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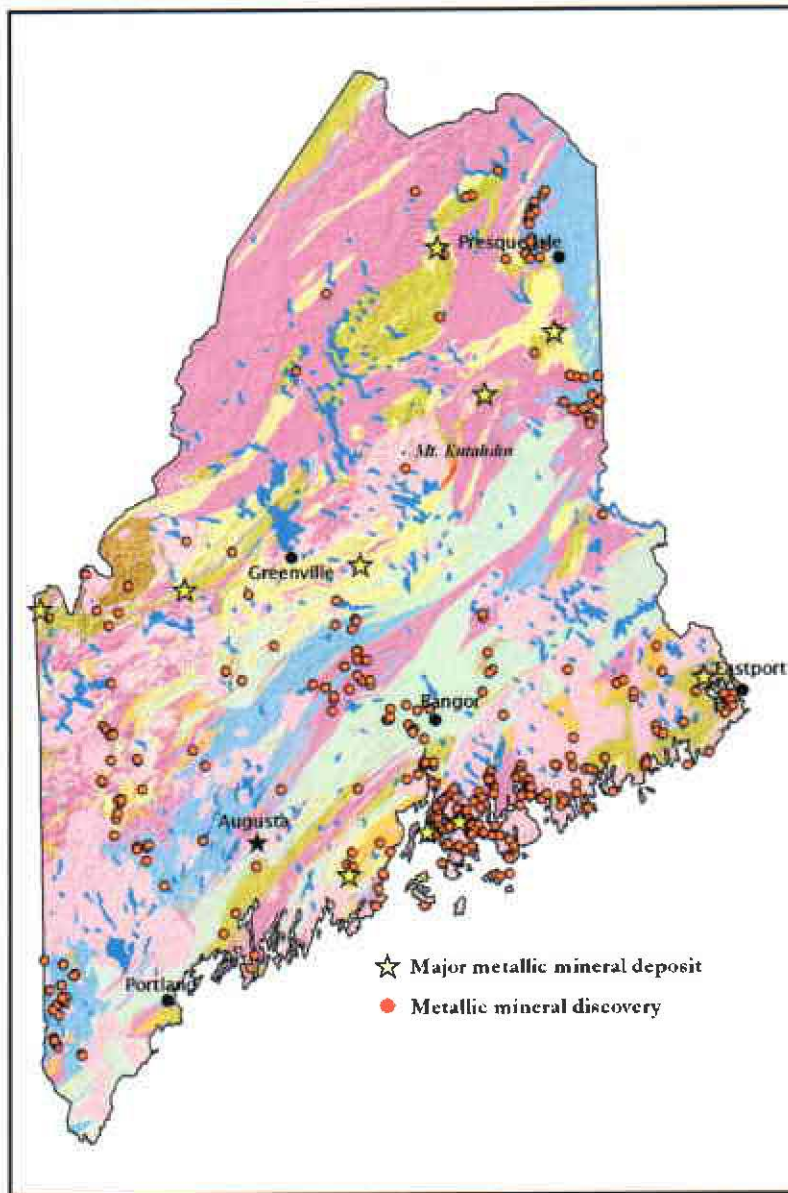
Geological Survey

11-9-2012

Maine Metallic Minerals Conference Abstracts

Geological Society of Maine

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MAINE METALLIC MINERALS CONFERENCE

November 9, 2012

Hosted by the
Geological Society of Maine
in cooperation with

University of Maine, School of Earth and Climate Sciences
Maine Geological Survey

Welcome from the President of GSM

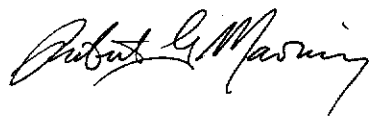
Welcome to the Geological Society of Maine's annual fall meeting! This year, we have teamed with the School of Earth and Climate Sciences at the University of Maine and the Maine Geological Society to provide a day long, educational program focused on metallic minerals geology, exploration, and development. For members, this is an opportunity to see colleagues and friends, as well as enjoy the program. For non-member registrants, I hope you find the presentations interesting and useful. If you have an interest in Maine geology, please consider becoming a member of our organization.



Welcome from the Maine State Geologist

It is my privilege to welcome you to this special conference on metallic minerals in Maine. The strong response from participants and sponsors has supported our belief that such a conference was needed. Whether you are a local landowner who would like to know more about geology, or a visiting geologist who would like to know more about the Maine landscape, I hope you find today's program useful and informative.

There are many reasons, both local and global, for the current upsurge in interest in Maine mineral resources, including economic forces and increasing demand for natural resources. As the State agency responsible for providing geologic information to the public, the Maine Geological Survey is pleased to cosponsor this program. I am especially grateful for the group of experienced and knowledgeable professionals who have agreed to speak today, on a broad array of complex topics. I hope this information will provide a foundation for future discussions on this important issue for the people of Maine. Please don't hesitate to contact me or visit our extensive web site for more information about Maine geology. Enjoy the conference!



