



CEMI
Centre for Excellence
in Mining Innovation

INNOVATION 16 ANNUAL REPORT

CEMI HELPS SOLVE MINING INDUSTRY CHALLENGES

• BY DELIVERING COMMERCIALY VIABLE INNOVATIONS TO IMPROVE SAFETY, PRODUCTIVITY AND ENVIRONMENTAL PERFORMANCE. WE HELP MINING COMPANIES ACHIEVE BETTER OPERATIONAL PERFORMANCE FOR A FASTER RETURN ON INVESTMENT.

CEMI CONTRIBUTIONS (2007-2016)

\$17M

for SME support

\$12.2M

on collaborations with mining companies, research organizations, consultants

\$36.5M

in support of innovations

\$7.3 M

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

153

FindMine, DeepMine, ValueMine, SustainMine & UDMN programs and projects

145

HQP Development: 145 students (Interns, College, Undergraduate, Masters, PhD, PDF, Research Assistants)

TABLE OF CONTENTS

2	ABOUT US
4	TABLE OF CONTENTS
5	MESSAGE FROM THE CHAIRMAN OF THE BOARD
6	MESSAGE FROM THE PRESIDENT
8	STRATEGIC DIRECTIONS
12	2016 INNOVATION UPDATE
22	SPOTLIGHT: RIO TINTO CENTRE
26	SPOTLIGHT: ULTRA DEEP MINING NETWORK
30	COMMERCIALIZATION AT CEMI
34	CEMI OUTREACH
38	INVESTING IN CORE INNOVATIONS
39	FINANCIAL STATEMENTS
40	CEMI TEAM
41	BOARD OF DIRECTORS
42	CEMI'S PARTNERS IN INNOVATION



MESSAGE FROM THE CHAIRMAN OF THE BOARD

The Board of Directors is pleased to reflect on another successful and results-based year. Our collaborative approach to mining innovation and business excellence is demonstrated in the results and accomplishments of our programs & projects. I would like to extend my gratitude to the CEMI staff, the many collaborators across Canada and the world for their continued efforts to advance mining innovation on a global scale.

This year marks the completion of two major collaborative research programs. The Rio Tinto Centre for Underground Mine Construction (RTC-UMC) was a \$10 million program created to undertake research in support of Rio Tinto's Mine of the Future™ programme with a focus on underground mining infrastructure and footprint reliability. This state-of-the-art research and knowledge centre was instrumental in the development and implementation of innovative step-change research and technology development for underground mines.

CEMI continues to lead the way in mining innovation by developing novel processes, products and technologies and bringing them to market. The Ultra-Deep Mining Network (UDMN) is funded federally through the Business-led NCE and is solving ultra-deep mining challenges by working with the network's member companies, including some of the deepest mines in Canada. The Network has helped to close the commercialization gap by providing its participants with business development services, as well as direct interaction with mining companies. As a result, the UDMN continues to position Canada as a global leader in commercializing mining innovation.

I want to officially welcome our newest board members who have joined us over this past year: Brian Buss, President, BWB Consulting Services Inc. to the UDMN Board; and Peter Edmunds, Senior Advisor to Atlas Copco Mining and Rock Excavation and President, Peter Edmunds Global Consulting, Steve Matusch, President, Ionic Engineering, and Peter Xavier, Vice President, Glencore Sudbury Operations, Sudbury Integrated Nickel Operations, A Glencore Company, to the CEMI Board.

Finally, I would like to express my sincere gratitude to Dr. Nigel Smith, Director at SNOLAB, who is stepping down after six years of dedicated service on the CEMI Board. His commitment to CEMI over the years is acknowledged by all his Board colleagues and is reflected in our continued success, most notably the joint partnership of the Mining Observatory Data Control Centre (MODCC) located at SNOLAB.

We welcome innovators in joining us as we meet the needs of the mining industry by continuing to make CEMI Canada's leading source of mining innovation and commercialization.

Roger Emdin
Chair of the Board





MESSAGE FROM THE PRESIDENT

CEMI continues its evolution as an organization that delivers innovation-driven productivity improvements to meet the challenges that confront the mining industry here, in Canada and globally. The global mining industry is still experiencing weak demand for metals and there is nothing that any of us at CEMI can do to invigorate demand. What we can do is develop innovations that lower the cost of mining, reduce the time from ore discovery to production and the risk involved in mining projects. Our focus at CEMI has been to improve ore production systems and the mine development process, while reducing the geotechnical and heat-stress risk of mining at depth and the energy necessary to operate deep mines. We also believe we have developed low-cost approaches that make it possible to reduce the impact of mining on the natural environment and will help accelerate the discovery and opening of new mines in remote locations.

As we continue to make progress on existing programs and projects, we appreciate the Ministry of Northern Development and Mines (MNDM) and the Northern Ontario Heritage Foundation Corporation (NOHFC) for their support and interest in helping CEMI achieve its innovation objectives. CEMI and UDMN were pleased to contribute expertise and knowledge towards the development of the new Ontario Mineral Development Strategy. We recognize the need to develop a more effective ecosystem for mining innovation in Ontario and we are glad to be able to support MNDM's vision in ensuring the mining industry's continued evolution in the face of a changing environment. We are deeply grateful to Minister Gravelle and his team for their continued support and encouragement. We hope that the result of our collective efforts will exceed the expectations of the Province for delivering innovation to the mining industry and help build a stronger economy.

The support from MNDM augments the Federal funding we receive from the Business-led Networks of Centres of Excellence (BL-NCE) program. Our two new Federal MPs, Paul Lefebvre and Marc Serré, have been effective advocates for developing awareness and understanding of why Sudbury is the best place for the federal government to invest in mining research and innovation. Northern Ontario has provided more significant developments in bulk mining technology, mineral processing and environmental remediation than anywhere in Canada.

The Smart Underground Monitoring and Integrated Technologies (SUMIT) for deep mines completed its 6-year \$6.7M program. The Program was one of the largest geotechnical research programs in Ontario. It succeeded in helping the mining industry deal with ground stability-related issues at depth, while optimizing its energy usage simultaneously. Researchers and industry sponsors presented the most significant results and outcomes at SUMIT's Annual General Meeting, in Sudbury in June 2016. SUMIT successfully brought in the best mining researchers and laid the groundwork for vital and commercially viable programs. These include the \$35M Business-led NCE Ultra-Deep Mining Network (UDMN) and the new Mining Observatory Data Control Centre (MODCC), in the development of big data analytics for the mining industry, located at SNOLAB.

This year also marks the completion of the Rio Tinto Centre for Underground Mine Construction at CEMI. This \$10M investment in Canada's mining innovation was created to undertake research in support of Rio Tinto's Mine of the Future™ programme with a focus on underground mining infrastructure and footprint reliability. The results of this collaborative centre have set the stage for large-scale mining operations, now and in the future.

Now in its third year, the 5-year Business-led NCE Ultra-Deep Mining Network is at peak operation. Expenditures this year will be almost \$7.5M and another \$7.3M anticipated in the coming year, before the program begins to ramp down. For the past two years, the Network focused mostly on project management and preparation for site demonstrations; it is now beginning to allocate resources for the commercialization phase. We are pleased with the real, tangible progress being made in achieving the Network's objective of making deep mining more financially feasible. All Network members, including mining companies, are looking forward to further the program extending beyond 2019.

CEMI's most recent area of strategic focus, BizMine, continues to evolve and this year it achieved an important milestone. The ColdBlock technology was supported from research to practical demonstration, through operational-scale implementation and now into the commercialization phase, generating revenue. We are very proud to have had the opportunity to work with the team at ColdBlock Technologies, in their journey toward commercialization success. We continue to establish commercial agreements with partners in our most active technical themes (DeepMine, ValueMine and FindMine) and build relationships with researchers and companies that have solutions to the mining industry's environmental challenges, for future inclusion in SustainMine projects.

The success of our efforts in providing business and commercialization services to innovative service and supply companies in the Greater Sudbury Region shows there are many more local opportunities to be identified and nurtured. As a result, CEMI's Innovation & Prosperity Office (IPO) will begin to expand its engagement with service sector companies across Northern Ontario and into other provinces. The IPO has two objectives: to help individual companies that service the mining industry build capacity and grow their business; and to provide a cooperative network, bringing ideas organizations together from across the country, to help strengthen the mining industry in Northern Ontario and in Canada. Ultimately, we hope our mining partners - mine operators, service and supply companies and consultants - will take Canadian innovation to mining operations around the world and make Canada a leader in the global mining industry.

I would like to express my thanks to the CEMI staff for their relentless energy and effort they bring to our work of innovation. After eight dedicated years with CEMI, Damien Duff, Vice - President - Geoscience & Geotechnical R&D, has officially retired. Damien has been instrumental in leading the academic programs and projects within the FindMine and DeepMine themes, contributing to the growth and development of many students across Canada. In recent years, Damien was also a Theme Leader for the Ultra Deep Mining Network.

Finally, I would like to thank the CEMI and UDMN Board for their efforts to sustain the organization. Too often, the work of the Board is taken for granted; in our case we genuinely appreciate the thoughtfulness, wisdom and commitment our members bring to Board meetings, as well as the help and advice they give through committee meetings and informal discussions throughout the year.

With the help and support of CEMI's industry partners, government funding agencies and research collaborators, we look forward to another year of challenge and success.

Douglas Morrison, President & CEO

"WHAT WE CAN DO IS DEVELOP INNOVATIONS THAT LOWER THE COST OF MINING, REDUCE THE TIME FROM ORE DISCOVERY TO PRODUCTION AND THE RISK INVOLVED IN MINING PROJECTS."
- D. MORRISON, 2016

STRATEGIC DIRECTIONS

MINING INNOVATION: AN ON-GOING NEED

CEMI co-ordinates and directs step-change innovation through the strategic areas of exploration, deep mining, mine productivity, underground mine construction and environmental impact. CEMI's objective is to lead innovation to help generate significant improvements in the performance of mine operations in Ontario, Canada and around the world.

Innovation is required to:

- 1. Improve the cost-effectiveness of the mining value chain:** utilizing less time, less money and fewer resources during the mineral production process helps create measurable gains in the total cost-effectiveness of the mining value chain.
- 2. Increase the rate of ore-body discovery:** reducing the time from discovery to production and ensuring environmental protection throughout the production process.
- 3. Impact of mining on the environment:** prudent management can reduce the impact on the natural environment; clean mining technologies can reduce the cost of long-term intervention, reduce the attendant liabilities and accelerate final reclamation.

