



Natural Resources
Canada

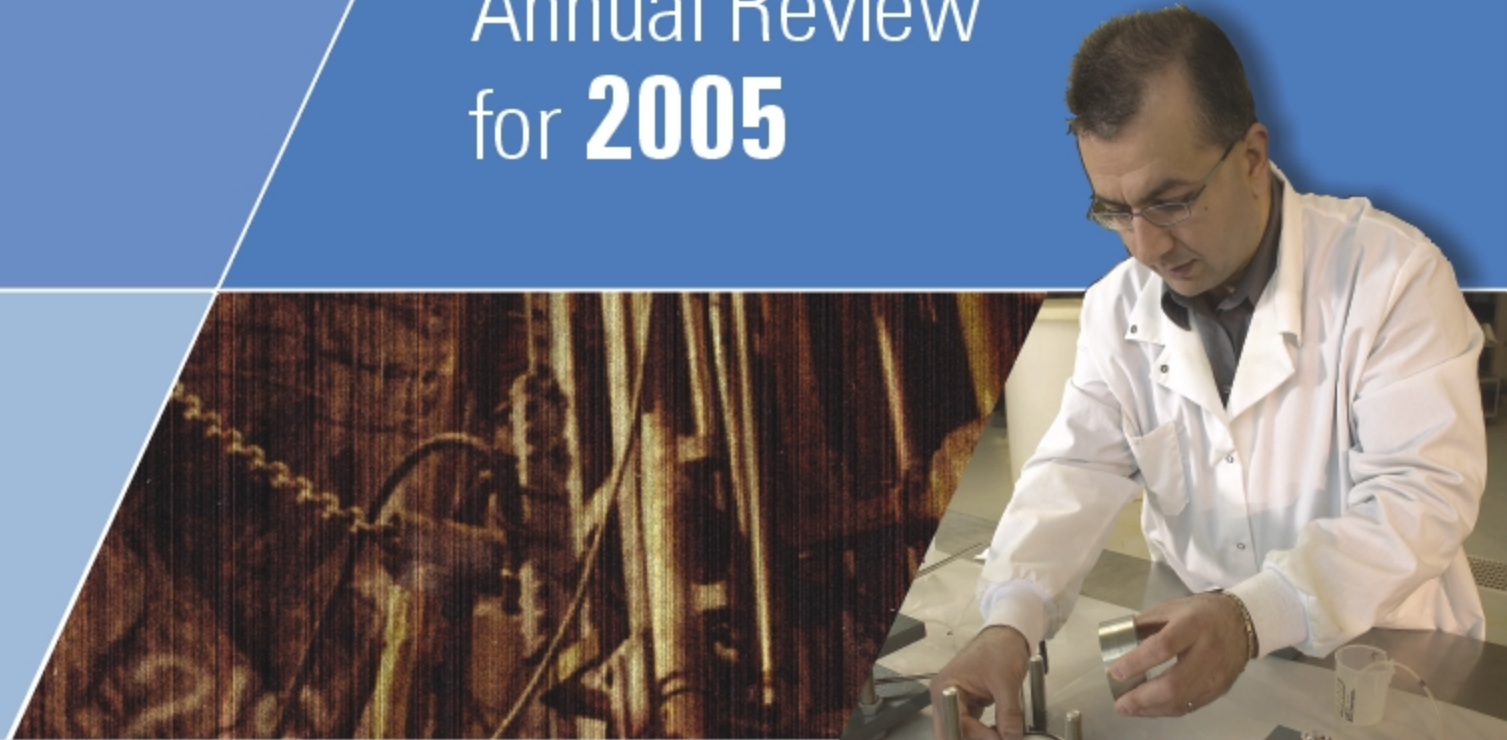
Ressources naturelles
Canada

Canada



CANMET Mining and Mineral Sciences Laboratories

Annual Review for **2005**



Mining, Mineralogy/Metallurgy and Environment

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We welcome your comments about the Annual Review for 2005. For information about our services to industry or collaborative R&D with CANMET Mining and Mineral Sciences Laboratories, please contact our Business Affairs office at:

CANMET Mining and Mineral Sciences Laboratories
Minerals and Metals Sector
Natural Resources Canada
555 Booth Street
Ottawa, Ontario K1A 0G1
CANADA

Telephone: 613-992-7392

Facsimile: 613-947-0983

E-mail: canmet-mmsl@nrcan.gc.ca

Web site: www.nrcan.gc.ca/canmet-mmsl

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Message From the Director



IT HAS BEEN SAID, "Mining is like a search-and-destroy mission." - *Stewart L. Udall (U.S. Secretary of the Interior, 1961-69)*

While this may well have been true in the past, it is no longer. We now have the ability to ensure that mining is a temporary use of the land. Because of major advances in the science of mining, and also in policies relating to the

management of mining, it is now possible to open, operate and close a mine in a safe and environmentally responsible manner. In many cases, within a decade or two of closure, it will be difficult to detect that a mine was ever there. Much of the science that makes this possible is being generated here at the CANMET Mining and Mineral Sciences Laboratories (CANMET-MMSL).

I am pleased to introduce you to our Annual Review for 2005. We are a diverse group of scientists, engineers, technologists, support staff and managers, all focused on providing the sound science needed for Canada's mining sector. We use this science to advise the Government of Canada (and occasionally the governments of individual provinces/territories and foreign countries) on the formulation of policies and regulations for the industry so that Canada and Canadians will obtain the economic and social benefits of the industry while minimizing environmental and other costs. We also provide scientific research to the industry itself, on a fee-for-service basis, to help meet its needs for environmental protection, health and safety, and productivity.

I am extremely proud of the quality, scope and impact of the research we undertake, which I hope you will see demon-

strated in the following pages. I am immodest enough to believe that we are among the premiere laboratories in the world for mining-related research when you look at the whole scope of environmental, safety and productivity activities. However, we are not alone. There are a number of other sources of excellent research in Canada, and one of our major objectives for the next year is to better liaise with other researchers and research organizations. Our intent is to foster wider knowledge of the research undertaken by all and to promote better cooperation within the research community.

One concrete action will be the creation of the MineCan web site to raise awareness among all stakeholders in the Canadian mining industry on the mining R&D projects currently being undertaken in Canada. Government research organizations, universities, mining companies, private labs and manufacturers will all be invited to participate. We expect the industry will benefit from a more-informed perspective on the state of research, research gaps, and the identification of potential collaborators for projects of interest.

In the following pages I trust you will find items that spark your interest - if you do, please feel free to contact the program manager of the relevant program or our business office.

A handwritten signature in black ink that reads "Thomas P. Hynes".

Thomas P. Hynes
Director, CANMET-MMSL

Message From the Deputy Directors

Mining Programs

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IN 2005, R&D in the mining programs focused on improving Health and Safety (H&S) and increasing productivity. For example, CANMET-MMSL has developed a rockdrill handle that decreases harmful vibrations by 60%, which will help alleviate health problems related to vibrations transmitted to workers (e.g., “Raynaud’s syndrome”). The Diesel Emissions Evaluation Program has tested and promoted 95% efficient diesel particulate filtration modules for production equipment and CANMET-MMSL is currently developing the world’s first hybrid scooptram, along with Mining Technologies International (MTI) and other partners. Diesel particulate is responsible for lung diseases in underground workers, and these developments will result in greatly improved underground air quality and energy efficiency (through a significant reduction in ventilation required to eliminate the pollutants associated with diesel engines). It is anticipated that underground testing of the hybrid scooptram will commence in 2006.



conditions associated with working at greater depth. In partnership with an explosives company and a quarry, CANMET-MMSL is assessing rock fragmentation after blasting. Better control on block sizes will reduce crushing/grinding, which will decrease energy consumption (cost) and greenhouse gas generation.

Lastly, we are pleased that our facility at the Experimental Mine in Val-d’Or is being used to help address the current and projected work force shortage by providing hands-on training to mine workers.

Louise Laverdure
Deputy Director, Mining Programs

Environment and Processing Programs

THE PRIORITIES of the Environment and Processing Programs are to provide support and advice on policy and regulation, to develop technologies to reduce environmental impacts, and to participate in cost-recovery projects where new technologies can be applied to specific industry problems.



With the number of mining projects coming into development increasing in recent years, more time has been devoted to the review of environmental assessments to ensure their timely completion. We have been active on regulatory advisory groups for base-metal smelters and for

revisions to the Metal Mining Effluent Regulations, and in international fora having an impact on the sale of Canadian mineral commodities. Our International Workshop on Metals in Soils attracted 60 participants from eight mining nations, and will lead to an international research program to deal with uncertainties related to impacts from metals in soils. Advice and expertise were provided to support environmentally sound mining in northern Canada. Activities included the provision of workshops to regulators, developers and the public in northern communities, and participation in projects on environmental planning, monitoring and remediation.

Research was conducted on a hydrometallurgical processing alternative to smelting for a Canadian base-metals deposit in cooperation with a major producer. This technology could provide a significant option as the cost of meeting increasingly stringent smelter emissions targets escalates. A new CANMET-MMSL proprietary process for higher recovery of silver in gold-silver deposits has also been shown to reduce cyanide consumption, thus reducing potential environmental impacts.

CANMET-MMSL continues to remain certified to ISO 9001:2000 for all of its activities as part of its commitment to excellence and continual improvement. In addition, CANMET-MMSL laboratories located in Bells Corners (Ottawa) and Sudbury are accredited by the Standards Council of Canada to ISO/IEC 17025 for specific tests. CANMET-MMSL is also accredited by the Standards Council of Canada for operation of its Proficiency Testing Program for Mineral Analysis Laboratories.



Significant progress was made within two special projects, Mine Environment Neutral Drainage (MEND) and the National Orphaned/Abandoned Mines Initiative (NOAMI). MEND saw the completion of a report on tailings covers in permafrost and the production of a manual on dry covers, while NOAMI produced a review of legislation with respect to liability and funding measures for various jurisdictions across Canada.

Jim Vance
Deputy Director, Processing and Environment



CANMET-MMSL Locations



Ottawa
(Booth Street Complex)

Ottawa
(Bells Corners Complex)



Sudbury
(Regional Laboratory)

Val-d'Or
(Experimental Mine)



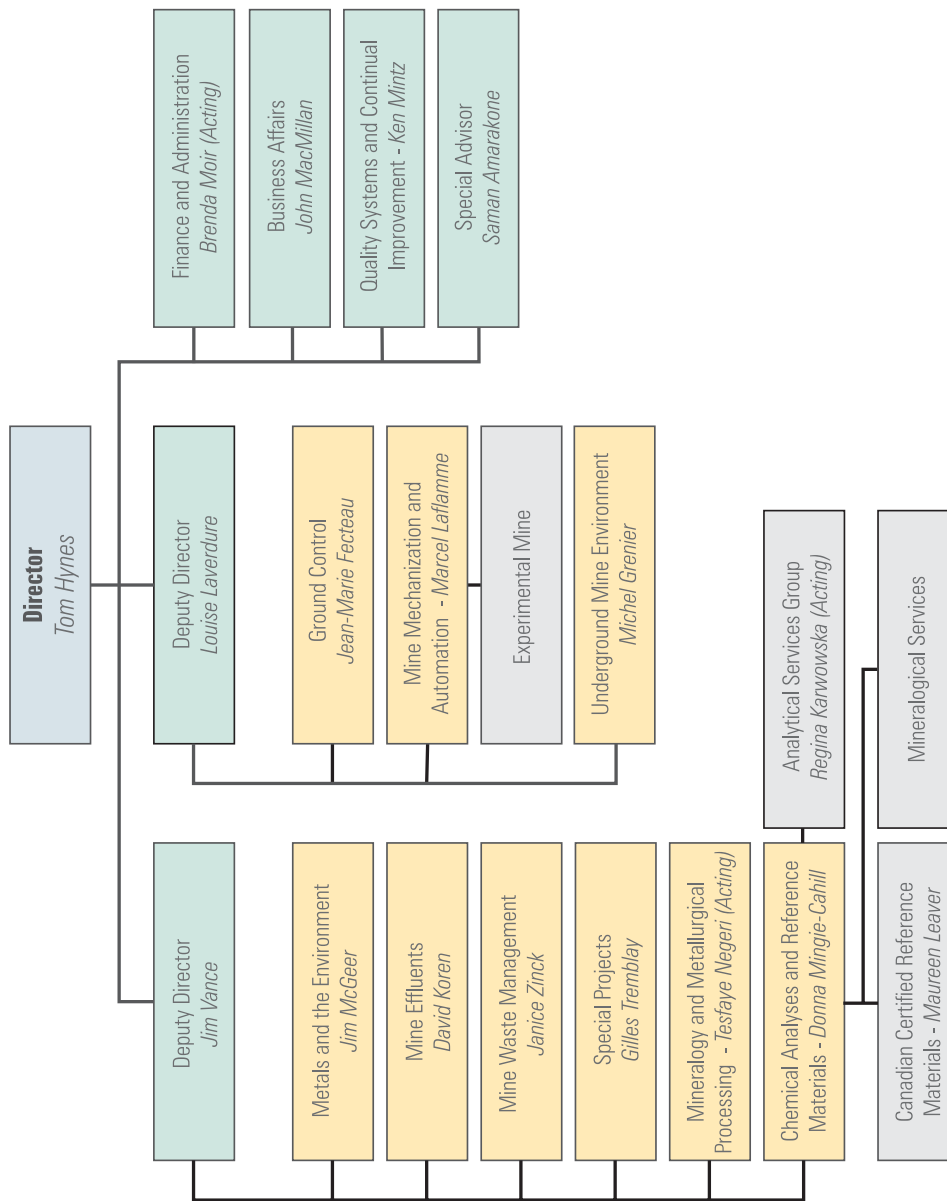
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CANMET-MMSL Organization Chart



Introduction

Position Within Natural Resources Canada

The Minerals and Metals Sector (MMS) of Natural Resources Canada is the federal government's primary source of scientific and technological knowledge and policy advice on Canada's mineral and metal resources and on explosives regulation and technology. MMS leads the government in promoting the sustainable development and responsible use of Canada's mineral and metal resources. It is also a leader in the generation and dissemination of knowledge about the Canadian minerals and metals industries. MMS interacts with a wide range of stakeholders, including its industrial and academic partners, environmental groups, Aboriginal peoples, provincial and territorial governments, other federal departments and agencies, and international organizations. It also collaborates with and provides research services to governmental, institutional and industrial clients (from mining to manufacturing) for the development of innovative technologies with economic, environmental and social benefits to Canadians.

