ANNUAL REPORT 2013

CEMI
Centre for Excellence in Mining Innovation

Fostering Innovation, Implementing Excellence

ABOUT US

INSIGHT. INNOVATION. IMPLEMENTATION. IMPACT.

The Centre for Excellence in Mining Innovation (CEMI) directs and coordinates step-change innovation in the areas of exploration, deep mining, integrated mine engineering, environment and sustainability for the metal mining industry. Our seasoned team of program and research directors lead industry-focused applied and academic research and development projects that extend from geology and engineering to the natural sciences. We are at the forefront of cross-sector collaboration. We offer a single point of entry for knowledge resources and human capital that enhances the scope, extent and impact of innovation for the metal mining industry globally.

At CEMI, innovation is regarded as a three-phase process: research, development and implementation (R&D+I). With implementation, innovative ideas are operationally integrated into best practices that are socially responsible and attuned to community needs and expectations. CEMI creates greater capacity for excellence in innovation and adds greater value to the economic development of the metal mining industry by:

1 | collaborating with major Canadian and global mining companies, universities, government researchers, technical consultants, and innovative SMEs across Canada, and around the world

2 | facilitating industry-focused research and innovation that advances concepts, processes and methodologies for improved productivity and cost efficiency

3 | developing and nurturing future generations of researchers, industry leaders and highly qualified personnel by providing training opportunities and in-field access to facilities

4 | implementing sound business practices with a focus on accountability, efficiency and effectiveness

5 | attracting global patrons, sponsors and government funding

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PROGRESS

"THE MINING INDUSTRY IS GOING THROUGH A NUMBER OF CHANGES. WE NEED INNOVATION TO THRIVE SO THAT THE MINING INDUSTRY CAN BE COMPETITIVE AND PROSPER. CEMI IS THE GO-TO SOURCE TO PROVIDE THAT INNOVATION TO THE MINING INDUSTRY."

ROGER EMDIN, MANAGER, SUSTAINABLE DEVELOPMENT
SUDBURY INTEGRATED NICKEL OPERATIONS-A GLENCORE COMPANY

MESSAGE FROM THE CHAIRMAN OF THE BOARD

On behalf of the Board of Directors, I would like to acknowledge the contributions made by CEMI Staff and their extensive team of collaborators over the past year. It has been a year of building new relationships and developing commercial partnerships that will enable the future growth of CEMI. I would also like to express the Board's continued appreciation and support of our Patrons and Sponsors during this difficult time for the industry.

CEMI continues to make progress towards fulfilling its mandate to keep the Canadian mining industry at the forefront of innovation, ensuring its long-term sustainability and prosperity. The most important accomplishment at the Board level was to oversee development of a three year Strategic Plan which focuses on the identification of new funding sources and the cultivation of relationships with a broader range of corporate Sponsors. Success in this area will allow CEMI to continue to meet the needs of the industry by strengthening rock mechanics network capacity, initiating projects that will significantly improve productivity in access development and mine production, and setting the stage for future growth in environmental projects.

The CEMI board continues to evolve with the addition of two new Board members who bring significant experience and expertise to the table: Mr. David Willick, Mining Regional Leader – North America, GE Mining Solutions and Mr. George Ross, Deputy Minister, Ministry of Northern Development and Mines. I would like to take this opportunity to thank Ms. Suzanne Herbert (former Deputy Minister for the Ministry of Northern Development and Mines) for the valuable guidance and support she has given to CEMI during its formative years.

This year also marks the end of my term as Chairman and Vale's representative on the Board. It has been an honour serving as Chairman over the past two years. I am pleased to announce that Mr. Conor Spollen, Vice President, North Atlantic Projects will be the new Vale board member. I would also like to welcome Mr. Dominic Giroux, President of Laurentian University, as he takes over as the Chair of the Board.

It is an exciting time to be a part of CEMI as it continues to broaden its network of solution providers to meet the needs of the ever-competitive global mining industry.

Sam Marcuson
Chair of CEMI Board

BOARD OF DIRECTORS

SAM MARCUSON
Chair of CEMI Board
Vice President
Vale Canada Limited

ROGER EMDIN
Manager, Sustainable Development
Sudbury Integrated Nickel Operations
A Glencore Company

FRED DELABBIO
General Manager
Underground Mining Innovation
Rio Tinto

GEORGE ROSS
Deputy Minister
Ministry of Northern Development & Mines

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Laurentian University

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Ring of Fire Secretariat
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DAVID WILLICK
Mining Regional Leader – North America
GE Mining Solutions

DOUGLAS MORRISON
President & CEO
Chair in Holistic Mining Practices
CEMI

MARION CAMPBELL JARIS
Assistant Deputy Minister
Natural Resources Canada
Minerals and Metals Sector
(External Observer to the Board)

MESSAGE FROM THE PRESIDENT

This year, CEMI's focus has been to build on the solid foundation we created in our first five years of operation. To that end, we are extending and strengthening our innovation capacity, focusing on our five strategic themes in order to anticipate and meet future industry needs. Achievements in these areas are described in this report in the *Innovation in Progress* section (page 13). It is a course of action that we continue to hold as a Centre for Excellence in Mining Innovation.

CEMI and its collaborators have developed and implemented a tremendous array of projects focused on deep mining rock mechanics, ventilation and exploration geophysics. Over the last two years, we have been developing geotechnical expertise to enable the introduction of continuous excavation equipment in large-scale cave mining operations. Some of CEMI's key research projects include: hydraulic fracturing techniques for use in the mining industry to manage rockmass stress distribution; SUMIT - Smart Underground Monitoring and Integrated Technologies for Deep Mines to help reduce and mitigate geotechnical risk; and Ventilation on Demand to make it possible to strategically re-design ventilation systems to maximize production.

NEW PROJECTS

We have invested time and resources to develop a broader range of technical projects and processes that focus on techniques to enable mine operations to increase production and productivity. These projects include: rapid development to change face activities involved in drift development in order to achieve much higher advance rates; cooling systems that will deliver low-cost fresh cool air to workplaces; development of software to facilitate the use of molar element ratio (MER), used to analyze mineralogical processes; development of novel low-energy methods to accelerate ore and waste transport; and integrated personal protective equipment – to create a more comfortable micro-environment for personnel, freeing them from mine air-stream contaminants and offering mine-wide communications systems for improved effectiveness. Time and resources are also being put toward investigating transportation technologies to assist new mines in remote locations in the Far North. These innovations will serve a three-fold purpose: to help promote earlier production within mines; to support the social and economic development of the surrounding communities; and reduce the mines' immediate impact on sensitive environment.

BUILDING RELATIONSHIPS

CEMI's goal is to make the development and implementation of innovations a common practice, and one of the best ways to accomplish this is working with the service and supply sector. CEMI's Innovation and Prosperity Office (IPO), co-funded with the Greater Sudbury Development Corporation (GSDC) has made significant progress in connecting to the mining SMEs to achieve this goal.

To assist in the practical application of innovation (equipment, process or methodology), we have engaged with national and provincial funding agencies, such as the Sustainable Development Technology Corporation (SDTC), the Innovation Demonstration Fund (IDF) and the Ontario Capital Growth Corporation (OCGC) to help bring innovative solutions to market.

We continue to build and strengthen relationships with: the Greater Sudbury Development Corporation (GSDC); SAMSSA (Sudbury Area Mining Service and Supply Association); Sudbury Chamber of Commerce; Ontario Chambers of Commerce (OCC); Northern Centre for Advanced Technology (NORCAT); Canadian Institute of Mining (CIM) Canada Mining Innovation Council (CMIC); and Ontario Mining Association (OMA). We also continue to work closely with the funding agencies that have long supported us (NOHFC, OCE, NCE, IRAP, and NSERC), the provincial Ministries of Northern Development and Mines, Transportation, and Research and Innovation.

To increase the overall capacity for research and innovation, and to eliminate duplication, we are working with major mining research groups in Ontario (CAMIRO, MERC, and MIRARCO), to streamline processes, and define the portfolio of projects that complement our areas of expertise to increase the overall capacity for research and innovation and eliminate duplication.

ACHIEVEMENTS AND APPOINTMENTS

Within our organization we have two important achievements to celebrate this year. In March, Dr. Peter K. Kaiser (Founding Director of CEMI and the current Director of CEMI's RTC-UMC Division) was honoured by the Engineering Institute of Canada with the prestigious Julian C. Smith Medal for achievement in the development of Canada. Second, in August, Robert Bewick (Program Coordinator for the RTC-UMC) was awarded a PhD by the Department of Civil Engineering at the University of Toronto, under the supervision of Dr. W. Bawden and Dr. P. Kaiser.

A new, three year Strategic Plan has been put in place to direct CEMI's focus towards expanding funding sources and broadening our innovation delivery to meet the needs of our constituency. Projects to improve productivity, achieve earlier extraction of ore, reduce overall mining costs with the potential for an earlier return-on-investment have been initiated to attract new Patrons and Sponsors, and address necessary environmental sustainability issues for the long term.

We have made some internal changes to support our plans: the appointment of Damien Duff to Vice-President for Geoscience and Geotechnical projects, Harvey Parsons to Vice President for Mine Productivity projects, and Sherry Greasley, as the Director of Business Administration. We expect that these appointments will enhance our ability to execute the three year Strategic Plan.

CEMI is very pleased to announce that the Northern Ontario Heritage Fund Corporation (NOHFC) has awarded CEMI $750,000 for the SNOLAB partnership of the Mining Observatory Data Control Centre (MODCC). Solution members also include: Mira Geoscience, CMIC, Objectivity, Vale, Rio Tinto, and Sudbury Integrated Nickel Operations – A Glencore Company. The joint expertise of CEMI and SNOLAB will increase the capacity to service science and engineering communities in the North and around the world.

Finally, CEMI has successfully completed the final stage of the application to the 2014 Business-Led Networks of Centres of Excellence (BL-NCE) program competition for the establishment of the Ultra-Deep Mining Network (UDMN). The program is worth an estimated $46 million over 5 years. In putting our application for the Ultra-Deep Mining Network (UDMN) together, we are deeply grateful to all the organizations who offered their support to this application. The top four successful applications will be announced in December 2013.

VISION OF THE FUTURE

CEMI's aim is to impact key aspects of mining through innovation to significantly improve or accelerate the cost-effective, safe production of metals. Our plan is to play an important role in changing mining practices locally and globally; help the industry prosper despite the vicissitudes of global economic conditions.

As the breadth and depth of CEMI's project and discipline portfolio expands, and the strength and extent of relationships increase, so will our ability to capitalize on the tremendous physical and human resources of the metal mining industry of the Canadian Shield - Northern Ontario, Quebec and Manitoba. Given the expertise that exists in the North, and mining operations offering unparalleled opportunities to engage scientists and engineers from around the world, we believe that no Centre of Excellence in Canada, is better positioned than CEMI to become the leading source of innovation to such a globally vital industry.

Our Vision is to be the leading source of innovation for the global mining industry. Our Mission is to accomplish this by developing the tools and highly qualified people the industry will need to find more ore, mine ore more effectively and safely, generate more value from ore, have a more benign impact on the environment and a more beneficial impact on communities. This is mining in the 21st Century.

Finally, we offer our profound gratitude to our Sponsors and Patrons who have the courage and fortitude to continue to support this mission despite the difficulties imposed upon them by global economic forces. Thank you.

Douglas Morrison
President & CEO

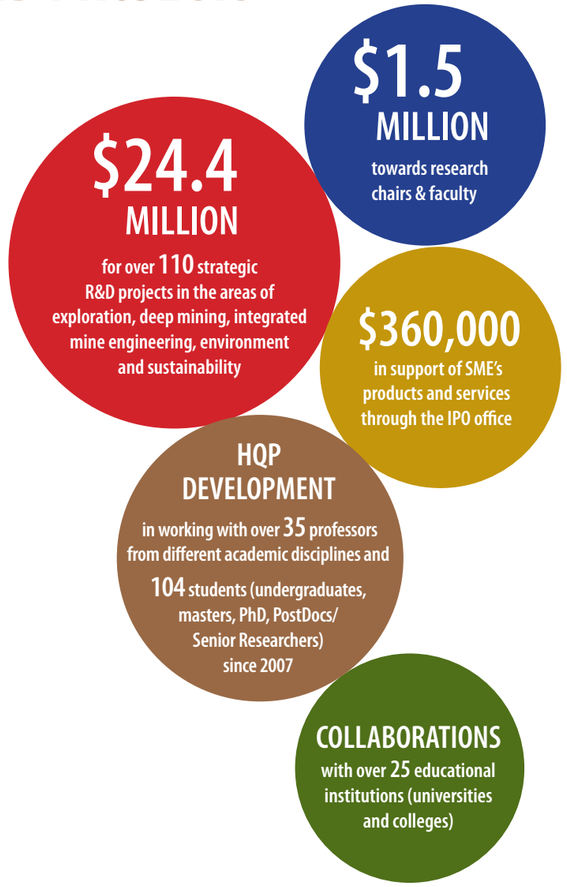
STRATEGIC RESEARCH PROGRAMS AND PROJECTS

CEMI IS ACHIEVING ITS MISSION TO DIRECT AND CO-ORDINATE STEP-CHANGE INNOVATION IN THE MINING INDUSTRY AND WITHIN ITS CORE STRATEGIC PILLARS

CEMI continues to meet the needs of the mining industry in its five core research and development project categories: FindMine, DeepMine, ValueMine, ConstructMine, and SustainMine. Since our inception in 2007, we have directed and coordinated step-change innovation in the areas of: exploration, deep mining, integrated mine engineering, environment and sustainability. Through cross-sector collaboration CEMI has initiated research development and implementation (RD&I) in living laboratories – underground mine sites for the real world, delivering measurable benefits to industry key performance indicators. Leading the way in industry-university-SME driven collaborative research, we have successfully achieved results by taking ideas and putting them to work. That takes a disciplined and strategic approach to the process of innovation.

INNOVATION AS A THREE-PHASE PROCESS: RESEARCH, DEVELOPMENT AND IMPLEMENTATION

Long lead times (3-5 years) and the need for convergence among different disciplines, various kinds of knowledge and practicality make the innovation process exciting and challenging for any business. CEMI's three-phase process, research, development and implementation (RD&I), is approached with strong and clear strategic focus to ensure purposeful, systematic innovation in each of our five core research and development project themes.



INNOVATION ONLY HAPPENS WHEN GREAT IDEAS ARE DEVELOPED AND INTEGRATED INTO MINING APPLICATIONS

Identification of new ideas is only the first step in a long aggregative process. Introducing ideas into the routine application of a mining operation is what makes it innovation. Our living laboratories program ensures that we are collaborating with patrons, sponsors and partners at specific mine sites. This gives us access to the world's deepest active mines in Ontario where we have the ability to conduct real world underground research, optimize experiments and provide real-world outcomes. This has allowed us to successfully inspire and implement innovations that improve efficiency in mine development, advance sustainability, increase safety, thereby enhancing productivity, performance and profit margins. It is the collaborative knowledge, disciplined approach and hard work of innovation that CEMI successfully brings to the table.

