

RECORDER



JUNE FOCUS:

Western Canadian Mineral Exploration Geophysics

HOW GEOSCIENTISTS
ARE MAKING POTASH
MINES SAFER

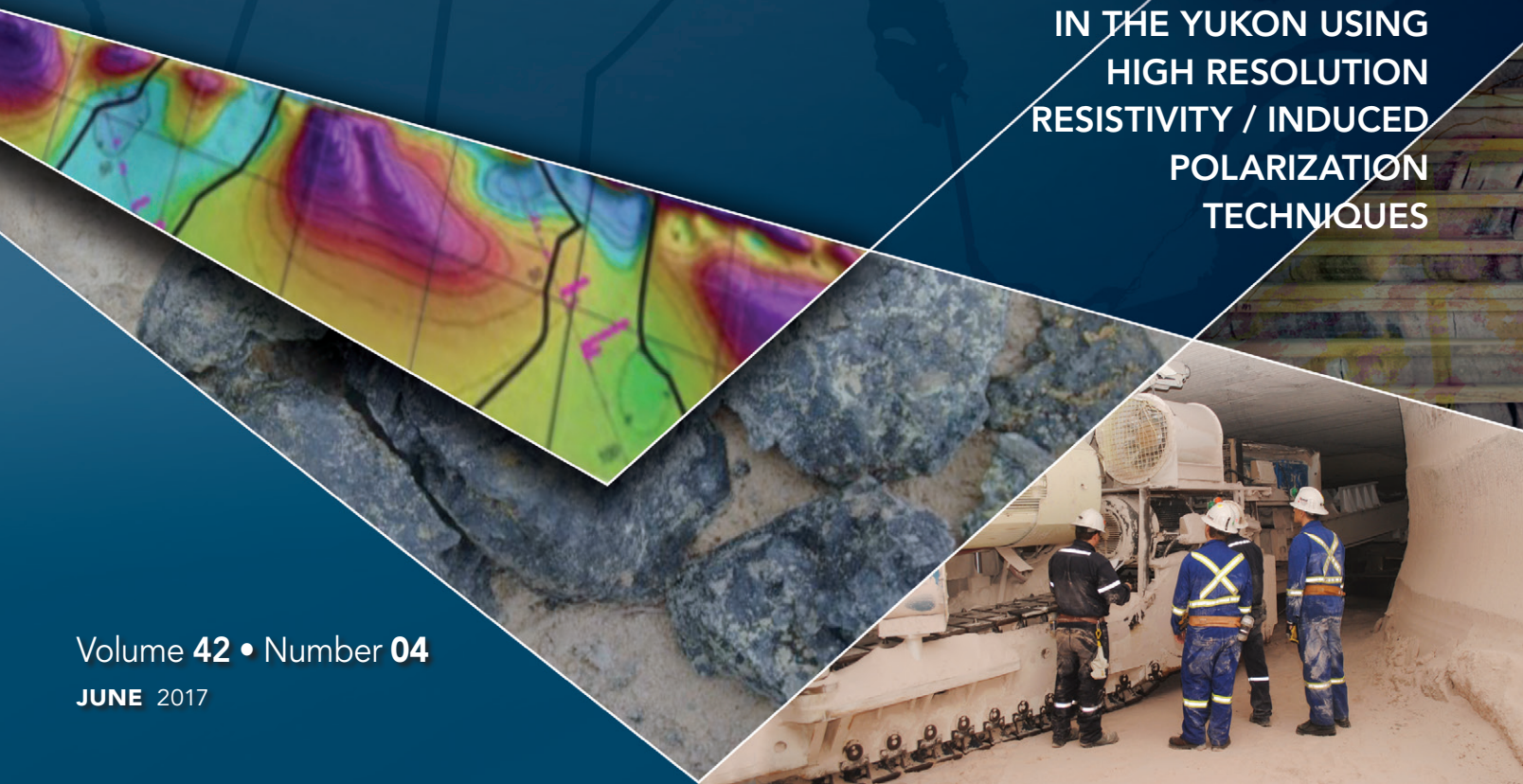
GEOPHYSICS ON FISSION
URANIUM'S PATTERSON
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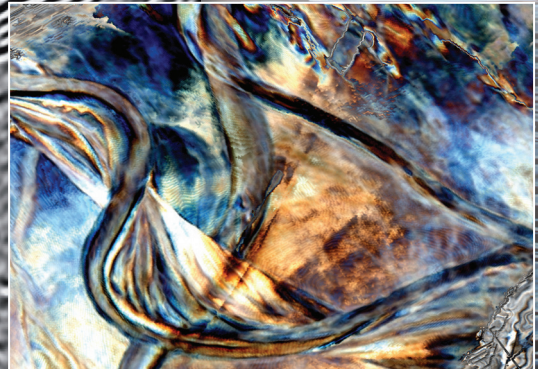
CASE STUDY
OF MINERAL DEPOSITS
IN THE YUKON USING
HIGH RESOLUTION
RESISTIVITY / INDUCED
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Volume **42** • Number **04**

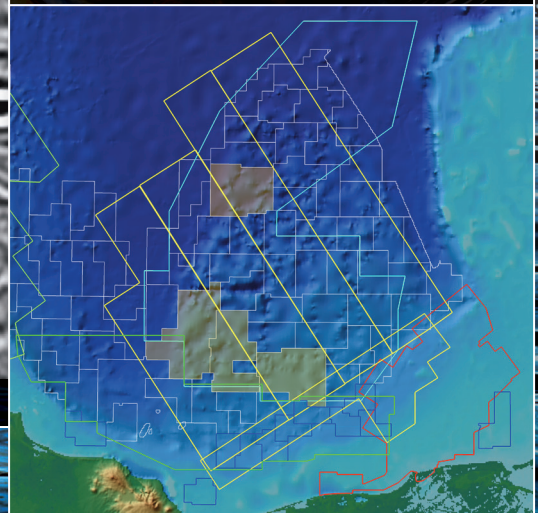
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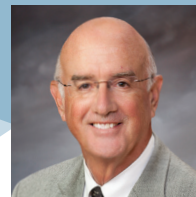
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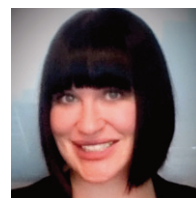
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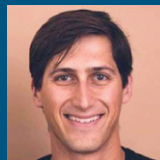
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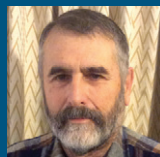
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PRESIDENT'S MESSAGE

Your CSEG Board has four themes that they are working on as part of the CSEG's short and long term strategies. They are:

1. Financial Health of the CSEG
2. Member Value
3. Promotion of the profession
4. Position of the CSEG as a professional society

When I committed to run for VP – President elect I promised that I would work towards a zero-deficit budget and would promote the value of geophysics in our industry.

In June 2016, a new committee was created to address the financial shortfall of our society. We called ourselves the New Initiatives Committee (NIC). It is a select group of individuals that have been successful in their own right and had the courage to work together to provide new revenue sources for our society at the risk of giving their fellow competitors fresh ideas. A number of ideas were discussed and dismissed, and a few, such as a digital RECORDER and website ads on the RECORDER website and our home page, to name a few, started to get some traction.

Getting some statistics on our website was one of the first steps that was initiated in consort with the Digital Media Committee (DMC). We just received some initial results that show that our webpage gets 30,000 hits a month; that is equivalent to 60% of the SEG's web page traffic. See Figure 1.

In the second half of 2016, an opportunity came along through the University of Calgary's Haskayne School of Business MBA marketing class. Jessica McPherson, a recent graduate of the program and a Senior Geophysicist at Cenovus, made a suggestion to her past professor, Derek Hassay. He jumped on the idea and proposed that his MBA marketing students would benefit greatly from doing a study on a "Trade Association" as part of their program. The program kicked off in January 2017 with the students talking to decision makers at over 30 operating, service,

and integrated service companies in Calgary. They will be looking for ways to provide new revenue sources for the CSEG. The NIC and the CSEG Board are looking forward to talking about the results in Q2 2017.

During 2016, along with members from the Value of Integrated Geophysics (VIG) Committee, we presented the value of integrated geophysics at various society breakfasts, luncheons, and conferences. It was in Q1 2017 that I decided to take the promotion of the CSEG and the VIG theme one step further and took the VIG presentation "Geophysics: Maximizing Success in a Business Team Environment" to New Zealand. I eventually presented the paper at three locations: Pepanz (Petroleum Exploration and Production Association NZ) offices in Wellington, the University of Otago in Dunedin, and the University of Auckland in Auckland. My take-away from the NZ tour was that their oil and gas industry is suffering to the same degree as we are, with a few encouraging highlights:

- ▶ Two large offshore marine surveys were being recorded in 2017.
- ▶ Most companies were moving out of Wellington due to the earthquake safety risk.
- ▶ New reserves are needed to replace the existing fields that are over 90% depleted.
- ▶ There are changes in water velocity that create "events" on seismic data due to depth, temperature and ocean currents.
- ▶ They are looking at gas hydrates as a potential source of hydrocarbons.
- ▶ They are drilling 1-3 ODP (Offshore Drilling Program) wells to understand their continental shelf.
- ▶ Transportation and livestock create more emissions in New Zealand than the oil and gas industry.

And most importantly, if you are presenting in parts of New Zealand and an earthquake occurs, do not run outside of

the building; find a table to hide under and wait till the all-clear is given.

My motivation for doing the NZ tour was also to promote my updated two-day Value of Integrated Geophysics Course "Maximizing Success Using Integrated Geophysical Solutions". What I then found out was that New Zealand does not have an APEGA equivalent, so training



Figure 1. CSEG website hit locations



L – R: Sebastian Clar (PhD student: 'Seismic characterisation of ocean water masses'), Jasper Hoffmann (PhD student: 'Shallow fluid flow structures on the continental shelf and slope'), John Duhault, CSEG President, Tim Lutter (MSc student: 'Gravity measurements and modelling applied to the Quaternary sedimentary basin underlying Dunedin'), Douglas Fraser (PhD student: 'Seismic characterisation of gas hydrates'), Andrew Gorman: Professor: University of Otago in Dunedin, New Zealand (PHOTO COURTESY OF JOHN DUHAULT)

time is not required as part of their annual industry activity. Therefore, promoting professional development in NZ is proving to be more difficult than I initially thought. They do however, have an annual conference.

危機

Crisis, are we in a crisis?

The Chinese characters that make up the word crisis are "danger and opportunity".

Image source: Wikipedia, en.wikipedia.org/wiki/Chinese_word_for_%22crisis%22

In these times of stress, finding new avenues to provide food for your family is a challenge.

As a member of the glass-is-half-full club, I do not have the answers to where we will all end up as an industry, but I do recognize that giving up is a "danger," but re-imagining ourselves – trying to figure out what we do best – is an "opportunity".

The GeoConvention has now come and gone; hopefully you had the opportunity to participate, to learn something new technically, and to grow stronger in your own personal abilities.

Stay strong, talk to your friends and family, and keep on talking and listening!

In closing, I leave you with my personal philosophy that I learned from Bishop Henry in the late 20th century:

*"Do your best.
Do what is right.
Treat people the way you want to be treated.
Everyone is special in some way."*



CSEG CALENDAR

JUNE			
7	CAGC Luncheon	Calgary, AB	cagc.ca
8	CAGC Tough Times Golf	Nanton, AB	cagc.ca
19	CSEG Technical Luncheon with Laurie Weston Bellman (Sound Q): "Data Interpretation and Integration from a Seismic Perspective – The Excitement of Innovation"	Bow Valley Club, Bow Valley Square, Calgary, AB	cseg.ca
26	9th Annual T-Wave Golf Tourney	Valley Ridge Golf Club, Calgary, AB	csec.ca

Do you find events using this calendar? Do you find events using the website calendar? Do you have a suggestion for what brief information we should begin to publish in the RECORDER? Blogs? Newly updated CSEG website pages?

Email editor@csegrecorder.com with your preferences and suggestions.

If you have an event that you want to post in the website calendar, email dmc@cseg.ca.



CHIEF EDITOR'S MESSAGE

Nicole Willson
Chief Editor

CSEG RECORDER
editor@csegrecorder.com

I recently attended a National Geographic presentation by Lee Berger. Dr. Berger told us the story of how his team discovered the latest hominin fossils, *Homo naledi*. The fossils were found at the very end of a huge, torturous cave system with small apertures too small for Dr. Berger to crawl through. He had to find and rely on scientists, equipment and techniques that he hadn't used before, and watched the events on a computer screen. At the end of his description of what it took to navigate the cave system and extract the fossils, he said that they used radar to delineate the extents of the cave system (see * for the article describing the delineation of the cave system).

In my mind, all I heard was, "geophysics".

Perhaps my perspective is a little too focussed.

William Wordsworth's poem "Nuns fret not at their convent's narrow room" presents the idea that limiting your focus to a single task is liberating. The book "How to write a sentence: and how to read one" describes the meaning further, "If the moves you can perform are prescribed and limited...each move can carry a precise significance" (Fish, 2011).

I like the idea that we can learn and accomplish more by focusing on a specific area of study because of the structure the area of study provides. So maybe my geophysics-filled point of view is okay.

This edition is composed of many mentions and examples of structure and exceling within that framework, everything from the terminology we use in the CSEG, our Professional Associations, our travels, to the technical articles and the Technical Luncheon extended abstract.

This is the last edition before our summer break. The next edition is September with the Focus: Value Integrated Geophysics. Continue checking the CSEG website for information on the CSEG and events taking place in July, August, and September.

Have a great summer!

Fish, S., 2011, How to write a sentence and how to read one, New York, HarperCollins Publishers, p.32.

*Kruger, Ashley et al., 2016, Multimodal spatial mapping and visualisation of Dinaledi Chamber and Rising Star Cave, South African Journal of Science. DOI: 10.17159/sajs.2016/20160032



LETTER TO THE EDITOR

I was perusing the March edition of the RECORDER online (by the way, I like the "flippable" version for online viewing) but is there a way to download the entire edition as one pdf to view on my ipad? I can download individual articles from the current edition, and I can download entire editions from the archive (October 2016 and earlier), but the current member-only versions do not seem to have the "entire edition" option. Does this mean I have to wait for the latest additions to move into archive before I can download as single pdfs? Copying each individual article as a pdf is a bit cumbersome.

Thanks, Ian Meades

A new PDF button has been added to new editions on the RECORDER website, csegrecorder.com. Nicole



What's Coming in Future Issues of the RECORDER...

Issue	Focus Article Theme	Coordinators* / Committee Assistants
September 2017	Value of Integrated Geophysics (VIG)	Louis Chabot* / Elwyn Galloway
Mid-October 2017	Processing	Rob Holt* / Fereidoon Vasheghani
December 2017	Water Exploration	Dr. Mel Best* / Steve Jensen
Mid-January 2018	Emerging Technologies: Machine Learning	Hoda Rashedi & Mark Dahl* / Elias Carciente
March 2018	Salt Dynamics	TBD* / Omid Aghaei
Mid-April 2018	Horn River Basin / Induced Seismicity	TBD* / Steve Jensen
June 2018	Archaeology	TBD* / Fereidoon Vasheghani

CALL FOR PAPERS – The RECORDER publishes articles on all areas of applied geophysics and disciplines which impact it. To submit an article: Please contact the RECORDER Editor at editor@csegrecorder.com. **To be considered for publication, articles need to be received at least two months in advance of the publication date** (e.g. by the 1st of July for publication in the September edition).

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TO BE improved,
CHALLENGED,
AND INCREASED
constantly,
OR IT vanishes.*”

Peter Drucker



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THE FOCUS OF THE CSEG ELECTED VOLUNTEER LEADERS FROM EXECUTIVES TO A BOARD OF DIRECTORS

Marian C. Hanna, ICD.D

Running a successful non-profit such as the CSEG takes an active board of directors and a dedicated staff led by a capable managing director. In general terms, the board of directors provides oversight and guidance to the managing director and the non-profit's staff members. The board ensures that the organization stays aligned with its strategic direction, mission and values in addition to complying with all federal and provincial laws and those rules as an official SEG Section.

During the past year, the CSEG elected volunteer leaders have migrated from referring to their collective positions as Executives to the CSEG Board of Directors. Therefore, the CSEG elected volunteer leaders have conducted themselves as a Board of Directors thereby contributing its fiduciary duty to the Society as commonly practiced in Canada. The CSEG Board of Directors is what is called a working board, since some operations do get carried out by the Board with the CSEG Staff.

This is analogous to a corporation's Board of Directors, while the CSEG Staff, particularly the Managing Director Jim Racette, is analogous to a CEO of the organization.

The day to day operations of the CSEG Society falls under the domain of the Managing Director, Jim Racette and Support Services Coordinator, Alyssa Middleton. The many outstanding volunteers who Chair and work on CSEG Committees carry out the operations of their committees while working with Jim and Alyssa with oversight and strategic input from the CSEG Board Director or Officer.

The strategic direction and focus is the joint responsibility of a Board of Directors and the management team in any organization. That strategic direction and oversight is the main responsibility for the CSEG Board, especially as the CSEG works on thriving during the current economic circumstances. An Executive role implies day to day operational responsibilities and within the CSEG, some CSEG elected volunteer leader positions have often gotten mired in the day-to-day minutia which are the responsibilities of the CSEG Staff and have sometimes left out the CSEG Staff in those operations.



Outgoing Board of Directors 2017

L-R: Rachel Newrick (outgoing Past President), Ken Gray (outgoing Dir. of Education Services), Marko Mah (outgoing Dir. of Communications.), Kevin Bianchini (outgoing Dir. of Member Services), Janine Ballingall (outgoing Dir. of Finance), Marian Hanna (President to Past-President), and John Duhault (VP to President).

Clarifying the CSEG Leadership and Management roles within the CSEG Bylaws; creating a CSEG Strategy Plan with the entire CSEG Board, staff and CSEG Foundation leaders with input from the CSEG members and creating a CSEG Governance policy to assist in the operations of the CSEG have all been part of migrating the CSEG Executive and Management roles to that of a CSEG Board of Directors, which includes the Managing Director.

If the CSEG is to survive and thrive then it should conduct itself as leading its own future especially during challenging times. Please welcome your CSEG Board of Directors and appreciate the strategic work each position holds for the Society which is comprised of outstanding CSEG members.



Incoming Board of Directors 2017

Back Row, L-R: Shannon Bjarnason (Asst. Dir. Communications), Elizabeth Atkinson (Dir. Communications), Geoff Fraser (Asst. Dir. Education Services), Neda Boroumand (Dir. Finance), Karen Chong (Dir. Member Services), Rebecca Daniels (Asst. Dir. Member Services), Graziella Kirtland Grech (Dir. Educational Services)

Front Row, L-R: Jim Racette (Managing Dir.), Marian Hanna (Past President.), John Duhault (President), Ron Newman (Vice President)

Not in photo: David Shorey (Asst. Dir. Finance)

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cynosure [sahy - nuh - shoo r]; noun

¹Something that strongly attracts attention by its brilliance, interest, etc.

²Something serving for guidance or direction.

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Should the Energy Sector Trust Canadians?

Written by Bill Whitelaw for the Waterloo Record in Ontario. Bill is president and CEO at JuneWarren-Nickle's Energy Group. Distributed by Troy Media.

A prevailing question is bouncing around the country: Should Canadians trust the energy sector?

It preoccupies a fair number of people, including academics and politicians. Many are intent on doing good by creating new ways of thinking through some of the country's complex energy challenges.

Creating trust is a cornerstone of this thinking. But trust must travel along a two-way street.

So why is no one asking the obvious corollary question: Should the energy sector trust Canadians?

The question is more than simply rhetorical. After all, trust doesn't travel well along the bumpy highway of hypocrisy. It seems increasingly obvious that most Canadians want to have their energy cake and burn it, too. Many Canadians just don't seem to want to do the intellectual heavy lifting when it comes to the tough conversations and choices that define energy production, transportation and consumption.

The complexity of our energy dynamic is daunting. In the complicated confluence of the fossil fuel sector's maturing and the rise of new alternatives, we have done a terrible job of sorting things out.

Energy suppliers exist because energy consumers exist. And yet people decry basic market-driven realities in which production and consumption move in lockstep.

Now, the average Canadian would be puzzled by the assertion they don't deserve the trust of the people and companies producing the energy that lubricates the cogs and gears of their lives.