Purpose of the Conference

Over the past year there has been much public discussion about Maine's mineral resources. Several participants in that discussion saw a general need for factual information about Maine's geology and modern techniques of mineral extraction, and proposed this conference in response. Although Maine has long-active industries in the quarrying and mining of sand and gravel, crushed rock, dimension stone, limestone, and gemstones, there has been a hiatus in metallic mineral production since the 1970's. As a consequence, many people making decisions about natural resources in the State have little experience with mineral potential, exploration, ownership rights, or modern mining techniques. Each of these key topics will be addressed during the day. Above all, we hope to bring together land owners, resource managers, exploration geologists, and others interested in talking to each other about concerns and opportunities presented by Maine's mineral resources.

The Geological Society of Maine is a non-profit organization dedicated to geological issues and education in Maine. The Society's membership includes teachers, students, working geologists, aspiring geologists, retired geologists and other interested persons. We seek to: 1) To further the public awareness and understanding of Maine's geology and of modern geologic processes that affect Maine's landscape and residents; 2) To develop and encourage continuing social contact and dialogue among geologists working in Maine; 3) To advance the professional improvement of its members; 4) To inform members and other interested persons of current and planned geologic programs in Maine.

MAINE METALLIC MINERALS CONFERENCE
November 9, 2012
Black Bear Inn
Orono, Maine

Program

8:00 Registration/refreshments

9:00 Welcoming Remarks – **Cliff Lippitt, S.W. Cole**

I. Background, mineral rights

9:10 1) Maine's Geology and Mineral Potential – **Robert Marvinney, Maine Geological Survey**

9:30 2) A History of Non-ferrous Metal Mining and Exploration in Maine – **Frederick M. Beck, F.M. Beck, Inc.**

10:00 Break

10:15 3) Legal and Regulatory Issues that Affect Mine Development in Maine – **Judy Woodbury, Pierce Atwood**

10:45 4) Mineral Development: Surface and Mineral Owner Perspectives – **Ray Kaczorowski, Natural Resource Partners – BRP LLC**

II. Modern mining techniques

11:15 1) Exploration and Mining in the 21 Century: Responsible Mineral Resource Development Options & the Role of High Technology – **David Lentz, University of New Brunswick**

11:45 2) Acid Rock Drainage and Metal Leaching Evaluations in Northern Latitudes: A Case Study of Geochemical Characterization and Evaluation of Closure Options for the former Cu-Ni mine near Lynn Lake, Manitoba, Canada – **Nikolay Sidenko, Stantec**

12:15 Lunch

1:30 3) Practical Considerations for Tunnels Used in Mining Applications – **Marco Boscardin, Boscardin Consulting**

2:15 4) Mine Dewatering Impacts on Local Hydrology in Fractured Crystalline Rocks – **Robert Gerber, Ransom Environmental**

2:45 Break

3:00 5) Evolution of Reclamation for Habitat at Sulfide mines in Northern Climates, with examples from British Columbia, Canada – **Natalie Tashe and Carol Jones, Stantec**

3:45 III. Summary / Discussion – **Cliff Lippitt, S.W. Cole**

4:30 Geological Society of Maine business meeting

5:00 Social hour

6:00 Dinner (optional at Black Bear Inn)

PRESENTATION ABSTRACTS AND BIOGRAPHICAL SKETCHES OF PRESENTERS

Robert G. Marvinney – *Maine's Geology and Mineral Potential*

Maine's complex geological history spans nearly one billion years of geologic time. While considerable debate continues concerning the nature and exact boundaries, it is generally accepted that the geology of Maine is composed of a mosaic of distinct terranes which were widely scattered microplates in the Iapetus Ocean. While in the same relative position as the present-day Atlantic between the North American and Euro-African continents, the Iapetus contained many island archipelagos of oceanic and continental character, perhaps similar to the present-day Malay Archipelago between the Asian and Australian continents.

Several tectonic events affected the rocks of Maine, the first being the Penobscottian orogeny during the Cambrian. This event is interpreted as a microplate collision within the Iapetus, rather than a collision with North America proper. During Middle Ordovician time, the Taconic orogeny affected the Cambrian through Ordovician rocks of northernmost Maine, primarily. Most geologists recognize this event as the collision of one or more island arc terranes with the eastern margin of North America. Limited igneous activity accompanied the Taconian orogeny.

In Late Ordovician time there was subsidence and renewed deposition along the eastern North American margin. Silurian rocks show evidence for rifting or divergence of plates, which is superimposed on the convergence structures of the older rocks. The Iapetus then consisted of a narrow basin which received sediment through Silurian and Devonian times from both the east and west.

