Metal Earth Overview

October 2019

METAL EARTH

A new Canadian research initiative funded by Canada First Research Excellence Fund.

CANADA FIRST RESEARCH EXCELLENCE FUND

Canada

Laurentian University
Université Laurentienne

HARQUAIL SCHOOL OF EARTH SCIENCES
ÉCOLE DES SCIENCES DE LA TERRE

MERC
Mineral Exploration Research Centre

Mineral Exploration Research Center (MERC)

o **MERC is a collaborative center for mineral exploration research and education supported by industry, government and Laurentian University**

o Focused on field-based collaborative research on Exploration and Precambrian Ore Systems

o More than 100 faculty, research scientists, and graduate students working across the globe

o Lead organization on Metal Earth project

o Membership in MERC provides a seat at the advisory board.
    Catharine Farrow Chair, Benoît Dubé, Science Advisor

MERC Foundation Members

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

BARRICK

KL | KIRKLAND LAKE GOLD

125 ANNIVERSARY Est. 1891 / Ontario Geological Survey

MERC Tier 1 Members

Tr Transition Metals

Teck

IAMGOLD

ALAMOS GOLD INC.

KINROSS

IVANHOE MINES
NEW HORIZONS

Laurentian University / Université Laurentienne
GOODMAN SCHOOL OF MINES / ÉCOLE DES MINES

MERC Tier 2 Members

BAT+ERY MINERAL RESOURCES

KGHM POLSKA MIEDŹ

NORTHERN SUPERIOR RESOURCES

PELANGIO

VALE

SUDBURY INTEGRATED NICKEL OPERATIONS
A GLENCORE COMPANY

Exiro MINERALS

McEWEN MINING
NYSE MUX TSX

PROGENITOR METALS CORP

GOLD FIELDS

HIGHLAND Copper Company Inc.

Metal Earth

o **METAL EARTH** is a **MERC** led collaborative research project focused on metal endowment in the Precambrian shield

o **THE GOAL** is to improve the science for targeting and finding new orebodies

o Fully-funded seven-year $104M applied R&D initiative.

o **Canada FIRST** Research Excellence Fund (CFREF) $49M, $5M from NOHFC, $1M from David Harquail and cash + inkind from 22 private sector and government survey partners

o Project started in summer 2017

Metal Earth Components

o **FUNDAMENTAL SCIENCE:**

Transform our understanding of Earth's early evolution and the processes that govern differential metal endowment

Improve the science for targeting and finding new orebodies

o **APPLIED INNOVATION AND COMMERCIALIZATION COMPONENT:**

Make Canada a global leader in mineral exploration research through open source delivery of new knowledge   and the development of transformative technologies targeted at increasing exploration success

Improve training of quality young geoscientists for the industry

MERC
AT THE HARQUAIL SCHOOL OF EARTH SCIENCES

METAL EARTH

CANADA FIRST
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Discovery Costs

Effect of focus on Brownfields environment
Maturing districts

Becomes more effective when availability of
exploration dollars is scarce
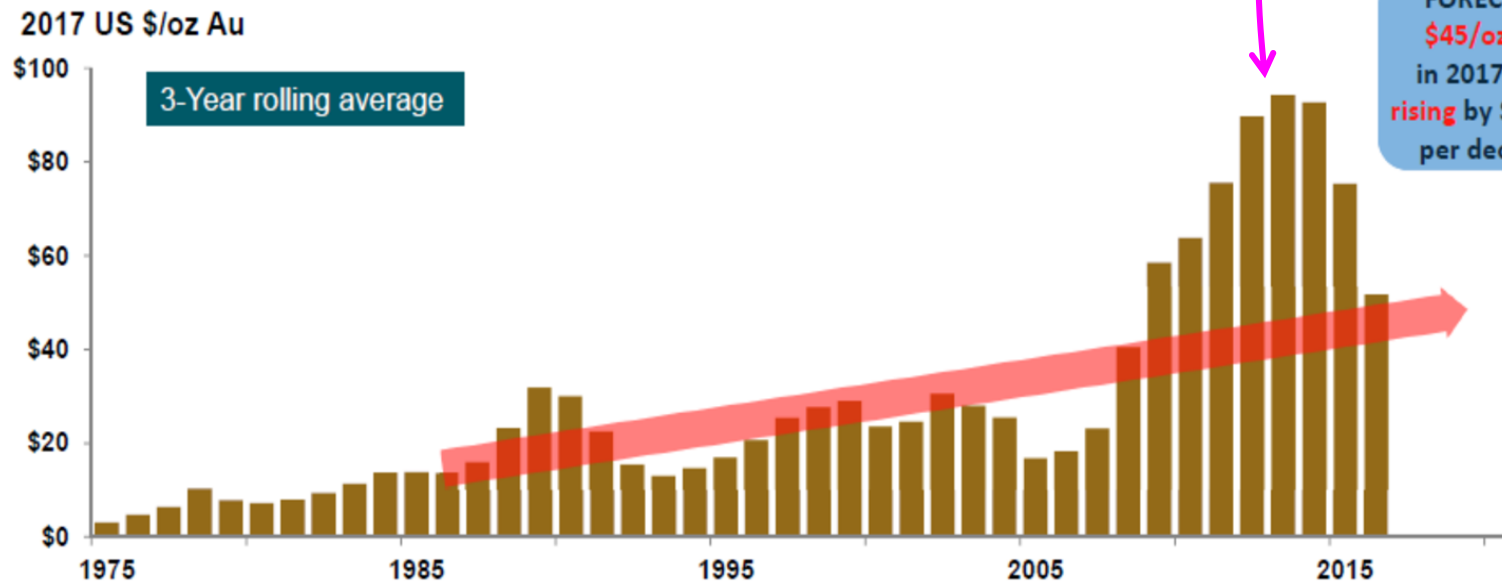
Discovery Costs

