GEOPHYSICAL SMORGASBORD: AIRBORNE & GROUND METHODS - ADVANCES & APPLICATIONS
KEGS FOUNDATION MINI SYMPOSIUM – 4-DEC-2018
UNIVERSITY OF TORONTO
EARTH SCIENCES BUILDING, ROOM ES 2093, 22 RUSSELL STREET

FINAL PROGRAM

No	Time	Speaker	Title
--	12:30-1:00		Coffee and Posters
--	1:00-1:05	Chair	Introduction
1.	1:05-1:30 (25min)	**Nasreddine Bournas** Geotech Ltd.	*Airborne EM methods applied to VMS exploration - Recent case studies*
2.	1:30-1:55 (25min)	**Adam Smiarowski** CGG Multiphysics	*Breaking through the 25/30 Hz barrier: Helitem35C case study from Fraser Range, Western Australia*
3.	1:55-2:20 (25min)	**Tom Bagley** Laurentian University	*Estimating overburden thickness in resistive areas from two-component airborne EM data*
4.	2:20-2:45 (25min)	**Mehran Gharibi** Quantec Geoscience Ltd.	*Azimuthal effects in 3D DC resistivity surveys*
5.	2:45-3:10 (25min)	**Francisca Maepa** Laurentian University	*Predicting gold mineral potential from geological and geophysical data in the Swayze greenstone belt using radial basis function link nets method*
--	3:10-3:25		Coffee and Posters
--	3:25-3:35		KF Scholarship Presentations
6.	3:35-4:05 (30min)	**Stephen Mosher** University of Ottawa (Collett Graduate Scholarship recipient)	*Characterizing Seismicity of Offshore Cascadia by Applying Advanced Statistical Learning to Ocean-Bottom Seismic Data*
7.	4:05-4:30 (25min)	**Hema Sharma** Western University	*Application of ambient seismic noise analysis and velocity modeling in mineral exploration*
8.	4:30-4:55 (25min)	**Stefan Ellief** Sander Geophysics Ltd.	*The interplay of sampling and accuracy in gravity surveys*
9.	4:55-5:20 (25min)	**Robert Hearst** Southern Geoscience Consultants	*Multi-method geophysical imaging of porphyry deposits – Case histories from the Americas*
--	5:20-5:25	Chair	Closing

Posters

No.	Presenter	Title
10.	**Qi Zhao** University of California, Berkeley	*Direct observation of fault evolution under micro-CT*
11.	**Nasreddine Bournas** Geotech Ltd.	*A new approach for kimberlite exploration using helicopter-borne TDEM data*
12.	**Yuu Wang** University of Toronto	*Low Frequency Laboratory Attenuation Measurements on 3D-printed Sandstone*
13.	**Karl Kwan** Geotech Ltd	*Interpretation of Cole-Cole parameters derived from helicopter TDEM data – Case studies*

No 1

Title: *Airborne EM methods applied to VMS exploration - Recent case studies*

Authors: *Nasreddine Bournas, Alexander Prikhodko, Karl Kwan and Jean Legault (Geotech Ltd),*

Presented at: XPLOR 2018

Speaker: *Nasreddine Bournas – Geotech Ltd.*

Abstract:

Airborne EM methods have played a key role in the exploration of Volcanogenic Massive Sulphide deposits due to their excellent electrical properties. Over the past decades, the continuous improvement of modern EM platforms operating either in time domain (VTEM) or with natural sources (ZTEM) has led to significant increase in depth of investigation and their detection power, making it possible to detect deep-seated deposits, which were not detectable in the past. In this presentation, we show some successful examples from VTEM and ZTEM survey results that have led to the discovery of VMS mineralization in various regions of the world.

