

ANNUAL REPORT 15



CEMI
Centre for Excellence
in Mining Innovation

CEMI IS CANADA'S LEADING EXPERT IN MINING INNOVATION. OUR AIM IS TO ENHANCE THE SCOPE, EXTENT AND IMPACT OF INNOVATION TO CREATE GREATER ECONOMIC VALUE AND CAPACITY FOR EXCELLENCE WITHIN THE MINING INDUSTRY IN CANADA AND AROUND THE WORLD.

The Centre for Excellence in Mining Innovation (CEMI) is a not-for-profit organization. We provide a single point of entry to identify, assess and manage resources and knowledge to skillfully direct and co-ordinate step change innovation within the metal mining industry. Our areas of focus include exploration, deep mining, integrated mine engineering, underground mine construction, environment and sustainability.

We engage in cross-sector collaboration with mining companies, universities, colleges, governments and forward-looking SMEs within the service and supply sector to manage industry focused mining innovation.

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MESSAGE FROM THE CHAIRMAN OF THE BOARD

On behalf of the Board of Directors, I would like to extend my appreciation to the CEMI staff and contributors across Canada and the world - for their continued efforts to advance our mining innovation programs and projects over the past year. Thanks to our collaborative approach, CEMI is leading the way in developing novel processes, products and technologies and bringing them to market.

CEMI's nationally recognized business-led NCE, Ultra-Deep Mining Network (UDMN) continues to position Canada as a global leader in mining innovation and as a knowledge-centre in deep mining. The Board is pleased to note that UDMN has 28 projects currently approved and underway. This suite of projects was enhanced by a national Call for Proposals, encouraging innovators to apply their commercially viable ideas to the ultra-deep environment from across Canada. These projects will aid in ensuring that CEMI and UDMN continue to deliver value to the mining industry at a national and global level. With the addition of Agnico Eagle Mines, the UDMN now has the three deepest mines in Canada within its membership.

I want to officially welcome our newest board members who have joined us over this past year: Rui Wang, Vice-President, Research, Laurentian University; William (Bill) Forsyth, General Manager, Underground Studies, Underground Centre of Excellence, Rio Tinto Copper, Growth & Innovation; and Dr. Magdi Habib, Director General, Canmet MINING (External Observer of the Board). A special thank you to Karen Clark-Whistler, Chief Environment Officer at TD Bank Financial Group, for her dedication and time served on the CEMI board.

As we grow and evolve to meet the needs of the mining industry, we welcome innovators in joining us by continuing to make CEMI, Canada's leading source of mining innovation.

Roger Emdin
Chair of the Board

MESSAGE FROM THE PRESIDENT

Looking back over the past year we can see the tangible results from our two main technical programs, SUMIT (Smart Underground Monitoring and Integrated Technologies) for deep mining and the UDMN (Ultra-Deep Mining Network). SUMIT was funded by the Ontario Research Fund and by industry in 2012. Since then, it has engaged over 7 academic institutions, with 15 university professors and 57 students. Damien Duff (Vice President – Geoscience & Geotechnical R&D, CEMI) has lead and managed the program, making sure projects achieved their objectives, maintaining engagement with our industry partners and ensuring student safety at mine sites.

Meanwhile, the UDMN has been getting into full swing this past year. Bora Ugurgel (Managing Director, UDMN) has made tremendous progress: implementing the network's business systems and work-flows; working with the Management Committee to review and select projects; appointing Theme Leaders; and ensuring theme leaders and our innovation partners are able to start their projects. There are 34 Network members with 28 selected and approved projects, almost equally distributed across the four themes of rock stress risk reduction, energy reduction, operational productivity and human health and effectiveness. We would like to thank all of our SUMIT and UDMN industry and academic partners for their continued support and dedication to innovation.

We are sincerely grateful to Minister Michael Gravelle, at the Ministry of Northern Development and Mines (MNDM) for the generous support to CEMI for the coming year, through the Northern Ontario Heritage Fund Corporation (NOHFC). We are also very pleased that the Greater Sudbury Development Corporation (GSDC), with the leadership of Mayor Brian Bigger, for extending its support for CEMI over the next five years, through the expansion of our co-funded business-focused programs—the Innovation & Prosperity Office (IPO), UDMN's Commercialization Attainment Program (CAP). And finally, we very much appreciate the continuing support we receive from Vale for several of our programs and projects.

This year, CEMI's business programs expanded significantly, providing a variety of services to small and medium enterprises (SMEs) to stimulate their innovation to commercialization efforts. So far, these services have been delivered primarily to the members of Northern Ontario's mining cluster, now recognized as one of the largest in the world. These efforts are not new; since its inception CEMI has invested over \$8 million in innovations in the North and the IPO and CAP initiatives simply formalize this effort. However, over the





last three years these programs have reached out to companies from Quebec to BC and we will continue to expand further to enabling-technology companies in Canada and around the world that will help Canada's mining industry progress.

Evidence shows that many potentially high-growth SME initiatives in the mining innovation space fail because of limited access to the financial resources necessary to bridge the innovation gap. Later this year we hope to be able to address this problem directly with our application to the Federal Centres of Excellence for Commercialization and Research (CECR) Program through the Network of Centres of Excellence. It is a great compliment that our Mining Innovation Commercialization Accelerator (MICA) program was accepted to the final round of the CECR competition, along with eight other applicants from across Canada. The objectives of the MICA Program are 'Clean' technologies to reduce the environmental impact of mine tailings and the application of the 'Lean' approach to the extraction process, to increase productive efficiency.

CEMI'S DEVELOPMENT

As CEMI begins to focus more attention on the business aspects of technical developments, we have come to understand just how crucial it is to the ultimate success of innovation – in mining as in the rest of the economy. Ultimately, any new technique, product or technology will only be adopted if it delivers an improvement in the safety and cost-effectiveness of routine operations. For innovation, success is a new, commercially-viable outcome—a new way of doing things; for research, success is the answer to a technical question—new knowledge. Research is essential to innovation but is only the first of four stages. Demonstration (bench and pilot scale) and implementation (in an operational setting) are often longer and more expensive than research because they have to draw on operational experience and practical ingenuity to overcome the barriers to achieving operational integration. Only once all this is achieved, can commercialization, the final stage in the RD + I&C process, be successful.

The growth of business analysis and commercial negotiations are the fulfillment of CEMI's original mandate in the Objects of the Corporation. In future, this will be reflected with the introduction of a new category, BizMine, representing the business aspects of innovation. Along with the five technical categories of FindMine, DeepMine, ValueMine, ConstructMine and SustainMine, BizMine will be a fundamental differentiator of CEMI in the Canadian mining research and innovation space.

CEMI PEOPLE

As the company changes, so do the people at CEMI. Over the year we have lost some old friends and attracted new potential for growth. Most important of all is to acknowledge the contribution of Allan Akerman who has been with CEMI from 2008 and most recently served as the Vice President - Mine Productivity. His knowledge, experience and dedication were instrumental to CEMI's success and we wish him a well-deserved, joyful and travel-filled retirement.

THE MINING INDUSTRY – THE WAY FORWARD

The underground metal mining industry, in Canada and elsewhere, is in a critical state. The last major innovation was over thirty years ago, with the transition to modern bulk stoping methods. There have been improvements since, but not enough to overcome the erosion of productivity caused by mines becoming deeper, hotter, geotechnically more challenging and logistically more difficult. The gradual erosion of productivity is now critical due to the continuing effects of the global economic crisis.

Many mining companies are retreating from investing in research and innovation at the very time when step-change in every aspect of the mining business is essential. CEMI believes the best way forward is collaborative support for innovation, not research alone—but the 'bold, persistent experimentation,' called for by Franklin Roosevelt in 1932. It is clear that the application of conventional approaches in the context of current market forces do not offer the industry productive solutions to mining deep ore-bodies or investors a return on investment. Mining is essential to the global industrial economy and to Canada's future. We need innovation to help us find new ore-bodies, new ways to mine ore-bodies effectively and safely, and new techniques that will help assure the public we can manage our impact on the environment responsibly.

Few will disagree these goals are desirable. Many who fear the cost and risk of change forget the even greater risk—crucial time lost to inaction. At CEMI, we recognize the vital necessity of planning objectives and taking action—and the need to rally support for these objectives from those with the best interests of the industry at heart.

We cannot promise the success of every project or a return on every dollar spent. But with our partners in industry, we will never be too far off the mark and will correct the course as we go on. So, we will always be closer to the solution than those who have taken no action or who need the assurance of success before they participate with others. We rely on the momentum of progress to carry us past interim failure to ultimate success. At CEMI, we value participation above all else, and believe the greater the collective contribution, the greater the collective success, recognizing that success for the mining industry means success for everyone in the global economy. So, we invite everyone who is committed to the success of the mining industry, in Canada and around the world, to join us in the journey forward.

Douglas Morrison
President & CEO

WE NEED "BOLD,
PERSISTENT
EXPERIMENTATION.
IT IS COMMON SENSE
TO TAKE A METHOD
AND TRY IT.
IF IT FAILS,
ADMIT IT FRANKLY
AND TRY ANOTHER.
BUT ABOVE ALL,
TRY SOMETHING."
- FD ROOSEVELT, 1932.

STRATEGIC DIRECTIONS

A MANDATE TO LEAD STEP-CHANGE MINING INNOVATION

CEMI is Canada's leading expert in mining innovation. Since 2007, CEMI has been directing and co-ordinating innovation through five strategic project categories of FindMine (exploration), DeepMine (deep mining), ValueMine (integrated mine engineering), ConstructMine (underground mine construction) and SustainMine (environment and sustainability). CEMI's mandate is to lead step-change innovation by introducing new practices, procedures, techniques, technologies and knowledge to help generate significant improvement in the performance and safety of mines.

INNOVATION AT CEMI: A STRATEGIC AND RIGOROUS PROCESS

CEMI's innovation approach across each of the five project categories (FindMine, DeepMine, ValueMine, ConstructMine & SustainMine) is focused, purposeful

and systematic to ensure solutions are sustainable and economically feasible for the mining industry. It is a four-phased aggregative process (RD + I&C). Research (R), an essential component, includes academic or university-based research. Equally important, is applied research to address practical applications.

$$\text{INNOVATION} = \text{RD} + \text{I\&C}$$

The identification of new ideas is only the first step. The Demonstration (D) phase assures the application and workability of the idea, while Implementation (I) is the element within the innovation process that investigates operational viability. And finally, Commercialization (C) ensures the market acceptance and adoption into the routine application of a mining operation. This final step is the proof of a successful innovation.

CEMI CONTRIBUTIONS (2007-2015)

\$15.6M
for SME support

FindMine, DeepMine, ValueMine, ConstructMine & SustainMine programs & projects and counting

129

\$33.2M
in support of innovations

\$6.6 M

in support of 28 educational institutions in Canada and around the world

\$11M

in collaborations with mining companies, research organizations, consultants

143

HQP Development: 143 students (college, undergraduate, masters, PhD, PDF & interns)



SUPPORT FOR INNOVATION COMMERCIALIZATION

Market acceptance of innovation is demonstrated through its commercialization, the achievement of operational integration into the day-to-day mining operations. CEMI has been supporting the development of commercialization with various organizations, including service and supply companies and other technology providers since 2013 through the Innovation & Prosperity Office (IPO). To formalize and communicate the growing emphasis on the commercialization aspect of innovation in its projects, CEMI is introducing a new theme and logo, **BizMine**.

BizMine programs and projects will concentrate on the business aspects of mining innovation. It will complement the five technical themes that have been the core of CEMI's activities, by providing support for the business development initiatives and activities with various innovation partners to help ensure successful acceptance of an innovation. The activities that will fall within BizMine relate not to the development of the innovation, but to aid in the market acceptability of the innovation. The primary objective of BizMine will be the analysis of the cost-benefit factors of any technical innovation in concert with the financial & management services CEMI delivers through the IPO.

