx II-4800V-15A	DC 1,2,4,8 and 16 seconds	3600 W	240 V, 50-60 Hz	32 kg	GRx8mini-4 or 8 channels		\pm 10 μ V to \pm 15V for any channel	Archer 2 PDA-512Mb RAM Allegro 2 PDA-512Mb RAM	3.1 kg
	TD	Tx4-4800V-20A	DC 1,2,4,8 and 16 seconds	5000 W	240 V, 50-60 Hz	40 kg	GRx8-32-8,10,16,24 or 32 channels	Chargeability; 1 μ V/V, Accuracy \leq 0.4%	\pm 10 μ V to \pm 15V for any channel	Archer 2 PDA-512Mb RAM Allegro 2 PDA-512Mb RAM	7.0 kg
	TD	Tx4-4800V-20A	DC 1,2,4,8 and 16 seconds	10000 W	240 V, 50-60 Hz	2 x 40 kg	Post-processing IP software				
	TD	Tx4-4800V-20A	DC 1,2,4,8 and 16 seconds	20000 W	240 V, 50-60 Hz	4 x 40 kg					
	TD	EM-IP Tx Controller	1 second on and above		2 X Li Ion batteries	4 kg					
	TD	TRM	Higher frequencies								

Manufacturer (Country)	(TD=Time Domain FD=Freq. Domain ϕ =Phase S=Spectral)	Transmitter Model No.	Cycling Time or Frequency	Transmitted Power	Transmitter Power Source (MG=Motor Generator)	Transmitter Weight	Receiver Model No.	Sensitivity or Accuracy	Voltage Range	Microprocessor Controlled/Data Memory	Receiver Weight
Phoenix Geophysics (Canada)	TD, FD, ϕ IP, SIP, CSAMT	T3	TD: 0.0625 Hz -30 Hz , FD: 0.125 Hz to 10 kHz TD: 50% FD: 100% duty cycle, external drive optional	3000 W	Battery or any single-phase generator	12 kg, mounted on backpack	V8 Multifunction Rx.			Yes/flash memory 512 MB (upgradeable)	7 kg
	TD	T4	5A, 50% duty cycle, 2.7* microsec 40A, 50% duty cycle, 2.7* microsec *loop size dependent	2.8 kW, max 130 V input, fast turn-off for EM operations	12 V batteries in series (24V-72 V)	10 kg, mounted on backpack					
	TD, FD, ϕ IP, SIP & CSAMT	TXU-30A	TD: Up to 60 A, 0.0625 Hz-30 Hz, 50% FD: 20 A @ 1000 V, 0.125 Hz to 9.6 KHz, 100%	20 Kw	Any 200-240 V commercially available 3-phase generator external drive optional	50 kg					
	TD, FD, ϕ IP, SIP & CSAMT	TXU-30B	TD: Up to 60 A, 0.0625 Hz-30 Hz, 50% FD: 25 A @ 1000 V, 0.125 Hz to 9.6 KHz, 100%	25 Kw	Any 380 V \pm 10% commercially available 3-phase generator external drive optional	50 kg					
Walcer Geophysics Ltd. (Canada)	TD & FD	IPT-1 & TX KW10	IPT-1: FD: "A" & "B" Models DC - 4 Hz TD: "A" Model- 2 sec. on / 2 sec. off "B" Model - Seconds on / off; in 1,2,4 & 8 seconds TX KW10: 1 sec., 2 sec., 4 sec., 8 sec.	IPT-1 75 - 1200V in 5 steps 3 mA - 10 Amps TX KW10 100 - 3200V in 10 steps 0.05 - 20 Amps Tested to 10.5 kVA	MG-1, MG-2, MG-6 and MG-12 Variable power 400 Hz/3 phase	IPT-1 18 Kg TX KW-10 44 kg					
Zonge (USA)	TD & FD ϕ IP & SIP	GGT-3	DC to 8 kHz	3 KVA	3 Kw MG 400 Hz	30 kg					
	TD & FD ϕ IP & SIP	GGT-10	DC to 8 kHz	10 KVA	5, 7.5 & 10 Kw MG 400 Hz	51 kg					
	TD & FD ϕ IP & SIP	GGT-30	DC to 8 kHz	30 KVA	32 KVA MG 400 Hz	93 kg	GDP-32 _n 6 channel	0.03 μ V	0.1 μ V to 32 V AGC	Yes/32 MB/RAM 4 GB/HD	13.2 kg incl. batt.
	TD & FD	NT-20	DC to 512 kHz	480 W	Batteries	5 kg					

Manufacturer (Country)	(TD=Time Domain FD=Freq. Domain ϕ =Phase S=Spectral)	Transmitter Model No.	Cycling Time or Frequency	Transmitted Power	Transmitter Power Source (MG=Motor Generator)	Transmitter Weight	Receiver Model No.	Sensitivity or Accuracy	Voltage Range	Microprocessor Controlled/Data Memory	Receiver Weight
Zonge (USA) Cont.	TD & FD	ZT-30	DC to 512 Hz	3.6 Kw	Batteries	8 kg					
	TD & FD ϕ IP & SIP	GGT-3	DC to 8 kHz	3 KVA	3 Kw MG 400 Hz	30 kg					
	TD & FD ϕ IP & SIP	GGT-10	DC to 8 kHz	10 KVA	5, 7.5 & 10 Kw MG 400 Hz	51 kg					
	TD & FD ϕ IP & SIP	GGT-30	DC to 8 kHz	30 KVA	32 KVA MG 400 Hz	93 kg	GDP-32 _n 6 channel	0.03 μ V	0.1 μ V to 32 V AGC	Yes/32 MB/RAM 4 GB/HD	13.2 kg incl. batt.
	TD & FD	NT-20	DC to 512 kHz	480 W	Batteries	5 kg	GDP-32 _n 16 channel	0.03 μ V	0.1 μ V to 32 V AGC	Yes/32 MB/RAM 4GB HD	19 kg incl. batt.
	TD & FD	ZT-30	DC to 512 Hz	3.6 Kw	Batteries	8 kg	GDP-32 _n 16 channel	0.03 μ V	0.1 μ V to 32 V AGC	Yes/32 MB/RAM 4GB HD	19 kg incl. batt.

