NSERC-TERRE-NET

Toward Environmentally Responsible Resource Extraction Network/terre-net.ca

CANADIAN MALARTIC MINE – HOST TO THE 2017 AGM'S FIELD DEMONSTRATION

Newsletter Issue 1

March 2019

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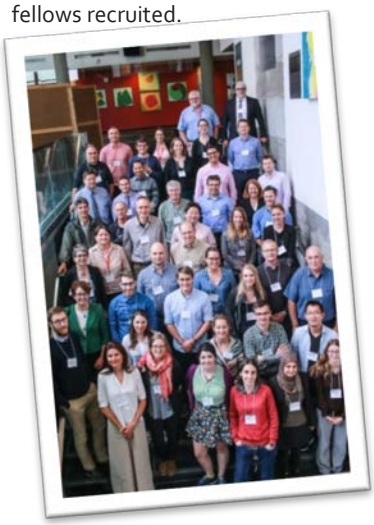
Years I & II Update

by S. Holland (TERRE-NET Network Manager, University of Waterloo)

The TERRE-NET program is a five-year initiative which includes 28 projects structured within seven integrated research themes, including: Theme 1 – Abandoned Mine Site Remediation; Theme 2 – Predictive Tools for Mine-waste Management; Theme 3 – Cross-cutting Methods and Technologies; Theme 4: Indigenous Knowledge Integration for Understanding Risks and Costs/Benefits of Resource Extraction; Theme 5 – Innovative Treatment Technologies for Mine-impacted Water; Theme 6 – Remediation Strategies for Mine Wastes; and Theme 7 – Mine Waste Design. TERRE-NET will provide direct stipend support to train more than 80 graduate students, post-doctoral fellows, and undergraduate co-op students. The overall goal of TERRE-NET is the environmentally responsible, socially acceptable handling of wastes generated during extraction of mineral and energy resources using cutting-edge approaches and technologies. TERRE-NET unites leading researchers from seven Canadian Universities with an extensive network of Canadian and international collaborators and partners representing the mining industry, industry organizations, and provincial, territorial, and federal government agencies. The TERRE-NET program has ramped up quickly in Years I and II, with 25 projects initiated, 11 field sites instrumented and sampled, and more than 45 students and post-doctoral fellows recruited.



Each year, TERRE-NET hosts an Annual General Meeting (AGM) to provide students and post-doctoral fellows with an opportunity to present their research findings, and to provide networking opportunities and promote collaboration among the students, co-investigators, and partner representatives.

The Year 1 AGM was hosted by co-investigators Bruno Bussière and Isabelle Demers, and their team at Université du Québec en Abitibi-Témiscamingue, Rouyn-Noranda, QC. The Year 1 AGM was attended by ~50 participants, including representatives from 13 partner organizations. The event included presentations from 13 students and post-doctoral fellows and the theme leaders, plenary talks provided by co-investigator Joyce McBeth, and Scientific Advisory Committee member and Board of Directors representative, Katie Walton-Day (United States Geological Survey), and a poster session. In addition, a field-site demonstration was held at the Canadian Malartic Mine (Malartic, QC) through partner support from Canadian Malartic Mines and Agnico Eagle Mines. Special thanks to Véronique Coulombe for all of her efforts in coordinating the Year 1 AGM!

The Year 2 AGM was hosted by co-investigator Tom Al and his team at the University of Ottawa, Ottawa, ON. The Year 2 AGM was attended by ~75 participants, including representatives from 17 partner organizations and two First Nations and Metis communities. The event included presentations by 29 students and post-doctoral fellows, a plenary talk provided by Tony Brown (Giant Mine Oversight Board), and two poster sessions. Special thanks to Sam Morfin for all of his efforts in coordinating the Year 2 AGM! For additional information regarding the TERRE-NET program, please contact Steve Holland (s2hollan@uwaterloo.ca), or visit terre-net.ca.