In the Early Devonian, the Acadian orogeny represented a collision between North America and a large microplate. The dominant NE-SW structural grain in Maine and high-grade metamorphism in the southwest are due to this event. The vast majority of igneous plutons in the state owe their existence to the Acadian orogeny.

Each terrane and tectonic event brought the potential for significant mineral deposits. The island arcs and associated rocks host VMS deposits of various sizes and grade. Some of the intrusive igneous bodies host porphyry copper-type deposits. Hydrothermal vein systems and contact metamorphic deposits are often associated with intrusions. The Maine Geological Survey has an excellent database of Maine mineral deposits at: <http://www.maine.gov/doc/nrimc/mgs/explore/mining/mrds/mrds.htm>

Biographical sketch

Robert G. Marvinney, Ph.D., C.G., Maine Geological Survey, 93 SHS, Augusta, ME, 04333
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Marvinney has been State Geologist and Director of the Maine Geological Survey since 1995. At the Survey, he oversees programs in groundwater assessment, geologic mapping, coastal geology, geologic hazards, economic geology, and geographic information technology. In his capacity as State Geologist, he brings his geologic expertise to policy development in administrative and legislative arenas.

Marvinney's graduate research projects at Syracuse University involved extensive mapping of volcanic and metasedimentary rocks in west-central Maine. Before assuming the role of State Geologist in 1995, he managed the Maine Geological Survey's geologic mapping program for eight years, with components in bedrock and surficial mapping. He is the author or co-author of more than one dozen geologic maps covering various parts of the state.

Prior to joining the Maine Geological Survey in 1987, Marvinney was employed as a research geologist at Exxon Production Research Company, Houston, Texas, where he helped develop GIS methodologies for analyzing the oil and gas potential of various prospects. He brought this GIS expertise to Maine where he helped establish the first modern geographic information system in Maine state government.

Frederick M. Beck – *A History of Non-ferrous Metal Mining and Exploration in Maine*

In the late 1870s and early 1880s there was a flurry of prospecting activity and small mine creation along the “Down East” Maine coast. Good outcrops and favorable host rock geology combined to make this possible. Most of these early prospects were sub-economic but were hyped by promoters unencumbered by modern day due diligence requirements. Only two of the deposits actually saw much production; the Douglass copper mine in Blue Hill and the Cape Rosier copper mine in Brooksville.

Since that time 130 years ago, there have only been three producing metal mines in Maine. Two of these, the Kerr American Mine in Blue Hill and the Callahan Mine in Brooksville were not new mines, however. They exploited the former Douglass and Cape Rosier mineral deposits which had been mined in the early 1880s and were mined again briefly during the First World War and again in the late 1960s and early to mid- 1970s. The only newly discovered deposit to go into production in the past 130 years was the Leach Mine, about 1 mile south of the Callahan Mine. The Kerr American Mine was an underground (shaft and decline) operation which produced approximately 1 million tons of ore grading 6.9% zinc and 0.9% copper during its operation from 1972 through 1978. The Callahan Mine was an open pit operation which produced approximately 800,000 tons of ore grading 4.91% zinc and 1.31% copper. The Leach mine produced approximately 5000 tons of high grade copper ore to the nearby Callahan mill during 1969 and 1970. Both the Kerr American and Callahan mines were closed when operating costs exceeded revenues. The Leach mine was closed due to an underground fatality and lack of local experienced underground miners. All three mines have reserves remaining in the ground.

The interior of Maine remained mostly unexplored until the mid-1900s. This was due to unwillingness of large tract landowners to grant exploration and mining leases to prospectors, paucity of outcrops, lack of good geologic maps, poor understanding of the origins of certain types of mineral deposits and lack of modern-day geochemical and geophysical tools. Modern non-ferrous metallic mineral exploration began with the development of electro-magnetic geophysical equipment and advanced geochemical methods in the 1950s. From that time until the early 1990s there were well over 50 companies which conducted exploration in Maine. Some of this was concentrated near the old 1880s era prospects, but most was in interior Maine where host rock geology was considered favorable but outcrops scarce. Approximately \$50 million was spent by these companies on grass roots exploration and resulted in the discovery of at least 16 significant new mineral deposits, including the largest so far, the Bald Mountain deposit west of Portage. Of the 16 new deposits, 11 were discovered by the J. S. Cummings consulting group of Bangor working for a consortium of companies from 1967 to the early 1980s. Since passage of the 1991 Maine mining regulations, there has been very little if any grass roots exploration in Maine. In addition to the \$50 million spent on grass roots exploration, over \$50 million was spent from 1977 to 1995 on deposit delineation, engineering and environmental permitting at three of the newly discovered deposits.