From Dan Wood's SEG newsletter

Value of discoveries less than the exploration investment

Unsustainable as an industry

Requires new search space to change

        Deep
        Covered
        Remote

Needs new tools to be effective in this spaces

... from page 1   Transforming the Business of Gold Exploration: Adapting to Deeper Exploration (c

Commodity	Exploration Spend (2016 $b)		No of Discoveries #		Tier 1+2 Discoveries		Estimated Value (2016 $b)		Value / Spend
Gold	$65	33%	320	37%	4 + 17	26%	$30	32%	0.46
Copper	$35	18%	102	12%	3 + 15	22%	$17	18%	0.47
Nickel	$7	4%	34	4%	0 + 4	5%	$3	4%	0.47
Zinc + Lead	$11	5%	30	3%	1 + 4	6%	$5	6%	0.50
Uranium	$10	5%	28	3%	1 + 7	10%	$6	7%	0.61
Diamonds	$6	3%	11	1%	0 + 1	1%	$1	1%	0.19
Iron Ore	$20	10%	143	16%	0 + 3	4%	$6	7%	0.33
Coal	$24	12%	64	7%	1 + 6	9%	$8	8%	0.33
Other	$21	11%	135	16%	2 + 12	17%	$16	17%	0.75
	----	------	-------	-------	------	-------	-------	-------	-------
TOTAL	$197	100%	867	100%	12 + 69	100%	$92	100%	0.47

FIGURE 2. Discovery performance by commodity, 2007 to 2016. Value of discoveries (US$ 2016) estimated as $2 billion, $500 million, $80 million, and $10 million for tiers 1, 2, and 3 and unassigned, respectively (excludes unreported discoveries). Value/Spend is the ratio of the value of all discoveries to the total cost of exploration (break even = 1.0). From Schodde (2017), used with permission.

From Wood, SEG Newsletter, Jan. 2018

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METAL EARTH

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Understand what you are looking for

Targeting is a business decision

Tend to be found early in new jurisdictions

FIG. 9. Incremental NPVs for all major gold deposits discovered in low-risk countries between 1985 and 2003, ranked by cumulative percent of the total number of deposits found, cumulative tonnes of contained metal, and cumulative NPV. Caution—Note that the analysis did not include the NPVs associated with deposits smaller than 1 Moz.

7 discoveries out to 64 with NPV greater than $250M (12%)

Made up 30% of total metal

53% of total value
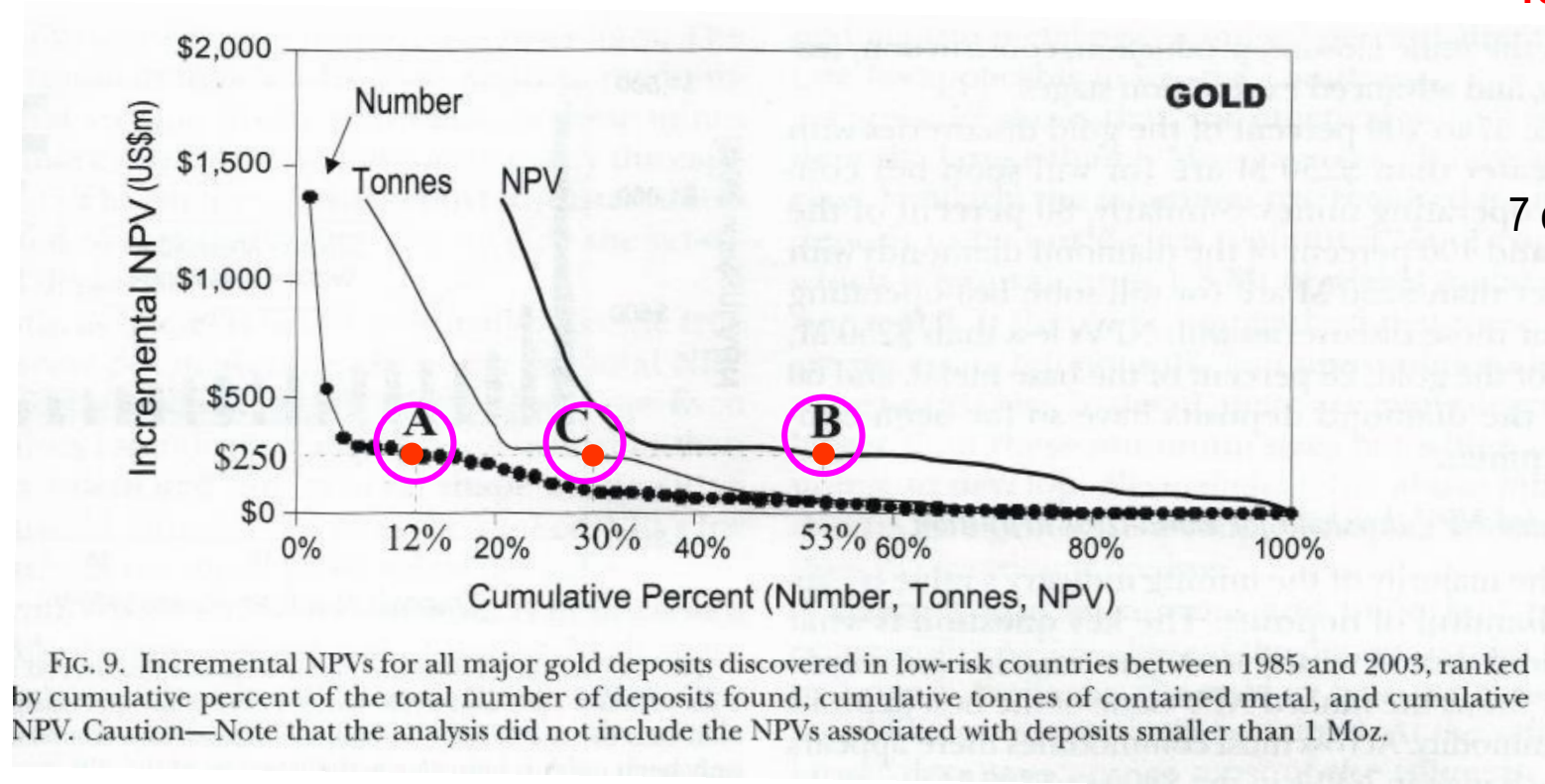
Schodde and Hronsky, 2006

