Mineral Exploration Research Centre
AT THE HARQUAIL SCHOOL OF EARTH SCIENCES

October 2016 - Newsletter

Message from the Director, Dr. Harold Gibson

Without a doubt, September 6, 2016 will stand out in Laurentian University's history for two reasons. First, the success of Laurentian University's, Canada First Research Excellence Fund (CFREF) application, Metal Earth, was announced making it the largest research grant ever received by the university. Second, the donation by David Harquail's family (President of Franco Nevada Corp.) of $10M in support of Earth Sciences and MERC at Laurentian and the renaming of the Department of Earth Sciences to the Harquail School of Earth Sciences. These two momentous events, along with the Stan Bharti donation and renaming of Laurentian Engineering to the Bharti School of Engineering (2011), the donation by the Ned Goodman Family and the creation of the Goodman School of Mines (2012) and of Laurentian – Mining Initiatives and Technology (L-MIT – 2016)) to foster collaboration amongst Laurentian University's four mining research centres lead by a new Associate VP Mining Initiatives, have cemented the vision to become Canada's premier university in Mining research, from Mineral Exploration through to Reclamation. In that regard, MERC welcomes a new Foundation and Advisory Board Member….

David Harquail

It seems fitting that this newsletter should focus on Metal Earth, as it will become Canada's largest mineral exploration research project. We provide a background on Metal Earth, how the research program was conceived, our research partners and the scientific capacity of the Metal Earth team, and a summary of planned research activities.

However, first we provide an update on MERC's upcoming professional development and education activities, and the speaking notes from an invited testimony to the House of Commons Standing Committee on Natural Resources.

SUDBURY, ON (September 6, 2016) – David Harquail announced today that his family foundation is making a $10 million investment to support **Laurentian University's Department of Earth Sciences** *and its* ***Mineral Exploration Research Centre.***

Professional Development and Educational Opportunities

- **March 5, 2017; 1 Day MERC Short Course at PDAC; New exploration methods for base and precious metal deposits: How to increase success in Greenstone Terranes.**
  - Contact jayer@laurentian.ca
- **April 2017; 1 Day Abitibi Exploration Research Symposium** associated with the Northeastern Ontario Mines and Minerals symposium in Timmins. Presentations by MERC faculty & students.
  - Contact jayer@laurentian.ca
- **May 2017 ; 7 Day Greenstone Gold and Base Metal Mapping Course:** Exploration Models and Methods. To be held in the Timmins area.
  - Contact jayer@laurentian.ca

Field School in the Rouyn-Noranda area.

Upcoming Modular Courses

- **Dec. 2016; Exploration Geochemistry**
  - Contact mlesher@laurentian.ca
- **Apr. 2017; Exploration for Hydrothermal Ore Deposits**.
  - Contact mleybourne@laurentian.ca
- **Aug. 2017; Structure, Tectonics and Mineral Exploration** (field-based).
  - Contact blafrance@laurentian.ca
- **Oct. 2017: Hydrothermal Ore Deposits** (Ottawa).
  - Contact mark.hannington@uottawa.ca
- **Dec. 2017; Exploration Geophysics.**
  - Contact rssmith@laurentian.ca