A KEY TO SUCCESS—COLLABORATION

CEMI has always recognized that collaboration is a critical success factor in the achievement of any innovation, and especially in mining given the long lead times (3-5 years) and need for convergence of different disciplines. CEMI engages with collaborators from all sectors with the agility and mindset to deliver innovation success. These include:

Mining Industry: Relies on CEMI to focus and manage efforts towards step-change innovation, while mitigating the impact of incidental failures and try using them to open new avenues of investigation toward future success. CEMI works with Industry in two ways. The first, directly with a specific mining company, as an extension of their internal research effort and provide potentially unconventional ideas through applied research and the process of system design to arrive at practical solutions for implementation into operations. The second is when industry collectively identifies a problem that requires a solution and provides some overall direction. This

approach allows the sharing of resources, costs, knowledge and solutions, as well as lowering investor risk. It takes advantage of CEMI's ability to guide the direction, priority and access to additional funding for the industry collaborators as a whole.

Mining Supply and Service Companies: Partner with CEMI to overcome constraints on size and resources and obtain assistance in developing, refining or demonstrating innovative solutions for the mining industry. CEMI, through the IPO can help in filling the resource gaps by providing technical and business guidance, facilitate complementary partnerships and research as well as help sort through the barriers to commercialization. For SMEs the benefits are clear—the opportunity to grow and develop their businesses.



Research Institutions: Essential to the viable development of innovation is knowledge. Research institutions and universities are indispensable to the development of knowledge, a requisite component for innovation. They have proven intellectual rigour, important to the innovation process. With CEMI's ability to manage cross-functional teams and with the ability to support the essential iterative knowledge-building process, the ensuing collaboration can bring viable solutions and knowledge that can be utilized within a technology.

Government Institutions: Innovation development results in clear economic benefits such as job creation, industry development & growth, social stability, knowledge development and the potential for a more robust economy. Governments are able to leverage their funds through industry partnerships through CEMI, which can be managed in a streamlined and efficient manner.

CEMI's "Living Laboratories" (actual underground mine sites) demands collaboration with mining companies, consultants, researchers and operational managers to research and assess the viability of innovations, while providing in-situ access to the world's deepest active mines.

CEMI is situated at the crossroads where industry knowledge, expertise, imagination, practical management know-how, business acumen and collaboration networks exist to provide scientific and technical advances that are essential, to turn ideas into workable and implementable solutions. It is this disciplined approach to innovation that CEMI successfully integrates in working with its collaborating partners.

STRATEGIC PROJECTS

SMART UNDERGROUND MONITORING AND INTEGRATED TECHNOLOGIES (SUMIT) FOR DEEP MINES

Having just completed year four of its five-year program, SUMIT continues to develop and advance smart engineering methods, technologies and tools to facilitate step-change advances in productivity, efficiency and effectiveness in underground mining at depth.

Researchers and students from Laurentian University, the University of Toronto, Queen's University and the University of Waterloo have been working on 18 core projects, focusing on Geo-Risk, Rapid Underground Development and Mine Sustainability/Energy Optimization. All the SUMIT projects have progressed in the past year, and with significant advancements in the following:

ENERGY OPTIMIZATION AND ELEMENTS OF UNDERGROUND ROCKMASS SUPPORT

At Laurentian University, PhD candidate Mr. Sidney Shafrik, attained study outcomes crucial to the numerical and experimental verification of computational fluid dynamic (CFD) codes for the simulation and analysis of a natural heat exchange area (NHEA) in a mine. Likewise, PhD candidate, Ms. Michelle Levesque, developed a

novel energy auditing methodology incorporating Fourier Analysis. This will make a significant impact when conducting energy management initiatives for the mining industry. Mr. Alberto Romero and Mr. Harvard Ferrant, also PhD candidates, made advances on the design and control of mine energy systems with distributed energy resources and, in the field of lightweight airfoil designs for multiple-blade wind turbines, respectively. PhD candidate, Mr. Xin Wang, working on a case study to simulate ground motion due to a fault-slip event in an underground mine, identified a need for a new approach to model ground motions around excavations that uses a non-uniform velocity model.

Mr. Navid Bahrani, in completing his PhD studies, investigated estimations of confined strengths for jointed rock masses at depth. Lastly, Mr. Christoph Schaub, who completed his MSc. thesis on determining the feasibility of a real-time geophysical magnetic and electric measurement system for monitoring strain underground, discovered that more work is required to demonstrate progress in-field, although laboratory results suggested otherwise.

REAL TIME MONITORING OF GEOPHYSICAL DATA AND PETROPHYSICAL LAB STUDIES

The aim of this work at the University of Toronto, was to develop new tools and techniques that could permit the use of geophysics as a proxy to monitor stress distribution. Three current graduate students are working on various aspects: Mr. Ramin Saleh (PhD) and Mr. Jianing Zhang (MSc.) are engaged in computational studies to advance acquisition, processing and inversion capabilities of geophysical data; Mr. Ken Nurse (PhD) is researching new wireless seismic sensors for deployment underground. To date, new software for modeling of peak particle velocities in a 3D mine has also been developed and tested and the final data acquisition program at Nickel Rim South mine was completed in July, 2015. A further PhD candidate, Ms. Maria Wu, was recruited to assist with ongoing geotechnical analysis of drill core and the integration of borehole geophysical data. Collaborative input is being provided through the University of Alberta.

UNDERSTANDING ROCKMASS BEHAVIOUR AND STRESS AND DAMAGE DEVELOPMENT

At Queen's University, PhD candidate Mr. Gabe Walton successfully defended his thesis. It investigated how to make improvements to the quality/reliability of inelastic continuum models for rock mass behaviour in mines as well as to our understanding of stress and damage development in pillars. His work demonstrated that constitutive model (mathematical models describing the mechanical behaviour of materials) choices and the incorporation of dilation are significant for correct modelling and interpretation, with the latter playing a critical role in pillar stabilization. MSc. Candidates, Mr. Shaun O'Connor and Mr. Connor McAnuff, are attempting to quantify uncertainty, including interpretive uncertainty and its effects on geotechnical evaluations. As well, they are developing methods where far-field stresses can be more accurately estimated through inversion of tunnel deformation measurements, with collaborative input from Carleton University. Both projects, once completed, should offer new insights into mine design.

EXPERIMENTAL EVALUATION AND NUMERICAL SIMULATION

Two PhD candidates, Mr. Behrad Bahrani and Ms. Atena Pirayehgar, at the University of Waterloo, continue to make progress on two studies focused on the experimental evaluation of a Distributed Brillouin Sensing system and the numerical simulation of pre-conditioning of naturally fractured hard rock using hydraulic fracturing. Findings from the first project suggest that results from a commercially available strain measurement system are as expected when tensional force is applied. Under shear displacement, however, reliable and repeatable results are not so easily arrived at and more tests are required. Findings on the second project suggest that there is an optimal fluid injection distance for producing the desired rock mass response and that this needs to be incorporated into the rock mass pre-conditioning design process.

SUMIT ACHIEVEMENTS TO DATE



62 participants

conference presentations 60

14 refereed papers accepted

48 peer-reviewed journal articles published

14 articles in the review process

190 citations in general literature

SUMIT HQP DEVELOPMENT



2 post doctoral fellow

18 doctoral students

25 master's students

12 undergraduate students

1 research engineers

15 researchers

**ULTRA DEEP MINING NETWORK:
THE BUSINESS OF MINING DEEP—BELOW 2.5KM**

In 2013, CEMI identified an emerging need within the mining industry that required urgent attention—the need to solve ultra-deep mining challenges. Although some of the needs of the ultra-deep environment were being addressed through CEMI's DeepMine, ConstructMine and ValueMine themes, solving the special challenges of the ultra-deep environment required a more intense focus and attention. The Ultra-Deep Mining Network (UDMN) was the result. CEMI, together with its network of collaborating partners, was successful in getting federal funding for the UDMN through the Business-Led Network of Centres of Excellence (BL-NCE). UDMN brings a specific focus to the ultra-deep environment by utilizing and building on CEMI's disciplined approach to RD + I&C (research, demonstration + implementation & commercialization) to mining innovation. The commercialization aspect of the Network is one of the key reasons that the UDMN was awarded \$15M, which was further leveraged, resulting in a \$46M business-driven national network. The UDMN program will make CEMI the leading organization in Ultra-Deep (below 2.5km) bulk mining research and innovation, solving the challenges that impact resource extraction in these environments.

UDMN: THE NETWORK

The UDMN is a national business-led Networks of Centres of Excellence (BL-NCE), managed through CEMI, and supported by members of the mining, oil & gas industries, and with the active participation of small-to-medium sized enterprises, industry agencies, research facilities and academia. To date, the Network has 34 members, including three of the deepest mines in Canada, as well as two mining companies that principally operate in Quebec, and membership continues to grow. The UDMN has 28 approved projects that have been activated, including 20 projects that were part of the original BL-NCE application.

Greater Sudbury UDMN member mining supply and service companies will also benefit from additional local funding earmarked specifically for local members. In recognizing of the importance of UDMN, the Greater Sudbury Development Corporation (GSDC) is



UDMN'S FOUR AREAS OF FOCUS

 ROCK STRESS RISK REDUCTION	<p>Improve the control of stability in deep underground excavations <i>Current Projects: 9</i></p>
 ENERGY REDUCTION	<p>The 40% Mine; improve the energy consumption profile of deep mines <i>Current Projects: 7</i></p>
 MATERIAL TRANSPORTATION & PRODUCTIVITY	<p>Novel methods of material transport and productivity; increase the rates of development and production in mines <i>Current Projects: 8</i></p>
 IMPROVED HUMAN HEALTH & EFFECTIVENESS	<p>Enhance the human environment in deep mines <i>Current Projects: 4</i></p>

contributing \$1 million towards UDMN's Commercialization Attainment Program (CAP). CAP will assist small and medium sized businesses in Greater Sudbury to take maximum advantage of the UDMN project's large research network and realize emerging commercialization opportunities. CAP will operate as bridge between larger projects and local small-to-medium sized enterprises. The program will also assist local companies to identify opportunities, encourage local entrepreneurs to bring forward ideas and prototypes, and support the costs of testing and evaluation as local companies work to bring ideas to the market.

The UDMN also benefits from an affiliation with the Ontario Centres of Excellence (OCE). As a participant of OCE's Voucher for Industry Association R&D Challenge (VIA), the UDMN is able to connect with industry associations or groups of companies to address sector-wide research and development challenges. The UDMN is able to leverage OCE partnerships to further support start-ups, SMEs and large companies through projects with Ontario's publicly funded academic research institutions.

By supporting solution providers capable of creating the industry-needed tools and technologies, UDMN will lead the way in helping the ultra-deep mines operate more effectively and safely. The objective of the UDMN is to help the mining industry develop and adopt commercially viable research and development projects that result in the deployment of proven innovative technologies.

THINKING DEEP: PROPOSALS AND SELECTION RIGOUR

The UDMN established the Think Deep Program. Under this Program, project proposals for each of the four UDMN themes can be made. A cross Canada Call for

Proposals (CFP) was established in 2014, which generated 65 applications from small to medium sized enterprises (SMEs), suppliers, academia, research institutions and original equipment manufacturers (OEMs). Upon review of the proposals, 24 were accepted for the next stage and the selected participants were asked to submit a more detailed plan. Of the proposals moving up to the next stage, 83% were submitted by SMEs, 12% by academic institutions and 5% by OEMs. The CFP helped increase the awareness behind the UDMN, and importantly, set an unbiased tone for how ideas were accepted—the best ideas for ultra-deep mining, regardless of the industry or size of the organization.

This approach to project selection increased the confidence and credibility of the UDMN program. The process introduced a broader selection of ideas, established new connections and identified candidates for new UDMN projects.

To ensure a rigorous approach to the selection of proposals, the UDMN established the Industry Consultation Group (ICG), a third party group made of industry leaders. The mandate of the group is to provide input and guidance in the selection of projects that would benefit the future of Canadian underground mining innovations with a view to direct applications for operations. The ICG aided in determining a project proposal's viability and potential value for the industry. The ICG provides rigour and transparency to the selection process. Regardless of the business size or industry type, the projects are evaluated based on whether the solutions have the potential to address the needs of deep mining and have the potential to become viable businesses. The ICG is an essential component in assuring the success of the the UDMN in helping to solve Industry's deep mining challenges.