OVERCOMING BARRIERS TO INNOVATION

Based on experience to date, CEMI recognizes two key impediments to innovation. These are critical to the development and adoption of new technologies, techniques, processes and products.

Innovation Gap

Basic or fundamental research helps to germinate and develop the initial concept for innovation. Progression beyond the concept development can falter due to a technical flaw or if the economics of innovation become excessive (resources, time, or costs). This is the Innovation Gap. CEMI is able to help surmount this gap, given its knowledge and experience, by providing additional technical investigation or input, leveraging resources (identifying the experts, facilities, funding required), or offering different perspectives to help solve the innovation impediment.

Commercialization Gap

Once an innovation has undergone the developmental, demonstration and implementation stages to validate the process or technology the next gap to overcome is the Commercialization Gap. CEMI's insights and understanding of the mining supply chain, knowledge of where the innovation fits within the mining process, and if the process has to be adapted or changed, help navigate the commercialization gap.

SUSTAINING INNOVATION

CEMI's goal is to facilitate and develop innovations that will improve the performance of the metal mining industry in Ontario, Canada and globally. Development of technical innovations through CEMI's strategic pillars—FindMine (ore discovery), DeepMine (heat & rock stress), ValueMine (mine productivity), SustainMine (environmental impact)—meet these goals. A key measure of success for innovation is to ensure that it moves through both the innovation and commercialization gaps, and delivers a viable, market-ready product or service. Commercialization of the technical innovations through CEMI's BizMine (commercial viability) strategic pillar aims to facilitate market adoption.

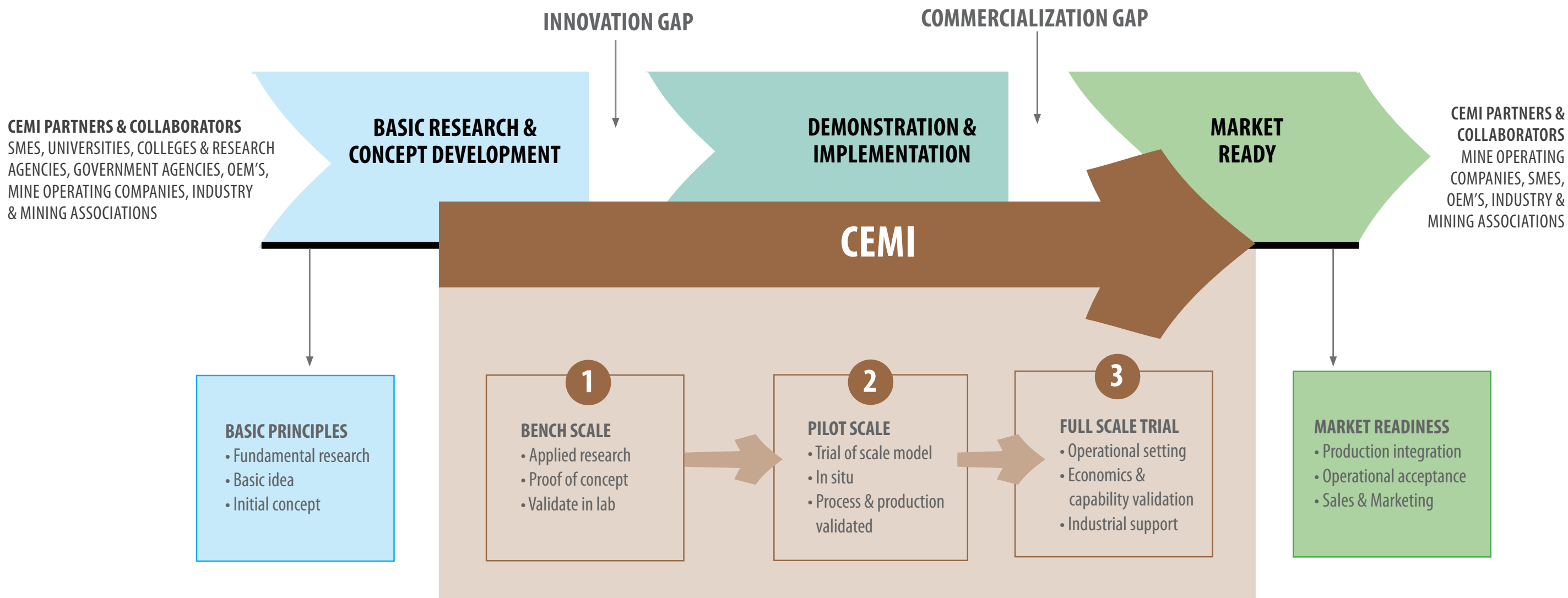
As a not-for-profit organization, CEMI's aim is to reinvest the benefits of its commercial involvement to sustaining future innovation efforts for the metal mining industry.

CEMI'S INNOVATION PROCESS— OVERCOMING THE GAPS

CEMI's Innovation Process closes the Innovation and Commercialization Gap. It is focussed, purposeful and systematic, helping to ensure the innovations are sustainable and economically feasible for the mining industry.

CEMI'S INNOVATION PROCESS

CLOSING THE GAP



The Innovation and Commercialization Gaps are overcome by three key steps of CEMI's innovation process—Bench Scale, Pilot Scale and Full Scale Trial

INNOVATION FOCUS IN FOUR TECHNICAL AREAS

**DEEPMINE:
HEAT & ROCK STRESS**

**FINDMINE:
ORE DISCOVERY**

**VALUEMINE:
MINE PRODUCTIVITY**

**SUSTAINMINE:
ENVIRONMENTAL IMPACT**

EXPLORING THE STRUCTURE OF THE SUDBURY IGNEOUS COMPLEX TO UNDERSTAND HOW NEW ORE BODIES MAY BE DISCOVERED

The Sudbury Igneous Complex (SIC) and its footwall rocks is one of the most significant centres of Ni-Cu-PGE mineralization, globally. CEMI has supported geoscience projects, to better understand how Sudbury footwall ore bodies are formed and potentially, to understand how new ones may be discovered. Dr. Ulrich Riller (University of Hamburg, Germany) and his students have been studying the emplacement of mineralization as part of a three-year research programme funded by CEMI and Vale.

The nickel-copper deposits in the SIC are considered to be related to processes resulting from a large meteorite impact 1.85 billion years ago and its post-impact orogenic deformation. The most economically valuable mineral resources occur either at the basal contact of the SIC (contact deposits) or in host rocks close to basal contact (footwall deposits). Transport and emplacement of the respective mineral phases in the tectono-thermal aureole of the SIC are thought to depend on the deformation processes that occurred in the brittle to brittle-ductile period. The activation of prominent faults during the post-impact deformation may have also significantly displaced mineral deposits.

Knowledge of the following structures is essential for mineral deposit exploration in the East Range of the Sudbury Basin:

1. The geometry of the basal contact
2. The structural processes controlling transport and emplacement of Ni- Cu-PGE mineral phases
3. A sense and magnitude of displacement on prominent faults

The post-impact deformation created unprecedented natural laboratory conditions to investigate igneous, metamorphic and deformational processes occurring at the base of a large impact crater. In total, 7 graduate and 10 undergraduate student projects are funded. The project activities include: structural field and drill core analyses; inference of fault segment orientations from LiDAR data; 3D-kinematic restoration of kilometre scale fault zones; inversion of fault-slip data; interpolation of principal strain axes; microstructural and quantitative image analysis of grain-scale mineral fabrics; and analogue modelling experiments. The projects have been conducted in close collaboration with Lisa Gibson and Dr. Peter Lightfoot, both with Vale.

KEY LEARNINGS:

- Kinematic restoration of the deformed SIC and its footwall rocks in the East Range revealed thickness variations of the SIC that are not apparent in geological maps and can be spatially related to footwall deposits. These confirm that mass redistribution occurred at the base of the SIC after crater formation and contributed to the formation of footwall deposits.

- Current examinations of sulfide veins in drill core provide insight as to the physical conditions of footwall rocks during formation of the respective deposits.
- Collectively, the (micro)structural, field and kinematic modelling studies help to better understand the mechanisms of footwall deposit formation. These should significantly advance our understanding of the structural evolution of the East Range and the deformation mechanisms operating during mineral deposit formation at the base and below the Main Mass of the SIC.



Students from Hamburg University in Germany in the field. From left to right: Martin Clark (Ph.D. candidate), Torben Wüstemann (M.Sc. candidate), Björn Bombach (B.Sc.) and Lisa Bendschneider (M.Sc. candidate).

ELEMENT RATIO ANALYSIS: A SIMPLE AND RIGOROUS APPROACH

Element Ratio Analysis (ERA) is a simple technique that is rigorously consistent with the complex laws of thermodynamics that control mineral transformations in rock. It can investigate and quantify all kinds of rock forming and rock alteration processes, including hydrothermal alteration, metamorphism,

and igneous fractionation. ERA has been grossly under-utilized because of the perception that it is difficult to use. CEMI is supporting the development efforts of Dr. Tony Beswick of Laurentian University and Dr. Cliff Stanley at Acadia University to make it easier to use and understand. The real value of ERA will come from combining it with modern geospatial analyses.

ERA CAN HELP DEVELOP MORE KNOWLEDGE AND UNDERSTANDING OF THE SUDBURY BASIN

The application of ERA to the noritic rocks that host nickel ore in the Sudbury Igneous Complex reveals that only two of the essential minerals in the norite underwent crystal sorting. This suggests that these rocks were created by endogenic igneous processes, making it unlikely that the copper-nickel ore-bodies are derived from a single melt sheet generated by an exogenic impact event. The genesis of the Sudbury Basin is very complex, but the further development of ERA techniques offers a new approach to understand the genesis, nature, and distribution of valuable sulphide ore-bodies. In particular, applying a combination of geospatial and ERA analyses to Sudbury data might make it possible to vector in more of the high-value, PGM-rich copper vein deposits that display enigmatic relationships with the more common massive nickel ore-bodies.

A NEW UNDERSTANDING OF FAULT SLIP POTENTIAL IN UNDERGROUND MINES

The relationship between mining activities and mining-induced seismicity is vital. Having a better understanding of it allows mine operators to anticipate and plan for necessary ground support and to reduce those risks which might compromise the safety and productivity aspects of a mine. Drs. Hani Mitri and Atsushi Sainoki with the Department of Mining and Materials Engineering of McGill University, working with Vale Canada Limited's



Copper Cliff Mine, undertook a comprehensive investigation and evaluation of the fault-slip potential in an underground mine.