Biographical sketch

Frederick M. Beck, F.M. Beck, Inc., 1 Main Street, Yarmouth, ME 04096
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Mr. Beck is president of F. M. Beck, Inc., a geologic consulting firm operating in Maine and New England since 1978. Prior to that, he was Chief Geologist and Vice President, Exploration, for Callahan Mining Corporation. His 11 years with Callahan were preceded by one year with the Maine Geological Survey and 6 years with Kerr McGee Oil Industries in their minerals division. He received his BS and MA degrees in geology from the University of Wyoming, with a 2-year hiatus for military service as a ski and mountain climbing instructor.

Mr. Beck's geologic specialty is mineral exploration, principally for base and precious metal deposits. This has included uranium exploration in Wyoming and Arizona; porphyry copper exploration in Arizona, New Mexico and Nevada; gold exploration in Nevada, Oregon and Alaska; shale-hosted base metal exploration in the Yukon; tungsten exploration in California and massive sulfide base metal

exploration in New England. As a consultant, he has managed exploration programs for numerous corporations, large and small.

In addition to his exploration work, he started a geochemical and assay laboratory in the early 1980s to serve the needs of his clients and others exploring in the east. Operating as Northeast Geochemical and Assay Company, this lab was the only commercial lab of its kind east of Denver. As eastern US exploration activity lessened in the mid- to late- 1980s the lab turned to environmental customers and eventually changed its name to Maine Environmental Laboratory. Maine Environmental Laboratory continues operation in Yarmouth today with 10 employees.

In 1989, Mr. Beck formed a geophysical company to serve the environmental engineering community in Maine. That company, Northeast Geophysical Services, was sold to its two principal employees in 1995 and continues, from Bangor, to serve a variety of engineering, geotechnical and governmental agencies throughout the eastern states. Mr. Beck currently consults to large and small landowners on a variety of issues related to surficial and bedrock resources. He also conducts near-shore marine geophysical surveys, with the City of Portland currently being the most active client.

Judith Fletcher Woodbury – *Legal and Regulatory Issues that Affect Mine Development in Maine*

The bulk of this presentation will address traditional land use issues that mine operators need to be aware of such as operating on state lands, tunneling near or under Great Ponds and state roads, surface rights, and mineral rights. We will also discuss Maine's Mining Excise Tax, including how it is paid in lieu of certain real estate taxes and how the tax may be assessed on either gross proceeds or the value of facilities and equipment. We will take a look at zoning ordinances and other municipal issues related to mining such as the availability of Tax Increment Financing.

This presentation will not focus on Maine State environmental statutes and regulations affecting metallic mining in Maine. Those regulations, when they are issued to the public, will be a subject of future forums. The Maine Department of Environmental Protection (DEP) is currently re-writing regulations that govern environmental impacts regulated by the State, as directed by a Statute passed this year that changes many aspects of how the DEP will regulate mining activity and reclamation. The Maine Land Use Regulation Commission will continue to manage the zoning of land within the unorganized territories. Some municipalities have written lengthy regulations affecting mining in their jurisdictions. Federal law, such as the Clean Water Act, Clean Air Act, and the Endangered Species Act may generate a need for federal permitting.

Biographical sketch

Judith Fletcher Woodbury, Attorney with Pierce Atwood, LLP, Portland, ME, 207-791-1386,
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Ms. Woodbury received her J.D. from University of Maine School of Law and a B.A. degree from the University of Maine. She is a Partner at Pierce Atwood and head of their Real Estate Group. She previously served as an Assistant Attorney General for the State of Maine. She is admitted to the Bar in Maine, Massachusetts, and the U.S. District Court, District of Maine. Her real estate experience includes commercial and residential acquisitions, sales and financing, title abstracting and search services, commercial closing services and title insurance underwriting for commercial and residential transactions.

Judy enjoys tackling multifaceted real estate problems raised by surveyors and working out missing interests as much as designing easements that will govern the use of land for generations to come. She manages the real estate aspects of significant, complex, multi-site projects in New England, including representation of parties in both the acquisition and sale of projects for which separation of functions is required, involving complex property divisions with reciprocal easements and agreements and interpretation of survey plans. Judy has worked for a national title insurance underwriter, is an agent for all the major title insurance companies and has made title insurance claims on behalf of clients. She has advised clients involved in large Maine land transactions involving the transfer of mineral rights.

Ray Kaczorowski – Mineral Development: Surface and Mineral Owner Perspectives

Mineral development typically occurs under a *lease agreement* whereby the lease serves as the development contract by which the Lessor, (*mineral owner*) and its business partners, the Lessee (*mineral developer*) operate under during the mineral development, production & reclamation phases of the project. The basic purpose of the *lease* (contract) is to strive to create value through the commercial development of mineral resources, while also serving as the operating agreement between the parties (*Lessor & Lessee*) as the project evolves. The mineral estate can be owned by the surface owner or another party, separate and apart from the surface owner – potentially creating a situation where conflict may exist or develop.

