MERC
Mineral Exploration Research Centre

METAL EARTH

Laurentian University
Université Laurentienne
HARQUAIL SCHOOL OF EARTH SCIENCES ÉCOLE DES SCIENCES DE LA TERRE

Dr. Harold Gibson
Director, Metal Earth
Porcupine Geological Discussion Group 10/2017

METAL EARTH:

A $104 million research project that will help industry unlock Earth's mineral wealth

Outline

- A brief description of MERC, the Mineral Exploration Research Centre, at the Harquail School of Earth Sciences
- Canada First Research Excellence Fund – the foundation of Metal Earth
- What is Metal Earth: goals, strategy, and research activities
- Preliminary results

WHO WE ARE

Established in 1997, MERC is world-class, self-sustaining, geoscience centre focused on Exploration, and Precambrian ore systems research

Conducts cutting-edge, field-based, collaborative research, educates and trains highly qualified geoscientists and professionals, and develops new exploration tools

Expends >$2.0 M annually in research, with funding from industry, NSERC and government sources

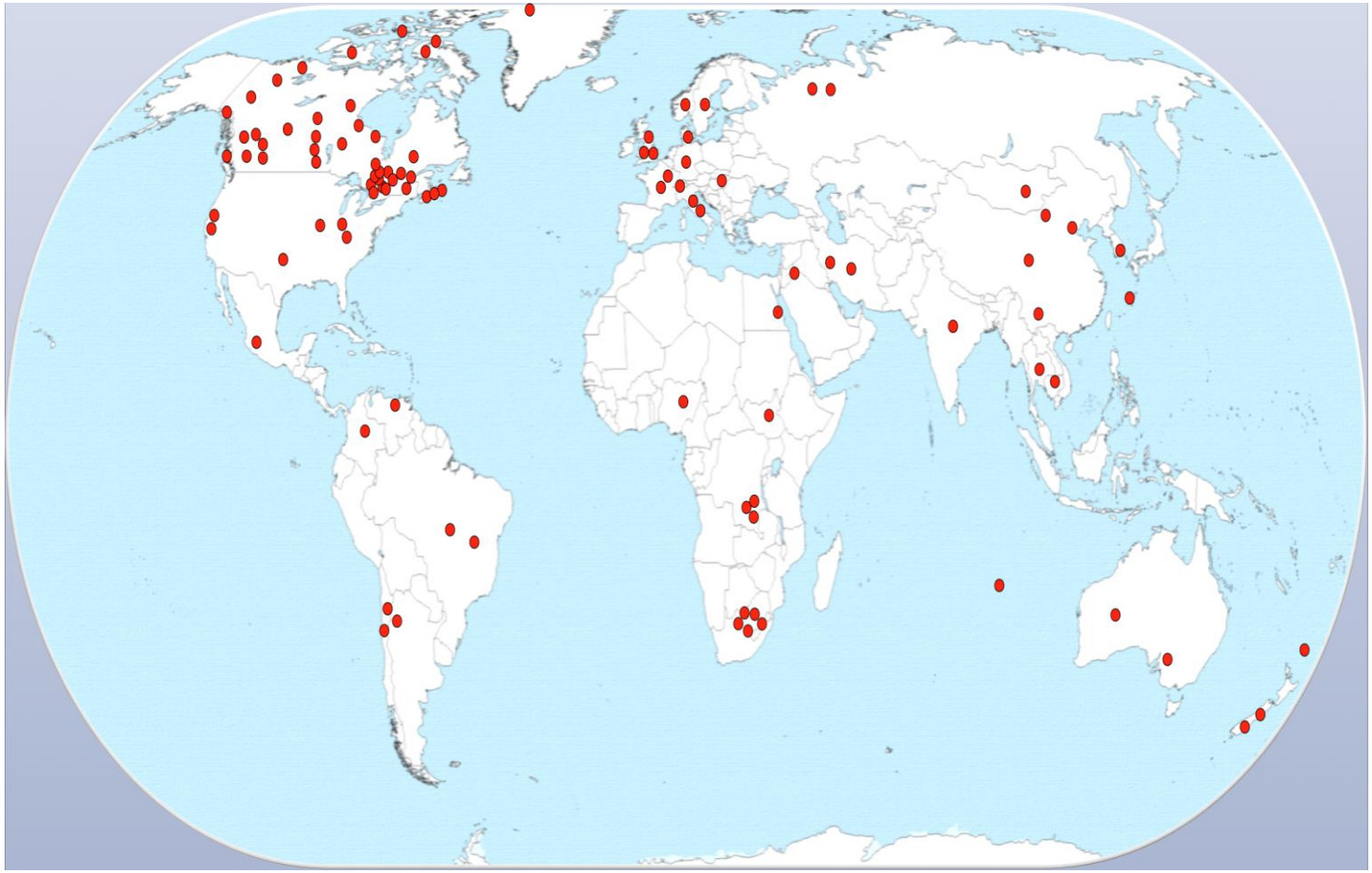
>100 faculty, research scientists, and graduate students working globally

– Largest centre in North America and with Global Reach!

GLOBAL REACH

Ore systems studied:

- Gold
- Zinc-copper
- Chromite
- Ni-Cu-PGE
- Rare-metals
- Zinc-lead
- Uranium



ANALYTICAL FACILITIES

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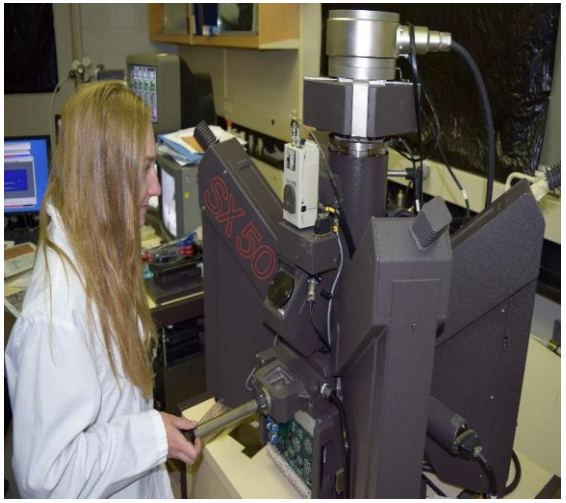

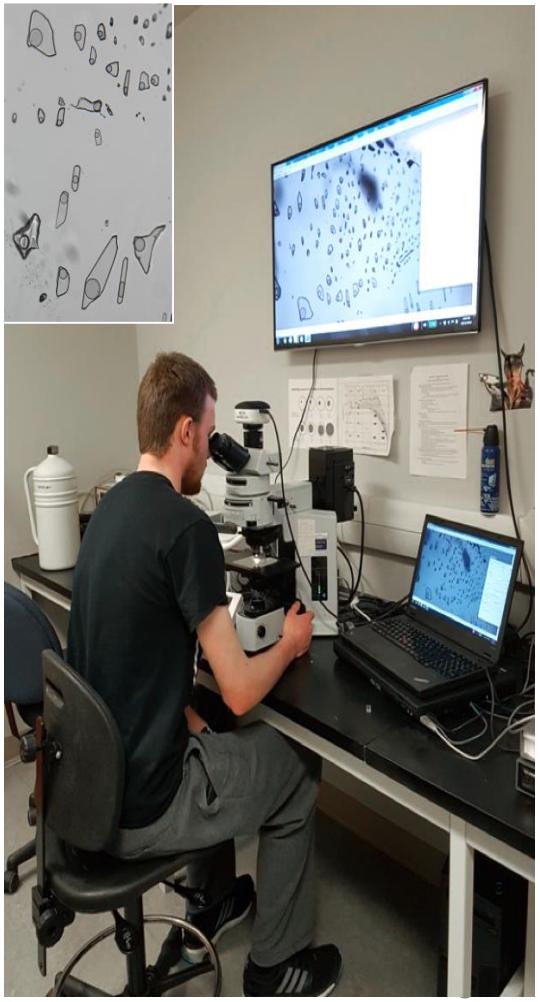

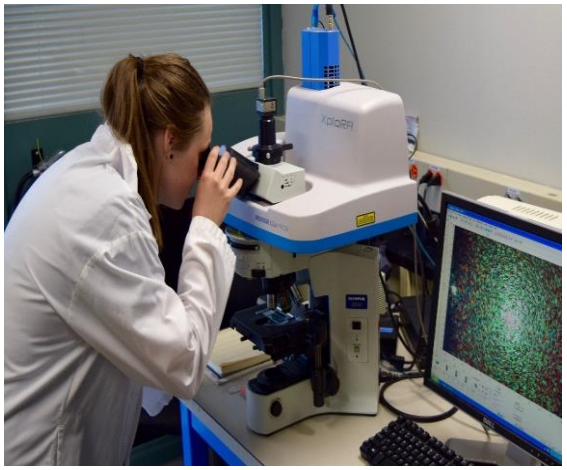

ANALYTICAL FACILITIES

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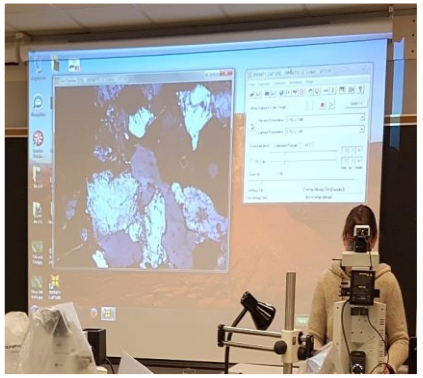
A new laser ablation multi-collector ICP-MS instrument will be installed in the coming months.



$500K microscope lab!

MERC Research Partnerships

Funding Sources through Collaboration

- ✓ National Science and Engineering Research Council (NSERC) of Canada, Collaborative Research and Development (CRD) Grant. Opportunity to leverage industry cash (match) and in-kind contributions to research projects.
- ✓ Other government research programs: e.g. NSERC Engage, NSERC Accelerate, MITACS
- ✓ Partnership with Provincial and Federal government surveys: e.g. MERC-Ontario Geological Survey Mapping program, NRCan's TGI and GEMS programs
- ✓ Direct Industry Funding

THE MERC DIFFERENCE

- ✓ MERC's focus on mineral exploration, not mineral deposit research, differentiates MERC from other global research centres
- ✓ MERC develops exploration models – a step beyond traditional ore deposit models
- ✓ Metal Earth is a natural evolution of MERC's exploration research focus

MERC Members

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Foundation Members

BARRICK

KLG | KIRKLAND LAKE GOLD

125 Anniversary 1891 Ontario Geological Survey

Université Laurentienne Laurentian University

GOODMAN École des Mines School of Mines

Tier 1 Members

DETOUR GOLD

GOLDCORP

IAMGOLD CORPORATION

IVANHOE MINES NEW HORIZONS

KINROSS

Teck

Tier 2 Members

KGHM

SUDBURY INTEGRATED NICKEL OPERATIONS A GLENCORE COMPANY

McEWEN MINING NYSE MUX TSX

NORTHERN SUPERIOR RESOURCES

PELANGIO

Taseko

VALE

METAL EARTH: WHAT IS IT?

- **Fully-funded** seven-year $104M applied R&D initiative led by MERC

- $49M CFREF + $55M cash and in-kind from Laurentian, and 22 Federal, Provincial, Territorial, academic, private sector, and industry partners

- A consortium of outstanding Canadian and international researchers from academia, government and industry

METAL EARTH

METAL EARTH: WHAT is CFREF?

Canada First Research Excellence Fund – CFREF (National Research Initiative)

Mission:

- Help post-secondary institutions excel globally in research areas that create long-term economic advantages for Canada

The Fund helps competitively selected institutions:

- Turn key strengths into world leading capabilities
- Make breakthrough discoveries
- Seize emerging opportunities and strategically advance their greatest strengths on the global stage
- Implement large-scale, transformational, and forward-thinking institutional strategies
- http://www.cfref-apogee.gc.ca

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METAL EARTH: WHAT is CFREF? MERC

Canada First Research Excellence Fund – CFREF

Goal was to select Canadian research groups that are in the top 10% in the world and invest to make them global leaders

Round 1, $350M awarded in July 2015 to Laval, Sherbrooke, UBC, Saskatchewan, and Toronto (LU did not apply)

Round 2, $900M awarded in Sept 2016 to 13 universities in Canada (51 universities applied to the program). LU was only application in Geosciences – Exploration

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STRONGEST SCIENTIFIC MERIT

"The panel was of the opinion 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."

Canada First Research Excellence Fund (CFREF) Scientific Review Panel, Sept 2016

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METAL EARTH: FUNDED FOR DISCOVERY

- **$104 million over 7 years (09/2016 – 08/2023)**
- **Largest mineral exploration research program in history**
- **Compares to:**

- **Footprints Project**, NSERC-CRD and Canadian Mining Innovation Council, 2013-2018, $13M/5yrs
- **Targeted Geoscience Initiative 5** (NRcan), 2016-2020, $25M/5yrs
- **Geo-Mapping for Energy and Minerals** (NRcan), 2014-2020, $100M/7yrs
- **Lithoprobe**, 1980-2001, $141M/21 yrs
- **Neptune Canada** (Ocean Networks Canada), 2003 – present, $160M/18yrs
- **International Ocean Drilling Program** (Canadian Component), 2004-present $8.2M/17yrs

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METAL EARTH: CLOSING THE GAP

- Established working groups to identify knowledge gaps in our understanding of Precambrian gold and base metal deposits
- Consulted recognized industry experts
- Held discussions with government and academic colleagues
- Held industry and academic workshops

The take away:

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.