UDMN'S INDUSTRY CONSULTATION GROUP (ICG) OF ORGANIZATIONS:

- DUNDEE PRECIOUS METALS
- TOREX GOLD
- FALCO RESOURCES
- GOLDCORP
- SUDBURY INTEGRATED NICKEL OPERATIONS - A GLENCORE COMPANY
- KIDD OPERATIONS - A GLENCORE COMPANY
- GLENCORE - RAGLAN
- GLENCORE - MATAGAMI MINES
- HUBBAY MINERALS
- IAMGOLD
- VALE



FINDMINE | EXPLORATION

Step-change research in the area of exploration (new deposits, expanded mines) and geophysics, both surface and underground, is strategically important to mining sustainability.



INDUSTRIAL RESEARCH CHAIR IN GEOPHYSICS 2010-2015

The Industrial Research Chair in Exploration Geophysics, held by Dr. Richard Smith, will have completed its five year mandate in September 2015. The objectives of the Chair were to: increase the discovery and development potential of new ore bodies or mines through the creation of advanced geophysical tools; develop new methodologies for a better understanding of rock mass physical

properties in order to reduce the risk profile associated with underground mining; and train students to become highly qualified personnel (HQP) in new geophysical methods in order to explore for mineral deposits more effectively. In all, 25 students have been trained in Geophysics since the establishment of the Chair in 2010.

RESEARCH RESULTS

THEME 1: APPLICATION OF GEOPHYSICS TO THE STUDY OF GEOLOGICAL PROBLEMS IN THE SUDBURY BASIN.

- A. Modelling has shown that there could be a dense (possibly mafic) block that had been thrust upwards close to the surface, potentially bringing host rocks for contact deposits within 4 km of the surface.

THEME 2: PHYSICAL PROPERTIES MEASUREMENTS—THE LINK BETWEEN GEOPHYSICS AND THE GEOLOGY.

- A. Different tools for measuring conductivity have different ranges of sensitivity, so in order to characterize rocks, a number of tools will be required depending on the type of task(s).

THEME 3: COLLECTING AND PROCESSING ELECTROMAGNETIC DATA.

- A. A novel methodology for collecting electromagnetic data, deployed with multiple receivers and transmitters, can result in increased signal-to-noise ratios. It has greater depth reaching capacity than conventional tools.
- B. A tool for displaying all the data from this new system was developed.

THEME 4: DEVELOPING NEW TOOLS TO MODEL ELECTROMAGNETIC DATA.

- A. A tool for modelling radio imaging (RIM) data.
- B. Synthetic RIM data for more complex situations.

SPATIAL DISTRIBUTION AND GENETIC MODELS OF CU-NI-PGE SYSTEMS ASSOCIATED WITH THE SUDBURY STRUCTURE

Five sub-projects were initiated in 2010 with the Mineral Exploration Research Centre (MERC) within the Department of Earth Sciences at Laurentian University.

Two of the projects are complete. An update on the remaining projects is summarized below:

UPDATES

UPDATE 1: EXPERIMENTAL STUDIES OF THE ROLE OF BI, TE & AS IN PGE FRACTIONATION AND REMOBILIZATION DURING SULFIDE LIQUID FRACTIONATION DURING METAMORPHISM.

- A. Au, Pt and Rh fractionated from other HSE's and were transported away from the sulphide mass between 900°C and 600°C.
- B. Neither As, Te nor Bi were responsible for fractionation or the transport of HSE's.
- C. Hydrothermal fluid was not necessary for fractionation or mobilization.

UPDATE 2: EVOLUTION OF THE SUDBURY IGNEOUS COMPLEX CONTACT METAMORPHIC AUREOLE AND CONTROLS ON ANATEXIS.

- A. Identified, defined and mapped the distribution of an extensive zone of two-pyroxene hornfels rocks that definitively outline the SIC contact metamorphic aureole in a portion of the South Range.
- B. No significant mineralization was observed spatially associated with partial melt patches on surface; however, one partial melt patch in drill core was associated with Cu (>2900 ppm) and Ni (1158 ppm) mineralization.

UPDATE 3: THE ROLE OF FLUIDS IN THE FORMATION AND MODIFICATION AND FORMATION OF CU-NI-PGE SYSTEMS.

- A. The hydrothermal system in the upper part of the SIC is characterized by an incursion of two fluid types (as determined from fluid inclusions).
- B. Extensive mineralogical and textural evidence for pervasive metasomatism extending from the SIC contact to the distal footwall.
- C. Alteration assemblages can be used as a vector towards mineralization but become inconsistent in the distal footwall.



THE SEARCH FOR UNCONVENTIONAL ORES AT THE SUDBURY STRUCTURE: OFFSET DYKE AND SUDBURY BRECCIA-HOSTED DEPOSITS

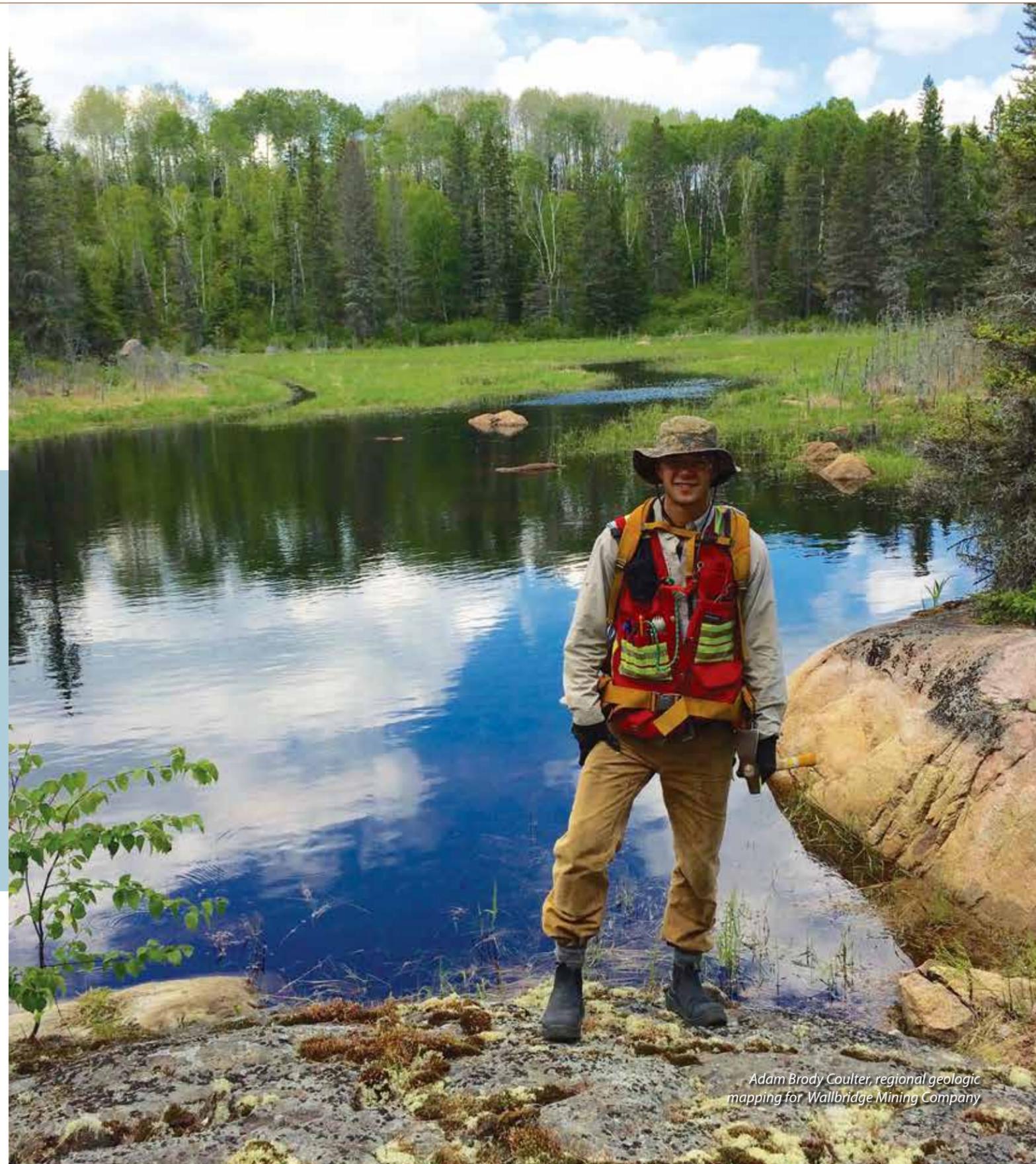
A partnership between CEMI, Wallbridge Mining Company Limited, Mitacs and the University of Western Ontario was established to study one of the most important mining sites in Canada—the Sudbury Structure. The research continues to answer a series of questions concerning the origin of Sudbury Breccia, host to footwall vein deposits, and Offset Dykes at Sudbury and their mineralization.

This project involves 11 students (2 MSc., 2 PhD, 3 PDFs, 4 undergrads) working alongside Dr. Gordon Osinski of the University of Western Ontario.

In June, 2015, Dr. Osinski was awarded a renewal of his NSERC IRC (Industrial Research Chair). Named the NSERC/MDA/CSA/CEMI Industrial Research Chair in Earth and Space Exploration, the award for \$750K covers a 5-year period.

FINDINGS

- 1 Current evidence is more consistent with the single injection and flow differentiation method of emplacement of offset dykes.
- 2 Data analysis shows that QD and IQD are similar in terms of major and trace element concentrations, but differ slightly in terms of Sr and REE concentrations.
- 3 QD and IQD from the North Range are compositionally distinct from equivalent phases in the South Range in terms of major and REE concentrations.
- 4 Major and trace elements are consistent with the formation of Sudbury Breccia by in-situ melting and do not require a component of the SIC.



Adam Brody Coulter, regional geologic mapping for Wallbridge Mining Company

DEEPMINE | DEEP MINING

New technologies and processes to ensure safe, profitable mining at depth, with a focus on risk mitigation, mechanized underground excavation, cost reduction and product enhancement.



EVALUATION OF FAULT-SLIP POTENTIAL IN UNDERGROUND MINES

CEMI and Vale are working with McGill University's Dr. Hani Mitri and Dr. Atsushi Sainoki (PDF) on two projects. The first is to establish and validate a numerical simulation technique to adequately describe the dynamic behaviour of fault-slip in underground mines. The second, the development of a practical methodology for the estimation of fault slip potential in terms of locations and magnitudes for a planned sequence of mining activities.

A case study on both these projects is currently underway at a Vale mine in Sudbury. Dynamic numerical modelling of fault slip will be performed with FLAC3D and 3DEC. The knowledge gained from this study will help in the detection of burst-prone areas in deep mining, based not only on the stress state, but also on geological data, especially fracture properties (density, length and orientations).

METHODOLOGY

FLAC3D - DYNAMIC

- Generating a numerical model encompassing geological structures and an orebody with mining sequence
- Determining initial stress states and a dynamic friction law with back analysis in terms of seismic source parameters and PPV

REGRESSION ANALYSIS

- Correlating factors pertaining to fault slip, such as mining rates, initial stress states, fault properties, with the seismic source parameters and PPV

Research Methodology that uses a case study approach to validate a numerical simulation technique to estimate fault slip potential in a deep mine.

UPDATING MOFRAC: FRACTURE NETWORK MODELING CODE WITH A DIFFERENCE

MOFRAC, the discrete fracture network modeling software is unique because it pays strict attention to fundamental geology principles, respecting geological input data better than any other tool of its kind.

The project, led by CEMI, in partnership with Ontario's Nuclear Waste Management Organization (NWMO), MIRARCO, as well as R. Mohan Srivastava—the original developer of the computer software, is being upgraded so that it can be used more broadly and effectively by the mining and nuclear waste management industries.