After all, people pay for gasoline, airline tickets and home heating bills, and daily buy multitudes of products created from refined petroleum.

So, what more do energy companies want?

To be trusted the same way people trust other sectors and companies that supply other staples of their lives, such as education and health care.

That doesn't mean people should stop voicing concerns or pushing for improved environmental performance. It does mean they should be more knowledgeable about what's already being done and pushing from that perspective.

Perhaps then the voices will take on a different, more constructive, tenor.

But the reality is that the everyday Canadian is energy apathetic and the consequence is problematic.

Many people, through ignorance and complacency, have had their perspectives hijacked by the special interest and activist voices that oppose all things energy. Many ordinary citizens have become the unintentional puppets of small interest groups opposing energy development and the processes by which society makes energy policy and regulation.

These groups have co-opted the Canadian unconsciousness and put their voice to it. Unfortunately, it may not be what Canadians would say should they reflect on their role as energy consumers.

But it's why their trustworthiness is suspect.

They spend so little time in reflection that the energy sector can't really know what's on their customers' minds.

Surveys tell us the majority don't actively oppose energy development. But what surveys don't reveal is what Canadians actually know about energy's tough choices.

Canadians think so little about their role in the energy systems matrix that they may actually come to accept the views of the strident opposition as their own opinion on why the energy sector needs to shut down.

Trust is slippery and elusive. It's often contingent and contextual, and must be consistently earned in a relationship of give and take.

Do Canadians have a right to demand energy producers do better and more to earn their trust? Absolutely. And most energy sector folks would agree they haven't done the best job in earning that trust.

Conversely, energy producers and transporters have the right to ask their customers to think about their consumption needs and behaviours – and the sometimes-difficult decisions required to evolve our energy systems. In other words, to think their own thoughts and put voice to them.

But will Canadians step up? It would be nice to think they will and bring some balance to our energy dialogues. Perhaps then we can begin working on something that resembles mutual trust.

From Brainy Quotes:

If you are going through hell, keep going.
WINSTON CHURCHILL



INTRODUCTION TO JUNE FOCUS:

Western Canadian Mineral Exploration Geophysics

Special Coordinators: Jean M. Legault and Oliver Kuhn

Western Canada is well known for its oil and gas sector, but the minerals sector is also an important part of the resource extraction economy. For CSEG readers not familiar with the minerals sector, a closer look will reveal many parallels with the oil and gas world: dramatic up and down swings in the prices for mineral commodities such as gold, copper, uranium and potash, the use of geophysics to reduce exploration risk, the integration of different types of geospatial data, and so on. The four articles selected for this month's focus theme feature some of the techniques being used in Western Canada to help explore for and extract minerals.

We would like to note that while the minerals geophysical sector is dwarfed by the oil and gas equivalent in terms of dollars spent, the range of methods used is arguably broader. Many quite different airborne and ground survey methods are actively being used, and these articles just scratch the surface in terms of the type of work being done.

In "How Geoscientists are Making Potash Mines Safer" authors Craig Funk, Janelle Appleyard, Jennifer Braun, and Jodi Derkach describe the use of in-mine GPR technology to reduce the risk of cave ins. The topic covered is unique and interesting in several ways. We are familiar with geophysics aiding exploration, perhaps production, but in this case geophysics is used to improve safety. The emphasis on improved HSE practices has been a prominent and positive trend in both oil and gas and mining and here is an example of how companies truly are improving safety. The article also offers insights to how intangible human factors such as cultural resistance to change are often bigger challenges than the technical ones such as involved in conducting real time GPR surveys in an operating mine.

Mel Best and Isaac Fage ("Case study of mineral deposits in the Yukon using high resolution resistivity/induced polarization techniques") present the results of a survey test of a new multi-electrode high resolution resistivity and IP system. This innovative system application was introduced to the Yukon in 2013 for polymetallic gold deposit exploration. The HHRIP system had been in common use for environmental and engineering applications, such as mapping aggregates and groundwater leachate studies, but here it proved quite useful for mapping narrow but often very rich, near-surface (<100 m depth) vein systems that typify the Yukon mineral exploration environment. The HHRIP's survey speed and efficiency, and its minimal environmental footprint proved superior to larger conventional IP-resistivity systems that are typically used. The original study commissioned by the Yukon Geological Survey was over nine various and known mineral deposits, but in this article Mel and Isaac focus on their test survey over the Klaza breccia gold-silver deposit in the rugged Tanana terrane near Mt Nansen in west central Yukon.

Patterson Lake South is the newest uranium camp in Saskatchewan's prolific Athabasca Basin and the Triple R

deposit is the first and largest to be discovered in 2012 by Fission Uranium, who won the PDAC's Bill Denis award for Prospector of the Year in 2014. What distinguishes it from other uranium deposits, such as Dennison Mines' Phoenix deposit (also presented in this issue), is both the fact that it's situated on the western side of the Athabasca Basin, as well as being just outside the Basin, occurring in graphitic Precambrian rocks along the Patterson Lake South corridor that extends away from the Athabasca sandstone contact. In "Geophysics on Fission Uranium's Patterson Lake South Uranium Deposit", David Bingham, geophysical consultant for Fission Uranium, chronicles the Triple R blind discovery below thick glacial overburden using a combination of multi-parameter airborne and ground geophysics.

In a second uranium article, "Geophysics of the Phoenix uranium deposit, Saskatchewan", Sharpe, Petrie and Stephen focus on the differences between previously acquired 2D DCIP + MT data and a recent full 3D survey. Similar to the kind of debates that were stimulated by the advent of 3D seismic, the minerals geophysics community is full of active discussions around the advantages offered by new state of the art 3D DCIP + MT surveys over more traditional 2D survey configurations.

We would like to acknowledge the contribution of Rob Hearst who also helped to coordinate these focus articles.



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Polytechnique of University of Montreal, QC. He has worked in the airborne and ground geophysics service sectors since 1985. He is currently chief geophysicist at Geotech Ltd. (Aurora), a worldwide airborne geophysical service provider, where he is mainly interested in airborne geophysical methods as geological mapping tools in mineral exploration. He is co-chair of the SEG Mining Committee and member of the SEG, ASEG, SAGA, EAGE and KEGS.



Oliver Kuhn is currently President and CEO of Quantec Geoscience Ltd., a global geophysical service company specializing in ground DCIP and MT surveys. Prior to 2014 he worked in seismic processing, mainly in Calgary plus stints in Singapore, New Zealand

and Australia. He is a past president of the CSEG (2006), and former editor of the RECORDER.



How Geoscientists are Making Potash Mines Safer

Craig Funk, Janelle Appleyard, Jennifer Braun, Jodi Derkach

POTASH CORPORATION OF SASKATCHEWAN INC.,
SASKATOON, SASKATCHEWAN, CANADA

Within the vicinity of Saskatoon, Saskatchewan, potash is conventionally mined by three operating companies at five different mines. Continuous boring machines (borers) cut the potash out of the seams at about one kilometer depth.

The stratigraphy of the roof above the mined-out rooms (salt-beam) in the Saskatoon area mines consists of a series of salt beds separated by well-known and regionally distributed planar clay seams. When geological disturbances or anomalies are encountered during mining, conditions can become hazardous to personnel and equipment due to failure in the roof, which can cause significant volumes of rock to fall. These incidents are known as unplanned falls-of-ground. Mining crews are well-trained in the mining procedures and how to identify hazardous conditions, but occasionally subtle geological anomalies can be difficult to identify. Such scenarios are concerning because a combination of subtle geological anomalies can create conditions for falls-of-ground that occur with little to no warning.

There is no silver-bullet solution to prevent unplanned falls-of-ground. Typically, such events occur due to a combination of seemingly remote factors aligning – the classic “Swiss Cheese model”. In this paper, we describe the development of a standardized suite of mining practices at three Saskatoon area mine sites operated by Potash Corporation of Saskatchewan Inc. (PotashCorp). Geoscientists played a major role in the development of these standards because it was recognized how important it was that the crews had a working knowledge of the geology at their jobsites. Education of crews was vital in this effort and the ground control standards were used as a foundation for the updated training materials. To help the miners better understand the geology above them, in the mined-out rooms, geophysicists worked with engineers to develop a borer mounted ground penetrating radar (GPR) package. Its purpose is to provide real-time mapping of roof stratigraphy to help to determine if conditions, which might lead to instability, are present in the mine roof. This development is the first known successful trial of real-time, continuous upward looking GPR on potash boring machines and it offers the potential of increasing mining safety.

Introduction

Conventional underground potash mining in Saskatchewan occurs within a comparatively narrow, 500 km long corridor running from the Saskatoon area to the southern border with Manitoba (Figure 1). This corridor roughly parallels the shallow northern sub-crop edge of the

Prairie Evaporite salts which host potash deposits at depths of 925 to 1200m. Currently there are eight mines in Saskatchewan where potash is mined using conventional underground mining techniques, and there are three solution mines. Within about a 100 km radius of Saskatoon there are five such mines, of which three: Cory, Allan and Lanigan, are owned and operated by PotashCorp. These mines produce potash from the Upper Patience Lake Potash Member (known as the A-zone) of the Prairie Evaporite Formation, where continuous boring machines are used to cut the potash out of the flat-lying host rock.

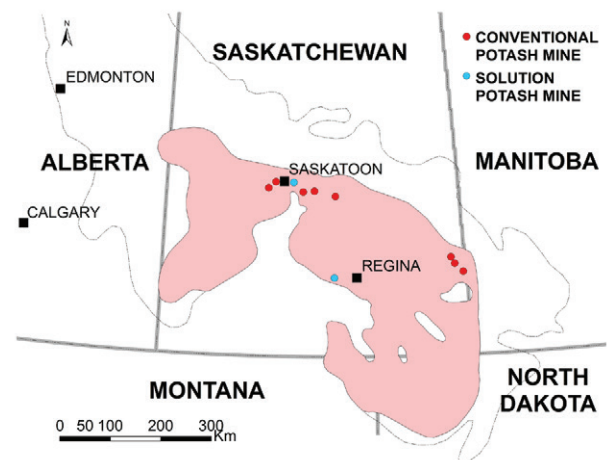


Figure 1. Map of western Canada showing the potash rich zones in the Prairie Evaporite Formation.

The Upper Patience Lake Member (in which the A-zone is mined) is mostly composed of potash and salt which makes for a relatively soft mine rock. Various configurations of continuous mining machines are used to mechanically cut and grind the potash rock to gravel-size, for transport to surface for refinement. Extraction ratios are generally kept below 45%, leaving enough pillars to protect mine rooms and overlying strata. In response to mining, localized room failure comes from steady creep rather than sudden explosive breakage. Numerous horizontal, laterally continuous, sub-parallel clay seams occur throughout the geological formation and compound the plastic behavior of the ore body. Over time, these clay seams will serve as planes of weakness within the flat-lying host rock and lead to falls-of-ground characterized by the delamination of thick sheets of roof rock. Traditional mining methods such as “Room-and-Pillar” cannot be

used since failure along these planes of weakness will occur quickly. Instead, a specialized type of mining called “Stress-Relief Mining” was developed to address this problem.

Stress-Relief Mining involves the use of short-term sacrificial mine rooms to draw the mining-induced high horizontal stresses away from nearby long-term entries. This significantly increases the time frame before the roof will deteriorate. The method was pioneered in Saskatchewan and has made potash mining in the province safer. In fact, in areas of normal geological conditions, the Stress-Relief Mining method has mostly eliminated the need for the installation of rock bolts and other ground support for the salt-beam (for further information refer to Jones and Prugger, 1982). Small localized geological anomalies that disrupt the normal bedded rock sequences are routinely encountered (Figure 2) in mining rooms. These anomalies often result in a thinner-than-normal beam in the salt-beam. In these circumstances, ground conditions can become hazardous and rock-bolting is often relied upon to help stabilize the salt-beam. Crews are well trained on how to recognize hazardous conditions; however, we came to realize that subtle geological changes, with potential for causing Serious Injuries or Fatalities (SIF), were not always recognized. What follows is a description of how we developed standardized mining practices and GPR technology to minimize these SIF potentials.

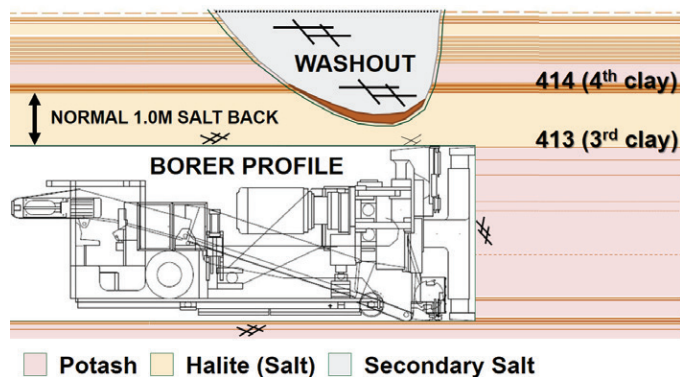


Figure 2. Illustration of a potential fall-of-ground hazard created by mining underneath a washout anomaly.

Development of Standardized Mining Practices

On the 24th of February, 2013, at the PotashCorp Cory mine, the night shift was beginning to mine a new entry when one of the miners noticed some unusual deformation developing in the roof over the working area. The borer operator was notified and immediately the decision was made that the crew should evacuate the area. As they were leaving the roof failed and a fall-of-ground of several hundred tonnes occurred into the working area. No one was injured but there was significant damage to the mining equipment.

The post-accident investigation revealed that the salt-beam was 60 cm or less in thickness in many places near the fall-of-ground, rather than the more common 100 cm. Normally, when the salt-beam in the roof is

that thin, there are tell-tale signs in the stratigraphy in the mined-out rooms of abnormal geology and rock-bolts are installed to maintain the roof integrity. However, in this case there were no indications that the geology was unusual so normal mining practices were being followed.

The Cory fall-of-ground in 2013 might have resulted in multiple fatalities; fortunately no one was injured. It was recognized that by following normal operating procedures, workers were not able to identify the SIF potential in the working area. The mining industry in Saskatchewan has had an average of one fatality a year for the past 40 years; PotashCorp has historically had a fatality every 2 to 4 years. Our goal is to be one of the safest resource companies in the world, so we asked ourselves “What do we need to do to have an SIF event frequency of zero?” There is no off-the-shelf silver-bullet solution, so we started developing an integrated approach focussing on better standardized mining procedures, more in-depth training, and development and application of GPR technology to help crews recognize when hazardous conditions with SIF potential are developing in the salt-beam. Geoscientists at PotashCorp played a key role in these pursuits because a common factor identified in the mining SIF potential was geology.

PotashCorp operates three conventional mines extracting potash from the A-zone: Cory, Allan and Lanigan (Figure 1). To understand the actual underground mining procedures used at the mines we started the process of reviewing the mining procedures by asking three questions:

1. What do the mine sites say they do?
2. What do they actually do?
3. What should they be doing?

As we investigated the first question (“*What do they say they do?*”), we found that each site described the geology using different terminology. In other words, there was no common lexicon used to describe the ground conditions. This is due to the history of each site, being originally independent of each other, operated by separate owners. These sites were acquired by PotashCorp in the late 1980s, but aspects of the culture remained unchanged to this day. It’s obvious to Geoscientists how beneficial a common geological language is, but it never occurred to us the importance of this from a safety perspective. By establishing a common geological lexicon across our mines sites, we could ensure that:

1. identical names are used for in-mine geological features and anomalies,
2. the underground workplace can be described in a common and consistent manner at any site.

To develop the geological lexicon, a technical team led by two geologists was formed. The team brought together mine geologists, engineers and a geophysicist. After consultation meetings and historical research, a lexicon was finalized which gives consistent definitions to eight different kinds of geological anomalies encountered in A-zone mining and specifies key identifiers (attributes) and hazards associated with each kind of anomaly. The lexicon was written such that a person

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with no geological training could understand the document. This is especially important because often our most important observers are mine personnel, who are working in the geology, but typically have no formal training in geology. If they are to identify the potential geological hazards in their workplace, they must be able understand the language used to help them identify the hazards. Historically, analysis of these geological features was motivated by the need to understand the underlying geological processes that caused the anomalies, and to understand their potential economic impact on mining (Mackintosh and McVittie, 1983). Our greatest pursuit is to ensure the safety of our workers. Therefore, the lexicon was influenced by safety in general and the impact of geology on safety rather than geological influences, such as the root geological causes for the anomalies.

To communicate the lexicon to the workforce, Geology Classification Guides were developed and printed on posters which were distributed at all the mine sites. Photos were included with the drawings to help illustrate the geological concepts in a manner understandable to underground mine workers. All underground mining teams were trained on how to use the guides. Copies of the guides were permanently placed at all lunch tables underground. The lunch tables do not have permanent fixed locations because they move with the mining, yet they function as a “common” area where each crew meets when their shift starts and where they take their breaks. Supplies needed for mining and safety gear are also kept in the area.

To understand the second question (“*What do they actually do?*”), the team set out to determine if we were practicing what was written in the mining procedures for each site. Underground tours were initiated with an emphasis on engaging in conversations with both mining operators and supervisors. In total, 17 tours were completed over 44 days. It should not be surprising that the conclusion of these tours showed that we were not doing what we said we do (in the written procedures). In other words, our procedures may have been followed at one point in time, but they did not stay current with our mining practices. Actual procedures aren’t static “things”, they change over time due not only to advances in technology or improvements in understanding, but also due to changes in risk tolerance and culture (i.e. baby boomer workforce transitioning to predominantly millennials). Written procedures must be living, peer-reviewed documents.

The third question (“*What should they be doing?*”) was answered by endeavoring to understand “what are the *right* things to do?” ... to make us one of the safest resource companies in the world. This led to our ‘Ground Conditions Hazard Assessment Standard’ for A-zone mining. This best-practices guidance document was a team effort, which included leadership from the President of Potash, and various levels of executive and mine management ranging from VP’s and General Managers to Operations Superintendents and Chief Mine Engineers. The team also included staff from our Technical Services group and Safety, Health, and Environment (SHE) group. The team was facilitated by a geologist and a SHE expert. Several “brainstorming sessions” were held over a period of three months to gather the input needed for the guidance document. The document was formally recognized

as a “Tier 2 Standard” which means that it is a standard in place for a specific mineral (potash in this case) and is approved by the President (of potash) and upper management. Being a standard implies that it must be followed, or amended if needed, as improvements are made, or as oversights are discovered. Support from the executives was critical to achieving success in this endeavor – it might not have been possible otherwise because culture change is never easy.

The Tier 2 Standard had a major impact on ground control strategies, such as installation of rock bolts. It caused us to shift our risk tolerance from being reactive in ground control strategy to proactive, by changing our perception of the severity and influence of geological anomalies towards SIF potential. Now we are installing bolts in ground which used to be considered “safe”. This also required changes to our operations, since the mine sites had less rock bolters than mining crews (i.e. three rock bolters for eight mining crews). Now every mining crew has a rock bolter available, so that the crews aren’t idle while they are waiting for the mobilization of a bolter. This gives the miners an “additional layer of defense” (Conklin, 2012) against falls-of-ground.

The Role of Ground Penetrating Radar

Historically, the mine operators assessed ground conditions by observing the geology they could see. They are very good at recognizing anomalous ground conditions that could become hazardous. It was believed that anomalous ground conditions in the salt-beam, above the mining room, would have stratigraphic indicators or markers in the visible geology in the mining rooms. Typical indicators of anomalous geology would be compressed clay seams, salt intrusions, or disturbed geology. At the location of the Cory fall-of-ground from February 2013, there were no obvious, telltale signs of a thin salt-beam. Even by adopting a policy of proactively installing rock-bolts, we may not have prevented this fall-of-ground because the geology was considered “normal” (i.e. rock-bolts aren’t installed in normal geology). This led us to pursue installation of Ground Penetrating Radar (GPR) devices on the mining machines.

GPR has been actively tested in potash mines for some 40 years. Initial investigations focussed on mapping the geological stratigraphy and assessing potential hazards for water influx. The first applications of the underground GPR method at potash mines began in 1976 by Dr. Don Gendzwill (University of Saskatchewan) and Dr. Peter Annan (Sensors & Software). These initial trial results were reported by Annan et al. (1988). Funk et al. (2016) summarize the past 15 years of GPR technology advancements in Saskatchewan potash mines.