SIGNIFICANT CHALLENGES FACING EXPLORATION

CMIC Footprints Project - 2013-2018

Metal Earth

Brownfields Exploration Deep Mature Camps	Greenfields Exploration Remote & Covered Areas
1. Multi-parameter footprints and 3D vectoring · *Detecting edges and vectoring to ore*	1. Characterization of fertile terranes and districts · *How do we select fertile ground?*
2. Techniques to unravel deep 3D geology · *Deep penetrating detection and mapping techniques*	2.Techniques to map sub-surface geology · *Drilling, data integration* · *Data density for detection*
3. Real-time down-hole data collection · *Real-time decision*	3. Secondary dispersion · *Understanding mechanisms* · *Developing techniques*

(From the Canadian Mining Innovation Council (CMIC) 2013)

METAL EARTH: GOALS

MERC

- To transform our understanding of Earth's early evolution and the processes that govern differential metal endowment – *the fundamental science component*

- To make Canada a global leader in mineral exploration research and world-class innovator through open source delivery of new knowledge and the development and implementation of transformative technologies targeted at increasing exploration success – *the applied, innovation and commercialization component*

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METAL EARTH: STRATEGY

1) Focus on Archean greenstone belts, which represent 60% of Earth history, 30% of Canada's Far North rock exposure, and almost 50% of Canada's metal wealth

1) Resolve ore system-scale controls at craton - greenstone belt - district - deposit scales

2) Image ore and non-ore systems at full crust-mantle scale

3) Relate deep earth features to distribution of ores

4) Develop transformative 3D-4D data integration, analysis, and visualization tools that will aid discovery of new districts and new deposits

METAL EARTH: STRATEGY

Building Scientific Capacity: 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 and Alteration
- **Prof Réal Diagnault**, U Québec - Chicoutimi, Precambrian tectonics and structure
- **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**, 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

METAL EARTH: STRATEGY

MERC

Building Scientific Capacity: Academic and Government Partners

Consortium of outstanding Canadian and International researchers from academia, government, and industry – 21 research partners

- U Alberta
- U Laval
- U Ottawa
- U Québec - Chicoutimi
- U Toronto (JSL)
- U New South Wales

- Geological Surveys
  - Manitoba
  - Northwest Territories
  - Nunavut
  - Ontario
  - Quebec
  - Geological Survey of Canada

METAL EARTH: STRATEGY

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Building Scientific Capacity: Academic and Industry Partners

- Carnegie Institute for Sciences (US)
- Centre for Exploration Targeting (AUS)
- Centre of Excellence in Ore Deposits (AUS)
- Mira Geosciences
- MIRARCO
- CEMI
- TMAC Resources Ltd
- Noront Resources
- Vale Canada Ltd
- ***More to come***…

METAL EARTH: STRATEGY

Building Scientific Capacity: New Faculty and HQP

5 *new* full-time Faculty Positions
Chair in Exploration Targeting (LU) – Dr. Ross Sherlock
Exploration Seismology (LU) – Dr. Mostafa Naghizadeh
Precambrian Geology (LU) – Dr. Stephane Perrouty
Earth Systems Modeling and Data Analytics (LU) – Dr. Leo Feltrin
Economic Geology (UQAC) – Dr. Lucie Mathieu

35 Research Associates/PDFs
9 technical support positions
30 PhD, 40 MSc, 105 BSC students

METAL EARTH: PARTNERS

NORONT

Ministère de l'Énergie et des Ressources naturelles
Québec
Direction générale de Géologie Québec

UNIVERSITY OF ALBERTA

uOttawa

UNIVERSITY OF TORONTO

CARNEGIE INSTITUTION FOR SCIENCE

TMAC RESOURCES

CERM
Centre d'études sur les ressources minérales

125 ANNIVERSARY Est. 1891
ONTARIO GEOLOGICAL SURVEY

UQAC
Université du Québec à Chicoutimi

UNSW
THE UNIVERSITY OF NEW SOUTH WALES

VALE

CODES
ARC CENTRE OF EXCELLENCE IN ORE DEPOSITS

Centre for EXPLORATION TARGETING

Mirarco
MINING INNOVATION

UNIVERSITÉ LAVAL

CANADA-NUNAVUT GEOSCIENCE OFFICE
BUREAU GÉOSCIENTIFIQUE CANADA-NUNAVUT
KANATAMI-NUNAVUMI GEOSCIENCE TITIGAKVIIT

DIVEX
DIVERSIFICATION DE L'EXPLORATION MINÉRALE AU QUÉBEC

Manitoba

Ontario
Northern Ontario Heritage Fund Corporation
Société de gestion du Fonds du patrimoine du Nord de l'Ontario

Northwest Territories

CEMI
Centre for Excellence in Mining Innovation

METAL EARTH: Research Activities

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1) **Craton-scale research** to understand greenstone belt architecture and the interaction of greenstone belts with their surrounding granitoids during terrane assembly and ore district formation – ***initiated 2017***

2) **Transect research** where more detailed studies will resolve the lithospheric-crustal architecture and fluid (magma/heat) pathways, providing a framework to resolve the differential endowment of terranes and structures – **Mantle-crust slices** – ***initiated 2017***

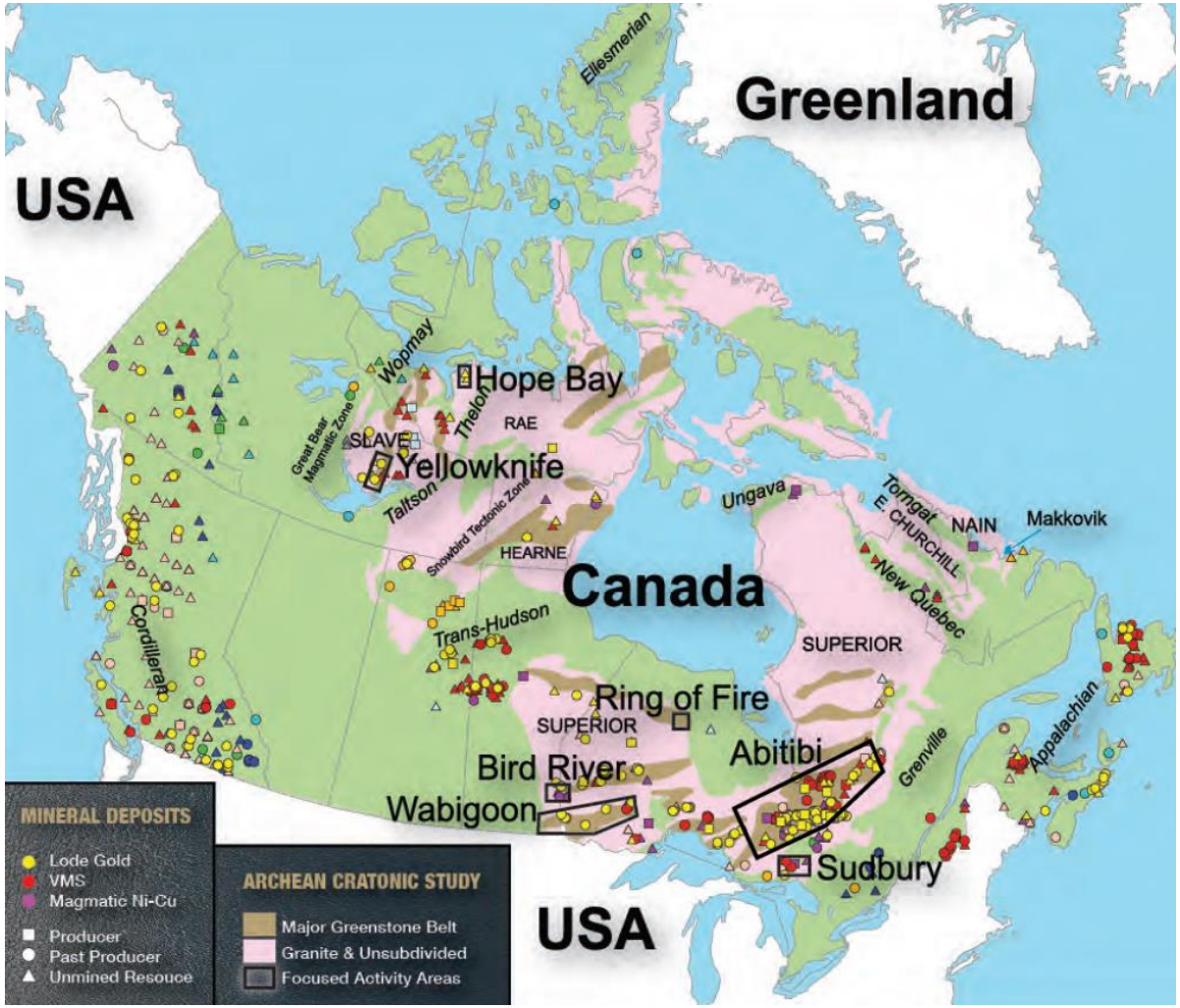
3) **Thematic research** from craton to deposit scales will address specific processes or questions on metal endowment - ***to be initiated 2018***

4) **Data Analytics research** to develop new data integration, analysis and interpretive tools to predict metal endowment – ***to be initiated 2018***

METAL EARTH: RESEARCH AREAS

4 Integrated Activities:

1. Craton Scale Research
2. Transect Scale Research
3. Thematic Research
4. Data Analytics



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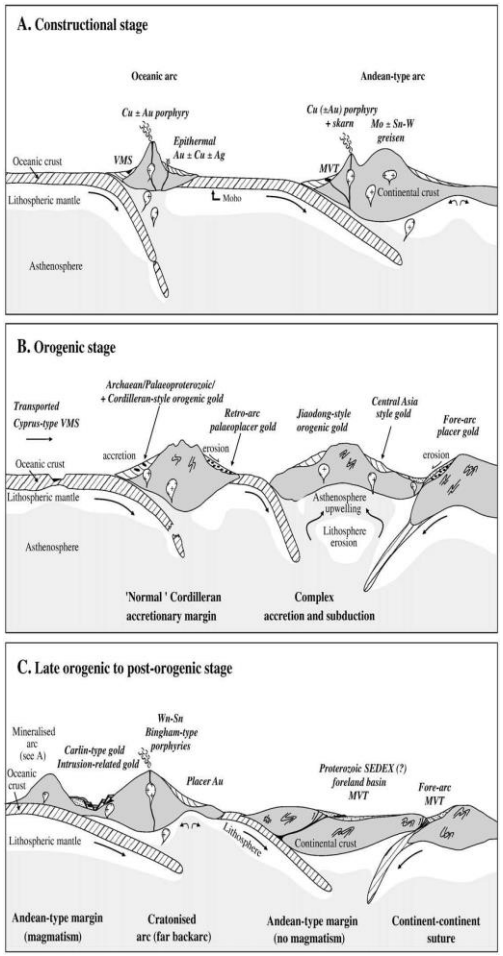
Metal Earth : 4. Data Analytics Research

Data Analytics research will **transform** existing data integration, analysis and interpretive tools to predict metal endowment and guide exploration.

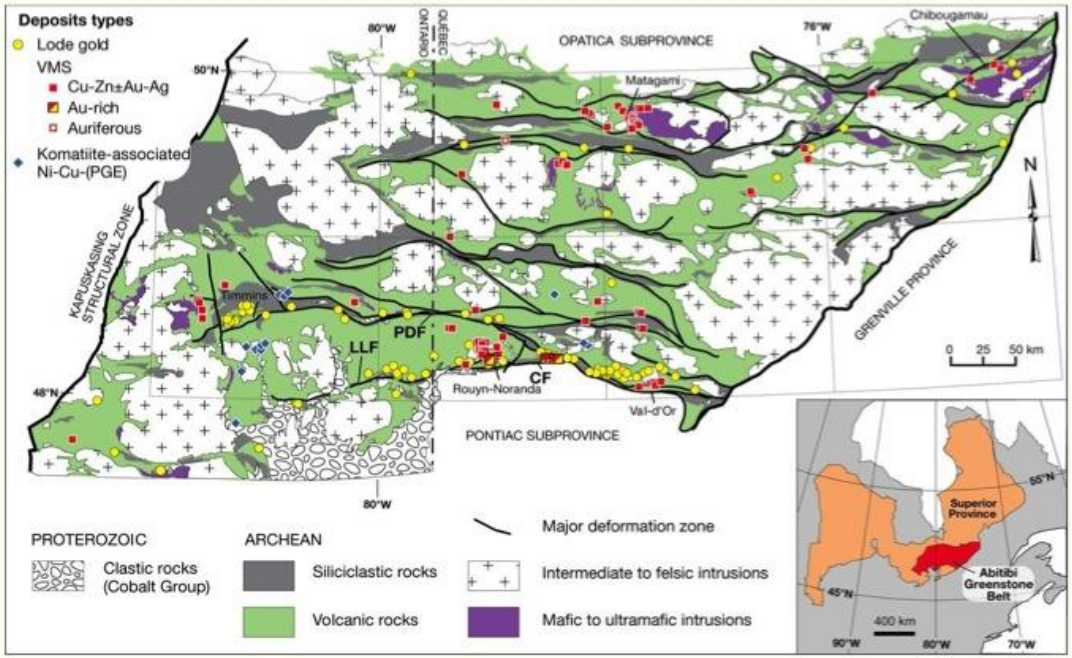
- Data integrated, analyzed, interrogated and visualized using a goCAD Common Earth Model
- Build on established best practices from Laurentian-led “CMIC Footprint” project
- Visualization using Virtual Realty Labs
- Partnership with MIRA Geosciences and CEMI Mining Data Control Control Centre at SNOLAB
- Evaluate potential Artificial Intelligence partners e.g. IBM
- Develop new transformative technologies, modeling algorithms, software tools, and techniques to integrate, interpret and visualize data to aid exploration
- Commercial exploration targeting products starting Year 2019
- **Initiate in 2018**