OUR PARTNERSHIPS TO CREATE INNOVATION IN THE METAL MINING INDUSTRY HAVE THRIVED

Inside we have featured some of the flagship projects and collaborative activities both currently in progress and completed, a result of the efforts of our solution team network . . . our Innovators.

We are excited about the collaborative innovation projects presented here and optimistic about the future. As we continue to integrate knowledge and seek innovative ways of addressing complex problems, we will build on our systematic, integrated innovation system. We thrive in a culture that fosters the highest caliber of creativity, collaboration and innovation implementation, a space that engages our local and global mining communities to work together towards innovation excellence.

CEMI recognizes and champions the idea that taking an idea from concept through implementation is the crucial step in innovation and the only way to ensure solutions are sustainable and economically feasible. This is evidenced in CEMI's delivery of the following tools to market:

- Fugitive Dust Control Guidelines
- Pre-concentration assessment Tool (Ore sorting & upgrading)
- GeoHazmap Tool & Phases2 Tool
- Burst Support Tool and SGMAT
- Manual: Structural Geology Guidelines for Burst-Prone Mines
- Acadia's Litho-Geochemistry Software: MERLIN

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

With the approval of the SUMIT program in 2011, we have further demonstrated our capability for the development, execution and management of major strategic research programs. CEMI successfully obtained $6.7 million in financial support to develop and advance smart engineering methods, technologies and tools to facilitate step-change advances in underground mining at depth. Field work is proceeding at Creighton, Coleman and Nickel Rim South mines in Sudbury. As well, datasets from other international mines are forming the basis of ongoing work. Through collaborative research and development, SUMIT is currently supporting 18 core projects focusing on three major challenges associated with deep underground mining:

1. **GEO-RISK:** Evaluation and mitigation of risks associated with mining in high stress, structurally complex ore zones to enable safer, smarter and more efficient mining at depth
2. **Rapid Underground Development:** innovations to accelerate mine construction for faster mine construction to increase economic returns
3. **Mine Sustainability:** Footprint reduction in deep mines through energy optimization with underground environmental controls

A RICH PARTNERSHIP OF ACADEMIC AND PRIVATE SECTOR RESEARCH TEAMS

Laurentian University is leading SUMIT in partnership with Queen's University and University of Toronto bringing leading academics to the forefront of the 18 core projects. In addition, significant contributions are being made by researchers from Carleton University, University of Waterloo, University of Alberta and the University of British Columbia. Collectively, CEMI has engaged 15 researchers and 20 students (1 PDF, 18 PhD, 8 MSc and 10 undergraduates) to collaborate with industry sponsors and partners at specific mine sites. Currently, 4 research engineers are working with students to produce outputs that generate significant knowledge transfer for the benefit of project sponsors and the mining industry as a whole. These collaborative interdisciplinary research teams are addressing many of the barriers currently delaying the establishment of new mines and the deepening of existing mines. These outstanding teams are helping to develop new ways to mitigate and manage risks, accelerate mine development and reduce energy consumption by:

• Capturing and sharing data in innovative ways from underground environments to optimize deep underground mine design and construction techniques

• Developing communications hardware/software, data storage, security and sharing control systems and related technologies

• Advancing knowledge and techniques to better calculate, calibrate and communicate information for the adoption of step-change technologies to optimize energy usage and reduce mine footprints

SUMIT: INVESTING IN KNOWLEDGE TRANSFER AND BUILDING HUMAN CAPITAL FOR DEEP UNDERGROUND MINING

The SUMIT program significantly contributes to the development of graduate students, with 1 PhD; 7 MSc and 5 undergraduate students having received their degrees since commencement of the program. To date 34 conference presentations have been made by SUMIT researchers, 14 refereed conference papers accepted and 12 peer reviewed journal articles published. A further 13 articles are currently in the review process. SUMIT related peer reviewed publications have been cited 15 times in scientific and engineering literature.

RIO TINTO CENTRE FOR UNDERGROUND MINE CONSTRUCTION (RTC-UMC) AT CEMI

The Rio Tinto Centre for Underground Mine Construction (RTC-UMC) at CEMI was created to undertake research in support of Rio Tinto's Mine of the Future™ programme with focus on underground mining infrastructure and footprint reliability. This state-of-the-art research and knowledge centre plays a role in the development and implementation of innovative step-change research and technology development for underground mines, designed to minimize delays and create value through speed and geo-risk mitigation. Rio Tinto designates a significant portion of funding for shared programmes, as part of its annual budget allocation with CEMI. This funding, which can benefit from potential government (Ontario & Canadian) leveraging programmes, is intended to engage other companies in R&D projects that are of relevance to Rio Tinto. Research aims at overcoming key challenges in mine construction and mechanized excavation, and addresses the challenges related to introducing new technologies to perform in highly stressed and naturally variable ground.

THE 2013 RTC-UMC PROGRAMME AIMS TO:

- develop new and innovative technologies utilizing world-wide expertise for improved speed and quality of underground infrastructure construction
- monitor and better characterize rockmass behaviour to reduce geo-risks
- assess and develop ground control processes to support advances in rapid mechanized development systems for vertical and horizontal applications
- improve footprint reliability, stability and support
- improve identification of strainburst potential, mitigation and management with support
- enhance stand-up time for raise, in tunnels excavated using drill & blast and Tunnel Boring Systems (TBS)

Research undertaken at the Centre supports mechanized excavation programmes for tunnel boring systems (TBS) along with development of

technology to better anticipate ground behaviour. These are tied directly to the key driver for the development of large underground operations, namely rapid development and excavation stability. In practice, this means faster development through optimal layouts, low risks for delays, cost reductions achieved through stable pillars and drawpoint design, stable raises and ore passes, and optimal support with less rehabilitation.

Using field data to reliably characterize ground for improved mine design modeling and support design, RTC-UMC is developing advanced stability assessment methodologies and technologies to improve and ensure support effectiveness in highly stressed, broken ground, and is developing reliable pillar/drawpoint support techniques. Field data, digital mapping, and back analysis will be used to obtain rock mass strength, skin damage properties, and improved raise stability assessment information from boreholes.

The RTC-UMC operates with a small number of employees and a large number of networked solution team members that bring the required skills to serve the mining industry's needs. In order to meet the requirements of the technical roadmap set out for the Centre, researchers and consultants from Canada, the U.S.A, Europe, and Australia have been retained to increase the delivery capacity, increase its network and provide an active knowledge base that allows for effective interaction with the Centre's solution team members.

The Centre uses an observational research approach, analyzing measurements in mines to prove innovative concepts and to assist in deriving value. A Rio Tinto internal consortium guides in the collection and interpretation of relevant data from mines in a systematic manner by back analysis. The Centre's solution team network including researchers from universities in Canada, the U.S.A., Europe, and South Africa will bring deep expertise to the development of best practices that will generate significant value for future underground mines. It is anticipated that the RTC-UMC will define best practices that consultants and testing laboratories can follow to realize more realistic rock performance predictions and procedures that will generate significant value for future underground mines. The projects currently underway will identify economic solutions that work with acceptable geomechanics risks.

PROGRESS AND OUTLOOK

The Centre continues to host Dr. Florian Amann from the Federal Technical University of Zurich, an expert in engineering geology and tunnel boring machine (TBM) performance. Dr. Amann's work is related to best practices for rock characterization. He was recently joined by Dr. Jean Hutchinson from Queens University and Dr. John Hadjigeorgiou from the University of Toronto to develop best practices in the selection of effective rock support systems.

With the new roadmap well underway, RTC-UMC is working to create next generation technologies for mining operations that result in improved safety, greater efficiency, lower production costs, improved health and environmental performance with more attractive working conditions – all essential elements for the success of large-scale mining of the future. Collaborating organizations include Itasca U.S.; Golder Associates; SRK Consulting; Aker Wirth; Atlas Copco; MIRARCO; Laurentian University; Queen's University; Universities of Arizona and Toronto; University of British Columbia, Delft University, The Federal Technical University of Zurich, and others to be determined based on required expertise.

AN ASSESSMENT ON CEMI'S INNOVATION IMPACT: THE EVIDENCE NETWORK RESEARCH STUDY

While it is clear that CEMI has delivered results over its five years of operation, we felt it imperative to measure our impact on innovation in the metal mining sector and gain knowledge from independent research to ensure that we were meeting our mandate. The results show positive impact, both direct and indirect in its five core research and development project categories.

In Fall (Nov/Dec) of 2012, CEMI conducted a research survey with The Evidence Network, a third party company specializing in measuring the impact of Innovation Intermediaries to validate its impact on delivering innovation excellence within the metal mining industry. 44% of the participants in the study were mining companies, 22% service or supply companies and 29% consultancy firms.

KEY FINDINGS AND IMPLICATIONS:

CEMI is achieving its mission to direct and co-ordinate step-change innovation in the mining industry and within its core strategic pillars.

- 82% of respondents whose company had developed new or improved products, processes or services reported that CEMI contributed to their ability to innovate. Out of all the indirect impact performance measures, CEMI had the greatest impact on companies' ability to innovate (79%), investment received, time to market (61%), and research investments (59%)
- 57% of respondents described their engagement with CEMI in the area of deep mining (DeepMine); 56% were engaged in the area of integrated mine engineering (ValueMine) and 31% were engaged in the area of environment and sustainability (SustainMine) and over 50% were engaged in underground mine construction (ConstructMine)

CEMI has a direct impact on companies' resources and capabilities, which also strengthens its indirect impact on companies' performance. CEMI contributed to the following resources or capabilities in a significant way:

- Technical Knowledge (87%); Technology development (83%)
- Strategic Research Knowledge (83%); R&D Funding (75%)
- Linkages to researchers (80%); Linkages to companies (72%)
- Equipment or facilities (67%); Promotion opportunities (67%)
- Overall the average direct impacts of CEMI on company performance increase with the intensity of use of CEMI's services
- CEMI's direct impact on the hiring opportunities (exposure to HQP /students during research) and its facilitation of research linkages are significant predictors of indirect impact on company performance

The services CEMI provides/offers are unique, in that 65% of all respondents indicate that it would be difficult to acquire similar services or assistance from another source, suggesting that CEMI's services have little overlap with what is available within the marketplace.

- 92% of respondents indicate that CEMI is important to the long-term sustainability of mines or mining in their region
- 94% of respondents reported that their company invested in applied research since first engaging with CEMI or CEMI-supported researchers
- 60% reported less that 10% of expenditures went towards research investments
- 60% would avail themselves on the collaborative research provided by CEMI (moderate, moderate-high, high intensity of usage)
- 45% would take advantage of the technology transfer or professional development offered.
- 67% of respondents reported positive impact on their ability to introduce their most recent product/service (within the last 2 years) to be attributable to CEMI
- 53% whose company had improvements in operating or capital performance reported positive impact on their ability to be attributable to CEMI
- CEMI is achieving significant impact on younger, smaller companies and CEMI's greatest impact is occurring in the supply chain of the larger mining companies

CEMI's strategic focus has resulted in five core research and development project themes: FindMine, DeepMine, ValueMine, ConstructMine and SustainMine. Each is wide-reaching and helps to advance innovation and enrich knowledge for the metal mining industry.

CONTENTS

EXPLORATION | FindMine

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

DEEP MINING | DeepMine

Research and development of new technologies and processes to ensure safe, profitable mining at depth, with a focus on risk mitigation, mechanized underground excavation, cost reduction, and productivity enhancement.

INTEGRATED MINE ENGINEERING | ValueMine

Strategic research and development in the areas of: Mine Process Engineering and Mine Design to enhance safety and performance, minimize impact and cost risk and emphasize best practices; Enabling Technologies that will result in advances in data and knowledge transfer.

INTEGRATED MINE CONSTRUCTION | ConstructMine

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

ENVIRONMENT & SUSTAINABILITY | SustainMine

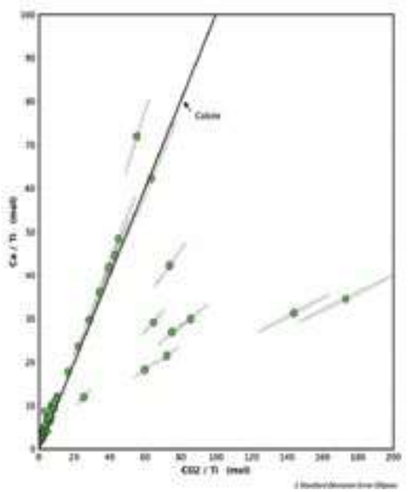
Research is underway to try to identify processes that might lead to more environmentally benign results and better stewardship of mineral resources. Strategic research in the areas of environmentally responsible processes, environmental studies and sustainability is underway. Initiation of novel or reconsideration of previously abandoned techniques for the secondary processing of mine waste.

DEVELOPMENT OF JAVA-BASED MERLIN SOFTWARE TO PLOT MER DIAGRAMS

THE ISSUE: Over the years, molar element ratio (MER) analysis has become both highly adaptable and extraordinarily useful in determining the mineralogical controls in rocks. Pearce element ratio (PER) analysis and general element ratio (GER) analysis are two different but complimentary forms of MER analysis that identify the mineralogical controls in igneous and sedimentary rocks, mineral deposit alteration zones and chemical weathering. As powerful as MER analysis is, it has not gained the following it deserves amongst geoscientists, in large part due to the lack of updated computer software that can plot data in a way that facilitates the interpretation of MER diagrams. These diagrams can clarify the mineralogical history of rocks and help minimize interpretational ambiguity.

THE SOLUTION: Drs. Clifford Stanley and James Diamond of Acadia University designed and developed Java-based software that simplifies the accurate plotting of both PER and GER diagrams, and accelerates their interpretation. Programming the software in Java makes the software available to virtually all laptops, desktops or workstations, including those running MS-windows, Apple OS X, Linux or Unix. The features of the program and the flexibility of Java will make the software more accessible to a wider population of geoscientists with differing skill sets.

THE RESULTS: MERLIN software in Java script is now available. The new program provides a quantitative and objective method to measure data in order to understand the impact and extent of hydrothermal reaction on mineralization, and important step in mineral exploration. It can also be used to examine fractionation processes and so gain a better understanding of the genesis of igneous rocks. MERLIN will be available for download to all geoscientists and to the global mining industry on the CEMI website at www.miningexcellence.ca



Here is a simple graph examining the lithogeochemistry of turbidites from the Castlepoint area of New Zealand (North Island), with information about it below.

This PER diagram tests for compositional control by calcite. Samples plotting on the calcite compositional control line (m = 1) contain calcite; samples plotting with higher ratios along this line contain more calcite. Samples plotting to the right of the calcite compositional control line (m = 1) contain siderite, whereas the sample plotting significantly above the calcite compositional control line (m = 1) contains apatite.