The vision of MMS is "to advance policies, science, regulations and knowledge that will increase the contribution of the minerals and metals industries to Canada."

The CANMET Mineral Technology Branch (MTB) is the science and technology arm of MMS and, as such, conducts research and development throughout the entire minerals and metals cycle, from mining and mineral processing to mine waste management and closure technologies. MTB is largely a client-driven organization that strives to ensure the sustainable development of the minerals and metals sector, including economic productivity, health, safety and security, protection of the environment, and sound technical input to codes and regulations.

The vision of CANMET-MTB is "to be recognized globally and nationally for excellent, relevant, focused science supporting sustainable development in minerals and metals."

To fulfill this vision, CANMET-MTB addresses client and public-good issues by achieving timely delivery of solutions or recommendations for these issues while maintaining scientific excellence and integrity. The global scope of some issues provides opportunities to form international partnerships with both developed and developing countries.

CANMET-MTB comprises two laboratories: the Materials Technology Laboratory (MTL) and the **Mining and Mineral Sciences Laboratories** (MMSL). MMSL is the focus of the remainder of this report.

Role and Structure of CANMET-MMSL

CANMET-MMSL provides quality research and sound scientific advice to the mining and minerals industries and to provincial/territorial and federal departments involved in promoting or regulating these industries. CANMET-MMSL conducts research and development on a wide range of processes and technologies throughout most of the mining cycle, from extraction and processing to environmental management and mine closure. CANMET-MMSL also makes a significant technical contribution towards the formulation of government policy and regulatory initiatives. Technology transfer is another key component of CANMET-MMSL activities through the organization of various technical symposia and as Secretariat for several special programs.

Laboratories are situated in Ottawa, Sudbury and Val-d'Or, and research is focused on three principal target areas to promote sustainable development in Canada:

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Nand Davé – Dr. Davé is a Senior Research Scientist with extensive experience in environmental impact assessment and the rehabilitation and decommissioning of mines.



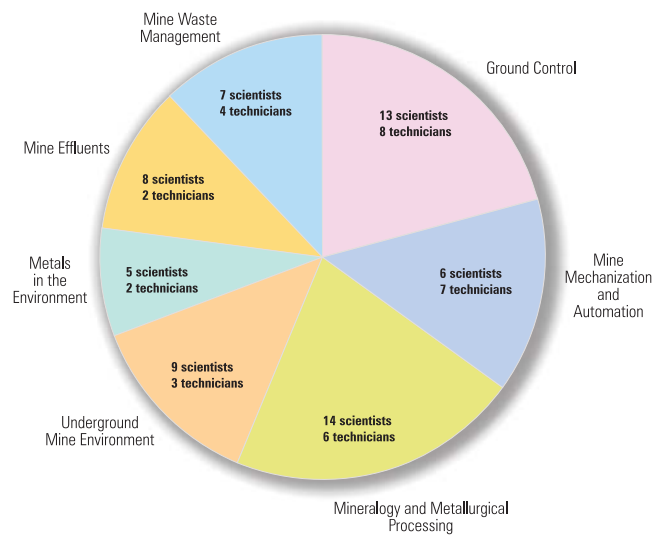
- Improving health and safety in mine operations;
- Developing technically sound solutions to environmental challenges; and
- Improving industry competitiveness through enhanced productivity.

CANMET-MMSL is divided into the following research-based programs:

- Mineralogy and Metallurgical Processing
- Ground Control
- Mine Mechanization and Automation
- Underground Mine Environment
- Mine Waste Management
- Mine Effluents
- Metals in the Environment

Research Programs

The **Mineralogy and Metallurgical Processing (MMP)** group undertakes R&D in metallurgical processing, minerals and metals recycling, and applied mineralogy. The primary objective of the group is to improve process efficiency by optimizing existing mineral processing techniques and to develop new, cost-effective treatment processes. State-of-the-art techniques are used to assist clients, and the ability to integrate mineralogical characterization studies with a comprehensive understanding of metallurgical processes is a key strength that allows better definition of problems and the development of effective solutions.



Scientific Staff Distribution by Program

The **Ground Control Program** promotes a safe mining workplace by developing tools and methods to assess and



monitor the stability of mine openings, and by making these tools and methods available to the Canadian mining industry. The Program helps to improve the long-term economic viability of the industry, primarily by reducing the risks associated with mining in weak rock masses or under high stress conditions at great depth. A better understanding of rock and ground support behaviour, along with the optimization of mine design and delivery of practical tools and economical solutions, help ensure a safe, efficient and sustainable workplace. With specialists in geomechanics, geodynamics, ground support, instrumentation, numerical modelling and induced seismicity, our leading-edge science and interdisciplinary approach ensures that the best knowledge and expertise are applied to solve complex ground control challenges facing the industry.

The **Mine Mechanization and Automation Program** works with the mining industry to enhance health and safety in underground mining operations, facilitate mechanization and automation, improve mine profitability, and provide sound science to Canadian regulatory agencies. The Program consists of specialists in mechanical, mining, electrical and electronic engineering, and focuses primarily on mechanization and automation in narrow-vein mines, improved communication and personnel monitoring systems, and fuel cell technology for underground applications. The CANMET-MMSL Experimental Mine in Val-d'Or, Quebec, provides unique underground and surface industrial-scale facilities to develop and improve underground mining equipment and systems.

The **Underground Mine Environment Program** specializes in mine ventilation (including ventilation automation), diesel-engine emissions control and certification, and monitoring and control of underground contaminants. The principal goals of the Program are to improve air quality and safety in the underground mine environment and to evaluate approaches that may provide savings in both capital and operating expenses. CANMET-MMSL collaborates with

mine operators, workers, suppliers and regulators to provide cost-effective underground environmental technology solutions.

The **Mine Waste Management (MWM) Program** develops and assesses long-term, scientifically sound and sustainable options for the disposal, management and rehabilitation of mine wastes, including tailings, waste rock and treatment sludge. The Program takes a multi-disciplinary approach to projects and has a wide range of scientific expertise that enables staff to assist Canadian mining companies at all stages of a mining project. Current activities are largely focused on molecular characterization of mine wastes, long-term disposal options for hydrometallurgical residues, and novel reclamation options for site remediation. In addition to research, the MWM Program provides technical reviews of mining and rehabilitation-related studies and environmental impact assessments, and is active in environmental capacity-building activities in developing countries.

The **Mine Effluents Program** is focused on the development of treatment technologies to help the mining industry meet effluent regulations. The Program consists of experts in chemistry, microbiology, soils, and biotechnology. It is the integration of chemical and microbial expertise that provides a better understanding of natural and engineered degradation processes, and is the real strength of the team. Staff work directly with industry on the treatment of mine, mill and metallurgical effluents to develop and adapt effluent management strategies, including prevention and remediation technologies. The Mine Effluents Program is extensively involved in technology transfer activities, particularly with respect to metal leaching and acid rock drainage.

The **Metals in the Environment Program** specializes in research concerning the environmental effects of metals, from aquatic toxicology and geochemistry to metallurgical processing and the characterization of metal-bearing substances. This knowledge is used in combination

with expertise in life-cycle assessment (LCA) to integrate information in the context of environmental sustainability. This unique multi-disciplinary team enables CANMET-MMSL to play a leading role in developing and promoting a sound scientific foundation for protocols related to metals and metal products, as well as environmental protection decisions at both the national and international levels.

CANMET-MMSL also has a **Special Projects Program** that is the Secretariat for both the **Mine Environment Neutral Drainage (MEND) Program** and the **National Orphaned/Abandoned Mines Initiative (NOAMI)**. This program also coordinates the review of Environmental Impact Assessments (EIAs) by CANMET-MMSL staff on mining-related projects.

The MEND Program is a Canadian partnership with industry, federal and provincial/territorial governments, and non-governmental organizations that agrees to cooperate in technology development and to transfer knowledge to improve environmental management in mining. Initiated in 1989, the original MEND Program was enormously successful and succeeded in reducing the liability to Canadian mining companies and provincial/territorial and federal departments, as a result of acidic drainage, by at least \$400 million. Natural Resources Canada and The Mining Association of Canada share funding for the MEND Secretariat.

NOAMI was established in 2002 following an endorsement from Canadian mines ministers on the importance of developing a large-scale program for the rehabilitation of orphaned/abandoned mine sites in Canada. A multi-stakeholder advisory committee was set up to study various issues and initiatives relating to the development of partnerships in the implementation of remediation programs across Canada. The Advisory Committee takes direction from mines ministers and reports back to mines ministers via the Intergovernmental Working Group on the Mineral Industry



Steve Hardcastle - Dr. Stephen Hardcastle is recognized internationally as a mine ventilation specialist. His work on ventilation optimization has produced significant health and energy conservation benefits.

(IGWG). For more information, visit the NOAMI web site at www.abandoned-mines.org.

CANMET-MMSL also operates the **Canadian Certified Reference Materials Project (CCRMP)**. For over 30 years, the CCRMP has prepared and certified over 130 reference materials. These materials consist of finely powdered Canadian rocks, ores, concentrates, alloys, tailings, soils, sediments and radioactive materials for which the concentrations of various elements have been accurately determined. These materials are used by analytical laboratories related to the mining industry in the assessment of the accuracy and precision of their results.

Research activities are supported by the Analytical Services Group (ASG) and Mineralogical Services. The ASG provides specialized analytical services primarily in support of R&D activities at CANMET-MMSL, and also focuses on in-house method development for both research and cost-recovery projects. Mineralogical Services focuses on micro-analytical quantitative studies. Principal areas of expertise are: identification of minerals, determination of the elemental composition of minerals, determination of mineral quantities, liberation analysis, mineral association, deportment of precious minerals, surface analysis, and molecular scale characterization.

As with any organization, a very competent administrative support team greatly assists in the completion of R&D projects.

Specialized Facilities and Equipment

CANMET-MMSL possesses a wide range of facilities and test equipment that permits specialized, detailed research and encourages collaboration amongst internal programs and with outside organizations. A cross-section of these facilities and equipment is provided below.

- The CANMET-MMSL Experimental Mine in Val-d'Or, Quebec, is a hard rock mine that provides an ideal site for testing equipment and delivering professional, technical and university training to mine personnel;
- Load frames for laboratory testing of geo-materials: 4.5 MN MTS servo-hydraulic load frame, 17.8 MN Gilmore hydraulic load frame (both in Bells Corners), 10 MN Terratek hydraulic load frame (in Sudbury);
- Full diesel engine test facility including a 600-HP-capacity AC dynamometer and a state-of-the-art gas cart and diesel particulate characterization instrumentation package. The facility is used for diesel control research and CSA and MSHA diesel engine certification;
- Drop Weight Test Frame for dynamic testing of ground support tendons, with 3-metric tonne weight capacity, 2.1-metre drop height, and data acquisition over 12 channels;
- Mine-wide micro-seismic monitoring system with 30 channels providing complete data acquisition and localization of seismic events;
- State-of-the-art acoustic emission data acquisition system, with 12 channels and complete recording and display of acoustic events;
- Facilities for backfill quality control, specimen preparation, curing and testing;
- More than 23 000 m² of mill and laboratory space for pilot-scale studies;
- Low-temperature test facilities for environmental research;
- Aerobic and anaerobic growth chambers;
- Culture and ecotoxicity testing facilities for plants, invertebrates and fish;

- Wetland/passive treatment testing facility;
- Bench and pilot-scale membrane separation facilities;
- Two mobile mine water treatment mini plants;
- Molecular biology facilities;
- Access to advanced characterization equipment, e.g., Synchrotron facilities;
- Mobile field laboratory.