3. THEMATIC RESEARCH



Thematic research from craton- to deposit-scales will address specific processes or questions on metal endowment and exploration – ***2018 start***

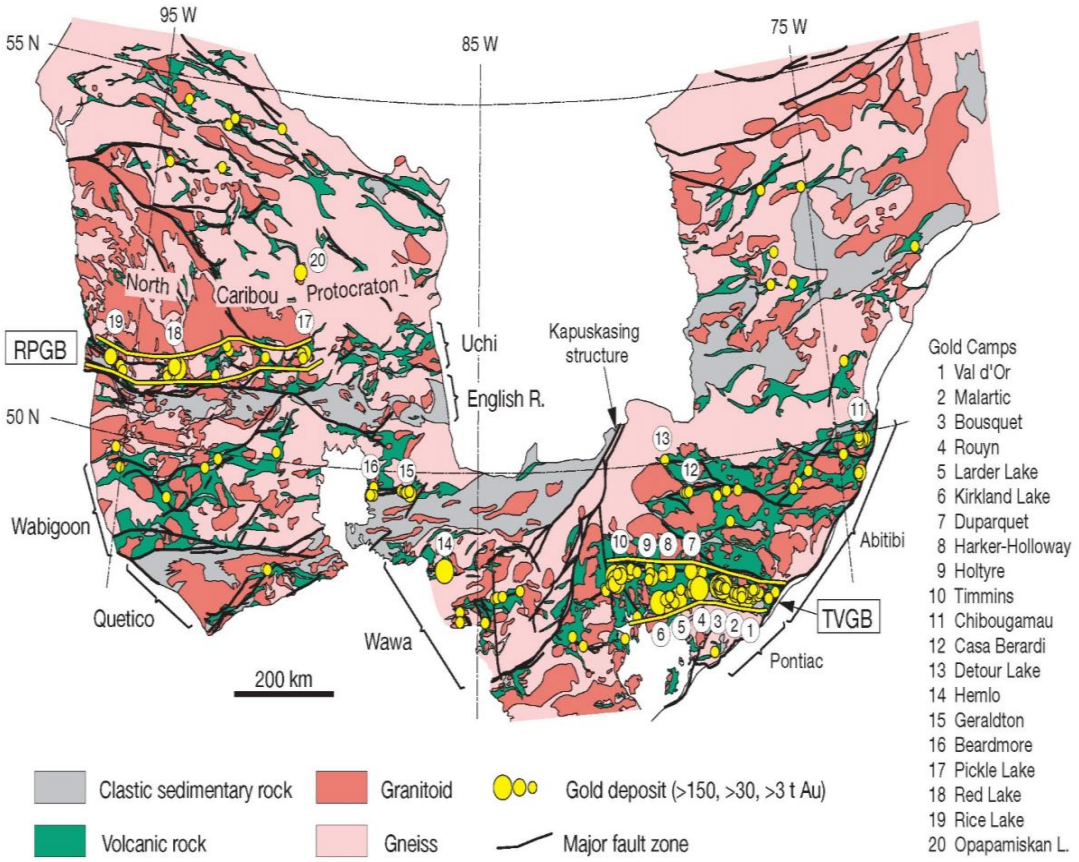
Location of Distribution of VMS Deposits
Abitibi Greenstone Belt
(Mercier-Langevin et al., 2014)



METAL EARTH: 1. Craton Scale

Craton Scale
Superior -Slave Provinces
2017-2022

- New Understanding of 3D and 4D craton architecture
- Compilation of geophysical data (Esi Eshaghi PDF)
- New zircon Lu-Hf, Sm-Nd and O isotopes to map time slices of the secular variations in the assembly of cratons and mantle-crustal pathways (David Mole, Jeff Marsh PDFs)
- The lithospheric architecture an be imaged by isotopic techniques and used to identify regions of higher prospectively
- Mantle metal reservoirs (U of A, Carnegie institute for Science)



1. CRATON SCALE RESEARCH

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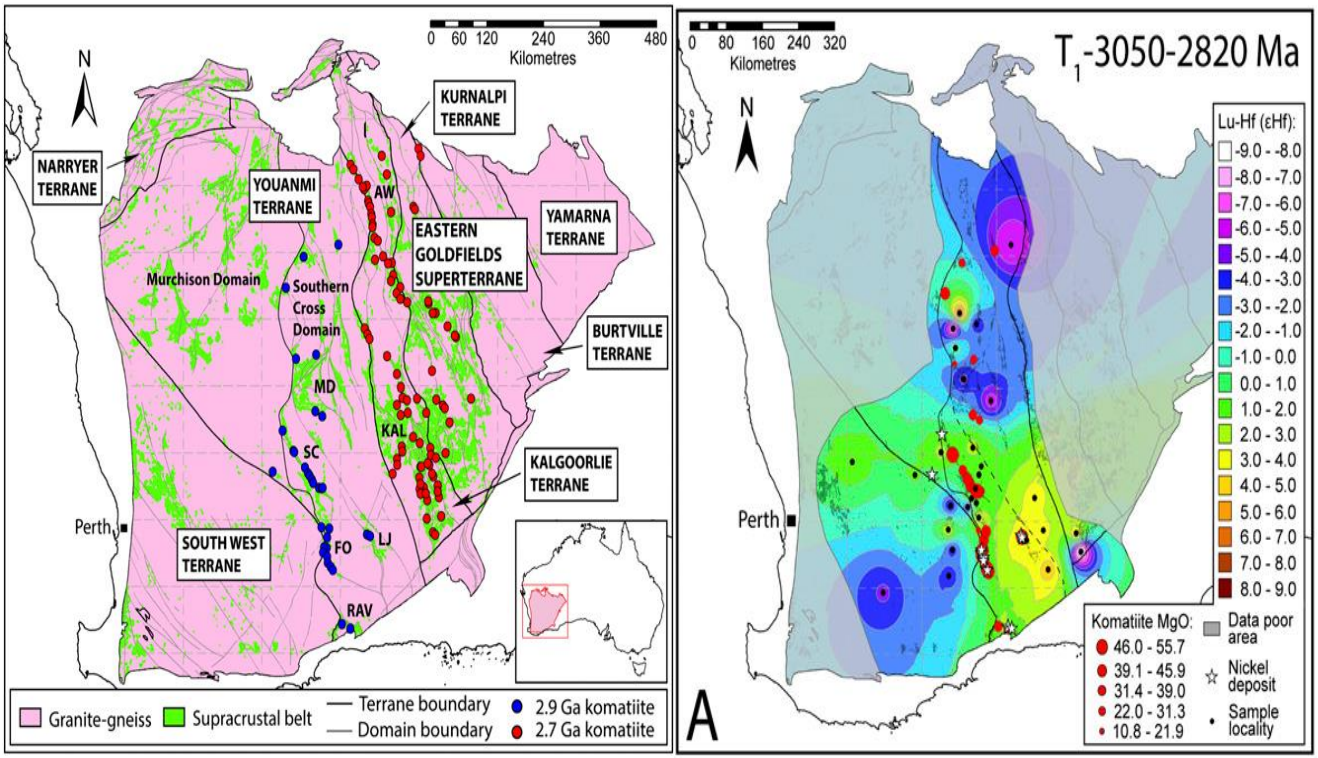
Goal is to determine the controls of greenstone belt architecture and craton assembly on ore district location and formation



Craton Scale Targeting Maps

1. Time-slice lithospheric architectural maps

2. Geophysical compilation and interpretation maps of crustal architecture

METAL EARTH: 2. Transect Scale

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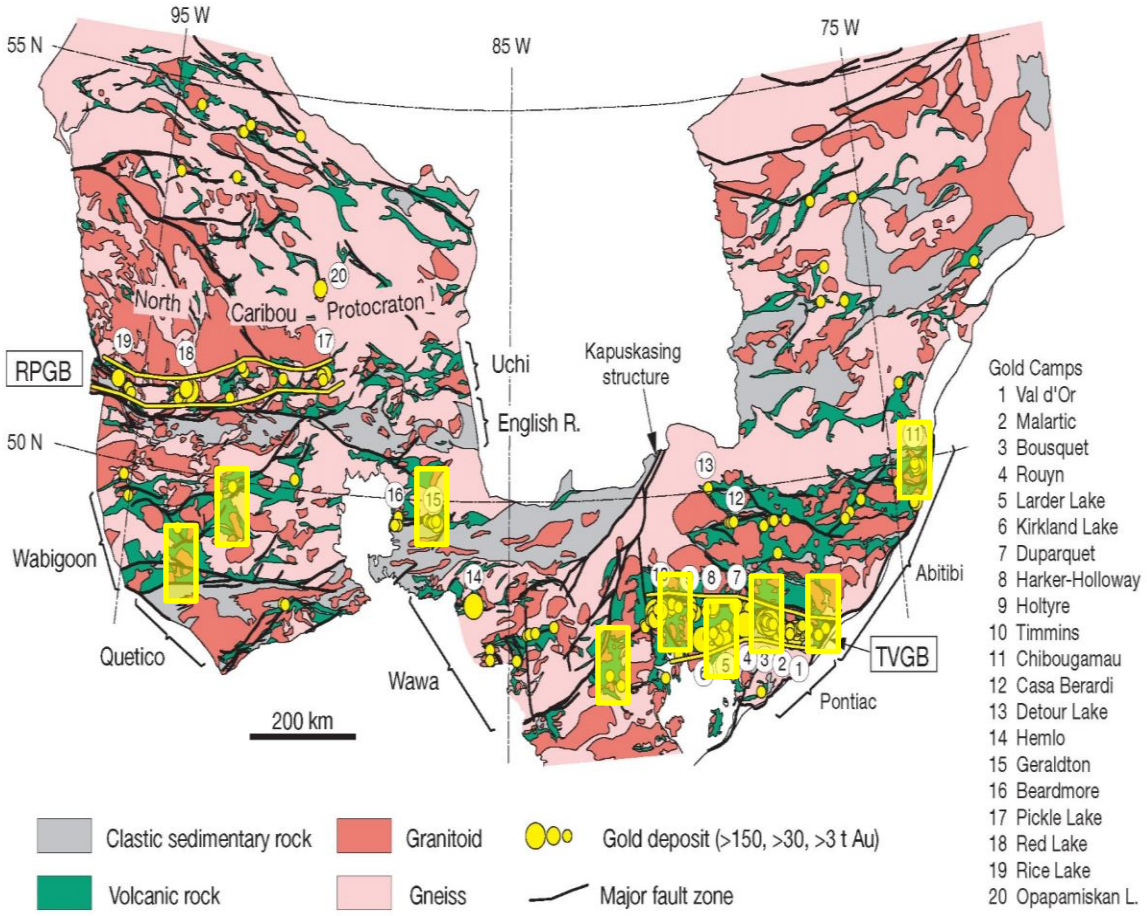
Transect Scale
2017-2021

Southern Abitibi
+ Chibougamau

Wabigoon
- Geraldton
- Dryden
- Fort Francis

Considering endowed and less endowed areas with same level of consideration



From Robert et al. (2005)

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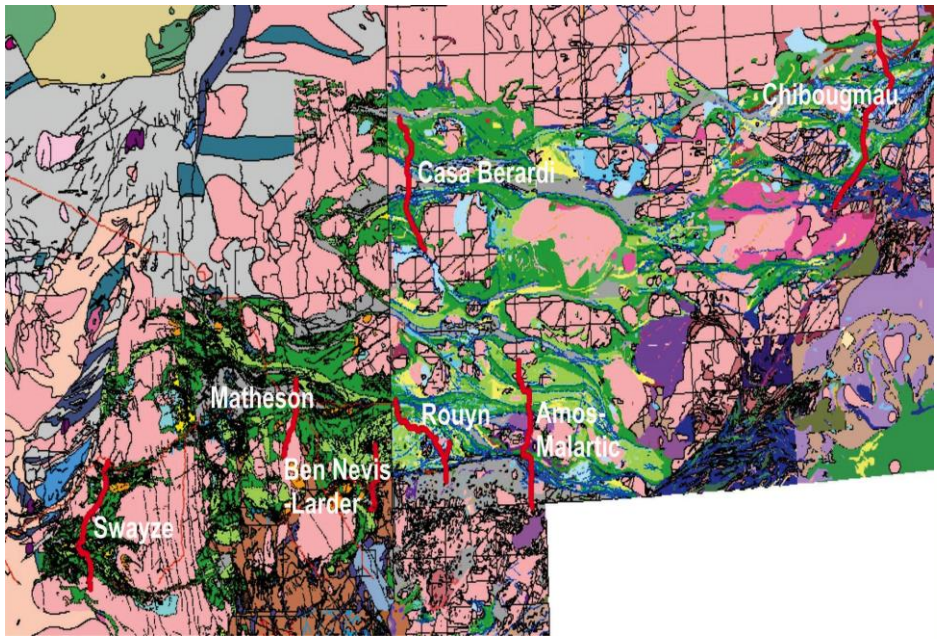
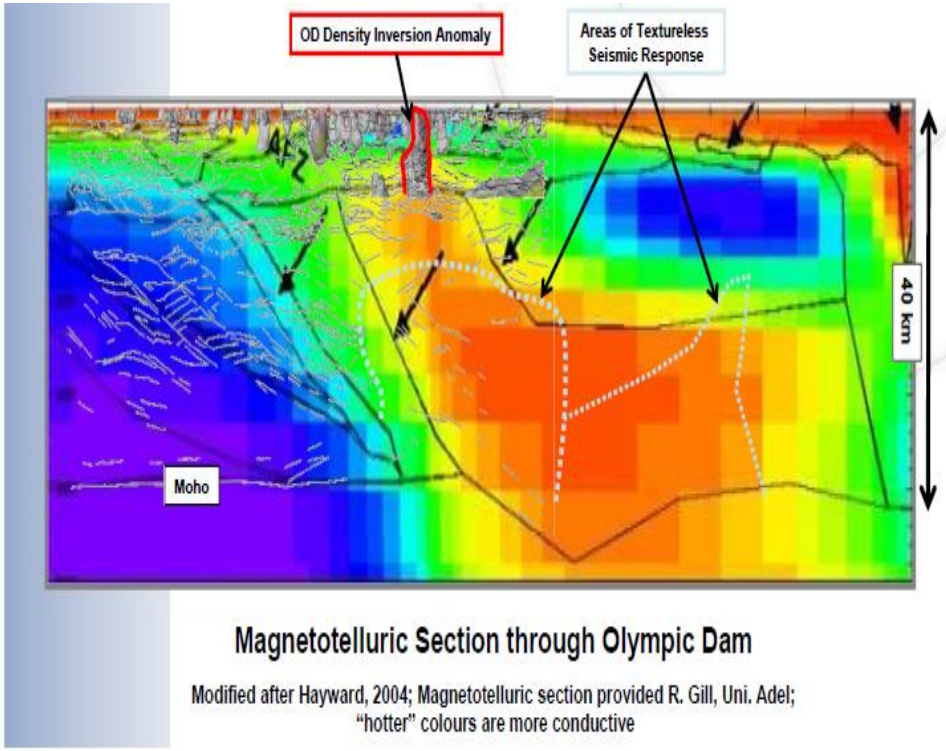
2. TRANSECT SCALE RESEARCH MERC