Additional research is required to further develop and optimize the tool. In 2015, Dr. Ming Cai of Laurentian University was awarded an NSERC grant in the amount of \$406K over 4 years for his project titled, "Improving the Reliability of Geotechnical Design by Incorporating Realistic 3D DFN Modeling". The grant will also fund the following: a Computational Sciences Master's study at MIRARCO; 1 PDF at MIRARCO; 1 Computational Sciences MSc at Laurentian University; 1 Engineering PhD at Laurentian University; and 1 Engineering PhD at the University of Alberta.

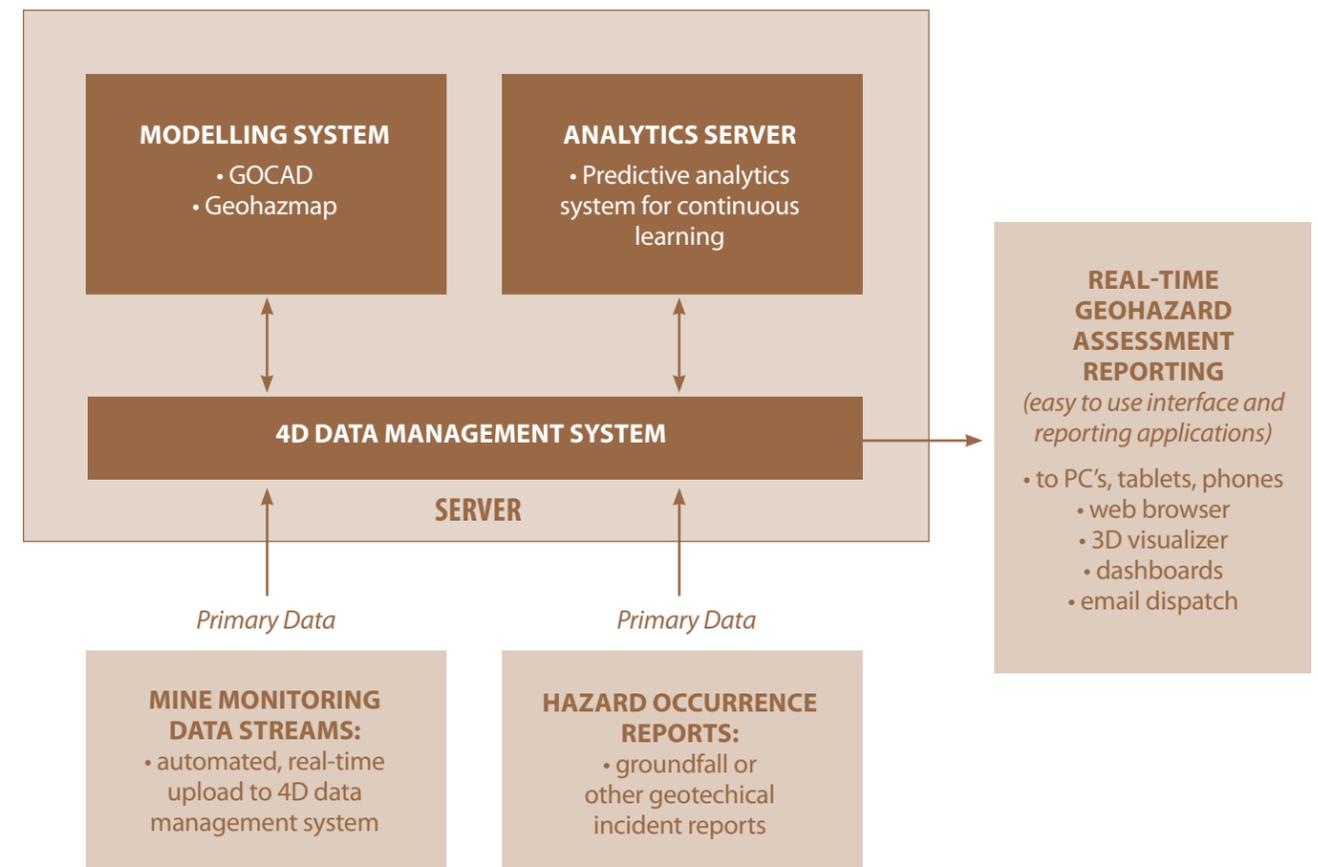
MINING OBSERVATORY DATA CONTROL CENTRE (MODCC)

MODCC will become the secure hub to store and manage data for the global mining industry. This project is a collaborative effort with CEMI, SNOLAB, CMIC and NOHFC. Located in Sudbury as a surface installation at SNOLAB, MODCC will be a significant contributor for economic development and investment in Northern Ontario. Construction at the MODCC is almost complete. Objectivity and Mira Geoscience, two SMEs specializing in mining data analysis, will initially occupy the facility and provide specialized data analysis/management services.

Mira Geoscience's 4D data management system, "Geoscience INTEGRATOR"—initially funded through SUMIT and MODCC programs, will continue its development within CEMI's UDMN program. When completed, the system will support, track, and automatically report on 4D dynamic mine models and associated geohazards by facilitating real-time access and use of primary data. John McGaughey, President, Mira Geoscience remarked on the impact and value of the MODCC to researchers and industry, that it "...facilitates deep mining research by creating an appropriate structure for collecting, standardizing, storing and sharing mining datasets with research and development entities in a controlled manner."

Objectivity's DRX Drillhole Optimizer is designed to connect and retrieve data from the Mira Geoscience INTERGRATOR 4D database. With this capacity, the DRX will be able to query historical drillholes and geology shapes within the INTEGRATOR system.

Also a part of the MODCC, CMIC's "Footprints Project Data Integration Specialist" is focused on preliminary statistical analysis of large case study data sets. It will enable the development of knowledge/technology transfer mechanisms between the SME community, industry and academic researchers.



System schematic for development of the 4D data management approach.

VALUEMINE | INTEGRATED MINE ENGINEERING

Innovations in mine process engineering, mine design and enabling technologies to enhance safety and performance, increase production rates and minimize impact and cost risk.



IMPROVING MINE PERFORMANCE

The batch mining process commonly used in underground base-metal mines is capital intensive. CEMI continues to investigate and push forward in finding ways to improve the cost effectiveness and lean the underground production process by re-designing the individual, discrete tasks in a process so they can be managed as a series of simple, linked tasks. This will help to maximize the utilization of the face and facilitate productive utilization of the stope. The goal is to extend this as a series of mining processes, understand their interconnectedness and look for ways to improve overall productivity. In turn, this will facilitate process automation.

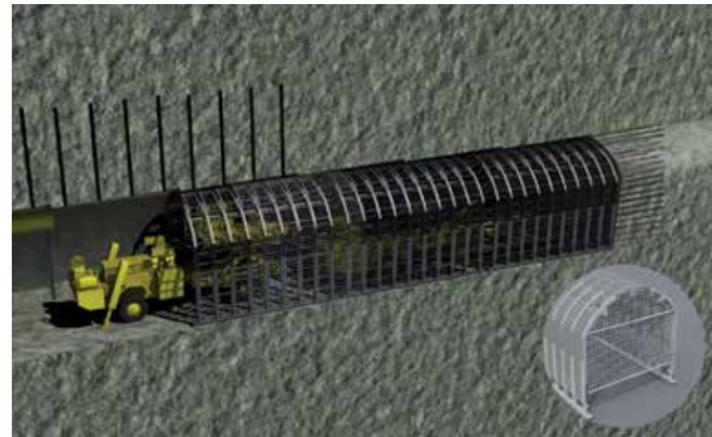
CEMI has initiated four projects through a collaborative effort between industry, SMEs, consultants and researchers in identifying needs, addressing issues and developing potential solutions.

IMPROVING DRIFT DEVELOPMENT

CEMI's approach to drift development is to maximize utilization of the face. Underground mine development has been a linear process—removing broken rock from the face (mucking), installing ground support, drilling the face (including preparatory activities for drilling) and charging the holes with explosives and initiators. The sequential nature of these activities and the time lost to equipment entry and re-entry reduces face utilization and decreases the rate of advance.

Single Heading Lateral Development— 3 Canopy System

This system protects the face machine and operators and provides support to protect ground support equipment and operators, allowing for drilling and charging of the face to occur concurrently while ground support is being installed behind the face equipment. Functionality tests and strength test for the canopy have been performed on the prototypes—aboveground and at the former MTI (now Joy Global) underground test mine site. Simulation tests were also conducted to help further refine the design for field trials. This is to ensure if the canopy design has addressed the issues of what is required to move forward for in-situ use.



Canopy system allows for the canopies to be adjusted as required. At the face (right), is the Face Advancing Canopy, with a face shield (see inset for close-up) that fully protects both crew and machinery. The Jumbo is protected within the canopy system and is able to advance as required. To the left is the area where ground support installation is done with a bolting unit. The screen is held in position by the canopy.

Next steps include the development of prototypes to be used for actual operational trials and time studies to quantify productivity gains, and optimize performance and convenience. A number of mining organizations are interested in the outcome given the benefits.

BENEFITS

INCREASED PRODUCTIVITY—reduce cycle duration by allowing face drilling and concurrent ground support installation, and eliminate the need to bolt and screen the face.

IMPROVED SAFETY—consistent performance of an engineered structure, helps eliminate worker exposure to unsupported ground (back, walls, face), immediately and throughout the entire cycle; large falls of ground can be supported in static and dynamic applications.

FLEXIBILITY—can be modified to work with existing equipment and drift designs to: add or remove components; change the length for coverage of specific equipment; vary drift profiles and dimensions to the operational requirements.

ACCEPTABILITY AND CHANGE MANAGEMENT—the only change to the drift development process is the simple movement of the 3 canopy system into and out of the heading. No additional training/retraining to overcome.

EFFICIENT SCREEN HANDLING & REPAIRS—exposure of workers to unsupported ground and screen handling equipment can be eliminated. The screen is preloaded onto the canopy (under supported ground) and rock bolts are installed on a determined pattern for ground support.

IMMEDIATE RE-ENTRY WITH IN-CYCLE SHOTCRETE—can be installed immediately after shotcrete application, providing full protection to the crews, eliminating delays associated with shotcrete cure times.

Multiple Heading Development— Single Canopy System

A single canopy, with a retractable face shield can be used to improve efficiencies and safety in multiple heading scenarios. In the process of developing the 3 canopy system, CEMI realized that there is a need and opportunity to investigate a canopy system to address multiple headings. This project has been initiated and is under testing. Benefits include:

PRODUCTIVITY/EFFICIENCY IMPROVEMENT—reduced cycle time due to the elimination of bolting and screening of the face and more efficient screen handling.

IN-CYCLE SHOTCRETE—installation of the canopy system immediately after shotcrete application, providing full protection and eliminating delays due to shotcrete cure times.

PRODUCTION DRILLING—protection for crews while drilling and loading in production mining applications.

DRAW POINT MUCKING—brow protection for scoop operators with quick installation in draw points.

DRIFT REHAB—safely and efficiently performs drift rehabilitation.

EMERGENCY—quickly moves into an emergency area to aid in rescue efforts.



Mucking

This is the removal of broken rock or ore, before work starts on taking the next round advance. The current approach is using a front-end loader, a Load-Haul-Dump (LHD) unit to dig into the pile of rock, fill the bucket, retreat and perform a 3-point turn and drive forward to dump into a truck or another location. The process is repeated until all the rock is removed. The implications of this process is two-fold: the pile of rock is untouched 80%-90% of the total cycle time during transport of each load; need to excavate short tunnels perpendicular to the main tunnel to allow the LHD to turn around, adding about 15% of extra tunnel length and increased costs. A continuous mucking system (CMS) for rock removal will contribute to increased advance rates by reducing the time taken to remove the broken rock from the face, allowing the face advance equipment to return to the face. CEMI is currently considering the simulations and cost-analysis of this equipment necessary to fully understand all the implications and complexities of its use.