HES/MERC Faculty

- Harold L. Gibson, Professor and MERC Director: Economic Geology, Volcanology
- Bruce Jago, Professor and Executive Director, Goodman School of Mines, Economic Geology
- Pedro J. Jugo, Associate Professor: Igneous Petrology, Economic Geology
- Alesandro Ielpi, Assistant Professor: Clastic Sedimentology to begin in January 2016
- Daniel J. Kontak, Professor: Economic Geology
- Bruno Lafrance, Professor and DES Chair: Structural Geology, Economic Geology
- Matthew Leybourne, Associate Professor: Geochemistry
- C. Michael Lesher, Professor: Economic Geology, Igneous Geochemistry
- Andrew M. McDonald, Professor: Mineralogy
- Jeremy Richards, Professor: Economic Geology, Tier 1 Canada Research Chair in Metallogeny starting July 2017
- Michael Schindler, Associate Professor: Environmental Mineralogy, Hydrology
- Graeme A. Spiers, Associate Professor: Environmental Geochemistry
- Richard S. Smith, Professor, Exploration Geophysics
- Phillips C. Thurston, Adjunct Professor: Precambrian Geology
- Douglas K. Tinkham, Associate Professor: Metamorphic Petrology
- Elizabeth C. Turner, Associate Professor: Carbonate Sedimentology, Invert. Paleontology
- Currently advertising for 4 new faculty (see http://hes.laurentian.ca/faculty-recruitment):
  1. Research Chair in Exploration Targeting
  2. Professor of Exploration Geophysics
  3. Professor of Precambrian Geology
  4. Professor of Earth Systems Modelling

Speaking Notes: Testimony to the Canadian House of Commons Standing Committee on Natural Resources on October 25, 2016

Good morning Mr. Chair, and Honourable Members. Thank you for this opportunity to speak to the challenges facing the Canadian Mining Industry. I am Director of the Laurentian University's, Mineral Exploration Research Centre (MERC) and Metal Earth, a new $104M R&D program funded by the Canada First Research Excellence Fund (CFREF - $49.26M). Metal Earth is the largest mineral exploration research program ever conducted in Canada and it will transform how we explore for metals

My testimony, will focus on Exploration, the process of discovering the new resources required to build Canada's new mines, and the research required for exploration to be successful. Exploration is the scientific R&D component, and first phase of a sustainable mining life cycle of Exploration – Development – Mining – Reclamation, where the environment is the first and foremost concern throughout that life cycle.

Facts:

A healthy Mining industry is essential to Canada and successful Exploration is essential for healthy Mining Industry. Without new metal resources there will be no new mines, no mining, and no sustainable northern development.

Mineral resources are essential to Canada. They comprise 18.2 % (2014) of Canada's exports and constitute 4% of Canada's GDP. Mining is, and will continue to be, a major economic driver of the Canadian economy, and the only economic driver for the Far North.

The Mining Industry is the largest employer of First Nations people in Canada (about 10% of the workforce). The exploration sector is often the first opportunity for First Nation Communities to make contact with the Mining Industry.

Historically, Exploration Research in Canada has been of the highest quality, but is fragmented, poorly funded, and dispersed throughout the Canadian University system. In Australia, Mineral Exploration Research over the past two decades has benefited from their government focusing research to key university research centres that are well funded and undertake the large, big- science projects required to address key industry challenges. Canada has slipped behind Australia as the world leader in mineral exploration research.

Challenges:

The decline in Canadian (and global) metal resources (Fig. 1) is a threat to global sustainability, and security. Since 1980, the most dramatic decline has been in lead (97%), zinc (82%), nickel (82%) silver (80%) and copper (36%). Almost all the zinc and lead produced are used for electric cars, and rust-proofing (anodizing), they are considered "green metals" and there have been no major discoveries of these metals for over 20 years. The real challenge is that the need for metals is going to increase exponentially due to increasing global industrialization and the shift in the economic status of billions of people. We need to discover the new resources required for global sustainability, security, and growth.

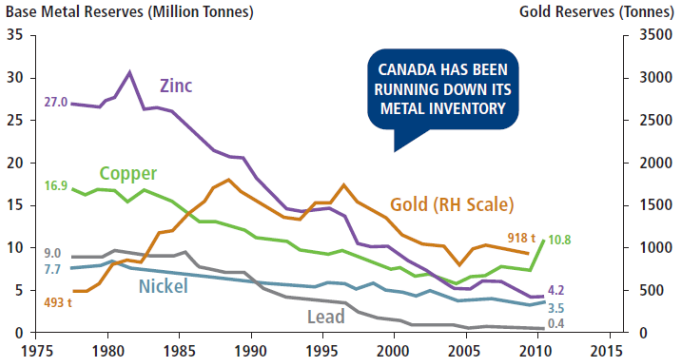


Figure. 1. Canada's Metal Resources. NOTE: Refers to metal contained in Proven and Probable Mineable Ore in Operating Mines and Deposits committed to Production. SOURCE: NRCan.