University Affiliations

Several CANMET-MMSL scientists are Adjunct Professors at universities in Canada and abroad. In addition, staff are frequently external examiners for graduate student theses.

Dr. Suzanne Beauchemin, Department of Natural Resource Sciences, Faculty of Agricultural and Environmental Sciences, McGill University, Adjunct Professor since 2003.

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Dr. Marc Bétournay, Department of Mining, Metals and Materials Engineering, McGill University, Adjunct Professor since 1997.

Dr. Doug Gould, Department of Earth Sciences, University of Waterloo, Adjunct Professor since 2005.

Dr. Doug Gould, Department of Biology, Carleton University, Adjunct Research Professor since 1991.

Dr. Doug Gould, College of Environmental Science and Forestry, State University of New York, Syracuse, Adjunct Assistant Professor since 1983.

Dr. Marcel Laflamme, Department of Applied Science, Université du Québec en Abitibi-Témiscamingue, Adjunct Professor since 1996.

Dr. Ken Mintz, Department of Chemical Engineering, Dalhousie University, Adjunct Professor since 1992.

Dr. Dogan Paktunc, Earth Sciences Department, University of Ottawa, Adjunct Professor since 2004.

Dr. Allen Pratt, Department of Earth Science, University of Western Ontario, Adjunct Professor and member of the Faculty of Graduate Studies since 1998.

Dr. John Udd, Department of Mechanical and Aeronautical Engineering, Carleton University, Adjunct Professor since 2002.

CANMET-MMSL also participated in a McGill University panel on career options in the Public Service of Canada for advanced degree candidates aimed at informing and illustrating the range of positions and prospects that exist in the areas of federal research, policy and regulation for engineering and science students. The panel was held in conjunction with Graduate Student Career Week on a day dedicated to Sciences and Engineering students and included individuals involved in science policy and federal research, as well as a representative from the Natural Sciences and Engineering Research Council of Canada.

Awards

John E. Udd, Principal Research Scientist, received the Richard S. Ladd Standards Development Award from ASTM International for the development of a standard terminology relating to frozen soil and rock (co-authored with Erwin Long).

The Year in Numbers

THE FOLLOWING ITEMS highlight the overall productivity of the 95 scientific and technology transfer personnel at CANMET-MMSL in 2005.

- 20 refereed journal publications
- 8 refereed journal publications in press
- 42 papers in conference and workshop proceedings
- 30 oral presentations at conferences and workshops (no paper)
- 33 internal reports completed
- 25 other publications
- 64 confidential client reports for revenue-generating projects
- 53 different clients for CANMET-MMSL revenue-generating projects
- 8 technical reviews on Environmental Impact Assessments for major Canadian mining projects
- 11 conferences and workshops organized
- 250 mine workers trained in health and safety at CANMET-MMSL's Experimental Mine facility in Val-d'Or, Quebec (training provided by Or-et-des-Bois School Board)
- 6 technical projects completed through the MEND Program
- 14 projects currently ongoing or completed through the MEND Program
- 350 MEND reports sold
- 10 Adjunct Professor positions at universities
- 8 students and 3 interns employed by CANMET-MMSL
- 38 MMSL employees enrolled in part-time language studies; 25 in French and 13 in English
- 20 CANMET-MMSL scientific and technology transfer staff participated in a four-day study tour of mine sites in the Sudbury and Elliot Lake (Ontario) areas

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Impact of CANMET-MMSL Activities

MANY OF CANMET-MMSL's R&D and other activities have demonstrable positive impacts on outside organizations and the Canadian public. Examples of these impacts include:

Environmental Evaluation for an Improved Tailings Disposal Method at IOC

The Iron Ore Company of Canada (IOC) initiated discussions with CANMET-MMSL in 2004 on a proposed new tailings disposal method utilizing a polyacrylamide flocculant to remove suspended solids from its final effluent at Wabush Lake in the province of Newfoundland and Labrador. This strategy has the potential to reduce environmental impacts and at the same time significantly reduce capital costs related to tailings disposal by more than \$100 million. IOC engaged CANMET-MMSL scientists to consider the experimental results and to identify any questions or concerns that should be answered before proposing the idea for regulatory approval.

Subsequently, several areas of possible concern were identified, including the potential toxicity of the flocculant, the stability of this product and its potential for biodegradation in the natural environment, and the need to characterize the material that was causing a red coloration of the lake waters with the existing tailings disposal method. A multi-disciplinary team, consisting of members from all CANMET-MMSL Environment and Processing programs, was assembled to answer these concerns. The results showed the flocculated material to be stable and non-toxic, and the information is now under review by government regulators in consideration of the IOC request for approval to adopt this improved tailings disposal method. If approved, it will result in reduced environmental impacts at Wabush Lake, including control of the current discoloration of lake waters and a reduction in the size of the environmental footprint of the operation. An added benefit is that part of the substantial capital cost savings would be available for reinvestment in other plant improvements that could result in

increased sales and improved employment security for the work force.

The successful completion of this project was the result of good interdisciplinary communication and cooperation of scientists and technicians who rearranged priorities and worked diligently to deliver within the required timeframe.



Reduced Vibration During Drilling Operations

Many operators of hand-held pneumatic drills suffer from various vibration-related disorders, such as Raynaud's phenomenon (or "white finger") and carpal tunnel syndrome. These disorders can cause serious problems both for the workers themselves and for society as a whole. The rehabilitation cost for a single mine worker with Raynaud's phenomenon can be several hundred thousand dollars in direct costs and considerable associated social costs. In collaboration with the University of Sherbrooke and a manufac-

turing company, CANMET-MMSL has developed a drill handle that reduces harmful vibrations by 60 percent. The handle has huge market potential, both in Canada and abroad.

Diesel Emissions Control in Mines

The Diesel Emissions Evaluation Program (DEEP) will be concluding in 2006. A founding member of the DEEP consortium, CANMET-MMSL has been very active as Secretary, Chair of the Technical Committee and member of the Management Board. In 2005, CANMET-MMSL was actively involved in the last DEEP field demonstration project that evaluated the performance of high-efficiency (90-95%) diesel particulate matter (DPM) filtration modules. As a result of this work, Inco Ltd. has installed this technology on several heavy-duty production vehicles at mines in Sudbury. Falconbridge's Brunswick mine, located in Bathurst (N.B.), also supports the use of this technology as a result of a similar DEEP project in collaboration with CANMET-MMSL.

Seismic Monitoring for Heavy Oil Extraction

The economic recovery of oil from Canada's oil sands relies on thermal processes such as steam stimulation, which may lead to occurrences of fluid escaping through cracks in well casings. When a casing failure occurs, production losses are estimated at \$25 000 per day and, if the entire pad is affected, investments and oil reserves valued at up to \$60 million can be jeopardized. Significant environmental contamination of surface and ground water can also occur. In collaboration with a Canadian company, CANMET-MMSL developed software that automatically classifies seismic events and provides real-time monitoring of potential casing failures. The company has committed to using this technology as an early warning system for casing failures, which greatly reduces the risk of environmental consequences and improves productivity.

New Leaching Approaches for Improved Extraction of Silver and Gold

Fundamental research in cyanidation has focused on the leaching mechanisms of calaverite, a gold telluride, known to have slow leaching kinetics. Using mineralogical expertise to synthesize calaverite and surface analysis to quantify the surface reaction products, new leaching mechanisms, which appear to be related to the key selected parameters, were identified. It was demonstrated that calaverite can dissolve at a significantly faster rate than under conditions normally employed. Following a detailed laboratory investigation completed at CANMET-MMSL, a gold producer in Mali made modifications to its plant that reportedly resulted in a 4% increase in gold recovery and an additional 16 000 ounces per year in gold production.

Technology Transfer

The dynamic approach used in transferring information through MEND, NOAMI and the Global Alliance is extremely effective in advancing environmental performance and the understanding of sustainable development as it relates to mining and society. These multi-stakeholder initiatives deliver information to a network of over 1500 participants from the mining industry, governments, academia and consultants around the world, and are very useful in establishing research gaps, minimizing the duplication of research activities, and decreasing environmental liabilities.



Elizabeth Giziewicz – Dr. Elizabeth Giziewicz is Editor-in-Chief of CANMET-MMSL's RNet Recycling Newsletter. The Newsletter has been published twice per year for the past nine years, providing up-to-date information about new technology in the field of recycling. The final issue of RNet was published in March 2006.

List of Clients

In addition to supporting government initiatives, CANMET-MMSL provides R&D services to meet the needs of individual mining companies and related organizations. This work provides a measure of the relevance of CANMET-MMSL operations, and this close contact with the industry helps anticipate and establish future research directions.

In 2005, 64 confidential client reports were generated in addition to the publications listed in this document. We appreciated the opportunity to work with these companies and look forward to continuing collaboration with these and other companies and organizations in 2006.

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- Alberta Research Council
- Agnico Eagle Mines Ltd.
- Aur Resources Inc.
- Association Minière du Québec
- Barrick Gold Corporation
- B.C. Ministry of Environment
- B.C. Ministry of Energy and Mines
- Bema Gold Corporation
- Breakwater Resources Ltd.
- Cambior Inc.
- Cameco Corporation
- CAMIRO
- CIDA
- Cummins Inc.
- DCL International Inc.
- École Polytechnique de Montréal
- Environment Canada
- European Powder Metallurgy Association
- Falconbridge - Brunswick Mine
- Geological Survey of Japan, AIST
- GMS Technologies Ltd.
- Golder Associates
- Government of Newfoundland and Labrador
- Grande Cache Coal Corporation
- Hydro Québec
- INCO Ltd.
- Indian and Northern Affairs Canada
- Iron Ore Company of Canada
- Iveco Motors of North America
- Klohn Krippen Consultants Ltd.
- Lafarge Canada Inc.
- Laurentian University
- Memorial University of Newfoundland
- Mine Beaufort
- Mine Niobec
- MINTEK
- Mitsubishi Engine North America Inc.
- Nature Works Remediation Corporation
- Nickel Producers Environmental Research Association
- Noranda Inc.
- Northwest Community College
- Placer Dome Ltd. (Porcupine Joint Venture)
- Potash Corporation of Saskatchewan
- Public Works and Government Services Canada
- Royal Canadian Mint
- SOREDEM
- Surface Science Western Laboratories
- Testmark Laboratories Inc.
- Transport Canada
- University of Waterloo
- University of Windsor
- Voisey's Bay Nickel Company
- Wesdome

Science/Policy Linkages

MANY OF CANMET-MMSL's projects and activities have direct linkages to policy or contribute directly to policy and regulatory issues. Examples of this include:

Advisory Committees

As part of its role to provide advice to regulators, MMSL was active on two major advisory boards providing input to Environment Canada during the year. As part of the Base-Metal Environmental Multi-Stakeholder Advisory Group (BEMAG), recommendations were provided regarding the proposed new control measures for emissions of sulphur dioxide and particulate matter from base-metal smelters. CANMET-MMSL also contributed to the Metal Mining Effluent Regulations Multi-Stakeholder Advisory Group (MMERMAG) through the review of proposed revisions to the MMER.

Mining Environmental Impact Assessments (EIA)

EIA reviews provided by CANMET-MMSL are a valued component of the *Canadian Environmental Assessment Act* process, especially with the burgeoning growth in the Canadian mining industry. In 2005, CANMET-MMSL provided comprehensive technical reviews of EIAs for the following major Canadian mining and related projects:

- Kemess North
- Mount Klappan
- Victor Diamond
- Meadowbank Gold
- Red Chris
- Wolverine
- Doris North
- Sea-to-Sky Highway

Transformation/Dissolution (T/D) of Metals

CANMET-MMSL data on the T/D characteristics of nickel metal powder have been used in the European Union (EU) environmental risk assessment for nickel metal. In addition, CANMET-MMSL data for an iron-copper alloy are being used in other EU environmental protection measures. CANMET-MMSL is also a participant and lead laboratory in the validation study on the Draft OECD (Organization for



Economic Cooperation and Development) T/D Protocol for Metals and Sparingly Soluble Metal Compounds.

Training Mine Workers

CANMET-MMSL's Experimental Mine, in conjunction with the Or-et-des-Bois School Board, continues to deliver training modules to mine workers. This is a specific requirement of the Quebec mining regulations. More than 2000 mine personnel have been trained at the CANMET-MMSL Experimental Mine in Val-d'Or, Quebec, over the past 10 years.

Monitoring the Exposure of Miners to Diesel Particulate Matter (DPM)

The solid component of diesel exhaust contains several known human carcinogens, which makes the at-source control of DPM emissions very important. As a result, several provinces have modified, or are in the process of modifying, the laws concerning the exposure limits to DPM in the mining workplace. CANMET-MMSL undertook a collaborative study with the Institut de recherche Robert-Sauvé en santé et en sécurité du travail (IRSST) at two Quebec mines and in several urban bus garages to compare DPM analytical methods and to help determine the levels of exposure in mines and elsewhere. CANMET-MMSL staff participated in meetings of the Ontario Mine Legislative Review Committee's Diesel Sub-Committee to discuss



Lucie Morin – Lucie Morin is a Technologist who is also very active in CANMET-MMSL's Emergency Response Team and the Occupational Health and Safety Committee.

findings of the study and their implications. Previous CANMET-MMSL involvement in legislative review has led to important reductions in the limit of exposure to DPM in Quebec (from 1.5 mg/m³ to 0.6 mg/m³) and to the adoption of a very precise DPM analytical procedure in Saskatchewan.