CANADIAN COMPANIES OFFERING AIRBORNE GEOPHYSICAL SURVEYS AS A CONTRACT SERVICE 2020

Compiled by P.G. Killeen, 9759 Hwy 509, Ompah, ON K0H 2J0

(21/May/2020)

COMPANY (President or Senior Officer)	ADDRESS OF MAIN OFFICE	TELEPHONE NO/FAX NO, E-MAIL/WEBSITE	TYPES OF SURVEY OFFERED*
CGG Multiphysics Canada (Davin Allen)	2505 Meadowvale Blvd. Mississauga ON L5N 5S2	Tel: 905-812-0212 Fax: 905-812-1504 davin.allen@cgg.com www.cgg.com/en/what-we-do/multiphysics	H: AM, TEM, CAM/TEM, CAM/AR, CAM/TEM/AR, AGG (HELIFALCON), CAM/AGG, FEM, CAM/FEM, CAM/FEM/AR, Gradient AM (MIDAS) FW: AM, CAM/TEM, CAM/TEM/AR, CAM/AR AGG (FALCON, FALCON PLUS, FULL SPECTRUM FALCON), AG, CAM/AGG, CAM/AG
Dias Airborne (Jonathan Rudd)	Unit 2-3111 Millar Avenue Saskatoon, SK, S7K 6N3	Tel: 416-795-1263 sales@diasgeo.com	H: AM (Full tensor magnetic gradiometer)
Discovery Int'l Geophysics (Dennis Woods)	147 Robin Crescent, Saskatoon, SK S7L 6M3	Tel: 306-249-4422 www.discogeo.com	H: HeliSAM: (TD, 2.5-7.5 Hz) Inductive Ground Loop Tx Galvanic Grounded Bipole
EON Geosciences Inc. (Khaled Moussaoui)	4018 boul. Côte -Vertu St-Laurent QC H4R 1V4	Tel: 514-341-3366 Fax: 514-341-5366 info@eongeosciences.com www.eongeosciences.com	FW: AM, AG, CAM/AR, VLFEM Horizontal Gradiometer H: AM, AG, FEM, TEM, CAM/AR, VLFEM CAM/AEM/AR, CAM/AEM
Expert Geophysics Ltd. (Andrei Bagrianski)	19 Lionel Heights Cres., Toronto ON M3A 1L8	Tel: 647-402-8436 info@expertgeophysics.com www.expertgeophysics.com	Natural Field EM: MobileMT, CAM/AEM
Geodata Solutions Inc. (Mouhamed Moussaoui)	1054 des Pervenches Laval QC H7Y 2C7	Tel: 514-867-9990 Fax: 450-689-1013 mmoussaoui@geodatasolutions.ca www.geodatasolutions.ca	FW: AM, CAM/AR H: AM, CAM/AR
Geophysics GPR International Inc. (Claude Robillard)	2545 Delorimier Street, Suite 100 Longueuil QC J4K 3P7	Tel: 450-679-2400 Fax: 514-521-4128 Claude.Robillard@GeophysicsGPR.com www.GeophysicsGPR.com	H: AM, AR, Transverse, Longitudinal, Vertical Gradiometry VLFEM, Geophex FEM, GPRTEM
Geosphair Aviation Inc. (Olivier Ayotte)	767 Mont-Royal East Montreal QC H2J 1W8	Tel: 514-585-4314 Fax: 514-527-6726 Olivier_Ayotte@yahoo.com www.Geosphair.com	FW: AM, CAM/AR,VLFEM

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

CANADIAN COMPANIES OFFERING AIRBORNE GEOPHYSICAL SURVEYS AS A CONTRACT SERVICE 2020

Compiled by P.G. Killeen, 9759 Hwy 509, Ompah, ON K0H 2J0

(21/May/2020)

COMPANY (President or Senior Officer)	ADDRESS OF MAIN OFFICE	TELEPHONE NO/FAX NO, E-MAIL/WEBSITE	TYPES OF SURVEY OFFERED*
Geotech Ltd. (Ed Morrison)	245 Industrial Parkway N Aurora ON L4G 4C4	Tel: 905-841-5004 Fax: 905-841-0611 info@geotech.ca www.geotech.ca	H-TEM: VTEM, AeroTEM Natural Field EM (AFMAG): ZTEM, AirMt, H-FEM: Impulse, CAM/AEM, CAM/AEM/AG, CAM/AR FW: CAM/AG, CAM/AR, CAM/ZTEM/AG, ZTEM Transverse, Longitudinal and Tri-Axial Magnetic Gradiometer
GeoVision Geosciences Inc. (Richard Osmond)	23678 108th Loop, Maple Ridge, BC, V2W 1B2	Tel: 604-466-0425, Cell: 604-805-0314 rosmond@shaw.ca	H: CAM/VLFEM
MPX Geophysics Ltd. (Daniel McKinnon)	355 Harry Walker Parkway Newmarket ON L3Y 7B3	Tel: 905-947-1782 Info@ MPXGeo.com www.MPXGeo.com	FW: AM, CAM/AR, VLF-EM H: AM, CAM/AR, VLF-EM, AG FEM TEM
New-Sense Geophysics Ltd. (Glenn Slover)	195 Clayton Drive Unit 11 Markham ON L3R 7P3	Tel: 905-480-1107 Fax: 905-480-1207 info@new-sense.com www.new-sense.com	FW: Horizontal AM, CAM/AR, VLFEM H: CAM/AR, VLFEM
Novatem Inc. (Pascal Mouge)	1087, Chemin de la Montagne Mont-Saint-Hilaire QC J3G 4S6	Tel: 450-464-1655 Cell: 514-966-8000 Mouge@NOVATEM.com www.NOVATEM.com	H: COLIBRI AM, CAM/AEM, CAM/AR, CAM/AEM/AR; NOVATEM TEM & Resistivity FW: CAM/AR