Notwithstanding the current recession in the Mining sector, in the period of 2005-2010, there has been an unprecedented drop in the number of significant discoveries despite record exploration expenditures (Fig. 2).

Every discovery is important, but World-Class discoveries are essential as 80% of global metal resources are contained in the largest 20% of deposits. Real economic and societal impact only comes from the discovery of World-Class deposits. Metal deposits are rare (metal concentrations of 1000x their average crustal abundance is required), small, and more difficult to find than a needle in a haystack (the surface footprint of an average underground mine is less than 3 city blocks; all mining activities in Ontario occupy <0.05% of the provincial landmass). To compound this, new deposits are more difficult to discover because they are increasingly hidden and "deeper", and the resources in existing brown fields mining districts are finite. However, in remote or "Greenfields" parts of Canada. where real opportunities exist for the discovery new World-Class deposits, exploration is challenging, and this is reflected in lower success rates. In part, this reflects a lesser understanding of the geology of Canada's North and Far North and the limited effectiveness of current exploration tools and models in such remote environments. We clearly need new tools and concepts to identify the most metal endowed and prospective areas of our vast North and Far North.

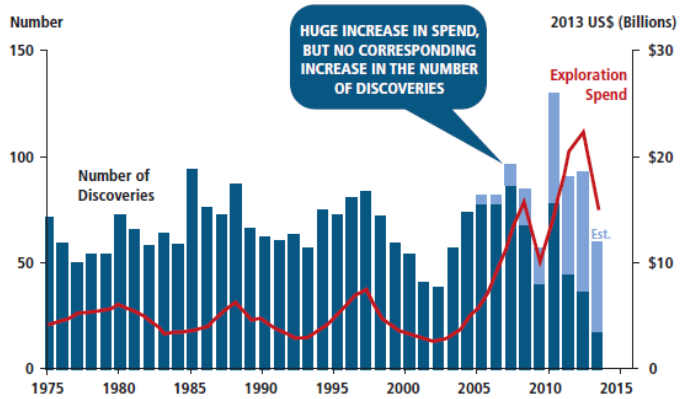


Figure 2. Canadian Exploration Expenditures and Discoveries. NOTE: Based on Moderate, Major and Giant discoveries. Excludes satellite deposits within existing Camps. Also excludes Bulk Mineral discoveries and expenditures. Source: MINEX consulting, Sept., 2014.

Exploration dollars are leaving Canada. For decades Canada was the preferred destination for global exploration expenditures. From 2003-2013 exploration expenditures in Canada have dropped by 40% ($18 Billion in lost investment), compared to 24% for Australia, our closest competitor. Australia is now the preferred destination for global exploration dollars. Fewer exploration dollars means fewer discoveries and fewer mines.

90% of Canada's known resources are south of 60˚ north latitude, and over 95% of our mines are south of 55˚, yet the same geology extends throughout Canada's Far North. How do we focus exploration in such a vast area as Canada's North and Far North, and how do we increase discovery rates?

There are 100s of millions of tonnes of "stranded, uneconomic" base and precious metal resources in Canada's Far North which would be developed if there were adequate infrastructure and a return to slightly better metal prices.

Recommendations:

To increase discovery rates, increase investment of global exploration dollars in Canada, to discover the mines, and to fully engage First Nations peoples to be leaders in the sustainable development of Canada's North and Far North we need to (list not prioritized):

- Upgrade our fundamental geoscience data coverage: the existing one quarter million scale geological mapping of Canada's North and Far North, and the current mapping of the Far North (e.g. GSC-GEMS II) although welcomed, does not have the required resolution and level of detail to support effective exploration. We need higher resolution geological mapping of areas with known resources e.g. Hackett River district, Nunavut (last mapped in 1972), and areas known to have higher metal endowment. This will require increased funding to support geoscience and targeted mapping surveys- geological mapping, geophysics and geochemistry - traditionally conducted by NRCan, provincial, and territorial geological surveys, or possibly through new mechanisms, such as university-based research centres.