Crust to Mantle slices will resolve the lithospheric-crustal architecture and fluid (magma/heat) pathways, providing a geological framework to resolve the differential endowment of terranes and structures





Magnetotelluric Section through Olympic Dam

Modified after Hayward, 2004; Magnetotelluric section provided R. Gill, Uni. Adel;
"hotter" colours are more conductive

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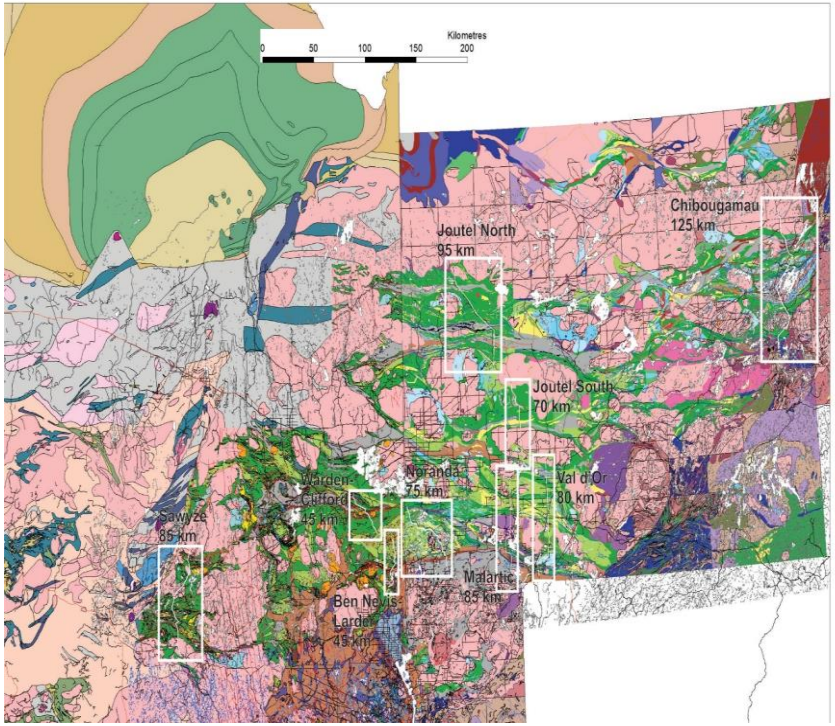
2. TRANSECT SCALE RESEARCH

Chibougamau Transect – Seismic Survey Initiated

(Mostafa Naghizadeh, David Snyder, Saeid Cheraghi)



Chibougamau District Seismic Transect

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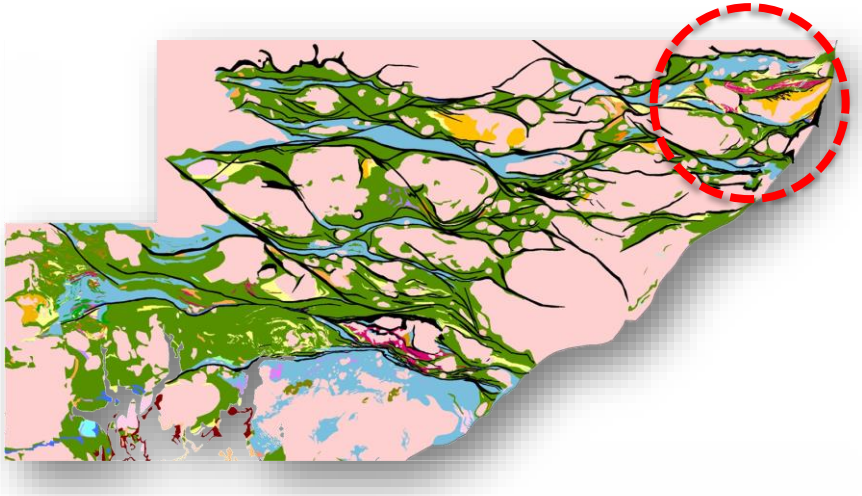