Area Selection

Exploration is about reducing risk
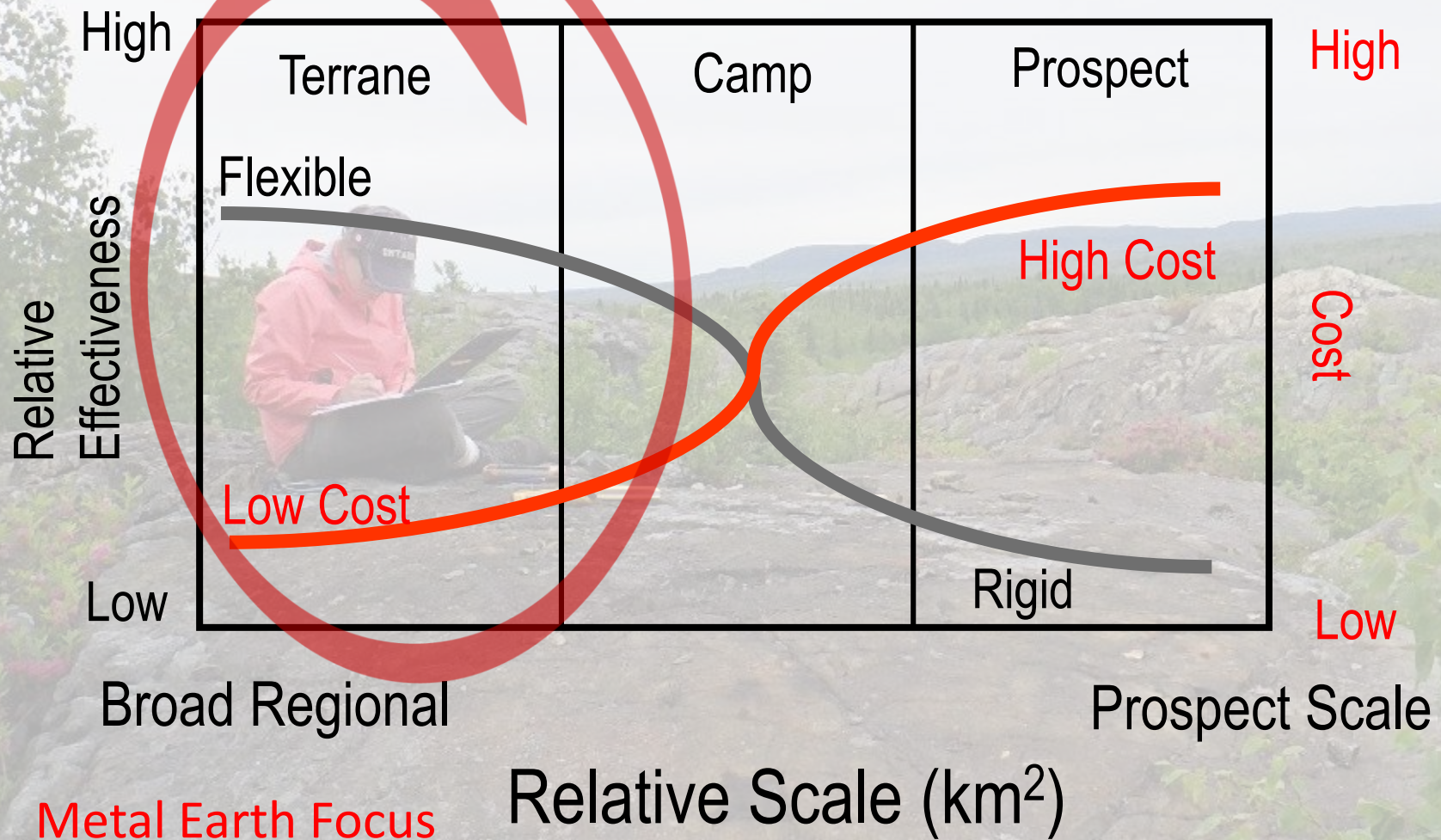
Area Selection / Metal Endowment

>160M oz Gold Produced

Dubé & Gosselin, 2007

Legend:
- Granitoid rock
- Mafic intrusion
- Volcanic rock
- Proterozoic cover
- Sedimentary rock
- Major fault
- World-class orogenic gold deposits
- World-class gold-rich volcanogenic massive-sulfides
- Other gold-rich VMS
- Other gold deposits
- LLCF — Larder Lake - Cadillac Fault Zone
- PDF — Porcupine – Destor Fault Zone

Map labels: Casa Berardi, Hollinger - McIntyre, Pamour Dome, Kirkland Lake, Kerr Addison, Horne, PDF, Doyon Bousquet-LaRonde, LLCF, Malartic Sigma-Lamaque, 100 km, 200km