Update from the Board of Directors

by D. Kemp (Chair of the Board)

As we enter into Year 3 of the TERRE-NET program, I am heartened to see the continued co-operation from all researchers and the sharing of ideas and expertise. So often in my past experience, research would be carried out with a strong "in house" emphasis rather than looking outward to find others who may have more experience or knowledge in a particular area or sub field. TERRE-NET tries to break this thinking by working with those most knowledgeable in a particular field or sub discipline as needed by each project.

Mine waste management is a long-term problem for everyone, even new entrants to the mining industry, and yet it is all too often treated with a short-term view with respect to budgets and management.

Mine waste management and protection of the environment is seen by industry as a cost rather than an opportunity. Government agencies, particularly regulatory ones, are caught in a multi-faceted dilemma. They must appease industry, NGOs, and the general public while spending within a budget that is often seen as necessary while adding very little to the GDP of the country.

There are many possible solutions, but the overall one is for everyone to take a long-term view of the problem. A prime example of the persistence of mine waste problems, are the places in the United Kingdom where mining was conducted during Roman times. A number of sites are still producing acid mine drainage today! Were you able to ask one of the miners of that time if he thought there would be problems 2000 years later, I am sure he would think you were joking!

I see many similarities between long-term mine waste management and the current topical subject of climate change. They are both so problematic that no one approach can provide all the solutions and certainly not within one or two generations. Persistent action using the best technology available at the time, coupled with a long-term view supported by consistent funding is one answer to keeping the problem controlled.

The TERRE-NET program is one such measure that is taking new ideas and testing them in real situations, while bringing the best expertise to the problems. Although some projects have been a little slow to start, I see them all now moving ahead at a good pace, bringing worthwhile knowledge and advancement to the fields.

On behalf of the Board of Directors, I congratulate everyone on their persistence, hard work, and especially their contributions to making TERRE-NET a success. I would also like to thank NSERC for their flexibility and continued support in ensuring these projects succeed.

Making the most of a TERRE-NET Exchange

by Emma Charbonneau (TERRE-NET Theme 7 MSc student, UQAT)

Worldwide, the recent high rates of tailings impoundment failures are prompting the mining industry to develop new and more appropriate waste-management methods that will reduce environmental risks. The development of paste rock is part of this approach. Initially proposed by Brawner (1978), and studied by Wilson et al. (2001, 2003, 2010) and Wickland (2006, 2010), paste rock is a mixture of waste rock and tailings, blended to ensure that the voids within the coarse waste rock are filled with tailings. The resulting material has a low saturated hydraulic conductivity, a high water-retention capacity, low compressibility, and a high shear strength.

Paste rock has the potential to provide the desired hydrogeological properties of tailings and the geotechnical properties of waste rock. Preliminary laboratory studies have yielded promising results for saturated hydraulic conductivity (~ 10^{-6} cm/s). However, these results suggest possible internal instability due to the bimodal particle size of the material. My MSc project will enhance the characterization of paste rock to provide a better understanding of its properties and the factors of influence. For this purpose, several ratios of tailings/waste rock are considered; for each ratio, column permeability tests, Proctor tests, and shear tests have been completed.

As part of the TERRE-NET program, and with financial support from the TERRE-CREATE program, I participated in a four-month exchange at the University of Alberta in Edmonton, which included a week at Golder Laboratory in Vancouver, under the supervision of Ward Wilson and Leonard Perrey. During my exchange, I also audited the Engineering Properties of Soil course at the University of Alberta. Participation in this exchange has allowed me to address the mechanical testing component of my Master's degree research, including direct shear tests performed on different mixture ratios, and on pure tailings. Participation in

this exchange also provided me with the opportunity to improve my oral and written communication skills in English – a skill that is very valuable in the research world.