The project, supported by CEMI and NSERC through a Collaborative Research & Development grant examined and analyzed mining induced fault-slip, microseismicity, and violent shear rupture data using conventional continuum numerical modeling techniques and a new, advanced discontinuum modelling approach. Commercially available software, FLAC3D and 3DEC, was also used.

SIGNIFICANT FINDINGS OF VALUE

The outcome of the investigation led to two major findings:

1. Development of a methodology to distinguish aseismic fault-slip from seismic fault-slip by using numerical modelling techniques and microseismic data to investigate whether the shear movement along the targeted fault is seismic or not (Figure 1). Currently, positive fault-slip potential in mines is perceived as a strong indicator of the likelihood of a future seismic event thereby requiring implementation of potentially unnecessary and costly preventive measures, such as the installation of dynamic support. Avoiding this would represent real value to mines. The developed methodology achieves this by enabling the ground control specialist to make informed decisions on the need for dynamic support element deployment, based on the type of anticipated future fault-slip potential, (i.e. whether seismic or aseismic).

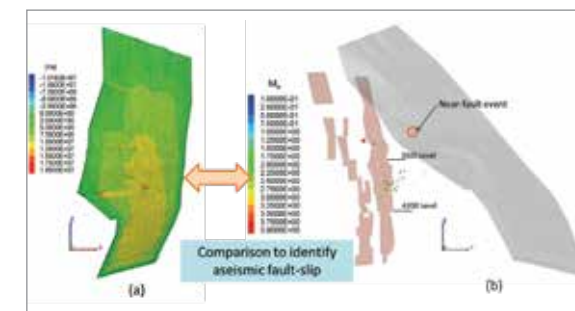


Figure 1

2. Development of a new perspective on the cause of mining-induced seismicity that takes place away from mine openings. It is common belief that mining-induced stress change causes seismicity in a massive, highly stressed rockmass. While this is true, the stress state numerically analyzed or measured away from mine openings, is often less than the critical threshold needed to create seismic activity. The McGill study has shed light on the influence of fracture networks in the rockmass and on the associated occurrence of mining-induced seismicity. A discontinuum numerical analysis successfully demonstrated that complex interactions of fractures away from mine openings can accumulate sufficient elastic strain energy to cause localized violent shear rupture (rockbursting). The result is an index of fracture-network-induced strain energy (Figure 2). A guideline or index such as this makes it possible to assess the severity of potential mining-induced seismicity, allow for optimization of mine planning, support system selection and mine design. Theoretically, this could enable reliable productivity improvements and potentially, lower costs.

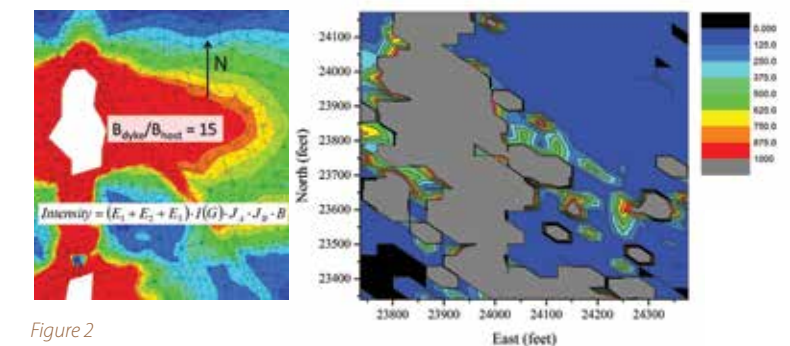


Figure 2

GEOSCIENCE INTEGRATOR: MANAGEMENT OF 4D MULTI-DISCIPLINARY MINING DATA

As mines become deeper and as geotechnical problems become more acute, the need for a system to support, record, and communicate geotechnical interpretation based on a multiplicity of data streams, at a greater data flow & volume, and with real-time data access is imperative.

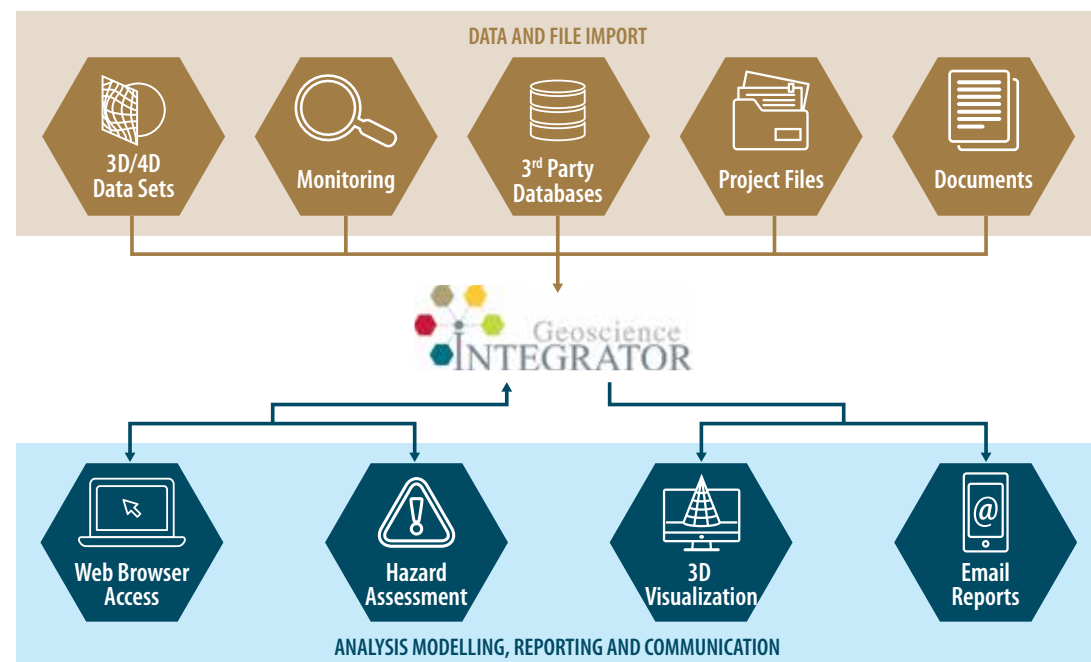
Geoscience INTEGRATOR was originally conceived to accommodate the data management needs of SUMIT, a multi-disciplinary, collaborative research programme involving academic institutions, mining companies, SMEs and managed through CEMI. SUMIT required a comprehensive data management system to facilitate researchers' needs to solve complex problems through collaborative analysis and interpretation of underground mine data and associated metadata.

Geoscience INTEGRATOR, having met its original objective to "provide SUMIT researchers with user-friendly access to mine datasets and their contextual information, to facilitate and optimize research efforts", continues to evolve. Within the follow-on "Mining Observatory Data Control Centre" (MODCC) project at CEMI, exploration data themes and a powerful 3D visualization and query interface were added. Geoscience INTEGRATOR, now also part of CEMI's UDMN project, supports, tracks, and

automatically reports on 4D dynamic mine models (a new feature), and associated geohazards. It is also being deployed to manage multi-institution, multi-site data of the largest mineral exploration research effort ever undertaken in Canada—the NSERC-CMIC Industrial Research Network project—"Integrated Multi-Parameter Footprints of Ore Systems: The Next Generation of Ore Deposit Models."

With inspiration and initial funding originating from SUMIT, Geoscience INTEGRATOR has evolved into a significant going concern. Although it will be released commercially in October 2016, it already has 2 major pre-release commercial contracts, 6 new permanent full-time software development positions, and 1 senior consultant position at MODCC (permanent). It is the data repository for SUMIT and Footprints project, the data management system for MODCC and is the foundation of the UDMN R&D system at Glencore's Nickel Rim South.

GEOSCIENCE INTEGRATOR



The industry's most comprehensive and advanced geotechnical data management and hazard computation system; automated from import to report.



ACHIEVING RAPID DEVELOPMENT IN UNDERGROUND MINES

In the last thirty years, advance rates of development headings in underground mines have declined steadily. This decline was driven by two factors: the increased size of access drifts (tunnels) to accommodate larger production equipment; and the need for more support to ensure safety and stability. Both of these make the ground control component of the development cycle longer. The result is slower advance rates, increased capital cost, an increase in the time to first production from the new ore-body, and a depressed ore-body net present value (NPV).

PHASE 1: MINE DEVELOPMENT CANOPY SYSTEM

The Mine Development Canopy System (MDCS) is the first phase of CEMI's strategic project on Rapid Development in underground mines. The primary goal of the Rapid Development Project is to reduce the time to first production in new underground ore-bodies, reduce overall mining cost by increasing the effective utilization of the face, not the utilization of the equipment. In addition, it improves safety and productivity.

CEMI's MDCS provides a physical barrier to the rock-related hazards in development headings in high-stress conditions, enabling simultaneous activities in the heading and effectively reducing the development cycle time.

Current drift development practice generally involves four sequential activities: removal of blasted rock (mucking), installation of the ground control system (bolting), drilling the face holes and charging them with explosives. This four-stage sequence of activities requires the re-entry of four pieces of equipment, and critical time is often lost between the re-entries. No face activity can be carried out until the ground control is complete and in some cases, support has to be installed on the face of each heading after each blast. This increases the duration of the development cycle and further reduces the advance rate.

The robust, engineered, movable canopy can be brought into the development heading to protect personnel and equipment from rock falls and rock-bursts and allow simultaneous activities in the heading. The Mine Development Canopy System is comprised of three individual canopies. The front canopy, with a face shield when necessary, will protect the face drills and the drill carrier from rock-related hazards and allow equipment to return to the face as soon as the mucking cycle is complete.

The canopy is designed to allow for the necessary look-out to drill the wall and roof control holes. The back canopy protects the equipment and operators and allows ground support activity to be completed while the face is being drilled and charged. The middle canopy protects workers as they travel between the front and back canopies.

CEMI has developed the Mine Development Canopy System for single heading lateral development. Functionality and strength tests have been performed on prototypes both above and underground. Nordic Minesteel Technology (NMT) of North Bay, Ontario, has been involved with the design and testing of the system components. The System is in the final stages of pre-commercialization, undergoing operational field testing, to be completed by early 2017. NMT will construct commercial units and will market the MDCS to the mining industry.



CEMI and Nordic Minesteel successfully complete Phase 2 testing.