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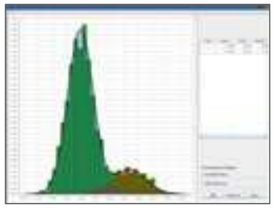
Kelly Russell, University of British Columbia
Jim Nicholls, University of Calgary
Tony Beswick, Laurentian University (Professor Emeritus)

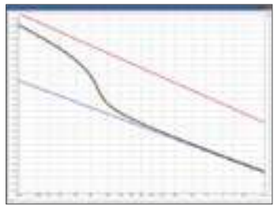
TRANING PROBPLOT SOFTWARE TO A MULTI-PLATFORM APPLICATION

THE ISSUE: ProbPlot analysis of exploration geochemical data is a highly effective means of identifying samples with common geochemical signatures and classifying them into related groups. ProbPlot software was widely used for this analysis and became an industry standard for serious geochemical reports in the 1980's and early 1990's. The ProbPlot software was originally developed for the DOS operating system but was not upgraded to the Windows operating system. As valuable as ProbPlot software was, its use eroded over time, solely due to the discontinuation of DOS software and hardware. As such, ProbPlot geochemical data analysis is no longer commonly used by mineral explorationists.

THE SOLUTION: Drs. Clifford Stanley and James Diamond of Acadia University have undertaken to redesign/upgrade the ProbPlot software to give it more functionality and make it more accessible. It is being developed in Java so that it is accessible on virtually all laptops, desktops or workstations, including those running MS-windows, Apple OS X, Linux or Unix. As well as having all of the functionality of the original program, it will incorporate many new features (e.g., interactive graphics, consequence-based interpretation) that will significantly increase understanding of cumulative frequency data, the element concentrations used in mineral explorations and its value to mineral exploration and the mining industry in overall.

INNOVATION IN PROGRESS: The development and testing of the software is in progress through the summer and fall of 2013. Beginning in January 2014, this CEMI-funded project will be available for download to all geoscientists and to the global mining industry on the CEMI website in the short term until the means of web distribution are finalized.





Figures 1 and 2 present a probability plot and its corresponding histogram of an element concentration generated by the SOPP software. The program has been used to optimally fit the underlying frequency data with two normal sub-populations (straight lines on the probability plot, blue and red bell curves on the histogram). The resulting frequency model (curved black lines on both plots) can be used to determine the most appropriate thresholds to classify the samples into two categories (e.g., 'anomalous' and 'background', 'sandstone' and 'shale', 'ore' and 'waste', etc.) and thus facilitate accurate geochemical data interpretation.

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A COMPARATIVE STUDY OF MINERALIZED AND UNMINERALIZED BRECCIAS ALONG THE WHISTLE OFFSET DIKE IN THE NORTH RANGE OF THE SUDBURY IMPACT STRUCTURE

MERC

THE ISSUE: Breccias, such as Sudbury breccia and metabreccia, are preferred hosts to Cu-Ni-PGE mineralization in footwall country rocks and offset dykes of the Sudbury Igneous Complex. The ability to identify and distinguish unmineralized and mineralized metabreccia along offset dikes would help focus exploration efforts.

THE SOLUTION: The main objective of this research project is to develop criteria for discriminating between unmineralized and mineralized metabreccia. By providing tools that aid in the recognition of mineralized metabreccia, exploration efforts and dollars can be focused on the most favourable host rocks.

THE RESULTS: Metabreccia is one of the main hosts of Cu-Ni-PGE mineralization along the Whistle offset dike. Petrographical, modal mineralogical, image analysis, mineral chemistry, and lithogeochemical observations do not suggest any significant differences between mineralized and unmineralized metabreccias.

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EXPERIMENTAL STUDIES OF THE ROLE OF Bi, Te, As IN PLATINUM GROUP ELEMENTS (PGE) FRACTIONATION AND REMOBILIZATION DURING THE CRYSTALLIZATION OF A SULFIDE MELT

MERC

THE ISSUE: The Platinum Group elements (PGE) in the footwall ores in Sudbury are typically found as Platinum Group Metals (PGM) that contain arsenic, tellurium, and bismuth (e.g. michenerite, moncheite, froodite, sperrylite). To understand the distribution of PGE in Cu-Ni-PGE systems (and the influence of magmatic vs. hydrothermal processes in ore formation), it is necessary to constrain how these three elements (As, Te, Bi) affect the behaviour of PGE.

THE SOLUTION: Experiments are being conducted in the Laboratory for Experimental Petrology Applied to Ore Deposits at Laurentian University involving the synthesis of sulfide melts, enriched in Bi, Te, As, and PGE to constrain how separation of a Cu-rich sulfide melt from a Fe-rich sulfide residue and separation of a Bi-Te melt from a Cu-rich sulfide residue affect the fractionation of PGE. Synthesis is being done at temperatures ranging from 1200 °C to 550 °C and either at atmospheric pressures (in evacuated silica tubes) or at 5 kbar (in a piston-cylinder press). Synthesized samples were analyzed for distribution and partition-ing of PGE among different phases to determine the temperatures at which Bi-Te melts form and to establish how PGE fractionate in the presence of As, Bi, and Te.

INNOVATION IN PROGRESS: Experiment results indicate that gold, palladium, and platinum can be mobilized away from a main mass of sulfides without the need of hydrothermal fluids, at temperatures down to 600 °C. Below 600°C, any PGE mobilization will likely be hydrothermal. Main results were presented at the GAC-MAC conference in May 2013 and a paper will be submitted for publication by end of 2013. Additional experiments on different aspects of the system are in progress.

Platinum, palladium, and gold arsenides synthesized experimentally at 900 oC. Light grey grains with square and trapezoidal sections is sperrylite (PtAs2). The lighter (almost white) rounded grains are Au-Pd arsenides (likely from immiscible arsenide melt droplets). Darkest grey areas are Fe-Ni sulfides. The intermediate-grey region in the right-hand side are Cu-Fe sulfides (from a Cu-rich sulfide melt).

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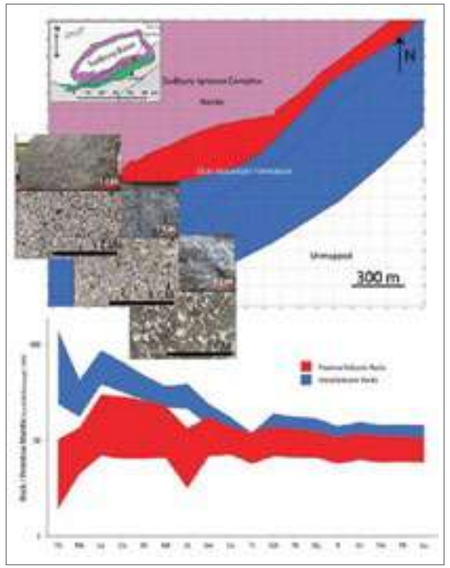
EVOLUTION OF THE SUDBURY IGNEOUS COMPLEX CONTACT METAMORPHIC AUREOLE AND CONTROLS ON ANATEXIS

MERC

THE ISSUE: Much of the Ni-Cu-PGE mineralization in the Sudbury Structure was generated and modified within the anatectic and contact metamorphic aureole of the Sudbury Igneous Complex (SIC). To increase our chances of exploration success in this complex environment, new and novel exploration techniques are needed, yet few studies have been conducted that show how to identify the presence of a contact metamorphic aureole around the SIC. This is critical for a deeper understanding of the thermal architecture during the development of some types of contact and footwall ore deposits.

THE SOLUTION: Defining field, microscopic and geochemical criteria to establish the nature and extent of partial melting, metamorphic devolatilization, and fluid interaction within the SIC contact metamorphic aureole and the overprint of the aureole by regional metamorphism will provide the context to understand the thermal structure and evolution around the SIC.

THE RESULTS: Field observations indicate that large portions of the South Range metamorphic aureole surrounding the SIC can be resolved despite complications due to post-metamorphic events, primary lithologic heterogeneities, and the geometry of the SIC contact. Geochemical data has proven useful in establishing fingerprints to distinguish rocks that are highly affected by contact metamorphism compared to similar rocks in the more distal part of the metamorphic aureole. This is extremely useful as new and existing geochemistry databases can now be studied to see if similar rocks outside the study area show the same characteristics. Finding rocks with matching characteristics would indicate their proximity to the SIC during cooling and solidification of the SIC melt sheet.



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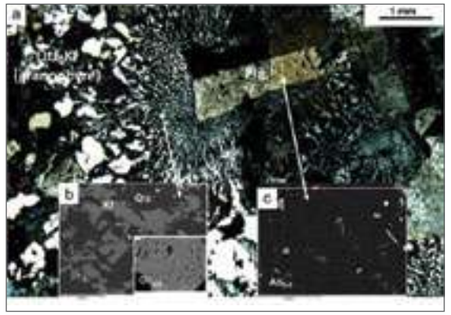
THE ROLE OF FLUIDS IN THE FORMATION AND MODIFICATION OF FOOTWALL Cu-Ni-PGE SYSTEMS

MERC

THE ISSUE: The Sudbury Igneous Complex (SIC) and its footwall rocks constitute one of the most significant centres of Ni-(Cu)-PGE mineralization globally. Previous work indicates that fluids have contributed to the low-temperature evolution of the footwall mineralization, but details remain poorly defined. Similarly, there has been relatively little work done to assess the role of the hydrothermal system process in the formation, upgrading and mobilization of ore zones in the SIC and what aspects of these alterations are conducive to mineralization.

THE SOLUTION: Conduct a characterization and evaluation of fluid-related alteration within both the granophyre unit and footwall setting (Nickel Rim South) by integrating field observations, petrography, whole-rock and mineral chemistry, stable isotopes, and chemistry of fluid inclusions. These data will be used to address several fundamental issues regarding the role of fluids in the SIC and mineralized settings. This project links directly with two other projects currently underway that are focusing on the generation of melts in the contact aureole of the SIC and the role of trace metals in mobilization of sulfide ores and PGE.

INNOVATION IN PROGRESS: Data collected in this study, using a wide variety of analytical methods, suggest that the granophyre interacted extensively at high fluid:rock ratios with two thermally distinct, but chemically similar fluids in terms of their bulk chemistry. These two fluids record the initiation and subsequent collapse of hydrothermal fluid circulation related to the SIC. The early high-T fluid may be internally derived and was responsible for the pervasive metasomatism observed in the granophyre. The later lower-T fluid records the ingress of an external fluid as the hydrothermal system collapsed. This latter fluid, fuelled by the cooling SIC, gave rise to massive sulfide mineralization (Zn-Pb-Ag) found at the top of the Onaping Formation which overlies the granophyre. Ongoing study will compare and contrast the characteristics of the hydrothermal alteration documented in the granophyre with that associated with the footwall system of the large Nickel Rim South Ni-Cu-PGE deposit. These results are underway and will be presented in 2014.



Dissolution-reprecipitation texture (Figure 1a) from granophyre unit, SIC. K-feldspar (Figure 1b) and plagioclase (Figure 1c) grains contain pitted textures, produced by dissolution-precipitation reactions at ~300-350°C. Some pits contain secondary phases.

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METAMORPHIC, STRUCTURAL, AND GEOCHRONOLOGICAL EVOLUTION OF THE SOUTH RANGE OF THE SUDBURY IMPACT STRUCTURE

MERC

6b

Fig6b staurolite: Photomicrograph of syn-kinematic staurolite porphyroblast.

THE ISSUE: The South Range of the Sudbury impact structure has been affected by several orogenic events that have displaced and folded Huronian footwall rocks and Ni-Cu massive sulphide deposits at the base of the Sudbury Igneous Complex. New and novel exploration approaches are needed to increase exploration success.

THE SOLUTION: A 4-D interpretation of the tectonic evolution of the South Range before and after the Sudbury impact event has been developed. This integrates structural geology, metamorphic petrology and geochronology, and provides further clarity and understanding of the geology of the nickel-rich south rim of the Sudbury Igneous Complex.

Fig8c think section GF: Photomicrograph showing micro drag folds showing southeast-sid-up reverse thrusting towards the northwest, Grenville Front.

8c

THE RESULTS: A new interpretation of the tectonic evolution of the South Range has been developed and multiple deformational phases postulated, providing a new framework for evaluating the present shape and distribution of Ni-Cu massive sulphide deposits along the south rim of the Sudbury Igneous Complex.

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UPDATING MOFRAC: DISCRETE FRACTURE NETWORK MODELING SOFTWARE

CEMI
Centre for Excellence in Mining Innovation

THE ISSUE: Underground fractures in the earth's crust pose a number of problems for the mining and nuclear waste management industries. For the mining industry, determining the composition of the earth's crust – the structure and nature of the rock, the concentration and distribution of stresses and where the rock is fractured is important for safe and effective mine design. For the nuclear waste disposal industry, it is critical to understand the location of fractures and faults when burying nuclear waste because of the risk of ground water contamination and other dangers such as leeching.

MOFRAC software models fracture networks in the earth's crust by heavily relying upon known actual geological controls. However, it was initially developed in Fortran, a now outdated computer language and not user friendly.

THE SOLUTION: In a project lead 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 code, the software is being upgraded so that it can be used more broadly and effectively by the mining and nuclear waste management industries. MOFRAC is unique because it pays strict attention to fundamental geology principles, respecting geological input data better than any other tool of its kind. It is expected that this application will produce a more accurate representation of the geological structures in the rock than other tools which claim to do the same thing. This will reduce uncertainty and increase safety for both the mining and nuclear waste management industries.

INNOVATION IN PROGRESS: This project is being managed in two phases. The first phase, which is now complete, has updated the computer language and developed a rudimentary graphical user interface (GUI) for the software. Initial validation exercises were also done in which data was input from known fracture networks and the results from the application were compared to the actual structures. Phase two, currently under development, will include the development of a more comprehensive GUI as well as more complex testing and validation of the program at real sites (a nuclear waste site in Finland and at possibly at a Glencore mine in Sudbury).

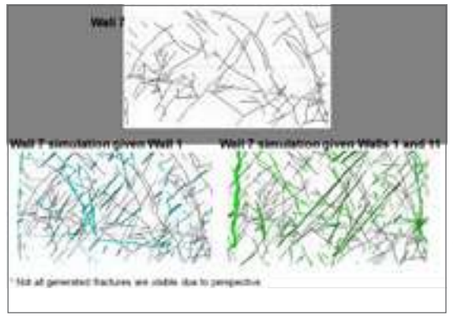

Photo Courtesy of Lorrie Fava

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INTEGRATED PERSONAL PROTECTIVE EQUIPMENT (IPPE) – A NEW IMAGE OF THE UNDERGROUND MINER IN THE 21ST CENTURY

CEMI
Centre for Excellence in Mining Innovation

THE ISSUE: Due to the financial unpredictability/risk of finding and developing new mines, there is an increasing emphasis on extending the life of existing mines by digging deeper. The deeper a mine, the harsher the environment for the people and machines working at those depths for a variety of reasons (e.g., increased heat, physical protection due to rock wall instability, fresh air, contaminants in the air, communication, navigation, etc.). Mitigating those risks is expensive, with almost half of the cost of ultra deep mining being attributed to the cost of maintaining an environment in which humans and machines can function. The current solution is to provide traditional support gear (helmets, air, etc.) and then strap on devices as necessary to provide additional capabilities, which can in fact, impede productivity and even safety. As yet, there is no integrated protective solution that enables workers to function safely, comfortably and efficiently at these extreme depths.