In general, GPR is an excellent tool for imaging the stratigraphy in the overlying salt due to the very dry and homogeneous salt. With typical dielectric constants ranging from 5 to 6, the salt is practically opaque to GPR. In the A-zone potash mines, the 414 clay seam above the beam of salt has a typical thickness of 10 cm to 15 cm (Figure 2). Frequencies of 250MHz and higher do not penetrate through this clay seam, so such GPR devices are not able to image stratigraphy above the 414 clay seam. However, with respect to mine operations, the primary concern is the

thickness of the salt-beam itself, which is defined by the thickness of the salt member between the roof and the 414 clay seam. As such, high frequency GPR devices (typically 1000MHz) are well suited for imaging this clay seam. GPR data consists of time records of propagated EM pulses, with typical transit times being in the tens of nanoseconds. Conversion to depth is straight-forward, using the velocity of 0.12 m/ns to convert to depth.

We have found that the highest quality GPR data is obtained by using ground coupled antennas. This approach ensures maximum energy transfer into the ground and minimal energy leaking into the surrounding air. An example of a ground-coupled 1000 MHz Noggin GPR antenna mounted on a Kubota ATV (GPR-RTV) is shown in Figure 3. Such configurations allow for rapid collection of upward looking high quality GPR data that can be used to identify hazardous conditions in the overlying salt (Figure 4). Development of the GPR-RTV is discussed in Funk et al. 2016. GPR-RTV's make collection of GPR data relatively easy, but they do not solve the challenge of collecting GPR at active mining faces where the fall-of-ground hazards are more significant. Mining machine mounted GPR effectively addresses this need.

The main purpose for mounting GPR on an active mining machine is to give the operator real-time measurements of the salt-beam thickness above the working area. Placing a GPR system in such an environment is challenging but not insurmountable. Several attempts have been made, over the past two decades, to obtain a fully functional real-time GPR unit on an active mining machine. The prototypes were unsuccessful; eventually all of them were severely damaged and rendered inoperable by the normal mining operations. Furthermore, even when the units were working, the interference from the back-scattered EM waves bouncing off the metal on the mining machine completely obliterated any useful signals.



Figure 3. Kubota ATV used to collect upward-looking GPR in a typical potash mine entry.

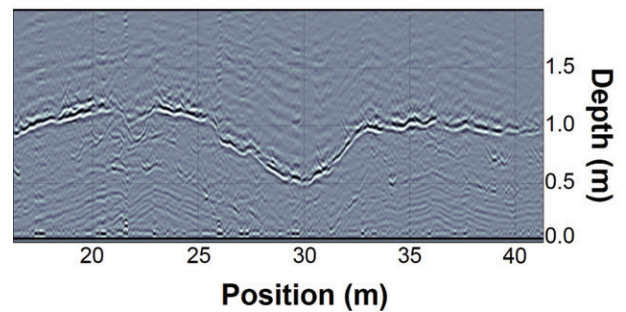


Figure 4. Typical example of upward-looking GPR data. The strong reflection is from the 414 clay horizon that varies in elevation above the entry from about 50 to 140cm. A few smaller features are observed which are associated with localized variations or heterogeneities in the salt.

After the February 2013 fall-of-ground at the Cory mine, we decided to pursue development of a new prototype system for collecting GPR from an operating mining machine. The mechanical portion of the prototype was somewhat like the landing-gear on an airplane in that it deploys when needed, but is otherwise tucked safely away (Figure 5). The GPR sensor only needs to be deployed while mining (grinding out ore from the rock-face) and tucked away to prevent damage to the sensor during maneuvering operations. The degradation in signal quality from the back-scattered EM waves was overcome by incorporating shielding into the sensor housing. A Sensors & Software Noggin 1000MHz GPR sensor was mounted inside a rectangular steel container with an open top. The top of the container was covered with a thick high density wearproof polyethylene cover. The interior of the container was lined with radio frequency absorbing material. This material absorbs any EM waves that are not traveling into or out of the salt-beam. This absorbing material is perhaps one of the most important components of the design as it allows for collection of exceptionally clean (high signal to noise) GPR data. Previous systems we experimented with were never able to collect such exceptional GPR data while mining. Real-time GPR images of the strata above the borer in the freshly cut room are displayed in the operator cabin. Within six weeks of the fall-of-ground, the prototype was built, installed and collecting excellent GPR data (refer to Funk, Brewster, and Brehm, 2016 for further discussion).



Figure 5. Picture of a mining machine (looking from front to back) at the Cory mine with the GPR sensor in the deployed position.

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The overall goal for this project is to provide the miner operator with real-time salt beam thickness, which can warn of actively developing ground hazards in the salt-beam. To adequately meet the goal, a certain level of sophistication had to be built into the GPR software. In general, the quality of the GPR data has been exceptional, and with some training, borer operators become proficient at recognizing developing hazards. The high-quality data allowed for the incorporation of an automated picking algorithm into the GPR software. The algorithm identifies the main clay seam of interest in the GPR data and actively follows the seam as new data come in. From this information, the software can display the salt-beam thickness in the salt-beam above the borer. If the salt-beam becomes too thin (per design limits) an alarm condition is raised and the operator is notified. At that instance, further assessment is carried out and the operator will execute recommended ground control procedures.

In parallel with installations of GPR systems on the borers, crews were trained on how to use the technology. A typical training session for a crew would take about half a day. Anecdotally, the borer mounted GPR is not unlike a fish finder on a boat. From our experience, we found that the crews warm-up to the technology quickly. For example, on April 21, 2015, an operator at the PotashCorp Cory Mine successfully used the GPR to recognize the development of a thinning salt-beam in an advancing mining face (Figure 6). Per ground control procedures, such a situation required either abandonment or installation of pattern rock-bolting. The operator discussed the situation with his supervisor and the decision was made to abandon the mining face and barricade it off. Such success stories give the technology credibility amongst the crews, leading to further acceptance. This is an excellent example of how the GPR technology, in combination with robust procedures, is used to reduce SIF potential at the mining face.

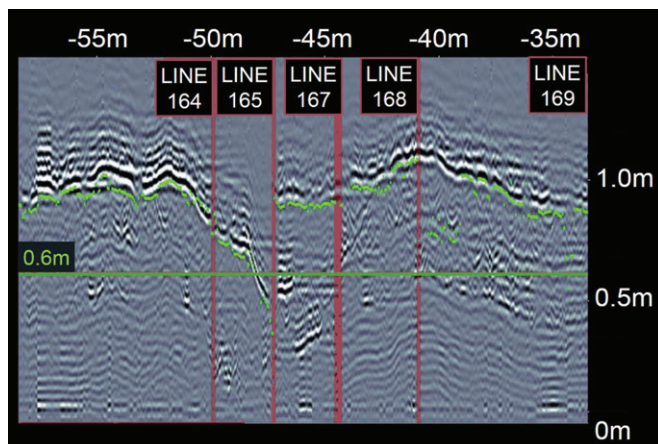


Figure 6. Example of a salt-beam fall-of-ground hazard identified by a borer operator. The borer advances from left to right. The thinning salt-beam started just before Line 164. When the salt-beam became too thin, the borer stopped at Line 165. The drift was abandoned and the remainder of the data to the right of Line 165 was collected in a new mining drift.

Conclusion

The development of the standardized mining practices and borer mounted GPR has been a major success; the implementation required the collaboration and commitment of many individuals from several disciplines. The buy-in from the operating crews is a testimonial to the solution's efficacy and practicality.

This work started by recognizing that a change in culture was needed across our company if we were to make our mining operations safer. It's still ongoing because culture doesn't change quickly. Our moment of epiphany was when we came to realize that accidents can't be engineered out of our processes: accidents will occur. So, we added levels of control that give us better defenses – they give us a soft landing when an unusual condition which could lead to an accident happens. GPR systems mounted on our borers and proactive rock-bolting are the additional levels of control in our processes. GPR also provides the operators with information they need to make informed decisions of developing hazards in real-time, instead of having to rely on external, specialized analysis (typically from geophysicists, who may not be available when the borer operator encounters a developing geological hazard).

Acknowledgements

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About the Authors



Craig Funk, P.Eng, P.Geo is the Director of Earth Sciences at PotashCorp. Craig studied at the University of Saskatchewan where he earned a B.Sc. in Engineering Geophysics and an M.Sc. in Geophysics. Craig has worked in hard- and soft-rock mining, geotechnical consulting, and

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Janelle Appleyard, P. Eng., is the Director of Mine Engineering at PotashCorp. Janelle studied at the University of Saskatchewan where she earned a B.Sc. in Geological Engineering in 2002. Her 15-year career in potash has been spent exclusively with PotashCorp. During that time,

Janelle has been fortunate to work in a variety of technical, operational and expansion related areas in the corporation including Technical Services, Rocanville and Cory Mine, and Rocanville Expansion with the Scissors Creek shaft sinking.

Janelle has been leading the Mine Engineering group of Technical Services since 2015. The team is actively involved in supporting potash operations by providing high quality technical support and mining risk mitigation.



Jennifer Braun, P. Geo., is a Geologist in the Technical Services Department at PotashCorp. She studied Geology at the University of Regina, where she earned her B.Sc. in Geology in 2008. Jennifer started working in the potash mining industry immediately after graduating, and has been fortunate to have spent many hours underground since then.

Jennifer started working for PotashCorp in 2013. While there, she has played a significant role in developing and implementing standardized ground control practices across the PotashCorp potash mine sites.



Jodi Derkach, P. Geo is a Senior Geologist in the Earth Sciences group at PotashCorp. Jodi studied at the University of Saskatchewan where she earned a B.Sc. In Geology in 2007. She also earned a Certificate in Geographic Information Systems for Resource Management from

Saskatchewan Polytechnic in 2010. Her 10-year career was spent in the diamond exploration and potash mining industries. Jodi has been with the Earth Sciences team at PotashCorp since 2010.

EPP REPORT

DODGEBALL TOURNAMENT

The CSEG Emerging Professional Program and SeisWare participated in and sponsored the University of Calgary's Dodgeball Tournament hosted by the Palliser Club on March 30th. Any doubt of the geophysical community's athleticism was put to rest as both CSEG teams reached the final in an epic battle. The event wrapped up at The Den for networking and celebration between CSEG members, the Rundle Club and host Palliser Club.



The University of Calgary Palliser Club were great hosts and a fun time was had by all. Special thanks to Dana Mears for her leadership. Thanks to everyone who participated, Austin Newman, Stephen Harvey and Stephen Kotkas for coordinating things from the CSEG side of the event and SeisWare for sponsoring the event. We look forward to the event next year! If you are interested in learning more about the CSEG EPP please contact epp@cseg.ca.

The EPP Committee



Geophysics on Fission Uranium's Patterson Lake South Uranium Deposit

David Bingham, P. Geo.
BINGHAM GEOSCIENCE

The Triple R deposit on Fission Uranium Corporation's Patterson Lake South (PLS) property is located in Canada's Athabasca Basin, home to the world's richest uranium mines. The deposit is accessible by all-weather Highway 955 which continues north to the UEX-AREVA Shea Creek deposit and former AREVA Cluff Lake uranium mine (Figure 1). It is the only major, high-grade deposit in the region that is potentially open-pittable and is the largest mineralized trend in the region – currently standing at over 3 km in length. Growth is driven by a highly skilled, award-winning technical team and successful entrepreneurial management. Fission has 100% ownership of the PLS Property, which comprises 17 claims totaling 31,039 ha.

The PLS discovery has been previously documented and some content is borrowed from these presentations: 2012 Saskatoon Geological Open House, 2013 Saskatoon Geological Open House and the Fission Web Site <http://www.fissionuranium.com>.

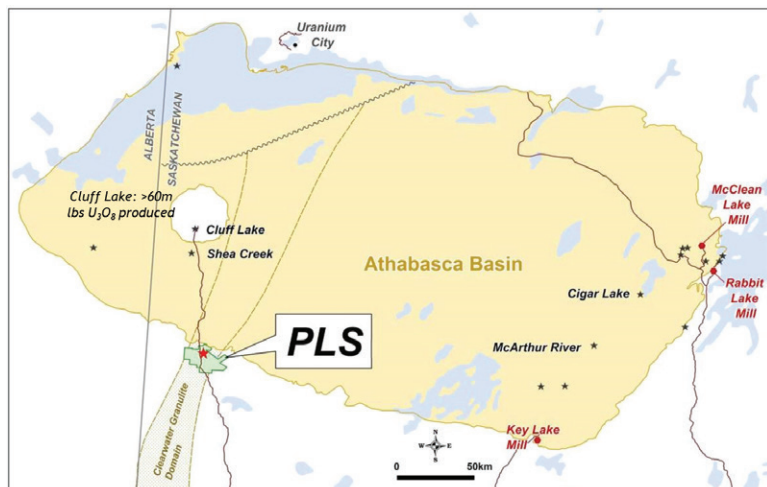


Figure 1. Patterson Lake South (PLS) and Canada's Athabasca Basin

Athabasca Deposit Geophysical Character

The Athabasca Basin major uranium deposits and mines (Figure 2) are generally proximal to graphitic conductors (reducing environment) and accompanied by an alteration 'halo' which is usually a resistive low, but can also be silicified (resistivity high). The sandstone environment is normally highly resistive which makes things ideal for EM detection of weaker graphitic conductors at depth.

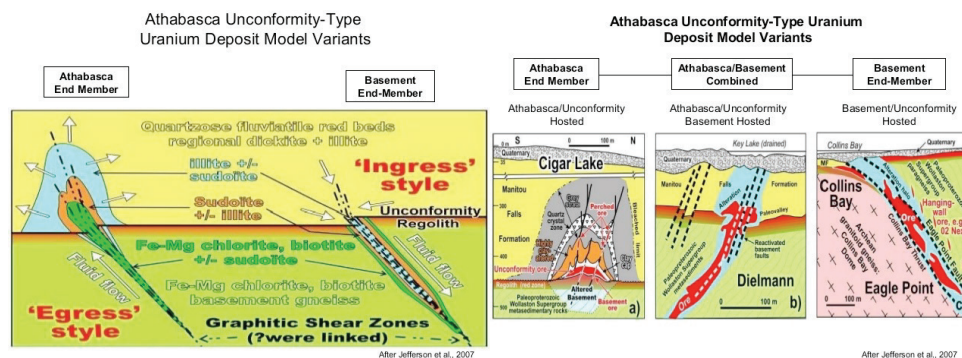


Figure 2. Unconformity Deposit Models and Examples

The east side of the Athabasca Basin hosts virtually all the major high grade deposits with the exception of Cluff Lake and the deep Shea Creek deposits and now the new deposits in the Patterson Lake Corridor. Cluff Lake is an anomalous occurrence and is located on the Carswell Dome, not within the Athabasca Basin. Exploring outside of the basin margins is somewhat unconventional as there is no present unconformity surface, but there may have been in geological history. The Millennium and Roughrider deposits showed the basement is not to be ignored.

Events Leading to Discovery

The initial phase of work leading to the discovery consisted of research. A review of historical assessment reports (late 1970s) showed strong radon anomalies coincident with EM conductors 3 to 4 km west of the deposit. A subsequent airborne radiometric and magnetic survey was instrumental in focussing ground prospecting for radioactive boulders. Follow-up prospecting and trenching with Quaternary geological analysis developed a conceptual section for potential mineralization (Figure 5). The conceptual section was invaluable in planning further work and selecting targets. Airborne and ground geophysical surveys identified a number of prospective target areas, and drill testing resulted in the massive pitchblende discovery in November 2012 (Figures 3 and 4).

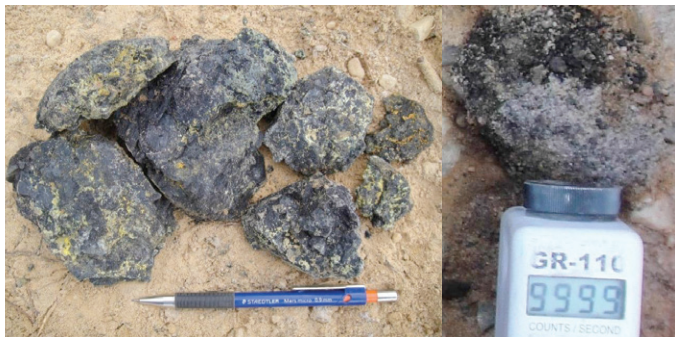


Figure 3. Massive Pitchblende Boulders



Figure 4. Discovery Hole PLS12-22 Massive Pitchblende

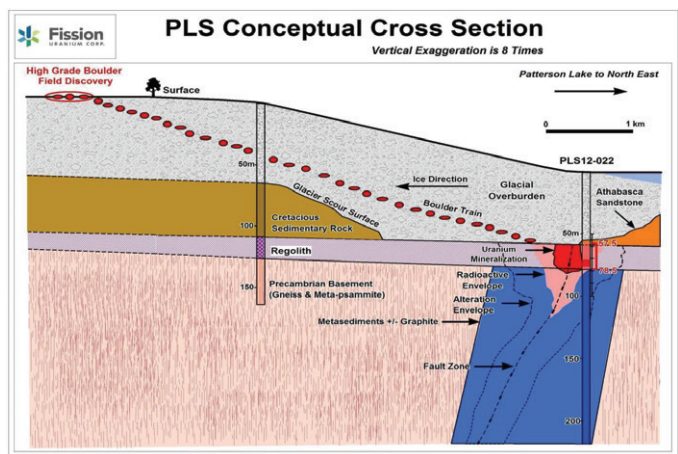


Figure 5. Quaternary Snapshot; Window of Opportunity

2009-2012 Airborne Geophysics

Airborne geophysics consisted of an initial property wide radiometric and magnetic survey. The 2009 airborne radiometric survey was instrumental in locating the boulder field. Some innovative proprietary focussed crystal arrays were used on a small fixed wing aircraft. A low level tight drape flight pattern at 50 m line spacings was used for extremely detailed coverage. The survey was carried out by Special Projects Inc., of Calgary, AB.

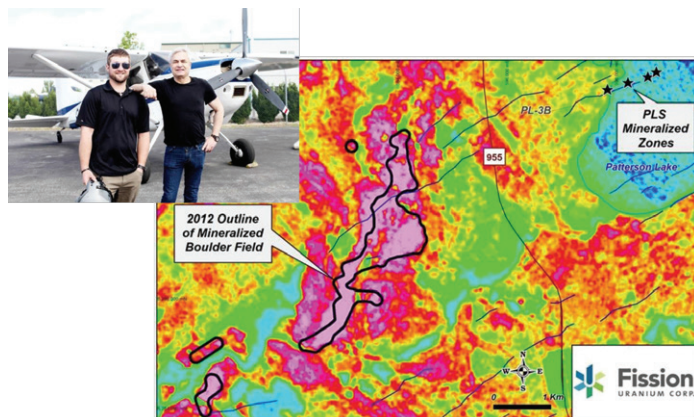


Figure 6. 2009: Airborne Radiometric Survey

Initial surveys were MaxMin Horizontal Loop. Some of the MaxMin profiles encountered a 'conductive overburden' response masking bedrock features, so a property-wide VTEM™ (Versatile Time Domain Electromagnetic) survey was conducted in 2012 and successfully outlined numerous conductors throughout the property. The calculated conductivity was used as an initial indicator in defining priority drill targets. The conductivity is based on the VTEM decay of the Z (vertical) component. The Z component is used for this calculation as it is the stronger and cleaner response. The conductivity peaks do not appear at the location of sub-vertical conductors but are on the shoulder of the Z component response. Of considerable interest was the conductive 'bright spot' in an up-ice direction from the radioactive boulder train along a complex PLS main conductor trend.

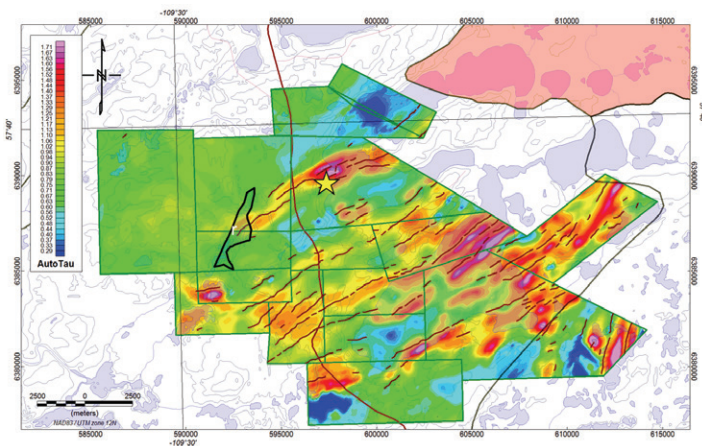


Figure 7. Feb 2012 – VTEM Conductivity

2011 – 2012 Ground Geophysics

The initial interpretation of the airborne VTEM encountered complex multiple sub-vertical conductors which were poorly resolved with the in-loop geometry of the VTEM EM system. There was also some difficulty correctly spotting drill targets over the complex areas. Further ground geophysics prior to discovery and during delineation consisted of DC (Direct Current) Resistivity and EM surveys.