PHASE 2: REDUCING THE DURATION OF THE MUCKING CYCLE

The second phase of the Rapid Development project is to reduce the duration of the mucking cycle that removes broken rock from the heading, allowing face advance activities to re-commence. Conceptual work on the technologies for this second phase has begun. CEMI is working with Labrecque Technologies to simulate the rock-removal process in order to target the kinds of technological developments needed to further reduce the development cycle time and to accelerate access to new ore-bodies.

RECOVERY OF METALS FROM TAILINGS WASTEWATER

The environmental impact from legacy mining and tailings sites comes from heavy metal contamination, particularly arsenic. Removing these metals from mine waste and wastewater is critical to minimizing the impact on the environment. However, applying conventional technology to remove these metals, while also achieving the arsenic levels required by the Provincial Water Quality Objectives (PWQO) is a daunting and prohibitively expensive challenge.

CEMI's objective is to develop a new approach to the disposition of mine waste, tailings and waste water from metal mines that is more effective, less expensive and more reliable.

A NEW APPROACH TO ELIMINATE ENVIRONMENTAL IMPACT

CEMI's approach to the recovery of heavy metals from mine waste and wastewater is to combine enhanced mineral processing techniques with a more efficient means of purifying wastewater using algae. Initial tests demonstrated the ability to use specific algae to capture and accumulate several of the most common heavy metals, and removing them from tailings wastewater. Laboratory tests have confirmed the ability of the algae-based technique

to remove arsenic from a metal-contaminated tailings leachate. The initial un-optimised trial reduced arsenic levels by 92% from samples with 600 µg/l and the level of reduction held at around 90% across a range of temperatures from room temperature to near zero. More trials are required to determine how the technique can reliably capture all metal contaminants from more complex multi-metallic sources.

A major advantage of the algae technique is that it is applicable to both batch and continuous flow situations and is ideally suited to the kinds of novel mineral techniques being developed by CEMI's mineral processing partner. We are finalizing a methodology that will be able achieve the remediation of legacy sites, while meeting regulatory discharge requirements.

ALTERNATIVES TO MONITOR THE ENVIRONMENTAL IMPACT

CEMI is engaged in developing a technique for continuous monitoring of dissolved metal content in mine wastewater. This is essential for successful field trials because the current requirements for water sampling is both expensive and time-consuming and is effectively impossible for remote sites. The new technique is more cost-effective and can be remotely programed to meet different discharge rates between winter and spring run-off. During the redistribution of tailings continuous wastewater monitoring quickly identifies the need to take corrective action to ensure the project remains in compliance with regulatory requirements.

Arsenic-contaminated tailings from north-east Ontario.



SUMIT DELIVERS RESULTS



Photo courtesy of Gerry Kingsley

The SUMIT Program—Smart Underground Monitoring and Integrated Technologies for deep mines came to a successful conclusion in June, 2016. The aim of the Program was to develop smart engineering techniques, technologies, tools and knowledge to facilitate step-change advances in productivity, efficiency and energy optimization in underground mining at depth.

A SUCCESSFUL COLLABORATION

Managed by CEMI, this six-year \$6.7 million program was a collaborative R&D initiative involving academia, mining companies, SMEs and government. SUMIT was led by Laurentian University in partnership with Queen's University and the University of Toronto, with contributions from the University of Waterloo, the University of Alberta and Carleton University. Several field programs were executed at 4 active mine sites: Vale's Coleman & Creighton, Newcrest's Cadia East and Glencore's Nickel Rim South.

MINING DEEPER, SAFER, AND MORE ECONOMICALLY

Understanding and managing rock-mass failure in underground mines is critical to the industry. It is a real issue for deep mines, especially rock-mass failure caused by fault slip. This failure is a result of slippage occurring on a fault, caused by a disruption of the stress field in the area of the fault due to the mining process. Through collaborative research and development with the support of Vale, Sudbury Integrated Nickel Operations – A Glencore Company, Rio Tinto, and the Ontario Government, SUMIT focused on three challenges associated with deep underground mining:

- 1. Rock mass characterization** to "better see into the ground", anticipate risks and interpret dynamic processes
- 2. Enhanced mine development** for faster mine construction to increase economic returns
- 3. Sustaining deep mines** through energy optimization and underground environmental controls.

SUMIT enhanced understanding of energy demand and usage on mine sites and how new energy approaches may be adopted to lower demand, limit greenhouse gas emissions and reduce environmental footprints.

SUMIT KNOWLEDGE DEVELOPMENT

The SUMIT academic collaboration resulted in significant R&D advances to help the mining industry deal with ground stability-related issues and optimizing energy usage in mines. Listed below are a few of the accomplishments.

Laurentian University (Geomechanics Group):

- 1. **New industry guidelines** for the selection of ground support elements in underground mines
- 2. **New software tool to facilitate the selection of optimal ground support;** numerical modeling technique to study ground motion distribution and seismic wave propagation around excavations in deep mines
- 3. **A new approach to differentiate how rock mass strength** can be modeled in low and high confinement conditions

Laurentian University (Energy Group):

- 1. **New approaches and tools to help optimize energy usage and cost savings on mine sites**
 - a. Potential for significant annual energy savings using new energy auditing and flow tracking techniques - 4D Sankey Visualization Tool
 - b. Optimized cooling strategies for natural heat exchange areas using computational fluid dynamics modeling
- 2. **Demonstration of Hydraulic Air Compressor (HAC) technology** that could be used to provide energy efficient and cost effective ways to cool mines (UDMN project)

University of Toronto:

- 1. **New ideas for tools and techniques** using geophysics as a proxy to monitor stress distribution
- 2. **Development of the first dynamic (time variant, time stamped) 3D deep mine model,** integrating geology, physical rock properties, infrastructure, production and backfill data
- 3. **Design of a new strain meter** with multiple fiber Bragg grating (FBG) segments

University of Waterloo:

- 1. **Fiber optics cable borehole installation methodologies and performance measurement** studies to assess the evolving displacement field around mining blocks due to mining
- 2. **Optimized numerical modeling approaches** for the design and execution of hydraulic fracturing treatments

Queen’s University:

- 1. **Advancement and demonstration of techniques** for using continuum numerical models to replicate rock mass deformation and their ability to replicate actual behaviour observed in-situ
- 2. **An approach to treating LiDAR data** and optimizing its use for deformation change detection
- 3. **An approach to reducing geotechnical assessment uncertainty** as a function of the uncertainty associated with conceptual geological models



Group shot of the SUMIT Team of students, researchers and industry. Photo courtesy of Gerry Kingsley.

COMMERCIALIZATION OUTCOMES OF SUMIT:

- **Geoscience INTEGRATOR**, built to provide mine datasets and comprehensive data management for collaborative analysis to help speed up research outcomes, will be released commercially in October 2016
- **Spin-off of a new SME**, Electrale Innovation Ltd.; and continued business growth of existing partners
- **Filing of new patents** (11 patents pending) for new products/tools
- **Development new software tool** facilitating the selection of optimal ground support based on existing or anticipated rock mass conditions for mine designers and mine operators

Collaborative programs such as SUMIT help the Canadian & global mining sector to find innovative ways to reduce risk, accelerate mine development, improve production capacity, and reduce energy consumption. In the coming months, more information on SUMIT will be available.

SUMIT ACHIEVEMENTS TO DATE

83 conference presentations

98 participants

citations in scientific and engineering literature

205 publications

374

student hours of safe in-mine work

959

0 incidents or accidents

19 new positions for SUMIT student graduates

SUMIT HQP DEVELOPMENT

- 75 students
- 7 post doctoral fellows
- 19 doctoral students
- 30 master’s students
- 19 undergraduate students
- 17 researchers
- 1 research engineer

SETTING THE STAGE FOR LARGE-SCALE MINING OPERATIONS, NOW AND IN THE FUTURE.

RioTinto

SPOTLIGHT: RIO TINTO CENTRE FOR UNDERGROUND MINE CONSTRUCTION

Photo courtesy of Gerry Kingsley

The Rio Tinto Centre for Underground Mine Construction (RTC-UMC) at CEMI has been focused on three core areas essential to the success of large-scale mining operations.

1. Ground Control in Mechanized Excavations
2. Characterization of Rock Mass Quality and Strength in Deep, Massive, Veined Orebodies
3. Development of Innovative, Efficient and Effective Support Systems for Increased Footprint Reliability

Established in 2010, the RTC-UMC interacts and collaborates with academics, consultants and representatives from a consortium of Rio Tinto operations worldwide.

UNDERSTANDING GROUND CONTROL IN MECHANIZED EXCAVATIONS

Adverse rock behaviour and ground control issues can often lead to machine performance problems, delays or increase ground control costs, all of which can consume much of the benefits derived from advances gained in speed. RTC-UMC supported the Rio Tinto Tunnel Boring System (TBS) and Shaft Boring System (SBS) programs by incorporating geo-hazard management aspects to improve the understanding of the prototype machine performance relative to rock mass characteristics. A TBS trial at Northparkes Mines and a comparison of Tunnel Boring Machine (TBS) and Drill & Blast (D&B) methods on a parallel 4.6km section of the Loetichberg Base Tunnel provided the following learnings:

- **Rock Strength:** Cutting rate is dominated by areas of higher strength rock on the tunnel face. Consider the upper 25% of comprehensive strength distribution when forecasting intact rock strength. In addition to high abrasivity, TBS rates were negatively influenced by high abrasivity, stress-driven face instabilities and instabilities along the shield of the cutting wheel due to adverse orientations of rock mass structure and instabilities along the springlines.
- **Presence of vein stockworks can impact TBS advance:** Larger cuttings, which can decrease the handling rate of the apron and cause damage to the conveyor system. Blockiness in the tunnel face (Figure 1 - p. 24) has the potential to lead to misrepresentation of the rock mass conditions, and can also lead to unravelling from the face, if there is extended periods between cuttings.
- **Rock mass characterization based on classification systems alone, is inadequate to account for many of the factors impacting tunnel advance:** Non representative rock mass characterization may also lead to unnecessary support requirements. The post-tunnelling characterization also suggested that no structural support, only support to ensure workplace safety, was required for the first 60 m of the TBS tunnel at Northparkes Mines.
- **Improved reliability of characterization and optimization of the construction process were realized by:** logging of the pilot hole with optical and acoustic televewers; determination of the stress state near the TBS alignment to define the local stress field; and the use of the observational method during tunneling.



Figure 1. Blocky appearance of rock in TBS tunnel face at Northparkes Mine resulting from veined nature of rock.