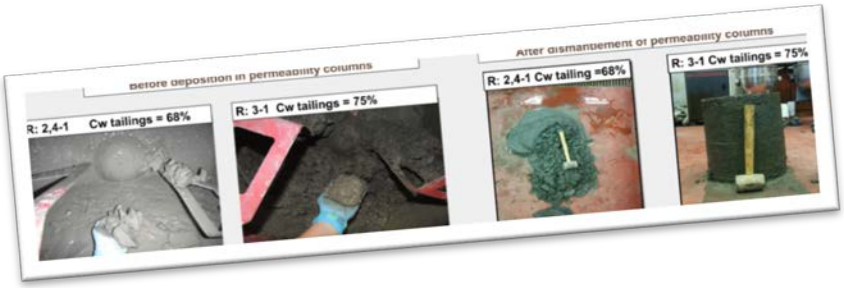
I would like to thank my supervisors, Bruno Bussière and Ward Wilson, TERRE-CREATE, and TERRE-NET for this wonderful opportunity and experience. These exchange opportunities are a major step forward in promoting inter-university transfer of scientific knowledge, and the collaboration between universities and mining companies (both at Canadian Malartic Mine and Golder Associates), which I believe is essential.

Developing new mine-waste materials to improve the physical and chemical stability of mine-waste disposal sites

by B. Bussière (TERRE-NET Theme 6 Leader, UQAT) & W. Wilson (TERRE-NET Theme 7 Leader, University of Alberta)

The Université du Québec en Abitibi-Témiscamingue (UQAT) is located in the heart of one of the most important mining regions in Canada. Since the early 1990s, issues related to "Mines and the Environment" have strongly influenced the development of research in mining at UQAT. This area of expertise has grown greatly in recent decades. In 2013, the Research Institute on Mines and Environment (RIME) was created. Focused on the environment and tailings management, RIME develops innovative solutions to environmental challenges throughout the entire life cycle of a mine. Within the TERRE-NET program, UQAT brings its expertise in mine site reclamation and mine waste management. Professors Bruno Bussière and Isabelle Demers are involved in Theme 1 on abandoned mine sites remediation, Theme 6 on reclamation strategies for mine wastes, and Theme 7 on new mine waste design.

One example of the contribution of UQAT in TERRE-NET is the research project that aims at developing new mine waste materials to improve the physical and chemical stability of mine-waste disposal sites. High rates of tailings impoundment failure are prompting the mining industry to develop new and more appropriate waste management methods that will reduce environmental risks. Conventional tailings impoundments require retaining structures for both solids and water, but the physical stability of these structures remains a serious risk. Moreover, hydraulic deposition produces a non-homogenous tailings mass with unsaturated regions and low strength characteristics that create difficulties with respect to final closure of the impoundment. This is especially problematic when the tailings have the potential to generate acid mine drainage (AMD). New and modified approaches, such as paste rock, have recently been proposed to increase the geotechnical and/or



geochemical stability of mine tailings. Paste rock is a material comprised of a mixture of waste rocks and tailings.

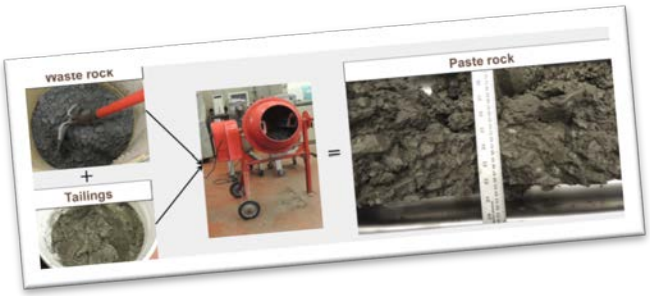
The objective of this co-mixing is to improve the physical stability of the wastes by integrating a high shear strength material (waste rock) with the tailings. At the same time, the chemical stability is increased because the water retention properties of the blended material help to maintain a high degree of saturation.

Thus, paste rock has the potential to provide both the beneficial hydrogeological properties of the tailings and geotechnical properties of the waste rocks. While initial research appears promising, an improved understanding of paste rock is necessary prior to implementing this mine-waste management strategy at full scale.

The objective of one of the research projects on paste rock in TERRE-NET is to demonstrate its potential use as a cover material for the reclamation of Canadian Malartic's mine wastes. The project involves laboratory- and field-based hydrogeological and geotechnical characterizations. In the UQAT laboratories, paste rock mixtures were characterized in terms of their hydrogeological properties. Paste rock blends with different ratios of waste rock and tailings were prepared using materials from various mines and characterized using large-scale instrumented column tests. Several samples were also characterized for their mechanical properties using a direct shear box thanks to the collaboration of Dr. G. Ward Wilson.