Continued from Page 19

DC Resistivity

In the Athabasca, mineralization is typically accompanied by a conductor and an alteration halo observed as a resistivity low in the lower sandstone. In the absence of the sandstone layer, the alteration takes on a different character consisting of a widening and /or increases in intensity of the basement resistivity.

In the Athabasca area, the very high input resistance of the sandstone section results in poor currents and poor to marginal chargeability measurements. Personal experience of limited studies in other areas has shown no correlation of chargeability and mineralization. A modified pole-dipole resistivity array used resulted in better resolution and improved data quality. For an enhanced array (Figure 8), the current electrodes are moved along the profile at $\frac{1}{2}$ of the "a-spacing" used to double the data density at almost no extra cost. This results in an excellent spatial sampling of data along the line. The high density data of the enhanced array both increases the resolution and improves data quality. The X2IPI toolbox is efficient and smartly removes current and potential electrode noise.

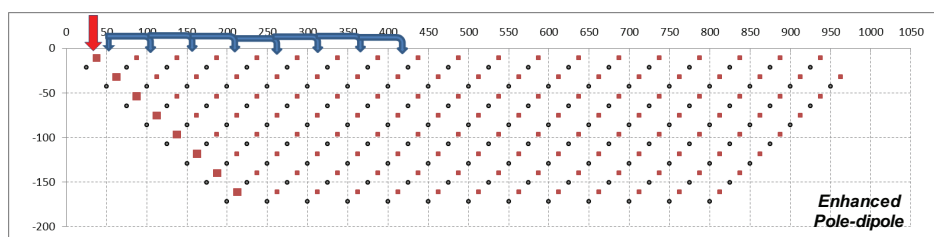


Figure 8. Enhanced or Double – Density PLDP Array

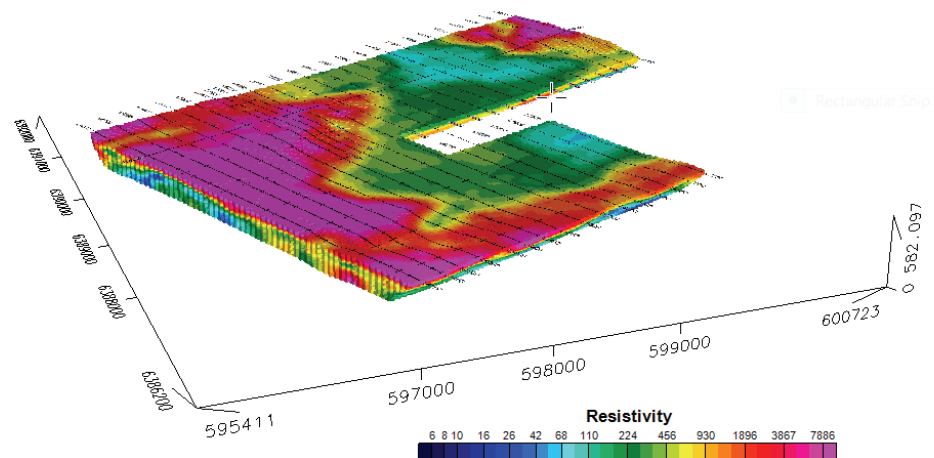


Figure 9. PLS 3D Inverted Resistivity

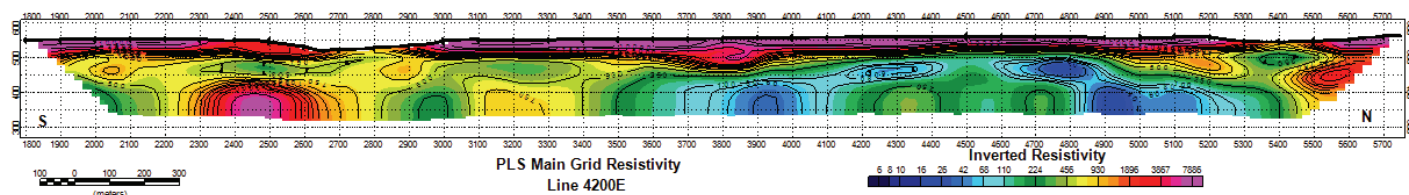


Figure 10. Resistivity Section

Inversion has become a necessity for IP (induced polarization) / resistivity arrays. It compensates for and removes geometrical effects such as "pant-leg" type responses and enables a more direct geological correlation of the resistivity data and the geology by distinguishing the source of any anomalies (i.e. deep or shallow). Resistivity / IP arrays are as sensitive to offline sources as they are to sources at an equivalent depth. An effective and economical way to overcome this drawback is to collect data in 2D, but invert in 3D.

The inverted resistivity (Figures 9 and 10) has a very large dynamic range from 1 to 30,000 ohm-meters. A logarithmically spaced color bar was used from 5 to 10,000 ohm-m. A deeper plan level was used to display the basement resistivity to avoid the till effects. (Figure 11). The basement resistivity showed a relatively wide conductive trend with numerous resistivity low 'bright spots'.

Analysis of the resistivity sections shows horizontal layers in the till which correspond to the Cretaceous conductive sediments. By taking a bench above the basement, and masking the high resistivity, the Cretaceous conductive sediments can be mapped with the resistivity (Figure 12). However, there is some contamination from the lake (fluids?). The conductive till mapped by the resistivity appears intermittent, but seemed to become much more apparent when another surveyed area was added in late 2012.

Ground EM Surveys

Initial MaxMin encountered some difficulty seeing through conductive Cretaceous sediments, and it was difficult to accurately locate complex conductors with the in-loop geometry of the VTEM survey. Instead, a Small Moving Loop EM design was used with a 20 m

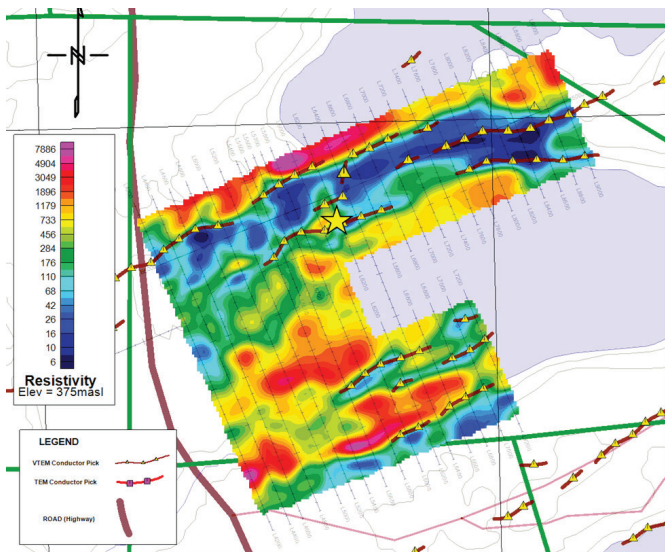


Figure 11. Basement Resistivity Plan with VTEM Conductor Picks

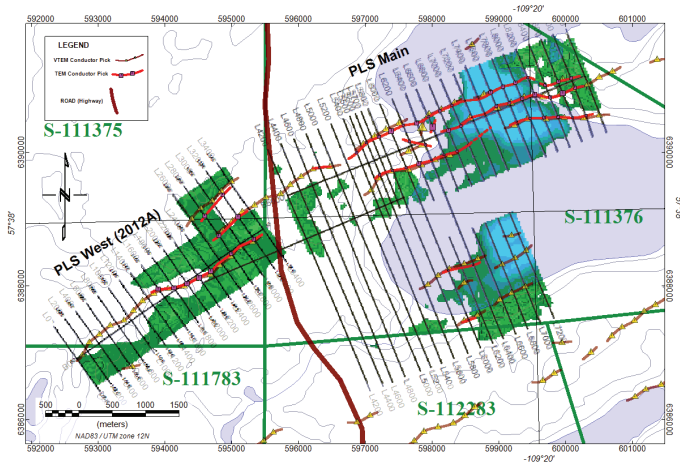


Figure 12. Resistivity Mapping of Cretaceous Till

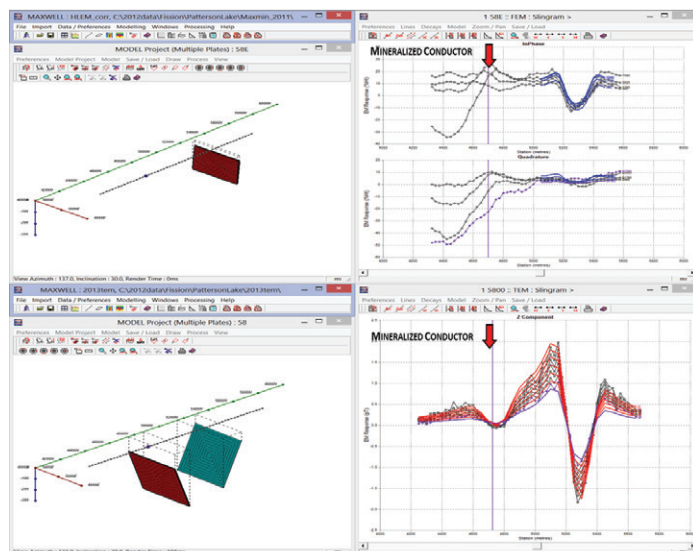


Figure 13. MaxMin versus Small Moving Loop Comparison

square multiple turn loop. A Super-conducting Quantum Interference Device (SQUID) sensor was used with a Slingram separation of 150 m at a frequency of 10 Hz. The low frequency enabled easy penetration through the conductive Cretaceous till. The increased sensitivity allowed for smaller TX (transmitter) loops (small loops = small crew = lower cost). Figure 13 shows a comparison of the MaxMin and TEM (Transient Electromagnetic) Small Moving Loop responses. Note the mineralized conductor is masked in the MaxMin response, but clearly visible in the small moving loop.

All the ground EM profiles were interpreted with Maxwell (www.electromag.com.au).

For moving loop surveys focussed at the proper depth of basement conductors, the responses are clear with a good signal to noise ratio. Model studies have suggested that characteristic peaks (or troughs) of complex conductors in close proximity may be displaced from the actual conductor location. Some further modeling shows the peak displacements are also affected by the conductor dips, conductivity, transmitter-receiver spacing and the direction of the survey. These effects are reduced for smaller transmitter loops. The overall shape and character of the conductor Z component response appears independent of the direction of the survey, but the peak displacements are not. This suggests it is necessary to generate models for each profile to determine the actual conductor locations. The procedure for interpreting EM data is to create relatively simple models with Maxwell to determine dips, positions and relative conductivity of complex conductors. This helps to compensate for any geometric effects of complex conductor systems. Figure 14 shows the location of interpreted plate conductors. The ground conductor interpretation is indicated by the red polylines, while the VTEM picks are brown with a yellow filled triangular symbol. Note there are a number of areas where the ground interpreted conductor location is offset from the VTEM conductor pick. There has been a very high success of conductor intersection with drilling based on the Maxwell interpretation of the ground EM.

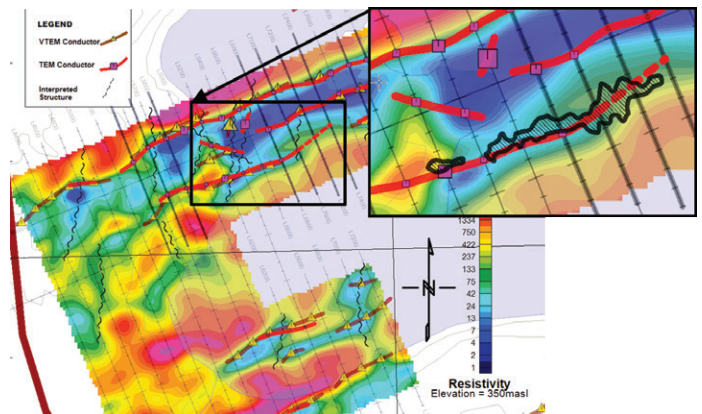


Figure 14. EM Interpretation with Basement Resistivity and Deposit Outline

Continued on Page 22

Continued from Page 21

The deposit shows excellent correlation with both an interpreted conductor and a resistivity low segment. Also significant is the evidence of cross structure seen in the resistivity at the west side of the displayed deposit outline. This also happens to be at the location of the discovery hole.

Miscellaneous Geology and Surveys

Among a number of follow up surveys, a Radon-in-Water survey (Figure 15) detected anomalies associated with the mineralized deposit. A longitudinal section (Figure 16) illustrates the shallow nature of the deposit as of September 2016.

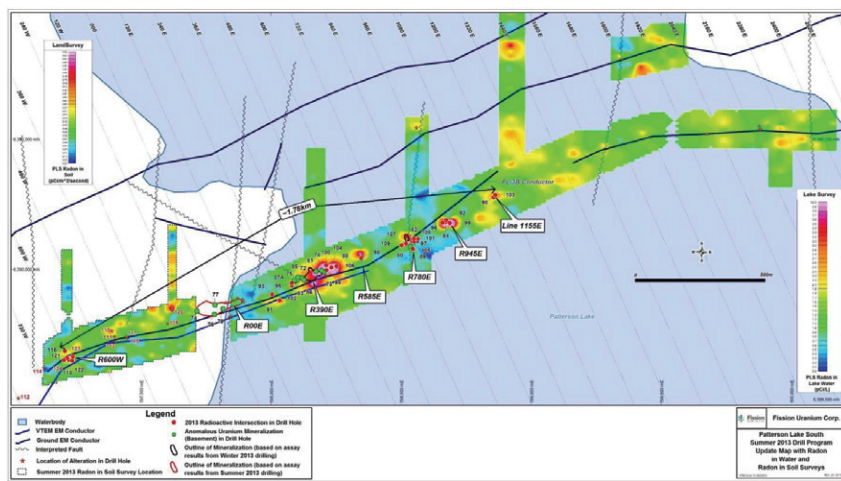


Figure 15. Radon Survey: Several Anomalies

Fission Website (Sep 2016)



Figure 16. Longitudinal Section – September 2016

Following in Figure 17 are some images of some outstanding holes. Ross McElroy, President, COO, and Chief Geologist for Fission, commented: "Hole PLS14-187 has returned total composited off-scale width results 46% more than hole PLS14-129, which itself ranks with the top drill holes in the Basin. Not only does the new hole set a new record at PLS but its location means the winter program has now succeeded in merging four high-grade zones (R390E, R585E, R780E and R945E) into one much larger one (R780E)."



Figure 17. Core Pictures from Outstanding Holes

Conclusions

The PLS discovery is truly a combined team success effort using skills from management, research, geology and an array of geophysical techniques along with a lot of work by contractors and consultants. Some "outside the box" thinking and innovative practices using the scientific method have contributed to the successful detection of this new uranium deposit.

The deposit shows excellent correlation with a VTEM conductive 'bright spot', an interpreted conductor and a resistivity low segment. Also significant is the evidence of cross structure seen in the resistivity at the west side of the displayed deposit outline.

The continued success of the resource delineation and expansion is attributed to the dedicated Fission staff for all the required office and field tasks required to bring the project forward. From Discovery to Resource Estimate, the Triple R Deposit was achieved in just two years of drilling. The Preliminary Economic Assessment (PEA) filed on Sept. 14, 2015 has an indicated Mineral Resources estimate of 81,111,000 lbs U_3O_8 (2,011,000 tonnes @ 1.83% U_3O_8) and an inferred Mineral Resources estimate of 27,157,000 lbs U_3O_8 (785,000 tonnes @ 1.57% U_3O_8). The indicated and inferred mineral resources are stated using a cut-off grade of 0.2% U_3O_8 for open pit and 0.25% U_3O_8 for underground.

Acknowledgements

Thanks to the management and directors of Fission Uranium Inc., as well as to all members of the technical team, consultants and staff contributing to this project.





VALUE OF INTEGRATED GEOPHYSICS (VIG) SHORT LIST UNDERWAY

The VIG Committee is in the process of putting together an online listing, which we're calling the VIG Short List, aimed at helping CSEG members teach others about the value of integrating geophysics into their corporate business plans. By "others", we're referring to engineers, geologists, upper management, investors, and other stakeholders. Papers will address such topics as:

- ▶ exploration
- ▶ reserves estimation
- ▶ well placement
- ▶ steam injection
- ▶ fracking programs
- ▶ groundwater delineation
- ▶ waste disposal
- ▶ geotechnical challenges
- ▶ identification of karst zones
- ▶ estimation of cap rock integrity
- ▶ measurement of induced seismicity
- ▶ play-specific case studies, etc.

The Short List will be a simple listing of technical papers in bibliographical format. Due to copyright laws, it cannot be a compilation of actual papers, but will point you in the right direction with links. Papers published by the CSEG will be easily accessible to members. The VIG Short List will neither endorse nor warrant any particular method described in the papers. It will be a perpetual work-in-progress and kept relatively small, for ease of use.

So, if you have a favourite paper that you would like to share, please send the title and reference information to the VIG Committee for review. Please direct your emails to the Chair of VIG, Paul Hausmanis, at Paul.Hausmanis@cenovus.com. Tell us why you think the paper would make a good candidate for inclusion on the Short List.

We think the VIG Short List will be a valuable resource in helping open channels of thought between geophysicists and other professionals.

The VIG Committee



29th Annual CSPG/CSEG/CAPL 10km/5km Road Race and Fun Run

Wednesday, September 20, 2017

Registration OPEN!

Registration closes: Tuesday September 19th at 12:00noon

To register please go to www.cspg.org – Events – Road Race & Fun Run

Member rate: \$40+gst | Non-member rate: \$50+gst | Student & In-Transition rate: \$25+gst



ORION 3D Deep Resistivity Imaging at the Phoenix Uranium Deposit

Roger Sharpe¹, Larry Petrie², Jimmy Stephen¹

¹QUANTEC GEOSCIENCE LTD., TORONTO

²DENISON MINES CORPORATION, SASKATOON

An ORION 3D DC/IP survey was conducted over the Denison Mines Phoenix Uranium Deposit at the Wheeler River Project in Northern Saskatchewan. The survey results provided 3D models that successfully delineated the known deposit at a depth of 400 m and provided an enhanced understanding of the three-dimensional geometry of the area NE of the deposit. In addition, significant differences in the characteristics of the rock units below and above the unconformity were accurately imaged.

INTRODUCTION AND HISTORY

The Wheeler River Property, comprising the Phoenix and Gryphon uranium deposits, is located in the southeastern Athabasca Basin, approximately 600 km north of Saskatoon, in northern Saskatchewan (Figure 1).

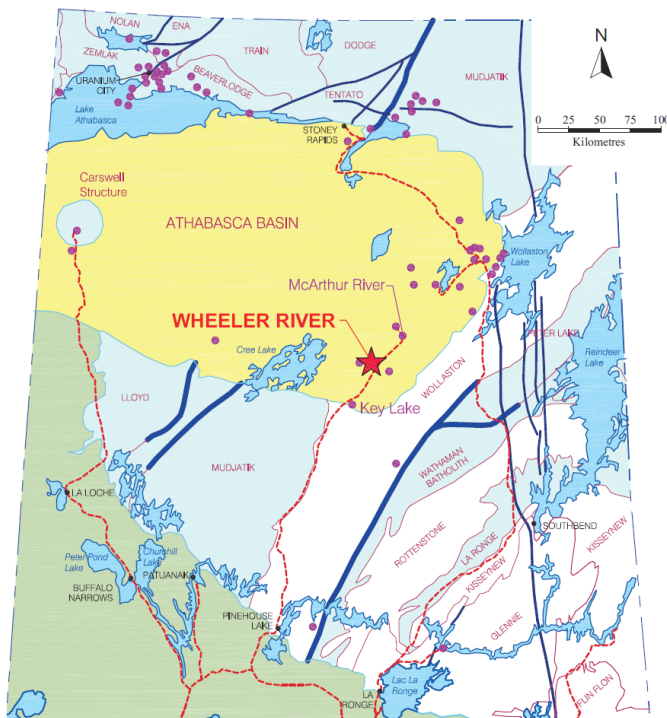


Figure 1. Location of the Phoenix deposit (after Roscoe 2014).