UNDERSTANDING CHARACTERIZATION OF ROCK MASS QUALITY & STRENGTH IN DEEP, MASSIVE, VEINED OREBODIES

This program utilized a systematic approach in the collection and interpretation of geotechnical data to enable more reliable forecasting of veined rock at depth. The result is the development of a comprehensive “best practices” guideline. A number of related studies were also completed and incorporated in the preparation of the guidelines. The key outcomes and practical implications of this program include:

- **Specific Guidance:** When characterizations systems such as Geologic Strength Index (GSI) are applied to rock masses without consideration of their defected nature, the rock mass strength may be severely underestimated. In some cases, essentially massive rock masses may appear to be very blocky and of relatively low rock mass quality due to opening of veins broken during drilling or blasting. The guidelines provide specific direction on distinguishing natural versus induced breaks and in establishing whether GSI is applicable or not, at different scales (Figure 2).
- **When to make modifications:** Adjustments to standard testing procedures are required when testing brittle and defected rock types and it is critical to filter specimens by failure mode.

Using Approximations and Parameters:

The challenges in simulating brittle rock mass behavior with traditional continuum numerical models requires several approximations to make the model fit the rock mass response to mining. In particular, extreme care is needed when selecting post-peak strength parameters.

- **Study Recommendations:** A related study addressed the challenges associated with obtaining in-situ stress measurements in highly fractured/veined rock and recommended use of a modified doorstopper and a higher frequency of strain measurement. Another related study used co-located borehole and shaft data to address the development of realistic DFNs and provided recommendations for drilling program design.

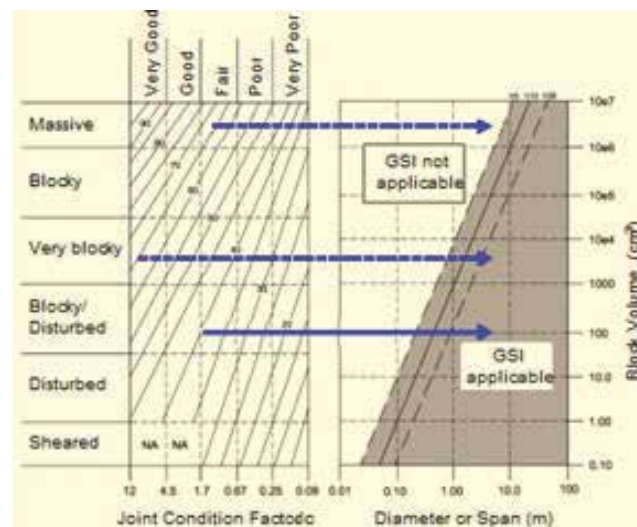


Figure 2: Graph to assess applicability of the GSI approach depending on engineering problem scale. Arrows indicate for a 6 m wide tunnel that, GSI = 40 is applicable (full arrow) whereas GSI = 65 is not.

DEVELOPMENT OF INNOVATIVE, EFFICIENT AND EFFECTIVE SUPPORT SYSTEMS FOR INCREASED FOOTPRINT RELIABILITY

Support systems must be able to handle large deformations and control brittle failure processes whether they are static, time-dependent or violent (bursting) in nature. The mechanism of how support components

work and most importantly, how they change the rock mass behavior is not fully understood. This is due to the complex rock mass conditions and the lack of investigation tools to study the rock failure mechanisms.

This program addresses the role that rock support plays in stabilizing highly stressed ground through state-of-the-art numerical simulation tools combined with field observations. The goal is to develop a better understanding of support effects on the behavior of brittle rock, its response to mining induced stress changes and the associated deformations. The key outcomes of the program were:

Development of the “gabion support concept”:

A significant outcome is the development of a deformation-based support selection approach called the “gabion support concept”. This has the potential to provide strong confinement to the rock mass in tunnels walls and pillar cores. A semi-empirical approach with a spreadsheet based tool was developed to estimate deformations imposed on ground support by stress fractured ground near excavations, resulting in preliminary specifications for a gabion support design.

Potential to reduce excavation vulnerability:

A critical assessment of the current mine support design principles for dynamic loading concluded that the primary rockburst damage mechanism is often a seismically-triggered or a dynamically-loaded strainburst—not momentum transfer or dynamic shaking. This suggests that a reliable means of identification of mining-induced strainburst potential could substantially reduce excavation vulnerability. Additionally, pillar strainbursting was simulated with a Bonded Block Model (BBM) approach in Universal Distinct Element Code (UDEC) to confirm the hypothesis that appropriate ground support encourages more stable expenditure of energy under these conditions.

Development of cave load guidelines:

An improved understanding of pillar loading within extraction levels (from undercutting through to cave draw) and the role of draw control in managing pillar loads was developed. Analysis of in situ data from the Deep Ore Zone (DOZ) cave at Grasberg indicated that areas under low or no draw tend to attract and accumulate stresses over

time, while the results of physical modelling studies demonstrated that cave stresses are able to shift easily around the footprint, moving from undrawn to drawn areas (and back again) as draw is moved around the footprint. Based on these learnings, quantitative guidelines for cave load prediction were developed and encapsulated in REBOP, a gravity flow simulator.

- **Advancements in simulation tools for improved decisions:** Bonded Block Modelling (BBM) technology was significantly advanced as a practical, state-of-the-art tool for simulation of brittle spalling and the associated ground support performance around excavations in three dimensions. This realistically simulated veined rock fracture (via back analysis of lab tests), in situ spalling and bulking phenomena and the response of ground support to intense localized stretching and shearing at discrete spalls (via back analysis of a wide range of published pull-out and shear tests). Simulation of practical tunneling and ground support scenarios suggest that ground support is most critical during unloading and small equivalent surface pressures can be very effective at reducing bulking (Figure 3). The benefits of cable debonding were also clearly identified.

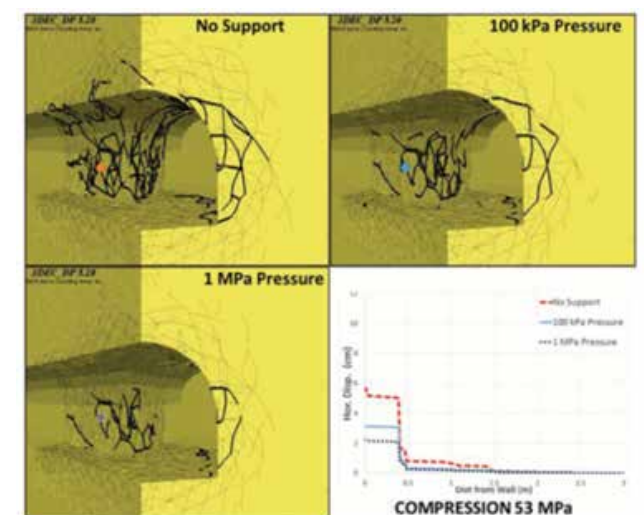


Figure 3. Example of a 3D BBM model of an extraction level intersection showing the impact of surface pressure on the damage, fracture opening (black lines) and bulking (as indicated by extensometers located at the colored dots) under abutment stress loading.

SPOTLIGHT: ULTRA DEEP MINING NETWORK

Photo courtesy of Gerry Kingsley

The focus of the Ultra-Deep Mining Network (UDMN) is to help to solve the challenge of mining in ultra-deep environments. As a national business-led Network of Centres of Excellence (BL-NCE), the UDMN is managed by CEMI. The UDMN is supported by members of the mining, oil and gas industries with active participation from small-to-medium sized enterprise (SMEs), industry agencies, research facilities and academia.

THE BUSINESS OF MINING DEEP—BELOW 2.5KM

The Network is working with some of the deepest mines in Canada to help the mining industry develop and adopt innovative technologies that are commercially viable. UDMN is becoming the

leading expert in Ultra-Deep mining (below 2.5km) by supporting solution providers capable of creating the industry-needed tools and technologies that can be used by mining companies.

Now in its third year of operation, UDMN has concentrated on managing the program, ensuring that the projects are progressing, refining the processes and standards of operations and taking corrective action where necessary. The Network helps to close the commercialization gap by providing participants with business development services and direct interaction with mining companies as well as nurturing the next generation of highly qualified personnel (HQP). As the Network matures, some projects are moving into their demonstration and commercialization phases.

One of the big success stories is that since January of 2015, UDMN Proponent Mira Geoscience increased its employee level from 35 to 55: a 57% increase.

Currently another 5 positions are waiting to be filled, which will increase the company to 60 personnel.

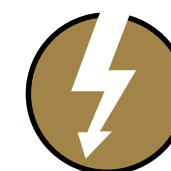
2015/2016 INVESTMENTS TOTTALLING \$5,688,502