Metal Endowment

75% of gold is in 5km of the southern Abitibi
Source region
Transport effectiveness
Preservation
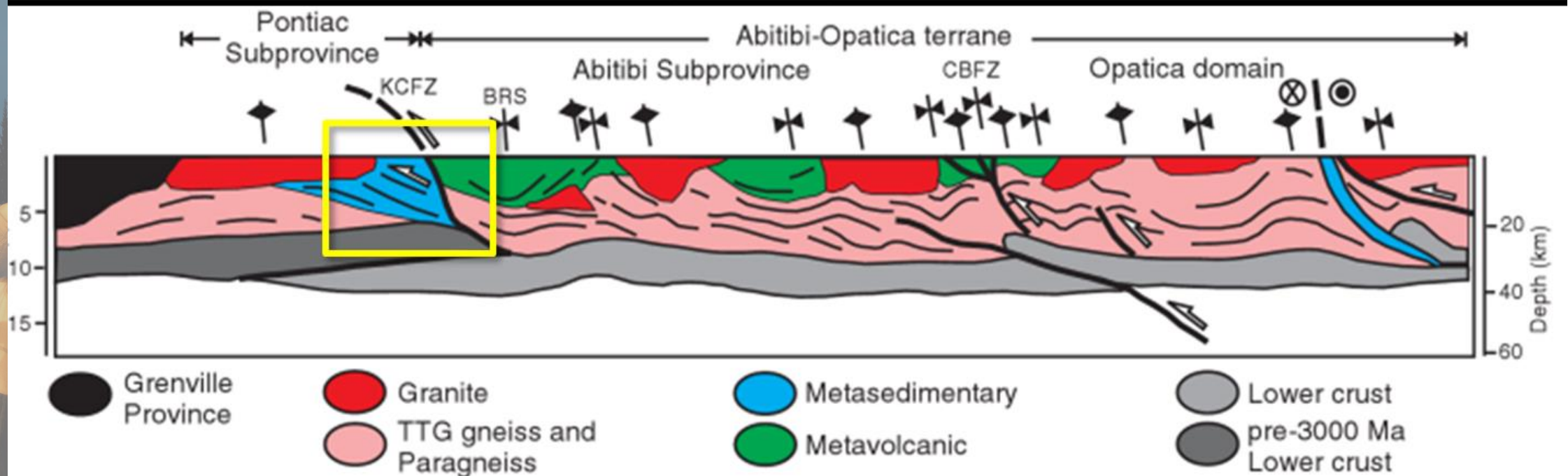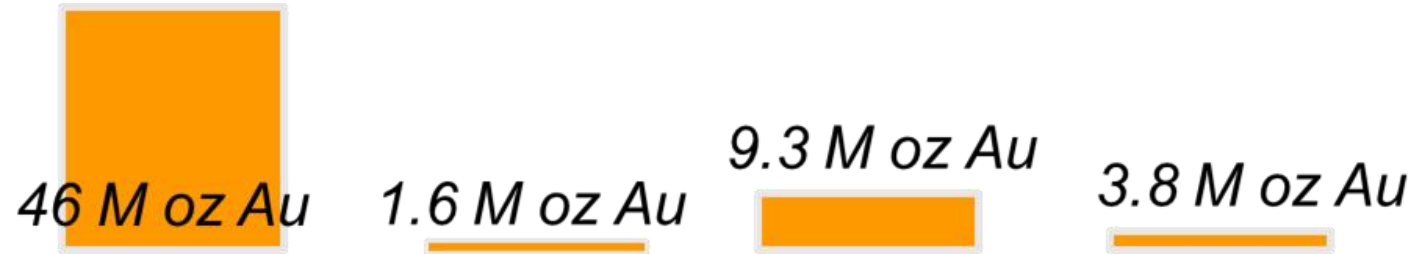
Metal Earth Strategy

o Focus on Archean greenstone belts, which represent 60% of Earth history and almost 50% of Canada's metal wealth