THE SOLUTION: CEMI is leading a project to develop the next generation of IPPE that will integrate many of the "add-on/strap on" functions available current technology and that will also integrate with other protective gear components that is required for ultra deep mining (e.g., thermal control, comms, navigation). It is anticipated that this IPPE will manage or be a part of an integrated system that ergonomically manages and enhances the wellbeing/safety of miners working at ultra deep levels, including cooling, filtered breathing, air quality monitoring, position tracking (RFID), noise reduction, medical monitoring (e.g., heart rate, breathing) and mine alerts. In addition, IPPE will enhance miner efficiency with features such as lighting, power supply, computerized heads-up display, communications, navigation/mapping, recording (still and video images) and operations manuals on demand.

Photo courtesy of Omer Hacomeroglu Design

INNOVATION IN PROGRESS:
Development of the Integrated Personal Protective Equipment (IPPE) is underway. Functional requirements specified in the design phase will focus on individualized environmental control, and ergonomic and safety components that will make mining in ultra-deep environments far more efficient. The improved level of protection will increase the value proposition of an optimized human-driven production system, highly effective people underground, generating significantly higher value than at present. It addresses the critical operational health and safety risks to facilitate Ultra Deep Mining. This will lower the cost of creating and maintaining a safe work environment at these extreme levels. More broadly, it will be easier for mining companies to expand production, and maintain investor confidence, because more is being extracted from existing mines rather than taking on the financial risk of developing new mines.

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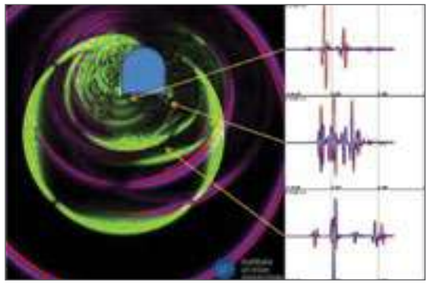
S-GMAT GROUND MOTION ASSESSMENT TOOL

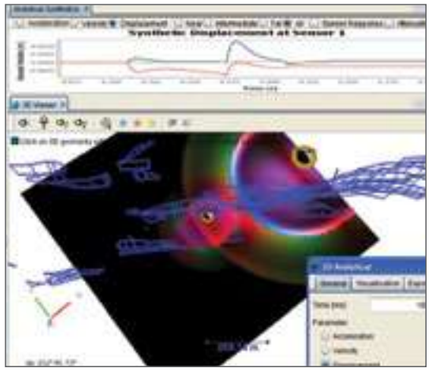
institute of mine seismology

THE ISSUE: Existing methods for estimating ground motions resulting from mine seismicity near potentially vulnerable excavations are currently too simplistic and do not reflect today's more advanced understanding of microseismic monitoring capabilities. Furthermore, ground motions can only be monitored at selected points and conditions in between are unknown.

THE SOLUTION: CEMI, working with the Institute of Mine Seismology (IMS) in South Africa and Australia, developed a Synthetic Ground Motion Assessment Tool (S-GMAT). The tool permits estimation of the ground motions produced near potentially vulnerable excavations located at varying distances from a seismic source. Tool outputs are in 3-D format capable of being incorporated into existing modeling and visualization platforms at mines. S-GMAT also provides input for forensic analyses of excavation damage. This is now being utilized for case studies to improve excavation stability.

THE RESULTS: First Phase work on the S-GMAT tool is now complete. For more information, contact the IMS at www.imseismology.org. The next phase of this project will be to validate and then integrate the S-GMAT with BurstSupport, a tool developed by MIRARCO to help deal with dynamic rock support element selection in burst prone mines.





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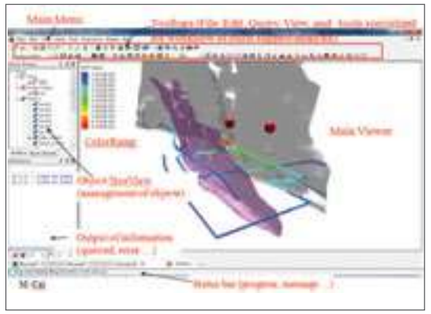
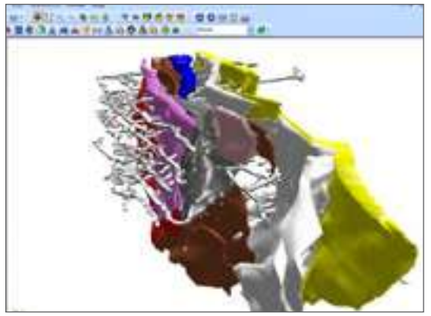
BURSTSUPPORT TOOL





THE ISSUE: While huge progress has been made to increase safety in burst prone ground, there is an ongoing need to develop more reliable approaches for dealing with dynamic ground support requirements and formulating appropriate ground support strategies in underground burst prone mines.

THE SOLUTION: The development of BurstSupport, a new software tool released in 2013 for use by rock mechanics engineers at mines, improves rock support design strategies in areas of a mine affected by large seismic event, by enabling the selection of appropriate ground support elements when dealing with dynamic loading conditions from fault-slip events in underground mines.

This powerful, user-friendly, Windows-based 3D tool, provides mining and civil engineers the ability to conduct rock support design in deep underground mine drifts or civil tunnels. Users can visually assess load, displacement and energy demands at multiple drift locations by considering anticipated seismic event magnitude and location, stress, drift orientation and rock mass quality simultaneously. BurstSupport allows safety and geo-risk management through integration of all relevant engineering design components. It is envisioned that rockburst risk management can be significantly improved using this tool.

THE RESULTS: This tool greatly improves the utility of the Canadian Rockburst Support Handbook (to be published in an updated guide). The next phase of this project will aim at validating and then integrating BurstSupport with S-GMAT, a synthetic ground motion modeling tool used to estimate ground motions produced in response to fault rupture. The BurstSupport Tool is now available for licensing. For more information contact Ming Cai.

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STRAINBURST POTENTIAL IDENTIFICATION AND MITIGATION

THE ISSUE: New research data suggests that it is time to re-think standing assumptions made when assessing rockburst damage and by implication when designing support in burst-prone ground.

THE SOLUTION: A critical assessment of the current mine support design guiding principles led to the conclusion that the primary damage mechanism to an excavation site is often a seismically triggered strain-burst or self-initiated strainburst and damage is often not rooted in momentum or dynamic shaking from a remote source. For example at the Jinping II tunnel in China, over 500 strainbursts were encountered without any triggering earthquakes or fault slip events. As a result, rockburst damage is primarily related to the state of stress and the local mine stiffness at the potential damage location and only indirectly related to the seismic ground motion. A reliable means of identification of mining induced strainburst potential will lessen vulnerability of an excavation. Further, once strainburst potential is identified, failure may then be mitigated by using methods of hydraulic fracturing that allow for the creation of fracture networks, thereby damaging the rockmass prior to mechanical excavation.

INNOVATION IN PROGRESS: Research is underway to build a strainburst database with related excavation vulnerability assessment parameters and a methodology to assess deformation potential as a strainburst trigger is under development. Forensic analysis to review the damage to an excavation or its support will aid in better understanding the cause of failure and necessary design parameters. The BurstSupport Tool - created through earlier related research projects - will then be updated to assist in strainburst support analysis. Related step-change innovations are being explored to overcome existing deficiencies of hydraulic fracturing technology, namely the use of stimulation and solids injection for application in mining. It is anticipated that the results will also find application in the oil and gas sectors. Two keynote industry lectures by P. K. Kaiser at Support'13 in Perth, Australia, and at Rasim8 (rockburst and seismicity in mines) in Russia (2013) address the need to re-think standing assumptions made when assessing rockburst damage and by implication when designing support in burst-prone ground.

Photo courtesy of Brad Simser

Photo courtesy of Kidd Creek Mine

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A GUIDE TO ROCKBURST SUPPORT SELECTION

THE ISSUE: The Canadian Rockburst Support Handbook (Kaiser et al., 1996) presented an engineering approach to selecting rock support for burst-prone mines by systematically assessing both support demands and support capacities. Since its publication, technology of rockburst support has seen many new developments. A number of key insights, changes in thinking, and new concepts have emerged over the last two decades. In some cases, the practical implications have been immediately apparent, whereas in other cases, the full implications are only now emerging with the development of new methods of analysis and new design approaches. Development of "The Canadian Rockburst Support Selection" is an update of the handbook. It addresses the fundamental principles, methodologies and procedures in rockburst support design, and will assist practicing engineers in following systematic design procedures.

THE SOLUTION: Intended for ground control engineers with a sound background in engineering design, rock mechanics, stress modeling, and static ground control principles, *A Guide to Rockburst Support Selection* (Cai & Kaiser, 2014), focuses on aspects that are most important for rock support in burst-prone ground, particularly within the context of the current situation in hard rock mines and civil tunnels in Canada, Australia, Chile, South Africa, China, and many other countries. Extensive field and laboratory testing of support elements and systems under both static and dynamic conditions have generated key data for design, and have led to new insights concerning the mechanisms or behaviour by which rock support dynamically interacts with the ground. In addition to the conventional grouping of rockburst types into strainburst, pillar burst, fault-slip burst, a distinction between static-load-induced or dynamically triggered and dynamically loaded strainbursts is essential for the support demand estimation. As well, identification of three distinct rockburst damage mechanisms involved in most of the damage caused by rockbursts in deep underground mines form the fundamental basis for the design approach presented in this Guide:

- Sudden volume expansion or bulking of the rock due to fracturing of the rockmass around an excavation
- Rockfalls (or falls of ground), which have been triggered or loaded by seismic shaking
- Ejection of rock caused by: (1) momentum transfer from violently bulking (larger) blocks or slabs of rock to smaller blocks that are free to eject (e.g., between bolts), and (2) energy transfer from large remote seismic events to fractured rock near a stressed excavation

For each of these mechanisms, the Guide presents detailed methods of analysis for support design. The guide treats support design as a two-stage engineering process: determining the expected loading conditions or demand on support; and integrating the various elements into a support system to achieve a support capacity that exceeds demand.

INNOVATION IN PROGRESS: The *Guide to Rockburst Support Selection* is scheduled for publication in 2014. Workshops and short courses will be offered in support of the guide. In addition, a software tool (BurstSupport) has been developed in tandem to assist in applying the design methodology to a computer aided design package that rapidly executes design calculations at all affected tunnel locations.

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USING HYDRAULIC FRACTURING TO HELP SHED STRESSES IN DEEP UNDERGROUND MINES

THE ISSUE: Rock instability in deep mines can potentially create two problems: 1) the possibility of rock bursts and strainbursts, which can compromise the safety of personnel and capital assets; 2) significant disruptions to production schedules. Hydraulic fracturing, the mechanical process of fracturing rockmass, can be used to induce changes to its characteristics which may be helpful for stress management in underground mining operations. Traditionally used in large block cave mines for cave inducement and fragmentation purposes, hydraulic fracturing can also be used for stress re-distribution, including in conventional stoping operations.

THE SOLUTION: CEMI and a consortium of companies and research institutions have initiated a 3-year research program to investigate hydraulic fracturing as a means to re-distribute stress in deep mines away from where it can potentially cause harm. Fracture network creation technologies as well as the characteristics of the created networks will be examined by undertaking a series of drill-through and mine-back experiments in active mines.

This research aims to better understand how to use hydraulic injection to manage stresses locally, and potentially at a block scale; improve our understanding of the processes during hydraulic fracturing in tight shale formations; better able to relate geophysical observables (e.g., micro-seismicity, stress change, tilt etc.) to the created fracture networks; and better able to optimize numerical modeling approaches for simulating hydraulic fracturing and hydraulic stimulation.

INNOVATION IN PROGRESS: Three hydraulic fracture case studies have been identified, with expected completion and results in 2015. These are:

1) Experimental design and execution of drill through trial at Newcrest's Cadia East mine in Australia, and extending at least one borehole to the production level at 1,425m to execute stimulation and hydraulic fracturing tests.
2) Low level injection trial, including a mine through.
3) Large production-scale application and technology transfer for eventual usage in conventional stoping operations.

It is anticipated that hydraulic fracturing will make mines safer and potentially render unmineable ore reserves mineable. It also has applications for the energy (oil and gas and geo-thermal) industry, in terms of validating existing models. interpretations will allow for better predictability and planning, thereby reducing operating and capital costs.

Courtesy of Newcrest Mining Limited and CSIRO-Integrated HF Tool

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LOW OR ZERO CARBON CRYOGENIC VENTILATION FOR DEEP MINES

THE ISSUE: To develop a new air cooling technology for underground mining that will decrease the overall carbon footprint and reduce operating costs, especially as mines deepen and their cooling loads increase.

THE SOLUTION: CEMI is working with MIRARCO to design a system that uses the shaft work from a wind turbine rotor to drive the compressor in an air liquefaction plant. The motivation is that if utilizing wind energy to drive the liquefaction process is practical, work from such a wind turbine would be available at very low marginal cost and with very low CO2, eq emissions – in contrast to liquefaction by means of grid electricity powered liquefaction plants. The research will include determination of the feasibility of using wind powered liquefaction plants to produce liquid air used to cool underground workings (as deep as 2-3 kilometres) and compare this approach with that of conventional mine cooling practice.

INNOVATION IN PROGRESS: Wind turbines and liquefaction plants are established, commercial technologies. It is the integration of these two technologies where innovation arises. An important distinction between conventional liquefaction approaches and the CryoVent approach is the variability and intermittency of wind energy resources that dictate the rate of work input delivered by a wind turbine, versus the steady input delivered by an electric motor. Can a CryoVent wind turbine system be designed to accommodate the intermittent and variable work input and still produce a relatively steady output rate of cryogen? Development of a numerical model of the liquefaction process to assess system performance has been completed. Predicted performance will be verified using a proof-of-concept laboratory scale rig assembled at Laurentian University. SCADA data from two Vestas V52s wind turbines, held by the Camborne School of Mines at the University of Exeter, UK, will be used to characterize the variability in torque and rotational speed from direct observations to drive the rig variably, while the output cryogen production rate is monitored.

This project has the potential to deliver a compact, renewable energy technology to the mining industry that will result in lower overall operating costs as well as a cleaner operation. CEMI has provided funding to support Saruna Kunwar's work on the project; funding for equipment has been secured from the Canada Foundation for Innovation and the Ontario Research Fund.

The liquid air in the Dewar Flask is at minus 190°C and atmospheric pressure. If it was at atmospheric pressure and temperature instead, the same amount of air as in the flask would occupy around 1m³.

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Canada Foundation for Innovation – Leaders opportunity fund
Ontario Research Fund – Small infrastructure grant

SOT+: EXTENDING THE APPLICATION OF THE SCHEDULE OPTIMIZATION TOOL

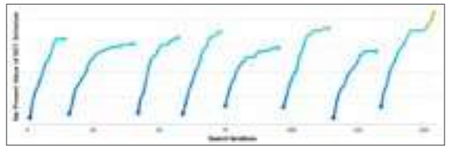
THE ISSUE: For over 4 years, MIRARCO's Schedule Optimization Tool (SOT) has provided benefit to mining companies as the only software on the market to optimize the net present value of long-term schedules for selective underground mining operations. These include both access development and production within operational resources, and precedence constraints for thousands of excavation activities. With case studies available for review, what additional optimization extensions can be added to enhance the SOT software?