BACKFILL PRODUCTION: PASTE AND HYDRAULIC

Cemented hydraulic tailings have been the preferred means of backfilling in underground metal mining operations for decades, with many Northern Ontario mines already invested in the hydraulic backfill system. With the onset of bulk mining methods and open stoping, the cement content had to be increased to significant levels to ensure stability of free-standing stope walls (at least 60m high). The result was a significant increase in cost from preparation for filling, from materials and labour to build fill barricades, installation of drainage towers, and increased pour times to ensure sufficient time for the transportation water to drain. This all contributed to constraining the backfill rate and increasing the stope cycle time.

Paste tailings backfill have been used since the 1990s, which use a higher percentage of fines to retain the water and prevent separation of solids and water. The advantage of the tailings paste process is that it is a tightly controlled mix design, which allows for

a designed performance of the fill, and the lower porosity of the material means less cement for a given in-situ design strength. The benefit of tailings paste fill is a higher reliability of backfill product placed, with designed performance characteristics and a reduction in stope cycle time.

CEMI employed Labreque Technologies Inc. to perform simulations of a standard, bulk open-stoping-with-fill production system and compare the stope cycle time for hydraulic fill and for paste fill (Figure 1). The cost of a paste fill plant has a higher capital cost, but it is important to understand all aspects of the cost including: input costs (cement), impact of higher strength, decrease in stope cycle time, impact on production and operating costs.

The findings show that by introducing paste fill, it is possible to increase production rate by 40-50%, in Scenario 3 & 4. In contrast, the same scenarios increase the stope cycle time due to the increase in the number and duration of the delays related to preparing stopes for backfilling with hydraulic fill.

Actual mucking time can be defined as time generating revenues (revenue time), while the time for other activities is considered time absorbing costs (cost time). Scenarios 1, 2 & 3 indicate mucking at 16% for hydraulic system, regardless of the number of LHDs or the amount of drilling; and dropping to 12% for Scenario 4 because of the delays for fill preparation. For the paste fill system, mucking time increases in Scenario 3 & 4, and the increased amount of drilling allows the amount of mucking to increase by about 30%. Mine production is constrained by the backfill rate. Since the overall fill rate of paste is faster than hydraulic fill, there is an opportunity to increase the production rate.

Overall, the simulation results show that a superior, backfill system, with the correct mix design can significantly increase the amount of production or reduce the cost of a given production rate. Significantly, with the hydraulic backfill system, production is limited regardless of what additional equipment is brought to bear and production cannot

be increased. The study findings have been made available and can be downloaded on the CEMI website.

MINE DESIGN

CEMI has been investigating mine design innovations to help reduce or better manage up front capital costs when it comes to accessing and mining new orebodies. The conventional approach is to identify the lowest production level and invest in mine infrastructure by mining bottom-up using open-stoping with fill. The consequence of this approach is a delay in first production caused by the need to complete capital infrastructure to the lowest production horizon. Technical advances such as high-strength paste-fill make it possible to consider top-down production using open-stoping with backfill. The top-down approach allows for incremental capital development, no more than one or two levels below the lowest production horizon. The potential benefits are a reduction in the up-front capital cost and a shortened time to first production, but at the expense of higher direct cost for blasting and backfilling activities.

Simulations conducted by Labreque Technologies Inc., on behalf of CEMI indicate:

1. Shorter time to first production;
2. Lower upfront capital demand; and
3. Higher net present value (NPV).

These findings are of particular interest given the industry's need to mine deeper, requiring an increased amount of development to manage the ambient stress and with each stope offering fewer tonnes as well, the need for faster cycle time. Regardless, there is a need to identify and investigate mine design innovations that will help the industry proceed sooner to finding new orebodies by better managing their ability to release capital fund and providing shareholders with a timely return on their investment.

STOPE LIFE SCENARIOS:	1. PASTE VS. HYDRAULIC FILL-1LHD	2. PASTE VS. HYDRAULIC FILL-2LHD	3: PASTE VS. HYDRAULIC FILL-2X DRILLING, 1LHD	4. PASTE VS. HYDRAULIC FILL-2X DRILLING, 2LHD
STOPE CYCLE TIME:				
Paste:	51.1 days	48.3 days	33.8 days	30 days
Hydraulic:	58.4 days	58.4 days	64.2 days	75.7 days
% OF TIME SPENT: OTHER ACTIVITIES (Cost Time)				
Paste:	82%	81%	72%	69%
Hydraulic:	84%	84%	85%	88%
% OF TIME SPENT: MUCKING (Revenue Time)				
Paste:	18%	19%	28%	31%
Hydraulic:	16%	16%	15%	12%

Figure 1: Simulation results of the stope cycle time of various scenarios.

CONSTRUCTMINE | UNDERGROUND MINE CONSTRUCTION

Strategic research and development for safe, rapid, mechanized development of underground mines.



RIO TINTO CENTRE FOR UNDERGROUND MINE CONSTRUCTION

The Rio Tinto Centre for Underground Mine Construction (RTC-UMC) at CEMI continues to push forward in developing and designing innovative support methods for different excavation systems and also investigating advanced rock mass characterization technologies for pillar design and underground excavation stability.

ENHANCED FOOTPRINT RELIABILITY

In 2015, RTC-UMC continued its focus on delivering value to Rio Tinto and its operations through “enhanced footprint reliability”, which implies less unforeseen rehabilitation, fewer losses of drawpoints, and thus fewer delays in ore recovery. This will help to ramp-up projects with less uncertainty while introducing more flexibility into the production schedules. Improved support design has been the focus of work since being

identified as a key factor in speeding up development, while reducing ongoing rehabilitation costs. The work program, initiated in mid-2014, recognizes that in order to improve support of the footprint (extraction level), one needs to anticipate both the demand on, and deformation response of extraction level pillars.

To date this year, a combination of experimental (lab), in-situ, and numerical studies (Figure 1) were carried out to substantially improve knowledge of, and enhance predictive techniques for extraction level demand/response and support performance. The ultimate goal being, to provide improved support design guidelines tailored to extraction level development in deep, massive rock. To achieve these goals, RTC-UMC worked with partners in Rio Tinto, academia and consulting in Canada, Chile and the USA.

On the pillar demand side, RTC-UMC worked with MIRARCO and Rio Tinto staff to implement a pillar monitoring study at two mines. The aim of the study is to quantify the impact of draw control strategy on pillar loads and deformation using borehole stress meters and

extensometers, which were installed in both the minor and major apexes of pillars located in areas of active draw. The Centre will start to work with Rio Tinto staff on analysis and interpretation, now that data from the installation has become available.

In parallel with these in-situ studies, a number of lab studies employing scaled physical models were carried out at the University of Chile in order to pursue a more systematic investigation of pillar loads as a function of draw strategy. The studies, concluded in June, reached a number of practical conclusions regarding the potential maximum and minimum loads that might be experienced (relative to average cave load) and provided preliminary recommendations for draw control in order to avoid load concentrations.

On the pillar response side, RTC-UMC continues working with Itasca, the University of British Columbia and

the University of Toronto to further develop Bonded Block Modelling (BBM), as a state-of-the-art tool for the prediction of explicit spalling, bulking and ground support performance in extraction levels. This work presents a significant challenge as it demands three-dimensional analysis (due to the significant geometric controls on pillar performance at extraction drift/draw drift intersections) and requires careful consideration of the highly localized straining of support elements at discrete fractures that are both opening and shearing. A number of key advances were achieved. The plan is to put this technology in the hands of Rio Tinto staff by the end of 2015, so that it can be tested, validated and applied within ground support studies across a number of projects and operations.

KEY ADVANCES

- The successful back analysis of a number of triaxial tests on veined rock with BBM.
- The development of techniques for construction and simulation of 3D extraction level models, that can exhibit realistic fracturing and bulking under load cycling.
- In the simulation of support elements that can resist (or fail in the presence of) both opening and shear fractures and also be plated and made sensitive to changes in confinement.

BEST PRACTICES GUIDELINES

Building on the procedure developed in 2014, the Centre continues to work with Rio Tinto in refining the Best Practices for logging, testing and strength characterization of rock masses. In 2015, the Centre will deliver a companion document covering Best Practices for ground support design, with special consideration of the spalling ground conditions and large deformations that characterize deep extraction levels in higher quality rock. The results of in-situ studies by MIRARCO (field testing

of hybrid bolts) and numerical studies at Simon Fraser University (optimizing support in burst-prone ground) will provide data to assist in the development of these guidelines.

The Centre will also deliver a report in 2015 that documents the outcomes of the first 5 years of RTC-UMC and provides a road map for the future, building on the successes of the Centre to date.

ROAD MAP FOR THE FUTURE BASED ON THE OUTCOME OF THE FIRST 5 YEARS OF RTC-UMC

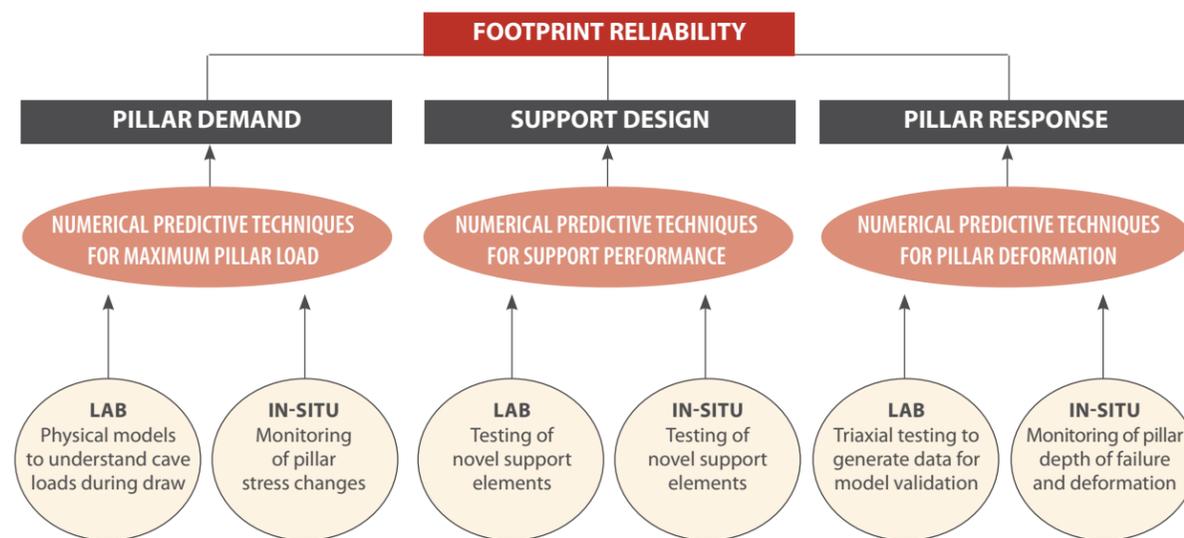


Figure 1: Research plan to support improvement of footprint reliability at Rio Tinto caving operations.

SUSTAINMINE | ENVIRONMENT & SUSTAINABILITY

Research and innovation projects that focus on the identification of processes in order to achieve more environmentally benign results and better stewardship of mineral resources.



TAILINGS REMEDIATION APPROACH

A viable and scalable mineral processing approach to facilitate long-term sustainable remediation of abandoned/orphaned small-to-medium tailings sites (less than 1 million tonnes). The key challenge for remediating these sites is the ability to access processing facilities and transportation, without incurring prohibitive costs. The opportunity and benefits for tailings remediation include the ability to:

- Convert sites that currently pose hazardous effects to humans, animals and plants to environmentally benign sites that meet government discharge standards to water and air.
- Minimize the cost of long term care and maintenance of the sites.
- Recover economic mineral in the form of saleable concentrates to assist in mitigating the cost of site remediation.

To date, a fully integrated roadmap detailing all the activities has been prepared. It outlines the objectives (business and technology), identifies the project management systems and processes, methodology and approach, scope, timelines, budget estimates, potential stakeholders, project framework and responsibilities.