Table 1. Historic progression of work in the deposit area (after Roscoe, 2015).

1978-present	The area was previously explored by AGIP and SMDC (Cameco). Since 1978, several airborne and ground geophysical surveys have defined 152 km of conductor strike length in fourteen conductive zones.
1986-1988	AGIP, SMDC, and Cameco drilled a total of 192 drill holes encountering sub-economic uranium mineralization in the M Zone (1986), O Zone (1986), and K Zone (1988). Rare earth element mineralization was also discovered in the MAW Zone (1982).
2004	Denison assumed operatorship in 2004 and initially focussed on the footwall side of the quartzite ridge (west side of the Property) intersecting sub-economic uranium mineralization.
2008	In 2008, three resistivity targets were drilled leading to the discovery of the Phoenix deposit.
2008-2012	During the period 2008 to 2012, drilling predominantly focussed on defining the Phoenix deposits.
2012-present	Subsequent drilling has discovered the Gryphon deposit.

PHOENIX AND ORION 3D

The Wheeler River Property lies in the southeastern part of the Athabasca Basin where undeformed, late Paleoproterozoic to Mesoproterozoic sandstones, conglomerates, and mudstones of the Athabasca Group unconformably overlie early Paleoproterozoic and Archean crystalline basement rocks. The Phoenix deposit was discovered in 2008 and contains a significant uranium mineral resource.

THE PHOENIX DEPOSIT

The local geology of the Property is consistent with the regional geology of the Athabasca Basin. The Phoenix deposit occurs at the unconformity between the Athabasca Basin and basement rocks, approximately 400 m below surface (Figure 2). The sandstones are altered 200 m above the unconformity. Alteration is focussed along structures propagating upward from the shear and does not exceed 100 m width across strike.

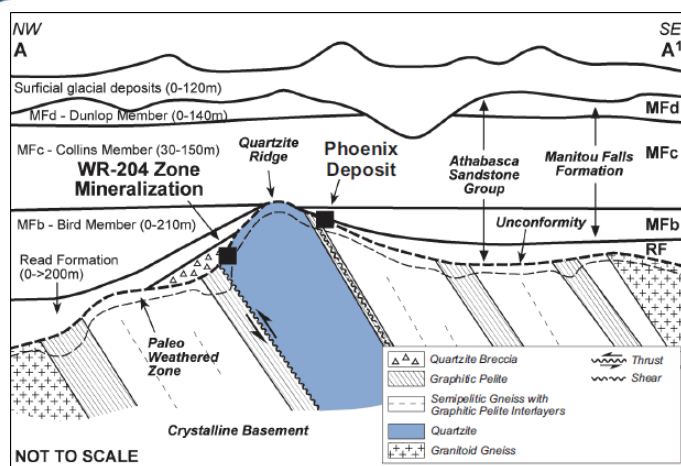


Figure 2. Schematic cross-section through the Phoenix deposit (after Roscoe 2014).

Figure 3 shows photos comparing the sandstones above the unconformity with the character of the deposit.



Figure 3. Photos of core of overlying sandstone (upper) and Phoenix deposit (lower between arrows) in the unconformity domain (after Reipas, 2016).

THE ORION 3D SURVEY

The ORION 3D method is an evolution into 3D acquisition based on the successful characteristics of the TITAN 24 system. This distributed multi-parameter data acquisition system penetrates deeper than conventional geophysics using a combination of DC Resistivity, IP, and MT. Typical depths of exploration are 700 – 1,500 m. The surveys are effective for exploration at long offsets, and in noisy or mine site environments due to a combination of performance features such as 100% duty cycle transmits, high data density from combined Pole-Dipole and Dipole-Pole, monitoring of the current using an acquisition channel, time-series data acquisition and digital signal processing resulting in approximately 2000 samples per half-cycle (4 seconds), 24-bit sigma-delta filtering, a high input impedance (80 Mohm) and a sophisticated calibration model (for AMT).

ORION 3D is an omnidirectional DCIP and MT system that collects resistivity and IP data simultaneously across an array of receiver dipoles. The ORION 3D paradigm prefers an equal distribution of in-line and cross-line dipoles. This survey design allows data to be collected without geometry (or strike) bias and is the fundamental innovation of the ORION 3D method. Conceptually, the 3D inversion method progressed as follows: First, 2D survey lines were provided to the 3D inversion engine. It was quickly realized that 3D inversion of these data provided little additional information versus 2D inversion. The reason is that there is little cross-line information content. Next, 2.5D surveys were conceived where transmits might be offset from the receiver array, or 3 or 5 parallel receiver arrays might be deployed while the transmits occur on the center line. This provides crossline information and enhances understanding of the deep part of the model, but shallow information may be compromised because the small n-spacings are null-coupled. This is particularly true if the transmits are never run on the receiver lines (i.e. the transmits are only run between the receiver lines). One method to overcome the cross-line null coupling of small n-spacings and preserve the shallow information is to run cross-line dipoles. These may be run on a few tie lines, or, in an ultimate sense, be deployed in equal numbers in both in-line and cross-line directions. ORION 3D was conceived in this ultimate sense. Figure 4 shows one of the six-channel autonomous loggers that are distributed during an ORION 3D survey. The six channels are configured with dipoles, three in each of the two orthogonal directions.

Data at Phoenix were collected using a layout (Figure 5) consisting of 294 @ 100 m sized receiver dipoles (Figure 4) and 297 current injections, resulting in over 140,000 data points to investigate a 2.1 km by 2.1 km area. Data were processed with Quantec's proprietary software, and inverted using UBC 3D (Li and Oldenburg, 2000), Loke (Loke 2001) and ERTLab (Fischanger and LaBrecque, 2006) inversion codes. The resulting DC resistivity models provided information well below the unconformity at 400 m depth.

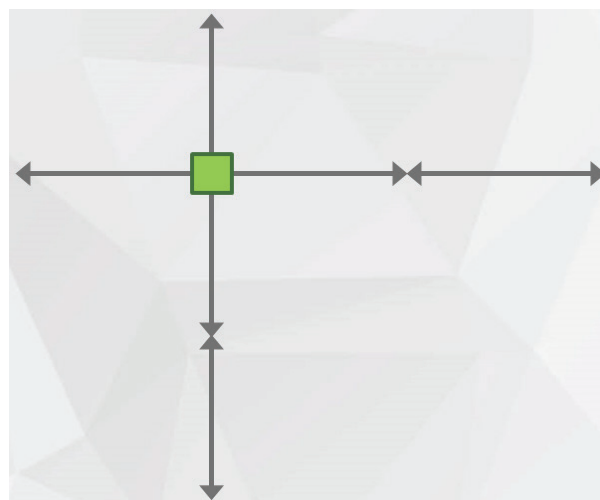


Figure 4. ORION 3D six-channel autonomous logger in green showing an ideal 3D deployment of three in-line and three cross-line dipoles.

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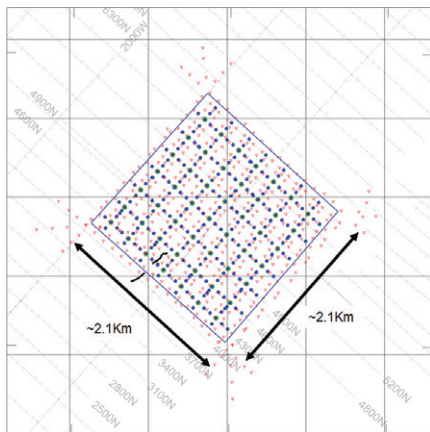


Figure 5. ORION 3D survey plan at Phoenix (blue symbols show receiver dipoles and red symbols show transmits).

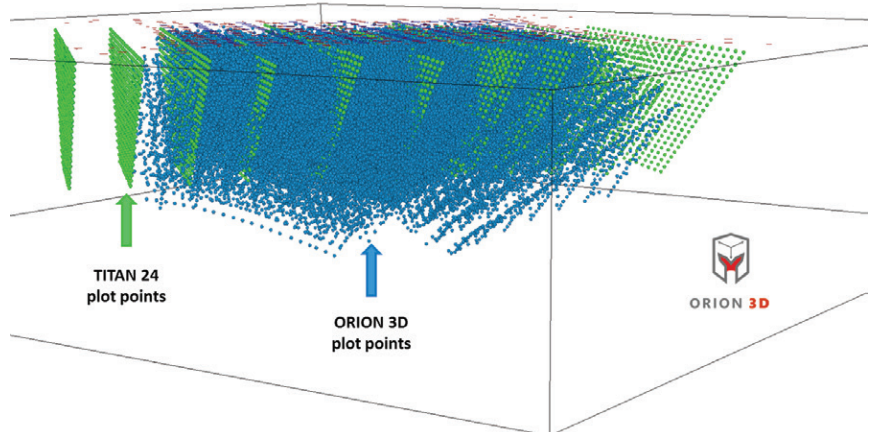


Figure 6. ORION 3D data plot-points (blue) vs TITAN 24 2D data plot-points (green 2D pseudo-sections).

SURVEY RESULTS

The 3D survey mapped the WS conductor in correlation with the Phoenix deposit (Figure 8). The resolution and accuracy of the ORION 3D survey is demonstrated in Figure 9, showing the difference between images from above (UC+100) and below (UC-100) the unconformity.



Figure 7. Resistivity colour distribution for the following figures.

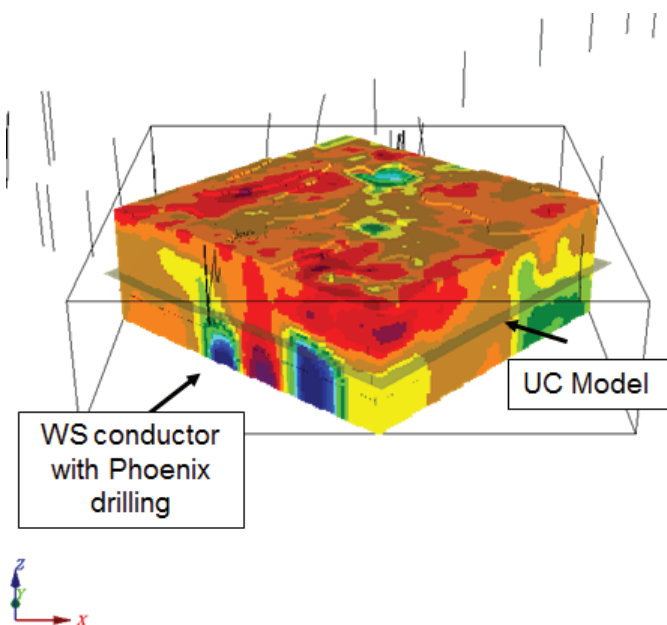


Figure 8. Resistivity cube after inversion, looking north.

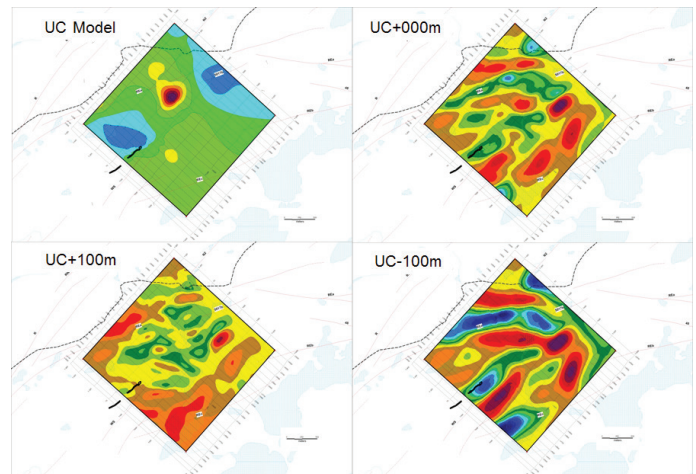


Figure 9. Resolution above and below the unconformity showing (upper left) basement topography at the unconformity; and plan view of resistivity layer extracted from the inversion cube at (upper right) the unconformity, (lower left) 100 m above the unconformity and (lower right) 100 m below.

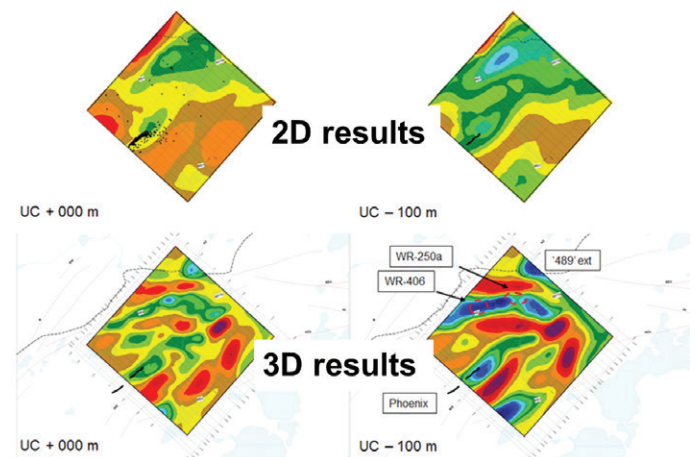


Figure 10. Comparing plan views of resistivity at (left) the unconformity horizon and (right) 100 m below the unconformity horizon; from inversions of (upper) stitched 2D survey and (lower) the Orion 3D survey.

When the historical 2D results are compared with 3D results (Figure 10) the character of the basement is much better resolved and additional features are mapped in the latter. High and low resistivities are more intensely separated, and edges are better defined. The complex strike directions mapped in 3D are consistent with foliation mapping (Figure 11) from drill results.

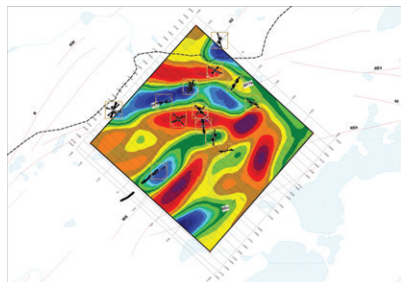


Figure 11. Foliations from drilling plotted on 3D view shown in Figure 9

Decomposition of the data into line directions permits confirmation that the 3D information is preserved. The

cross-line direction is parallel to general strike and the WS conductor width is less well-defined, but truncation is perhaps more consistent with the strike length of the deposit. Figure 12 shows the 3D inversion results of decomposed datasets.

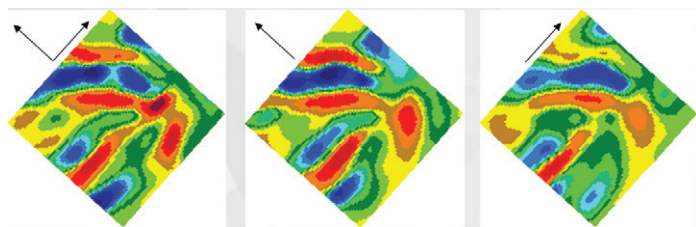


Figure 12. 3D inversion results of the decomposed datasets shown at 455 m depth – complete ORION3D dataset (left), in-line oriented dataset (center) and cross-line oriented dataset (right).

CONCLUSIONS

The high resolution of the 3D models obtained from the ORION3D survey provided geophysical results that were VERY consistent with the KNOWN basement and overlying geology. The correlation between the ORION3D inverted data and the drill hole information (foliation directions and major contacts in particular) is very good and helps resolve the geology in areas where the 2D acquisition failed, in part due to line orientation (oblique to geologic strike). The 3D models displayed more detail and reflected the geometry of the geologic system better than previous results from 2D surveys.

MT and IP results are also available from the ORION 3D survey. Decomposition of the dataset has improved the understanding of the information in the dataset.

ACKNOWLEDGEMENTS

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About the Authors



Prior to joining Quantec Geoscience in 2006, **Roger Sharpe** was senior geophysicist for Noranda Exploration in Manitoba, Saskatchewan, NWT and the US; and was chief geophysicist for Hemlo Gold (later Battle Mountain Gold) operating primarily in Ontario, Canada; Nevada, Mexico and Bolivia.

Roger then spent five years with Multi-phase Technologies contributing to instrumentation manufacture and software development for 3D ERT systems. With Quantec, Roger was GM of the US Field office, then Chief Geophysicist for South America and now is responsible for Quantec's R&D. Roger has been based in Toronto since 2011.

Larry Petrie received his B.Sc. from the University of Waterloo in 1985 and M.Sc. from the University of Toronto in 1995. From 1995, he worked as a geophysicist involved with the search for base metal deposits with Noranda Inc. and later joined the Geological Survey at the New Brunswick Department of Natural Resources as a contract geophysicist. In 2005, he joined International Uranium Corp. which subsequently merged with Denison Mines Inc. in 2007 and presently holds the position of Geophysicist, in Saskatoon, Saskatchewan.



Jimmy Stephen holds M.Sc.Tech. and Ph.D. degrees in Geophysics. Presently he is a Senior Geophysicist at Quantec Geoscience Limited. His main focus is geophysical data analysis, inversion and interpretation for the mining sector. After graduation from India, Jimmy joined the National Geophysical Research Institute (NGRI) at Hyderabad. His project and research accomplishments at NGRI earned him the Indian National Science Academy (INSA) Young Scientist Medal for the year 2005. Prior to joining Quantec, Jimmy worked at Sander Geophysics Limited and was actively engaged in managing various airborne geophysical surveys around the world. He is a member of SEG and AGU and holds Professional Geoscientist (P.Geo.) registration with the Association of Professional Geoscientists of Ontario (APGO).

Case Study of Mineral Deposits in the Yukon Using High Resolution Resistivity / Induced Polarization Techniques

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GROUNDTRUTH EXPLORATION, DAWSON CITY, YUKON

During 2013 and early 2014 a test program was carried out to evaluate a multi-electrode, High Resolution Resistivity/Induced Polarization (HRRIP) system over 9 mineral deposits within the non-glaciated region of the Yukon. The HRRIP system was chosen over conventional resistivity/IP systems used in the mining industry for the following reasons: 1) The lack of glacial material overlying these deposits means they can be mapped at depths less than 70 to 80 m, 2) conventional systems require the use of large generators to generate the current, with corresponding large field crews, and often require line cutting whereas the HRRIP systems can be used with limited or no line cutting, 3) the HRRIP systems only require a battery operated current source with a crew of 3 to 4 personnel and are therefore portable and light weight, 4) this means the HRRIP systems are faster, cheaper, and leave a smaller environmental footprint. The HRRIP systems are therefore an economic and environmentally friendly way to explore for these targets because exploration costs are reduced with smaller crews and less time spent collecting the data in the field.

HRRIP systems have been used within the environmental and engineering geophysical community for more than 30 years. Typical applications include locating aggregate, groundwater mapping, salt water intrusion into fresh water aquifers, contaminant and leachate mapping, shallow landslide hazard mapping of slip planes, porosity and potential debris volumes and locating buried tunnels and sink holes. These systems are ideal for follow-up of exploration targets in non-glaciated environments since they can map shallow resistivity and IP structures potentially associated with mineralization and/or alteration products to depths between 70 and 80 m.

The geology of the nine deposits is well known and they have been extensively drilled to outline mineralization. They are perfect deposits for testing the HRRIP system. The deposits were selected to provide different deposit types, different structural styles and different metal content (Au, Ag, Cu, Pd, Zn). The resistivity and IP responses depend on the host rock of the deposit as well as the type of mineralization associated with the deposit. For example, the stockwork structure of a porphyry copper deposit containing disseminated sulphide mineralization has a distinct IP response.

The primary goal of the study was to investigate if these high resolution systems could be used to map known mineralization and structure. In particular, for which deposit types and/or geological situations does the method work and are there deposits where the inversions are

inconclusive or incomplete. By understanding the geophysical response over deposits with known geology and mineralization we learn how the HRRIP method can be more effectively utilized in prospective areas where the geology and mineralization are not that well known. A second goal was to investigate which array type(s), if any, were most effective for mapping the different deposit types. The nine deposits selected to test the HRRIP method provided a cross section of the target types and mineralization outlined above.

This paper summarises the main results of the study and provides example inversions from the Klaza gold deposit.