Sludge Management

CANMET-MMSL's sludge management research has directly resulted in changes to guidelines on secondary waste disposal in British Columbia. Based on the research conducted by CANMET-MMSL, the proponent must now predict the quality and quantity of any secondary wastes produced in the treatment process and provide an acceptable disposal plan that addresses the issues of physical security and geochemical stability. Research on treatment sludge stability in various disposal environments was used to support these guidelines.

Contributions Towards Canadian Mining Regulations

Many of the ongoing CANMET-MMSL research activities (such as those described in this report) are laying the foundation for improvements to worker health and safety standards contained in existing mine regulations. For example, the non-destructive testing of mine hoisting wire ropes will have a direct impact on regulations and lead to modifications in best practice, especially in deep mines.

Science Highlights



THE FOLLOWING HIGHLIGHTS constitute a cross-section of the range of science activities undertaken at CANMET-MMSL. The highlights are broken out into those that are related to R&D, those that pertain to Technical Consultation, and those that are Special Projects and Support Services.

Research and Development

Mining Programs

Heat Stress in Mining

CANMET-MMSL, in collaboration with the University of Ottawa and under the Deep Mine Research Consortium (DMRC), initiated a project aimed at reducing the incidence of heat stress/strain on workers in deep mines. The scope of this multi-year project is broad, encompassing a literature review, an evaluation of heat monitoring devices routinely used underground, global guidelines and regulations applicable to deep Canadian mechanized mines, and the characterization of mining tasks and evaluation of the associated strains under controlled conditions. When completed, this work will lead to the selection of suitable instrumentation for the monitoring of heat stress, the development of progressive and more protective guidelines and, ultimately, the development of regulations. This work will also identify the parameters responsible for the hot conditions and mechanisms to promote or inhibit cooling in order to better protect workers. These mechanisms could include modified mining methods, innovative fabrics, cooling vests, and air-conditioned micro-climates.

Mine Ventilation on Demand

Ventilating large underground diesel mechanized mines is very costly, and many underground production areas are continually being supplied with large volumes of air in spite of the fact that they may only be actively mined for a small percentage of their lifespan. The rising cost of energy and

fierce international competition are bringing the need for centralized control of the ventilation infrastructure to the forefront. Ventilation-on-demand will help mitigate the costs associated with ventilation and will assist mine operators in providing better working conditions by sending dilution air wherever it is needed based on real-time monitoring of mining activity. CANMET-MMSL is actively collaborating with the private sector and mining partners to bring together all of the components required to successfully implement this concept in a working mine.

Backfill and Ground Support

Under a mandate from the Deep Mining Research Consortium (DMRC) and in close collaboration with several Canadian companies, CANMET-MMSL carried out laboratory investigations to study the properties and the behaviour of a novel backfill system, termed gelfill. The parameters studied included the influence of curing environments, mixing sequences, flocculants and gel additive. When completed, the study findings will have a valuable impact on the mining industry by defining specific applications for gelfill compared to other types of backfill. The DMRC is also supporting another project related to the determination of ground support characteristics under static and dynamic loading, i.e., the behaviour of support elements such as cone and friction bolts. This project is helping to fill knowledge gaps concerning the behaviour of support tendons, and will help to direct future industry-driven R&D activities related to the performance of ground support systems for deep and high-stress mining environments.

Rock Characterization and Ground Behaviour

A series of tests were carried out on concrete specimens using CANMET-MMSL's rock testing facility to verify the efficiency of various sealing agents used for reducing the permeability and improving the performance of concrete products. The stability of the equipment and the range of pressures available were critical for generating and maintaining a uniform, minimal flow through the

specimens over several hours and providing accurate measurements. Triaxial compression tests were carried out on large intact and altered rock specimens to determine both their maximal and residual strengths. These properties are essential for predicting the short- and long-term stability of wells, tunnels, surface excavations and underground openings. High quality controls and versatility of the equipment allowed the continuous and complete recording of strength curves without disruption of loading or imposition of any bias to the behaviour of rock specimens.

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Deformability Testing at the Experimental Mine

In parallel with the laboratory activities described above, CANMET-MMSL was also active in field studies related to the determination of stress regimes and assessment of the stability of mine openings. In 2005, a series of drillholes were completed at the Experimental Mine in Val-d'Or to sample rock materials and to determine the deformability of the rock in place. The holes were drilled in different rock types, representative of the host mine geology. This work is part of a long-term research project carried out with researchers from École Polytechnique de Montréal and the Institut de recherche Robert-Sauvé en santé et en sécurité du travail (IRSST) to analyze and predict the behaviour of rock materials and rock masses in relation to the scale of openings and the level of damage observed at their perimeter. Results from this project will help improve the quality of computer models used to assess the stability of openings, and ultimately enhance the safety of underground mine workers.

Rock Size Reduction Efficiency Improvement Technologies for Energy Savings and GHG Reductions

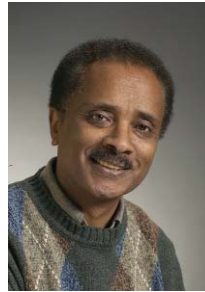
In 2005, CANMET-MMSL used its large pool of expertise in ground control, open-pit and underground mine engineering, mineral processing, information technology and applied mineralogy to launch a mine-to-mill research initiative. The objective was to optimize the distribution of rock breakage energy between blasting, crushing and grinding activities, thereby maximizing the energy utilization efficiency within



comminution processes. Tests were designed to demonstrate that such approaches can reduce energy consumption, thereby contributing to the reduction of GHG production in the Canadian mining industry. This work, completed in collaboration with DynoConsult and Dyno Nobel Canada Inc., demonstrated that such an approach can indeed result not only in a reduction of energy consumption by rock breakage processes, but also in increased comminution plant throughput.

Alternative Energy Sources for Mining Vehicles

A number of initiatives are under way at CANMET-MMSL to provide underground mining operations with alternatives to fossil fuels, particularly diesel, in an effort to improve the work environment. For example, an R&D project is being carried out to develop a 1.5-m³ load-haul-dump vehicle in collaboration with Mining Technologies International (MTI) and other partners. It has good potential in terms of improving energy efficiency and the quality of the work environment while decreasing greenhouse gas production. In 2005, the prototype design was completed and the components were selected. Underground testing is expected to begin in mid-2006.



Tesfaye Negeri – Dr. Tesfaye Negeri is a Senior Mineral Processing Research Engineer specializing in flotation. He is also the Manager of the Mineralogy and Metallurgical Processing Program.

Mine Hoist Safety

The functional safety of mine hoists is a priority for CANMET-MMSL, which has state-of-the-art expertise in the field. The increased use of programmable electronic systems (PES) to control the operation of hoists poses a serious challenge to ensuring safety at all times. In 2005, a major project to develop and publish a technical guide on the use of PES-controlled mine hoists was completed. CANMET-MMSL is also continuing to test many mine hoists in Canada and abroad.

Wireless Underground Communications

Work carried out in 2005 with the Université du Québec at Abitibi-Témiscamingue's Underground Communications Research Laboratory has advanced the state of knowledge of wave propagation in underground environments. Testing was carried out with a wireless 10-GHz system, which covered distances of up to 500 m. The efforts will ultimately make it possible to transfer information in real time between the surface and underground operations, making mines safer and more efficient. A monitoring system for personnel working alone was also developed and tested at the Experimental Mine which, in the event that a worker working alone cannot report in as planned, initiates a series of actions to inform those in charge of the operation.

Environment and Processing Programs

Ettringite for the Stabilization of Mine Waste Products

Portland cement is used as a binder in mine backfill and for stabilization of mine waste products. However, it is expensive. CANMET-MMSL, in close collaboration with a Canadian company, investigated the synthesis of a low-cost binder for stabilization of mine backfill, leach residues and sulphide tailings using inexpensive by-product materials, such as slag, power plant fly ash, lime, and gypsum. These components, when combined in judicious amounts and under the appropriate mixing conditions (grind, stirring,

temperature and water content) resulted in the solubilization of ions that, under appropriate alkaline conditions, can combine to form a cementing binder. The primary binder candidate in this work was the mineral ettringite, which has successfully been synthesized and used to solidify and stabilize nonferrous granulated slag and a laterite leach residue.

High Efficiency Flotation Pulp Conditioning Improves Grade and Recovery

A strategic research alliance between COREM and CANMET-MMSL over the last five years has resulted in a number of process technologies with significant potential. The efficiency of the flotation process is very dependent on pulp pre-treatment conditions prior to flotation itself. The High Efficiency Conditioning (HEC) is one of those technologies that has been piloted and proved to significantly improve flotation efficiency. Further in-plant testing of this technology is planned for 2006.

Research in Base-Metal Hydrometallurgy Continues to Make Significant Impacts

The productivity of the Canadian metallurgical industry was enhanced by the elucidation of the behaviour of various elements in copper electrorefining circuits and the clarification of the leaching of zinc sulphide minerals at atmospheric pressure. In particular, the behaviour of gold during copper electrorefining was investigated and a comparison of the Mossbauer and XANES techniques for the definition of the valence state of gold was made. This was the first use of XANES for gold in copper refining products, and the work showed the unexpected dissolution of some gold in the sulphate-based refining electrolyte. Further studies are under way to attempt to extend the XANES technique to antimony in copper refining circuits. Numerous other promising avenues of research were undertaken, including the leaching of sphalerite in ferric sulphate media for zinc concentrates, causes of poor silver recoveries during cyanide leaching, sequestration of toxic elements by jarosite-

type compounds, and novel techniques for the processing of electric arc furnace dust.

Disposal Option for Hydrometallurgical Pressure Oxidation Leach Residues

Many hydrometallurgical processes generate residues that, like other mining wastes, have specific disposal requirements. CANMET-MMSL in cooperation with a Canadian company is conducting long-term laboratory studies to evaluate on-land and underwater disposal of these leach residues. Two types of leach residues are being tested: an iron oxide residue containing elemental sulphur, and a gypsum/ferrihydrite containing neutralization residue. The development of appropriate disposal and long-term management strategies for process leach residues will support the application of hydrometallurgical processes as a replacement to smelting, which indirectly minimizes air quality issues associated with metallurgical processing.

Guyana Environmental Capacity Development (GENCAPD) Project

The GENCAPD project was designed to develop environmental expertise in several of the key institutions involved with the mining sector in Guyana, and to develop a regulatory framework that will promote the sustainable development of Guyana's mineral resources. The six-year, \$3.75 million Phase I, financed by the Canadian International Development Agency (CIDA) and completed in 2005, focused on the development of technical and managerial capacity within the key mining sector institutions of Guyana, including the Guyana Geology and Mines Commission (GGMC), the Environmental Protection Agency (EPA), and the Guyana Gold and Diamond Miners Association (GGDMA). CANMET-MMSL has proposed a Phase II, targeted at activities to fill gaps observed during Phase I. The three-year Phase II is expected to be approved in 2006 and will focus on practical training reinforced by theory. The aim is to progressively rely on Guyanese stake-



holders to deliver training as a means of fostering sustainability.

Arsenic Mobilization

More than eight decades of silver mining in the Cobalt mining camp in northern Ontario has left large volumes of As-bearing mine wastes widely distributed in and along watercourses in the Cobalt area. The area drainage is consequently contaminated with dissolved As at concentrations that are at least an order of magnitude higher than the current Canadian drinking water criterion of 0.025 mg/L. To clarify the prevalent As transformation and mobilization processes, detailed studies were conducted with tailings sediments sampled from a wetland located in North Cobalt. Field deployment of anionic exchange membranes coupled with laboratory sorption/desorption experiments showed that the submerged tailings are likely a source rather than a sink of As to the local streams. The paucity of ferruginous phases also made Al-minerals the main sorbents for As with significant competition from P for the available sorbing sites. Redox experiments complemented with synchrotron analyses indicated that changes in As species readily occurred with changes in redox conditions, resulting in rapid As remobilization. Microbial analyses suggested that sulphate reduction occurs locally in the wetland, leading to possible co-precipitation of As with framboidal pyrite. These observations are useful for developing practical remediation schemes to attenuate the aqueous transport of As in the historic mining camp.



Critical Review on Deep Sea Tailings Placement (DSTP)

Aiming to provide a comprehensive review of the current science and technology related to DSTP, CANMET-MMSL, in collaboration with the Australian Commonwealth Scientific and Industrial Research Organization (CSIRO), undertook a critical review to identify knowledge gaps without invoking value judgments. Although areas of additional research required to advance DSTP were detailed, no priorities were set. By revisiting the reviewed information from the perspective of a qualitative assessment of the risks and benefits of DSTP and incorporating additional information from a focused literature survey, the key issues concerning DSTP today were identified. Priority work to enhance its acceptability was also suggested. In addition, the perceived and real risks of DSTP with respect to biological, chemical and physical impacts were elucidated.