ROCK STRESS RISK REDUCTION

Improve the control of stability in deep underground excavations

Current Projects: 7
\$779,435



ENERGY REDUCTION

Improve the energy consumption profile of deep mines

Current Projects: 7
\$2,036,904



MATERIAL TRANSPORTATION & PRODUCTIVITY

Increase the rates of development and production in mines

Current Projects: 7
\$1,141,654

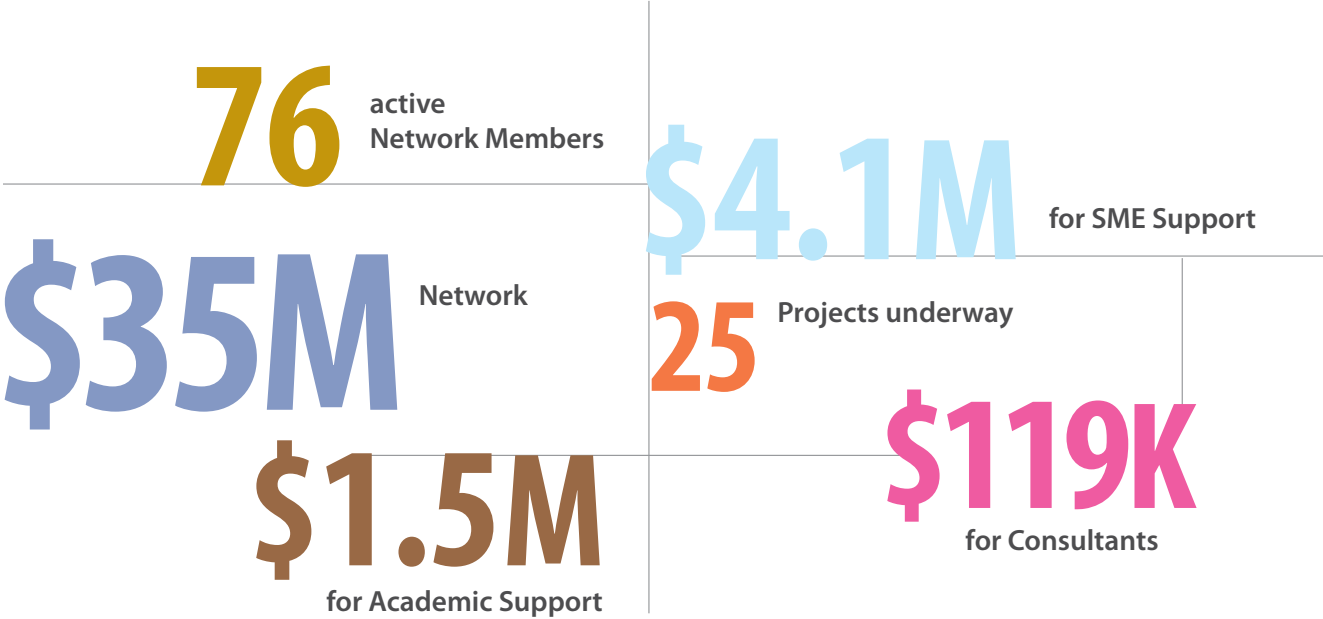


IMPROVED HUMAN HEALTH & EFFECTIVENESS

Enhance human environment in deep mines

Current Projects: 4
\$1,730,509

2016 UDMN NETWORK MEMBER SUPPORT



UDMN SYMPOSIUM

UDMN hosted its first Network Symposium in December 2015. The Symposium brought together Network Members and mining companies to discuss projects, share insights, identify potential synergies and understand the commercial likelihood of their projects. A total of 22 projects were presented and the potential significance of the projects to help solve the issues of the deep mining environment for the mining industry.

A special industry led panel shared their insights on the technological trends affecting the mining industry and how mines implement new technologies. Panellists' included Zachary Mayer (Manager, Mine Technical Services) from Kidd Operations, A Glencore Company; Steve Runnalls (Manager, Mines Technical Services) from Vale, Ontario Operations; Shayne Wisniewski (General Manager of Mining Projects) from Sudbury Integrated Nickel Operations - A Glencore Company; Douglas Morrison (President and CEO) from CEMI; and was moderated by Roger Emdin (Vice President of Projects) from Harte Gold and Chairman of the CEMI/UDMN Boards. Attendees

and panellists were able to have robust discussions regarding: the pressing technological problems facing the deep underground mining industry; challenges in accessing mine sites; mining industry support; change management in mine operations; and the types of return on investment that the industry prioritizes. The positive response to the Symposium has now made it an annual event.



Network members at the first annual UDMN Symposium (Courtesy of Gerry Kingsley)

COMMERCIALIZATION SERVICES

The UDMN team meets Network members with the potential for commercial viability, to assesses their capability regarding: Innovation Readiness, Administrative Readiness, Market Readiness, Operational Readiness, People Readiness, Financial Readiness and Global Readiness. The outcome of these meetings are recommendations to help reduce the cost and time required to achieve commercialization.

1. Innovation Audit

15 Innovation Audits were conducted within the last year. These audits play a vital role in discovering a SME's ability and capacity to innovate, its strengths, opportunities and weaknesses. An Innovation Risk Assessment is also conducted at each site. As result of these audits, 9 companies are developing their IP Strategies that may lead to patents being filed or further IP investigations. Network members have access to these services free or at a discount, due to UDMN's partnership with Gowling WLG to help facilitate the commercial success of the network and its members.

2. Commercialization Attainment Program (CAP)

Funded by the Greater Sudbury Development Corporation, CAP assists SMEs of the Greater Sudbury area to achieve commercialization of their deep mining related innovations.

Key deliverables of the program include:

- 1. Strengthen the innovation and commercialization capacity of the mining service and supply SMEs
- 2. Develop the ability of mining service and supply SMEs to address deep mining opportunities
- 3. Provide SMEs first exposure advantage to UDMN research outcomes and their commercial value
- 4. Provide SMEs exposure to emerging remote mining service needs

To date, the CAP has engaged 58 Greater Sudbury firms in areas such as innovation audits, connections to funding/investment opportunities and IP assistance. The resultant outcomes are 40 deep mining development opportunities, 9 patent/IP investigations and 3 new businesses created in the Sudbury region.

3. Engaging Mining Companies—Call for Proposals

Engaging mining companies continues to be a priority for the Network. Following the success Call for Proposals (CFP) in 2014, which focussed on small and medium enterprises, suppliers, academia, research institutes and original equipment manufacturers, the 2015 CFP focussed on mining companies who are members of the UDMN Industry Consultation Group. The objective of the 2015 CFP is to: ensure Network projects align with problems facing industry; increase the chances of collaboration between mining companies and other Network members. A successful outcome of the 2015 CFP is a new consortium of Vale, Glencore, KGHM and Barrick Gold, on the Mine Ventilation - Efficient System Management project.

4. Industry Consultation Group (ICG)

This third party group of industry leaders (14 mining companies) ensures a rigorous approach to the selection of proposals. The ICG aids in determining a proposal's viability and potential value for the industry. This year, three new companies joined, McEwen Mining Inc, Richmond Mines Inc. and Agnico Eagle Mines Limited. Agnico Eagle Mines also supported the Network with cash and in-kind contributions. The ICG is an essential component in assuring the success of the UDMN in helping to solve Industry's deep mining challenges.

MAKING INNOVATION SUCCESSFUL



CEMI has long recognized that for mining innovation to be successful, it has to succeed in two key areas—development of technical innovation and the market acceptance of the innovation. CEMI's four strategic areas of focus, FindMine, DeepMine, ValueMine, SustainMine help support technical innovations. Market acceptance, can only be achieved by overcoming the commercialization challenges of operational integration and delivering a viable, market-ready product or service into day-to-day mining operations. In recognition of this, CEMI's fifth area of strategic focus, BizMine (Commercial Viability), was established in 2015 to support the commercialization aspects of mining innovation.

SUPPORTING INNOVATION: COMMERCIALIZATION

BizMine will provide the necessary commercialization support to the technical innovations being developed in the areas of exploration, deep mining, mine productivity and managing the environmental impact of mining. It will help ensure the commercial

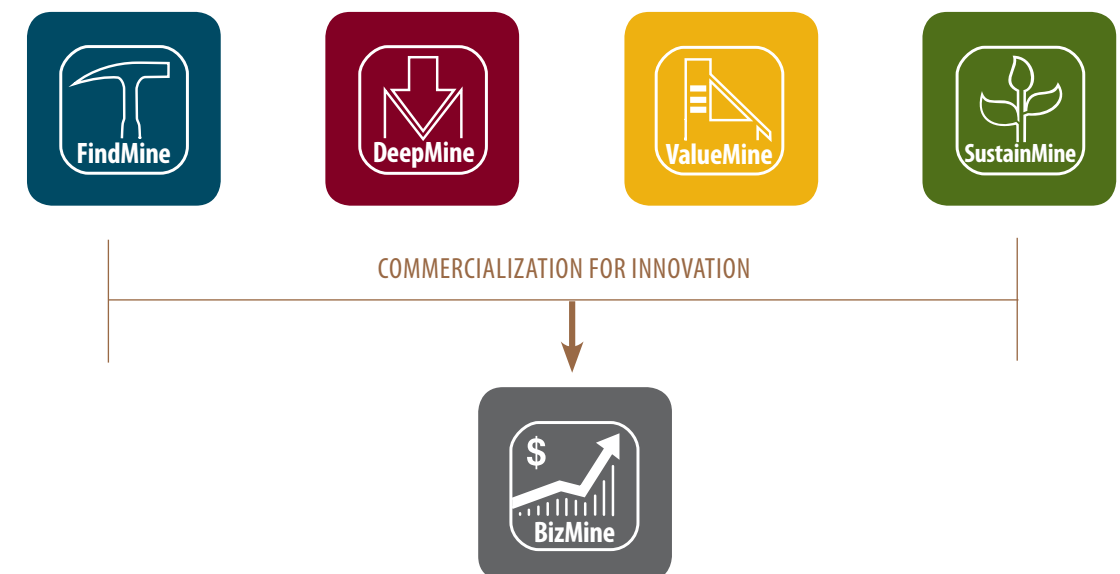
viability of the mining innovations and help our project partners navigate the many obstacles of the commercialization phase to help accelerate the innovation process.

The benefit of addressing and managing both the technical and commercial aspects of innovation within CEMI's Innovation Process is the flexibility and seamlessness of the tasks required in closing the existing gaps. It allows for the necessary collaboration and communication required between the technical and commercialization aspects in order to help integrate the innovation into an operational setting while still meeting market acceptability requirements and validating the economics and capabilities of the innovation.

BIZMINE: SUSTAINING INNOVATION

Collaboration is a key element of innovation success, and BizMine will engage with all sectors and disciplines—those that need, inspire, work, fund, use—innovation.

COMMERCIALIZATION SUPPORT FOR CEMI'S STRATEGIC AREAS OF TECHNICAL FOCUS



CEMI's BizMine helps close the commercialization gap within the innovation process by helping ensure commercial viability of mining innovation within CEMI's areas of technical focus.

SECTOR COLLABORATIONS

CEMI's ability to manage cross-functional teams and support the essential iterative knowledge building process, helps to bridge the technological innovation gaps. BizMine will work and engage with:

- 1. Mine Operating Companies**, to build the business case through cost-benefit analysis and feasibility studies to help implement innovations (processes, technology, products) into mining operations.
- 2. Government Departments & Agencies**, to seek funding for the development of mining innovations that offer clear economic and social benefits such as job creation, industry development & growth, social stability to help build the potential for a more robust mining economy. Governments are also able to leverage their funds through CEMI's industry partnerships, and can be managed in an efficient manner.
- 3. Industry and Mining Associations**, to provide insights on the issues and needs of the industry at large, facilitate co-ordinated advocacy work for the industry and provide networks for innovation support.
- 4. Universities, Colleges and Research Agencies**, to develop the knowledge requirements for innovation. In addition, they have the intellectual rigour, a requisite component for innovation.
- 5. Innovation Service and Supply Companies**, by partnering with them, to help them overcome the constraints of size and resources for both the technical and business guidance, primarily through the Innovation & Prosperity Office (IPO).