HRRIP methods

Multi-electrode, high resolution, shallow resistivity/IP systems are a light weight version of traditional resistivity/IP systems used for mineral exploration. Their main advantage is they are portable, light-weight, and do not require large generators for the current. For example, an 84-electrode 2D array with an electrode spacing of 5 m covers a distance of 415 m and, depending on the array used, images the upper 50 to 100 m of the subsurface. In addition, the smaller electrode spacing provides good lateral resolution. Longer lines are obtained using roll-along techniques similar to those utilized within the seismic industry. These systems can collect data using common arrays (Fig. 1) such as dipole-dipole, pole-dipole, pole-pole, and Wenner-Schlumberger (or inverse Wenner-Schlumberger), as well as specialized arrays such as the strong gradient array developed by Advanced Geoscience Inc (AGI). See Best et al. 2014 for further details of the arrays. Each array has its strengths and weaknesses when imaging the subsurface. A comparison of using a battery versus a generator was carried out at the Brewery Creek case study (Figure 4). The results showed that batteries provided a more stable current (Best et al, 2014). Hence all the case study tests were carried out using batteries.

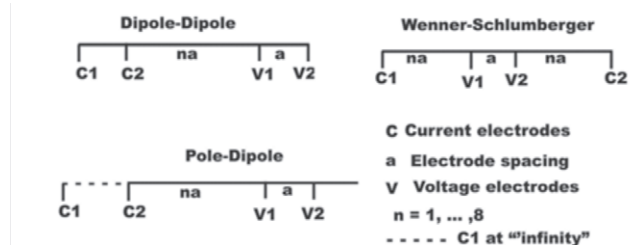


Figure 1. Common electrode arrays

An Advanced Geosciences Inc. (AGI) Supersting multi-electrode resistivity/IP system with 84 electrodes was used to collect the resistivity and induced polarization (IP) data. The electrode spacing was fixed at 5 m for this case study, providing a spread length of $83 \times 5 = 415$ m. Most lines were short enough so that only a single spread length was necessary. Those lines longer than a spread length were obtained using the roll-along option of the Supersting System.

The current (I) and voltage (V) were measured for each electrode pair and converted to an apparent resistivity (ρ_a) using the following formulas (Sumner, 1976).

Dipole-dipole $\rho_a = \pi (V/I) n(n+1)(n+2)a$; **Pole-dipole** $\rho_a = \pi (V/I) n(n+1)a$; **Schlumberger (inverse Schlumberger)** $\rho_a = \pi (V/I) n(n+1)a$; **Wenner** $\rho_a = 2\pi (V/I)$

where V is the measured voltage (volts), I is the injected current (amperes), a is the spacing between the electrodes (m) and n is a multiple of the electrode spacing (5, 10, 15 m, etc., i.e. $n = 1, 2, 3$, etc.). The apparent resistivity computed from the above equations equals the actual resistivity of the subsurface only for the case of a homogenous earth. The inverse Schlumberger array is the same as the Schlumberger array except the current and voltage electrodes are interchanged (reciprocity theorem).

The resistivity data were presented as an apparent resistivity pseudosection (Fig. 2). If the subsurface was not a simple homogenous layer then the actual resistivity must be determined from inversion of a forward model. The forward model can be a 1D, 2D or 3D. We used a two-dimensional inversion program (Earthimager software developed by AGI) because 3D data collection is time-consuming and expensive and we collected the profiles with lines placed parallel to known strike in order to keep the interpretation as close to 2D as possible.

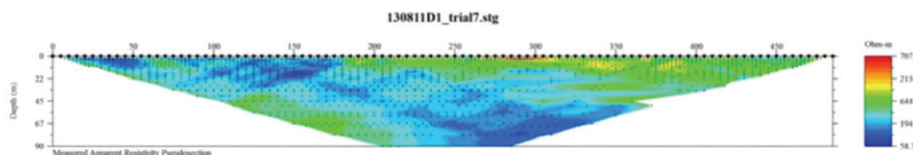


Figure 2. Example of an apparent resistivity pseudosection for a dipole-dipole array.

The Supersting system measures the induced polarization and apparent resistivity at the same time. The unit of induced polarization measured by the Supersting is chargeability (M) with units of mV/V or ms. Chargeability is a measure of the integrated decay voltage as shown in Figure 3 (Sumner, 1976) and is computed from integrating the voltage decay curve after the current is turned off; in other words:

$$M = 1/V_p \int V(t) dt \text{ (integrated from times } t_1 \text{ to } t_2)$$

where the voltage V_p is the same voltage used in the equations for the apparent resistivity and is the voltage just before the current is turned off as shown in Figure 2.

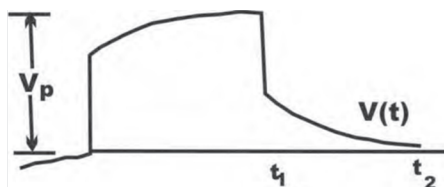


Figure 3. Schematic of IP voltage decay versus time (from Sumner, 1976).

The Supersting collects the IP data in 6 time windows starting from time zero and spaced logarithmically. The six voltages (or subset of them) are averaged and divided by the initial (time zero) voltage V_p to provide the chargeability. The voltages in the 6 time windows are stored so the user can determine which ones to use during further processing. At least 4 of the voltages must be used in order to produce statistically meaningful chargeability values.

The IP data were plotted as IP pseudosections. The Earthimager software uses

a forward model (Sumner, 1976) in order to obtain the sub-surface chargeability distribution. The process is similar to that carried out for resistivity inversions.

Minimal line cutting was needed for the AGI Supersting system since the multi-element cable is lightweight and required little effort to move it around in the field. The cable is segregated into 6 sections, each with 14 electrodes to make up the 84 electrode system. Three sections were placed behind the console and 3 were placed in front of the console, making the console the center point of the spread. When a line required roll-along either one or three of the back sections were moved to the front and the console was moved to the new center position. In most instances it only took a few hours to get a single spread ready for data acquisition. Soaking the electrodes to reduce the contact resistance and ensuring they are properly connected to the cable takeouts required the most time. Once all of the electrodes were connected and soaked it took several hours per array type to collect all combinations of current and voltage electrodes for a single spread. A significant amount of the time is for averaging the voltage signal to improve signal-to-noise. The same spread, however, was used for multiple array types without making any physical changes to the cable layout.

The final 2D resistivity and chargeability inversions were output as xyz files for input into Geosoft to produce the sections in the report.

Location and regional setting

The locations of the 9 case studies are shown on the Yukon terrane map in Figure 4. Brewery Creek (CS-1), Dublin Gulch (CS-2), and Flame/Moth (CS-3) are east of the Tintina fault and lie within the Selwyn basin. The other case study targets are located west of the Tintina fault and lie within the Yukon Tanana terrane, a pericratonic sequence that extends from northern British Columbia, through Yukon, and into southern Alaska (Colpron et al., 2006; Wainwright et al., 2011). The Yukon Tanana terrane consists of Paleozoic schist and gneiss that were deformed and metamorphosed in the late Paleozoic, and intruded by several suites of Mesozoic intrusions that range in age

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from Jurassic to Eocene (Mortensen, 1992; Colpron et al., 2006). From Late Permian to Early Jurassic, the rocks were tectonically stacked along foliation-parallel thrust faults (Mortensen, 1992; Berman et al., 2007).

Klaza (CS4) example

Geological setting

The Klaza property (Figure 4), a gold-silver vein/breccia occurrence in the south Dawson Range, is located in the Mt. Nansen area west of Carmacks within the Paleozoic Yukon-Tanana terrane. Mineralization is hosted in Mid-Cretaceous granodiorite and is associated with four distinct southwest-dipping faulted zones: the Klaza, BYG, Herc, and BRX zones. Lewis and Burke (2011) described galena, arsenopyrite, pyrite and sphalerite-bearing veins and breccia, and noted phyllic and argillic alteration of breccia clasts and in the adjacent granodiorite wall rock. The high resolution resistivity/IP survey was carried out over the BRX and Klaza zones (Figure 5).

Geophysical survey

Field work

Dipole-dipole extended (see Best et al., 2014), inverse Schlumberger, and strong gradient array data were collected on lines KL-050E and BRX-600E (Figure 5). The length of these lines was 415 m (a single spread length) for all arrays. The average RMS error of fit for these 6 arrays (3 per line) was 2.91% with the highest value equal to 4.2% for the dipole dipole extended array on line BRX-600E. These lines had a very high signal-to-noise ratio providing excellent high quality data.

Interpretation

The resistivity and chargeability inversions for the dipole-dipole extended array for line KL-050E, including borehole geology and gold grade, are shown in Figure 6. The black outline is a resistivity low associated with a chargeability high over the mineralized vein and breccia zone. The HRRIP survey indicates these features extend in depth, consistent with the borehole results showing the mineralization also continues at



Figure 4. Location of the 9 case studies overlain on the Yukon terrane map.

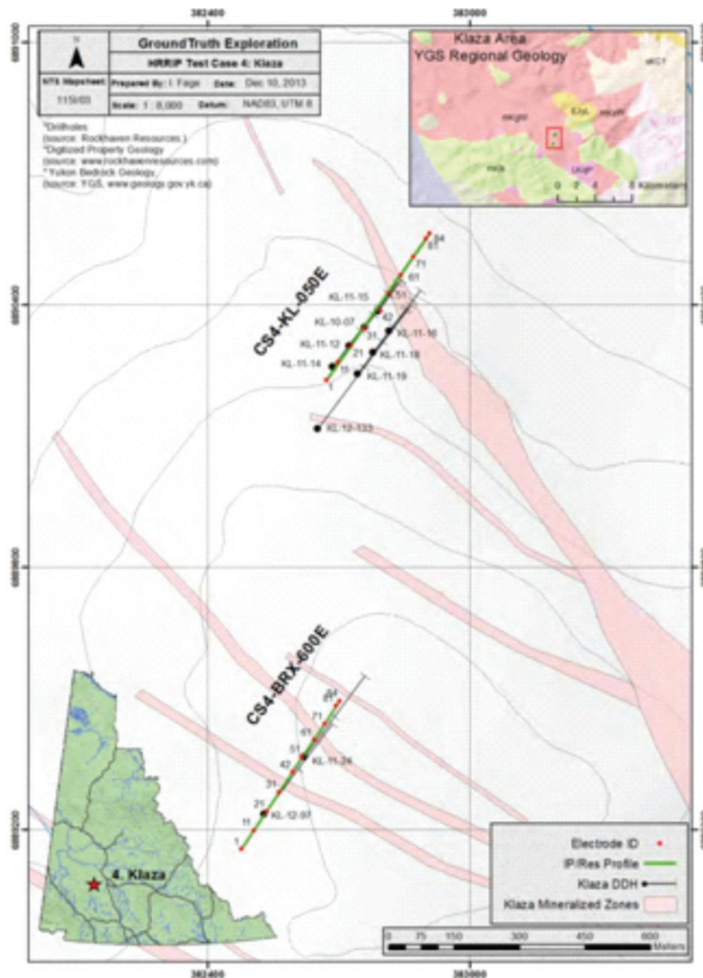


Figure 5. Location of geophysical lines overlain on the surficial geology map of the Klaza property

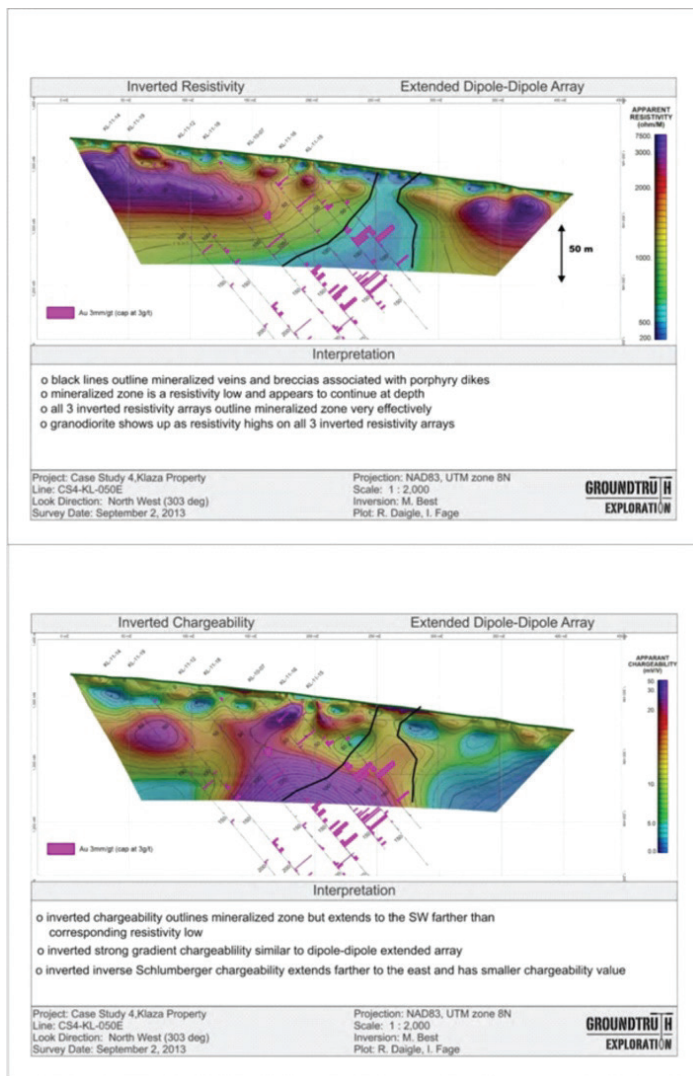


Figure 6. Resistivity (upper) and chargeability (lower) inversions of the dipole-dipole extended array for line KL-050E. Gold grades are indicated on the boreholes.

depth. All 3 arrays (dipole-dipole extended, inverse Schlumberger, and strong gradient) on this line showed similar results. The granodiorite showed up as a resistivity high as expected. However, the chargeability values were quite variable. The individual veins and fracture zones did not show up since they were too narrow, but the mineralized zone containing all these individual fractures showed up quite nicely.

The resistivity and chargeability inversions for the inverse Schlumberger array on line BRX-600E is presented in Figure 7. The results were generally consistent with those for line KL-050E. There were two mineralized zones along this line (outlined by black lines) with resistive granodiorite surrounding them. As before the inverted resistivity tended to agree more closely with the mineralization than the chargeability, although they both outlined the general mineralized zones. The mineralized zone at the NE end of the line had a large chargeability feature associated with it but the zone near the SW end only had a moderate

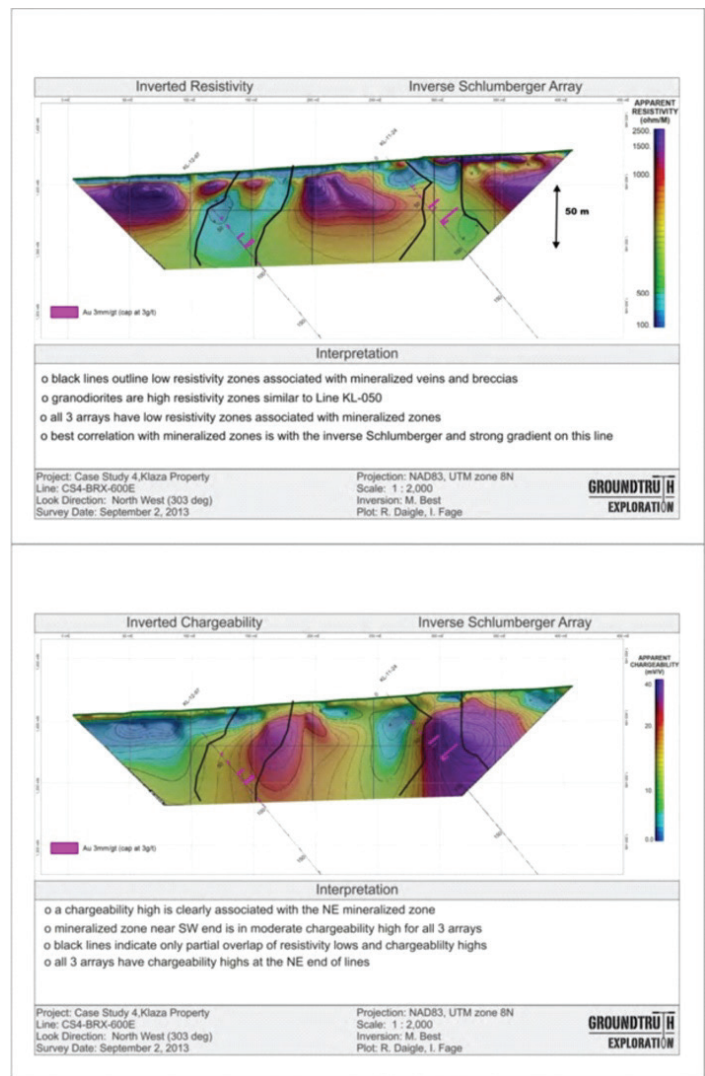


Figure 7. Resistivity (upper) and chargeability (lower) inversions for the inverse Schlumberger array for line BRX-600E. Gold grades are indicated on the boreholes

chargeability. This was consistent with all three of the arrays. The black lines indicated only partial overlap between resistivity lows and chargeability highs on this line.

Summary and conclusions

The HRRIP method turned out to be a fast, efficient, and environmentally friendly approach to explore for mineral deposits in non-glaciated regions of the Yukon. Agreement between known geology and mineralization and the inverted profiles was generally good. In some of the test cases chargeability was effective in locating areas of mineralization and in others resistivity outlined structure and geological formations.

Below are a few general observations.

- ▶ gold mineralization associated with sulphide and/or clay alteration often produced a chargeability response.

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- ▶ resistivity lows were usually related to metasedimentary rocks. Mineralization can be associated with the contact between metasediments and the surrounding resistive rocks (see for example the Eagle deposit case study (CS-2) in Best et al., 2014).
- ▶ inverted resistivity profiles provided information on structure and geology which can be used for locating targets of potential mineralization.
- ▶ most of the inverted resistivity profiles contained a near surface (approximately the upper 10 to 15 m) section containing numerous high resistivity features related to patches of permafrost.

The study, however, did identify inconsistencies between inversion results, both resistivity and IP, from different arrays along the same line (Best et al., 2014). This points out the importance of using both for interpretation.

The study showed that different geological settings and/or type of mineralization influenced the response of a given array type. The characteristics of one deposit type leads to low resistivity values, for example clay alteration and/or sulphide mineralization, whereas the characteristics of another deposit type leads to high resistivity values, for example quartz veins. Similar arguments hold for how deposit type affects chargeability.

Dipole-dipole and extended dipole-dipole arrays have been shown to have excellent lateral resolution, particularly for inverted resistivity. On the other hand the inverse Schlumberger array, and its extended version were effective at locating chargeability features associated with mineralization. The strong gradient array was somewhere between these two with regard to resistivity resolution and imaging mineralized zones with the chargeability. The location of the "infinity" current electrode influenced the response of pole-dipole arrays and led to asymmetric pseudosections. The depth of exploration for a pole-dipole array is approximately 50% more than the other arrays for a given "a" spacing and fixed number of electrodes. Near-surface resolution, however, was poorer for the pole-dipole array than for the other arrays. Merging pole-dipole data with "infinity" electrodes placed at opposite ends of the spread eliminated any asymmetry associated with single "infinity" locations.



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About the Author



Melvyn Best has close to 40 years geophysical experience in industry and government, working with Shell and Teknica Resource Development Limited in Calgary, Houston and The Netherlands and the Geological Survey of Canada in Dartmouth, NS and Sidney, BC. In 1997, he took early retirement from the GSC and started a geophysical consulting practice in oil and gas exploration and production as well as ground water and environmental studies. He is a past adjunct professor at the University of Victoria and the University of Calgary. Mel has published over 50 journal and GSC papers.



MARCELLUS & UTICA SHALE PSDM CASE STUDY – IMPROVED STRUCTURAL IMAGING AND ROCK PROPERTIES

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Joel Starr – EQT Production, Pittsburgh

In this abstract, we highlight the performance of PreStack Depth Migration (PSDM) on an ION GeoVentures multiclient survey from northwest Pennsylvania, the GroundhogSCAN 3D. The survey area of interest and a representative crossline are shown in Figure 1. Compressional tectonics during the Appalachian Orogeny shortened the geology above the Silurian-age Salina Salt; here the salt acted as a detachment surface. The overlying Devonian-age Marcellus Shale is heavily faulted and folded, but the underlying Ordovician-age Utica Shale appears relatively undeformed.