THE SOLUTION: SOT 1.2 was released in the fall of 2012 with additional features including capacity analysis, capacity flexing, containment costs and pinning (fixed timing) which were features previously restricted to proprietary users. SOT is commercially available and licensed through 3 distributors - CAE Mining, MineRP and Deswik.

SOT+ aims to advance the functionality of the software for selective mining methods and to expand the software to handle bulk mining. In partnership with Vale, Newmont, CAE Mining and Deswik and project managed by CEMI, SOT+ is focused on five research themes, each of which will be anchored with a case study.

Themes include: ore blending, ventilation constraints, geotechnical constraints, schedule optimization for bulk mining methods (block cave and/or surface mining), and advanced valuation. The research team includes partners from MIRARCO, Laurentian University, Curtin University and Chasm Consulting/Ventsim. Each theme will support a specialist with knowledge of mine planning and the relevant research theme. Recruitment is currently underway for additional mine planning specialists for this project. Mining companies interested in sponsoring a case study or learning more about SOT+ should contact Seppo Haapamaki at CEMI.

INNOVATION IN PROGRESS: The first case study is currently underway at Vale, with a focus on integrating and optimizing the schedule of a multi-orebody operation. The research will involve sensitivity analysis (mineral prices, costs, and mineral grades) and implementation of an advanced valuation methodology to enhance the robustness of mine plans in the presence of uncertain project parameters.



Learning curves' from a SOT run as it uses artificial intelligence techniques to optimize the net present value of a mining operation.

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RAPID DEVELOPMENT: STEP-CHANGE INNOVATION AT THE DEVELOPMENT FACE

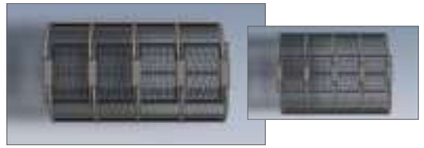
CEMI
Centre for Excellence in Mining Innovation

THE ISSUE: The ability to access ore bodies efficiently and effectively is critical to the success of the underground mining industry. The Development Cycle has not kept pace with innovations found in other key steps of the mining process, despite the introduction of powerful and efficient new equipment. Today, advance rates are at historic lows, currently at less than 4m/day vs. the 12m/day achievable 25 years ago.

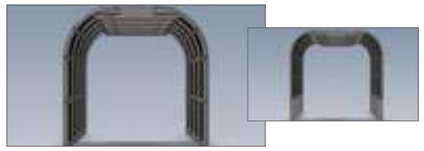
THE SOLUTION: Currently, all 5 steps of the Development Cycle are separate, executed sequentially and requiring specific equipment. The process is inherently time consuming and costly, leaving the face inactive for significant periods. The Rapid Development Project consists of 3 separate research projects to be conducted within live mine sites. This research has the potential to bring about step-change innovation by integrating the machinery and process steps required to access ore bodies, with the goal to dramatically increasing time at the face. These are: (1) Development of an advanced canopy designed to withstand falls of ground that will allow for parallel activities through the integration of Support & Drill processes; (2) Configuration of equipment to utilize Jumbo for also load holes without disrupting the work of the bolter; (3) Development of a continuous mucking machine, where material removal is constant and the total mucking time is reduced.

INNOVATION IN PROGRESS: Preliminary simulations indicate that there are significant efficiencies to be found in integrating processes and executing in parallel. Based on the three projects identified, CEMI has projected improvements to advance rates of 2.23 m/day, totaling 7.24 m/d over the current 5.01 m/day. This is an increase of 45%. The next step will be to configure the required equipment and conduct research within live mine sites. The benefits are clear—increased utilization of face time for machinery and human resources leads to the earlier extraction of ore, increased safety and productivity, the reduction of overall mining costs and the potential for an earlier return-on-investment.

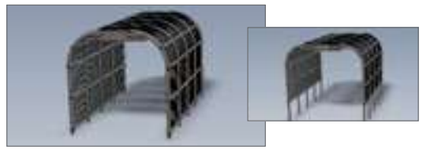
Canopy TOP contracted and expanded.



Canopy FRONT contracted and expanded.



Canopy collapsed and expanded.



Photos courtesy of MTI

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SOLUTION TEAM NETWORK AND KNOWLEDGE CENTRE

RioTinto

With an investment of $10 million dollars, Rio Tinto established the Rio Tinto Centre for Underground Mine Construction (RTC-UMC) at CEMI. The Centre assists in creating step-change advances to support Rio Tinto's Mine of the Future™ programme with research focused on mechanized excavation in support of high-speed underground mine construction and on enhancing footprint reliability with innovative and effective support systems. The RTC-UMC at CEMI is the fifth global research centre established by Rio Tinto.

THE ISSUE: After extensive consultation and completion of its start-up phase projects, the RTC-UMC has set out a technical roadmap for the next few years with a focus on rockmass characterization, horizontal and vertical development/construction, and footprint/undercut reliability. Research projects focused on each of these technical issues have early deliverables in 2014. RTC-UMC operates with a small number of employees and a large number of networked solution team members that bring the required skills and expertise to serve the mining industry's needs. After careful assessment of needs and opportunities, and taking into the consideration the industry-wide challenge of attracting highly qualified employees, it was determined that the Centre had to expand its resource pool, expand its advisor capacity, and increase its solution team network.

THE SOLUTION: In order to rapidly increase the delivery capacity of the Centre and provide an active knowledge centre, RTC-UMC is in the process of retaining internationally recognized experts to the equivalent of three or more person years by retainer or subcontract extending over several technical projects. Researchers and consultants from Canada, the U.S.A., Switzerland, and Australia are currently being retained to increase the delivery capacity. The Centre has created a link to the Geological Engineering Department at the Federal Technical University of Zurich and is working to link other European universities to the Centre's network, allowing for the creation of a European node with identified resources to capture expertise related to rapid underground construction and ground control.

Photo courtesy of Rio Tinto

Photo courtesy of Rio Tinto

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Pierre Labrecque, Labrecque Technologies; Sean Maloney, MIRARCO; Matt Pierce, Itasca

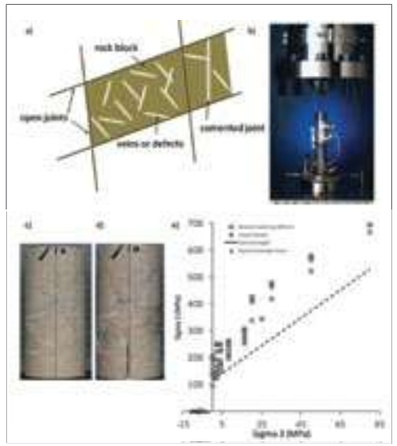
ROCKMASS CHARACTERIZATION AND BEHAVIOUR FOR GROUND CONTROL – COLLABORATIVE MONITORING PROGRAMME

With an investment of $10 million dollars, Rio Tinto established the Rio Tinto Centre for Underground Mine Construction (RTC-UMC) at CEMI. The Centre assists in creating step-change advances in support of Rio Tinto's Mine of the Future™ programme with research focused on mechanized excavation in support of high-speed underground mine construction and on enhancing footprint reliability with innovative and effective support systems. The RTC-UMC at CEMI is the fifth global research centre established by Rio Tinto

THE ISSUE: The RTC-UMC has established that strength at depth is systematically and significantly underestimated by standard rockmass characterization approaches and thus cannot be reliably determined by current characterization means. The economic impact of poor deformation and strength characteristics of brittle failing rock is reflected in ground control challenges. Hence, to improve support design procedures for cost-effective deformation management in stressed ground, develop pillar design principles with semi-empirical data for footprint design, and establish a foundation for pillar monitoring to assist cave controls requires collaborative monitoring, systematic data collection, and interpretation with dissemination.

THE SOLUTION: The RTC-UMC is engaging with various Rio Tinto operations to collect relevant data at various mine sites, including green field mines, mines under development, and operational mines. The objective is to guide the collection and interpretation of data in a systematic manner by improved data interpretation and back analysis.

The Centre has the expertise to develop procedures from the data that can be used as best practice guides for Rio Tinto consultants and testing laboratories. These best practices derived from the collaborative monitoring programme will translate into cost savings in terms of enhanced footprint reliability. With less production delay, better excavation reliability, less rehabilitation of stress fractured ground and the optimization of support to facilitate standard drill and blast or mechanical excavation damage to footprints will be minimized. Safety at operations will be enhanced through the adoption of best practices.



(a) The challenge is characterizing defected rock masses (consisting of rock blocks bound by open joints and containing a stockwork of cemented veins or defects). (b-e) The development of a best practice guide to determine the intact strength of this type of material. (b) lateral strain controlled stiff testing frame with triaxial confining stress capability up to 80MPa. (c) Defected specimen for strength testing before and (d) after testing. (d) Shows failure through intract rock (i) and along defects (ii). This is clearly not intact rock strength. (e) Making sense of lab data from defected rocks for the determination of true intact rock strength. One of the base input parameters for the Hoek-Brown failure criterion and GSI.

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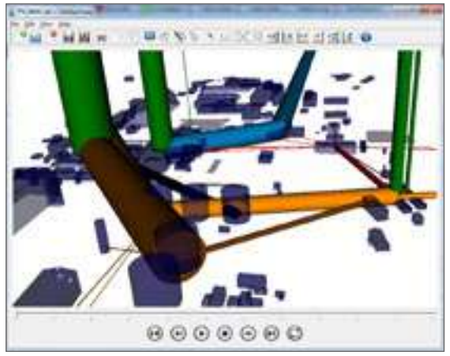
SANKEY TREES: VISUALIZATION OF ENERGY FLOWS A SUMIT PROJECT

THE ISSUE: Reduced energy consumption for mining operations is a desirable goal, however understanding the opportunities for optimizing energy consumption is not always clear. The Sankey diagram, which has been used for over 100 years to visualize the flow of energy, materials, or cost through various processes provides an option, but there are drawbacks to this approach: i) the picture presented is static, offering no way to visualize how energy flows vary in time, ii) the picture presented ignores spatial relations between the components it describes; energy that might be wasted at a particular location, could be used at another, if the latter was in range, but if the usage location is remote from the source, the opportunity must be reprioritized.

THE SOLUTION: To develop an application to augment the Sankey diagram with a 4D spatio-temporal visualization capability that supports decision-making relating to energy flows and usage by mine operators.

THE RESULT: A new energy flow visualization technique called Sankey Trees has been developed. Sankey Trees is an application for creating 4D visualizations of energy flows between processes. Process locations are defined within a 3D model of the site being studied, and the magnitude of the flow between each pair of processes considered is replaced with a time series. Sustained and diminishing flows are represented through a variation of geometric properties and are animated to indicate the direction of flow and its transportation from one form of energy to multiple processes. Sankey Trees is now available for download at http://www.mirarco.org. This work was developed with the framework of research projects for Smart Underground Monitoring and Integrated Technologies for Deep Mining (SUMIT)



A screenshot of the SankeyTrees 4D energy flow visualization tool developed by Adam Turcotte as part of the SUMIT Project. It can be downloaded for free at: www.mirarco.org/ercm

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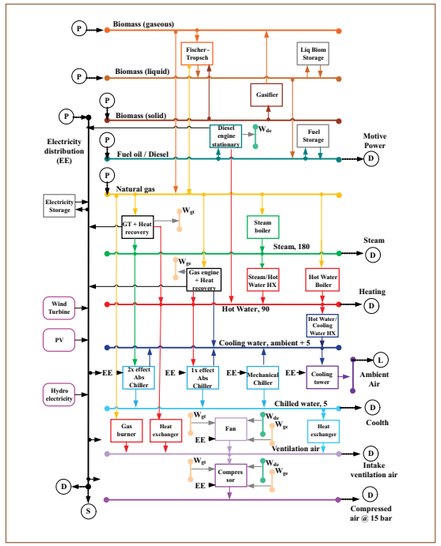
CONCEPT DEVELOPMENT OF OPTIMAL MINE SITE ENERGY SUPPLY A SUMIT PROJECT

THE ISSUE: Sustainability of deep mining is reliant on the reduction and optimization of energy consumption. With many approaches available for consideration (different equipment, different operating practices, etc.), it is essential to have a systematic, rational method available for mines to determine the best set of options. A review of precedent energy management practices in mineral operations has highlighted the energy challenges characteristic of the sector, and has informed the formulation of optimal mine site energy supply; choosing the best combination of fuels, energy supply technologies as well as identifying the best way to operate the equipment.

THE SOLUTION: This study, developed within the framework of research projects under Smart Underground Monitoring and Intergrated Technologies for Deep Mining (SUMIT) outlines the priorities of investigation, development and demonstration of new concepts and technologies to improve energy efficiency and reduce consumption of primary energy in the mining sector. Specific requirements and constraints of mineral production operations are considered against methodologies that have worked well for other sectors, such as cogeneration (the process whereby a single fuel source is used to generate two forms of useful energy) and polygeneration integrated energy supply systems that simultaneously generate two or more energy carriers (e.g. electricity and heat), in order to gain new perspective for on-site energy supply of mine sites.

INNOVATION IN PROGRESS: Scenarios with substantial economic potential in which renewables are advantageous have been identified, alone or in combination with conventional generation systems and/or utility connections. Scenario analysis based on the capability to identify optimal energy supply systems for specific load profiles helps: identify potential reductions in energy or production costs; improve the resilience of energy supply to ensure energy availability, with the added benefit of realizing a potential reduction in greenhouse gas emissions. To date, the formulation efforts are complete, and the solution team is focusing on developing a new mine-user-friendly software tool to implement the optimal mine site energy supply analysis. While the research is applied and has a Canadian focus, the work is of global scientific importance and its theoretical extensions are of generic applicability for all integration studies across disciplines.



An energy supply superstructure for a mining operation. Horizontal lines show the energy utilities supplied. Blocks show the energy conversion technologies that may feature in the optimal mine site energy supply solution

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APPLICATION OF A POLYGENERATION OPTIMIZATION TECHNIQUE FOR A HOSPITAL IN NORTHERN ONTARIO - A SUMIT PROJECT

THE ISSUE: Polygeneration systems are integrated energy supply systems that simultaneously generate two or more energy carriers (e.g. electricity and heat); where the output or byproduct of one process can be the input for another energy supply process). Hospitals are considered good candidates for polygeneration systems due to their sustained and relatively high energy requirements (heat, steam, coolth, and electricity), and their need for high power quality and reliability. The complex energy requirements of a hospital are similar to the energy requirements in the metal mining industry, and other industries, making the stand-alone hospital an ideal test site. Using a hospital in Northern Ontario with energy pricing and tariff arrangements that are specific to Ontario, MIRARCO was able to test their optimization methodology. The work aimed to identify the lowest annual cost of meeting site demand through determination of optimum polygeneration technologies, and the optimum manner for operating that set of technologies. CO_2 emissions could be simultaneously minimized in the procedure, if required.