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Precision GeoSurveys Inc. (Harmen Keyser)	Hanger 42, Langley Airport 31330 56 th Ave. Langley BC V2Y 0E3	Tel: 604 484 9402 Fax: 604 669 5715 info@precisiongeosurveys.com www.precisiongeosurveys.com	H: AM, CAM/AEM, CAM/AR Biaxial & Tri-axial Gradiometer, TEM, FEM FW: AM, CAM/AR, VLFEM UAV AM
Prospectair Geosurveys Inc. (Alain Tremblay)	15 chemin de l'Étang Gatineau QC J9J 3S9	Tel: 819-661-2029 Fax: 866-605-3653 contact@prospectair.ca www.prospectair.ca	H-TEM: ProspectEM H: AM, AR, CAM/TEM, CAM/AR, CAM/TEM/AR
Sander Geophysics Ltd. (Stephan Sander & Luise Sander)	260 Hunt Club Road Ottawa ON K1V 1C1	Tel: 613-521-9626 Fax: 613-521-0215 surveys@sgl.com www.sgl.com	FW: AM, AR, AG, FEM, VLFEM, CAM/AR, CAM/AG, CAM/AG/AR, CAM/FEM, CAM/AG/FEM, CAM/AR/FEM, CAM/AG/AR/FEM, CAM/AR/VLFEM Scanning LiDAR, Methane Sensing Transverse, Longitudinal, Vertical & Triaxial Gradiometer H: AM, AR, AG, VLFEM, CAM/AR, CAM/AG, CAM/VLFEM, Scanning LiDAR, Methane Sensing, Transverse & Vertical Gradiometer
Scott Hogg & Assoc. Ltd. (Scott Hogg)	85 Curlew Drive, #104 Toronto ON M3A 2P8	Tel: 416-444-8245 Fax: 416-444-4409 scott@shageophysics.com www.shageophysics.com	H: CAM-AR-VLFEM, Triaxial Magnetic Gradiometer
SkyTEM Canada Inc. (Mandy Long)	36 King St. East, 4 th Floor Toronto ON M5C 3B2	Tel: 647-256-6716 Cell: 647-625-1311 mlo@skytem.com www.skytem.com	H: SkyTEM 304, 312, 306HP, 312HP CAM/AR, CAM/AEM, Single, multi and dual moment TEM
Terraquest Ltd. (Howard A. Barrie)	301-2900 John Street Markham ON L3R 5G3	Tel: 905-477-2800 Fax: 905-477-2820 info@terraquest.ca www.terraquest.ca	FW: AM, Transverse, Longitudinal, Vertical Gradiometer/CAM/AR, VLFEM (Matrix), AG (CMG GT2A) H: AM, CAM/AR, Matrix and XDS VLFEM, CAM/AEM

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CAPABILITIES OF AIRBORNE GEOPHYSICAL SURVEY CONTRACTORS 2020

Compiled by P.G. Killeen, 9759 Hwy 509, Ompah, ON K0H 2J0

(21/ MAY/2020)

COMPANY (Country) Telephone No. Web site	AIRCRAFT Fixed Wing = FW Helicopter = H Unpiloted Aerial Vehicle = UAV (Positioning)	AEROMAGNETIC T=Total Field, G=Gradient L, TT, V=Longitudinal, Transverse & Vertical	AIRBORNE ELECTROMAGNETIC (Time domain = TD) (Frequency domain = FD)	AIRBORNE RADIOMETRIC (R), GRAVITY (G) & GRAVITY GRADIENT (GG) Remote Sensing (RS)
Aerogeophysica Inc. (Russia) T: 7-495-641-1230 www.aerogeo.ru	Antonov-An-26,An-2 FW Ilyushin-II14 H Kamov-KA25,26 H (Ashtec GPS/Glonass)	Scintrex & Geometrics Cs Vapour (T, VG, LG)	6 Freq. Coax/coplanar FW AGP AEM H Towed Bird 4 Freq. Explorer HEM	Picodas PGAM 1000 R (50 l) Picodas/PEI GRS 410 (33.6 l) AGP G
Aerophysics (Mexico) T: 52-555-590-9928	Cessna 206, FW Piper PA-31 Navajo H Leased H (PNAV-GPS + Video)	Cs Vapour Helimag PMAG 3000 (T)	Explorer HEM H Towed Bird 5 Freq. Coaxial/coplanar	Picodas PGAM 1000 R 256 chan (16 l or 33 l down, 4 l up)
Bell Geospace, Inc. (USA) T: 281-591-6900 www.bellgeo.com	Basler BT-67 FW Cessna 208B	Geometrics G822A Cs Vapour (T)	NA	Lockheed Martin FTG GG Full Tensor Gravity
CGG Canada Services (Canada) T: 905-812-0212 www.cgg.com/en/what-we-do/multi-physics	Cessna 208B FW Basler BT 67 H Chartered Helicopters H (DGPS, RT-DGPS, DVideo)	CGG DAS FW Scintrex & Geometrics Cs Vapour (T, LG, TTG, VG, Triaxial) (T, LG, TTG, VG, LTTVG H Triaxial)	TD; TEMPEST FW TD; HELITEM H (3 axis Rx (x-y-z), concentric, 8-40 ms pulse width, square Tx waveform, 6.25-30 Hz, 200k-600k NIA), MULTIPULSE FD; RESOLVE (6 Freq. 400 Hz - 140,000 Hz, 1 coaxial & 5 coplanar coil sets) or RESOLVE (5 freq. 900 Hz – 56,000 Hz, 2 coaxial & 3 coplanar coil sets)	Exploranium GR 820 FW R RSI RS-500 (256/512 chan) Exploranium GR 820, H R RSI RS-500 (256/512 chan) FALCON, FALCON FW GG PLUS, FULL SPECTRUM FALCON CMG GT-1A, GT-2A, FW G sGrav FALCON H GG