- Remove roadblocks to global exploration investment in Canada by reducing areas withdrawn from exploration, or lands encumbered by First Nation Issues (e.g. Ring of Fire). First Nations need to be recognized as co-owners of Canada's northern mineral resources. For example, in Nunavut the Inuit own many of the known mineral tenures and the mining industry works well with them, and in the USA a Native group is co-owner of the World-Class Red Dog mine. We cannot have First Nations feeling solely as adversarial owners of environmental protection. Co-ownership of mineral tenure would broaden their veiwpoint.

- Provide industry with the new tools, protocols and models needed to make the next generations of Greenfields exploration discoveries and new mines. This cannot be done by traditional ore deposit research or by individual researchers working alone. To be successful, to innovate, we need to financially support and grow our mineral exploration research centres such as MERC at Laurentian and MDRU at the University of British Columbia, as they can assemble, grow and sustain the multidisciplinary research teams required to solve fundamental research problems and to innovate. An example is MERC's Metal Earth mega-project, which will change our understanding of the processes responsible for metal transport and economic concentration during Earth's early evolution, and transform how we explore for metals by providing new tools and knowledge to aid exploration.

- Increase government funding directly and/or through federal agencies (e.g. NSERC) to leverage more industry dollars to support successful exploration research within university-based research centres and by directly supporting applied exploration research driven by industry consortiums such as the Footprints Project of the Canadian Mining Innovation Council (CMIC), which represents a consortium of 27 mining companies and 24 universities. CMIC coordinates research efforts on some of the big challenges facing the Canadian Exploration Industry. The big-science, multidisciplinary, mineral exploration research programs such as Metal Earth conducted by university research centres like MERC provide the only mechanism to bring the best minds in Canada (and globally) together and to provide students (HQP) with the education and training needed to become Canada's next generation of thought-leaders in mineral exploration research. Young graduates with the appropriate education and skills are the key to the discovery of future mines.

- New funding to develop programs that target Aboriginal youth (high school level) for careers in the mining sector, and to develop and support new mining and mining related programs at both colleges and universities including Indigenous Access programs that provide transitions and pathways into the fields of Geology, Engineering, and Environmental science.

METAL EARTH

Members of the Harquail School of Earth Sciences in attendance at the CFREF funding announcement on September 6, 2016.

Metal Earth is a Seven-year $104 million applied Research and Development initiative led by MERC. The funding consists of a $49.3M grant from the Canada First Research Excellence Fund (CFREF) and $55 million cash and in-kind from Laurentian University, Federal, Provincial, Territorial, Academic, and Industry Partners. Outlined below is a summary of Metal Earth, how it was developed, its' goals, scientific capacity and partnerships, and research activities.

The CFREF Proposal was developed by:

- Establishing working groups within the Harquail School of Earth Sciences to identify knowledge gaps in our understanding of Precambrian gold and base metal deposits
- Consulting with recognized industry experts
- Discussions with government and academic colleagues
- Industry and academic workshops
- What we learned is that a major impediment to exploration success is how to identify metal endowed areas from the vast areas that are geologically similar, but have less or no metal endowment

Notification of the success of the Metal Earth proposal was received in September 2016. The CFREF Scientific Review panel indicated that "the Metal Earth proposal presented the strongest scientific merit among the proposals considered by the Panel and that it was the most clearly presented, being driven by clear scientific hypotheses that demonstrated strong internal scientific leadership."