After the lease is negotiated and in-place, the Mineral Developer (Lessee) undertakes the tasks required for mineral development and commercialization including exploration, reserve assessment, economics, financing, permitting, public relations, project construction, mineral production, and mineral sales. The period from a mineral discovery to commercial production varies greatly: from a few months the case of Oil and Gas to years in the case of Base Metals and some other mineral commodities. Fluctuations in commodity prices can significantly affect the development schedules of most mineral projects. These price swings also play a role in the focus of marketing efforts; for example, at the moment Oil and Base Metal Projects are much higher priority than Gas or Construction Aggregates projects because of low price (in the case of Natural Gas) and the sluggish economy (in the case of Construction Aggregates).

Since Mineral Ownership in the United States is generally “superior” to the surface ownership, the owner of the mineral estate typically can appear to have more rights than the surface owner – meaning: 1) the surface owner, like it or not, typically can’t restrict the mineral owner from accessing the mineral estate nor 2) from developing the minerals beneath the surface estate even if it causes inconvenience or temporary property loss to the surface owner – provided the development is done in compliance with existing law, rules, regulations and custom. However, that is not to say that the relationship between the surface owner and the mineral owner is necessarily rosy and congenial - there are real, potential, and perceived conflicts that can become very contentious and egregious if not handled appropriately. This presentation will address the issue of mineral ownership and mineral development from the perspectives of both The Mineral Owner and the Surface Owner and offer some suggestions on how to avoid conflict and anxiety that can be associated with mineral projects.

Biographical sketch

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Mr. Kaczorowski has been in the mineral development industry for the past thirty years in a variety of capacities, roles and positions of increasing responsibility including Exploration Geologist, Senior Geologist, Manager, and President of GCO Minerals Company; Vice President, Long Bell Petroleum Company; Vice President, IP Petroleum Company; Vice President, International Paper Realty Company; Vice President, Federal Forestlands, Inc.; Vice President, IP Farms, Inc.; Vice President, Coval Leasing Company, LLC; Vice President Lake Superior Land Company; and Vice President Operations - BRP LLC a Natural Resource Partners controlled JV company (current position).

He is a member of the American Association of Petroleum Geologists, Society for Mining, Metallurgy and Exploration (SME), Houston Geological Society, former Board Member and Trustee of the National Stone, Sand & Gravel Association and former Board Member of the North American Carbon Capture & Storage Association

Education includes PhD - Geology, University of South Carolina; MS - Geology, University of Massachusetts, Amherst; BS -Geology, State University of New York; Rice University - Management Program Graduate; Licensed Geologist, Texas Board of Professional Geoscientists.

David Lentz – *Exploration and Mining in the 21 Century: Responsible Mineral Resource Development Options & the Role of High Technology*

Without a doubt we live in a high tech world these days. Although the common perception is that mining is an outdated industry, there is much evidence to the contrary. In fact the mining industry has been leading the way in many respects to shed old stereotypes, and forge a new respect as a leading industry. The reasons for this are twofold: first, governments and industry know that protecting the public is critical and that a license to operate is just as easily revoked as it is granted. Secondly, state-of-the-art practices in all aspects of industry protect investors, i.e., the companies themselves. Long gone are the days when mining and metallurgical industries ignore or are ignorant of best practices (21st century, 2012 innovations) in all segments of their work. In fact, many of the big mining companies showcase their record to highlight to the public, wherever they operate around the world, that they have excellent track records on all fronts. These include mine safety, social responsibility, environmental stewardship, as well as strong short- and long-term innovation to maximize profitability. The mantra is that they are the best citizens and their track record over the past 35 years shows this. However there are some legacy issues (pre-1980s) that are challenging to rectify, but even these are being addressed. Unlike many other industries, natural resources are indigenous to the area in which they were formed, so do not suffer from the extreme competition brought on by globalization. However there are challenges with competition and, although the mineral resource sector is not immune to these issues, it has been dealing with them through the employment of high tech solutions and development of highly qualified people. Deep mining and tailing disposal are at the forefront of these technological innovations. Mineral resource development is known to foster the economic building blocks to stronger growing economies, but also sustaining economic growth in strong economies, as we have seen throughout North America.

Biographical sketch

David R. Lentz, Professor, University of New Brunswick, Department of Earth Sciences, Box 4400, 2 Bailey Drive, Fredericton, NB E3B 5A3, 1-506-447-3190, dlentz@unb.ca