First, we show how conventional seismic time processing (PSTM) can increase drilling risk by causing false seismic structures and positioning errors, and by blurring faults and steep dips. We show how PSDM overcomes these hurdles. PSDM can also improve the accuracy of azimuthal velocity anisotropy (HTI) analysis, an indicator of differential horizontal stress (and/or natural fractures), by removing false HTI effects caused by lateral velocity variation. We show evidence that we have detected – only by using PSDM – a vertical change in regional horizontal stress across the Salina Salt.

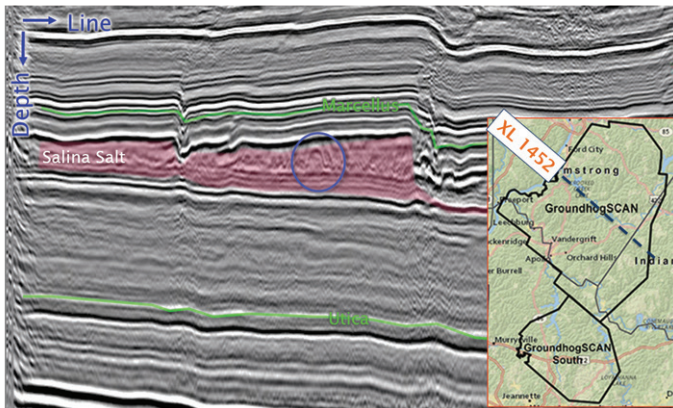


Figure 1. GroundhogSCAN survey (data courtesy ION Geophysical). The 378 square-mile survey is located east of Pittsburgh, Pennsylvania, in Westmoreland and Armstrong Counties. The results shown in the presentation focus on XL 1452; a PSDM section through XL 1452 shows how the Salina Salt varies in thickness considerably (and in internal composition – see blue circle). These variations in salt thickness drive lateral velocity variations that distort the Marcellus and Utica horizons in time.

PSDM Improves Structural Imaging

PSDM reduces the risk of dropping out of zone during horizontal drilling. Lateral variations in seismic velocity cause distortions on PSTM images. As Figure 2 shows, if velocity anomalies fit between existing well control, a driller might believe that the time structure represents actual geology. While corrections could be made with LWD data, it's likely that the confusion caused by the false seismic structure would lead to "porpoising" and reduce the well's productivity. On the other hand, PSDM can, with an accurate velocity model, remove false seismic structures and help keep the drill bit in zone.

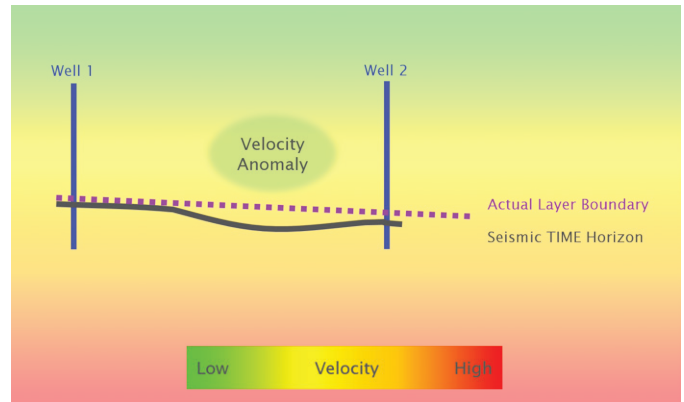


Figure 2. Low velocity anomaly causes time sag (top), which is corrected by PSDM (bottom)

Lateral velocity variation also blurs the imaging of fault planes and steep dips and causes lateral mispositioning of these key features. Figure 2a illustrates how the reflection points for the traces in a common midpoint gather are actually spread over 700 ft. In this case, when we stack the Utica Shale event on a PSTM offset gather, we're also stacking across 700 ft of midpoint. We stand the risk of smearing steep dips and faults, as Figures 3-5 show. PSDM overcomes this deficiency.

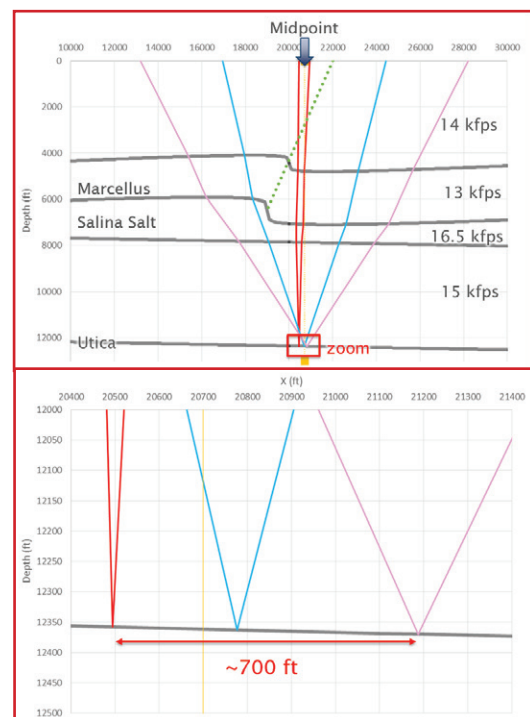


Figure 2a. Simple raytracing experiment. Top: near-, mid-, and far-offset rays (sharing a common midpoint) traced from surface to Utica. Bottom: Zoom on the reflection points. Though the Utica Shale dip is only 0.5°, the lateral velocity variations cause over 700 ft of reflection point dispersion.

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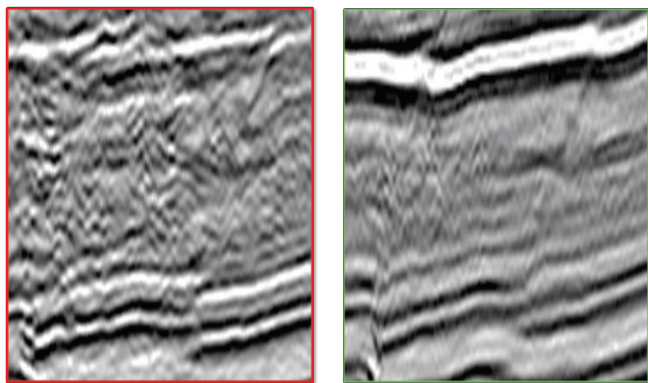


Figure 3. XL 1452 zoom above the Marcellus. Left: PSTM. Right: PSDM. PSDM shows improved fault focussing. Data courtesy ION Geophysical

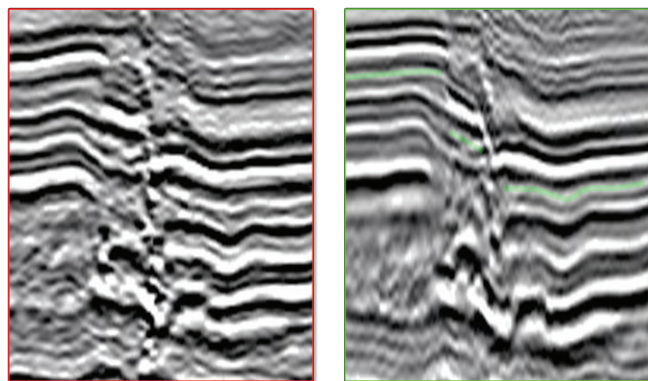


Figure 4. XL 1452 zoom around the Marcellus. Left: PSTM. Right: PSDM. Approximate Marcellus pick is shown in green. Note how the Marcellus horizon appears more geologically "simple" on the PSDM than on the PSTM. Also, note how the deep folded structures – imaged well by PSDM – are distorted and smeared on the PSTM image. Data courtesy ION Geophysical.

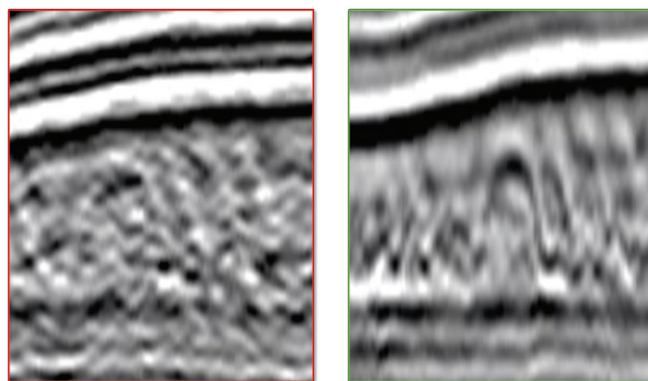


Figure 5. XL 1452 zoom inside the Salina Salt. Left: PSTM. Right: PSDM. PSDM images apparent internal salt thrust structures, probably interbedded clastics. Data courtesy ION Geophysical.

PSDM Improves Azimuthal Anisotropy (HTI) Analysis

Idealized vertical fractures and/or differential horizontal stress are known to cause seismic velocities to vary as a function of azimuth. This is known as azimuthal anisotropy (HTI). By measuring HTI with seismic data

(azimuthal traveltime variations), we can infer the presence and direction of the fractures or differential horizontal stress. This has obvious implications for the optimization of hydraulic fracturing.

In theory, vertically-oriented fractures will produce a sinusoidal traveltime pattern versus azimuth. We typically measure two attributes from OVT (Offset-Vector Tile) gathers – " $V_{fast}-V_{slow}$ ", an estimate of the magnitude of the HTI effect, and " V_{fast} azimuth", the direction of the fast velocity.

However, lateral velocity variation can cause significant false HTI effects to manifest on OVT PSTM gathers, as Figure 6 below shows. An operator might mis-interpret the false HTI effect as a localized zone of fractures and/or mis-interpret the direction of maximum horizontal stress. Luckily, PSDM correctly handles lateral velocity variations, and can remove false HTI effects from OVT PSDM gathers.

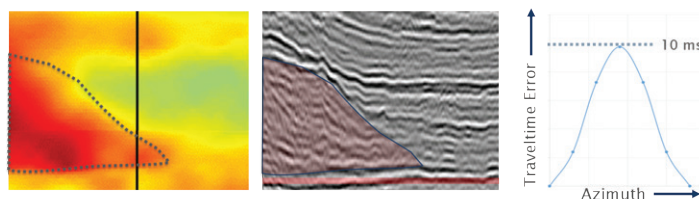


Figure 6. 2.5D isotropic raytracing experiment from West Texas. Left: velocity model with "wedge" of high velocity (orange) corresponding to Central Basin Platform (carbonate), juxtaposed against lower-velocity sediments (green). Black line = experiment location. Center: PSDM image of shelf edge. Raytrace from the surface to the flat red horizon. Right: Raytraced traveltime versus azimuth. Although the target is flat and the model isotropic, we see a significant false 10 ms HTI response.

Figure 7 below displays a map, centered on XL 1452, comparing the RMS $V_{fast}-V_{slow}$ HTI attributes at the Marcellus Shale, generated by PSTM and PSDM. Although the calculations are made in exactly the same way, the magnitude, on average, is smaller on the PSDM-derived attribute. This indicates that PSDM has likely removed some false HTI effects, leaving behind the true HTI response.

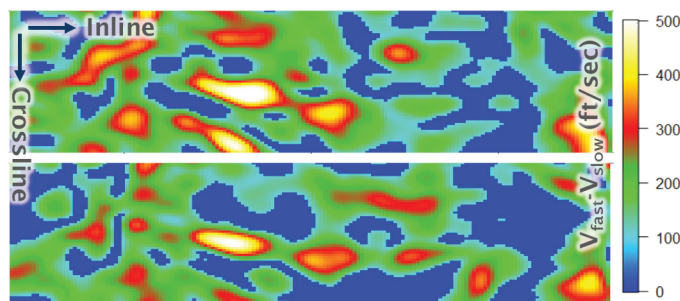


Figure 7. RMS $V_{fast}-V_{slow}$ (magnitude of HTI effect) analysis at the Marcellus Shale for a 3 square mile area centered on XL 1452. Top: derived from OVT PSTM. Bottom: derived from OVT PSDM.

Originally, most HTI analysis didn't correctly handle vertical variations in HTI orientation – the calculations were "RMS" in nature. The "Generalized Dix Equation" was introduced in 1999 by Grechka et al., and enables us to derive interval HTI attributes, as Figure 8 illustrates.

Even when we use interval HTI analysis, the HTI response measured from PSTM will be contaminated by lateral velocity variation. This problem will become acute when we perform HTI analysis on the deep Utica

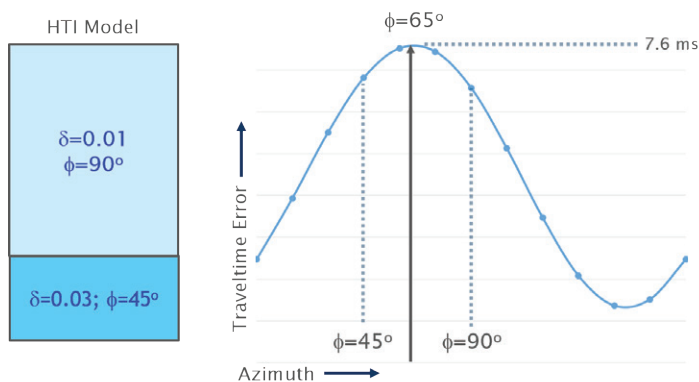


Figure 8. Justification for interval HTI analysis. We performed azimuthal HTI raytracing in a two-layer model (left), with a 45° change in HTI orientation (ϕ). Right: Computed azimuthal traveltime, from the surface to base of bottom layer. The curve forms a sinusoid with a 7.6 ms magnitude. The apparent V_{fast} azimuth, 65°, is different from the V_{fast} azimuth of either layer! An interpreter would infer an incorrect fracture orientation. Interval HTI analysis is robust to this issue.

Shale, because of the significant variations in Salina Salt thickness above the Utica. Figure 9 below illustrates interval HTI analysis at the Utica Shale, using both PSTM and PSDM inputs. PSTM provides a muddled view of V_{fast} azimuth, whereas PSDM provides a far more consistent V_{fast} azimuth, differs from the shallow V_{fast} azimuth.

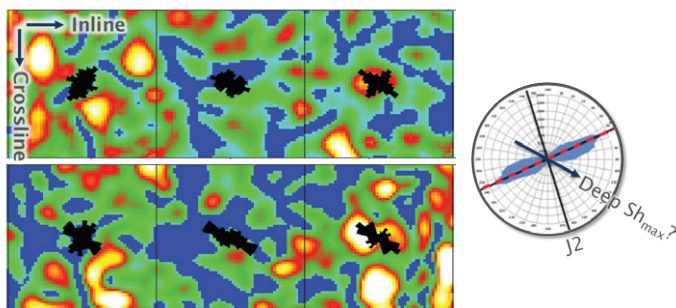


Figure 9. Interval HTI analysis at Utica Shale on the same 3 square-mile area shown in Figure 6. Each of the three marked subdomains contains about 3,000 analysis points. Therefore, in each subdomain, we have 3,000 measurements of V_{fast} azimuth, which we can use to construct a rose diagram. Top-left: rose diagrams from PSTM. There doesn't seem to be any dominant V_{fast} azimuth direction in the PSTM-derived attribute. Bottom-left: rose diagrams from PSDM. The PSDM-derived V_{fast} azimuth attribute appears to consistently indicate a NW-to-SE direction. Right: rose diagram displaying the shallow dominant stress orientation for the Marcellus Shale, the orthogonal "J2" fracture direction, and the "Deep SH_{max} " direction measured at the Utica.

Interpretation

Figure 10 compares the V_{fast} azimuth direction computed at the Marcellus (green) and at the Utica (blue). In general, V_{fast} azimuth is believed to align with present-day SH_{max} . V_{fast} azimuth from the surface to the Marcellus is, *interestingly*, perpendicular to the direction of compression. The green arrow aligns with the SH_{max} from the World Stress Map. Although the Appalachian Orogeny no doubt caused compression of the shallow section, if the shallow section was currently under compressive stress, we'd expect shallow SH_{max} to be parallel to the compression; instead, it is roughly perpendicular. Intriguingly, the deep V_{fast} azimuth direction that we measured at the Utica is aligned with the direction of paleo compression.

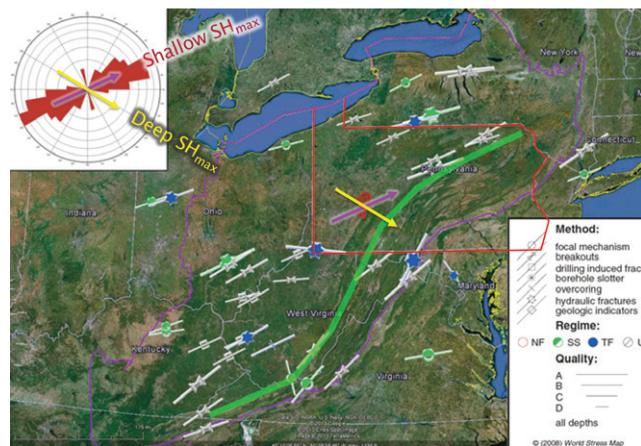


Figure 10. World Stress Map around Pennsylvania. Yellow line illustrates trace of Appalachian Mountains. The state of Pennsylvania and the GroundhogSCAN survey are outlined in red. Green arrow illustrates regional SH_{max} at the Marcellus. Blue arrow illustrates the deep SH_{max} measured from interval HTI analysis at the Utica.

Conclusions

We demonstrated that PSDM has significant utility in the Western Pennsylvania Shale Basin, although the technology has not (to date) been frequently utilized. PSTM appears to yield a "good image" in most areas, but there are subtle-but-crucial differences in the structural image quality (faults and steep dips), caused by lateral velocity variations. Additionally, PSDM appears to "simplify" local structures around the Marcellus Shale that are horizontal drilling targets.

Secondly, we demonstrated how PSDM provided a superior input for HTI analysis. By removing false HTI effects from OVT gathers, PSDM produces more reliable azimuthal attributes. Intriguingly, by utilizing interval PSDM HTI analysis at the Utica Shale, we detected a consistent V_{fast} azimuth direction (not interpretable on the PSTM attributes) which differed from the shallow V_{fast} azimuth. From available well data, we observe a change in the differential stress across the salt, so it is reasonable to see a stress rotation as well. For what it is worth, the measured deep V_{fast} azimuth is perpendicular to the trace of the Appalachian Mountains, and presumably parallel to the paleo SH_{max} direction.

Acknowledgements

We thank the management of NEOS for permission to publish, and to ION Geophysical for the right to show the data examples. We also thank for their valuable feedback many colleagues at NEOS, as well as countless attendees of geophysical luncheons where this work has been previously presented.



About the Author

Dr. Morgan Brown holds degrees in applied mathematics (BA, 1997) from Rice University and in geophysics (PhD, 2004) from Stanford University. He worked in geophysical R&D at Hess Oil and 3DGeo, before joining a depth imaging startup, Wave Imaging Technology Inc.. He served as CEO from 2008 to the company's sale in 2013 to GeoCenter. After consulting for two years, he recently joined the NEOS Seismic Imaging Group in Denver as a Geophysical Advisor in Depth Imaging.

CSEG SCHOLARSHIPS 2016

Every year the CSEG Scholarship Committee awards scholarships to deserving candidates in continuing education across Canada. In the 2016 scholarship year, 42 high-quality applications were received from across Canada and 12 scholarships were awarded. Eleven awards of \$2,000 were made to geophysics students enrolled in university degrees and one award of \$1,000 was made to a student technologist.

In order to qualify for a university student award, students must be enrolled at a Canadian university in an academic program leading to a career in exploration geophysics. Scholarships are awarded on the basis of academic performance, financial need, interest in geophysics and extra-curricular activities. In 2012, the Foundation introduced a new scholarship in response to the emergence of geoscience technology programs across the country. To be eligible for this scholarship, students must be enrolled full-time at an accredited educational institution in Canada leading to a degree in geoscience technology. In addition to continuing the award of technologist scholarships, the Foundation awards two new university entrance scholarships to high school students. Scholarships are awarded to students who are planning on pursuing a science-based post-secondary education or are the children of CSEG members. High school scholarships will be awarded in July 2017.