Disposal, Reuse and Reprocessing Options for Treatment Sludge

Sludge management is an ever-increasing issue as the inventory of sludge continues to grow through perpetual treatment of acidic drainage and mill effluents. Current sludge management practices, in general, are ad hoc and frequently do not address long-term storage, and in some cases, long-term stability issues. CANMET-MMSL completed a review of sludge management options and practices for the MEND Program. This review examined technologies related to the storage of treatment sludge and assessed technologies available for long-term sludge management, including conventional disposal technologies, reprocessing options for metal recovery, novel sludge reuse technologies, and reclamation of sludge disposal areas.

Water Quality Criteria and Aquatic Toxicology

In 2005, CANMET-MMSL continued to utilize its aquatic toxicology facilities to conduct research related to toxicity and the establishment of water quality criteria. Site-specific water quality criteria, including the derivation of copper criteria for two mine sites, were developed. The work also

included the completion and validation of a chronic biotic ligand model (BLM) for copper to *Ceriodaphnia dubia*, validation of chemical speciation models and existing acute models, and the development of an acute nickel BLM for *Daphnia pulex* in softwater. Further work on the characterization of the acute aquatic toxicity of various inorganic substances on Canada's Domestic Substances List (DSL) was also completed. The toxicological data were developed using the sensitive aquatic invertebrate *Daphnia pulex* acclimated to ion-depleted waters. Information was delivered to Environment Canada to contribute to Categorization decisions as provided for in the *Canadian Environmental Protection Act '99*.

Hazard Identification of Metals

CANMET-MMSL continued to be a participant and the lead laboratory in an international round-robin testing program to validate the Draft Transformation/Dissolution Protocol (T/DP) for metals and sparingly soluble metal compounds within the framework of the OECD (Organization for Economic Cooperation and Development). The study comprised 128 tests yielding 3012 metal analyses for each



lab. In 2005, preliminary statistical analyses of inter-laboratory results and a draft report were completed. The report proposed that the data produced by the T/DP are reproducible, and therefore the T/DP is a reliable method for measuring the rate and extent to which metals and metal compounds release metal ions to aqueous media and meets the purpose of hazard identification.

Metals in Soils

CANMET-MMSL is in the process of advancing a research program on metals in soils. The program was initiated via an international workshop held in Ottawa to discuss both key research directions for addressing uncertainty associated with the potential impacts of metals in soils, and the development of a document aimed at delineating current research needs and policy gaps as a means of laying the groundwork for building a strong research program.

Life-Cycle Assessment (LCA)

CANMET-MMSL is Co-Chair of the Society of Environmental Toxicology and Chemistry (SETAC) North America Annual Meeting. This meeting will be held in Montréal in November 2006 and is expected to attract several thousand delegates to more than 100 platform sessions. In addition, CANMET-MMSL represents Canada on the direction committee of the UNEP/SETAC Life Cycle Initiative, and chairs the Task Force that is currently addressing the challenge of representing resource depletion in the life-cycle assessment context. Along with representatives from the aluminum, iron and steel industries and the International Council on Mining and Metals, CANMET-MMSL is developing methodologies to assess recycling within LCA. It is clear that LCA issues regarding metals need to be clarified and, to this end, CANMET-MMSL made a presentation on sustainable material management at a technical workshop of the OECD and has been invited to speak on the environmental impacts associated with trade at a workshop in Japan.



Chantale Doucet – Chantale Doucet is a ground control engineer specialized in evaluation of geomechanical aspects of mine design and backfill characterization.

Biological Systems for the Treatment of Effluent Toxicity

CANMET-MMSL has had a great deal of success in the study of biological systems for the mitigation of effluent toxicity as a result of cyanide and nitrogen species in gold mine effluents, and has played a major role in its promotion in Canada through research, presentations, publications and its discussions with industry. With initial assistance from CANMET-MMSL, one Canadian company established and is now operating a full-scale biological treatment plant. This is among the first large-scale applications of this technology in Canada and will no doubt encourage its implementation at other mine sites, which will help the sector meet its requirements for the production of non-toxic effluents as part of the new Metal Mining Effluent Regulations. Further work in this area is being discussed with equipment suppliers.

Metal Leaching (ML) and Acid Rock Drainage (ARD)

Case studies were produced for three mine sites in British Columbia. The objective was to provide information on generic requirements and practical limitations of different approaches, the effectiveness of the ML/ARD strategies that were put into place, and ongoing management implications. ML/ARD assessment and mitigation is a relatively new endeavour (last two decades) and there is little long-term operating experience with most material characterization and mitigation strategies. As a result, there is a real need to show the practical benefits and limitations of these practices based on actual data from the sites where they have been applied. The information presented included pertinent site conditions, design and performance parameters, monitoring results and outstanding challenges. This information will provide guidance to industry, regulators and the public as they assess closure strategies being considered for a particular site. The data will also help to better estimate mine-site liabilities and future environmental impacts. As part of this work, a check list of potential information requirements and factors to consider in ML/ARD assessment and mitigation was produced and is available on the MEND web site.



Technical Consultation

In addition to the review of Environmental Impact Assessments for mining projects under the CEAA process, CANMET-MMSL staff are frequently called upon to provide formal and informal technical advice or guidance on a variety of topics and to various organizations, including provincial and territorial governments.

Cape Breton Development Corporation (CBDC)

The Cape Breton Development Corporation is in the process of shutting down its operation and disposing of its assets. The CBDC has initiated a site closure program that involves all land within the CBDC property portfolio. To assist in various aspects of the program, several working groups have been formed. CANMET-MMSL is a member of the Remediation/Reclamation Working Group and provides expert advice towards its remediation/reclamation projects and/or closure plans. In 2005, activities included the provision of peer review for site-specific closure technologies and the organization of and participation in a workshop on Passive Treatment and Mine Pool Evolution, held at CBDC offices in Sydney, Nova Scotia.

The North

One of CANMET-MMSL's general objectives is to act as a technical resource for northern (territorial) governments, especially in relation to current environmental technologies for the safe development of new mines and the closure of existing mines. At the request of Indian and Northern Affairs Canada (INAC), CANMET-MMSL organized and delivered a one-day workshop in Yellowknife on the technical implications of mine waste management in the North. This workshop was very successful and provided an overview of the best practices currently in use, emerging

technologies, and an overview of the scope of resources available to INAC staff through CANMET-MMSL.

Assistance to Aboriginal Groups

CANMET-MMSL provided technical guidance to the Gitksan Hereditary Chiefs on the environmental impact assessment of mining in traditional territory for the British Columbia Environmental Assessment Office. In addition, a workshop on acidic drainage and prediction at the North American Indigenous Mining Summit was organized. Guidance was also provided to the Wet'suwet'en Hereditary Chiefs.

Special Projects and Support Services

MEND

(Mine Environment Neutral Drainage)

Canadian priority issues examined under the MEND Program in 2005 included: cold temperature studies, sludge management, guidelines on acidic drainage/metal leaching (AD/ML) assessment and mitigation, and prediction. Technology transfer activities were carried out through workshops, newsletters, reports and presentations. One of the main activities was the organization of the 12th Annual British Columbia – MEND Workshop in Vancouver on challenges in the prediction of drainage chemistry. The MEND Secretariat is also a regional partner of the Global Alliance and involved in the production of a Global ARD Guide.

NOAMI (National Orphaned/Abandoned Mines Initiative)

The legacy of orphaned/abandoned mines continues to be a serious issue facing Canada. Through NOAMI, a report entitled *Capacity Building for a National Inventory of Orphaned/Abandoned Mines in Canada* was completed that recommended the creation of a web-based, map-interfaced inventory of orphaned and abandoned mines. Natural Resources Canada was selected to host the web portal, and a working model of the database has been developed. NOAMI also initiated a jurisdictional review of legislation, regulations and policies for both orphaned/abandoned and operating mines across Canada. In addition, a workshop was held in Ottawa on the Assessment of Liabilities and Funding Options for Orphaned/Abandoned Mines; it attracted 70 multi-stakeholder delegates, including many communities of interest.

Canadian Certified Reference Materials Project (CCRMP)

The CCRMP began the development of five new reference materials. These included a gold ore-environmental material, a platinum group element-massive sulphide material, a lead concentrate, a zinc-tin-copper-lead ore, and



a nickel-copper-cobalt ore. The last four materials are replacements for previous generations of popular materials.

The Proficiency Testing Program—Mineral Analysis Laboratories (PTP-MAL) completed its eighth year of operation with approximately 50 participating laboratories from Canada, the United States, Brazil, Argentina, Australia, Chile, Guinea, Indonesia, Ireland, Morocco, Peru, South Africa, and Tanzania. PTP-MAL provides laboratories with exploration-grade samples to assess their proficiency. Successful participants earn a certificate that indicates their performance compared to other laboratories. A final report summarizes all of the results while preserving the anonymity of the participants. PTP-MAL is operated in full accordance with ISO/IEC Guide 43-1 and ILAC Guide 13:2000 to meet the needs of Canadian analytical laboratories. Participation in PTP-MAL is not obligatory, but is required in order to obtain or remain accredited to ISO/IEC 17025.

Additionally, a CCRMP group member is the Canadian representative on an ISO Committee for reference material producers. CANMET-MMSL ensured that the interests of Canadian companies were protected when revisions to Guides were prepared by this Committee.

Analytical Services Group (ASG)

The ASG developed several new methods, including: cyanide speciation in gold leachates by flow injection analysis; the determination of acrylic acid and acrylamide by ion chromatography for mine waste disposal; and major and trace anions, CNO, sulphur speciation, etc., by ion chromatography for effluents and mine wastes. Specialized methods to improve detection limits were also developed for trace analysis of metals in the environment by inductively coupled plasma–optical emission spectroscopy. Specialized analyses were also performed for major elements to assess the stability and homogeneity of reference materials.

Other Activities

Workshops and Conferences Organized

In addition to presenting technical papers at conferences, CANMET-MMSL was also actively engaged in the organization of several conferences and workshops, including:

- Canadian Mineral Processors 37th Annual Operators Conference, Ottawa, Ontario, January 2005.
- International Workshop on Metals-in-Soils: Science Gaps and Regulatory Needs, Ottawa, Ontario, February 2005.
- Northern Latitudes/Canadian Land Reclamation Association Mining Conference, Dawson City, Yukon, May 2005.
- Introduction to Metal Leaching and Acid Rock Drainage, week-long course at Northwest Community College, Smithers, B.C., June 2005.
- Best Practices for Managing Acidic Drainage workshop and Prediction workshop at the North American Indigenous Mining Summit, Edmonton, Alberta, July 2005.
- B.C. Mine Reclamation Symposium, Abbotsford, B.C., September 2005.
- Passive Treatment and Mine Water Workshop (CBDC), Sydney, Nova Scotia, October 2005.
- 11th Mining Diesel Emissions Conference (MDEC), Toronto, Ontario, October 2005.
- Workshop on Assessing Liabilities and Funding Options (via NOAMI), Ottawa, Ontario, November 2005.
- Mine Waste Management in the North – Best Practices and Emerging Technologies, Yellowknife, N.W.T., November 2005.
- MEND Metal Leaching and ARD Workshop, Vancouver, B.C., November 2005.

Lectures Organized

Throughout the year, CANMET-MMSL organized several in-house lectures by external speakers.

- *CIM – Partner for the Future*, Jean Vavrek, Executive Director, Canadian Institute of Mining, Metallurgy and Petroleum, April 2005.
- *Production and Characterization of Poly-b-Hydroxyalkanoate Copolymers from Burkholderia cepacia Utilizing Xylose and Levulinic Acid*, Dr. Jim Nakas, State University of New York, Syracuse, May 2005.
- *The Diamond Industry*, Louis Perron, Programs Branch, Minerals and Metals Sector, NRCan, June 2005.
- *Reference Materials Production at CETEM*, Maria Alice Cabral de Goes, CETEM, Brazil, October 2005.
- *The Canadian Copyright Law and You the Federal Public Servant*, Elizabeth Blackburn, Manager, Intellectual Property Management Office, NRCan, November 1, 2005.

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Oral Presentations

In addition to publishing conference papers, CANMET-MMSL staff gave oral presentations at conferences, workshops and universities, including:

Beauchemin, S. (2005). *Environmental application of synchrotron radiation: molecular-scale characterization of metal contaminants in mining wastes*. Invited speaker to UQAM/McGill GEOTOP Research Centre, Department of Earth and Planetary Sciences, McGill University, Montréal (Quebec), January 21, 2005.

Bonnell, G. and Grenier, M. (2005). *Exposure to diesel particulate matter (DPM) and regulations in Canadian mining provinces*. Presented at the Mining Diesel Emissions Conference (MDEC), October 13, Markham (Ontario), MDEC: 19 pp.