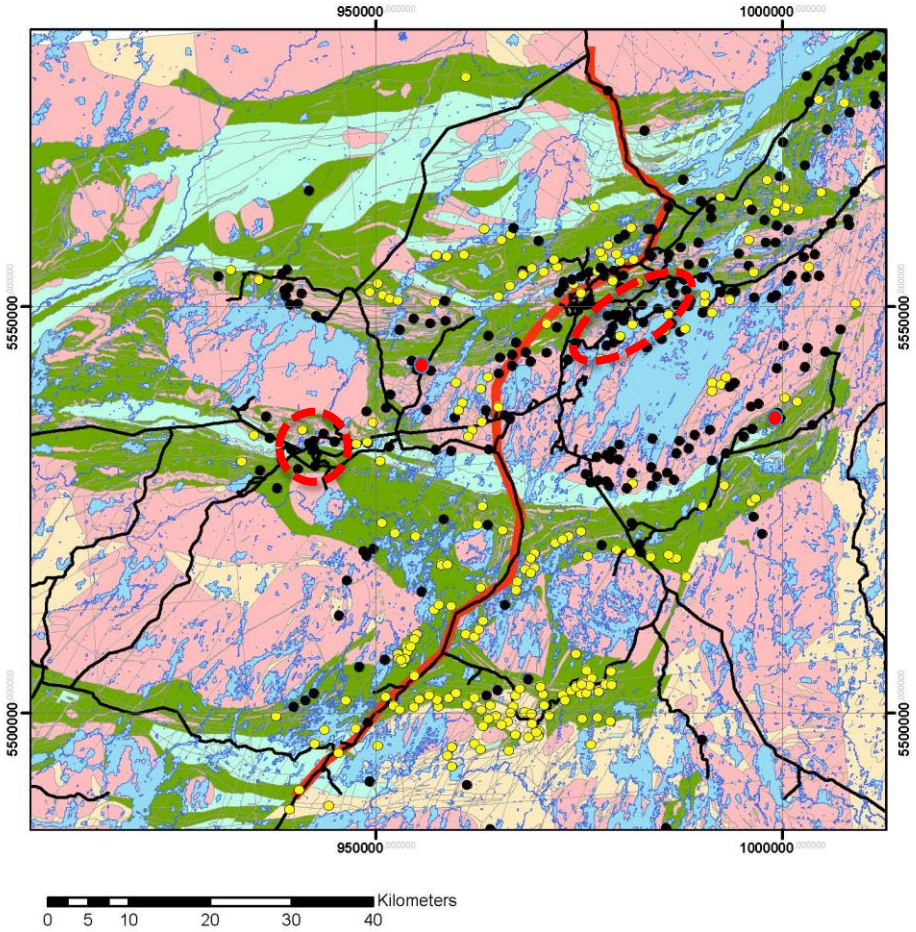

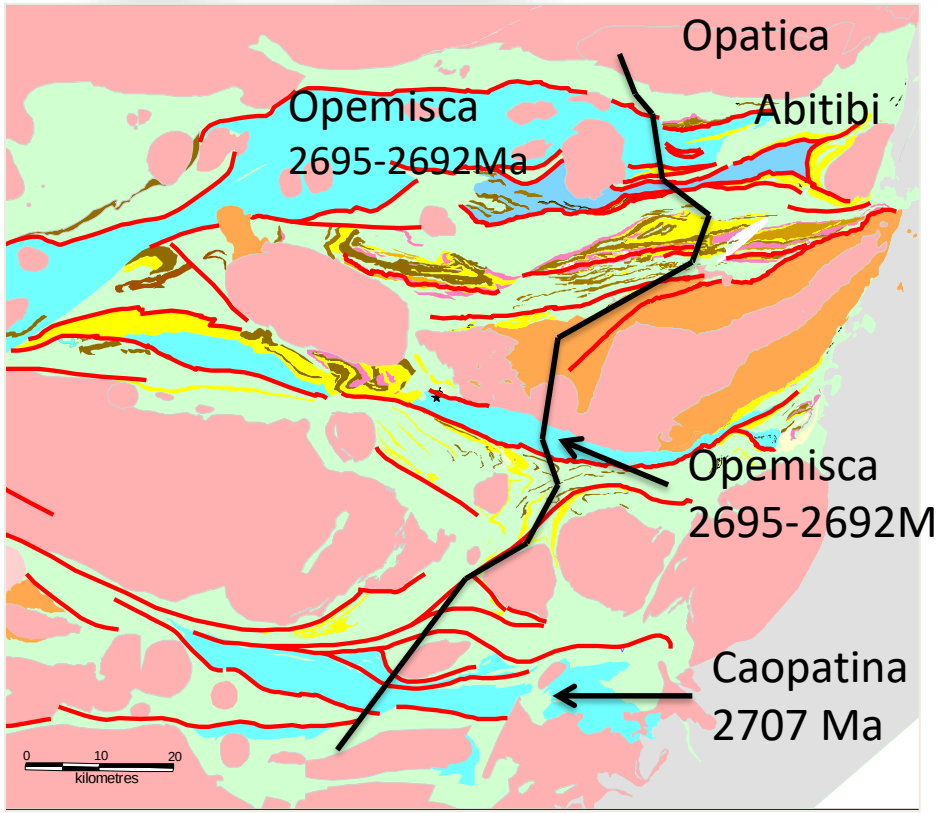

From Daigneault, 2017

Chibougamau District Seismic Transect

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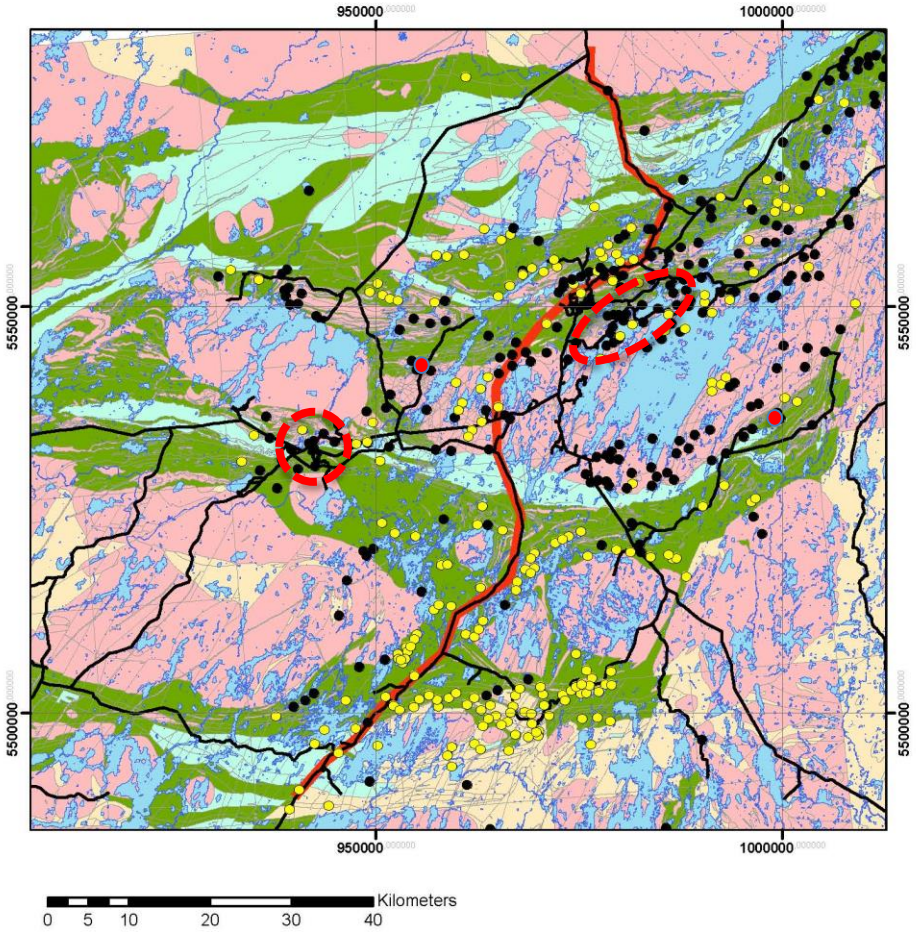
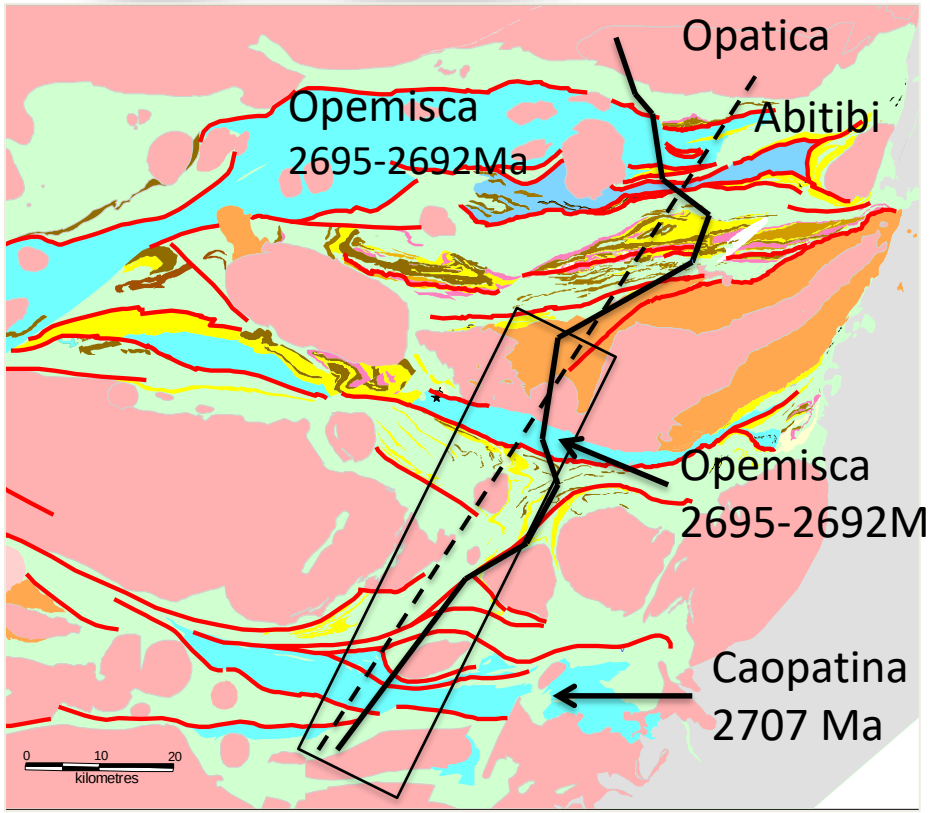
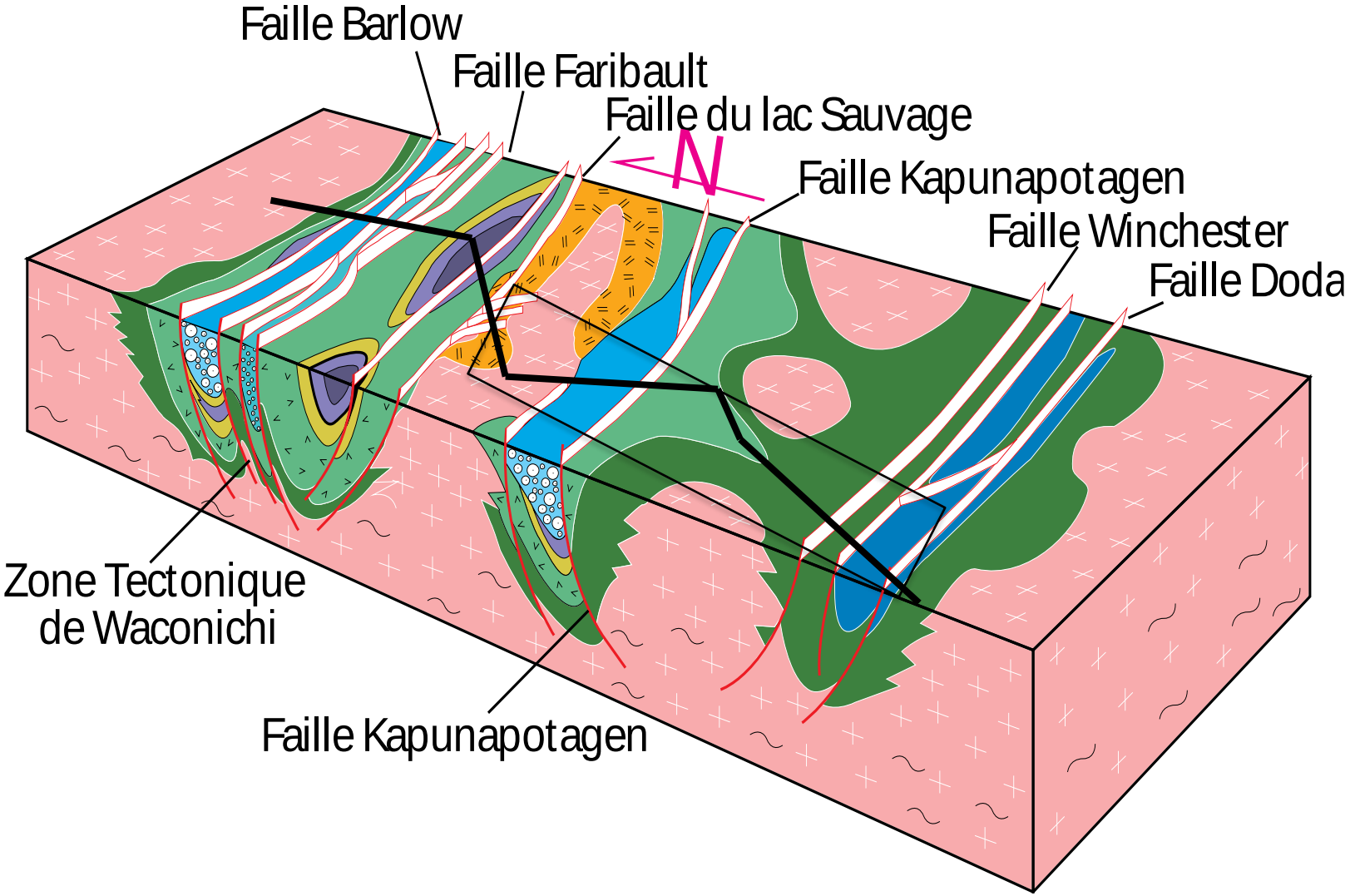




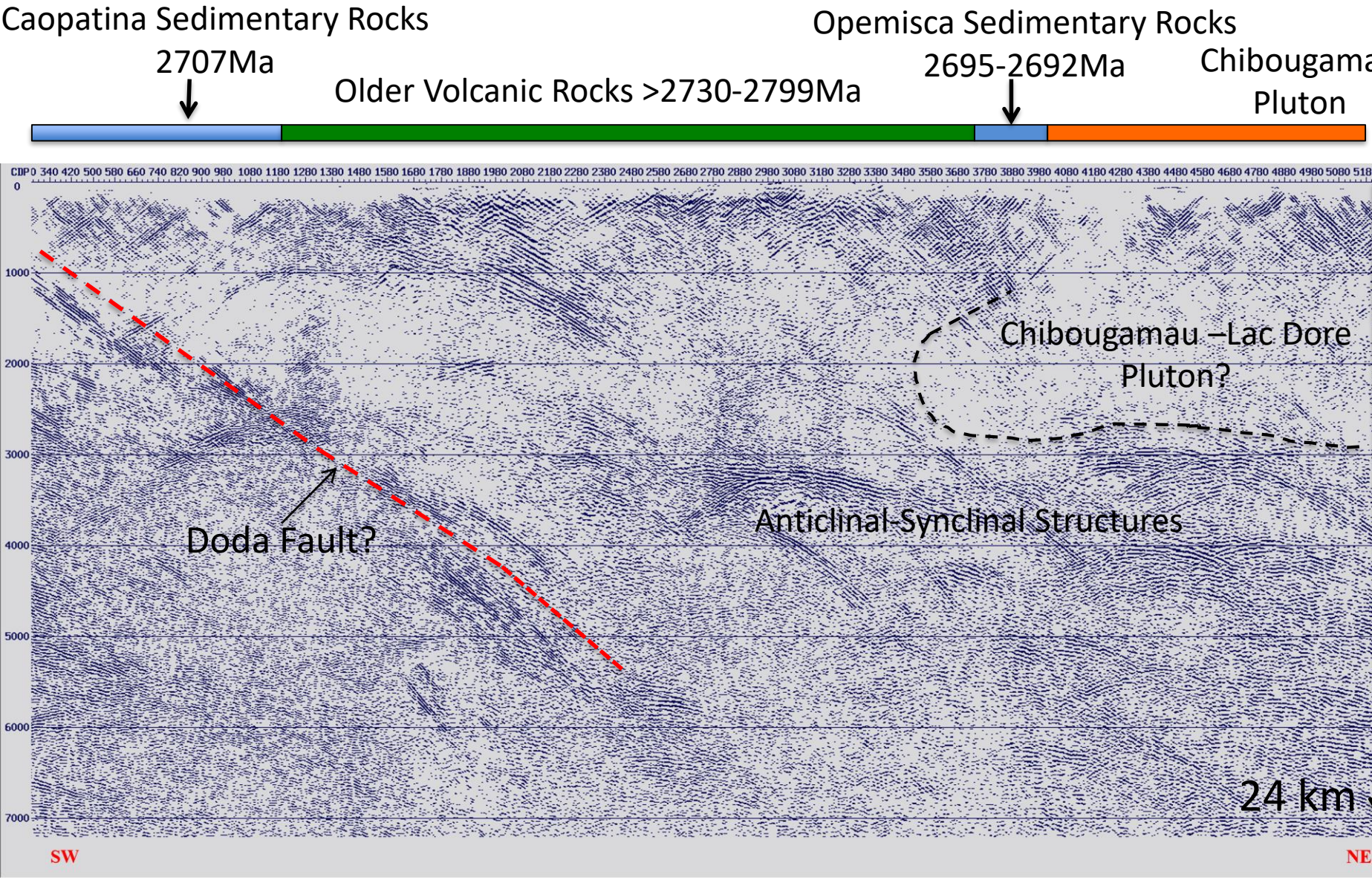
From Daigneault, 2017

E) Activité des failles E-W

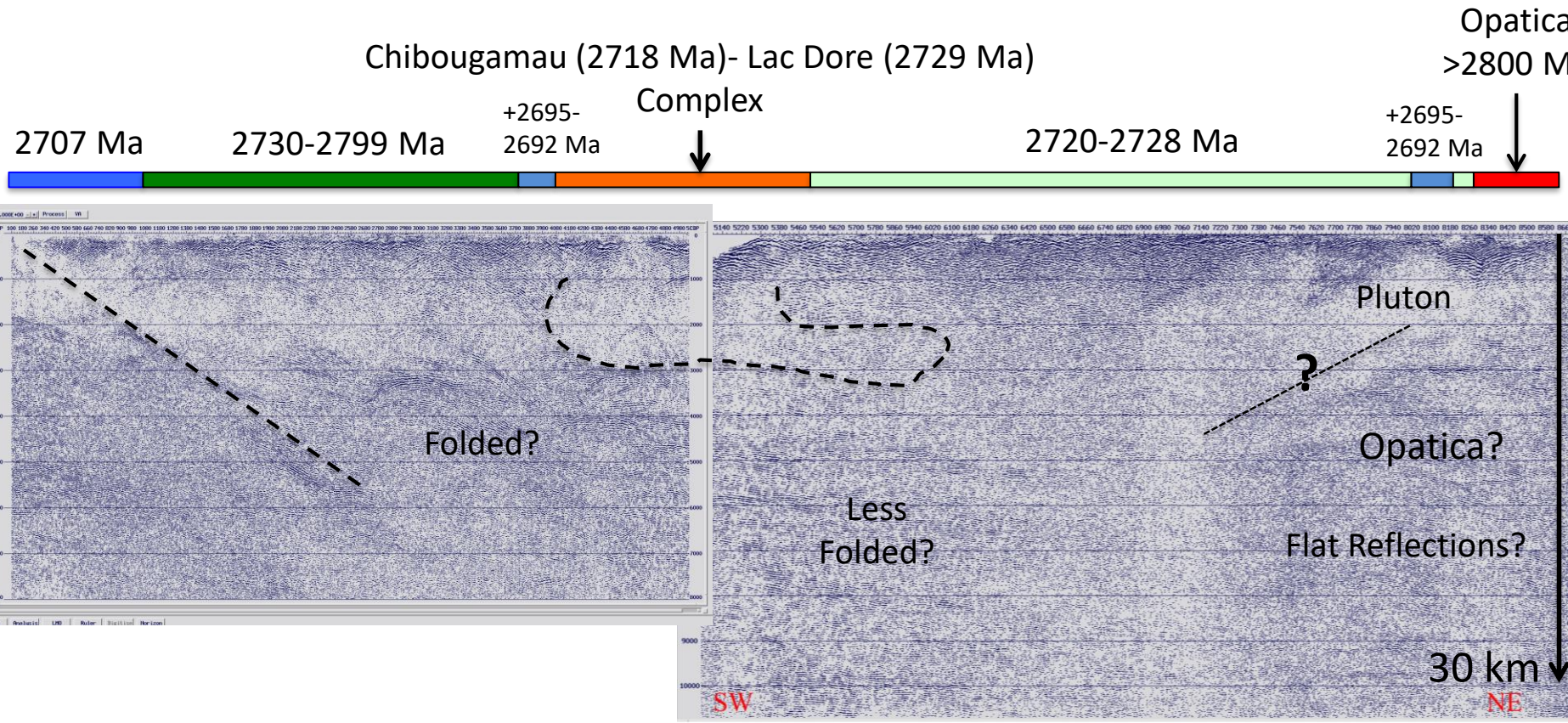


Daigneault 1991

PRELIMINARY – SOUTHWEST TO NORTHEAST SEISMIC PROFILE (Looking West)