No 2

Title: *Breaking through the 25/30 Hz barrier: Helitem35C case study from Fraser Range, Western Australia*

Authors: *Adam Smiarowski and Andrew Fitzpatrick*

Presented at: AEM 2018

Speaker: *Adam Smiarowski – CGG MultiPhysics.*

Abstract:

Low-base frequency operation has proven difficult for AEM systems because of the requirement to limit motion of the receiver coils. Previous attempts with base frequencies below 25 Hz have been ineffective because coil motion induces higher noise levels, and the reduced ability to reduce noise through stacking. Recent significant re-design and development of the Helitem system has enabled operation at 12.5 Hz with suitably low noise levels for effective exploration. Here we describe the use of the Helitem35C system, a 12.5 Hz base frequency and with a long, high powered transmitter pulse. The system uses an all-new suspension system to reduce coil motion noise and allow low-base frequency operation. Survey data at 12.5Hz is compared to data from a 25Hz base frequency survey, and is used to demonstrate the value of the extended measuring time in increasing exploration depth. In some areas of the survey the signal in the last time channel of the Helitem35C data exceeded noise levels by a factor of 100. We demonstrate the effectiveness of the 12.5Hz at mapping geology beneath the conductive cover in the Fraser Range.

No 3

Title: *Estimating overburden thickness in resistive areas from two-component airborne EM data*

Authors: *Thomas Bagley and Richard Smith*

Presented at: SEG 2018

Speaker: *Thomas Bagley – Laurentian University.*

Abstract:

An overburden with variable thickness can obscure the response of underlying geophysical features. For example, the gravity response of an increased thickness of low density overburden might not be distinguishable from a deeper sandstone hydrothermally altered to clay. When the overburden is conductive, its thickness can be determined from the rate of decay of the off-time airborne electromagnetic data. However, the off-time decay of a thin or resistive overburden is small and difficult to measure. Previous studies have used the on-time resistive-limit response of a single component to successfully map apparent ground conductance in resistive areas. Quantitative resistive-limit models exist for thin-sheet, half-space, thin-sheet over half-space, and thick-sheet over half-space models. This study uses horizontal and vertical component data to estimate the thickness (and conductivities) of a two layered model across the survey profile.

No 4

Title: *Azimuthal effects in the 3D DC resistivity surveys*

Authors: *Mehran Gharibi, Roger Sharpe, and Robert Hearst*

Presented at: SEG 2018

Speaker: *Mehran Gharibi – Quantec Geoscience Ltd.*

Abstract:

Developments in instrumentation and processing tools have made 3D resistivity surveys an effective approach in delineating complex geological environments. In the performance of these surveys a large number of data points are produced, and the properties of the dataset should be explored to optimize and coordinate interpretation efforts. In this study, a field 3D dataset was geometrically decomposed into near maximum-coupled (so-called radial) and near null-coupled (so-called tangential) subsets and inverted using a 3D approach. The results indicate that these two models may represent the subsurface at regional and local.

No 5

Title: *Radial Basis Function Link Nets method for predicting gold mineral potential from geological and geophysical data in the Swayze greenstone belt (SGB)*

Authors: *Francisca Maepa and Richard S. Smith*

Presented at: SEG 2018

Speaker: *Francisca Maepa – Laurentian University*

Abstract:

The radial basis function link network (RBFLN) machine learning method is a neural network technique that has gained favor in the mineral exploration realm for its robustness and ability to discriminate between deposits and non-deposits. As mineral deposit targets become deeper and harder to find, spatial data modelling and machine learning techniques that help to predict regions that hold potential for new deposits are sought. The identification of new mineral deposits becomes possible with greater understanding of the mineral systems that were involved in the deposition of mineral deposits. The Swayze greenstone belt hosts a few low-grade high-tonnage deposits and reviewing the mapable criteria that resulted in gold mineralization could help in the discovery of new drill targets and possibly new mineral deposits. Using geological, geochemical, structural and geophysical datasets that are markers for processes that led to gold deposition and proxies to mineralization, RBFLN can make predictions to produce mineral prospectivity maps. Receiver operator characteristic (ROC) curves are used to evaluate the sensitivity and specificity of predictive models. Overall, RBFLN shows an area under curve of 0.88 and an efficiency of classification of 83%. The results show that RBFLN was successful at delineating new areas for more detailed exploration.