- Chen, T.T., Dutrizac, J.E. and Poirier, G. (2005). **Characterization of waelz kiln products from the recycling of EAF dust.** Presented at the Minerals, Metals and Materials Society (TMS) Annual Meeting, February 13-17, San Francisco (California), TMS: 27 pp.
- Dixon, B.M. (2005). **Zambia: Environmental management in mining (2001-2003).** Presented at the Department of Mining Engineering, University of British Columbia (UBC), November 15, Vancouver (British Columbia), UBC: 30 pp.
- Labrie, D., Conlon, B. and Poirier, G. (2005). **Capabilities and experiments in permeability testing at CANMET Mining and Mineral Sciences Laboratories.** Presented at the 4th Decovalex THM-C Workshop, October 4-6, Ottawa (Ontario), Canadian Nuclear Safety Commission (CNSC): 14 pp.
- Laflamme, M. (2005). **CANMET-MMSL Mine Mechanization and Automation Program (MMAP).** Presented at the 9th Annual Meeting of the Canadian Association of Chief Inspectors of Mines and CANMET-MMSL, April 22, Toronto (Ontario), in conjunction with the 105th Canadian Institute of Mining, Metallurgy and Petroleum (CIM) Annual General Meeting: 10 pp.
- Laflamme, M. and Bétournay, M.C. (2005). **Current development and future opportunities of the fuel cell mining initiative.** Presented at the 105th Canadian Institute of Mining, Metallurgy and Petroleum (CIM) Annual General Meeting, April 24-27, Toronto (Ontario), CIM: 20 pp.
- Lastra, R. (2005). **Image analysis applied to mineral processing and metallurgy.** Presented at the McGill University Professional Development Seminar on Mineral Processing Systems, May 20, Montréal (Quebec), McGill University: 54 pp.
- Laverdure, L. and Fecteau, J.M. (2005). **Axes of research for Canadian mines.** Presented at the Canadian Institute of Mining, Metallurgy and Petroleum (CIM) Mining Industry Conference and Exhibition, April 24-27, Toronto (Ontario), CIM: 25 pp.
- Lortie, L. and Gould, W.D. (2005). Short course on **Introduction to biological systems for the treatment of acid rock drainage and mine effluents.** Presented at the 3rd Northern Latitudes Mining Reclamation Workshop, May 24-26, Dawson City (Yukon), Canadian Land Reclamation Association (CLRA): 223 pp.
- McGeer, J., Nadella, S. and Wood, C. (2005). **The influence of acclimation to Cu or Cd on the toxicity and bioaccumulation of Cu and Cd.** Presented at the Society of Environmental Toxicology and Chemistry (SETAC) Annual Meeting, November 13-17, Baltimore (Maryland), SETAC: 15 pp.
- Mortazavi, S. (2005). **Mining and Mineral Sciences Laboratories Overview – Membrane Research.** Presented at the Canada-Russia Membrane Science and Technology Symposium, September 22-25, Gus-Khrustalny (Russia): 30 pp.
- Ouellette, S. (2005). **Chargeuse navette hybride – Aspects techniques.** Presented at the AMQ-conférence entretien, April 12, Val-d'Or (Quebec): 32 pp.
- Poirier, S. (2005). **Compilation of explosives storage and ventilation requirement regulations in Canadian provinces and territories.** Presented at the 9th Annual Meeting of the Canadian Association of Chief Inspectors of Mines and CANMET-MMSL, April 22, Toronto (Ontario), in conjunction with the 105th Canadian Institute of Mining, Metallurgy and Petroleum (CIM) Annual General Meeting: 22 pp.



Vincent Bouheret – Vincent Bouheret is part of the Informatics group at CANMET-MMSL, and is also making a valuable contribution towards automating process equipment.

Price, B. (2005). *Criteria used in material characterization and the prediction of drainage chemistry: Screaming criteria*. Presented at the 2005 BC MEND ML/ARD Workshop, November 30, Vancouver (British Columbia): 40 pp.

Price, B. (2005). *Development and use of British Columbia ML/ARD guidelines*. Presented at the International Network for Acid Prevention (INAP) meeting, December 2, Vancouver (British Columbia), INAP: 16 pp.

Price, B. (2005). *Addressing the environmental challenges with mining: Lessons learnt in British Columbia*. Presented at the Wet'suwet'en Mining Workshop, September 7-8, Smithers (British Columbia): 51 pp.

Schwartz, M., Vigneault, B., Gosselin, I., King, M., Beyak, J. and McGeer, J.C. (2005). *Understanding mine effluent toxicity: Beyond the usual suspects*. Presented at the 26th Annual Meeting of the Society of Environmental Toxicology and Chemistry (SETAC), November 13-17, Baltimore (Maryland), SETAC: 16 pp.

Skeaff, J.M. and McGeer, J.C. (2005). *Update on round robin testing of the OECD transformation/dissolution protocol for classifying the hazard of metals*. Presented at the International Copper Association (ICA) Environmental Program Advisory Committee Science Symposium, June 13, Toronto (Ontario), ICA: 36 pp.

Skeaff, J.M. and McGeer, J.C. (2005). *Preliminary results of the round robin testing of the OECD transformation/dissolution protocol (T/DP) for classifying the hazard of metals and sparingly soluble metal compounds*. Presented at the International Council on Mining and Metals (ICMM) Metals and Minerals Working Group Meeting, August 25, Prague (Czech Republic), ICMM: 43 pp.

Skeaff, J.M., Adams, W.J. and McGeer, J.C. (2005). *Update on the round robin testing of the OECD transformation/dissolution protocol for metals and sparingly soluble metal compounds*. Presented at the EU European Chemicals Bureau (ECB) Meeting on Environmental Classification and Labeling of Metals and Metal Compounds, September 27, Ispra (Italy), ECB: 41 pp.

Skeaff, J.M., McGeer, J.C. and Hardy, D.J. (2005). *Study of the draft OECD transformation/dissolution protocol for metals and sparingly soluble metal compounds*. Presented at the 26th Annual Meeting of the Society of Environmental Toxicology and Chemistry (SETAC), November 13-17, Baltimore (Maryland), SETAC: 32 pp.

Tremblay, G. (2005). *Canadian partnership programs – MEND and NOAMI*. Presented at the Chilean National Centre for Mining and Metallurgical Research (CIMM) Meeting, May 5, Santiago (Chile), CIMM: 37 pp.

Tremblay, G. (2005). *Canadian initiative on acid mine drainage (MEND) and abandoned mines (NOAMI)*. Presented at the 2nd Workshop of the The Mining Association of Canada (MAC) on Tailings Management and Lessons Learned, June 7-8, Toronto (Ontario), MAC: 39 pp.

Tremblay, G. (2005). *Canadian collaboration on environmental issues in the mining sector*. Presented at the North American Indigenous Peoples Mining Summit, July 27-30, Edmonton (Alberta), MiningWatch Canada: 83 pp.

Udd, J.E. (2005). *A pilot study of mining accidents in Ontario*. Presented at the 9th Annual Meeting of the Canadian Association of Chief Inspectors of Mines and CANMET-MMSL, April 22, Toronto (Ontario), in conjunction with the 105th Canadian Institute of Mining, Metallurgy and Petroleum (CIM) Annual General Meeting: 20 pp.

Vance, J. (2005). *Metallurgical processing alternatives*. Presented at the Mines Ministers' Conference NRCan Workshop: Solutions for Maintaining the Viability of Base-Metal Mining Communities, September 18, St. Andrews (New Brunswick): 13 pp.

Vance, J. (2005). *Environmental sustainability of mining communities*. Presented at the Mines Ministers' Conference NRCan Workshop: Solutions for Maintaining the Viability of Base-Metal Mining Communities, September 18, St. Andrews (New Brunswick): 14 pp.

Vigneault, B. (2005). Short course on *Acute and sublethal toxicity testing for mining effluents*. Presented at the 29th Annual British Columbia Mine Reclamation Symposium, September 19, Abbotsford (British Columbia): 128 pp.

Community Involvement

CANMET-MMSL staff are often called upon to take part in community-related activities. This may take the form of presentations to local school children on various aspects of the mining cycle, or it may be through participation in more formal events such as National Mining Week and the Science FunFest.

National Mining Week

National Mining Week was held from May 9 to 15, 2005. This year's theme was an important one for all to recognize - Mining and Aboriginal Communities: Working in Partnership. CANMET-MMSL participated in activities to celebrate the strong link between mining and the well-being of Aboriginal communities in Canada's remote and rural areas. For CANMET-MMSL, National Mining Week 2005 began on a high note with the re-opening of its newly refurbished experimental mill area in Ottawa. In conjunction with the mill opening, representatives from Aboriginal communities and industry associations were



provided with a tour of the CANMET-MMSL facilities. In addition, Hans Matthews, President of the Canadian Aboriginal Minerals Association, and Chief Charlie Okeese of the Eabametoong First Nation at the Fort Hope Indian Reserve in Eabamet Lake, Ontario, were invited to express their views on Aboriginal involvement with Canada's mining industries.

CANMET-MMSL staff also visited local classrooms to discuss mining and mineral sciences. The key themes addressed in the classroom presentations included: the importance of metals to our everyday lives, the mining industry's commitment to protecting the environment, and careers in mining, science and engineering.

Science FunFest

The Science Funfest is a fun and educational kickoff to National Science and Technology week, held from October 14 to 23, 2005. During this week, the Government of Canada participated in activities that demonstrate its leadership in science and technology, and inspire kids to pursue education in science, technology, engineering and mathematics. Many CANMET-MMSL staff eagerly volunteered their time to this cause, which featured a variety of interactive displays and activities such as panning for gold, chocolate chip cookie mining, treatment of mine water, mine rehabilitation, and environmental monitoring equipment. The event was very successful, attracting more than 3000 people, and provided an excellent opportunity to interact with the public, improve the image of mining, and to supply posters and other suitable materials for teachers and the general public.

Publications

Refereed Journal Publications

- Beauchemin, S. and Kwong, J. (2005). *Transformation of As species in wetlands historically used for mine tailings disposal, Ontario, Canada*. Goldschmidt Conference Abstracts 2005, *Geochimica et Cosmochimica Acta*, 69 (10), Supplement 1: A618.
- Bétournay, M.C., Bonnell, G., Edwardson, E. and Lidkea, W. (2005). *Suitability of PEM fuel cells for underground mining vehicles*. The Canadian Institute of Mining, Metallurgy and Petroleum (CIM) Bulletin, 98 (1085): 81 (extended abstract), full article on CIM web site.
- Bétournay, M.C., Laliberté, P., Lacroix, R., Kocsis, C., Hardcastle, S., Desrivières, G., Mousset-Jones, P. and Righettini, G. (2005). *Fuel cell versus diesel loader operation: Cost-benefit analysis study*. The Canadian Institute of Mining, Metallurgy and Petroleum (CIM) Bulletin, 98 (1087): 75 (extended abstract), full article on CIM web site.
- Bilodeau, M., Negeri, T., Orumwense, A. and Cotnoir, D. (2005). *Improved material balance methodology for fine particles*. *Minerals and Metallurgical Processing*, 22 (3): 153-160.
- Cabri, L.J., McDonald, A.M., Stanley, C.J., Rudashevsky, N.S., Poirier, G., Durham, B.R., Mungall, J.E. and Rudashevsky, V.N. (2005). *Naldrettite, Pd₂Sb, a new inter-metallic mineral from the Mesamax Northwest deposit, Ungava region, Quebec, Canada*. *Mineralogical Magazine*, 69 (1): 89-98.
- Chen, T.T. and Dutrizac, J.E. (2005). *Mineralogical characterization of a copper anode and the anode slimes from the La Caridad copper refinery of Mexicana de Cobre*. *Metallurgical and Materials Transactions B*, 36B (2): 229-240.
- Delabbio, F.C., Eastick, D., Graves, C., Sprott, D., MacKinnon, T. and Bétournay, M.C. (2005). *Fuel cell risk assessment, regulatory compliance and implementation of the world's first fuel cell powered mining equipment at the Campbell mine*. The Canadian Institute of Mining, Metallurgy and Petroleum (CIM) Bulletin, 98 (1087): 76 (extended abstract), full article on CIM web site.
- Deschênes, G. (2005). *Advances in the cyanidation of gold*. *Advances in Gold Ore Processing, Developments in Mineral Processing Series, Volume 15*, M. Adams, editor, Elsevier, Amsterdam (Netherlands): 479-499.
- Deschênes, G., McMullen, J., Ellis, S., Fulton, M. and Atkin, A. (2005). *Investigation on the cyanide leaching optimization for the treatment of KCGM flotation concentrate, Phase I*. *Minerals Engineering*, 18 (8): 832-838.
- Dutrizac, J.E. and Chen, T.T. (2005). *Factors affecting the precipitation of chromium(III) in jarosite-type compounds*. *Metallurgical and Materials Transactions B*, 36B (1): 33-42.
- Dutrizac, J.E., Chen, T.T. and Beauchemin, S. (2005). *The behaviour of thallium(III) during jarosite precipitation*. *Hydrometallurgy*, 79 (3-4): 138-153.
- Gagnon, R., Levasseur, M., Weise, A.M., Fauchot, J., Campbell, P.G.C., Weissenboeck, B., Merzouk, A., Gosselin, M. and Vigneault, B. (2005). *Growth stimulation of Alexandrium tamarense (Dinophyceae) by humic substances from the Manicouagan River, eastern Canada*. *Journal of Phycology*, 41 (3): 489-497.
- Guo, H., Deschênes, G., Pratt, A.R. and Lastra, R. (2005). *Leaching kinetics and mechanisms of surface reactions during cyanidation of gold in the presence of pyrite or stibnite*. *Minerals and Metallurgical Processing*, 22 (2): 89-95.