David R. Lentz received his B.Sc. (1983) and M.Sc. (1986) degrees in geology from the University of New Brunswick (UNB). He completed a PhD (1992) at the University of Ottawa, and then worked with the Geological Survey of Canada for three years. In 1994, Dr. Lentz joined the New Brunswick Geological Survey as their mineral deposits geologist. In 1999, he won the Harvey Gross Young Scientist Medal from the Geological Association of Canada (GAC). Since 2000, he has held the economic geology chair at UNB (ORE Group), with a research focus on the petrogenesis of ore deposits. Recently, Dr. Lentz was awarded GAC's Distinguished Service Award and CIM's Boldy Award and was the CIM's 2008-2009 Distinguished Lecturer. Most notably, he has edited three best-selling ore deposits-related books for GAC. He has published well over 100 journal articles and many more government publications, including several Guest editor journal volumes on skarn systems, IOCG deposits, carbonatite deposits, and volcanic massive sulfide deposits in the Bathurst Mining Camp. He is particularly well known for his short courses, workshops, and field trips. Dr. Lentz has been associate editor for *Mineralium Deposita* and *Canadian Mineralogist*, and is currently associated editor for *Geoscience Canada*, *Economic Geology*, the *Journal of Geochemical Exploration*, the journal *Tethys*, and special volumes editor for CIM's *Exploration and Mining Geology* journal. In addition to these, he is a Director for Cache Exploration Inc, and a technical advisor to several other companies involved in rare earth element exploration.

Nikolay V. Sidenko – *Acid Rock Drainage and Metal Leaching Evaluations in Northern Latitudes: A Case Study of Geochemical characterization and evaluation of closure options for the former Cu-Ni mine near Lynn Lake, Manitoba, Canada*

The first part of the presentation provides an overview of current methods for the evaluation of Acid Rock Drainage and Metal Leaching (ARD/ML) potential from prospective (i.e. “greenfields”) massive sulfide deposits being considered for mine development in northern latitudes. Strategies for the prevention and mitigation of ARD/ML issues arising at such a hypothetical new mine in the northeast region are also briefly discussed.

The second part of the presentation is an example application of the geochemical methods and evaluation of strategies for final closure of a former (and long abandoned) Cu-Ni mine, one of several that exploited the massive sulfide deposit beneath Lynn Lake, Manitoba, Canada over an approximate 6-decade period. The EL Mine site was a combined open-pit and underground mine that operated between 1954 and 1963 and closed in 1964. Some initial closure activities occurred at that time, including deposition of waste rock into the pit lake. Stantec was contracted in 2009 by Manitoba Mines Branch to undertake an Environmental Site Assessment (ESA) to characterize the current condition of the Site and to develop and implement a Closure Plan for rehabilitating this Site.

As part of the 2009-10 assessment and closure planning, geochemical studies focused on the use of the pit lake as a repository for residual mine wastes (including PAG materials) from the site. Placement of acid-generating wastes in the pit lake was evaluated as a remedial option by determining the expected effect on lake-water discharge quality. These evaluations indicated that because of the previous mine-waste placement in the pit lake, water quality in the lake water deteriorated over time, with an associated increase in pit-water metal concentrations. The current pit disposal option was found to be more expensive and logistically challenging compared with off-site disposal, which was selected as a preferred closure option in the final Closure Plan. Site closure included removal of a few remnant mine structures and some acid-generating waste materials previously spread across the site, capping the remaining shaft and vents, restoration of the historic drainage pathways, and enhancing the natural revegetation of the site that had spontaneously begun after initial closure in 1964. Stantec received a Certificate of Achievement Award from the Association of Professional Engineers and Geoscientists of Manitoba (APEGM) for the excellence of its work on the project.

Biographical sketch

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Nikolay Sidenko has a Ph.D. in Exploration and Environmental Geochemistry, granted by the United Institute of Geology, Geophysics and Mineralogy, in the Russian Science Academy, Novosibirsk, Russia. Dr. Sidenko has 15 years of academic and consulting experience focusing on acid-mine drainage and metal leaching. He is currently a Senior Geochemist with Stantec Consulting. He has broad experience with geochemical assessments through different stages of mine life cycles, from predictive pre-mining site-characterization studies to the development of Closure Plans and implementation of related mine-site remediation activities. He is a specialist in mineralogical and chemical methods of analysis and laboratory experiments involving column and batch tests. Dr. Sidenko has extensive experience with different methods of data interpretation and geochemical modeling including 3-D reactive transport simulations. His expertise has been applied to potential ARD-metal leaching problems in many biogeoclimatic regimes, including northern climates in Canada. Noteworthy is his 6-year experience in site characterization, contributions to groundwater modeling and contaminant-vector analyses, construction of contaminant-visualization models for

discerning contaminant fate, and investigation of innovative site-specific engineered wetlands as part of closure planning for the worst ARD contamination problem in Manitoba, the long-abandoned abandoned Lynn Lake East Tailings Management Area. He most recently designed and conducted geochemical assessments to support environmental licensing, a feasibility study, and closure planning, for a large proposed open-pit iron mine having a projected annual ore production of 16 million tonnes.