No 6

Title: *Characterizing Seismicity of Offshore Cascadia by Applying Advanced Statistical Learning to Ocean-Bottom Seismic Data*

Authors: *Stephen Mosher*

Speaker: *Stephen Mosher – University of Ottawa (Len and Genice Collett Scholarship recipient)*

Abstract:

The Cascadia subduction zone, which runs parallel to the west coast of North America, is characterized by the oceanic Juan de Fuca plate that dips beneath the continent. The interface that separates the oceanic and continental plates (i.e., the megathrust fault) is capable of generating catastrophic earthquakes and tsunamis that historically have recurred roughly every few hundred years. Such disasters could devastate much of North America's west coast, causing thousands of casualties. Therefore, understanding earthquakes in this region is of great concern to seismologists, engineers, and government authorities.

Currently, the megathrust fault is known to be locked, accumulating stresses from the known convergence of tectonic plates (~cms/yr) which will be released during future seismic events; however, the fault is surprisingly quiet, meaning that few large earthquakes have actually been observed in Cascadia with modern instrumentation. Due to this lack of observational evidence, very little is known about the spatial extent of fault locking and therefore the dimensions of the seismogenic zone, information which is vital to developing models of earthquake rupture, ground motion studies, and ultimately hazard assessment. Since a significant portion of the subduction zone is located offshore, land-based seismic stations are located too far away to observe any potential minor offshore seismicity associated with the fault. Therefore, utilizing data from ocean-bottom seismometers to fully characterize the seismicity of the Cascadia subduction zone is a crucial step toward improving our understanding the seismic hazard posed by this region.

The main objective of this research is to more completely characterize the seismicity and deformation of the Cascadia subduction zone using data obtained from ocean-bottom seismometers. Specifically, this research addresses the following questions:

1) *What are the patterns and mechanisms of seismicity within the Cascadia subduction zone?*
2) *How are earthquakes distributed within these plates, both laterally and with depth?*
3) *How do these distributions relate to present tectonic forces?*
4) *What does the distribution of seismicity, both onshore and offshore, reveal about Cascadia's seismogenic zone?*

Addressing these questions requires the ability to accurately detect and locate earth-quakes. But detection and location remain difficult problems in marine seismology, owing to the extremely noisy environment typically encountered in ocean-bottom seismic measurements [1]. To overcome, or at least mitigate this problem, this research is investigating the use of advanced statistical methods from machine learning (such as logistic regression). Focusing on statistically coherent features observed on multiple instruments rather than on data recovered from single stations has been shown to significantly increase seismic detection rates [2,3], and is well-suited to identifying weak signals buried in large volumes of data [4]. This research is focused on the effective adaptation of these methods, previously exclusively applied to land-based instruments, to data recorded by arrays of ocean-bottom instruments, thereby significantly enhancing our ability to detect and locate potential offshore seismicity in Cascadia. Furthermore, given the proliferation of networks of ocean-bottom instruments that have been installed over the past decade, by research programs such as the Cascadia Initiative and Ocean's Network Canada, there is an abundance of data available for this research.