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Dias Airborne (Canada) T :416-795-1263 sales@diasgeo.com	Chartered helicopter	QMAGT Full-Tensor Gradiometer	QAMT-AFMAG-MT	NA
Discovery Int'l Geophysics {Canada) T: 306-249-4422 www.discogeo.com	Chartered helicopter	Geometrics Cs Vapor (T)	HeliSAM: {TD, 2.5-7.5 Hz) Inductive Ground Loop Tx Galvanic Grounded Bipole	NA
EDCON-PRJ Inc. (USA) T: 303-980-6556 www.edcon-prj.com	Dragon Fly Ultralight Leased	FW H Geometrics Cs Vapour (T)	NA	NA
EON Geosciences Inc. (Canada) T: 514-341-3366 www.eongeosciences.com	Piper PA-31 Navajo; King Air A90 Cessna 206 Piper Cheyenne II Leased (DGPS, RT-DGPS, Digital Video)	FW H Scintrex & Geometrics Cs Vapour (T, TTG)	E-THEM TD Hummingbird FD Herz Totem-2A VLFEM	R G RSI RSX-5 1024 chan (32 l down, 8 l up) CMG GT-1A/GT-2A
Expert Geophysics Ltd. (Canada) T: 647-402-8436 www.expertgeophysics.com	Leased	H Geometrics Cs Vapour (T)	Natural Field EM: MobileMT	NA
Geo Data Solutions Inc. (Canada) T: 514-867-9990 www.geodatasolutions.ca	Piper PA-31 Navajo; ASTAR 350, Bell 206 Robinson R44 (RT-DGPS)	FW H Geometrics & Scintrex Cs Vapour (T, TTG)	Totem-2A VLFEM	R RSI RSX-5 (16 l down, 4 l up)
Geophysics GPR International Inc. (Canada) T: 450-679-2400 www.geophysicsgpr.com	Hughes 300 R44 Bell 206B/L ASTAR BA, B2, B3, Lama	H Geometrics Cs Vapour (T, LG, TTG, VG)	GEOPHEX HEM GEM-2A Towed Bird Multi Freq. Coaxial/Coplanar VLFEM GPRTEM	R Pico Envirotec (16 l)

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Geosphair Aviation Inc. (Canada) T: 514-585-4314 www.geosphair.com	Piper PA-31 Navaho x 1; FW Super-Cub x 1 (DGPS, RT-DGPS, DVideo)	GEM System K Vapour (T,TTG,VG)	Totem-2A VLFEM	Medusa MS-4000 R
Geotech Ltd. (Canada) T: 905-841-5004 www.geotech.ca	Cessna 206 x 1 FW Cessna 208B x 4 PAC750-XL x 1 Koala AW119 x 2 H AS350-B3 x 13 (DGPS, GLONASS + DVideo)	Geometrics G823A Cs Vapour FW (T, LG, TTG) (T, LG, Triaxial) H	Geotech VTEM TD H (systems configured for shallow to deep penetration) AFMAG ZTEM FW/H AirMt AeroTEM TD H IMPULSE FD H	RSI RSX-5 1024 chan R (32 l down, 8 l up) CMG GT-2A G
GeoVision Geosciences Inc. (Canada) T: 604-466-0425	Leased H	GEM System GSMP-30A	VLFEM	NA
GyroLAG (South Africa & Botswana) T: NA www.gyrolag.com	Maule M5-235C X 1 FW Trojan (1) Sycamore (1), Geoduster (1)-gyrocopter Agnav Guia/Linav (2) Novatel-DGPS (3)	Fluxgate (T, Vectors, TTG)	'SP' experimental device	MS 4000 (4 l Csl) R TAGS-6 G NIR,VIS,TIR, LiDAR RS
MagSpec Airborne Surveys Pty Ltd (Australia) T: 61-8-6260-2041 www.magspec.com.au	Cessna 210 FW Cessna 206 PAC750XL Leased H (Novatel L1/L2 + GLONASS)	Geometrics G822A Cs Vapour (T, G, TTG)	N/A	RSI RS-500 R CMG GT-2A G

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Microsurvey Aerogeofisica e Consultoria Cientifica Ltda (Brazil) T: 55-21-2445-1773 www.microsurvey.net	Cessna 208B FW EMB 820C x 2 Piper PA-31 Navajo	Scintrex Cs Vapour (T, G)	Ms Relief VLFEM SP-4 MT with 3 Coils	Picodas/PEI GRS 410 R (33.6 l) RSI RS-500 256-512 chan (16 l down, 4 l up) Exploranium GR-820 256 chan (16 l, 32 l or 48 l) Lockheed Martin FTG GG Full Tensor Gravity
MPX Geophysics Ltd. (Canada) T: 905-947-1782 www.mpxgeo.com	Cessna 206 FW Piper PA-31 Navajo Piper Aztek Leased H (DGPS RT-DGPS, Video)	Scintrex & Geometrics Cs Vapour (T, G, TTG)	PTHEM TD MICROTREM TD	RSI RS-500 R 256-512-1024 chan (50.4 l down, 12.6 l up)
New Resolution Geophysics (South Africa) T: 27-21-789-0509 www.airbornegeophysics.com	Pilatus PC6 x 2 FW Reims-Cessna F406 Caravan II AS350 series x 8 H (DGPS)	Scintrex CS-3 (T, LG, TTG, VG)	Xcite TD x 5 H	RSI RSX-4 x 8 R CMG GT-2A x 2 G
New-Sense Geophysics (Canada) T: 905-480-1107 www.new-sense.com	Leased: Piper PA-31 Navajo FW Cessna 206 Leased Bell 206 (stinger) H ASTAR (stinger)	Scintrex CS-3 (T, LG)	NA	RSI RSX-5 x 7 R (16 l down, 4 l up)
Novatem Inc. (Canada) T: 450-464-1655 C: 514-966-8000 www.novatem.com	Cessna 208 Caravan FW Piper PA-31 Navajo x 4 Leased ASTAR series H	Geometrics Cs Vapour (T, LG, VG)	NOVATEM TD H	RSI RSX-5 x 7 R (16 l down, 4 l up)