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

o Image ore and non-ore systems at full crust-mantle scale

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

Transect Scale Research, "cross sections" across greenstone belts

Completed summer 2017-2018, 2019 write up

To be completed summer 2018-2019, 2020 write up

To be started summer 2019-2020, 2021 write up

0   200   600km

☐ Gold Deposits

Manitoba

Red Lake

Ontario

Quebec

Abitibi / Wawa terrane

Wabigoon terrane

Timmins

Val d'Or

Thunder Bay

Sudbury

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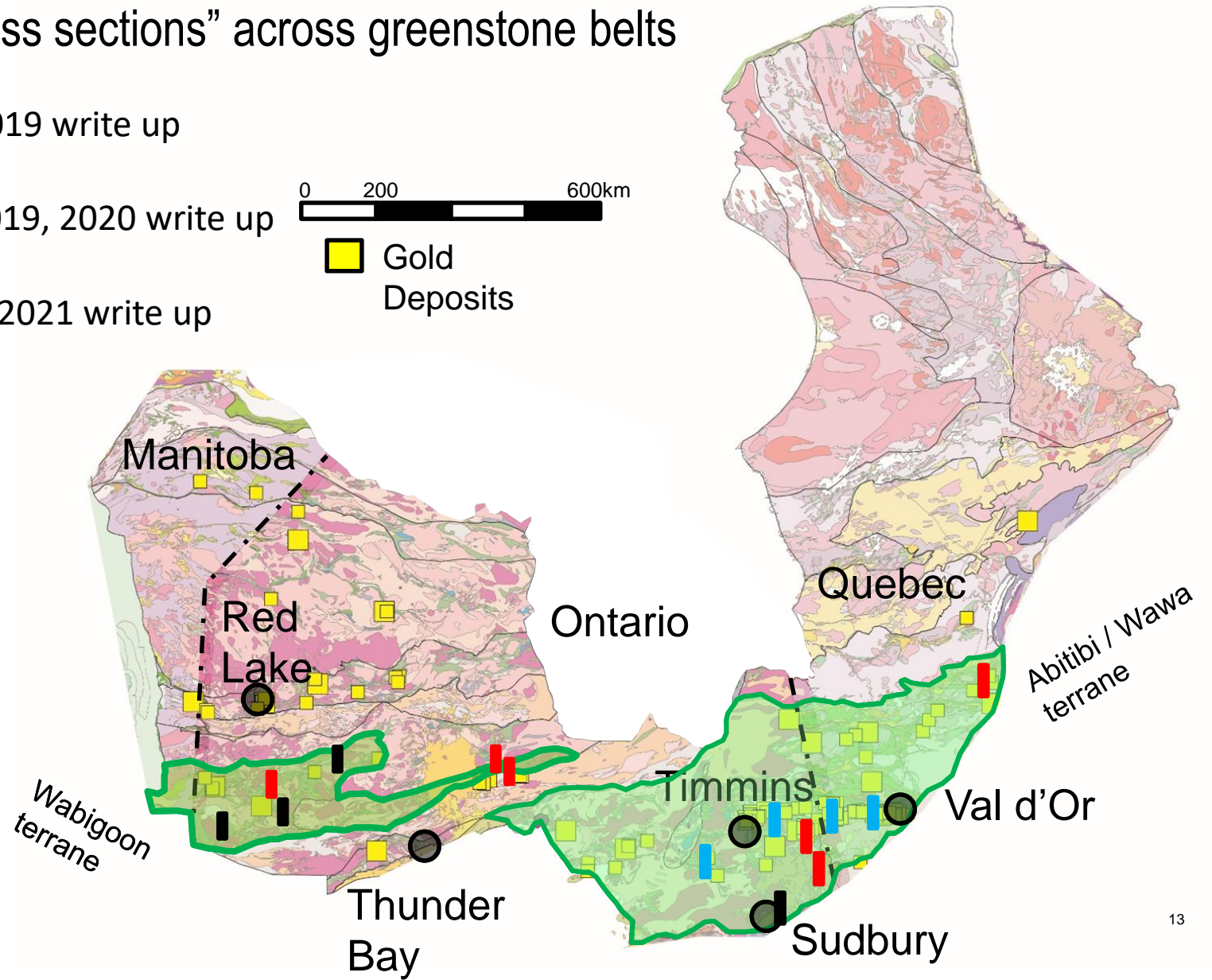
Metal Earth People (at Laurentian)

Faculty	5 (4 LU)
PDF/ RA	14
PhD (Geology)	10
MSc (Geology)	22
Total	46
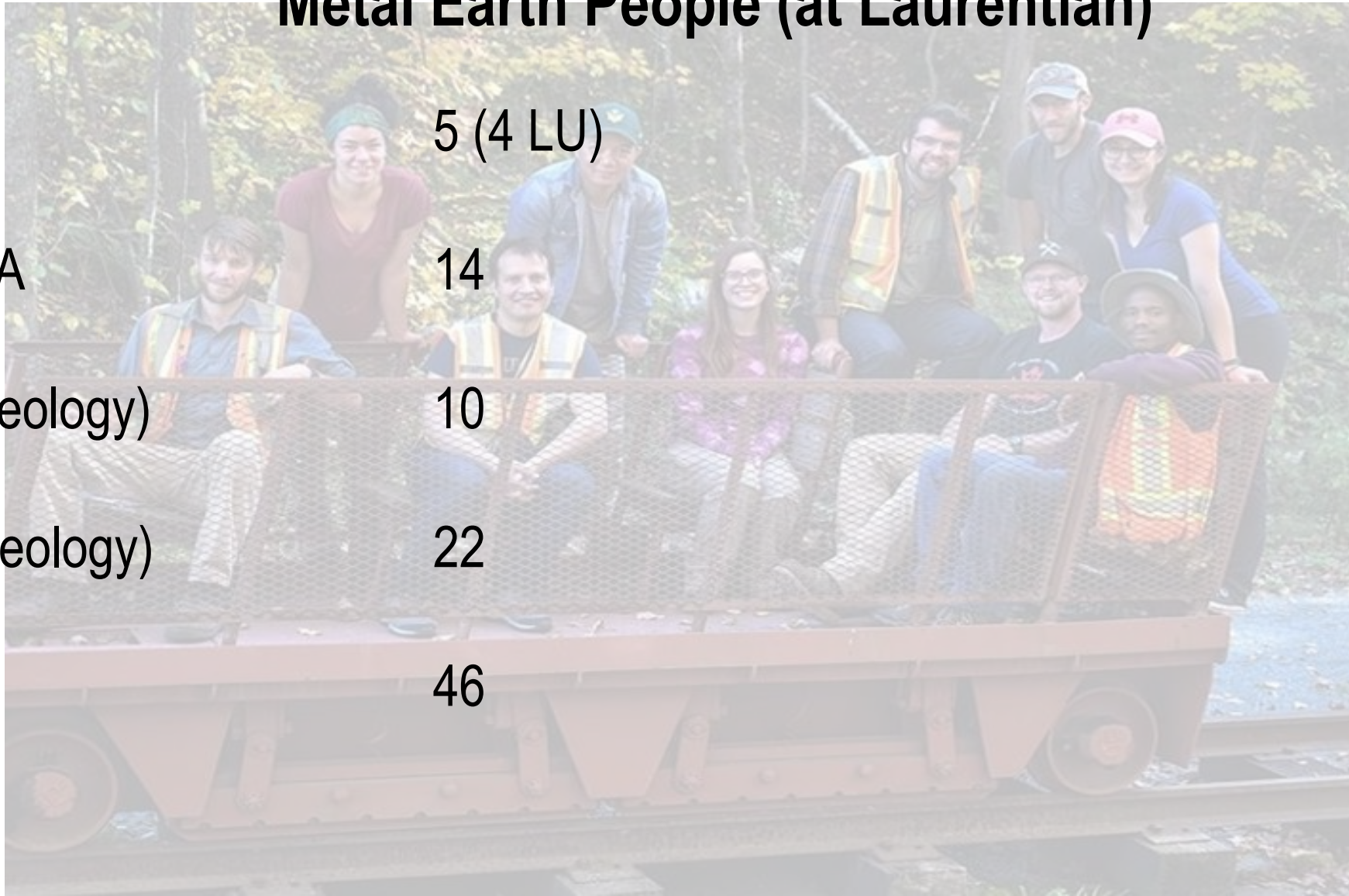
All research is underpinned by field work
Mentored/supervised by LU faculty