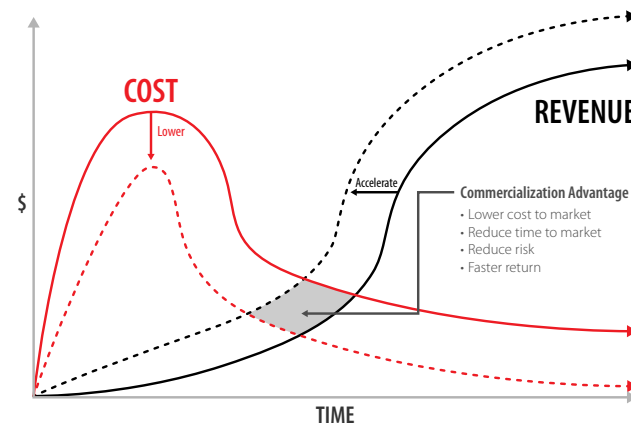
IMPACT OF INNOVATION FOR MINING

Commercialization of mining innovation helps the mining industry achieve better operational performance for a faster rate of return.

For Canada's mining industry to continue to grow and to be a global leader, it must solve the ever-present conundrum—lower costs, increase revenue and achieve this sooner than later. The innovations considered by CEMI are aimed at lowering operational

costs, without compromising on safety, accelerate the rate of discovery, improve productivity and ROI while improving the environmental performance and social impact of mining.

CEMI's Commercialization Advantage



INNOVATION & PROSPERITY OFFICE

The IPO was established in 2012 at CEMI, with the support of the Greater Sudbury Development Corporation (GSDC). The work of the IPO is to help the small-to-medium enterprise (SME) service and supply sector commercialize their processes, products and services of interest to the mining industry. Now, as part of BizMine, the IPO's mandate has extended to servicing the national SME community. IPO helps SME innovators with issues of: implementation, communication of the innovation value proposition, achieving the first sales or first transactions of the innovation, product launch support, pitch support, market development and branding and marketing.

Another area of IPO focus is intellectual property assistance. IPO has developed a close partnership with the legal firm Gowling WLG. This collaboration has made a significant impact in helping SMEs with their intellectual property strategies and in turning ideas into assets.

IPO also provides commercialization services for the Ultra-Deep Mining Network (UDMN). Activities include: executing innovation audits (measuring capacity and capability for commercialization), facilitating market development activities, matching new deep mining business development opportunities

to network members, help provide the linkages to funding and investment options and advancing commercialization outcomes. In the last year, IPO provided significant support to twice the number of companies (from 7 to 14) within the UDMN, in helping them commercialize their innovations.

Covergalls™ Incorporated

Covergalls is the first Canadian-made and designed coverall for women. There is a market for these coveralls within the mining industry, as 15% of the workforce is women. Launched in 2013, Covergalls is designed to accommodate the needs of women mining underground. Alicia Woods, founder of Covergalls has more than 15 years experience in the mining supply and service sector and through "observation-based innovation" identified a key opportunity in the market. IPO provided business advisory services, educational services (Course on

online marketing) and market development activities (mining sector leaders). Through the IPO's active engagement in the Council on Innovation & Commercialization of the Conference Board of Canada, it led to presenting the Covergalls story at the Council's meeting at 3M's Innovation Centre in Minnesota. The exposure at the meeting provided Covergalls the opportunity to reach new customers, strengthen ties with 3M, one of her primary suppliers and receive national media coverage through an article in the Globe and Mail.

Coldblock Technologies Inc.

IPO has worked with the company on the commercialization of ColdBlock™ Digestion. IPO has been a collaborating partner since 2009. The partnership with ColdBlock Technologies is a demonstration of the extent of commercialization activities IPO executes, to much success.



INNOVATION TALKS

CEMI actively sponsors and participates in lectures, technical presentations, conferences, workshops and industry forums to encourage discussion and collaboration between industry partners, academic institutions, students, SMEs and government regarding issues and new findings relevant to the metal mining industry.

ENERGY AND MINES TORONTO SUMMIT

CEMI supported and participated in the 3rd annual Energy and Mines Toronto Summit (October 2015), which brought together over 400 mining operators and energy professionals to discuss solutions for reducing energy usage and securing power for mines.

CEMI's Damien Duff presented "Collaborating on Energy Savings for Underground Operations", which highlighted innovative solutions between mining operators and industry partners to improve the energy consumption profile of deep mines.

CANADIAN SCIENCE POLICY CONFERENCE

Today, the mining industry is challenged to mine deeper to access ore deposits. As a result, mines are more costly to operate. The industry's historic resistance to new technologies is no longer affordable. It is imperative that the industry attract and retain new talent, prevent mine closures and improve the economic health of mining companies.

An Ultra-Deep Mining Network (UDMN) panel, "Challenges Associated with Transferring New Technologies to the Mining Industry" was held as part of the 7th Canadian Science Policy Conference in Ottawa, ON in November (2015). Featuring Douglas Morrison (President and CEO of CEMI and UDMN Network Director) Zachary Mayer (Manager, Mine Technical Service of Kidd Operations, A Glencore Company) Wayne Ablitt (President of Jannatec Technologies) Sylvie Nadeau (Professeure titulaire at École de technologie supérieure de Montréal) and Adi Treasurywala (President of ArrowCan Partners Inc.), the panel discussed three key ways in which the UDMN assisted in the successful transfer of new technologies.

1. Increased research and development (R&D) capacity through a networked solution team:

The UDMN network solution team strengthens the public-private sector relationship by engaging the mining service and supply sector, industry, academia, research institutions and government to develop new tools and expertise (highly qualified people-HQP) to meet the needs of the mining industry.

2. Change Management: Analyzing and reviewing current mining processes and adjusting them by embedding new technologies into existing and familiar systems for ease of adoption.

3. Improving research and development (R&D) receptivity at the mine sites: Increasing R&D receptivity within mine sites encourages and ensures more support for projects, allows for industrial trials to be built into the deliverables and potentially increase market acceptance for new tools and processes.

CIM CONVENTION

Eric Maag, UDMN Commercialization Director and Bora Ugurgel, UDMN Managing Director, promoted UDMN's 24 active projects, including an alpha prototype coverall as part of the Jannatec Thermal Garment project at the 2016 CIM Convention in Vancouver, BC in May.

At the convention's technical program, Damien Duff, CEMI VP-Geoscience & Geotechnical R&D and UDMN Theme Leader presented "The Ultra Deep Mining Network (UDMN)-Reducing the Risks Associated with Rock Stress"; and Damien Duff and Michele Levesque, of CANMET, a collaborating UDMN research partner, presented: The Ultra Deep Mining Network (UDMN)-Energy Optimization: The 40% Mine.

In recognition of the exceptional contributions made, Damien Duff was awarded the Julian Boldy Geological Society Service Award by the Geological Society of CIM at the Annual CIM Awards Gala. Allan Akerman, CEMI's Emeritus Technical Advisor, won the McParland Memorial Medal, for outstanding contributions to maintenance, innovation and research in the minerals industry.



(L-R) CEMI/UDMN attendees: Bora Ugurgel, Brian Jones, Damien Duff, Pearl Duff, Allan Akerman, Debbie Akerman and Eric Maag.



Bora Ugurgel at the CEMI booth with the Jannatec Technologies Thermal Garment coverall alpha prototype.

Background photo: Olivier Dubreuil and Pat Dubreuil. Photo courtesy of Gerry Kingsley

NATURALLIA 2015

CEMI organized “A Mining Overview: Addressing Mining Challenges with Innovation Solutions and Approaches” at the 4th edition of Naturallia, a business forum on natural resources. Panel participants included Rob Assabgui, Director, Mining & Milling (Ontario Operations), Vale; Peter Edmunds, Senior Advisor, Atlas Copco Mining and Rock Excavation; and Devin Cranston, Trade and Investment Marketing, Ontario Ministry of Northern Development and Mines. Discussions included challenges facing industry such as mine productivity and social & environmental issues, and how these are being addressed with innovative solutions.

GREATER SUDBURY CHAMBER OF COMMERCE - MINING PANEL

Douglas Morrison, CEMI President and CEO was a participant in the Greater Sudbury Chamber of Commerce Mining Panel, “Strengthening Ontario’s Mining Advantage”. The focus was on strategies to keep mining competitive, mining innovation, Aboriginal relations & partnerships, and what actions the Government of Ontario should take to ensure mining sector vitality. Other panelists included Chris Hodgson, president of the Ontario Mining Association; Hans Matthews, president and co-founder of the Canadian Aboriginal Minerals Association; and Stephen Lindley, vice president of the Aboriginal and Northern Affairs, SNC-Lavalin.

PDAC CONVENTION, TORONTO

As part of the 2016 PDAC conference in May, the UDMN hosted an Industry-led Panel, “Implementing Innovations into Mining Operation”, featuring Rick Howes, President & Chief Executive Officer, Dundee Precious Metals; Stephen Flewelling, Senior Vice President, Mining and Projects, Noront Resources; and Zachary Mayer, Manager, Mine Technical Services, Kidd Operations-Glencore Canada. The objective of the discussion was for mining companies (end users) to provide SMEs and other solution providers with valuable insight on: what is needed to improve

mines; current mining operations challenges; and how to best introduce innovative solutions required by the mining industry.

CEMI LECTURE SERIES

The CEMI Lecture Series provides learning on: new ideas, innovations and understanding the challenges of the mining industry. The three lecture series held this year include:

1. **“Using Inbound Marketing to Grow Your Organization” - David Terry, CEO/Founder of THE BRIT AGENCY**
2. **“The Practical Applications of Big Data, IoT, and Mobile Technology in Mining” - Dr. Sean Dessureault, Founder and President, MISOM Technologies Inc.**
3. **International Society for Rock Mechanics (ISRM) 13th online Lecture (recorded by CEMI) - “Challenges in rock mass strength determination for the design of underground excavations” - Dr. Peter K. Kaiser.**

ADVOCACY

The Canadian Chamber of Commerce is the largest and most influential business association in Canada, representing over 200,000 businesses from all sectors of the economy through a network of over 450 chambers. Canadian Chamber of Commerce AGM is where trade delegates from across Canada advance and debate policy resolutions of a national scope. In 2015, the Chamber collaborated with CEMI on the resolution “Support Canada to become a Leader in Global Mining Innovation”. The resolution called on the federal government to bolster efforts to support innovation and research in mining through the collaborative efforts of the mining industry, supply and service companies and cross-sector industries to better support implementation and commercialization efforts. Douglas Morrison, President and CEO at CEMI defended this resolution in Ottawa at the AGM, stressing the importance of investing in innovation that leads to commercialization and outlining the differences between research and innovation.