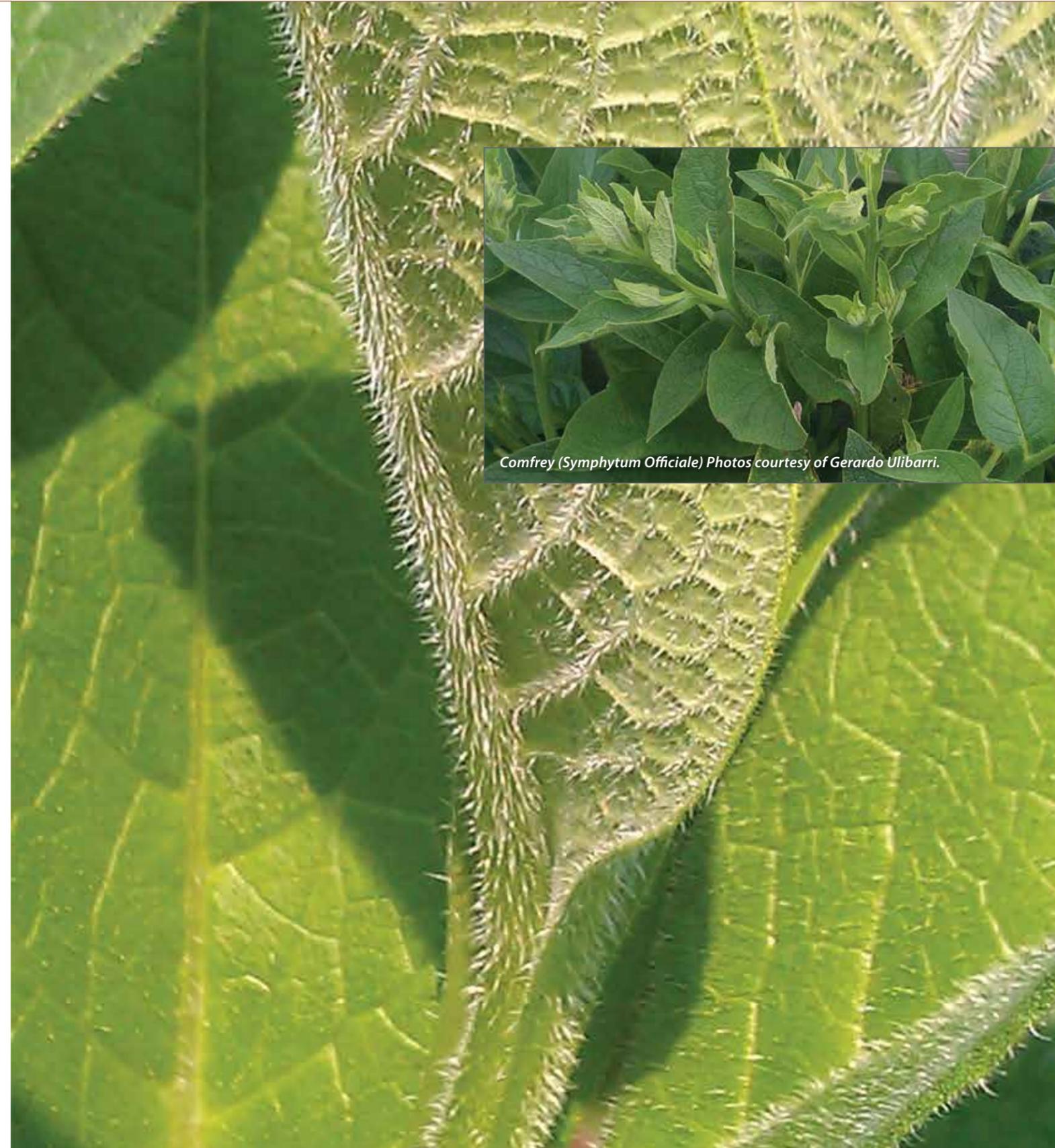
Initial discussions with the Ministry of Northern Development & Mines were positive and a Crown-controlled site approximately 100,000 tonnes in size near Sudbury was selected as a typical site for the pilot project demonstration proposal. A full project plan has been prepared which would incorporate all the elements of the modular pilot plant approach. Funding is now actively being sought for this project.

TEST BIO-REMEDIATION OF HEAVY METAL-CONTAMINATED TAILINGS UTILIZING COMFREY PLANT PROPERTIES

This project is a continuation of a previous investigation in assessing the utilization of comfrey plants in the absorption of heavy metal-contaminated tailings. Previous work showed that comfrey (*Symphytum Officiale*) successfully absorbed chromium, iron and zinc into the root system and nickel into the leaves and roots system.

The aim of the next phase of the project was to assess what additional materials were required to grow the plants on tailings and how this impacted the level of heavy metal uptake by the plants. Tests were conducted on various ratios of organics: tailings materials as a growth medium for the plants. The best growth medium ratio for the comfrey plants was a combination of 60% organic and 40% tailings. While there was uptake of heavy metals with 0% organic materials, the longevity of the plants' was limited. A ratio of 20% organics to 80% tailings was also less effective, as plants had difficulty growing. Tests included measuring uptake of various metals and the most significant was the uptake for Arsenic, Copper, Nickel and Lead. Other minerals of interest, like rare earth minerals, were also recovered. The growing need for these minerals as inputs for modern technologies may make extraction from tailings a viable option, since they are found in small quantities naturally, and the expense of extracting them through classical methods may be prohibitive.

Research is still required in understanding which organic materials would work the best. The next phase of the research, upon funding, will be to validate the process and assess for scalability, in terms of plants, absorption of metals, extraction of materials for re-use or further remediation of the smaller amounts. Other investigations would include the assessment of utilizing these plants for biofuels. Other benefits of growing these plants on tailings would be the potential of reducing fugitive dust through the establishment of a network of plant roots. Longer term, when the results of these investigations are available, this work could have a positive impact in new mine planning by addressing some of the tailings management issues.



Comfrey (Symphytum Officiale) Photos courtesy of Gerardo Ulibarri.

INNOVATION & PROSPERITY OFFICE (IPO)

ADVANCING INNOVATION

The Innovation & Prosperity Office (IPO) was established to work with the service and supply sector to help commercialize their mining innovations. This sector plays an essential role in the development of new products, technologies, services and processes, which contribute to improving productivity gains and enhancing profitability for the mining industry. In recognizing the importance of nurturing development of these innovations, CEMI established the IPO in 2011, with the support of the Greater Sudbury Development Corporation (GSDC).

CLOSING THE INNOVATION GAP WITH COMMERCIALIZATION

Successful acceptance of innovation goes beyond the technical validation and development of a product, service or process. A key impediment to the commercialization of innovations is operational acceptance. The role of the IPO is to bolster and support the mining service and supply SME's capacity for commercialization and speed to market for their innovations in order to achieve operational integration. This is the mark of successful innovation.

IPO services are based on a needs continuum. Depending on what is required, services can be general in nature, such as business advisory services, partnership development, industry networking and introductions to assist in collaborations. These services are offered at no cost and 58 companies took advantage of these opportunities during the year.

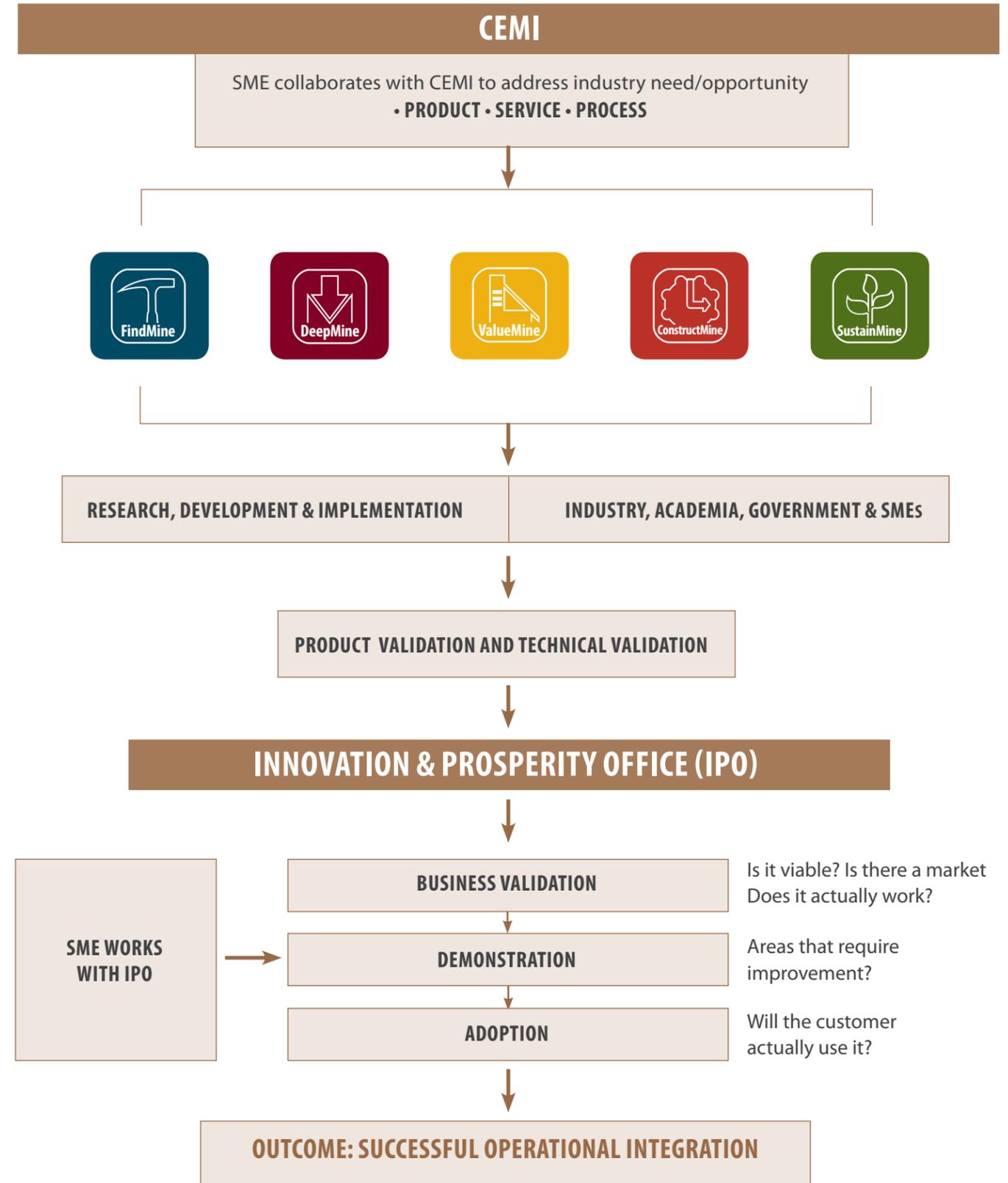
More intensive support is specific and tailored to the requirements of a particular SME. About two-thirds of the IPO involvement is in this area, and can include: in-depth advisory services, prototype development, demonstration projects, assessing manufacturing readiness, intellectual property & protection services, financial support, assisting in identifying resources (financial, advisory) market development and marketing support.

IMPLEMENTING INNOVATION SUCCESS

CEMI has set up the building blocks for the successful integration of mining innovation. Through the Innovation & Prosperity Office, service & supply SMEs can leverage CEMI resources and collaborate to achieve technical corroboration for their innovations. Working with industry, academia and government resources, potential innovations can be supported with research and validated through demonstration and implementation. Then, working with the Innovation & Prosperity Office directly, the SMEs can work to achieve operational integration and commercial acceptance.

The outcome of successful operational integration has multiple benefits. For individual SMEs, it is revenue growth, more resources and potentially, a wider market. For mining companies, it is productivity gains, improving operations and potential increase in profitability. For government, it is the development of a skilled labour pool, more jobs, stronger economic development and global leadership. For CEMI and the IPO, it is the continued growth and vibrancy of the mining industry and finding new ways to mine better, faster and safer.

WORKING WITH THE MINING SERVICE & SUPPLY SECTOR



IPO CONNECTIONS



IPO COLLABORATIONS

REVOLUTION MINING

Revolution Mining's flagship product, SOT, Schedule Optimization Tool, is the only software tool in the market to optimize the net present value of long term schedules for selective underground mining operations. The tool takes into account the precedence constraints for the myriad of excavation activities for access development and production within operational resources.