Metal Earth had 54 PDF's / students in the field in 2019

Metal Earth Transects

Metal Earth 2019 Field Trips

#'s on each field trip

136+ in total, not including transect leaders

Gold Deposits

Manitoba

Red Lake

Ontario

Quebec

Abitibi / Wawa terrane

28

Wabigoon terrane

13 16 12   12

Timmins

Thunder Bay

Val d'Or

30

25

Sudbury

0   200   600km
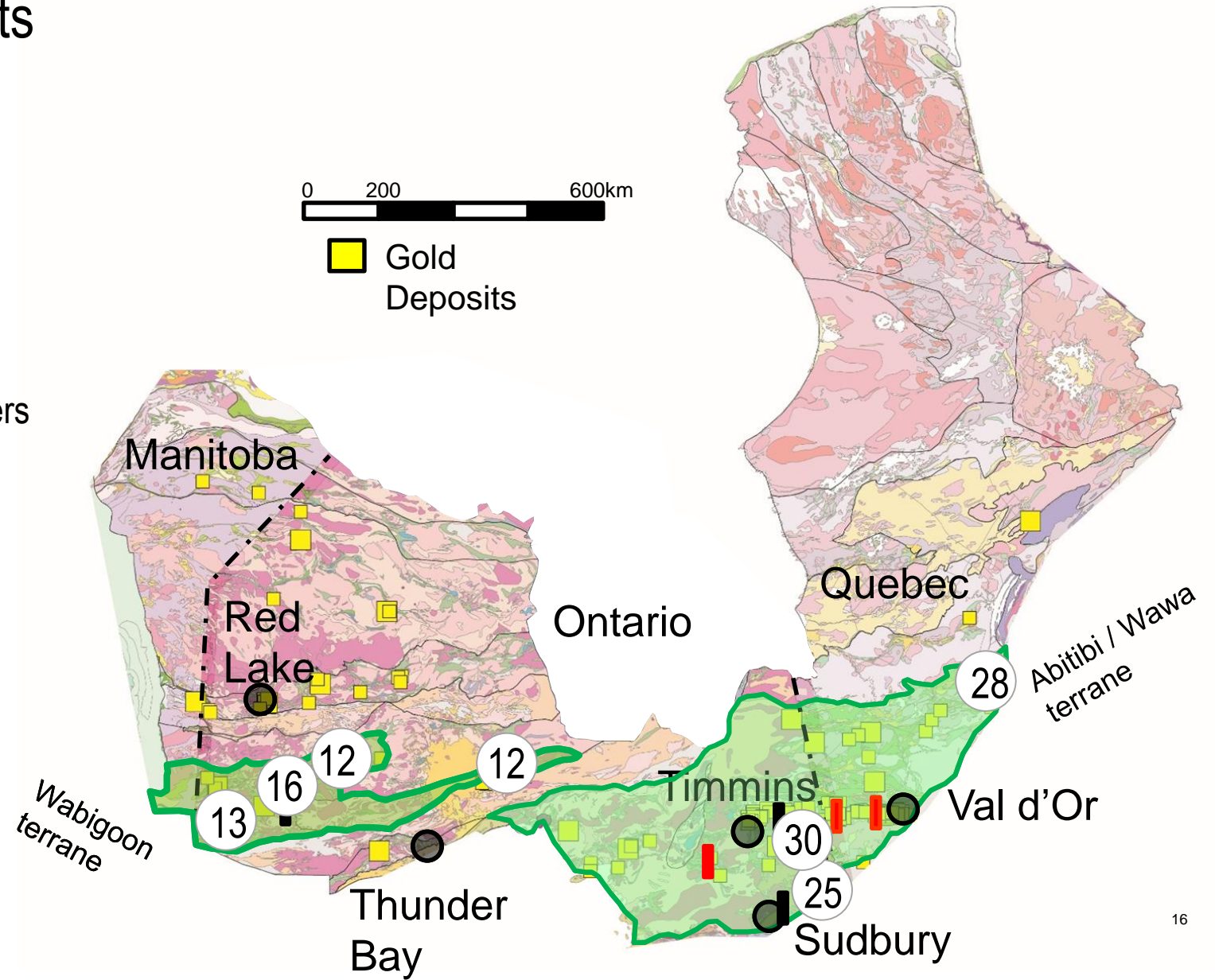
Metal Earth Transects

Metal Earth 2019 SoFW papers

19 Ontario
6 Quebec
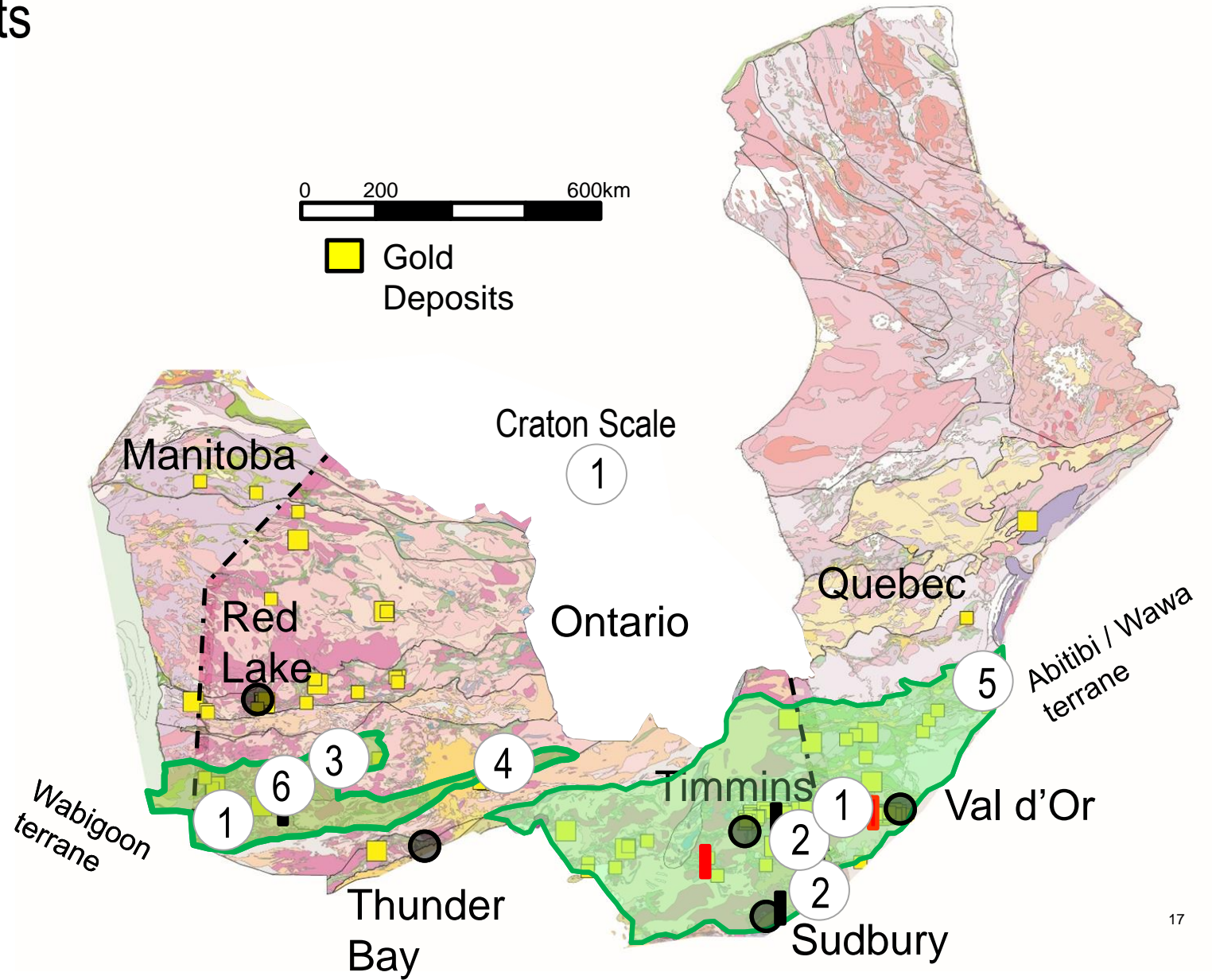