The UQAT team have access to field-scale experimental cells constructed at the Canadian Malartic mine site. This experimental facility includes control cells of uncovered waste rock and reactive tailings, as well as experimental cells with paste-rock covers placed on: i) reactive tailings; ii) horizontal waste rock; and iii) waste rock with an inclined surface (2.5:1). Observations from the experimental cells will be compared with observations from the control cells and with results from the laboratory experiments.

These studies will provide new knowledge that will form the foundation for improved waste management strategies. They will also provide innovative modelling tools for designing waste management strategies that incorporate paste rock as a cover material. This project exemplifies collaboration between two universities participating in TERRE-NET by bringing together the expertise of Dr. Bussière from UQAT and Dr. Wilson from UofA. For example, the UQAT Master's student Emma Charbonneau completed a three-month internship at the University of Alberta during which she performed geotechnical tests.



Community Engagement for Mine Remediation

by A. Keeling (TERRE-NET Co-investigator, Memorial University of Newfoundland)

Mine closure and remediation are more than simply technical challenges: they are critical parts of the mining cycle. Like other stages in this process, closure and remediation have effects on local communities and landscapes, including social, economic, and even cultural dimensions. Yet local communities, Indigenous governments, and other stakeholders historically have been left out of remediation planning, and few regulations required their engagement as part of closure plans. Negative results can range from social and economic dislocation, exclusion from the benefits and opportunities of remediation and monitoring activities, and lingering distrust of post-mining environmental conditions.

One example of mine closure planning is the Raglan Mine Closure Plan Sub-committee for the Glencore Raglan Mine in Nunavik (Quebec), where TERRE-NET members are participating in a unique, long-term closure planning process that includes mine employees, Inuit organizations, and Nunavik community leaders. Although closure is not anticipated for another 20 years, this group is working together to create a community-engaged closure and remediation plan involving the communities of Salluit and Kangiqsujuaq. The goal is to create a mine closure plan that not only meets the regulatory requirements of the Québec government, but also integrates Inuit knowledge and values, protects valued ecosystem components (especially food and water resources), and maximizes the economic benefits of closure. For instance, the group has discussed creating training opportunities for Inuit to undertake remediation and post-closure monitoring. There is also a strong desire to benefit the communities by repurposing mining infrastructure, such as roads, buildings, and other facilities, after the mine closes. For Inuit, who will live in the region long after mining companies have left, this long-term perspective on remediation is at the heart of effective and responsible mine closure.

This process builds on the long-term relations between the mine and Nunavimmiut. The Raglan Agreement, signed by Makivik Corporation, the communities of Salluit and Kangiqsujuaq, and then-owners Falconbridge Ltd. in 1995, was the first mining impact and benefit agreement in Canada. The agreement established a long-term relationship and dialogue between the parties on matters of mine operations through the Raglan Committee—the closure planning sub-committee is an extension of this committee.

Closure planning in the Nunavik region has its challenges. Nunavimmiut recall the negative legacy of the Asbestos Hill (Purtuniq) Mine, which closed in 1984 without consultation, and which remains a source of concern for local land users due to the limited remediation and lack of environmental monitoring. Other mines in the region (proposed or operating) have not committed to similar levels of engagement for post-closure planning. And for many community members, closure may seem like a distant prospect. People are still learning about potential environmental and socio-economic challenges closure could create.

As part of Theme 4 of the TERRE-NET project, we are working with community, government, and industry partners to better understand how local community values, concerns, and perspectives can be incorporated into mine closure and remediation planning. By participating in and studying closure planning activities, we hope to contribute critical perspectives and to identify best practices for community-engaged remediation at both abandoned and active mining operations.

A Partner Perspective

By T. Lépine (Technical Specialist, Environmental Management, Agnico Eagle Mines Ltd.)