Metal Earth will:

- Build on existing knowledge of ore deposits/districts to **resolve ore system-scale controls on metal endowment** on an unprecedented scale of cratons through greenstone belts to districts and deposits
- Image **entire ore and non-ore systems at full crust-mantle scale** to identify key geological-geochemical-geophysical attributes that explain the processes responsible for the extraction of metals from sources, transport pathways, and economic concentration.
- Relate **deep earth features to specific distribution of ores**
- Place **equal emphasis on less endowed areas** to identify fingerprint measurable differences that resulted in contrasting metal endowment
- Research, develop, and use **new 3D-4D data integration, analysis, and visualization** tools to address the significant challenges of deposit-to-craton scale data integration to aid in the discovery of new deposits

Building Scientific Capacity

Metal Earth's Principal Investigators:

Prof. Harold Gibson, Laurentian U, Director, VMS deposits, Volcanology, Geochemistry
Prof. Bruno Lafrance, Laurentian U, Associate Director, Structural Geology and Tectonics
Dr. John Ayer, Laurentian U, Adjunct Prof and MERC Associate Director, Precambrian Geology
Prof. Georges Beaudoin, U Laval, Stable Isotopes
Prof. Réal Diagnault, U Québec - Chicoutimi, Precambrian tectonics and Structural Geology
Prof. Michael Hamilton, U Toronto, Geochronology and Precambrian Geology
Prof. Mark Hannington, Ottawa U, Seafloor Tectonics and Metallogeny
Prof. Daniel Kontak, Laurentian U, Gold and Ore Fluids
Prof. Michael Lesher, Laurentian U, Magmatic Ore Deposits and Geochemistry
Prof. Graham Pearson, U. Alberta, Mantle Processes
Prof. Jeremy Richards, U Alberta / Laurentian U, Metallogeny and Tectonics
Dr. Steven Shirey, Carnegie Institute of Science, Precambrian Geology and Mantle Processes
Prof. Richard Smith, Laurentian U, Exploration Geophysics – Electromagnetics
Dr. David Snyder, Geological Survey of Canada, Geophysics – Seismology
Dr. Philips Thurston, Laurentian U, Adjunct Prof, Precambrian Geology

Geological Survey Partners:

Canada (GSC)
Ontario
Quebec
Manitoba
Northwest Territories
Nunavut

Academic Partners:

University of Alberta
University of Laval
University of Ottawa
University of Québec - Chicoutimi
University of Toronto
University of New South Wales

Research Centre Partners:

Carnegie Institute for Sciences (Washington, DC)
Centre for Exploration Targeting (Perth, AU)
Centre of Excellence in Ore Deposits (Hobart, AU)
MIRARCO (LU)
CEMI (LU)

Initial Industrial Partners:

Mira Geosciences
Noront Resources
TMAC Resources Ltd
Vale Canada Ltd
More to come…

New Faculty and Highly Qualified Persons (HQP):

5 *new* full-time Faculty Positions

- Chair in Exploration Targeting (LU)
- Exploration Seismology (LU)
- Precambrian Geology (LU)
- Earth Systems Modeling and Data Analytics (LU)
- Economic Geology (UQAC)

Over 100 HQP Positions

- 35 Research Associates/PDF
- 9 technical support positions
- 30 PhD
- 40 MSc
- 105 BSc

Metal Earth's Research Strategy is to:

- Initially focus on **Archean greenstone belts**, which represent 80% of Earth history, 30% of Canada's Far North rock exposure, and almost 50% of Canada's metal wealth
- Determine the **processes responsible for differential metal endowment** in the Archean and a new understanding of secular changes in the evolution of Earth's atmosphere, hydrosphere, lithosphere, mantle, and geodynamic processes and environments
- Conduct **Craton-belt-district-deposit scale** research and integration
- Study **endowed and less endowed** geological "equivalents"
- Undertake integration, analysis, and visualization of **multiparameter** geoscience data

Metal Earth involves Four integrated activities:

1. **Craton-scale research** to understand greenstone belt architecture and the interaction of greenstone belts with their surrounding granitic rocks during terrane assembly and ore district formation
2. **Transect research** where more detailed studies will resolve the lithospheric-crustal architecture and fluid (magma/heat) pathways, providing a geological framework to resolve the differential endowment of terranes and structures
3. **Thematic research** from craton to deposit scales will address specific processes or questions on metal endowment
4. **Data Analytics research** to develop new data integration, analysis and interpretive tools to predict metal endowment

Craton Research: Years 1-6 (fig. 3)

- New understanding of the 3D and 4D architecture of the Superior and Slave cratons
- Compilation of regional geoscience data
- New zircon Lu-Hf, Sm-Nd, and O isotopic data to map time-slices of the secular variations in assembly of cratons and identify mantle-crustal pathways
- Live and extinct radionuclide isotopic tracer systems and PGEs on mantle rocks and mantle-probing crustal rocks to map mantle metal reservoirs

Transect Research: Years 1-5 (figs. 4 & 5)

- Transects across endowed gold-rich ancestral fault systems and volcanic centres with gold and base metal deposits, twinned by transects across less endowed ancestral fault and volcanic centres with similar geology
- Collection, integration, interrogation, and visualization of complex multiparameter geoscience data (seismic, magnetotelluric, gravity, and surface geological, geochemical, geophysical data)
- 4D Slices from mantle to crust

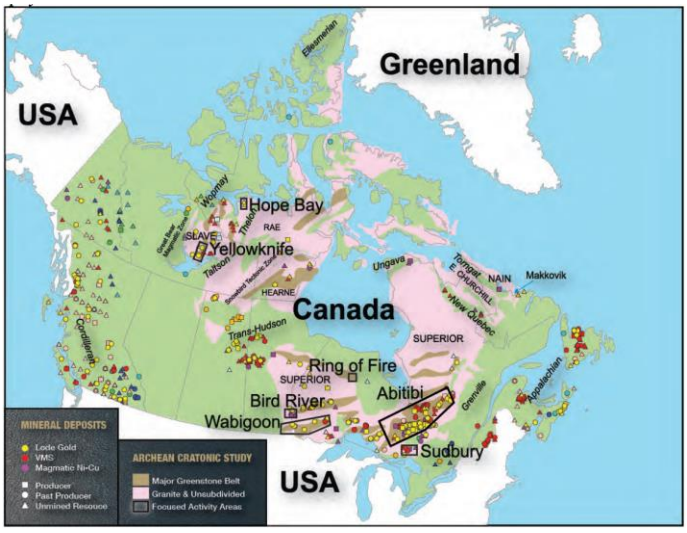


Figure 3. Metal Earth's areas of Focus within the Canadian Shield.

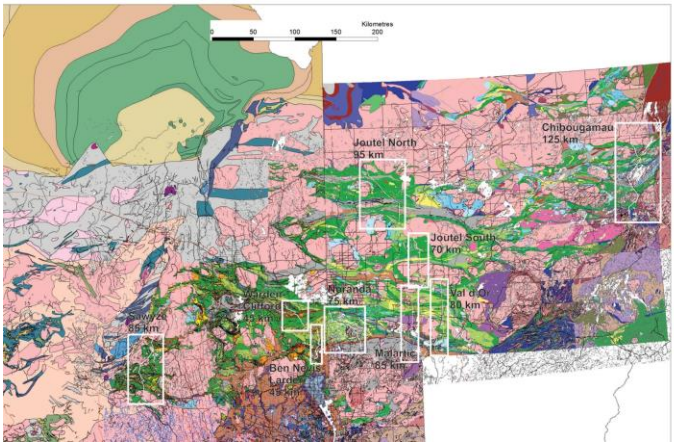


Figure 4. Proposed transects for seismic, magnetotelluric, and gravity surveys along with geological mapping and data collection in the Abitibi greenstone belt.