Marco D. Boscardin – *Practical Considerations for Tunnels Used in Mining Applications*

Tunnels can serve several types of functions in a mine. They may be used as main haul routes for the ore body, serve as temporary access for direct mining, house infrastructure for ore transport and processing, and serve as mine drainage/ground water control systems. For each one of these functions, there are generally different support, stability and performance criteria for the tunneling. In addition, the impact of tunnel-related subsidence, tunnel deformations, and ground water inflows on both surface and subsurface structures, equipment and facilities must be considered in design. Key features often associated with concentrations of ore materials include shear zones, fault zones, zones of hydrothermal alteration and intrusion contacts. These same zones tend to be significant features relative to stability, deformation and water transmission characteristics of the rock mass.

An important part of the site investigation and evaluation is the characterization of the rock mass properties for design and construction of underground openings which today includes the use of rock mass classification systems such as the Rock Mass Rating (RMR) system by Bieniawski, the Rock Tunnelling Quality Index (Q System) by Barton, and the Geologic Strength Index (GSI) by Hoek. These systems were developed based on correlations with field data and observed rock mass performance to permit the estimation of rock mass design properties that typically can not be measured directly. They are based on intact rock properties and observations of the rock structure, weathering, and discontinuity characteristics.

Key questions to be addressed during design include: stand up time of the unsupported openings; support requirements for safe working conditions; potential high stress conditions either with very deep mines or in areas of high lateral tectonic stresses that may lead to spontaneous rock bursts in brittle rocks or squeezing conditions in altered, softer more ductile rocks; and potential deformations that may affect the serviceability of underground openings or equipment (crushers, processors, conveyors) contained therein. Case history data have shown that water inflow to tunnels and caverns in rock tends to be on the order of 15% to 20% of that estimated using measured rock hydraulic conductivity data and general numerical modeling based on water in a granular porous medium vs. a fractured rock mass.

This presentation will address the selection of performance criteria and how they may vary depending on the type of function that the tunnel may serve. It will also examine types of analyses that may be appropriate for the various types of tunnel functions and provide examples of types of support, factors of safety, subsidence expectations, ground water inflows that may be anticipated for tunnels used in mining applications.

Biographical sketch

Marco D. Boscardin, PhD, DGE, PE, Boscardin Consulting Engineers, Inc.
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Dr. Boscardin is currently President of Boscardin Consulting Engineers, Inc., which he founded in 2002. He earned his BSCE degree (structural concentration) from the Massachusetts Institute of Technology and MS and Ph.D. degrees in (geotechnical concentration) from the University of Illinois at Urbana. Dr. Boscardin has worked in the underground construction industry for over 30 years, with 9 years on the faculty at the University of Illinois at Urbana and the University of Massachusetts at Amherst and 14 years at GEI Consultants, Inc. in Massachusetts, where he rose to Branch Manager and served on the Board of Directors.

Dr. Boscardin's consulting and research activities have included the evaluation of ground movements associated with underground construction, the tolerance of nearby structures and utilities to such movements, and design and construction related risks associated with development and use of underground openings. He has investigated and developed repair schemes to address mine sag and sinkhole subsidence events in the Illinois coal fields; investigated and designed foundation systems for a

hospital and other large structures located above several levels of underground coal and metal mines in Pennsylvania; inspected and developed repairs for a historic underground metal mine in Connecticut, consulted on the feasibility, stability, ground movements and ground water inflows related to open pit metal mines up to 600 to 700 m deep and associated infrastructure housed in underground tunnels and caverns in South America, and TBM driven rock tunnels to house water pipelines in sedimentary sequences in Colorado. He is currently consulting on an approximately 2.5 mile-long, 20-foot+-diameter 200 feet deep, storm water storage tunnel in sedimentary and intrusive basalt rocks in Connecticut; a water transmission tunnel in conglomerate and granite in California; and a large, 57-foot-diameter, 1.7-mile-long, up to 250 feet deep, TBM driven highway tunnel in soft to hard glacial soils in Washington.

Dr. Boscardin is the author or co-author of over 35 publications related to geotechnical, environmental, and underground construction engineering. He is a registered professional engineer in seven states, an LSP in Massachusetts, an ASCE Fellow and an Academy of Geo-Professionals Diplomate.

Robert G. Gerber – *Mine Dewatering Impacts on Local Hydrology in Fractured Crystalline Rocks*

The surface and groundwater impacts of mine dewatering will be of concern in the relatively humid climate of Maine where groundwater is relatively close to the ground surface in all but steep mountainous terrain, and wetlands and closely-spaced natural streams and ponds are common. Although the drawdown impacts of an open-pit mine can be estimated in fairly simple ways, the impacts of shaft and tunnel mining, especially at great depths, are not so easily determined. This presentation will use 3-D modeling with MODFLOW and MODPATH to emulate a single simple hypothetical terrain that would be typical of Maine. The models will be used to compare the effects of dewatering of several different mining schemes to depths over 2000' on lake and river water balances, and on small streams and typical residential wells that are simulated near the different mining schemes. Bedrock permeability decreases with depth below 700', in line with both Maine historical well data and research findings at nuclear waste repositories in deep crystalline bedrock caverns. We will present general findings that show that the impact of tunnel and shaft mining is much less than open pit mining and decreases as the depth of the mine increases. The impacts differ depending on whether the tunnels are aligned along groundwater flow lines or perpendicular to them. Deep tunnel and shaft mines may not have a significant adverse effect on Maine water wells of average depth, even though the mine is close to or even under the wells. Changes in groundwater regime and flow paths for both open pit and tunnel mines that have been allowed to refill after closure will be illustrated.