THE SOLUTION: In order to identify the optimal configuration, annual energy demands were estimated by the team and then validated against actual data for the hospital. A polygeneration superstructure for optimization (using MILP—Mixed Integer Linear Programming technique) of the energy supply system was created so that the energy demands of the hospital could be met and different scenarios of constraints could be investigated. Energy prices were determined and conditions arising from the regulatory framework were introduced.

THE RESULTS: Surprisingly, the optimal economic solution indicated that generating electrical power using an onsite energy supply technology from gas is more economical than connecting to the electricity grid – even when an electricity grid connection point is available close by. The methodology and findings have far-reaching implications, particularly for energy-intensive industries. This is of particular significance to mining operations relying on multiple energy utility sources. Similar to the hospital, mines too, must find ways to reduce production costs through improvements in the efficiency with which they consume energy resources.

Photo courtesy of Harvald Farrant

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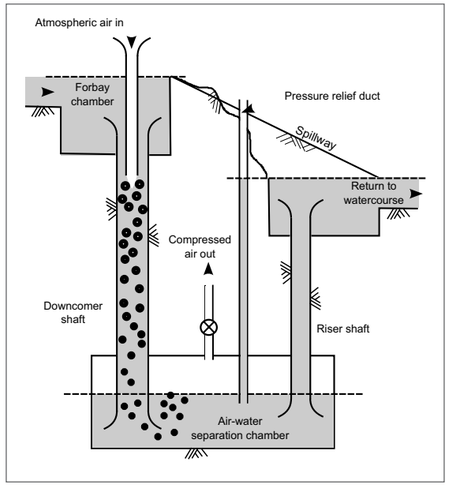
HYDRAULIC AIR COMPRESSOR FOR COOLING DEEP MINES A SUMIT PROJECT

This work was developed within the framework of research projects for Smart Underground Monitoring and Integrated Technologies for Deep Mining (SUMIT).

THE ISSUE: The Ultra-deep mining environment (below 2.5km) is of growing importance for the modern mining sector but presents key mining challenges. One of these is maintaining an acceptable working environment while the air temperatures at these depths, which can be upward of 40°C, before entering mine areas.

THE SOLUTION: Using the energy from water flow in a natural watercourse to produce compressed air is not new; 100 years ago such installations were termed hydraulic air compressors. Today, if natural hydropower resource can be harnessed, compressed air from this technology could be produced at close to zero marginal cost. Such a benefit forces reappraisal of processes and methods that were proposed for mines in the past, but eliminated due to the high cost of compressed air. One example of this is utilization of Hydraulic Air Compressors (HAC) to cool and dehumidify the bulk mine ventilation air in deep mines, the topic of investigation for this project.

INNOVATION IN PROGRESS: Based on research findings to date, a patent application has been made for novel uses of a Hydraulic Air Compressor. Ongoing studies will assess this method of cooling and dehumidifying deep mines. The technology also shows promise as a method of carbon capture from fossil fuel burning plants and as a method for domestic air conditioning.



The hydraulic air compressor (HAC) is driven only by water, held up by a dam, to create relatively low head (typically 10-20 metres), such that the developed hydropower is used to cause flow in openings deeper underground. Air is entrained in the water at the inlet to the sub-surface openings and is compressed as it is carried along by the deepening water flow. At depth air bubbles separate out of the water flow and are collected in a receiver space above the flowing water creating a reservoir of compressed air that is much drier than that would be produced from a contemporary mechanical compressor. Water, free of air, then passes back up a return shaft (up-pipe) and rejoins the river or stream flow. The HAC installed at Ragged Chutes, near Cobalt, Ontario operated near continuously for 70 years, supplying free air delivery of 40,000 cfm (68,000 Sm3/h) at a pressure of ~130 psi (8.9 bar) for around 70 years, only being stopped twice for repairs to its intake head.

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PEATLAND RESTORATION TRIALS

Bay Lowland. It adds to a body of knowledge, protocols and socially responsible practices that are attuned to community needs and expectations. The Peatland trials support ecologically-sound rehabilitation of mine sites in high boreal and subarctic regions of central Canada, especially around the Ring of Fire.

THE ISSUE: Mining activity is increasing in northern boreal and subarctic regions of Canada. Peatlands, also known as muskeg, dominate the landscape in the Hudson Bay lowland covering 98% of the landscape in the vicinity of the Victor Mine and 95% of the entire lowland. About 5000 hectares of peatland will be disturbed due to mining and construction activities. There is a need to develop peatland rehabilitation protocols that ensure a small mine footprint and the return to representative muskeg ecosystems after mine closures.

THE SOLUTION: Test whether fragments of Sphagnum mosses and protective covers are required to restore a vegetative cover of peat–forming plants over bare peat. To do this, Sphagnum fragments were spread over severely disturbed peatland and then peat blocks, local sedge mulch, coconut mulch, straw mulch and two densities of cottongrass *(Eriophorum)* tussocks were added and compared to putting no cover at all. Multiple parameters were examined to test the recovery of Sphagnum and the need for a mulch to reclaim disturbed subarctic peatlands in the region.

RESULTS: Over the course of a 3 year study, control plots without Sphagnum fragments did poorly but all those that received fragments had a >70% bryophyte cover and 30-60% Sphagnum cover, even without a mulch or companion plants. The spreading of fragments is therefore needed but no mulch or companion plants are required to restore these peatlands. The study shows progress towards the sustainable reclamation and revegetation of mine sites in the Hudson

Winter road from the air. Photos courtesy of Katherine Garrah.

Moss fragments coming back underneath a mulch in year 1 Photos courtesy of Angie Corson.

Angie Corson in her peatland mulch experiment plots. Photos courtesy of Daniel Campbell.

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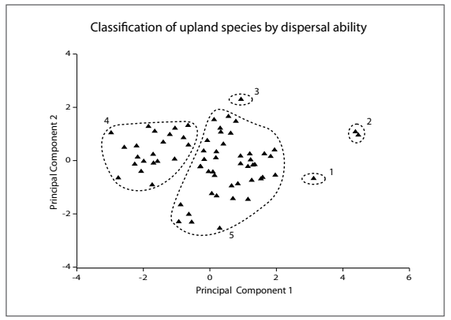
NATIVE PLANTS SPECIES FOR THE RECLAMATION OF UPLANDS

THE ISSUE: A major challenge in the reclamation of the Victor Mine and other mine sites in the Hudson Bay Lowland (HBL) is the selection of suitable plant species for the reclamation of these new uplands. How do we choose the best candidate species for the rehabilitation of mine sites, given the condition that they must be native and local?

THE SOLUTION: A functional assessment of upland native plants in the Hudson Bay Lowland was conducted to determine their potential to disperse, establish, grow, allocate resources and contribute to the ecosystem development. Sixteen simple traits (plant height, leaf thickness, stem density, ability to fix nitrogen, etc) were measured on three populations of 67 species near the Victor Mine. This produced a very large data base which was simplified using multivariate analysis.

RESULTS: Species can be easily separate and classified on the basis of key ecological criteria which will be important for ecological practitioners. A list has been complied of species and simplified classification of traits and their importance or use, abilities to perform which will help in the selection of suitable species at early, mid and later successional stages of mine reclamation. Candidate species will be investigated further in field trials.

Here is a shot of early successional plants along the river. Note the rocks, the lack of soil but the high diversity of plants.



An energy supply superstructure for a mining operation. Horizontal lines show the energy utilities supplied. Blocks show the energy conversion technologies that may feature in the optimal mine site energy supply solution

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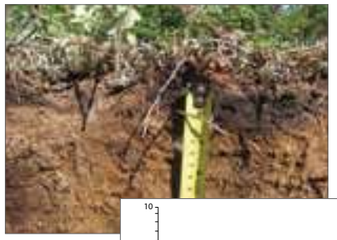
UPLAND REFERENCE CONDITIONS

THE ISSUE: Uplands without water-logged soils are rare in the vicinity of the Victor Mine. The question arises as to what the reference conditions or targets for restoration should be when reclaiming new upland deposits of mining wastes, roads and gravel pads. This is of particular importance when aiming to rehabilitate new upland features to sustainable ecosystems dominated by native subarctic vegetation.

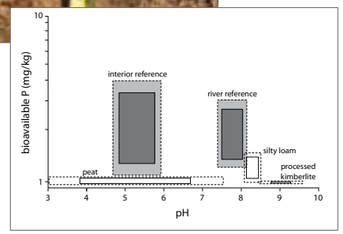
THE SOLUTION: 35 interior upland islands and 37 river uplands along the Attawapaskat River were sampled. At each site, multiple soil parameters were measured and samples were taken. In 10x10 plots, tree growth, plant cover, composition of plant species and soils were measured.

RESULTS: It is now possible to characterize the best reference conditions as targets for reclamation of new uplands at the Victor Mine through examination of soil and vegetation parameters on a univariate or multivariate basis. The upland reference conditions determined for the Victor Mine are taken from a broad landscape, and so should be applicable to other mine sites in the region within the limestone plain of the Hudson Bay Lowland (HBL).

Picture of Katie digging away. (Photo courtesy of Marisa Talarico)



Typical soil pit in interior upland. (Photo courtesy of Katherine Garrah)



Example of application of reference information using two soil = criteria, pH and bioavailable phosphorus. The idea is to make soil from = the mine waste materials to get within the river or interior reference = sites.

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Brian Steinback, Debeers Canada
Terry Ternes, Debeers Canada
Douglas Morrison, CEMI

PROOF OF PRINCIPLE OF COMFREY PLANT PROPERTIES TO BIO-REMEDIATE HEAVY METAL-CONTAMINATED MINING SITES

CEMI
Centre for Excellence in Mining Innovation

THE ISSUE: To determine if naturalized comfrey (*Symphytum officinale*), which is easily grown in tropical climates where farmers can produce multiple crops per year, will absorb metals from contaminated soils. Comfrey is a perennial plant with large foliage, a deep root system, is very resilient to diverse conditions and is easy to cultivate, growing rapidly and covering large areas at a time, which would make it an ideal crop for developing countries.

THE SOLUTION: In order to determine if some of the most toxic or abundant metals were absorbed, commercial black soil was spiked with several concentrations of water soluble salts of metals such as Nickel (Ni), Chromium (Cr) Iron (Fe) and Zinc (Zn). Plants were grown in artificial conditions at Vale's Greenhouse in Copper Cliff and at the end of the growing period, samples from roots, stem and leaves were tested for metal concentration levels.

THE RESULTS: Comfrey *(Symphytum officinale)* successfully absorbed chromium, iron and zinc onto the root system and nickel onto the leaves and root system confirming proof of principle. Use of Comfrey in developing countries where tailings waste have left a footprint, may offer local farmers an economic and environmental benefit. Farmers can not only remove and process metals for economic gain but the residue biomass can also be converted into energy to produce electricity. Furthermore, research unveiled which cyclic peptides were used to capture metals. This led to a further study into the possibility of artificially creating cyclic peptides for use in remediation.

Courtesy of Gerardo Ulibarri

Courtesy of Gerardo Ulibarri

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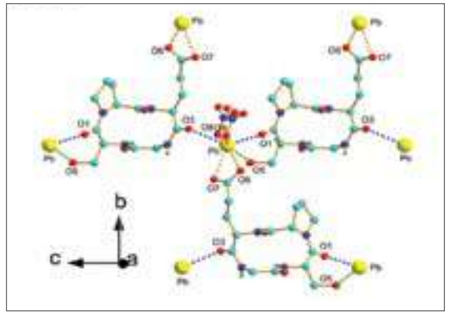
CYCLIC PEPTIDES SEQUESTER RESIDUAL HEAVY METALS FROM MINING TAILINGS

CEMI
Centre for Excellence in Mining Innovation

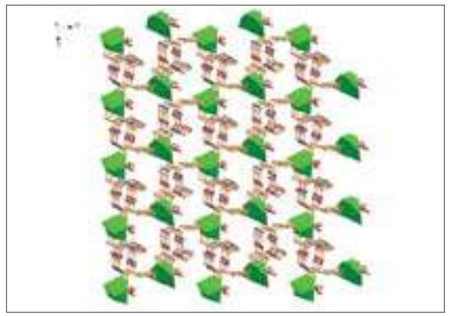
THE ISSUE: Heavy metals continue to constitute a global environmental hazard, with no affordable solutions for their removal to an acceptable concentration. There are multiple benefits that can be gained from the development of cyclic peptides in the laboratory that mimic plants that bio-remediate heavy metal-contaminated mining sites.

THE SOLUTION: Establish a methodology to create cyclic peptides in the laboratory that can be complexed with diverse metals present in tailings in order to establish applicability in the field of recovering metals from contaminated soils in a self sustainable manner.

INNOVATION IN PROGRESS: In-silico molecular simulations (assisted by Dr Gustavo Arteca) determined the optimal theoretical length and circular size of the cyclic peptide, complexed to a given metal. With successful proof of principle, the synthetic reproduction of cyclic peptides for diverse metals has the potential to become a secondary process for extracting or remediating metals from tailings. This provides an opportunity to extract more value from tailings waste and end up with a smaller environmental footprint (ie. reduce the potential of metal leaking into local aquifiers; reduction of metal contamination in mining areas and beyond) than we currently have.



Crystal structure of 2. Perspective view showing binding mode of cyclo(Gly-L-Ser-L-Pro-L-Glu) 1 to Pb(II) ion. Only hydroxyl O-H and amide N-H group hydrogen atoms are shown.



Polyhedral view in three-dimensional structure of 2. Color code: green, Pb: gray, C; blue, N; red, O.

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Azizah Al-Radhwan (MSc), Laurentian University

THE INNOVATION IN PROGRESS SOLUTION TEAM

Our highly qualified network of major Canadian and global mining companies, universities, government researchers, technical consultants, and innovative SMEs, coupled with access to funding, allows us to facilitate key projects in exploration, deep mining, integrated mine engineering, environment and sustainability, and enabling technologies.