Metal Earth

Working at variety of scales

Craton Scale

Lithospheric and crustal architecture – **the framework of major tectonic blocks, terranes and their boundaries – represents a fundamental first-order control on major geological systems**, including ore deposits and the location of world-class mineral camps. (David Mole et al.)

Partnership with GSC undertake research on Pb and Nd isotopic characteristics of gold endowed sequences through time
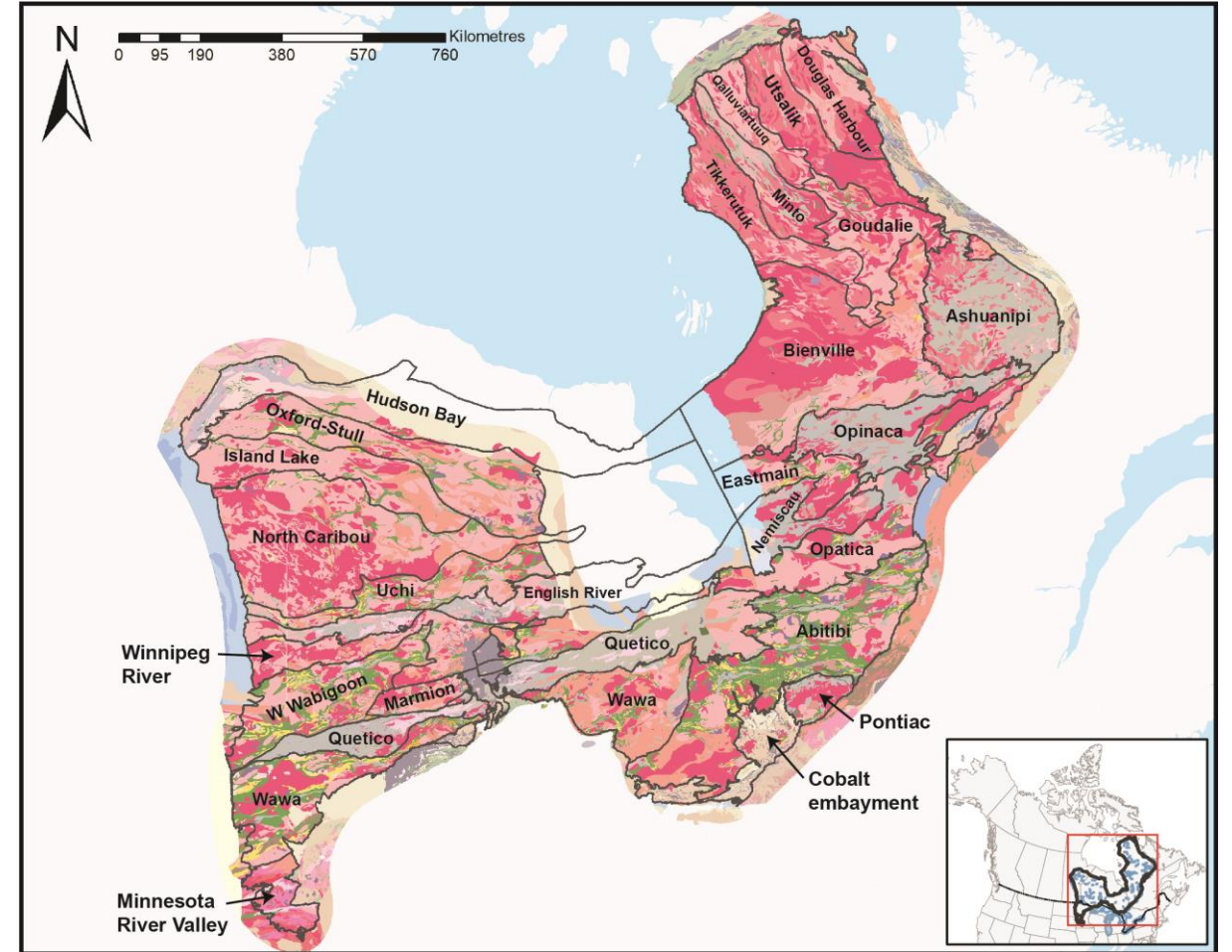
Metal Earth Seismic