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Precision GeoSurveys Inc. (Canada) T: 604-484-9402 www.precisiongeosurveys.com	Cessna 206 FW Piper PA-31 Navajo H Bell 206, Airbus AS-350 (GPS, DGPS) UAV	Scintrex & Geometrics Cs Vapour, & GEM K Vapour (T,G) (with attitude correction)	TEM, FDEM, VLFEM H	Pico Envirotec R GRS-10 + AGRS Spectrometers 256-512 chan Exploranium GR820
Prospectair Geosurveys Inc. (Canada) T: 819-661-2029 www.prospectair.ca	EC120B, R44 H (RT-DGPS)	Geometrics Cs Vapour (T,G)	ProspecTEM TD H	RSI RSX-5 R (16 l down, 4 l up)
Prospectors A. S. Ltda. (Brazil) T.: 55-21-2502-2526 www.prospectorsbr.com	Piper Chieftain x 2 FW Cessna 208B x 2 H Leased	Geometrics Cs Vapour (T, LG, TTG)	AeroTEM TD H	RSI RS-500 R 3 x (40 l down, 8 l up) CMG GT-2A G
Sander Geophysics Ltd. (Canada) T: 613-521-9626 www.sgl.com	Cessna 208B x 8 FW BN Islander x 2 H DHC6 x 1 Airbus AS-350B3 x 2 (DGPS, RT-DGPS + DVideo)	Geometrics Cs Vapour Sander SGMAG (T, LG, TTG, VG, Triaxial) FW (T,TTG, VG) H	SGFEM FD FW Herz Totem-2A VLFEM	Exploranium GR820 R (256 chan) (60 l) RSI RS-500 256-512 chan 50 l down, 8 l up Sander AIRGrav G
Scott Hogg & Assoc. Ltd. (Canada) T: 416-444-8245 www.shageophysics.com	Leased H (GPS)	Scintrex CS-3 Cs Vapour (T, LG, TTG, VG, Triaxial)	Totem 2A VLFEM	Pico Envirotec R 256 chan (32 l down, 4 l up)
SkyTEM Canada Inc. (Canada) T: 647-256-6716 www.skytem.com	Leased H (GPS)	Geometrics Cs Vapour sensors (T)	TD: SkyTEM 304 & 312 (Dual moment), 306HP (multi moment), 312HP (single moment)	Medusa R 256-512 chan; (16 l down, 4 l up)

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Spectrem Air (RSA) T: 27-11-659-1518 www.spectrem.co.za	Basler BT-67 FW (DGPS + DVideo)	Scintrex Cs Vapour (T)	Spectrem2000 TD FW	Exploranium GR820 R (32 l)
Terraquest (Canada) T: 905-477-2800 www.terraquest.ca	King Air C90 FW Cessna 206 Navajo 325 Leased H (DGPS + DVideo)	Scintrex & Geometrics Cs Vapour (T, LG, TTG, VG)	Matrix digital FW/H VLFEM	RSI RSX-500 R Pico Envirotec (4 l down, 2 l up) CMG GT-2A G
Thomson Aviation (Australia) T: 61-2-6960-3800 C: 61-4-9999-1963 www.thomsonaviation.com.au	PAC 750XL x 2 FW Cessna 210 x 4 Cessna 208B Fletcher FU24 Piper PA-31 Navajo x 2 UAV FW/H; Leased H (NovAtel OEMV-1VBS)	Geometrics G822A & G823A Cs Vapour (T, G)	BIPTM TD H	RSI RS-500 R (up to 67.2 l) CMG GT-2A G
UTS Geophysics (Australia) T: 61-8-9479-4232 www.uts.com.au	Same aircraft as Geotech Ltd.			
Xcalibur Airborne Geophysics (PTY) Ltd. (RSA) T: 27-12-543-2540 www.xagsa.com	Turbo Islander x 3 FW Airtractor x 2	Geometrics Cs Vapour (T, LG, TTG)	NA	Exploranium GR-820 R RSI RS-500