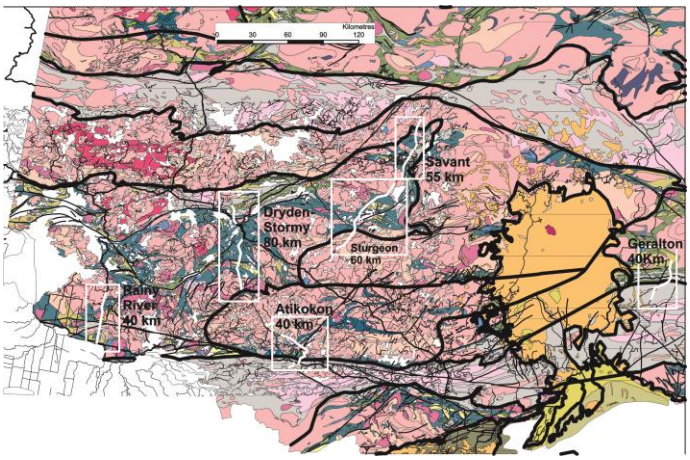


Figure 5. Proposed transects for seismic, magnetotelluric, and gravity surveys along with geological mapping and data collection in the Wabigoon Subprovince.

Other Transects Areas
Sudbury (active seismic)
Bird River Sill (active seismic)
Ring of Fire (passive seismic)
YellowKnife (passive seismic)
Hope Bay Belt (passive seismic)

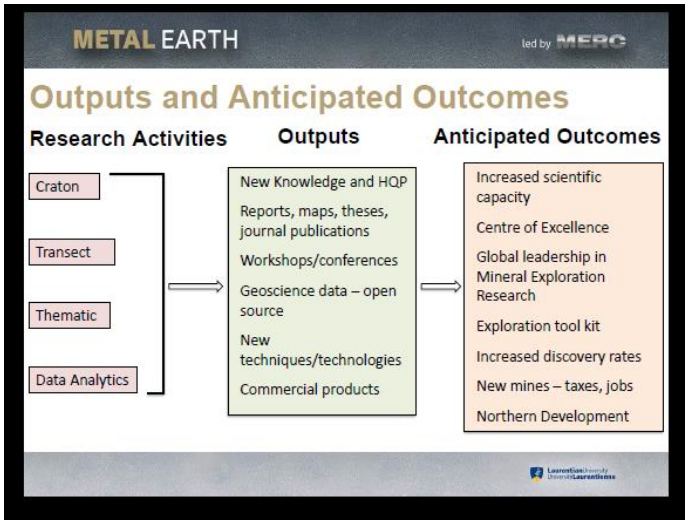
Thematic Research: Years 3-7

- Research at the craton- district- deposit scale directed at answering fundamental questions pertaining to features/processes associated with metal endowment
- General Themes
  - Fluid/magma/heat pathways
  - Subcontinental Lithospheric Mantle variations/differences in endowed and less endowed areas
  - Fluid and metal sources in mantle and crust
  - Archean tectonics and metallogeny

Data Analytics: Years 1-7

- Geoscience data from Craton, Transect, and Thematic studies will be integrated, analyzed, interrogated and visualized using a goCAD Common Earth Model
- Strategic partnership with MIRA Geosciences
- Explore other software - Geoscience ANALYST/INTEGRATOR, Geon IDV (time stamp data sets), Machine learning
- Build on established best practices from the Laurentian University-led “Exploration Footprint” project
- Visualization using Laurentian University and University of New South Wales Virtual Realty Labs
- Develop new integration, analysis, and visualization techniques for **multiparameter** geoscience data
- Commercialization

Metal Earth’s Outputs and Anticipated Outcomes



MERC Foundation Members

Ontario Geological Survey, Ontario Ministry of Northern Development and Mines

David Harquail

MERC Tier 1 Members

Detour Gold Corp.

Ivanhoe Mines Ltd.

Kinross Gold Corp.

KGHM International

Teck Resources Ltd.

MERC Tier 2 Members

Northern Superior Resources Inc.

Sudbury Integrated Nickel Operations
A Glencore Company