The resolution received overwhelming support and has now become the official policy of the Canadian Chamber of Commerce.

WORKSHOPS

4th Annual SUMIT Researcher Workshop

Six years ago the Ontario Research Fund, in conjunction with industry and institutional partners, provided \$6.7M in funding for SUMIT for mining-focused R&D led by Laurentian University in Sudbury and managed by CEMI.

In June 2016, CEMI hosted the final SUMIT Stakeholders’ meeting in Sudbury, ON. The intent of the meeting was to summarize the collective learning, and demonstrate practical and lasting value of SUMIT to sponsors (industry and government).

Open to the public and media, the workshop, provided an opportunity to celebrate the outstanding successes and outcomes achieved through the SUMIT program. Over 100 people attended, including the University of Toronto, Laurentian University, Queen’s University, University of Waterloo, the Ontario Government and Industry partners Vale, Glencore and Rio Tinto.



Damien Duff, CEMI VP, Geoscience & Geotechnical R&D and Dr. Sean Dessureault, Founder and President, MISOM Technologies Inc.

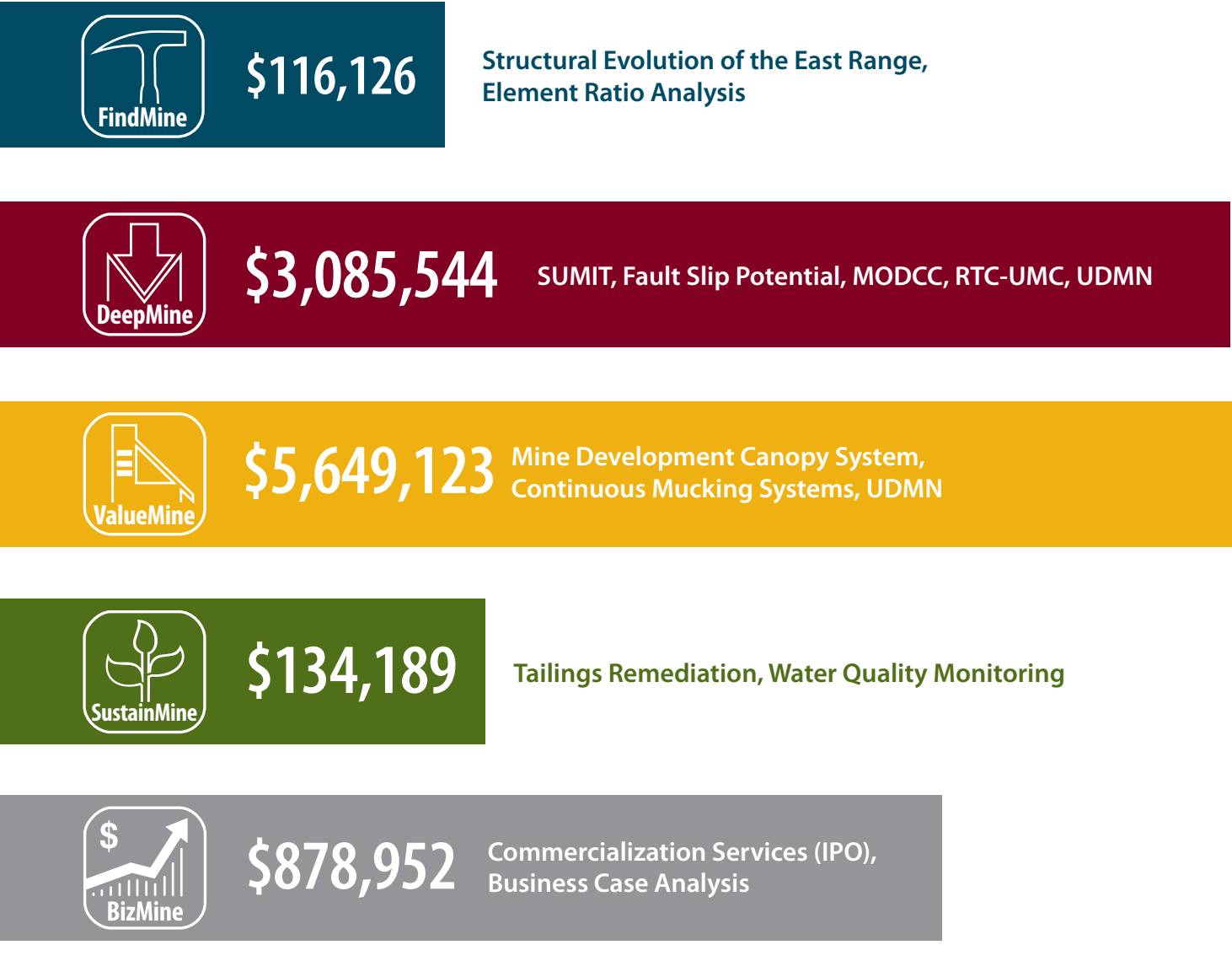


PDAC panel: (L-R) Zachary Mayer, Rick Howes, Stephen Flewelling and Douglas Morrison



SUMIT: Group shot of researchers, students and industry representatives

INVESTING IN CORE INNOVATIONS



TOTAL INVESTMENT IN CORE INNOVATIONS: \$9,863,934

During the 2015/2016 fiscal year, CEMI invested a total of \$9,863,934 into the development and implementation of step-change innovations. The graph reveals CEMI's financial contributions to its five core themes and a select group of the projects in progress during this period.

FINANCIAL STATEMENTS

CONSOLIDATED STATEMENT OF FINANCIAL POSITION		APRIL 30, 2016	APRIL 30, 2015
ASSETS			
Current Assets:			
Cash		\$2,566,000	\$6,985,000
Short-term Investments		1,005,000	-
Accounts Receivable		2,516,000	2,451,000
Prepaid Expenses		29,000	29,000
		\$6,116,000	\$9,465,000
Capital Assets		42,000	61,000
Long-term Investments		58,000	58,000
		\$6,216,000	\$9,584,000
LIABILITIES AND NET ASSETS			
Current Liabilities:			
Accounts Payable and Accrued Liabilities		\$1,459,000	\$2,293,000
Deferred Revenue		1,871,000	4,592,000
		\$3,330,000	\$6,885,000
NET ASSETS:			
Unrestricted		2,844,000	2,638,000
Equity in Capital Assets		42,000	61,000
		\$2,886,000	\$2,699,000
		\$6,216,000	\$9,584,000

CONSOLIDATED STATEMENT OF OPERATIONS		EQUITY IN		APRIL 30, 2016	APRIL 30, 2015
	UNRESTRICTED	CAPITAL ASSETS			
REVENUE					
Research and Other	\$6,773,000			\$6,773,000	6,175,000
UDMN-Federal NCE	5,341,000			5,341,000	2,849,000
Investment Income	33,000			33,000	40,000
	\$12,147,000			\$12,147,000	\$9,064,000
EXPENSES					
Salaries and Benefits	\$2,002,000			\$2,002,000	\$2,140,000
Projects and Research	8,860,000			8,860,000	6,260,000
Office and General	1,078,000			1,078,000	1,193,000
Amortization of Capital Assets		18,000		18,000	18,000
	\$11,940,000	\$18,000		\$11,958,000	\$9,611,000
Excess/(Deficiency) of Revenue over Expenses	\$207,000	\$(18,000)		\$189,000	\$(547,000)

The financial information was extracted from the organization's audited financial statements.

VERN DRYLIE
R&D PROGRAM DIRECTOR
OF ENVIRONMENT
& SUSTAINABILITY

PAT DUBREUIL
R&D PROGRAM DIRECTOR
UDMN THEME LEADER

DAMIEN DUFF
VICE-PRESIDENT - GEOSCIENCE &
GEOTECHNICAL R&D
UDMN THEME LEADER



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ASSOCIATE DIRECTOR -
RTC-UMC

COURTNEY FOLZ
COMMUNICATIONS
COORDINATOR

SHERRY GREASLEY
VICE PRESIDENT - OPERATIONS



BRIAN JONES
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UDMN COMMERCIALIZATION DIRECTOR



DOUGLAS MORRISON
PRESIDENT AND CEO
UDMN NETWORK DIRECTOR
CHAIR IN HOLISTIC MINING PRACTICES

CHARLES NYABEZE
DIRECTOR OF BUSINESS
DEVELOPMENT

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EMERITUS TECHNICAL ADVISOR



MATTHEW PIERCE
DIRECTOR - RTC-UMC

MIKE RICHER
IT ADMINISTRATOR

KIRK RODGERS
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UDMN COMMERCIALIZATION
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UDMN MANAGING DIRECTOR

DAVID VITONE
PROJECT MANAGER



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CHAIR OF THE CEMI & UDMN BOARD
VICE PRESIDENT PROJECTS, HARTE GOLD CORP.

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UDMN BOARD MEMBER
PRESIDENT, BWB CONSULTING SERVICES INC.

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SENIOR ADVISOR, ATLAS COPCO MINING & ROCK EXCAVATION

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EXTERNAL OBSERVER TO BOARD
SENIOR PROGRAM MANAGER,
NETWORK OF CENTRES OF EXCELLENCE

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DIRECTOR, OPERATIONAL & TECHNICAL SERVICES,
RIO TINTO COPPER & DIAMONDS

MAGDI HABIB

EXTERNAL OBSERVER TO BOARD
DIRECTOR GENERAL, CANMET MINING

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RUI WANG

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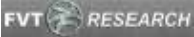
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PETER XAVIER

VICE PRESIDENT, SUDBURY INTEGRATED NICKEL OPERATION -
A GLENCORE COMPANY

COLLABORATOR

CEMI'S PARTNERS IN INNOVATION

ACADEMIC

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CARLTON UNIVERSITY • CURTIN UNIVERSITY • DALHOUSIE UNIVERSITY • DALIAN UNIVERSITY OF TECHNOLOGY • DELFT UNIVERSITY OF TECHNOLOGY • SWISS FEDERAL INSTITUTE OF TECHNOLOGY ZURICH (ETH) • ÉCOLE DE TECHNOLOGIE SUPÉRIEURE (ETS) • LAURENTIAN UNIVERSITY • MCGILL UNIVERSITY • NORTHERN COLLEGE • QUEEN'S UNIVERSITY • RYERSON UNIVERSITY • SIMON FRASER UNIVERSITY

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