References

[1] D. Suetusgu and H. Shiobara. (2014) Annu. Rev. Earth Planet. Sci. ***42****, 27-43*
[2] A. Reynen and P. Audet (2017) Geophys. J. Int., ***210****, 1394-1409.*
[3] Z. E. Ross et al. (2018) J. Geophys. Res.-Solid Earth, in review.
[4] A. Kohler et al. (2010) Geophys. J. Int., ***182****, 1619-1630.*

No 7

Title: *Application of ambient noise analysis and velocity modeling in mineral exploration*

Authors: *Hema Sharma, Sheri Molnar, Dan Hollis, and John McBride*

Presented at: SEG 2018

Speaker: *Hema Sharma –Western University*

Abstract:

A hard rock geologic setting of Canadian Shield makes mineral exploration using seismic techniques often difficult due to the complicated boundaries in the subsurface. Mineral exploration utilizes diamond drilling to explore below surface, but this approach is costly and only offers a narrow view of the subsurface environment. Other geophysical methods have been conducted, but either do not offer a resolution that is useful for exploration (gravity and magnetic), or they only offer a shallow range of view as they cannot model results accurately below a depth of 500 m (EM and IP). Therefore, to get subsurface properties for a large area, seismic data collected using non-invasive techniques can be utilized. Data acquisition using ambient noise sources is one of the non-invasive techniques, that is a much cheaper and viable method of analyzing the complex subsurface structure. The current study uses ambient noise data to analyze the noise sources and their direction, and to estimate the subsurface velocity structure at the Marathon PGM-Cu project in Marathon, Ontario, Canada. An initial 3D velocity inversion model from a larger 90-geophone array accomplished at the site has resolved westward dip of the gabbro slab in the upper 1.5 km.

No 8

Title: *The interplay of sampling and accuracy in gravity surveys*

Authors: *Stefan Elieff*

Presented at: SEG 2018

Speaker: *Stefan Elieff, Sander Geophysics Ltd.*

Abstract:

When presented with a gravity data set for any area, two numbers are typically of interest: the resolution and the accuracy. The resolution is the spatial size of the smallest features visible in the data; the accuracy quantifies the reliability of the features in the data. It is well understood that to resolve features, an area must be sampled with a spacing that is small enough to see those features. It may be less obvious that sampling can play an important role in determining the accuracy of a survey, either through undersampling or oversampling. The different sampling patterns of ground or airborne gravity surveys affect the accuracy of the resultant grids.

No 9

Title: *Multi-method geophysical imaging of porphyry deposits – Case histories from the Americas*

Author: *Robert Hearst*

Presented at: *SEG 2018 Workshop W-11: Review of Porphyry Cu-Au-Mo Deposits, Geology & Exploration and Development.*

Speaker: *Robert Hearst, Southern Geoscience Consultants.*

Abstract: *Porphyry systems are excellent geophysical targets and can be imaged using a variety of geophysical exploration methods. These methods include radiometrics, magnetics, and gravity, electrical methods (DC resistivity, IP chargeability and electromagnetic methods (active and passive). Individually these methods can be effective in defining the different parts of a porphyry system as defined by the classic model of Sillitoe. When two or more geophysical methods are combined not only with each other, but also with available geological and geochemical data, the image and understanding of the porphyry system is greatly enhanced. The ability to combine the results of various 2D and now 3D survey approaches into a combined image in 3D space provides the opportunity to start to understand the extent of the porphyry system being explored and where in the porphyry system the explorer may be.*

In this presentation we will look at case histories from Argentina, Peru and Chile that illustrate the power of using multiple complementary geophysical methods and the evaluation of these results to the known geology and the porphyry system model.

No 10 (Poster)

Title: *Direct observation of fault evolution under micro-CT*

Author: *Qi Zhao – University of California, Berkeley*

Abstract: *Understanding how microscopic fractures develop due to fault activation may directly improve our comprehension of fault slip behaviour. Due to the inability of accessing seismogenic fault zones in situ, the study of fault behaviour relies mostly on laboratory experiments. To date, these laboratory studies allowed only post-mortem examination of the deformed samples, making microscopic analysis of the fault evolution challenging. Using a novel rotary shear testing apparatus (ERDμ-T) specifically designed and assembled to conduct experiments inside the X-ray micro-computed tomography machine (μCT), we are able to continuously observe how the fault surface evolve and fractures develop during the shearing process and concurrently link them to the measured physical parameters*

No 11 (Poster)