COMPANY	TELEPHONE (FAX)	E-MAIL/WEBSITE	SENIOR OFFICER
ADVANCED GEOPHYSICAL OPERATIONS AND SERVICES INC. (AGCOS) 162 Oakdale Road, North York, ON M3N 2S5	416-747-8800 (416-747-5761)	info@agcos.ca www.agcos.ca	Igor Ingerov
CRONE GEOPHYSICS & EXPLORATION LTD 2135 Meadowpine Blvd. Mississauga ON L5N 6L5	905-814-0100 (905-814-8617)	info@cronegeophysics.com www.cronegeophysics.com	William (Bill) Ravenhurst
DUALEM INC. 540 Churchill Ave Milton ON L9T 3A2	905-876-0201 (905-876-2753)	inbox@dualem.com www.dualem.com	Rick Taylor
GEM SYSTEMS INC. 135 Spy Court Markham ON L3R 5H6	905-752-2202 (905-752-2205)	info@gemsys.ca www.gemsys.ca	I. Hrvoic
GEONICS Limited Unit 8, 1745 Meyerside Dr Mississauga ON L5T 1C6	905-670-9580 (905-670-9204)	geonics@geonics.com www.geonics.com	Miro Bosnar
GEOSENSORS INC. 66 Mann Ave Toronto ON M4S 2Y3	416-483-4691 (416-483-9909)	scott.holladay@geosensors.com	Scott Holladay
GEOSOFT-SEQUENT INC. 207 Queens Quay West-Suite 810 Toronto ON M5J 1A7	416-369-0111 (416-369-9599) 1-800-363-6277	info@geosoft.com www.geosoft.com	Lisa McGregor
GEOTECH LTD. 245 Industrial Parkway North Aurora ON L4G 4C4	905-841-5004 (905-841-0611)	info@geotech.ca www.geotech.ca	Ed Morrison
ICEFIELD TOOLS CORP. P.O. Box 30085 Whitehorse YK Y1A 5M2	867-633-4264 (867-633-4217) 1-877-423-3435	info@icefieldtools.com www.icefieldtools.com	Erik Blake
IFG CORPORATION 26 Bramsteele Rd, Unit 2 Brampton ON L6W 1B3	905-451-5228 (905-451-2877)	info@ifgcorp.com www.ifgcorp.com	Detlef Blohm
INSTRUMENTATION GDD INC. 860 Boulevard de la Chaudière, St. 200 Québec QC G1X 4B7	418-877-4249 (418-877-4054)	gdd@gdd.ca www.gdd.ca	Pierre Gaucher
KROUM VS INSTRUMENTS LTD. 2206-701 Don Mills R Toronto ON M3C 1R9	416-421-6313	kroum@kroumvs.com www.kroumvs.com	Kroum Stamenkov
LAMONTAGNE GEOPHYSICS LTD. 115 Grant Timmins Dr Kingston ON K7L 4V4	613-531-9950 (613-531-8987)	lamont@kos.net www.lamontagnegeophysics.com	Yves Lamontagne
MARINE MAGNETICS 135 Spy Court Markham ON L3R 5H6	905-709-3135 (905-479-9484)	info@marinemagnetics.com www.marinemagnetics.com	Melissa Marlowe
MIRA GEOSCIENCE LTD #309 – 310 Victoria Avenue Westmount, Quebec, H3Z 2M9	514-489-1890 (514 489-5536)	info@mirageoscience.com www.mirageoscience.com	John McGaughey
NUVIA DYNAMICS INC. 222 Snidercroft Rd Concord ON L4K 2K1	905-760-9512 (905-760-9513)	info@nuvia-dynamics.com www.nuvia-dynamics.com	Sandip Goswami
PATERSON, GRANT & WATSON LTD. 155 University Ave, St. 1710 Toronto ON M5H 3B7	416-368-2888 (416-368-2887)	pgw@pgw.ca www.pgw.ca	Stephen Reford
PHOENIX GEOPHYSICS LTD. Unit 3, 3781 Victoria Park Ave Scarborough ON M1W 3K5	416-491-7340 (416-491-7378)	yavram@phoenix-geophysics.com www.phoenix-geophysics.com	Yann Avram

Manufacturers and Principal Distributors of Mining Geophysical Equipment & Software in Canada 2020;
 Compiled by P.G. Killeen, 9759 Hwy 509, Ompah, ON K0H 2J0

(23/April/2020)

COMPANY	TELEPHONE (FAX)	E-MAIL/WEBSITE	SENIOR OFFICER
RADIATION SOLUTIONS INC. 5875 Whittle Road Mississauga ON L4Z 2H4	905-890-1111 (905-890-1964)	sales@radiationsolutions.ca www.radiationsolutions.ca	Jens Hovgaard
RMS INSTRUMENTS LTD. 6877-1 Goreway Dr Mississauga ON L4V 1L9	905-677-5533 (905-677-5030)	rms@rmsinst.com www.rmsinst.com	Onorio Rocca
SCINTREX Limited. 222 Snidercroft Rd Concord ON L4K 2K1	905-669-2280 (905-669-6403)	Scintrex@scintrexltd.com www.scintrexltd.com	Ed Quinton
SCOTT HOGG & ASSOC. 85 Curlew Drive, #104 Toronto ON M3A 2P8	416-444-8245 (416-444-4409)	scott@shageophysics.com www.shageophysics.com	Scott Hogg
SENSORS & SOFTWARE INC. 1040 Stacey Court Mississauga ON L4W 2X8	905-624-8909 (905-624-9365) (1-800-267-6013)	sales@senssoft.ca www.senssoft.ca	Peter Annan
W. SODIN (GRAVITY) LTD. Unit 18, 95 West Beaver Creek Rd Richmond Hill ON L4B 1H2	905-886-8632 (905-886-4477)		Wolf Sodin
SOUTHERN GEOSCIENCE CONSULTANTS (SGC) 15 Toronto Street-Suite 401 Toronto ON M5C 2E3	416-407-6355	Robert.Hearst@SGC.com.au www.sgc.com.au	Robert Hearst
TERRAPLUS INC. 120 West Beaver Creek Rd., Unit 15 Richmond Hill ON L4B 1L2	905-764-5505 (905-764-8093)	sales@terraplus.ca www.terraplus.ca	Claude B. Meunier
WALCER GEOPHYSICS LTD. 2106 Regional Rd 3 Enniskillen ON L0B 1J0	905-263-8767 (905-263-8766)	awalcer@rogers.com www.walcergeophysics.com	Alex Walcer