SOT was originally a project developed at MIRARCO and supported by CEMI. Lorrie Fava, President of Revolution Mining, oversaw the development of the tool, and understood the importance of the software in the marketplace. In 2014, she garnered the IP from MIRARCO and established Revolution Mining.

Working with the IPO at CEMI, Lorrie was able to navigate the licensing agreements, network with mining companies and consultants, get input in setting up an advisory board to help navigate the business development aspects. For Lorrie, the "IPO helped in making it a win-win for MIRARCO and Revolution Mining."

Although SOT has been commercially available for the last six years through Datamine and Deswik, the focus on commercialization through Revolution Mining has resulted in SOT gaining the attention of a number of mining companies, with eight new companies adopting the software into their planning activities.

For Lorrie, working with the IPO meant that she was not on this "journey alone".

COLDBLOCK TECHNOLOGIES INC

ColdBlock™ Digestion is a sample digestion technology used in laboratories to dissolve solid matter into a solution for instrumental multi-element analysis. It uses focused short-wave infrared radiation (IR) which allows laboratory technicians to shorten sample preparation time, accelerate sample throughput and achieve productivity gains. The benefits of the technology are accuracy and precision, rapid sample digestion, ease of use, and reduced requirement of hazardous reagents. It is a safer and greener technology.

CEMI has been a collaborating partner with ColdBlock Technologies for six years, along with other partners, Brock University, NSERC, OCE, BioLinc, RIC Centre,

Nucomat, Mantech and Barrick. The IPO is currently working with ColdBlock by assisting in the demonstration of the technology and gaining operational acceptance of the technology within the mining industry. Nick Kuryluk, president of Coldblock Technologies considers the work with the IPO as a "very exciting and successful collaboration."

IPO COLLABORATIONS



1 - Collaborators travelled to Sudbury from Vancouver, Nevada, Denver, and as far away as Perth Australia to participate in the SOT+ project workshop in May. Sponsor companies Vale, Newmont, Datamine and Deswik and Curtin University were present. 2 - Kirill Pereverzev, Product Specialist working on ColdBlock technology.



3 - ColdBlock sample digestion technology in action
4 - From left to right: Ron Emburgh (ColdBlock Technologies, President, Marketing & Sales), Kirill Pereverzev (ColdBlock Technologies, Product Specialist), Eric Maag (CEMI, IPO Director), Nick Kuryluk (ColdBlock Technologies, CEO), Dr. Matthew Leybourne (Laurentian University, Associate Professor)

CEMI actively sponsors, supports and disseminates knowledge related to relevant issues and research within the mining industry through knowledge transfer and by developing knowledge.

SPONSORING KNOWLEDGE TRANSFER

CEMI provides access to innovative research by actively sponsoring and participating in a series of lectures, training, technical presentations, short courses, workshops, forums and industry conferences, with robust participation from collaborating industry partners, academic institutions and students, SMEs, and government.

MINE BACKFILL - DESIGN AND INTEGRATION SHORT COURSE

The Mine Backfill educational session, a three-day short course, was offered by local SME, Paterson and Cooke and facilitated by CEMI's Innovation & Prosperity Office at the Willet Green Miller Centre. Comprising of 26 lectures, case studies and lab demonstrations, the objective of the course was to provide training on how to integrate backfill successfully within the mining cycle. Aspects of this intensive course included: understanding the requirements, the material properties, process engineering, hydraulic reticulation design, geo-mechanics, placement strategies and effective operational management.

The course was an ideal example of how CEMI and its Innovation and Prosperity Office work with local SMEs to bolster and support their capacity for commercialization and speed to market of their innovations.

CEMI President & CEO, Douglas Morrison was a guest lecturer at the course, promoting the innovative solutions at CEMI, UDMN and our partner organizations to a largely international audience. Over 30 participants from industry (mid-to-high management levels) attended the short course, representing 15 international companies.

SEVENTH INTERNATIONAL CONFERENCE ON DEEP AND HIGH STRESS MINING

The Seventh International Conference on Deep and High Stress Mining, held in Sudbury, Ontario showcased CEMI's contributions and expertise in deep underground mining research and innovation. Bringing together over 300 mining personnel, consultants and researchers from around the world, the conference provided an opportunity to present the research being done at CEMI in areas of continuous bulk production, rapid development rates and geotechnical risk and database management in deep, high stress mines.

Douglas Morrison, CEMI President & CEO, took part in a plenary session to discuss CEMI's approach to facilitate a cost-effective, semi-continuous ore production process with 100% utilization of the face and maximum productive utilization of the stope. He also presented CEMI's approach to increase development rates through a focus on face utilization, while ensuring the safety of the workforce at all times. Damien Duff, CEMI's VP of Geoscience and Geotechnical R&D, also presented CEMI's work in

translating new knowledge into practical and effective tools for geotechnical risk and database management in deep high stress mines.

CIM CONFERENCE 2015

CEMI's participation at the 2015 CIM Conference in Montreal, QC focused on the significant progress being made by the Ultra-Deep Mining Network. The network continues to work closely with its members to ensure the successful deployment of proven innovative technologies.

Jannatec Technologies, a network member with the UDMN, was in attendance at the CIM conference to

INVESTING IN KNOWLEDGE



1 - CEMI President and CEO, Douglas Morrison.
 2 - Jannatec and UDMN promoting their partnership at the CIM conference in Montreal. (L-R: Rey Boucher, Wayne Ablitt, Douglas Morrison and Stephen Podrucky)
 3 - Eric Maag, Commercialization Director, UDMN speaks with Michel Bisson, President and CEO of STC Footwear at CIM Conference.

showcase its two UDMN projects, which fall under the Improved Human Health theme:

Project 1: A wearable communication system designed to interface with high-speed wireless underground communication systems. It will feature tracking options, collision avoidance, proximity detection assistance and data management.

Project 2: A personal thermal management system designed to track, assess and manage the human/environmental interactions. It will have the capability for biofeedback, and the ability to track wet bulb temperatures, oxygen levels, and particulate matter concentrations and have the capacity for cooling, as required.

UDMN looks forward to showcasing more projects and network members at the CIM in 2016 in Vancouver, BC.

As part of the CIM technical program, CEMI President and CEO, Douglas Morrison and VP of Business Innovation Brian Jones, presented a paper on

CEMI's approach to developing and applying innovation through lean mining. As companies require 200% - 300% higher productivity, they must develop simple and continuous processes that use highly effective mechanical and tele-operational systems. Some of the innovations presented to improve mine performance and achieve lean mining included increasing drill and blast rates, improved production effectiveness through continuous draw-point mucking, paste fill, in-line crushing, waste sorting, continuous transport of sulfides and a reduction in energy requirements, as well as increasing human effectiveness through integrated Personnel Protective Equipment.

DISCOVERY OCE CONFERENCE 2015

Hosted by the Ontario Centres of Excellence (OCE), Discovery brings together over 2,600 key players from industry, academia, government and the investment community as well as entrepreneurs and students interested in pursuing collaboration opportunities.

Recognized as a leader in mining innovation, CEMI encourages collaboration opportunities with industry, small-to-medium enterprises (SMEs), academia, government and the investment community. As a representative of the mining industry and an active participant, CEMI shared information on important developments in the mining sector with attendees from other business sectors across Ontario and Canada. Highlighting the Ultra-Deep Mining Network's latest innovations side-by-side with its federal funding partner NCE demonstrated the collaborative approach to promoting BL-NCE programs, with the UDMN as a successful example of an ongoing NCE network.

PDAC CONVENTION 2015

CEMI was pleased to participate in the FedNor sponsored Northern Ontario Supplier Showcase as part of the Prospectors and Developers Association of

Canada's 2015 Convention. In addition to highlighting the work being done by the Innovation and Prosperity Office, the convention featured the introduction of CEMI's partnership with Canadian start-up ColdBlock™ Technologies Inc.

Addressing the need for more innovation in the mining industry, ColdBlock has partnered with several groups, including CEMI, to create its pioneering ColdBlock Laboratory Sample Digestion Technology. ColdBlock Digestion is a new and innovative sample digestion technology using focused short-wave infrared radiation to primarily energize the sample's particles. This unique method rapidly dissolves solid matter into a solution for instrumental multi-element analysis, offering mining operations a new alternative to achieve productivity gains.

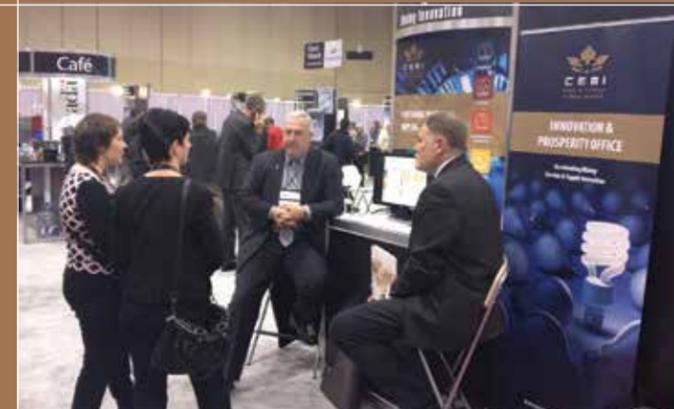
In addition to providing funding, CEMI has also been instrumental in supporting the commercialization of this innovative technology.

INVESTING IN KNOWLEDGE

7



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6



6 - Damien Duff, VP, Geoscience and Geotechnical R&D at CEMI, speaks with PDAC Delegate
7 - Dick DeStefano (SAMSAA), Kirk Petroski (Symbolicware), Don Duval (NORCAT), Brian Jones (Vice President, Business Innovation at CEMI) and Greg Baiden (Penguin Automated Systems Inc.) at Greater Sudbury Vital Signs Report Panel Discussion

8



9



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8 - Dr. Pinnaduwa H.S.W. Kulatilake, University of Arizona, with Damien Duff, VP, Geoscience and Geotechnical R&D at CEMI.

9 - Dr. Christopher Bown, Patent Agent and Mr. Jamie Hollingworth, Associate from Gowlings.

10 - Laurie Bissonette, Partner KPMG LLP, Geoff MacDonald, Partner, Tax & SR&ED, and Eric Maag, Director of Innovation & Prosperity Office at CEMI.

11 - Filming of the SR&ED Credits Lecture with Geoff MacDonald of KPMG.

GREATER SUDBURY VITAL SIGNS REPORT

In October 2014, the Sudbury Community Foundation launched its annual Greater Sudbury Vital Signs Report. The Vital Signs report is published and distributed Canada-wide. It measures the strengths and weaknesses of its communities, identifies significant patterns, and provides a snapshot of the quality of life of each community. Vital Signs is coordinated nationally by Community Foundations of Canada.

The 2014 Greater Sudbury edition focused on mining innovation. It highlighted some of the companies and organizations that are contributing to the future of today's mining industry.

As Honorary Chair of the 2014 Report, CEMI President and CEO Douglas Morrison, highlighted Sudbury as one of Ontario's greatest mining hubs, and a leader in mining innovation, contributing to improvements in health, safety and productivity. "In today's modern society, the mining industry continues to face new challenges in terms of productivity and mine waste management, and the Sudbury Mining Cluster will again be at the forefront of addressing these issues."

The report was launched together with a panel discussion on the state of mining innovation in Sudbury. Moderated by Dick DeStefano (SAMSSA), the panel featured local innovators Kirk Petroski (Symbolicware), Don Duval (NORCAT), Greg Baiden (Penguin Automated Systems Inc.) and Brian Jones (Vice President -Business Innovation at CEMI).

CEMI LECTURE SERIES ON DEMAND

The CEMI Lecture Series focuses on addressing new ideas, innovations, industry challenges and relevant topics within the mining field. Speakers include leading academic and industry keynote speakers from around the world. Topics covered include:

- a) "Required Data and Computational Techniques to Investigate Deformation and Stability around Underground Mine Excavations in Three Dimensions", presented by Dr. Pinnaduwa H.S.W. Kulatilake, University of Arizona.