Agnico Eagle Mines Limited (AEM) is a Canadian gold producing company that operates nine mines in Canada, Mexico and Finland. AEM is also managing a series of closed sites mainly in Canada. The tailings produced at the mine sites vary in their physical form (slurry tailings, thickened tailings and filtered tailings) and in their geochemical properties. The same applies for waste rock. In addition, the sites are exposed to various environments and climates, all this contributing to increasing the challenges with the management of these materials. In order to appropriately succeed in the management of all of these different types of materials, AEM has to construct, operate and close facilities that are adapted, robust and efficient for the complete life cycle (from exploration to post-closure). To achieve this objective, it requires the collaboration between many groups of specialists with a wide range of expertise.

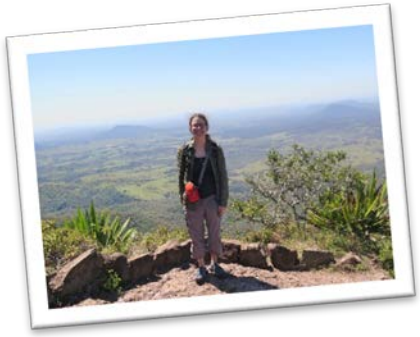
AEM is committed to apply best available/applicable practices when it comes to mine waste and water management. Integrated in that mindset, AEM believes that close collaboration with key players in the mine waste management and water treatment research community is a fundamental element to ensure that these objectives can be reached. This is one of the main reasons why a partnership with the TERRE-NET group can provide a benefit to the company. Via the network and its projects, there is a definite gain in knowledge that can be transferred to us through real applications. We also believe that such a partnership can be beneficial for both parties. On the one hand, it allows students, professors and researchers to continue with their research on real applications. And, on the other, it allows the industry to always improve its practices and ultimately to become more cost efficient in its use of new technologies. In today's mining industry, science and technology are essential ingredients to achieve success. For example, new water treatment technologies have contributed to further improve overall environmental performance and achieve water quality criteria that were not possible in the past at large scale.

This collaboration also allows us, to be able to communicate openly with the scientific community about our day-to-day challenges on the field. The TERRE-NET group is a good environment to create this possibility of interaction between operators and researchers. The group has grown considerably over the last 2 years and has made some great progress. I believe, however, that the best is still to come.

See the world, do science, learn new techniques; avoid the crocodiles.

by H. Shrimpton (TERRE-NET Theme 3 PhD student, University of Waterloo)

Selenium is a micronutrient that can be toxic at higher concentrations. It is known that Se can be removed from solution *via* a variety of microbial reductive processes. A change in the Se isotopic ratio is expected during the various possible removal processes (*e.g.*, reduction and precipitation, adsorption, etc.). The exact change in δ^{82}Se, or fractionation, will depend on the removal mechanism involved, but these fractionations must be carefully measured in laboratory settings before they can be applied to field conditions.



In order to consider Se isotopic fractionation during microbial or microbially assisted Se reduction, I went on a one-month research visit to the University of Queensland in Brisbane, Australia, to work in a laboratory with all of the necessary equipment and access to scanning electron microscopy. Two experiments were conducted, one using selenate (Se(VI)), the second, selenite (Se(IV)). Thus, a wider range of removal processes could be investigated during the limited amount of time available. The two sets of experiments were otherwise as identical as possible, to equalize the effect on isotopic fractionation of adsorption to the main reactive material, or precipitation with other elements in the input solution. Solid samples from these experiments were later imaged in the University of Queensland's Centre for Microscopy and Microanalysis (CMM). Should you ever visit the CMM's SEM preparation laboratory, it is considered thoughtful to bring them a snow globe from your country of origin.

Without funding from TERRE-CREATE, and the support of both my supervisor, host supervisor, David Blowes and Gordon Southam, and TERRE-NET, this experience would not have been possible, for which I am very thankful. I met a lovely bunch of fellow students who tackle remediation from a microbial perspective, learned new techniques, and what to do if a possum or gecko sneaks into the quarantine lab. A trip to a different research group, province, or country, is certainly recommended for all the enrichment it can bring to a master's or PhD experience.