PRELIMINARY – COMPLETE SOUTHWEST TO NORTHEAST SEISMIC PROFILE (Looking West)



2. TRANSECT SCALE RESEARCH

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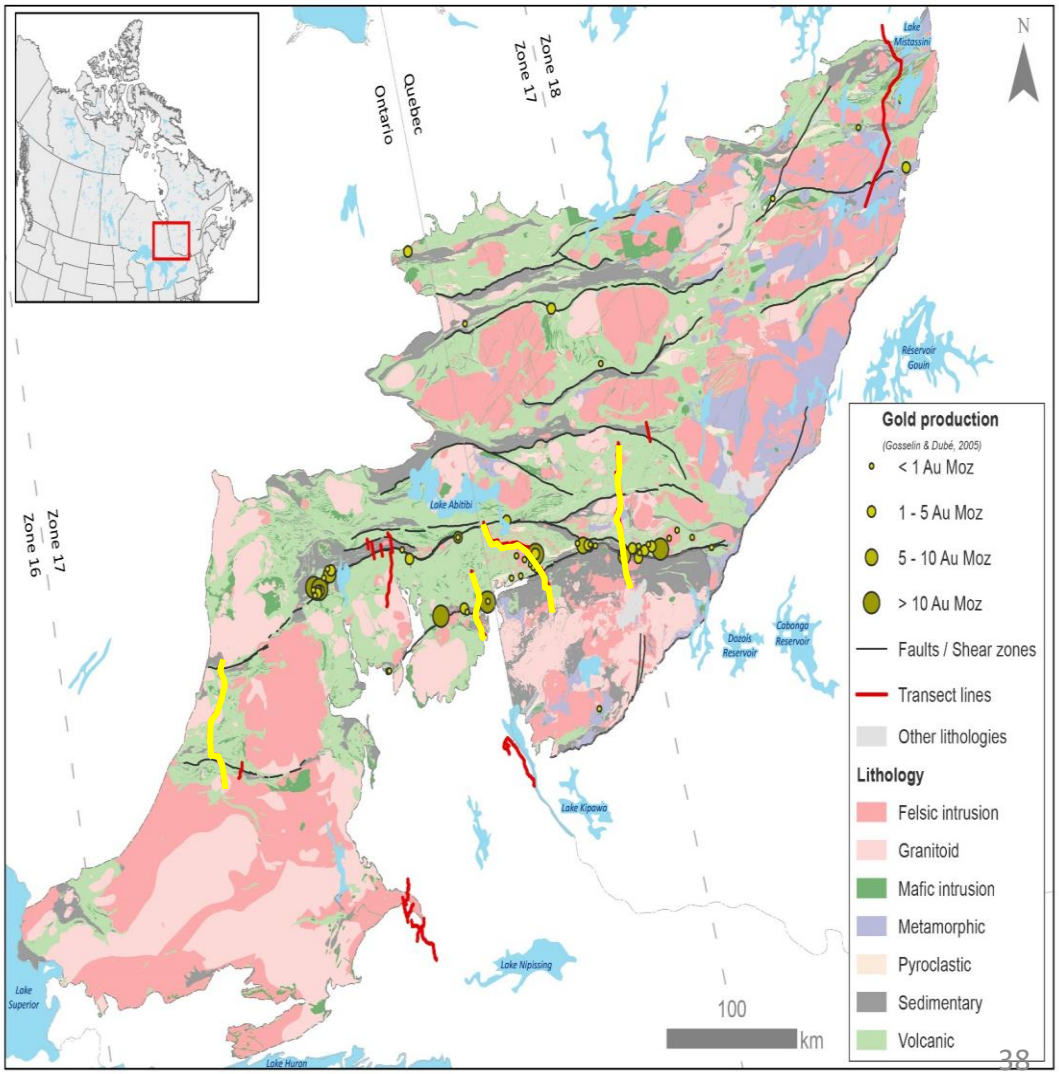
Targeted Gravity
Two MSc Students

- Amir Maleki to conduct a detailed gravity survey along the transects. Chibougamau, Malartic and Rouyn-Noranda transects completed in 2017.
- Will McNeice to undertake physical property measurements (magnetic susceptibility/density) along transects and to compile existing physical property data
- Both studies will be integrated with transect seismic, MT and geological data



METAL EARTH

2. TRANSECT SCALE RESEARCH

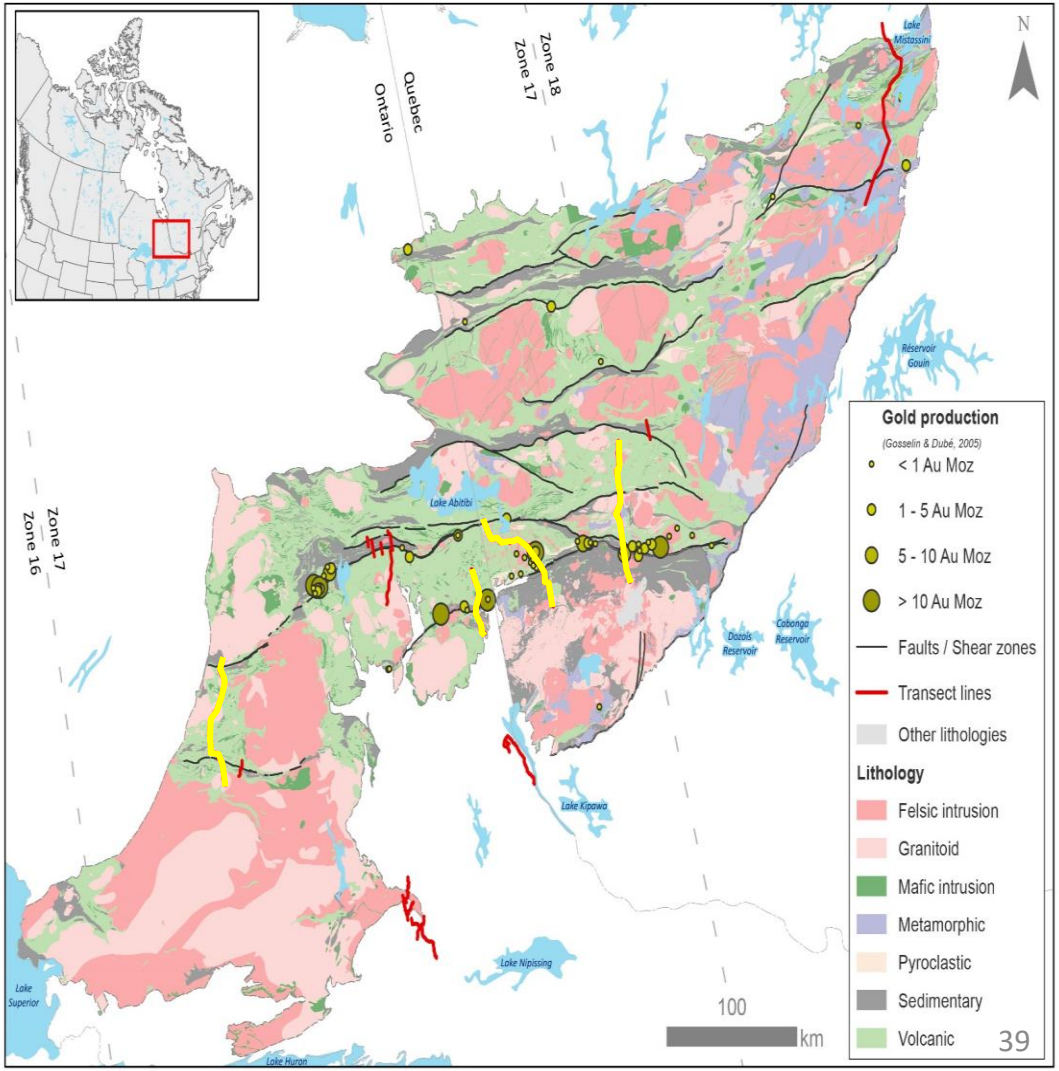
Targeted Geologic Mapping

Focused on unresolved geologic problems over transects

Four transects initiated in 2017

SoFW papers in OGS and MERN Publications this fall

Field Workshop and Field Guide completed - 09/17



2. TRANSECT SCALE RESEARCH

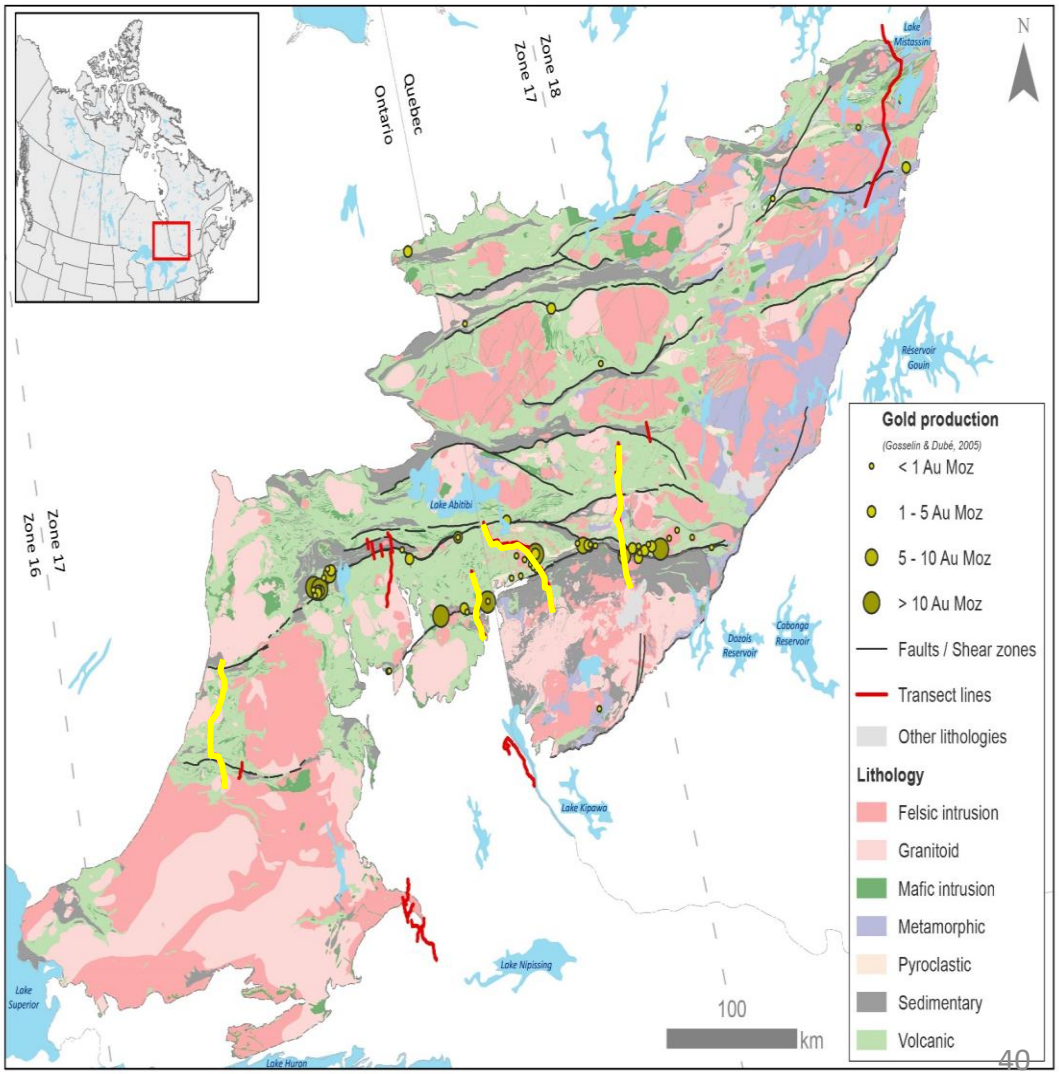
MERC

Targeted Geologic Mapping

Collect geological data (lithological, structural, geochemical, geochronological, mineralization, alteration, compile previous work)

Integrate newly acquired geological and geophysical data (seismic, MT, gravity) with historical data, to produce a **crust to mantle cross-section** through each Transect

Transects and cross-sections will be **compared to establish differences between endowed and less-endowed** greenstone belts