COLLABORATOR

- AkerSolutions
- Anadarko
- Atlas Copco
- Baffinland
- BENCHMARK SIX
- BESTECH
- CAE Mining
- CAMIRO
- canada mining innovation council
- CANMET
- c-core
- CIM ICM
- CIMMR
- Sudbury
- CODELCO
- ConocoPhillips
- De Beers
- DELTION INNOVATIONS
- Deswik
- esg solutions
- FedNor
- fuller
- GE
- GEOSYSTEMS, L.P.
- Golder Associates
- Canada
- HARDWARE SOLUTIONS
- HOVERTRANS SOLUTIONS
- Institute of mine seismology
- ITASCA
- JANNATEC
- KGHM INTERNATIONAL
- LANDMARK
- LCG Energy Management
- LKAB
- MANSOUR
- MERC
- MineSense
- Mira Geoscience
- mirarco
- nexen
- NEWCREST
- NEWMONT
- NGI
- NORCAT

COLLABORATOR

- Ontario
- NSERC CRSNG
- nwmo
- objectivity
- Ontario Centres of Excellence
- Ontario
- Rail-Veyor
- RioTinto
- ROCTEST
- SAMSSA
- Shell
- Simsmart Technologies
- SNOLAB
- srk consulting
- STRATOS
- symboticware
- VALE
- WALLBRIDGE
- XPS

ACADEMIC

- ACADIA
- College Boréal
- CAMBRIAN COLLEGE
- UNIVERSITY OF EXETER
- Carleton UNIVERSITY
- Curtin University
- TU Delft
- ETH
- ÉTS
- Laurentian University / Université Laurentienne
- Queen's
- Ryerson University
- SFU
- UNIVERSITY OF ALBERTA
- THE UNIVERSITY OF ARIZONA
- UBC
- UNIVERSITY OF CALGARY
- UAFM
- UNIVERSITÉ LAVAL
- Université de Montréal
- uOttawa
- Université du Québec en Abitibi-Témiscamingue
- UNIVERSITY OF TORONTO
- University of Waterloo

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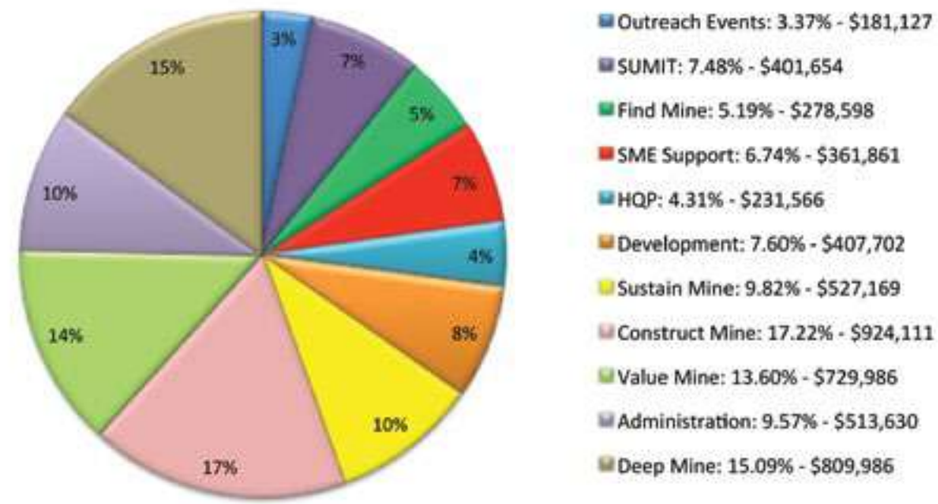
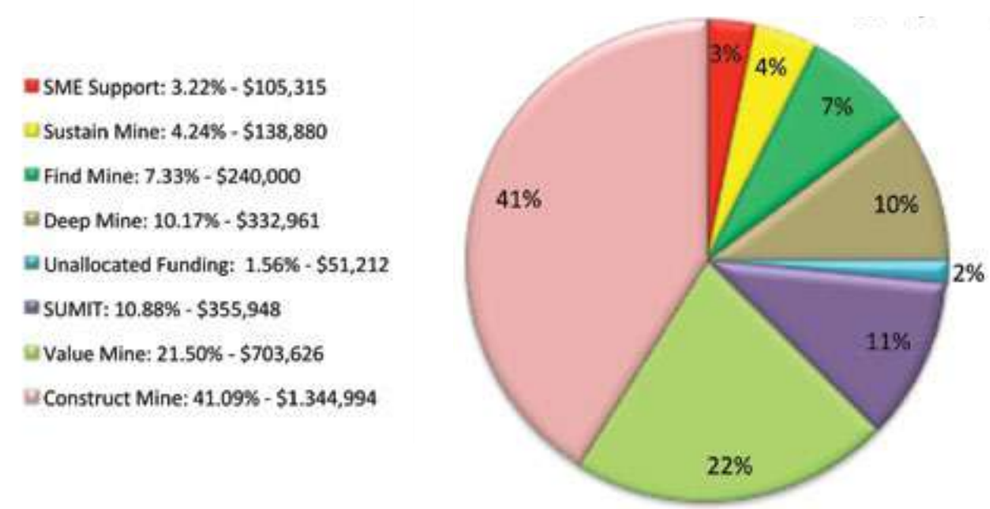
FINANCIAL STATEMENTS

2012 - 2013 EXPENDITURES $5,367,392



2012 - 2013 REVENUE $3,272,936



INNOVATION & PROSPERITY OFFICE (IPO) AT CEMI

The Innovation and Prosperity Office (IPO) was created in 2011, as part of CEMI's commitment to collaborate with local small to medium enterprises (SMEs) whose ideas, products or services may add value and contribute to the innovation in the mining industry. The IPO's mandate is to work with SMEs through all stages of RD+I including: assessment of the feasibility of their innovations; access to funding and other resources; access to resources and partnerships necessary to advance ideas to testing; and providing the necessary tools and resources to move projects from implementation to commercialization. It is a natural extension of CEMI, whose focus is to facilitate innovation and expand and strengthen the economic activity of the mining services and supply sectors within the Greater Sudbury area.

With an additional contribution of $300,000 from The Greater Sudbury Development Corporation (GSDC) over four years and matching funds from CEMI, the IPO was able to leverage funding to access an additional $100,000 in government funding to be used towards a program that specifically connects with SMEs who have innovative solutions that meet the relevant needs of the mining industry. To date, the IPO:

- Initiated contact with 21 SMEs in need of access to technical mining expertise and industry knowledge
- assisted SME with the adaptation of ideas and technology for development within the mineral industry in order to generate new mining products
- working with 5 SMEs on an ongoing basis to make connection and accelerate end user interest for the development of innovations that will have uptake in the mining industry
- held workshops to identify mining industry needs specific to ICT technology

Three workshops, supported by IRAP, were hosted in 2013 in its effort to: better understand the mining community's communications technology needs; attract new SMEs to the mining industry who specialize in wireless communications; and to facilitate collaboration between mining companies and SMEs who are already developing innovations in mining.

WORKSHOP 1: INDUSTRY BRAINSTORMING IN SUDBURY

Attendees representing 80% of the of the major Ontario mine operators identified current technology gaps in the market and the need for standardized industry communications for presentation to manufacturing, supply and service companies. Specific outcomes from this workshop include the creation of a mine operations communications steering team (MCST) and developing guidelines for its work, and providing a list of common issues to the SME community to influence its areas of innovation including: enabling improved automation productivity in mines; promoting safer operating conditions in mines; and advocating for standards supporting the upgrading, backward compatibility, installation, use, and systems maintenance.

BESTECH - RopeInspector project completed. The RopeInspector™ system automates regulated visual rope inspection by providing 360º coverage at full speed, meeting and exceeding legislative requirements.

WORKSHOP 2: WAVEFRONT M2M SUMMIT IN VANCOUVER

CEMI hosted a panel discussion for SMEs specializing in wireless communication and machine to machine communication. The purpose of the panel discussion was to create awareness of mining industry needs and to attract new SMEs to the industry. The workshop was successful in demonstrating the business opportunities for SMEs who are unfamiliar with the mining industry, for recruiting SMEs to the third event (below), and for establishing relationships that could engage SMEs in future event and opportunities.

WORKSHOP 3: SME SPEED NETWORKING IN TORONTO

The purpose of this event was to bring together SMEs from the mining industry and from the wireless networking sector in an effort to foster future collaborations. The intention is for those future collaborations to create innovative solutions to unaddressed needs within the mining community. Gaps within the mining industry were identified to attendees, resulting in a number of requests from SMEs for CEMI to facilitate potential future collaborations.

The workshops were a resounding success with significant suggestions and support being offered for the outlined objectives.

Industry brainstorming meeting in Sudbury.

"I WOULD LIKE TO THANK YOU FOR INVITING US TO THE PRESENTATION IN TORONTO. UPON OUR RETURN WE HAVE HAD SEVERAL MEETING WITH OUR R&D GROUP AND WE ARE VERY INTERESTED IN MOVING FORWARD WITH SOME OF YOUR SUGGESTIONS AND SOME OF OUR IDEAS. WE HAVE ALREADY CONTACTED SOME OF THE COMPANIES IN THE GROUP AND ARE STILL RESEARCHING THESE RESOURCES…"

WAYNE ABLITT
PRESIDENT, JANNATEC TECHNOLOGIES

KNOWLEDGE TRANSFER

CEMI actively sponsors and disseminates knowledge in the form of lectures, short courses, conferences, trade shows, workshops and publications. Participation with industry partners, consultants, academics, SMEs, students and government is robust with knowledge transfer forums that provide access to innovative research, training and technical presentations relevant to the mining industry on a wide range of mining and engineering topics.

STRUCTURAL GEOLOGY GUIDELINES FOR USE IN BURST-PRONE UNDERGROUND MINES SHORT COURSE

CEMI, together with Golder Associates and SRK Consulting, hosted a 2-day Structural Geology Guidelines short course for use in Burst-Prone Underground Mines. The course, comprised of both technical presentations and hands-on practical sessions, focused on providing attendees with an awareness of: risks posed in burst-prone mines; measure in drill core and drift mapping; aspects of structural geology and other geotechnical issues requiring particular attention; tools required to optimize design; and response effectiveness during project/mine design, development and operation. Held in Sudbury and again in Toronto, the event attracted a total of 94 participants, from industry (mid-to-high management levels), government, SMEs, consultants and graduate and PhD level students from across Ontario.

Course Instructors: Trevor Carter, PhD, P.Eng., Principal, Golder Associates; Wayne Barnett, PhD, Pr.Sci. Nat, Principal Structural Geologist, SRK Consulting; Rob Bewick, Ph.D, P.Eng, CEMI Program Coordinator, Rio Tinto Centre for Underground Mine Construction; and Benoit Valley, PhD, Eidgenössische Technische Hochschule Zürich (ETHZ), formerly at CEMI, Geomechanics Research Centre and MIRARCO.

CIM 2013 CONFERENCE

CEMI was a major participant at the CIM 2013 Conference, May 2013. The CEMI booth at CIM was an excellent example of collaboration and partnership. In addition to sharing booth space, CEMI showcased activities of partner organizations, including the Greater Sudbury Development Corporation (GSDC), Mansour Mining, Labrecque Technologies and Sudbury Area Mining Supply and Service Association (SAMSSA). In addition, CEMI and LU co-sponsored the GSDC Sudbury Event, "Opportunity Rocks", showcasing Sudbury's mining community for a second year in a row. During the conference, CEMI hosted its "Innovation Showcase" afternoon to a full house of 80 plus participants. Featured "Innovation Showcase" presentations by CEMI Research Directors included: Hydraulic Fracturing; SUMIT for Deep Mines; Ventilation on Demand for Production (VOD4P); Lateral Development--Improving Mine Performance; and Integrated Personal Protective Equipment. CEMI also hosted a VOD4P workshop. The recorded Innovation Showcase presentations Forum can be viewed on the CEMI website.

DISCOVERY OCE 2013 CONFERENCE

For the second year, the Ontario Centres of Excellence (OCE) invited CEMI to host a Mining Innovation Panel at the Discovery OCE conference. This Ontario Government sponsored conference showcases its investments in leading-edge technologies, best practices and research from various sectors, including: health, manufacturing, digital media & clean tech, including energy, environment and water.

As a result, CEMI is now a recognized leader in bringing Mining Innovation (from industry, academia, government and the investment community, including entrepreneurs and students) to this audience, and encouraging collaboration opportunities. The Panel Forum was introduced by Ross Bradsen, Regional Manager of OCE (Manufacturing) and moderated by Douglas Morrison. Guest speakers and panel participants included Richard Fink, Vice President at Cliffs Resources, Dick DeStefano, Executive Director of SAMSSA, Dean Millar, Director at MIRARCO and Research Chair; and Daniel Campbell, Director at MIRARCO. At the conference, the CEMI booth captured the interest of several high profile guests including: Premier Kathleen Wynne; Minister of Research & Innovation, Rez Moridi; and Director of Environmental Innovations, Tom Kaszas.

SUSTAINABLE CANADIAN UNDERGROUND MINING WORKSHOP: EXISTING AND PROSPECTIVE OCCUPATIONAL HEALTH AND SAFETY

In June 2013, CEMI organized and hosted a Sustainable Canadian Underground Mining Workshop: "Existing and Prospective Occupational Health and Safety". The workshop's aim was to understand occupation health and safety concerns surrounding ultra-deep mining environments, especially as mines expand deeper underground, testing the limits of work safety and worker comfort.

Workshop attendees included industry representatives, researchers, Ministry of Labour representatives and over 40 SMEs. The workshop participants were divided into four focus group discussions/brainstorming session including: Heat, Noise, Communications, Navigation, Ergonomics, Industry Hygiene, Dust & Contaminants, and Individual Protective Equipment. The outcome of the workshop was a confirmed letter of support from the Ministry of Labour. Additional interest was expressed Vale, Cliffs, and Xstrata Nickel, Iamgold and Agnico Eagle Mines, with requests for follow up meetings. The primary researchers, based in Quebec and Ontario include: ÉTS in Montreal, UQUAT in Rouyn, Ryerson in Toronto, Waterloo and Laurentian. The involvement of Quebec researchers and mining partners was a key accomplishment for CEMI. The importance of engaging the mining industry in R&D for occupational health and safety was identified as a high priority amongst all participants.

CEMI will continue to oversee this collaborative research program, assisting in the administration of each research component and the facilitation of partnerships between academia and industry.

1. Photo: (left to right) Wayne Barnett, Rob Bewick, Trevor Carter, Benoit Valley and Damien Duff during the Structural Geology Guidelines short course.
2. Photos: (top left to right) Seppo Haapamaki, Douglas Morrison, and Allan Akerman present CEMI's strategic research projects at CEMI's Innovation Showcase at the CIM conference.

3. Photos: (top) Guest speakers: Richard Fink, Cliffs Resources; Daniel Campbell, MIRARCO; Dean Millar, MIRARCO; Dick DeStefano, SAMSSA; Douglas Morrison, CEMI; and Ross Bradsen, OCE during the CEMI led Mining Innovation Panel at the Discovery OCE conference. (bottom) Premier Kathleen Wynne visits the CEMI booth, speaks with CEMI staff and collaborators Jim Ireland and Dan Turner, Hovertrans Solutions. **4.** Photos: (left) Group shot of workshop attendees at Dynamic Earth (right) Douglas Morrison, CEMI; Allan Akerman, CEMI; and Sylvie Nadeau, ETS.

KNOWLEDGE TRANSFER

CEMI LECTURE SERIES ON VIDEO

The CEMI Lecture Series features leading academic and practicing guest speakers. To further extend the transfer of knowledge, CEMI offers video coverage of each presentation, providing participants unable to attend, or in remote areas, with access to these new ideas and information. An on-line library, available at www.miningexcellence.ca offers video coverage of not only lectures, but symposia, short courses, workshops and conferences, and is an excellent source of new knowledge for the mining sector.