The CSEG Scholarship Committee is part of the CSEG Foundation, and is run each year by a minimum of three volunteers tasked with assessing scholarship applications. Scholarships are funded primarily through corporate and individual donations, and through interest generated by

memorial trust funds. If you are interested in contributing, we are gratefully accepting donations. Please contact a member of the committee or mail funds to the CSEG office with cheques payable to the CSEG Foundation. We ask that you clearly indicate that the funds are for a CSEG scholarship. All donations are tax deductible and a charitable donation receipt will be issued.

The CSEG Scholarship Committee would like to thank all of the generous scholarship sponsors for their support in 2016. Such sponsorship contributes greatly to the education of geophysics students, and to the advancement of the field of geophysics.

High School Scholarships 2017

Up to two high school scholarship awards of \$500 will be made in 2017. To be eligible, students must be high school students entering into a science-based university program in Fall 2017 or be a dependent of a CSEG member.

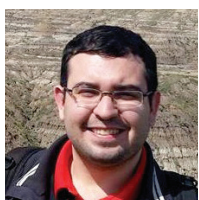
Applications open March 1 and the deadline for applications is June 15. Awards will be allocated July 1 for September 2017 payment against university tuition fees.

Craig Mosher (Repsol Oil and Gas Canada Inc., cmosher@repsol.com)

Steven Kim (Independent, stevenkim.cseg@gmail.com)

Ian Watson (Imperial Oil, ian.a.watson1@esso.ca)

2016 RECIPIENTS



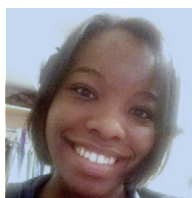
Mauricio Reyes Canales

University of Alberta

Sponsored by **Apache**

Mauricio Reyes Canales is a Geophysical Engineer from Simón Bolívar University in Venezuela. Before

he obtained his Diploma in 2015, he was an exchange student between 2013 and 2014 at the Norwegian University of Science and Technology, where he wrote his thesis on seismic interpretation. In the fall of 2015, he became a graduate student at the University of Alberta and a member of the Microseismic Industry Consortium. In January 2017, he transferred to the Ph.D. program in Geophysics. Currently, he is focussed on hazard analysis for induced seismicity.



Jacqueline Huggins

Laurentian University

Sponsored by

CSEG T-Wave and CSEG Foundation

Jacqueline Huggins is a first year M.Sc. student, studying at Laurentian University in Sudbury, Ontario, where she also completed her Bachelor's degree. Her current research focusses on the application of gamma-ray spectrometry techniques on Sudbury drill core samples. Components of this work relied on Jacqueline's ability to use aspects of geology while preparing thin sections in the lab. Jacqueline is also involved with Laurentian's residence community as a residence assistant. As a scholarship recipient, she would like to thank the CSEG Foundation for providing assistance to students who demonstrate an interest in geophysics. Her goal, upon graduation, is to work in industry.





Yichuan Wang

University of Saskatchewan

Sponsored by **Hampson-Russell**

Yichuan Wang received a Bachelor's degree in Geological Engineering from China University of Mining & Technology in Beijing in 2013. After receiving his Bachelor's, he studied petroleum geophysics at Montanuniversitaet in Leoben, Austria, for approximately one year. He joined the Joanneum Research Institute of Geophysics and Geothermics, where he completed his Master's thesis on seismic attributes. Currently Yichuan is pursuing a Ph.D. in Geophysics from the University of Saskatchewan, where his primary interests include acoustic-impedance inversion, elastic impedance, and time-lapse seismic monitoring.

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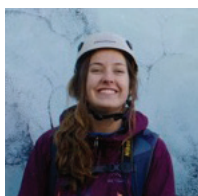
Adriana Gordon

University of Calgary

Sponsored by **Arcis**

Adriana Gordon completed her B.S. degree in Geophysics in June 2015 from Simón Bolívar University in Venezuela. During her stay at the University of Calgary in fall 2014, she did a research project with CREWES for six months as a visiting student. Adriana formally joined CREWES in the following year to pursue a M.Sc. Degree in Geophysics under the supervision of Dr. Don Lawton. Her research interests include seismic data processing, time-lapse monitoring and carbon capture storage.

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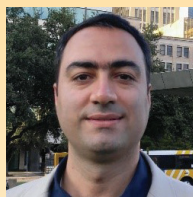


Meghan Sharp

University of British Columbia

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Feeding her curiosity and passion for the individuality of each planet, Meghan Sharp is completing her third year of an Undergraduate degree in Geophysics at the University of British Columbia in Vancouver. A lifestyle that combines the outdoors (through skiing, hiking, climbing, and surfing) with a need to know why and how drives her to work towards understanding geophysical phenomena. She aspires to research many topics throughout her career, ranging from volcanology to glaciology, snow formation, and planetary science. After returning from her studies abroad at the University of Iceland, Meghan will kick-start her research career in remote sensing at the National Research Council of Canada's Flight Research Laboratory.



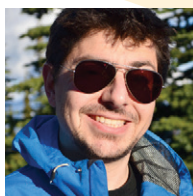
Shahpoor Moradi

University of Calgary

Sponsored by **CGG**

Shahpoor Moradi earned his B.Sc., M.Sc. and Ph.D. in theoretical physics from Razi University in Kerman-shah, Iran, where his research was focussed on quantum fields and quantum information. After finishing his Ph.D. in 2006, he held a faculty position at Razi University. He also worked as a visiting researcher in several institutes such as the Institute for Quantum Computing and the Perimeter Institute in Waterloo, ON, and the Institute of Quantum Information Sciences here in Calgary, AB. In 2013, Shahpoor joined CREWES and is currently focussing on seismic inversion and anelastic scattering.

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Max Salman

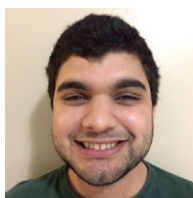
University of Waterloo

Sponsored by **"In the Rings"**

Doodlespiel Scholarship

Max Salman is a Master's degree candidate at the University of Waterloo specializing in geophysics. His main area of research involves the use of unmanned aerial vehicles and geophysical methods for precision agriculture. Max also completed an Honours Bachelor's degree in Geology at the University of Waterloo and is the holder of a Canadian Commercial Pilot License. The two skills fit very well together to lead to a career in airborne geophysics, where Max has worked as a processor, operator, co-pilot, and project manager.

Max has many extra-curricular interests, and is involved with several student groups at the University of Waterloo. He is on the Executive of the Graduate Students Association (GSA-UW) and is the Treasurer of the Ontario Graduate Students' Alliance (OGSA). In addition to these organizations, Max is the current President of the University of Waterloo Geophysical Society (UWGS), which is a Student Chapter of the Society of Exploration Geophysicists (SEG). Finally, in 2016, he was the President and an instructor of the University of Waterloo Swing Dance Club (UWSDC).



Deep Inamdar

McMaster University

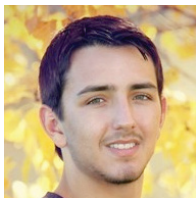
Sponsored by **Repsol Oil & Gas Canada**

Deep Inamdar is a fourth-year Undergraduate student enrolled in the Honours Integrated Science program with a concentration in Mathematics at McMaster University. He is expected to graduate summa cum laude at the end of April. Under the direction of Dr. Carolyn Eyles, Deep was inspired to explore the intersection of physics and geography. His mathematical studies gave him the necessary tools to fully study this relationship. This led to his work with the National Research Council (NRC), where he focussed on concepts surrounding hyperspectral imaging that encompasses many scientific disciplines, with added support from the European Space Agency.

After completing his Undergraduate degree, Deep will continue interdisciplinary study at McGill University in the School of Geography, where he will pursue a Master's degree. He will work under the co-supervision of Dr. Margaret Kalacska and Dr. George Leblanc of the NRC. Deep would also like to graduate with a Ph.D in Geophysics and work for the National Research Council of Canada at the Flight Research Laboratory.

REPSOL

Continued on Page 38



Taylor Fink

SAIT

Sponsored by **Seisware**

Currently, Taylor is attending Southern Alberta Institute of Technology (SAIT) and is enrolled in the Geoscience Information Technology program.

From the courses that Taylor has completed in this program, he has come to understand the importance of geophysics and its applications to geophysical software. Upon graduation from this program, Taylor plans to enter the Bachelor of Geographic Information Systems program and to continue his career in the oil and gas industry.



Melanie Postman

Western University

Sponsored by **Pulse Seismic**

Melanie Postman is completing an Honours B.Sc. in Geophysics at Western University with the intention of achieving a professional designation as a geoscientist.

Her geophysical interests include seismic, resistivity/IP methods as well as seismic hazard analysis, especially the field work and processing aspects, in Canada. Recently, she has conducted a passive seismic research study for her Undergraduate thesis that focussed on analyzing the surface vibrations of a wind turbine to produce an empirical relationship between vibration attenuation and distance. Between 2015 and 2016, she has participated in the Western Science Internship Program and interned as a processing geophysicist at Sander Geophysics Ltd. in Ottawa, ON. Through this program, Melanie acquired training and experience in airborne geophysical data processing and acquisition over the course of 16 months. As a member of the Society of Exploration Geophysicists' (SEG) student chapter at Western, Melanie assists in the organization of several fundraising and geophysical outreach campaigns. She has also received the NSERC Undergraduate Student Research Award (USRA) and will be conducting research at Western this summer with Dr. Sheri Molnar. This research will involve performing seismic risk assessments for future earthquakes using two different risk assessment software programs to quantify the uncertainty in earthquake loss prediction.

Melanie will be actively looking for employment opportunities during this time.



Sara McPeak

Carleton University

Sponsored by **Rob Shugg**

Sara McPeak is a Master's student studying Earth Sciences under the supervision of Dr. Claire Samson at Carleton University. Her research

focusses on 3D imaging of geological structures and estimation of surface roughness from point clouds at different scales. She is involved with providing undergraduate and teaching assistant mentorship by conducting various workshops for students to help them succeed in their academic program and prospective careers. After completing her Master's, Sara plans to continue as a Ph.D. student at Carleton University under the supervision of Dr. Claire Samson on a new project entitled "Using passive seismic detectors to map overburden thickness in a permafrost-rich environment with applications for diamond exploration: a feasibility study". Sara is enthusiastic about the new project this summer and her continuation in the field of geophysics.



Chris Williams

Memorial University of Newfoundland

Sponsored by **Imperial Oil & Ian Watson**

Christopher Edward Lloyd Williams is a fourth year student enrolled in the Faculty of Science, Memorial University of Newfoundland (MUN). He is majoring

in Earth Science with a minor in Physics. His geophysics interests involve the processing and interpretation of seismic data as well as incorporating potential field data to interpreted seismic data to gain regional context for the area of interest. His interests led him to compete in the Imperial Barrel Award (IBA) last winter. In addition, Chris has previous experience taking a summer position with Statoil in St. John's, Newfoundland, and has worked for the Department of Natural Resources in core storage facilities. While at MUN, he has developed code in microseismic detection. He has also had membership in the Canadian Society of Exploration Geophysicists (CSEG), Society of Exploration Geophysicists (SEG), and American Association of Petroleum Geologists (AAPG).

Chris has an active lifestyle in the summer months when he plays football and soccer, goes camping, boating, fishing, jogging and hiking. During the winter, he enjoys volleyball, basketball and snowmobiling. Chris will be pursuing his Master's degree at MUN, where he will spend his time researching shallow-surface geohazards offshore Newfoundland.



MARCH AGM & TECHNICAL LUNCHEON

WITH LUNCHEON SPEAKER ÖZ YILMAZ (SEG DISTINGUISHED INSTRUCTOR 2015, SEG HONORARY MEMBER) • MONDAY, MARCH 27, 2017



Easton Wren (CSEG President 1981) introduces Öz Yilmaz



Öz Yilmaz begins his presentation



John Duhault gives commemorative gavel to Past President Marian Hanna



Öz Yilmaz (left); Easton Wren (right)



Mark Jereoncic and Jim Racette (foreground), Öz Yilmaz and Easton Wren (background left), Mohammed Al-Ibrahim (background right)



Kim Tran from Earth Signal Processing



John Duhault introducing the new Board of Directors

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Column Contributor
Kristy Manchul

P: 403-585-5204

kristymanchul@gmail.com



TRACING THE INDUSTRY

I wanted to give some recognition to the Crew that organized the "It's a Break-Up... Spring Fling" social at the Unicorn Super Pub: Angela Spencer, Maggie Stratton, Mike Clement, Chris Heaver, Wendy Lambert and Sandy Lucas. This group of geo folk raised spirits and raised a total of \$164 for the Veterans Food Bank. "Yahoo!" is a shout-out from Bill Cox, President of Royal Canadian Legion Kensington Branch #264 who accepted the donation. Bill was also thrilled to update on the new Legion and restaurant opening up this June to the public: 1918 Taps & Table. They are extending a big welcome to anyone who wants to make the short jaunt from Downtown.

If you have any personal, company or industry news, please send me an email to: kristymanchul@gmail.com or call at 403-585-5204.



ON THE MOVE...

Mantu Sihota is pleased to announce he has joined **NAL Resources** as Chief Geoscientist; his new contact information is 403-538-8978 and msihota@nal.ca. Mantu will be responsible for managing exploration activities, A&D and technical advancements to help the company meet strategic growth targets. Mantu has over 23 years of experience in unconventional and conventional reservoirs. Prior to joining NAL Resources he was the manager of Geophysics at Long Run Exploration (Galleon) and Senior Geophysicist at Encana (PanCanadian).

Scott Reynolds has moved over to **Jupiter Resources**. His email address is sreynolds@jupiterresources.com and phone number is 587-747-2608.

Michelle Korodimas is happy to announce that she has joined **Serafina Energy**, and may be reached at Mkorodimas@serafinaenergy.com.

SOCIALLY SPEAKING...

T-WAVE GOLF TOURNAMENT

The 9th Annual T-Wave will be held on Monday, June 26th, 2017 at the Valley Ridge Golf Course in Calgary. Shotgun start at 1pm. Registration is now open! Check the CSEG website for additional information: <http://cseg.ca/social/t-wave-golf-tournament>. Any questions, please contact Chairman, Rob Curts at curtsr@echo-group.net.

WOMEN IN SEISMIC 2017

Bring on your leg warmers, big bangs (not theoretical ones), neon spandex (eww...) and your inner Randy the Macho Man Savage! Women in Seismic is flashing back to the 80s and will be racing at 88km in a DeLorean to Fox Hollow for another great round of networking on the golf course on Thursday, September 14th, 2017 for a 1pm shotgun start! Registration is now open! Go to the CSEG website at <http://cseg.ca/social/wise-golf-tournament>.

DOODLEBUG 2017

I'd like to extend an invitation to all CSEG members to join the Doodlebugs for the 65th Annual Doodlebug Golf Tournament in Banff this upcoming September 8-10th. This year, what is old is new! We are returning to Banff for the first time since 2000, and are holding the event in its traditional timeframe of the first weekend after Labor Day. We will also be streamlining the event to 2 nights and 2 days of golf, moving the golf to Saturday and Sunday, and eliminating the guest/warmup event. It is hoped that these changes, along with proximity to Calgary, will lead to improved enrollment of our CSEG members and their guests.

Registration is through our website and can be found at: www.doodlebuggolf.ca.

David Wardlaw, 65th Chairman

CORPORATE GRAPEVINE

Arcis is pleased to welcome **David Wilkinson** to Arcis' Processing and Reservoir Services team as a Senior Geophysical Advisor. He will provide technical support to the processing team and input to R&D to help guide new technology development and existing algorithm enhancements. David may be contacted by email, david.wilkinson@tgs.com or by phone at (403)781-5872.

Arcis Seismic Solutions Corp (Arcis) is a wholly owned subsidiary of TGS-NOPEC Geophysical Company based in Norway and Houston. Arcis was founded in 1996 and still has its head office located in Calgary, Alberta Canada. Arcis offers seismic solutions to the energy industry including seismic data processing, reservoir analysis, advanced imaging, multi-client surveys, geotechnical solutions, seismic acquisition services and access to an extensive 2D and 3D onshore and offshore seismic data library.

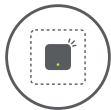




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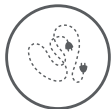
Lowest per Channel Cost
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Small Footprint
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Mobile App
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No Exposed Connector
in the Field



50_{days}

50 Days Operating Life
@ 25°C 1ms 12h ON/12h Off



1 kg

Light Weight
1 kg (including battery and spike)



8-32GB

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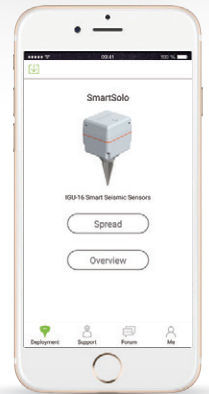
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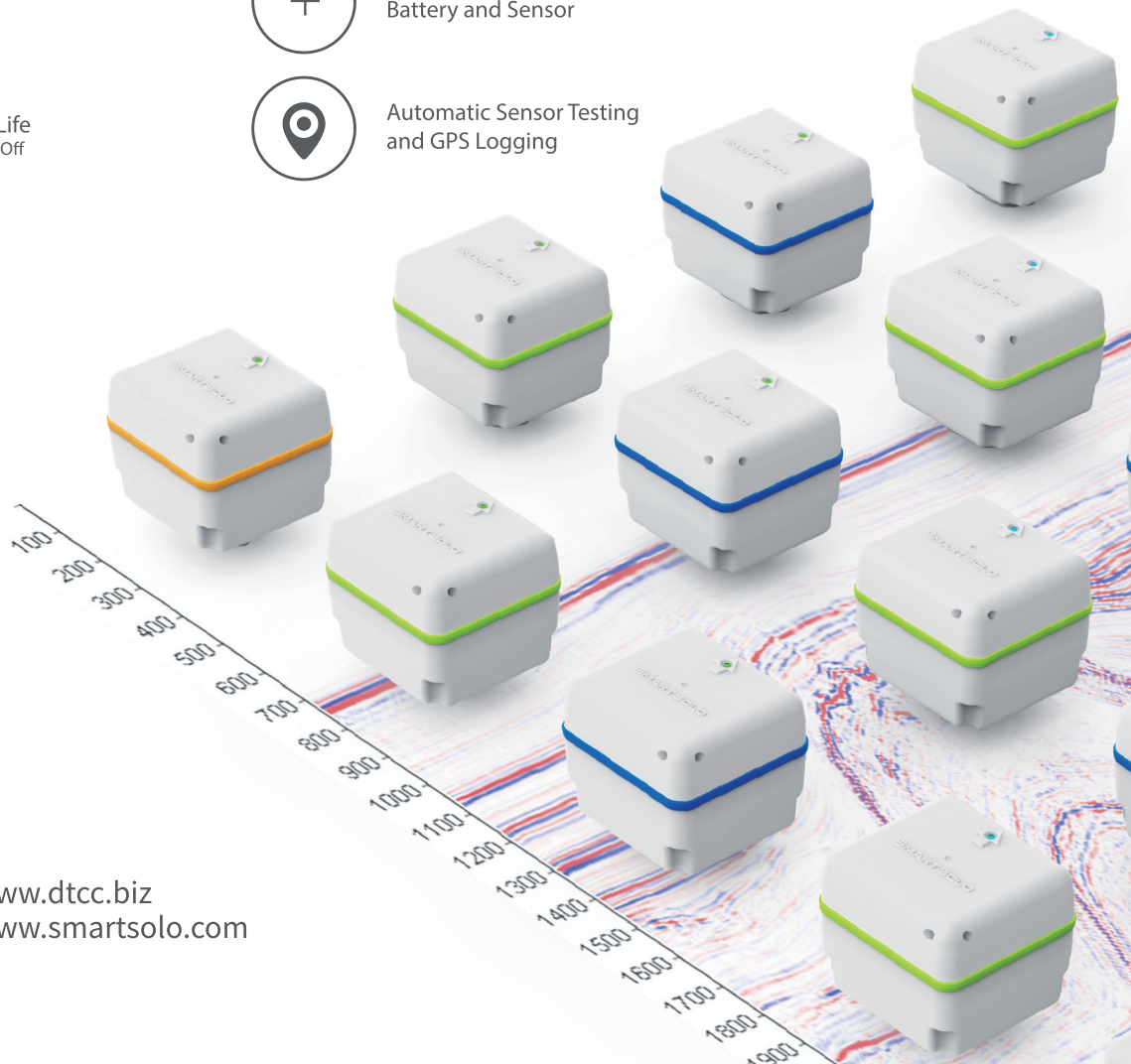


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