Currently available sophisticated, powerful 3-D stress analyses software does not have the capability to model the complex lithological system and the major discontinuity pattern that exist in rock mass. This complexity presents challenges in predicting, with any certainty, the deformation and stability around underground excavations in 3-D. Using previously conducted case studies, Dr. Kulatilake demonstrated the necessity in comparing numerical predictions with measured field deformations and stresses.

- b) "The Great Debate: Patent versus Trade Secret", presented by Dr. Christopher Bown and Jamie Hollingworth, Gowlings.

The answer to the all-important question, "Should I patent my intellectual property (IP) or keep it a trade secret?" is what every entrepreneur wants to know. Facilitated by the UDMN and IPO, participants were given the opportunity to learn about the legal differences between two types of IP, the pros and cons of patents versus trade secrets and how to decide which type of protection is best suited for their needs. The discussion concluded with a review of IP disclosure in a Merger & Acquisition context.

- c) "Scientific Research and Experimental Development (SR&ED) Credits", presented Geoff MacDonald, KPMG LLP.

A program of key importance for SMEs is the SR&ED program. Tax Partner, Tax Incentives Leader with KPMG LLP, Geoff MacDonald held a session featuring a basic overview of the SR&ED program, discussing the potential impact of recent changes to eligibility and recent court decisions outlining strategies to minimize risk.

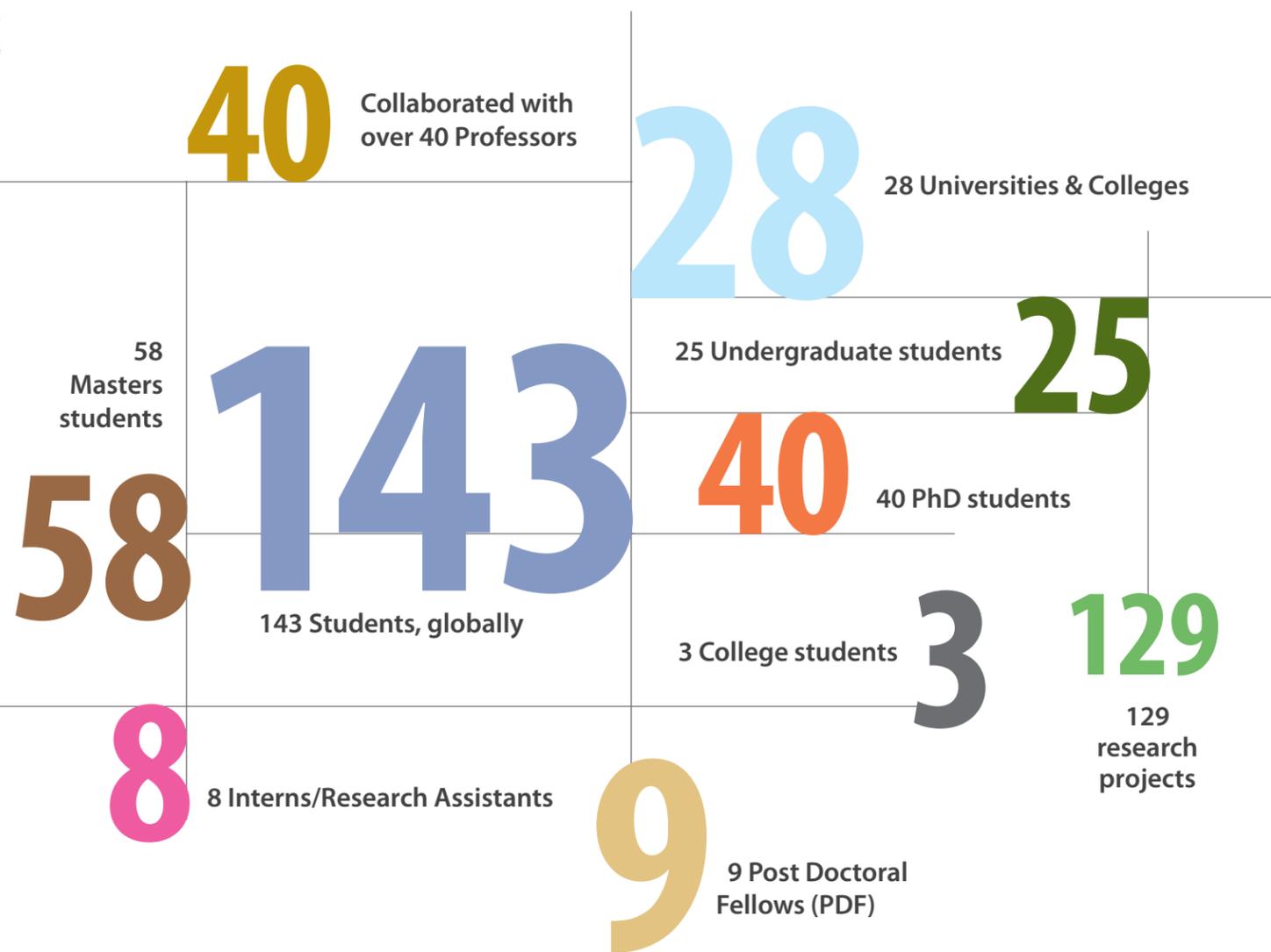
CEMI arranged for complimentary one-on-one consultations and assessment after the event to help organizations develop their own strategies and practices to better prepare themselves for SR&ED credit regulations.

DEVELOPING KNOWLEDGE – INVESTING IN STUDENTS:

Developing and nurturing the next generation of highly qualified personnel (HQP) and researchers is vital to the longevity of the mining industry in Canada. CEMI takes an active role by working with research and academic institutions in Ontario, across Canada and around the

world. CEMI takes great pride in also encouraging and inspiring local Sudbury elementary and high school students to consider pursuing a career in the mining industry by sponsoring student competitions and educational fairs.

HQP DEVELOPMENT SINCE 2007



3RD ANNUAL SUMIT RESEARCHER WORKSHOP

In April, CEMI hosted its third annual SUMIT (Smart Underground Monitoring and Integrated Technologies) Researcher Workshop at the University of Waterloo. The objective of the workshop was for researchers (8) and their students (33) to provide status updates on their current projects, location of experiments, work completed and planned projects. The discussions allowed for collaboration, identification of potential synergies and opportunities to optimize research outcomes as well as updating SUMIT stakeholders (mining companies, SMEs).

SUDBURY REGIONAL SCIENCE FAIR

On March 29th, 2015 the City of Greater Sudbury held its annual Sudbury Regional Science Fair competition at Laurentian University. Ms. Ivy Ireland-Murray, of R.L. Beattie Public School, received the CEMI Innovation Award for her project, titled "Yah or Nay: Sudbury Superstack". The Award recognizes projects that help illustrate the importance of mining research & technology development within society or the best project that contributes to the fields of earth sciences, geology, or engineering. Now in its fourth year, CEMI's Innovation Award aims to inspire and motivate students (grades 7-12) towards a science related career.

SUMIT VIDEO OUTREACH SERIES

A SUMIT video series showcasing the goals, milestones and results of the SUMIT program was completed and posted on the CEMI website. It features a series of student interviews from participating universities (including Queen's University, University of Waterloo, University of Toronto and Laurentian University). These videos demonstrate the important contribution that these students are making towards mining innovation-directed research. This video series will also serve as a resource and inspiration to high school students interested in mining.

MODERN MINING & TECHNOLOGY SUDBURY (MMS)

CEMI continues to support Modern Mining & Technology Sudbury (MMS), a week-long series of educational programs, where over 1,100 elementary and secondary level students attended this past year. In addition to participating on the MMS Committee, CEMI's Pat Dubreuil and Shannon Katary were guest speakers during the Mine Opportunity educational game day and for the Wild and Scenic Film Festival, which showcased winning entries from the OMA's "So You Think You Know Mining" video competition respectively. Sharing the global impact of these local successes and home-grown innovations with the next generation engenders a sense of community pride and encourages students to consider mining and the related sciences as a viable and exciting career option.



12 - SUMIT researchers and students at the 3rd annual workshop in Waterloo, Ontario. Credit: Photo courtesy of Gerry Kingsley.
 13 - Na Wang, PhD, SUMIT (University of Toronto). Credit: Photo courtesy of Gerry Kingsley.
 14 - Judy Kosmerly, Trustee, Rainbow Schools and Ms. Ivy Ireland-Murray, R.L. Beattie Public School, Sudbury Regional Science Fair.

INVESTING IN CORE INNOVATIONS



\$332,897

Industrial Research Chair; Offset Dyke and Sudbury Breccia-Hosted Deposits; Structural Evolution of the East Range



\$ 1,930,176

SUMIT, MOFRAC II, Burst Support Tool II, Drift Advance



\$ 3,082,354

Single Head Lateral Development I & II, SOT+, Top Down and Fill



\$ 1,864,187

Rio Tinto Centre for Underground Mine Construction (RTC-UMC)



\$293,980

Chair in Holistic Mine Practice, Tailings Remediation

TOTAL INVESTMENT IN CORE RESEARCH: \$ 7,503,594

During the 2014/2015 fiscal year, CEMI invested a total of \$7,503,594 into the development and implementation of step-change innovations. The graph reveals CEMI's financial contributions to its five core research themes and a select group of the projects in progress during this period.

FINANCIAL INFORMATION

CONSOLIDATED STATEMENT OF FINANCIAL POSITION

	APRIL 30, 2015	APRIL 30, 2014
ASSETS		
Current Assets:		
Cash	\$6,985,000	\$6,755,000
Short-term investments	-	36,000
Accounts Receivable	2,451,000	780,000
Prepaid Expenses	29,000	23,000
	\$9,465,000	\$7,594,000
Capital Assets	61,000	26,000
Long-term investments	58,000	162,000
	\$9,584,000	\$7,782,000
LIABILITIES AND NET ASSETS		
Current Liabilities:		
Accounts payable and accrued liabilities	\$2,293,000	\$929,000
Deferred revenue	4,592,000	3,607,000
	6,885,000	4,536,000
NET ASSETS:		
Unrestricted	2,638,000	3,220,000
Equity in Capital Assets	61,000	26,000
	2,699,000	3,246,000
	\$9,584,000	\$7,782,000

CONSOLIDATED STATEMENT OF OPERATIONS

	UNRESTRICTED	EQUITY IN CAPITAL ASSETS	APRIL 30, 2015	APRIL 30, 2014
REVENUE				
Research	\$6,175,000		\$6,175,000	4,254,000
UDMN-Federal NCE	2,849,000		2,849,000	290,000
Investment Income	40,000		40,000	47,000
	\$9,064,000		\$9,064,000	\$4,591,000
EXPENSES				
Salaries and benefits	\$2,140,000		\$2,140,000	\$1,804,000
Projects and Research	6,260,000		6,260,000	5,022,000
Office and general	1,193,000		1,193,000	953,000
Amortization of capital assets		18,000	18,000	33,000
	\$9,593,000	\$18,000	\$9,578,000	\$7,812,000
Deficiency of revenue over expenses	\$(529,000)	\$(18,000)	\$(547,000)	\$(3,221,000)

This summary financial statement was extracted from the organization's audited financial statements.

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OF ENVIRONMENT
& SUSTAINABILITY

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R&D PROGRAM DIRECTOR
UDMN THEME LEADER

DAMIEN DUFF
VICE-PRESIDENT - GEOSCIENCE &
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BUSINESS INNOVATION

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UDMN COMMERCIALIZATION DIRECTOR



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CHAIR IN HOLISTIC MINING PRACTICES

CHARLES NYABEZE
DIRECTOR OF BUSINESS
DEVELOPMENT

HARVEY PARSONS
EMERITUS TECHNICAL ADVISOR



MATTHEW PIERCE
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MIKE RICHER
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MARCUS THOMSON
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BORA UGURGEL
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DAVID VITONE
PROJECT MANAGER

ROCKY WEBB
VICE PRESIDENT - MINE PRODUCTIVITY



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GE MINING SOLUTIONS

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ACADEMIC

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