AIRBORNE EQUIPMENT					ELECTROMAGNETIC			GROUND EQUIPMENT Sus=susceptibility/G Meter=Gravity Meter								
COMPANY	Data Acquisition	Magnetometers	EM	Scint. Spectrometers	Drill hole	VLFEM	EM	Scint. Spectrometers	IP	Magnetometers	Resistivity	G Meter	Suscept Meters	Other & Software		
ADVANCED GEOPHYSICAL OPERATIONS AND SERVICES INC. (AGCOS)						GEPARD-4 & 8	<u>Receivers:</u> GEPARD-4 & 8 <u>Transmitters:</u> AT-100, AT-3000, AT-3000R, AT-4000, KR-10, KR-30, KR-75 and KR-175 <u>Electrical</u> <u>Sensors</u> ACE-84, ALCE-84A, ASCE-84AG. <u>Induction Coils:</u> AMS-11,12, 14 15, 27, 37, 47 <u>TDEM Loops:</u> MTEM-200, FTEM-100 & LTEM-25 <u>Precision Tripods:</u> TRI-3/30, -3/50, -1/30, -1/50, -1/30/1, -1/50/1		GEPARD-4 & 8 AT-100, AT-4000, KR-10, KR-30, KR-75, KR-175	AMS-11,12,14, 15, 27, 37, 47	GEPARD-4 & 8 AT-100, 4000 KR-10, 30, 75, 175					1. EM and Seismic software for modeling, data processing, editing, visualization and interpretation 2. Shallow Marine EM Receivers for coastal shelf 2AUSS-07A (2Ch) and 5AUSS-07A (5ch) and, SMMT (2ch) 3. Precision Field Tripods for induction mag sensor installation
DUALEM							DUALEM-1, 2, 21, 4, 42, 421 and 642									

AIRBORNE EQUIPMENT					ELECTROMAGNETIC			GROUND EQUIPMENT Sus=susceptibility/G Meter=Gravity Meter							
COMPANY	Data Acquisition	Magnetometers	EM	Scint. Spectrometers	Drill hole	VLFEM	EM	Scint. Spectrometers	IP	Magnetometers	Resistivity	G Meter	Suscept Meters	Other & Software	
GEM	GEM-DAS (Real time data display & Acquisition Software Compensation (post-processing or real-time))	Manned aircraft: GSMP-35A Complete Towed Birds: GSMP-35A(B) (MagBIRD) GSMP-35GA(B) (GradBIRD) GSMP-35GA3(B) (Tri-AxialBIRD) UAV: GFMP-35U (DRONEMag) GFMP-35U(B) (AirBIRD) GFMP-35UG(B) (AirGRAD)	Manned aircraft: GSM-90AV			GSMV-series: (VLF only) 19, 19W GSM-P series: (VLF attachment) 35V, 35GV (GSMP=potassium) GSM-series: (VLF attachment) 19V, 19WV, 19GV, 19GWV (19=Overhauser) 19TV, 19TWV, 19TV G, 19TGWV (19T=proton) (G=gradiometer; W=walking mode)									

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COMPANY	Data Acquisition	Magnetometers	EM	Scint. Spectrometers	Drill hole	VLFEM	EM	Scint. Spectrometers	IP	Magnetometers	Resistivity	G Meter	Suscept Meters	Other & Software
GEONICS					BH 43 BH 43-3D EM 39 EM 39S MAG 43-3D	EM-16 Tx27	PROTEM 67,47,57-MK2, CM, 67-Plus CMX EM42 EM61-MK2 EM61-MK2-HP EM61-HH-MK2 EM61-MK2A EM61-LX2 EM61 BLU26 ARRAY EM63-3DMK2 EM63 Flex Array GTEM				EM16R EM31-MK-2 EM34-3 EM31-S EM38DD EM38B EM38-MK2			DAT(31,34,39,38Mk2,61Mk2) DAS 70-AR2 Logger EM61LX2
GEOSENSORS	Custom	Multi-channel High Rate Processors	Custom FDEM, TEM Helicopter Towed Bird & Fixed Mount				EM Sensors							
GEOSOFT-SEEQUENT														S
ICEFIELD					Resistivity Conductivity IP Magnetic									

AIRBORNE EQUIPMENT					ELECTROMAGNETIC			GROUND EQUIPMENT Sus=susceptibility/G Meter=Gravity Meter						
COMPANY	Data Acquisition	Magnetometers	EM	Scint. Spectrometers	Drill hole	VLFEM	EM	Scint. Spectrometers	IP	Magnetometers	Resistivity	G Meter	Suscept Meters	Other & Software
IFG					Temperature Gamma Density Caliper Tilt Orientation Systems									
INSTRUMENTATION GDD INC.					Resistivity Conductivity IP Magnetic Temperature Gamma Density Caliper Tilt Orientation Systems SSW System: Probes 25 mm+ EM Conductivity Mag Suscept For Ni, Fe, etc.		TDEM Rx 3 or 8 channels EM-IP Tx controller TRM+Tx4 5Kw 2400V-20A Beep Mat		Tx: Tx III 1.8Kw Tx II 3.6Kw Tx 4 5,10,20 Kw EM-IP Tx controller TRM (higher frequencies) Rx: GRX 2-32 channels SCIP Tester: Resistivity and chargeability Borehole option				MPP-Probe: Mag suscept. and EM conduct	IP and EM post processing software
KROUM VS	KANA8	KMAG4												

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COMPANY	Data Acquisition	Magnetometers	EM	Scint. Spectrometers	Drill hole	VLFEM	EM	Scint. Spectrometers	IP	Magnetometers	Resistivity	G Meter	Suscept Meters	Other & Software
KROUM INSTRUMENTS	SDAS1-PPC													
LAMONTAGNE GEOPHYSICS														S
MARINE MAGNETICS					Magnum Magnetometer					Sentinel Base Stn. Mag.				
MIRA GEOSCIENCE LTD.														GOCAD Mining Suite Geoscience ANALYST Geoscience INTEGRATOR VP suite inversion codes UBC-GIF inversion codes Training
NUVIA DYNAMICS INC	IMPAC	IMPAC-M (integrated) PEICOMP-magnetic compensation	P-THEM	AGRS				PGIS-2 PGIS-2-1 PGIS-2-2 RADScout(drone installation)		PBM (diurnal variation station)				Praga4 (Spectrometer Processing) EMDataView MAPConvertD ATAView