Biographical sketch

Robert G. Gerber, P.E. & Certified Geologist with Ransom Consulting, Inc., Portland, ME, 207-838-1418, Robert.Gerber@RansomEnv.com

Mr. Gerber has a B.S. in Civil Engineering from MIT with an M.S. in Civil Engineering from Stanford University. After 20 years of running a consulting firm he founded in Maine, the company merged with Jacques Whitford of Canada (now part of Stantec). After 3 years in senior management at Jacques Whitford, he next managed an environmental consulting subsidiary of a large Maine law firm for 10 years. He now practices engineering and geology for Ransom Consulting from their Portland, Maine office.

Mr. Gerber has specialized technical expertise in all aspects of ground water exploration and groundwater contamination evaluation, including complex numerical simulation modeling. In addition to modeling for a number of Superfund sites and 7 nuclear power plant sites, he modeled the feasibility of storing high-level nuclear waste 2000 feet deep in DOE-proposed caverns under the Sebago Lake and Bottle Lake plutons in Maine in the late 1980's. He modeled the groundwater impact of the proposed Bald Mountain mine development for Boliden Resources in 1990. He was retained to model the groundwater impacts of the once-proposed RiverBank pump-storage site which would have constructed 2000-foot deep water storage caverns near the former Maine Yankee nuclear plant.

Natalie Tashe and Carol Jones – *Evolution of Reclamation for Habitat at Sulfide mines in Northern Climates, with examples from British Columbia, Canada*

Sulfide mineral mine wastes can be successfully reclaimed to other end land uses when the reclamation plan is integrated with the mine design necessary for the management of Acid Rock Drainage (ARD). The first part of the presentation provides historical mine examples illustrating the impacts that acidic metal-rich waters released from waste rock and tailings have on reclamation success when proper planning and appropriate control methods were not implemented. Examples from mines will visually show results of ARD conditions, such as low pH in the growth medium, and the limitations on successfully reclaiming the landscape. The second part of the presentation then contrasts the ways of the past with how and why we have modified mine design, particularly in northern locations, to allow for appropriate planning that includes predictive ARD models, waste rock spoil construction, cover designs, and water management that in turn improve reclamation success. As ARD prediction and control advancements have occurred, reclamation techniques and practices have also evolved. The final part of the presentation will show upcoming trends and the evolution of reclamation techniques for developing successful end land uses at sulfide mines, using examples from Canada.

Biographical sketch

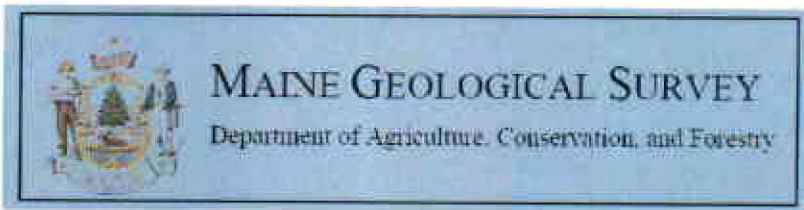
Natalie Tashe, P.Ag., Stantec Consulting Inc., Sidney, Canada
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Natalie Tashe is a reclamation specialist with Stantec Consulting and currently works on mine properties in northern latitudes, most recently in British Columbia and the Yukon Territory, Canada. Natalie Tashe has over fifteen years' experience in soils and terrain science, and vegetation ecology that she applies to mine reclamation. She is a Professional Agrologist registered in both British Columbia and Alberta, Canada. Natalie's career began working as a geology assistant in the nickel mining town of Thompson, Manitoba, Canada. Natalie then went on to complete her Master's Degree at Simon Fraser University, in British Columbia, Canada specializing in soil biogeochemistry that examined soil and plant interactions in Pacific coastal forests. Natalie's current focus is on mine reclamation and environmental planning, through different stages of mine life cycles, from the pre-development stage working with mine engineers on mine reclamation and closure plans to post closure reclamation monitoring and reclamation research programs. Natalie and Stantec's reclamation team have been leading initiatives on developing reclamation techniques to support endangered wildlife species habitat restoration, using biosolids as a reclamation amendment, native seed collection programs, and developing new seed mixes to be used in reclamation. Natalie has also had the opportunity to work with First Nations in developing reclamation plans that incorporate traditional land.

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