Harmer, S.L., Pratt, A.R., Nesbitt, H.W. and Fleet, M.E. (2005). *Reconstruction of fracture surfaces on bornite*. The Canadian Mineralogist, 43 (5): 1619-1630.

Jolliet, O., Dubreuil, A., Gloria, T. and Hauschild, M. (2005). *Progresses in life cycle impact assessment within the UNEP/SETAC life cycle initiative*. International Journal of Life Cycle Assessment, 10 (6): 447-448.

May, O., Jin, S., Ghali, E. and Deschênes, G. (2005). *Effects of sulfide and lead nitrate addition to a gold cyanidation circuit using potentiodynamic measurement*. Journal of Applied Electrochemistry, 35 (2): 131-137.

Paktunc, D. and Martin, R.F. (2005). *Metals in the environment and mine wastes*. The Canadian Mineralogist, 43 (4): 1129-1130.

Udd, J.E. (2005). *Arctic mining technology*. McGraw-Hill 2005 Yearbook of Science and Technology, McGraw-Hill, New York (New York): 17-19.

Udd, J.E. and Long, E. (2005). *Standard terminology relating to frozen soil and rock*. Annual Book of ASTM Standards, Section 4: Construction, Volume 04.09, Designation D 7099-04, ASTM International, West Conshohocken (Pennsylvania): 1506-1518.

Vigneault, B. and Campbell, P.G.C. (2005). *Uptake of cadmium by freshwater green algae: Effects of pH and adsorbed aquatic humic substances*. Journal of Phycology, 41 (1): 55-61.

Conference and Workshop Proceedings

Aubé, B., Clyburn, B. and Zinck, J. (2005). *Sludge disposal in mine workings at Cape Breton Development Corporation*. Proceedings of the International Conference on Mining and the Environment and Metals and Energy Recovery, June 27-July 1, Skellefteå (Sweden), Swedish Mineral Industry Research Organization (MITU), T. From, editor: 37-46.

Baiden, G., Bissiri, Y., Hardcastle, S.G. and Kocsis, C. (2005). *Justification of "on-demand" ventilation systems by means of simulation techniques*. Proceedings of the 32nd International Symposium on the Application of Computers and Operations Research in the Mineral Industry (APCOM), March 30-April 1, Tucson (Arizona), A.A. Balkema Publishers, S.D. Dessureault, R. Ganguli, V.J. Kecojevic and J.G. Dwyer, editors: 457-462.

Bétournay, M.C. (2005). *Failure mechanisms, stability aspects and analysis techniques for abandoned Canadian metal mines*. Proceedings of the Post-Mining 2005 Symposium, November 16-18, Nancy (France), Groupe de recherche sur l'impact et la sécurité des ouvrages souterrains (GISOS): 14 pp.

Bétournay, M.C. (2005). *Risk evaluation and related stability considerations for abandoned Canadian metal mines*. Proceedings of the Post-Mining 2005 Symposium, November 16-18, Nancy (France), Groupe de recherche sur l'impact et la sécurité des ouvrages souterrains (GISOS): 12 pp.

- Campbell, P.G.C., Fortin, C., Boulemant, A. and Vigneault, B. (2005). *Advances in our understanding of the role of speciation in trace elements uptake and toxicity*. Proceedings of the 8th International Conference on the Biogeochemistry of Trace Elements (ICOBTE), April 3-7, Adelaide (Australia), CSIRO Land and Water, E. Lombi, S. Tyrrell, A. Nolan, M. McLaughlin, G. Pierzynski, M. Gerzabek, N. Lepp, C. Leyval, M. Selim, F. Zhao, C. Grant and D. Parker, editors: 24-25.
- Chen, T.T., Dutrizac, J. E. and Beauchemin, S. (2005). *Characterization of gold in the anodes and anode slimes from a European copper refinery*. Proceedings of the European Metallurgical Conference (EMC), September 18-21, Dresden (Germany), GDMB Medienverlag, U. Waschki, editor: 165-182.
- Chen, T.T., Dutrizac, J.E. and Poirier, G. (2005). *Water and sodium carbonate leaching of EAF dust and Waelz oxide*. Proceedings of the International Symposium on Lead and Zinc Processing, October 17-19, Tokyo (Japan), The Mining and Materials Processing Institute of Japan (MMIJ), T. Fujisawa, J.E. Dutrizac, A. Fuwa, N.L. Piret and A.H.J. Siegmund, editors: 961-975.
- Côté, M. and Priscu, D.M. (2005). *Application of seismic hazard assessment to narrow-vein deposits*. Proceedings of the 6th International Symposium on Rockburst and Seismicity in Mines, March 9-11, Perth (Western Australia), Australian Centre for Geomechanics (ACG), Y. Potvin and M. Hudyma, editors: 205-209.
- Davé, N.K. and Lanteigne, L. (2005). *Surface reactivity of low sulphur Ni-Cu mine tailings under shallow water cover conditions*. Proceedings of the International Conference on Mining and the Environment and Metals and Energy Recovery, June 27-July 1, Skellefteå (Sweden), Swedish Mineral Industry Research Organization (MITU), T. From, editor: 201-212.
- Davé, N.K. (2005). *Decommissioning of low-grade uranium mines in Canada: Current status and long-term radium mobility*. Proceedings of the 4th National Conference on Waste Management, Decommissioning and Environmental Restoration for Canada's Nuclear Activities, May 8-11, Ottawa (Ontario), Canadian Nuclear Society (CNS), M. Garamszeghy and F. King, editors: 21 pp.
- Deschênes, G. (2005). *Technological developments in the cyanidation of gold*. Proceedings of the 37th Annual Operators Conference of the Canadian Mineral Processors (CMP), January 18-20, Ottawa (Canada), CMP, J. Starkey, editor, paper 5: 57-74.
- Deschênes, G. and Guo, H. (2005). *Cyanidation of gold*. Short course on gold extraction, in conjunction with the International Symposium on the Treatment of Gold Ores, August 21-24, Calgary (Alberta), The Canadian Institute of Mining, Metallurgy and Petroleum (CIM), G. Deschênes, editor: 51 pp.
- Deschênes, G., Ellis, S., McMullen, J. and Habner, M. (2005). *Implementation of a new leaching approach for the treatment of KCGM gold flotation concentrate*. Proceedings of the First Extractive Metallurgy Operator's Conference, November 7-8, Brisbane (Australia), Australasian Institute of Mining and Metallurgy Publication Series No. 9/2005, 35-39.
- Deschênes, G., Mulpeter, T., Guo, H. and Fulton, M. (2005). *Study of the kinetics of leaching gold from a soft sulphide ore from the Sadiola mine*. Proceedings of the International Symposium on the Treatment of Gold Ores, August 21-24, Calgary (Alberta), The Canadian Institute of Mining, Metallurgy and Petroleum (CIM), G. Deschênes, D. Hodouin and L. Lorenzen, editors: 339-352.

- Deschênes, G., Pratt, A.R., Fulton, M. and Guo, H. (2005). *Kinetics and mechanisms of leaching synthetic calaverite in cyanide solutions*. Preprints of the 2005 Society for Mining, Metallurgy and Exploration (SME) Annual Meeting, February 28-March 2, Salt Lake City (Utah), SME, T. Arnold, T. Rohrbacher, E. Bingham, G. Tomaino, R. Gertsch and P. Taylor, editors, paper 05-047: 6 pp.
- Desrivières, G., Bétournay, M.C., Velev, O. and Barnes, D. (2005). *The development of hydrogen mine vehicle power plant functions controllers*. Proceedings of the 32nd International Symposium on the Application of Computers and Operations Research in the Mineral Industry (APCOM), March 30-April 1, Tucson (Arizona), A.A. Balkema Publishers, S.D. Dessureault, R. Ganguli, V.J. Keckojevic and J.G. Dwyer, editors: 595-601.
- Durrheim, R.J. and Labrie, D. (2005). *Data-driven simulation of the rock mass response to mining, Part 2: Numerical modelling of the room-and-pillar experiment*. Proceedings of the 6th International Symposium on Rockburst and Seismicity in Mines, March 9-11, Perth (Western Australia), Australian Centre for Geomechanics (ACG), Y. Potvin and M. Hudyma, editors: 301-310.
- Dutrizac, J.E. (2005). *The kinetics of sphalerite dissolution in ferric sulphate-sulphuric acid media*. Proceedings of the International Symposium on Lead and Zinc Processing, October 17-19, Tokyo (Japan), The Mining and Materials Processing Institute of Japan (MMIJ), T. Fujisawa, J.E. Dutrizac, A. Fuwa, N.L. Piret and A.H.J. Siegmund, editors: 833-851.
- Hardcastle, S.G., Kocsis, C., Bissiri, Y. and Baiden, G. (2005). *Optimizing mine ventilation through the use of life-cycle production models*. Proceedings of the 8th International Mine Ventilation Congress, July 6-8, Brisbane (Australia), The Australasian Institute of Mining and Metallurgy (AUSIMM), A.D.S. Gillies, editor: 373-381.
- Huminicki, M.A.E., Sylvester, P.J., Evans-Lamswood, D., Lastra, R., Cabri, L.J. and Wilsoton, D.H.C. (2005). *First report of platinum-group minerals and in situ platinum group element analyses in sulphide phases from an amphibolite dyke in the vicinity of the SE extension of the Voisey's Bay Ni-Cu-Co deposit, Labrador*. Proceedings of the 10th International Platinum Symposium, August 7-11, Oulu (Finland), University of Oulu, A. Kärki and T. Törmänen, editor(s): 4 pp.
- Judge, K. and Bétournay, M.C. (2005). *Remote geomechanical instrumentation system development and experience*. Proceedings of the 32nd International Symposium on the Application of Computers and Operations Research in the Mineral Industry (APCOM), March 30-April 1, Tucson (Arizona), A.A. Balkema Publishers, S.D. Dessureault, R. Ganguli, V.J. Keckojevic and J.G. Dwyer, editors: 603-609.
- Kapoor, A., Bédard, P., Morin, L., Kuiper, A., Mortazavi, S. and Gould, W.D. (2005). *Use of a rotating biological contactor for the removal of nitrogenous compounds from gold mill effluents*. Proceedings of the International Symposium on the Treatment of Gold Ores, August 21-24, Calgary (Alberta), The Canadian Institute of Mining, Metallurgy and Petroleum (CIM), G. Deschênes, D. Hodouin and L. Lorenzen, editors: 485-496.
- Kawaja, J.D.E., Morin, K. and Gould, W.D. (2005). *A duplicate column study of arsenic, cadmium and zinc treatment in an anaerobic bioreactor on a system operated at Teck-Cominco in Trail, British Columbia*. Proceedings of the 29th Annual British Columbia Mine Reclamation Symposium, September 19-22, Abbotsford (British Columbia), BiTech Publishers, W.A. Price, B. Hart, B. Dixon, P. Jarman, B. Riordan, M. Freberg and C. Howell, editors: 11 pp.