The lecture topics covered in the last year include:

1

"How to Maximize Your SR&ED Credits" presented by Jonathan Campbell and Geoff MacDonald, KPMG

"DEM Models of Boundary Value Problems in Geotechnical Engineering" presented by Dr. Marcos Arroyo, Technical University of Catalunya (Barcelona, Spain)

3

"Confined Fractures of Quasi-Brittle Materials: Numerical Modeling via Interface Elements, and Experimental Validation" presented by Dr. Ignacio Carol, Technical University of Catalunya (Barcelona, Spain)

"The Potential for Mining Copper, Nickel, and Precious Metals in Minnesota" presented by Mr. Vern Baker, President of Duluth Metals Ltd, was a joint event with SAMSSA

"Microseismic monitoring of hydraulic fracturing operations in the oil and gas industry: Challenges and opportunities" presented by Dr. David Eaton, from the University of Calgary

4

5

2

1. Photo: (left to right) Jonathan Campbell, KPMG; Charles Nyabeze, CEMI; and Geoff MacDonald, KPMG explain the value of SR&ED Credits. **2.** Photos: Dr. Marcus Arroyo,Technical University of Catalunya, lecturing on DEM Models. **3.** Photos: Douglas Morrison, CEMI; Drs. Marcus Arroyo and Ignacio Carol, Technical University of Catalunya **4.** Photos: Vern Baker, President of Duluth Metals presents to a full house **5.** Photos: Dr. David Eaton, University of Calgary

BUILDING HUMAN CAPITAL- INVESTING IN STUDENTS

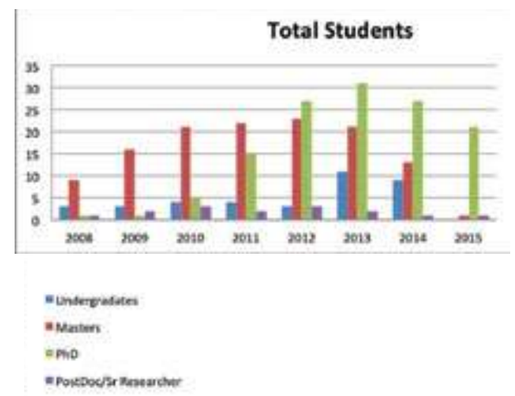
CEMI strongly believes in developing and nurturing future generations of researchers and highly qualified personnel within the mining industry. We work with research institutions in Ontario, across Canada and around the world, engaging engineers and scientists in a range of technical disciplines in order to help the mining industry address the challenges it faces today for future economic development.

A COLLABORATIVE APPROACH:

The establishment of Dr. Richard Smith as the Industrial Research Chair in Exploration Geophysics (geophysical data sets, property access) was the result of funding and in-kind support through CEMI, NSERC and four industry partners—Vale, Sudbury Integrated Nickel Operations – A Glencore Company, KGHM and Wallbridge Mining. A total of ten students (4 PhD; 2 MSc; 4 MSc candidates, 3 summer students) are currently working under the supervision of Dr. Smith. Five students are now working in industry partner offices with unprecedented access to properties, workshop facilities, boreholes, previous datasets, and geophysical expertise, allowing them to develop and contribute papers, theses and conference abstracts in their areas of study.

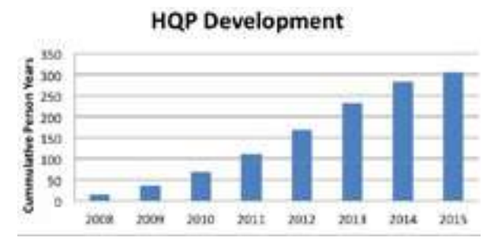
INVESTING IN STUDENTS:

By year-end 2013, CEMI will have contributed to a combined 233 years of graduate-student development in exploration and mining related sectors. 104 students are expected to graduate by the end of the 2013/14 academic year. CEMI currently collaborates with over 35 professors and more than 20 undergraduate, 44 masters students (MSc), 33 PhD students and 7 post-doctoral fellows working on CEMI's research projects.



HQP DEVELOPMENT:

To date, through various innovation projects including the SUMIT collaboration, CEMI is funding work with 25 colleges, technical institutions and universities in Canada and around the world. Some of these include: Acadia University; Université Laval; Queen's University; University of Toronto; University of Waterloo; Laurentian University; Ryerson University; Delft University of Technology; the University of British Columbia in Canada; Dalian University in China; Federal Technical University of Zurich; Camborne School of Mines at the University of Exeter; and Universidade Federal da Paraiba in Brazil. CEMI plans to expand these relationships to other universities in Canada and internationally, at Colorado School of Mines (US), and with Australian researchers in Perth and Melbourne.



1ST ANNUAL SUMIT (SMART UNDERGROUND MONITORING AND INTEGRATED TECHNOLOGIES) RESEARCHER WORKSHOP

In April, CEMI hosted its first Annual SUMIT Researcher Workshop in Toronto. The objective of workshop was for researchers and their students to provide status updates on their current projects, timing and location of experiments, work completed, and planned projects. The discussions allowed for collaboration, identification of potential synergies, and opportunities to optimize research outcomes. It also allowed for test site owners to gain a common understanding of SUMIT and re-affirm the value of their work to the industry. Project discussions included:

UNIVERSITY OF TORONTO
Ramin Saleh: Elastic Wave Propagation in a complex mine setting
Lin Zheng: Mapping Peak Particle Velocities – a modeling study
Qinya Liu: Computing Infrastructure for the SUMIT Seismic Projects
Ken Nurse: Wireless Multi-Component Sensor Networks
Patrick Kanopolous: Development of Fibre Bragg Grating Strain sensors for Rock Monitoring
Peter K. Kaiser (on behalf of Rob Bewick): Shear Rupture of Brittle Rock under Constant Normal Stress and Stiffness

BUILDING HUMAN CAPITAL- INVESTING IN STUDENTS

LAURENTIAN UNIVERSITY

Ming Cai (on behalf of Xin Wang): Numerical Modeling of Seismic Wave Propagation in Underground Mines – Research Plan

Christophe Schaub: Testing the Feasibility of using Electrical and Magnetic Measurements to Monitor Stress Underground

Navid Bahrani: Strength Degradation of Non-persistently jointed Rockmass

QUEEN'S UNIVERSITY

Alex Boivin: Characterization of Mining Induced Rock Displacements

Jennifer Day: Characterization for Complex Rockmasses

Courtney Poleski: Rockmass Blockiness: Controls and Characterization

Gabriel Walton: Dilation of Yield Rock and Rock Masses (change modeling)

UNIVERSITY OF BRITISH COLUMBIA

Masoud Rahjoo: Extensional Deformation Mechanisms in Response to Mining at Depth

UNIVERSITY OF WATERLOO

Behrad Madjdabadi/Leah Siczkar: Laboratory-scale Strain Response of a Distributed Optical Fiber Sensor

Atena Pirayehgar: Simulation of Hydraulic Fracturing in naturally Fractured Igneous Rock

1. SUMIT held its 1st Annual SUMIT meeting with its team of Researchers and Professors on hand to present project status reports. **2.** The CEMI Mining Innovation Award was awarded to Connor Gran, Lo-Ellen Park Secondary School with Courtney Folz, CEMI, Communications Coordinator. **3.** Maximilien Guillot taking readings with the KT-10 manetic susceptibility and conductivity meter.

GREATER SUDBURY REGIONAL SCIENCE FAIR

On April 14th Greater Sudbury held its annual Regional Science Fair. The CEMI Mining Innovation Award was given to Connor Gran, Lo-Ellen Park Secondary School for his project titled, "REFLEX: The Auto Pilot". CEMI congratulates Conner on this innovative science fair project.

ALROSA DIAMOND SUDBURY TOUR

In May, a Russian Delegation (5) from the Alrosa Diamond Company visited, to further their knowledge and understanding of CEMI's work with a view towards developing a partnership. Organized by the IPO office, the delegation was able to tour mines and listen to presentations. CEMI is currently in discussions with Alrosa, with a view of providing innovative solutions for the future.

OTTAWA SCIENCE AND TECHNOLOGY MUSEUM PROJECT

The general population is unaware of the importance of mining in providing the necessities of modern living. Everyday items such as cell phones and computers, building of homes and offices, cars and roads, even highly technical items such as knee and hip replacements or airplanes and satellites—all require mined minerals. The aim of the Ottawa Science and Technology Museum Project is to bring awareness of the importance of mining to the world—past, present and future.

The project will highlight the history of mining through the tools used, from crude mining extraction tools of the past to the highly advanced machines and processes used today. It will document the history of mining, including prospecting and mining of gold, nickel and other valuable minerals, the hardships miners and their families endured, the remoteness of the mining camps and the surrounding settlements and establishment of early businesses.

As part of the project, CEMI will assist by collecting stories and equipment from past and present mining camps. Mining areas once considered remote, where valuable mineral were first discovered, the areas of Red Lake, Elliot Lake, Sudbury and Capreol have already been visited. Plans are currently underway to visit Thunder Bay, Timmins, Kirkland Lake and Cobalt in Ontario; Thompson and Lynn Lake camps in Manitoba; Val D'or and Rouyn in Quebec; Nova Scotia; and Yellowknife.

4. CEMI and the IPO welcomed ALROSA, the largest diamond company in the world to Sudbury. Visiting from Russia, the group was given tours and presentations on hard rock mining practices and the innovations coming from this mining capital. **5.** Toburn Mine depicting mucking machine and ore cars operated in the 1950's. **6.** Richard Smith's students present project updates to industry sponsors.

CEMI TEAM

ALLAN AKERMAN
R&D Program Director

ROB BEWICK
RTC-UMC Program Coordinator

DAMIEN DUFF
Vice President - Geoscience & Geotechnical

COURTNEY FOLZ
Communications Coordinator

SHERRY GREASLEY
Director of Business Administration

SEPPO HAAPAMAKI
R&D Program Director

GEORGE HUGHES
R&D Program Director

PETER K. KAISER
Director of the RTC-UMC

SHANNON KATARY
Director of Marketing and
Community Relations

OLIVER KOSKI
Project Manager

NATALIE LAFLEUR-ROY
Finance and Operations

DOUGLAS MORRISON
President & CEO
Chair in Holistic Mining Practices

CHARLES NYABEZE
Director of Business Development

HARVEY PARSONS
Vice President - Mine Productivity

BORA UGURGEL
Innovation & Prosperity Office Coordinator

SOLUTION TEAM

COLLABORATION

COLLABORATOR
Aker Wirth
Anadarka Petroleum Corporation
Atlas Copco
Baffinland Iron Mines Corporation
Benchmark six
BESTECH
CAE Mining
CAMIRO
CMIC
CANMET
C-Core
Chasm Consulting
CIM
CIMMR
City of Greater Sudbury
Codelco
ConocoPhillips
Debeers Canada
Deltion Innovations
Deswik Mining
Engineering Seismology Group (ESG)
FedNor
Fuller Industries
GE Mining
Geosystems L.P.
Golder Associates
Government of Canada
Hardwear Solutions
HoverTrans Solutions
Institute of Mine Seismology (IMS)
Itasca
Jannatec Technologies
KGHM International
Labrecque Technologies
Landmark
LCG Energy Management
LKAB
Mansour Mining
MERC
MineSense
Mira Geoscience
MIRARCO
MTI
Natural Resources Canada (NRCan)
Nexen
Newcrest Mining
Newmont Mining
NGI
NORCAT
Northern Ontario Heritage Fund Corporation (NOHFC)
NRC-IRAP-Industrial Research Assistance Program

COLLABORATOR
NSERC
Nuclear Waste Management Organization (NWMO)
Objectivity
Ontario Centres for Excellence (OCE)
Provincial Government
Penguin ASI
Peregrine Diamonds
RailVeyor
Rio Tinto
Roctest
RocScience
SAMSSA
Shell Canada
Simsmart Technologies
SNOLAB
SRK Consulting
Stratos
Sudbury Integrated Nickel Operations – A Glencore Company
Symboticware
Vale
Wallbridge Mining Company
XPS – A Glencore Company

ACADEMIC
Acadia University
Boreal College
Cambrian College
Camborne School of Mines at the University of Exeter
Carlton University
Curtin University
Dalian University of Technology
Delft University of Technology
Swiss Federal Institute of Technology Zurich (ETHZ)
École de Technologie Supérieure (ETS)
Laurentian University
Queen's University
Ryerson University
Simon Fraser University
University of Alberta
University of Arizona
University of British Columbia
University of Calgary
Universidade Federal da Paraiba (UFPB)
Université Laval
University of Montreal
University of Ottawa
Université du Québec en Abitibi-Témiscamingue (UQAT)
University of Toronto
University of Waterloo

SPONSORSHIP

CEMI plays a leadership role in developing step-change innovation by providing a management interface between the mining industry in Ontario, academia, SMEs and service providers. These are the crossroads where industry knowledge, imagination and expertise exist to provide scientific advances, new ideas as well as the know-how, essential to turn ideas into workable solutions that can be implemented. CEMI's role is to engage with collaborators who have demonstrated excellence in their field, delivering innovation while helping to ensure that collaborators meet their individual measures of success.

PATRONS

CEMI Patrons recognize that to accomplish step-change innovation, there has to be support for an organization to play a critically important intermediary role between industry, academic researchers and other innovators. CEMI Patrons include Sudbury Integrated Nickel Operations, Sudbury Integrated Nickel Operations--A Glencore Company, Vale, Laurentian University, the Ontario Government, and Rio Tinto. Each of these CEMI Patrons, innovators in their own merit, understand that innovation is a managed process. They know that it cannot be developed with short timelines or as a linear process without some diversions along the way. The Patrons rely on CEMI to manage their effort towards step-change innovation, mitigate the impact of incidental failures and to learn from them to open new avenues of investigation towards future success.

SPONSORS

CEMI Sponsors are those organizations that recognize the need to make significant investments in order to influence major changes in the way their business operates. They acknowledge that supporting university researchers and innovative SMEs is crucial for creating innovative solutions. They help create an industry that offers dynamic and rewarding careers to the engineers, scientists and technicians of tomorrow. And they recognize the importance of providing support to projects in cash and in kind, that allows their financial investment in research to be leveraged to obtain additional funding from government agencies. CEMI Sponsors are committed to initiating and developing research programs that address the broader needs of the industry as part of collaborative projects, and are actively involved with projects on mine sites, working with academic researchers and innovators from the mine services community to investigate alternative approaches and implement possible solutions.

SNOLAB IS DELIGHTED TO BE PARTNERING CEMI ON THE MODCC AND UDMN PROJECTS, WHERE THE APPLICATION OF DATA MANAGEMENT TECHNIQUES USED WITHIN ASTROPARTICLE PHYSICS MAY AFFORD NEW INSIGHTS INTO ROCK MASS STUDIES. THE DEVELOPING CONNECTIONS BETWEEN THESE TWO LEADING INNOVATION GROUPS WILL PROVIDE NEW OPPORTUNITIES WHICH WILL BENEFIT THE LOCAL MINING COMMUNITIES, AND FURTHER STRENGTHEN THE REPUTATION OF SUDBURY AS A MAJOR RESEARCH CENTRE.

NIGEL SMITH, DIRECTOR, SNOLAB

OUR PATRONS

Ontario

VALE

SUDBURY INTEGRATED NICKEL OPERATIONS A GLENCORE COMPANY

RioTinto

Laurentian University Université Laurentienne

CEMI
Centre for Excellence in Mining Innovation

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