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2. TRANSECT SCALE RESEARCH

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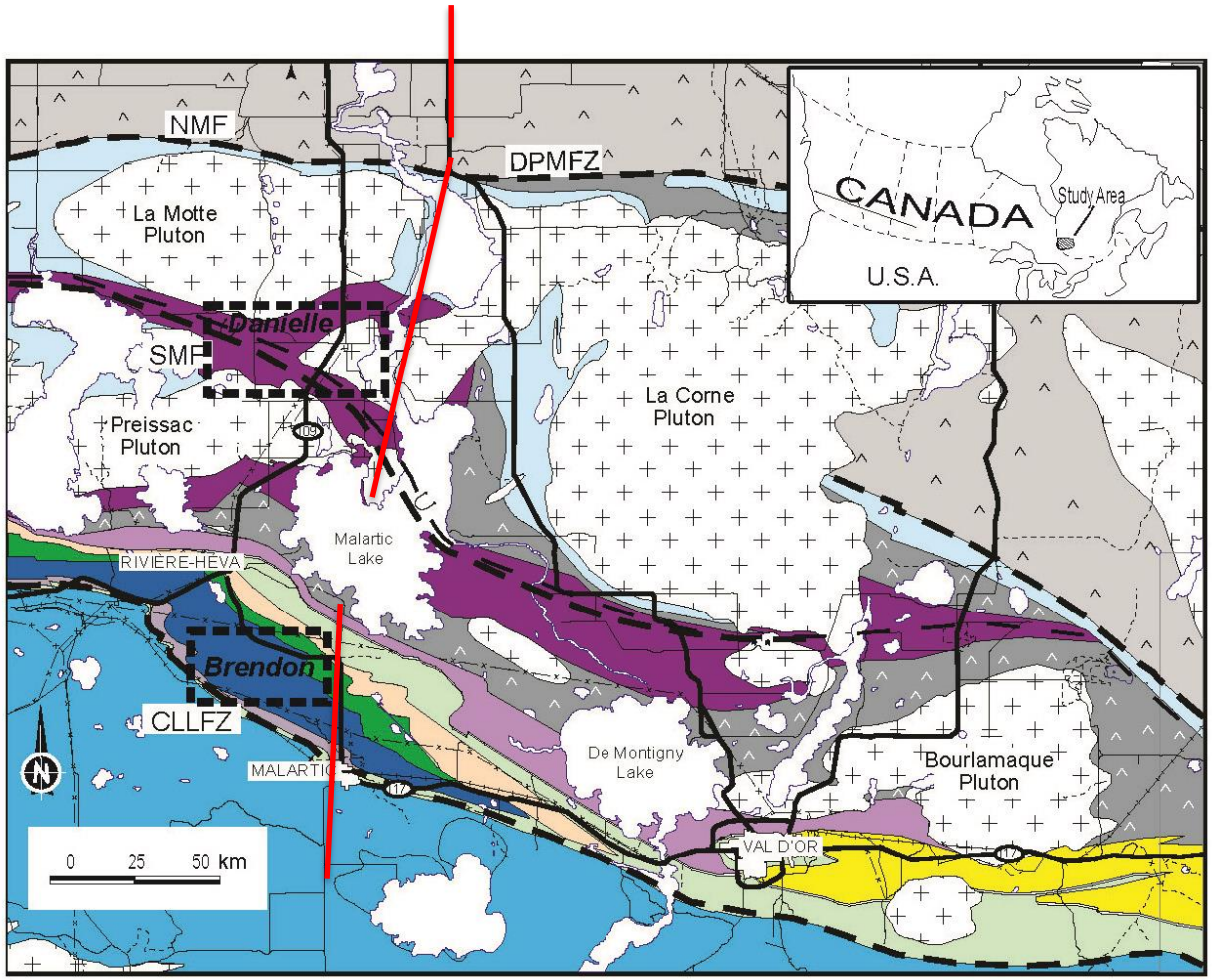
Xiaohui Zhou (R.A.)
Architecture of southern Abitibi & Pontiac subprovince; Structural control on mineral deposits

Danielle Shirriff (M.Sc.)
Lithologic and structural control on Ni mineralization at Cubric showing

Brendon Samson (M. Sc.)
Structural control on lode Au mineralization in Timiskaming and Cadillac group; Contact relationship, age, and provenance of two sedimentary groups



Modified from Mueller et al. (2008)

METAL EARTH

2. TRANSECT SCALE RESEARCH

MERC

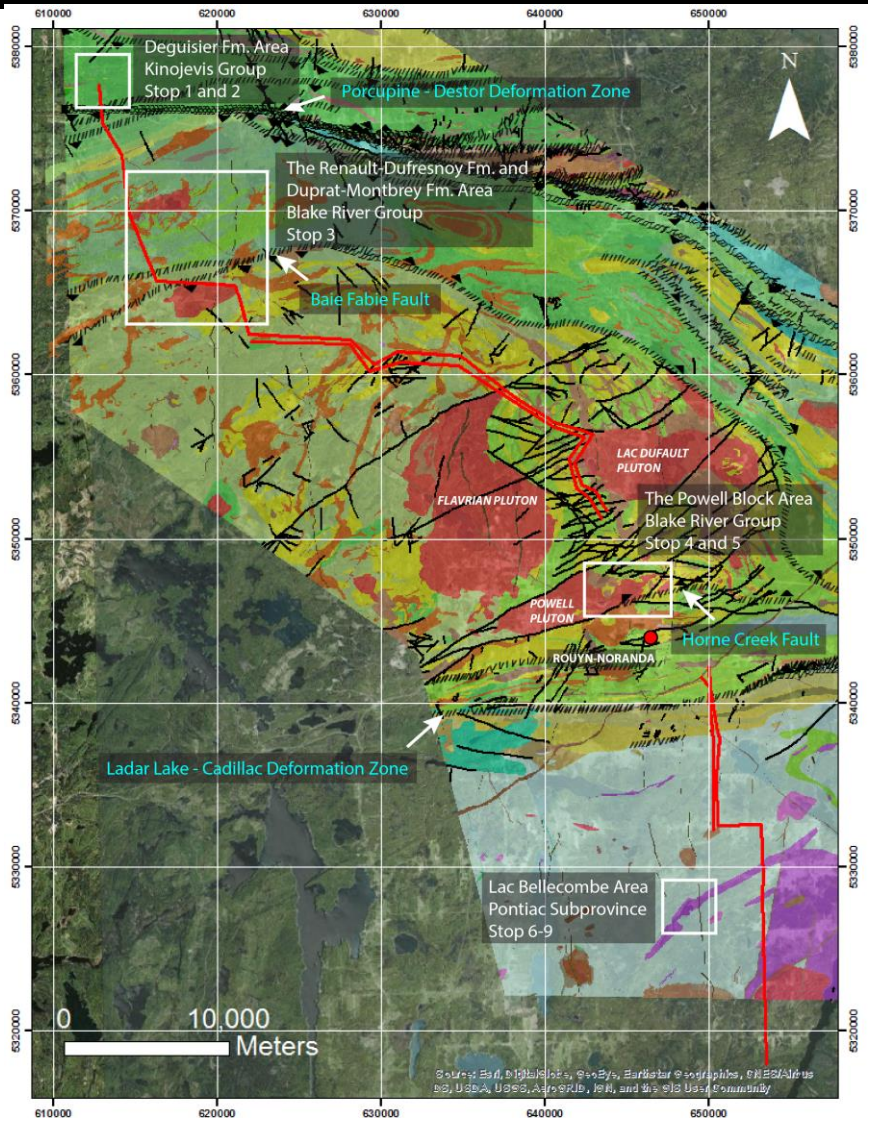
Rouyn-Noranda Transect
1 RA, 1PhD, 2 MSc

Taus Joergensen, RA. Volcanic stratigraphy, geochemistry and geochronology of the Kinojevis Group and definition of the Porcupine-Destor fault

Marina Schofield, PhD
Powell Block deformation history,volcanic stratigraphy/architecture and alteration; orogenic vs. synvolcanic style mineralization

Jonathan Sutton, MSc. Renault-Dufresnoy and Duprat-Montbrey formations volcanic stratigraphy, synvolcanic intrusions and VMS mineralization

Adrian Rehm, MSc. Emplacement mechanism for ultramafic and mafic metavolcanic rocks in the Pontiac Subprovince



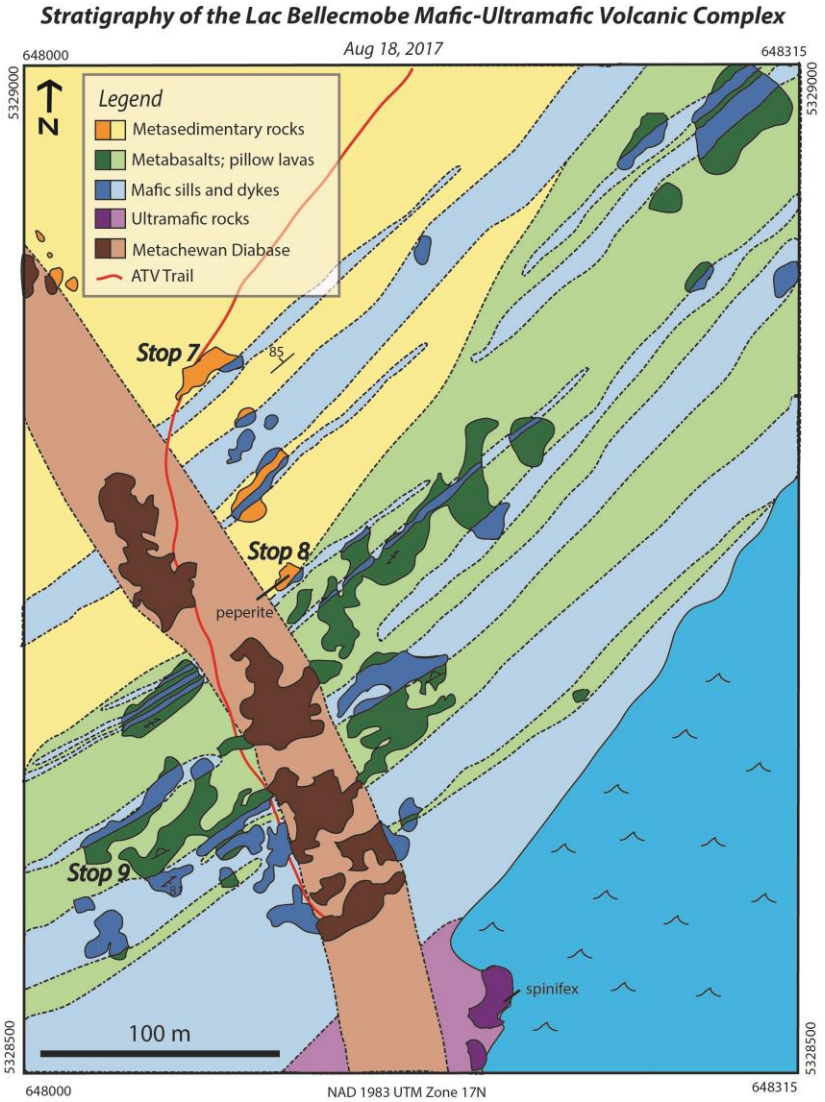
2. TRANSECT SCALE RESEARCH

MERC

Targeted Geologic Mapping

Pontiac Metasediments – Belcombe area

- Ultramafic and mafic metavolcanic rocks in the Pontiac Subprovince
- The objective of the research is to determine if the metavolcanic rocks were emplaced into the Pontiac metasedimentary rocks during deformation, or if they were emplaced during deposition of the metasedimentary succession
- A secondary goal is to characterize the metavolcanic succession, its stratigraphy and deformation history