- Kwong, Y.T.J. and Zinck, J. (2005): *Proven technology: A bliss or curse for mine reclamation in the North?* Proceedings of the 3rd Northern Latitudes Mining Reclamation Workshop, May 24-26, Dawson City (Yukon), Canadian Land Reclamation Association (CLRA), S. Marken, editor: 10 pp.
- Lastra, R. (2005). *Mineralogy of gold ores*. Short course on gold extraction, in conjunction with the International Symposium on the Treatment of Gold Ores, August 21-24, Calgary (Alberta), The Canadian Institute of Mining, Metallurgy and Petroleum (CIM), G. Deschênes, editor: 32 pp.
- Lastra, R., Price, J., Cabri, L.J., Rudashevsky, N.S., Rudashevsky, V.N. and McMahon, G. (2005). *Gold characterization of a sample from Malartic East (Quebec) using a concentration by hydroseparation*. Proceedings of the International Symposium on the Treatment of Gold Ores, August 21-24, Calgary (Alberta), The Canadian Institute of Mining, Metallurgy and Petroleum (CIM), G. Deschênes, D. Hodouin and L. Lorenzen, editors: 17-29.
- Li, G. (2005). *Calibration of the three-dimensional block-spring model (BSM) for analyzing large displacements in jointed rocks*. Proceedings of the 40th U.S. Rock Mechanics Symposium, June 25-29, Anchorage (Alaska), American Rock Mechanics Association (ARMA), G. Chen, S. Huang, W. Zhou and J. Tinucci, editors, paper 05-808: 7 pp.
- Li, G., Vongpaisal, S., Pakalnis, R. and Brady, T. (2005). *Influence of the intermediate principal stress on rock mass stability*. Proceedings of the 14th International Symposium on Mine Planning and Equipment Selection (MPES) and the 5th International Conference on Computer Applications in the Mineral Industries (CAMI), October 31-November 3, Banff (Alberta), The Reading Matrix (Publisher), R. Singhal, K. Fytas and C. Chiwetelu, editors: 700-720.
- Mitri, H.S., Rispoli, A. and Bétournay, M.C. (2005). *Strength and behaviour of biaxially loaded Indiana limestone rock*. Proceedings of the 40th U.S. Rock Mechanics Symposium, June 25-29, Anchorage (Alaska), American Rock Mechanics Association (ARMA), G. Chen, S. Huang, W. Zhou and J. Tinucci, editors, paper 05-796: 7 pp.
- Mitri, H.S. and Bétournay, M.C. (2005). *Progressive failure of norite rock under biaxial loading conditions*. Proceedings of the 105th Canadian Institute of Mining, Metallurgy and Petroleum (CIM) Annual General Meeting, April 24-27, Toronto (Ontario), CIM: 7 pp.
- Orumwense, A.O. (2005). *The effect of media type on regrinding with stirred ball mills*. Preprints of the 2005 Society for Mining, Metallurgy and Exploration (SME) Annual Meeting, February 28-March 2, Salt Lake City (Utah), SME, T. Arnold, T. Rohrbacher, E. Bingham, G. Tomaino, R. Gertsch and P. Taylor, editors, paper 05-006: 6 pp.
- Paques, J.J., Bourbonnière, R., Germain, L., Laflamme, M. and Bétournay, M.C. (2005). *Guide on the safety of computer-controlled mining hoists*. Proceedings of the 32nd International Symposium on the Application of Computers and Operations Research in the Mineral Industry (APCOM), March 30-April 1, Tucson (Arizona), A.A. Balkema Publishers, S.D. Dessureault, R. Ganguli, V.J. Kecejevic and J.G. Dwyer, editors: 435-438.
- Rubeli, B., Young, D. and Gangal, M. (2005). *Measuring the effects of simulated engine faults on the emissions of mechanically and electronically controlled diesel engines*. Proceedings of the Fall Technical Conference of the American Society of Mechanical Engineers (ASME) Internal Combustion Engine Division, September 11-14, Ottawa (Ontario), ASME, K.S. Chapman, editor, paper ICEF2005-1234: 7 pp.

- Talebi, S. (2005). *Ground motion and scaling laws of mine-induced seismicity*. Proceedings of the 6th International Symposium on Rockburst and Seismicity in Mines, March 9-11, Perth (Western Australia), Australian Centre for Geomechanics (ACG), Y. Potvin and M. Hudyma, editors: 541-546.
- Talebi, S. and Côté, M. (2005). *Implosional focal mechanisms in a hard-rock mine*. Proceedings of the 6th International Symposium on Rockburst and Seismicity in Mines, March 9-11, Perth (Western Australia), Australian Centre for Geomechanics (ACG), Y. Potvin and M. Hudyma, editors: 113-121.
- Tremblay, G. (2005). *Abandoned mines in Canada – Response to the problem*. Proceedings of the 2nd International Conference for Post-Mining Legacies, May 3-4, Santiago (Chile), Comision Economica de las Naciones Unidas para America Latina y el Caribe (CEPAL): 13 pp.
- Tremblay, G. and Hogan, C.M. (2005). *Canadian initiatives on acid mine drainage (MEND/NEDEM) and abandoned mines (NOAMI/INMOA)*. Proceedings of the Symposium on Environment and Mines, May 15-18, Rouyn-Noranda (Quebec), The Canadian Institute of Mining, Metallurgy and Petroleum (CIM).
- Udd, J.E. (2005). *A Canadian and ISMA bibliography on arctic mining technology*. Proceedings of the 8th International Symposium on Mining in the Arctic, June 20-23, Apatity (Russia), The Mining Institute of the Kola Centre of the Russian Academy of Sciences, N.N. Melnikov and S.P. Reshetnyak, editors: xvii-xli.
- Udd, J.E. and Plouffe, M. (2005). *Le contrôle de terrain à Ressources naturelles Canada*. Comptes rendus du 20^e Colloque en contrôle de terrain de l'Association minière du Québec (AMQ), March 22-24, Val-d'Or (Quebec), AMQ, P. Thibault, editor: 25 pp.
- Vigneault, B., Gagnon, C. and Turcotte, P. (2005). *Modeling the fate and the geochemistry of Cd, Cu and Zn from effluent discharges in receiving waters*. Proceedings of the 8th International Conference on the Biogeochemistry of Trace Elements (ICOBTE), April 3-7, Adelaide (Australia), CSIRO Land and Water, E. Lombi, S. Tyrrell, A. Nolan, M. McLaughlin, G. Pierzynski, M. Gerzabek, N. Lepp, C. Leyval, M. Selim, F. Zhao, C. Grant and D. Parker, editors: 594-595.
- Vigneault, B., McGeer, J.C. and Schwartz, M. (2005). *Utilisation et développement du modèle du ligand biotique pour des initiatives réglementaires reliées aux impacts potentiels des métaux dans l'environnement aquatique*. Comptes rendus du Symposium sur l'environnement et les mines, May 15-18, Rouyn-Noranda (Quebec), The Canadian Institute of Mining, Metallurgy and Petroleum (CIM).
- Zinck, J. and Griffith, W. (2005). *Cost effective lime neutralization and other options for mine water treatment*. Proceedings of the 3rd Northern Latitudes Mining Reclamation Workshop, May 24-26, Dawson City (Yukon), Canadian Land Reclamation Association (CLRA), S. Marken, editor: 13 pp.

Other Publications

- Beaudoin, R.J. and Bilodeau, M. (2005). *Évaluation de l'impact du dynamitage avec initiation électronique sur les opérations d'une carrière*. Comptes rendus de la 28^e Session d'étude sur les techniques de sautage, November 3-4, Québec (Quebec), Société d'énergie explosive du Québec (SEEQ), P. Dorval, editor: 45 pp.
- Bonnell, G. (2005). *Exposure to diesel particulate matter (DPM) and regulations in Canadian mining provinces*. Proceedings of the 11th Mining Diesel Emissions Conference (MDEC), October 12-14, Toronto (Ontario), MDEC, M. Gangal and D. Young, editors: 19 pp.

Davé, N. (2005). *Tailings and waste rock management in northern Canada*. Proceedings of the Workshop on Mine Waste Management in the North – Best Practices and Emerging Technologies, Yellowknife, N.W.T., November 2005, CANMET-MMSL: 73 pp.

Deschênes, G., Hodouin, D. and Lorenzen, L., editors (2005). *Treatment of gold ores*. Proceedings of the International Symposium on the Treatment of Gold Ores, August 21-24, Calgary (Alberta), The Canadian Institute of Mining, Metallurgy and Petroleum (CIM), Montréal (Quebec): 516 pp.

Dubreuil, A., editor (2005). *Life-cycle assessment of metals: Issues and research directions*. Proceedings of the International Workshop on Life Cycle Assessment and Metals, April 15-17, 2002, Montréal (Quebec), Society of Environmental Toxicology and Chemistry (SETAC), Pensacola (Florida): 307 pp.

Fujisawa, T., Dutrizac, J.E., Fuwa, A., Piret, N.L. and Siegmund, A.H.J., editors (2005). *Lead and Zinc 2005*. Proceedings of the International Symposium on Lead and Zinc Processing, October 17-19, Tokyo (Japan), The Mining and Materials Processing Institute of Japan (MMIJ), Tokyo (Japan): 1489 pp.

Gangal, M. and Young, D., editors (2005). *Proceedings of the 11th Mining Diesel Emissions Conference (MDEC)*. October 12-14, Toronto (Ontario), MDEC, Ottawa (Ontario): unpagged.

Gangal, M., Rubeli, B., Young, D. and Stachulak, J. (2005). *Laboratory evaluation of diesel particulate filters – INCO/DEEP filter project*. Proceedings of the 11th Mining Diesel Emissions Conference (MDEC), October 12-14, Toronto (Ontario), MDEC, M. Gangal and D. Young, editors: 24 pp.

Giziewicz, E., editor (2005). *R-NET Recycling Technology Newsletter*, 8 (2), Natural Resources Canada, Ottawa (Ontario): 12 pp.

Giziewicz, E., editor (2005). *R-NET Recycling Technology Newsletter*, 9 (1), Natural Resources Canada, Ottawa (Ontario): 12 pp.

Gould, W.D. (2005). *Biological approaches to mine waste management in the North*. Proceedings of the Workshop on Mine Waste Management in the North – Best Practices and Emerging Technologies, Yellowknife, N.W.T., November 2005, CANMET-MMSL: 72 pp.

Jambor, J.L., Dutrizac, J.E. and Raudsepp, M. (2005). *Neutralization potentials of some common and uncommon rocks, and some pitfalls in NP measurements*. Proceedings of the 12th British Columbia MEND Metal Leaching and Acid Rock Drainage (ML/ARD) Workshop, November 30-December 1, Vancouver (British Columbia), B.C. Ministry of Energy, Mines and Petroleum Resources, W.A. Price and K. Bellefontaine, editors: 26 pp.

Kwong, J. (2005). *Managing mine wastes in the North - An overview*. Proceedings of the Workshop on Mine Waste Management in the North – Best Practices and Emerging Technologies, Yellowknife, N.W.T., November 2005, CANMET-MMSL: 39 pp.

McGeer, J.C., Skeaff, J.M., Wood, C.M., McDonald, D.G. and Dubreuil, A.A. (2005). *Environmental toxicity and impact assessment models for metals*. Proceedings of the International Workshop on Life Cycle Assessment and Metals, April 15-17, 2002, Montréal (Quebec), Society of Environmental Toxicology and Chemistry (SETAC), A. Dubreuil, editor: 241-247.

Price, W.A. (2005). *Addressing the challenges of major mine reclamation in British Columbia*. Proceedings of the Mine Reclamation and Closure Workshop, February 1-3, Yellowknife (N.W.T.), Independent Environmental Monitoring Agency (IEMA): 74 pp.

Price, W.A. (2005). *Criteria used in material characterization and the prediction of drainage chemistry: Screaming criteria*. Proceedings of the 12th British Columbia MEND Metal Leaching and Acid Rock Drainage (ML/ARD) Workshop, November 30-December 1, Vancouver (British Columbia), B.C. Ministry of Energy, Mines and Petroleum Resources, W.A. Price and K. Bellefontaine, editors: 40 pp.

Price, W.A. (2005). *Neighbouring mine sites: Environmental lessons learnt in British Columbia*. Proceedings of the Wet'suwet'en Mining Workshop, September 7-8, Smithers (British Columbia), B.C. Ministry of Environment: 10 pp.

Price, W.A. and Bellefontaine, K., editors (2005). *Challenges in the prediction of drainage chemistry*. Proceedings of the 12th British Columbia MEND Metal Leaching and Acid Rock Drainage (ML/ARD) Workshop, November 30-December 1, Vancouver (British Columbia), B.C. Ministry of Energy, Mines and Petroleum Resources, Victoria (British Columbia): unpagged.

Price, W.A., Hart, B., Dixon, B., Jarman, P., Riordan, B., Freberg, M., and Howell, C., editors (2005). *The many facets of mine reclamation*. Proceedings of the 29th British Columbia Mine Reclamation Symposium, September 19-22, Abbotsford (British Columbia), BiTech Publishers, Richmond (British Columbia): unpagged.

Skeaff, J.M., McGeer, J.C., King, P., King, M. and Nadeau, J.C. (2005). *On the aquatic hazard classification of metals and alloys*. Proceedings of the International Workshop on Life Cycle Assessment and Metals, April 15-17, 2002, Montréal (Quebec), Society of Environmental Toxicology and Chemistry (SETAC), A. Dubreuil, editor: 230-239.

Thompson, A., Price, W.A., Dunne, K. and Jambor, J.L. (2005). *Guidelines for the determination of mineralogy and mineralogical properties*. Proceedings of the 12th British Columbia MEND Metal Leaching and Acid Rock Drainage Workshop, November 30-December 1, Vancouver (British Columbia), B.C. Ministry of Energy, Mines and Petroleum Resources, W.A. Price and K. Bellefontaine, editors: 39 pp.

Tisch, B. (2005). *Mine reclamation: An overview of principles and practices and implications for the North*. Proceedings of the Workshop on Mine Waste Management in the North – Best Practices and Emerging Technologies, Yellowknife, N.W.T., November 2005, CANMET-MMSL: 54 pp.

Tremblay, G. (2005). *An update of the MEND and NOAMI programs*. Proceedings of the 12th British Columbia MEND Metal Leaching and Acid Rock Drainage (ML/ARD) Workshop, November 30-December 1, Vancouver (British Columbia), B.C. Ministry of Energy, Mines and Petroleum Resources, W.A. Price and K. Bellefontaine, editors: 25 pp.

Zinck, J. (2005). *Mine water treatment options for the North*. Proceedings of the Workshop on Mine Waste Management in the North – Best Practices and Emerging Technologies, Yellowknife, N.W.T., November 2005, CANMET-MMSL: 75 pp.