AIRBORNE EQUIPMENT					ELECTROMAGNETIC			GROUND EQUIPMENT Sus=susceptibility/G Meter=Gravity Meter						
COMPANY	Data Acquisition	Magnetometers	EM	Scint. Spectrometers	Drill hole	VLFEM	EM	Scint. Spectrometers	IP	Magnetometers	Resistivity	G Meter	Suscept Meters	Other & Software
PATERSON, GRANT & WATSON LTD.														S
PHOENIX GEOPHYSICS LTD.							MTU-5C & 8A (AMT-MT) RXU-8A (AMT-MT) V8 (AMT/CSAMT /TD/FD/IP) T3 (CSAMT /TD/FD/IP-Tx) T4 (TDEM Tx) TXU-30 A/B (CSAMT /TD/FD/IP-Tx)		V8 T3 TXU-30 A/B Tx					EMpower (for AMT/MT) S EMpower (for TD EM) S
RADIATION SOLUTIONS INC. (RSI)				RS-500 series RSX-4 (16L) RSX-5 (16L + 4L) RS-501 I/F Console RS-600 series RS-602 I/F console RS-700 series RSX-0.5				Handheld: NaI: RS-120, RS-125, RS-230BGO Portable: RS-330NaI RS-332BGO Vehicle Mount: RS-600						

AIRBORNE EQUIPMENT					ELECTROMAGNETIC			GROUND EQUIPMENT Sus=susceptibility/G Meter=Gravity Meter						
COMPANY	Data Acquisition	Magnetometers	EM	Scint. Spectrometers	Drill hole	VLFEM	EM	Scint. Spectrometers	IP	Magnetometers	Resistivity	G Meter	Suscept Meters	Other & Software
RADIATION SOLUTIONS INC. (RSI)				(2L) RSX-1 (4L) RSX-3 (6L) RS-701 I/F Console RS-705 I/F Console				series RS-602 I/F console RS-605 I/F console RS-700 Series RSX-0.5 (2L) RSX-1 (4L) RS-701 I/F Console RS-705 I/F Console						
RMS INSTRUMENTS	DAARC 500 DAS 500 PDU 500 GP 300	DAARC 500 AARC 500 AARC 510, AARC 51/52(UAV) Compensator Geometrics-Cs mags	Herz Totem-2A (VLFEM)			Herz Totem-2A (VLFEM)				Geometrics Cs & Proton Mags				S ExportDARRC Support GP 300 Graphic Printer & Chart Recorder GP300 Support software
SCINTREX		CS-3								ENVI-CS		CG-6		Training Custom/Desig

AIRBORNE EQUIPMENT					ELECTROMAGNETIC			GROUND EQUIPMENT Sus=susceptibility/G Meter=Gravity Meter						
COMPANY	Data Acquisition	Magnetometers	EM	Scint. Spectrometers	Drill hole	VLFEM	EM	Scint. Spectrometers	IP	Magnetometers	Resistivity	G Meter	Suscept Meters	Other & Software
SCINTREX		CS-VL										RG-1 Gravilog A10 FG-5X gPhone-X		n-Consulting S Airborne Gravity Meter TAG-7 Ship Borne Gravity Meter Sea-III
SCOTT HOGG & ASSOC.	DAQNAV acquisition & navigation													S magnetic comp; AGG mag modeling
SENSORS & SOFTWARE							GPR: PulseEKKO/ PulseEKKO- Borehole NOGGIN BackTrak IceMap							S
SODIN												100 100T 200 200T		
SOUTHERN GEOSCIENCE CON														ImageRobot S

AIRBORNE EQUIPMENT					ELECTROMAGNETIC			GROUND EQUIPMENT Sus=susceptibility/G Meter=Gravity Meter						
COMPANY	Data Acquisition	Magnetometers	EM	Scint. Spectrometers	Drill hole	VLFEM	EM	Scint. Spectrometers	IP	Magnetometers	Resistivity	G Meter	Suscept Meters	Other & Software
TERRAPLUS		Gradient mag UAV/Drone System	GSM-90 AV VLF	RS-500 series	QL40 Series ABI-2G, OBI-2G FWS, GR, SGR ELOG, IP, DLL3, CAL, DEV, OCEAN, FTC, IND, MGS, SFM Heat Pulse Flow Meter, GyroShot MI5 RCAM-1000	GSMV-19 GSM Series 19V, 19WV, 19GV, 19GWV, 19TV, 19TWV, 19TGV 19TWGV	ProEx-GPR GroundExplorer-GPR GDP-3224 GGT-3, -10, -30 XMT-32 AMT/6 TEM/3 Stratagem Numis Lite, -Poly GEM-2 Promis	Hand-held Nal RS-120 RS-125 RS-230 BGO portable- RS-330 Nal RS-332 BGO RS-700 series RT-50 oreXpress PSR+	Elrec Pro Elrec 6 Distributed IP System Tipix VIP-3000 VIP-4000 VIP-5000 VIP-10000 IP/L QL-ELOGIP KT-20 IP	GSM-19 GSM-19W GSM-19G GSM-19GW GSM-19T GSM-19TW GSM-19TG GSM-19TGW GSMP-35 GSMP-35G	Syscal Kid Syscal Junior Syscal R1 Syscal Pro Ohm-Mapper		KT-10 v2 KT-10 Plus v2 KT-10R v2 KT-10R Plus v2 KT-10S/C KT-10 Plus S/C KT-10R Plus S/C KT-10R S/C KT-20 KT-20 Plus KT-20 S/C KT-20 Plus S/C	Geode ES-3000 StrataVisor SeisImager WellCAD Reflex Res2DINV Res3DINV Full Wave Designer Full Wave Viewer RadExplorer Object Mapper IX1D Surfer