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2. TRANSECT SCALE RESEARCH

MERC

2. TRANSECT SCALE RESEARCH

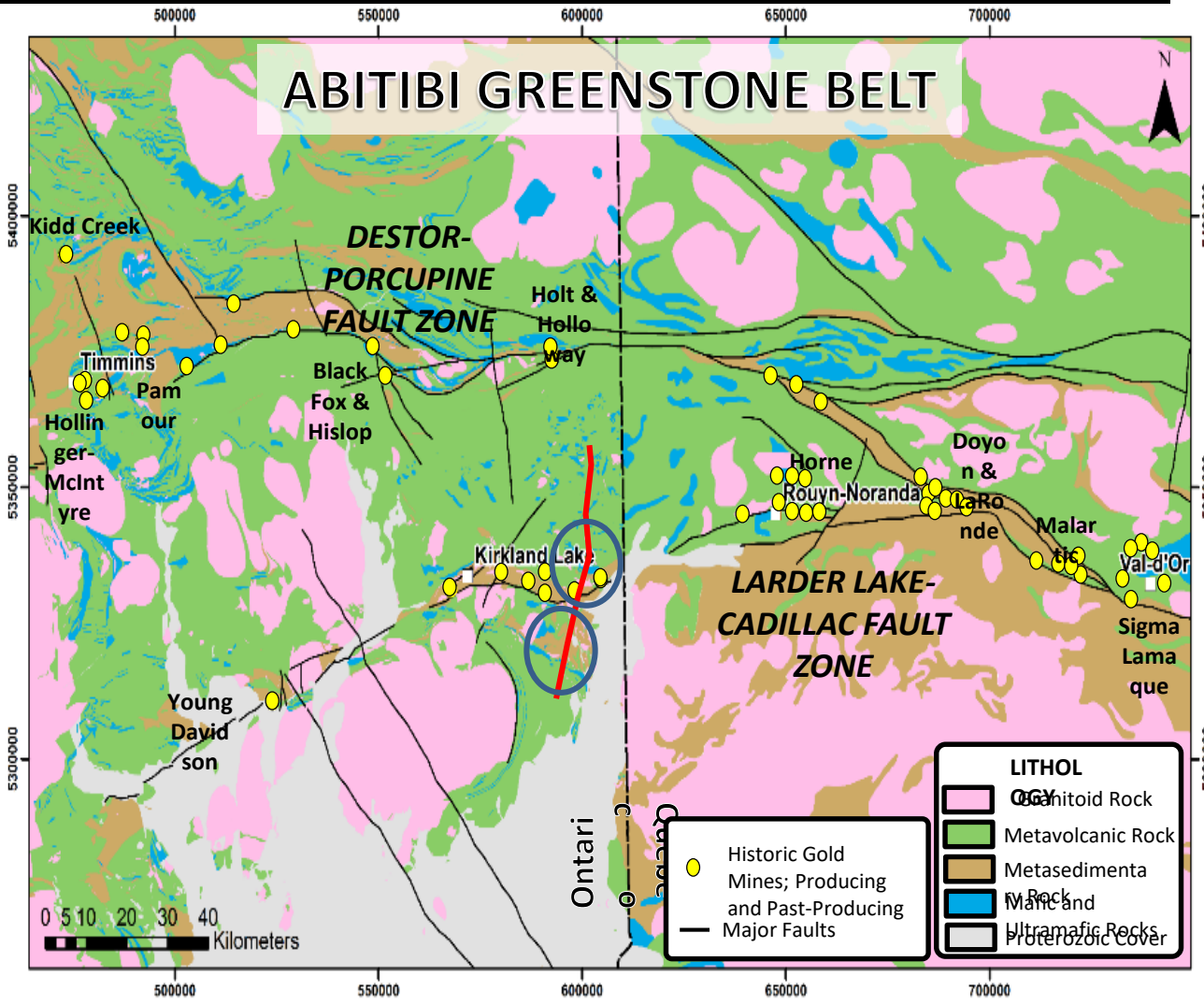
MERC

Larder Lake Transect

Two MSc Projects

Nadia St.Jean MSc. Kerr Addison structural framework and volcanic stratigraphy

Sean Brace, MSc. Gold and syenite intrusions in Skead township



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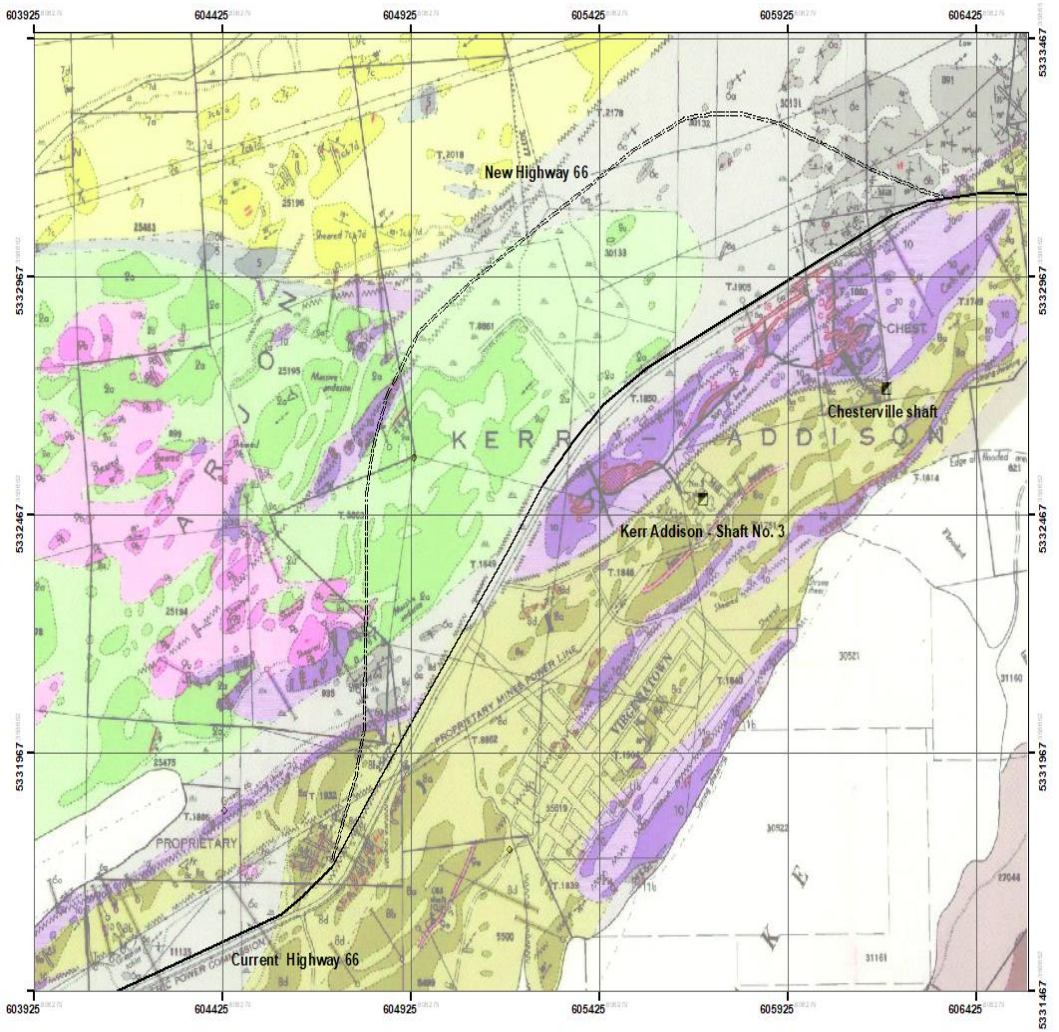
2. TRANSECT SCALE RESEARCH

MERC

Targeted Geologic Mapping
Larder Lake

- Examining the structural and stratigraphic framework of the Kerr-Addison deposit / relation to gold mineralization
- Nature of the contact with the between the Timiskaming sedimentary rocks and the Larder Lake (Piché) group



METAL EARTH

2. TRANSECT SCALE RESEARCH

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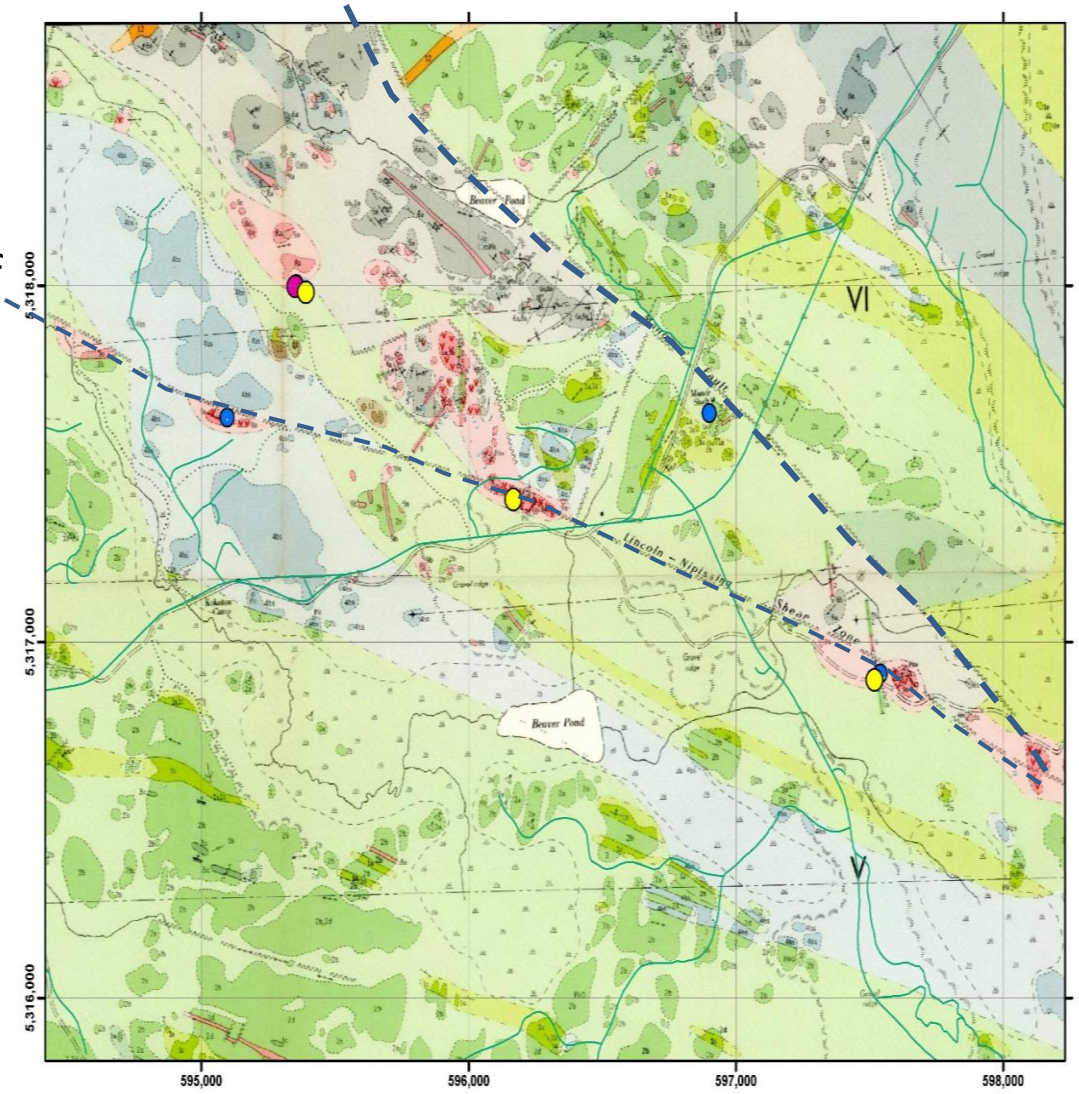
Targeted Geologic Mapping Larder Lake

- Examining the petrochemistry of the syenite intrusions associated with the Lincoln Nipissing shear zone
- Nature of the gold mineralization associated with the intrusions



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2. TRANSECT SCALE RESEARCH

MERC

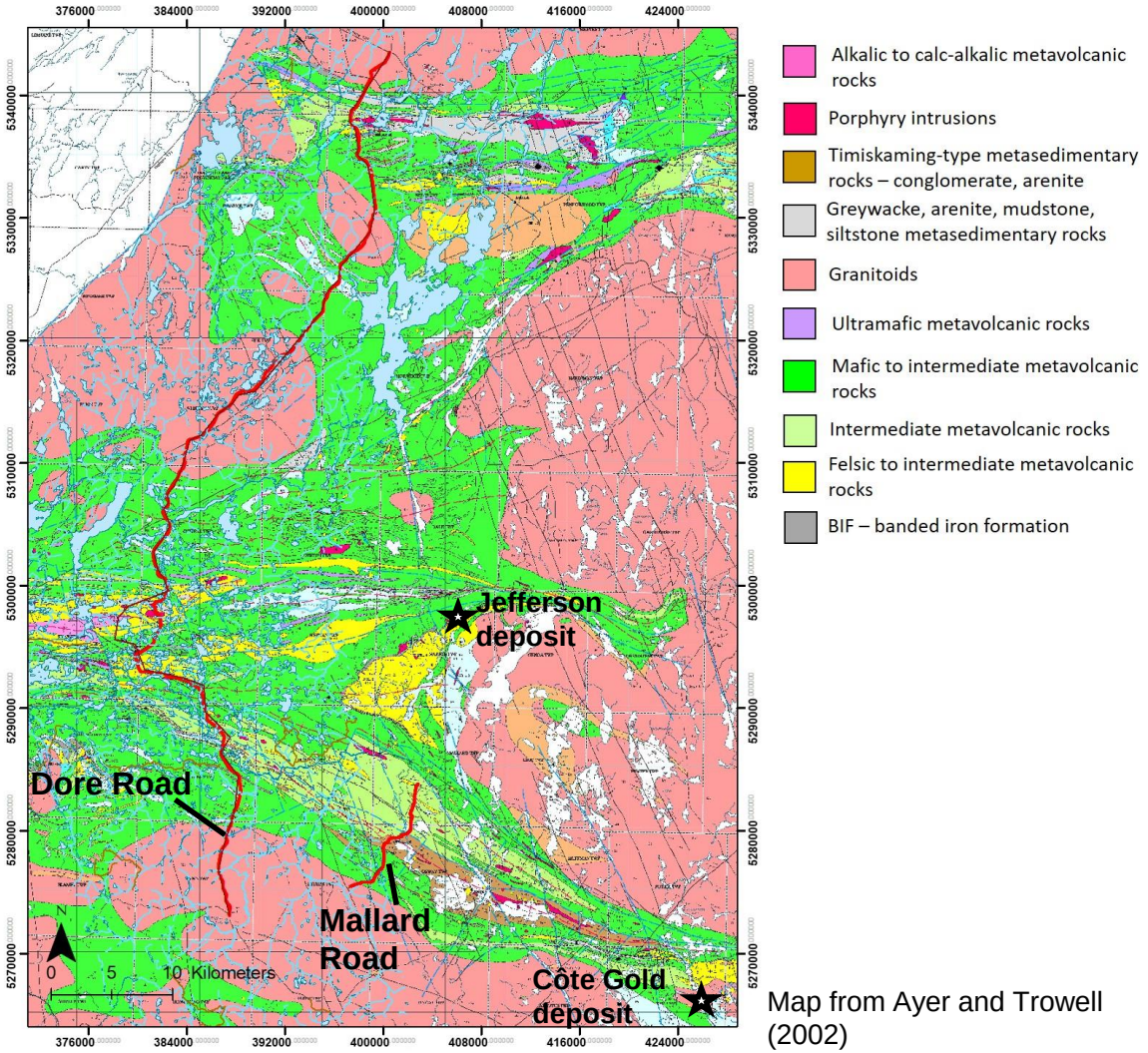
Swayze Transect

1 RA, 1 PhD, and 1Msc

Rasmus Haugaard, RA. The provenance, age and depositional environment of metasedimentary successions; Au Metallogeny

Tom Gemmell, PhD. Stratigraphy, geochemistry, architecture, age and base-metal metallogeny of volcanic successions.

Blake Mobray, MSc. Volcanic architecture, alteration, deformation and origin of base metal mineralization at the Jefferson occurrence.



Map from Ayer and Trowell (2002)

METAL EARTH

ANTICIPATED OUTPUTS AND OUTCOMES

Research Activity	Outputs	Outcomes
1.Craton 2.Transect 3.Thematic 4.Data Analytics	New Knowledge and HQP Reports, maps, theses, journal publications Workshops/conferences Geoscience data – open source New techniques/technologies Commercial products	Increased scientific capacity Centre of Excellence Global leadership in Mineral Exploration Research Exploration “tool kit” Increased discovery rates New mines Northern Development

METAL EARTH

It worked because of our students!

MERC

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MERC
Mineral Exploration Research Centre

METAL EARTH

Laurentian University
Université Laurentienne
HARQUAIL SCHOOL OF EARTH SCIENCES
ÉCOLE DES SCIENCES DE LA TERRE

Thank You

METAL EARTH: A $104 million research project that will help industry unlock Earth's mineral wealth