Title: *A new approach for kimberlite exploration using helicopter-borne TDEM data*

Authors: *Nasreddine Bournas, Alexander Prikhodko, Karl Kwan and Jean Legault (Geotech Ltd), Vitally Polianichko and Sergei Treshchev (Kimang, Ltda).*

Presented at: *SEG 2018*

Abstract:

In this paper, we propose a new exploration strategy for detecting pipe-like structures from airborne TDEM data. We first apply the Keating's pattern recognition technique to the EM resistive limit calculated from the early and mid-time decay channels and to the magnetic analytic signal for predicting conductive and magnetic pipes. The automated detection procedure yielded numerous solutions, whose number is downsized after a careful screening and fine-tuning of the obtained results. Further, the selected targets are classified into several categories according to their EM, magnetic and IP signatures. Finally, we perform 3D MVI and 1D EM inversion on selected targets to determine the size, the depth and the magnetic and electrical properties of these targets.

No 12 (Poster)

Title: *Low Frequency Laboratory Attenuation Measurements on 3D-printed Sandstone*

Speaker: *Yuu Wang – University of Toronto*

Abstract:

3D-printing technology allows us to digitally control the micro-structure and test our hypothesis on how micro-structure affects rock behaviour at the macro-scale. The samples tested in this work are printed by a 3D binder jet printer. Layers of sand are cemented together by layers of resin polymer, mimicking natural reservoir rock. The macroscopic mechanical properties studied in this work are the viscoelasticity of the dry 3D-printed cylindrical sandstone sample. Viscoelasticity is quantified as the attenuation of low frequency (0.1-100 Hz) seismic waves that propagate through the tested core sample. Viscoelasticity of Earth materials is of great interest in exploration geophysics. Application of viscoelasticity measurements range from locating subsurface hydrocarbon reservoirs to mapping geological structures. Attenuation measurements were carried out by subjecting the cylindrical sample to various sinusoidal axial loading conditions. Dynamic Young's modulus and attenuation were obtained from the amplitudes and the phase difference between the applied stress and the deformation of the sample. The attenuation measurement result demonstrated very limited frequency dependence at the low frequency range covered in the tests, while strain dependence was observed at large deformation. Both strain dependence and frequency independence are comparable to those of a Berea sandstone sample tested with the same laboratory setup, indicating the possibility for using 3D-printed sandstone as replica material to natural reservoir rocks.

No 13 (Poster)

Title: *Interpretation of Cole-Cole parameters derived from helicopter TDEM data – Case studies*

Authors: *Karl Kwan[1], Jean M. Legault[1], Ian Johnson[2], Alexander Prikhodko[1], and Geoffrey Plastow[3]*

1: Geotech Ltd, Aurora, CAN

2: Geophysical Consultant, CAN

3: Geosoft Ltd., Toronto, CAN

Presented at: *SEG 2018*

Abstract:

We introduce an improved Airborne Inductively Induced Polarization (AIIP) mapping algorithm, which can extract with precision the three Cole-Cole parameters (i.e., low-frequency background apparent resistivity, Cole-Cole chargeability m and time-constant), while keeping the frequency factor c fixed. The derived Cole-Cole parameters are related to physical properties. The interpretation of Cole-Cole parameters may be enhanced by considering the AIIP normalized chargeability m/□_0 and the AIIP tau-scaled chargeability (TSC). The former is analogous to the metal factor (MF). It responds well to most clays and is here given the label AIIP Clay Factor. The TSC is better suited for tracking relatively more chargeable materials with relatively longer Cole-Cole time-constants. The implications of AIIP normalized and tau-scaled chargeabilities for mineral exploration are demonstrated with cases from the Tli Kwi Cho kimberlite complex in Lac de Gras, NWT, Canada, the and the Cerro Quema high sulphidation epithermal gold deposits in Panama and the Nuqrah SEDEX deposits in Saudi Arabia.