o Complete +1,000km reflection seismic at regional and semi-detailed scale
o Passive Seismic Survey over Larder Lake September –December, ongoing (Data Quality ?)
o Schlumberger Software Donation (Petrel) and MOVE software suite from Petroleum Experts Ltd. (Petex)

Metal Earth MT Survey

o MT / AMT Survey complete
o Eric Root, PhD thesis
o Third party processing Phil Wannamaker

Metal Earth Gravity

o Gravity survey complete
o Integrate with regional datasets and inversions

Abitibi Transects

Metal Earth

Transect Scale Research

Larder Lake Transect

Blake River Grp.

C-LL

Hearst ass. &
Larder Lake grp.

L-N

Prot.

Skead Volc.

5 km
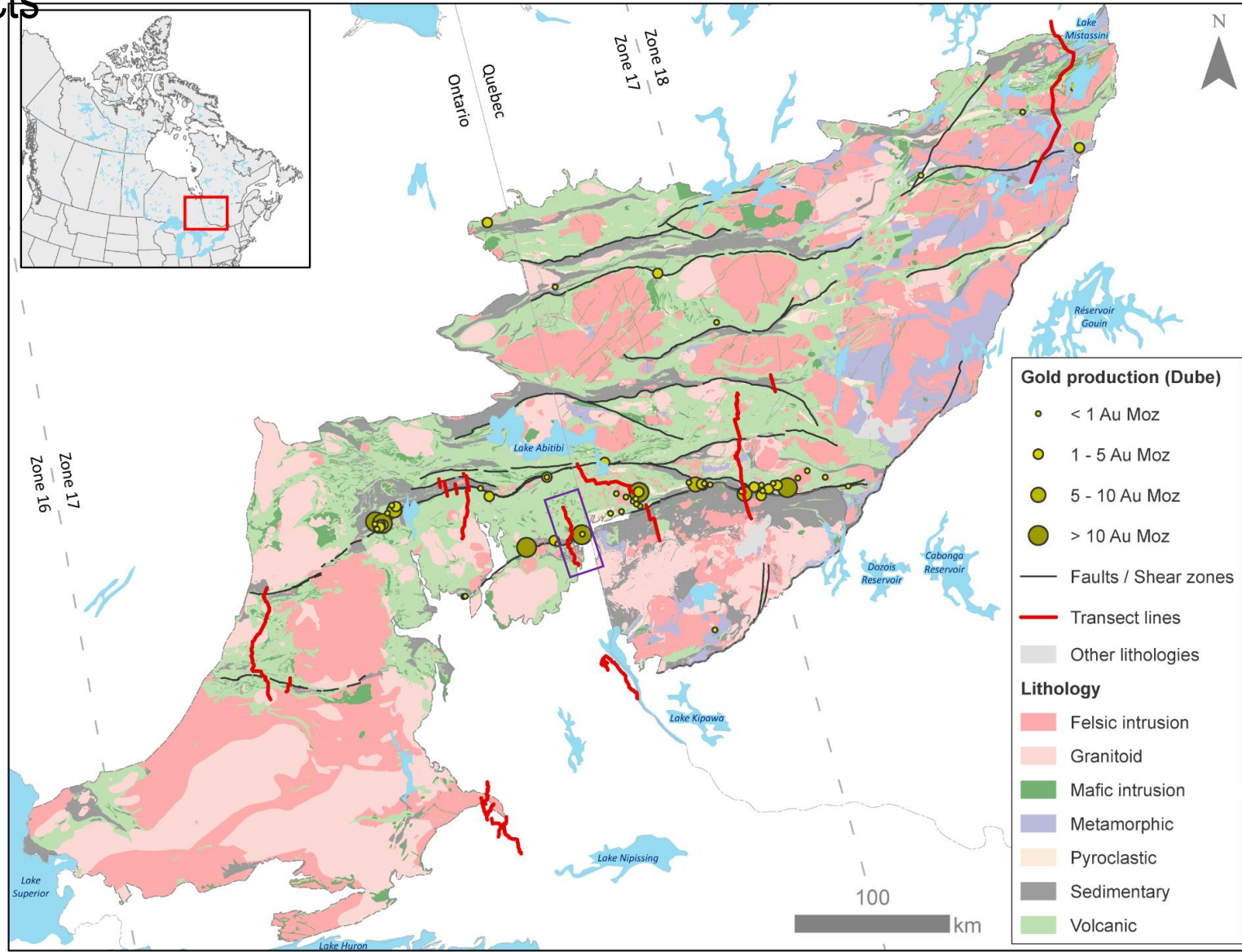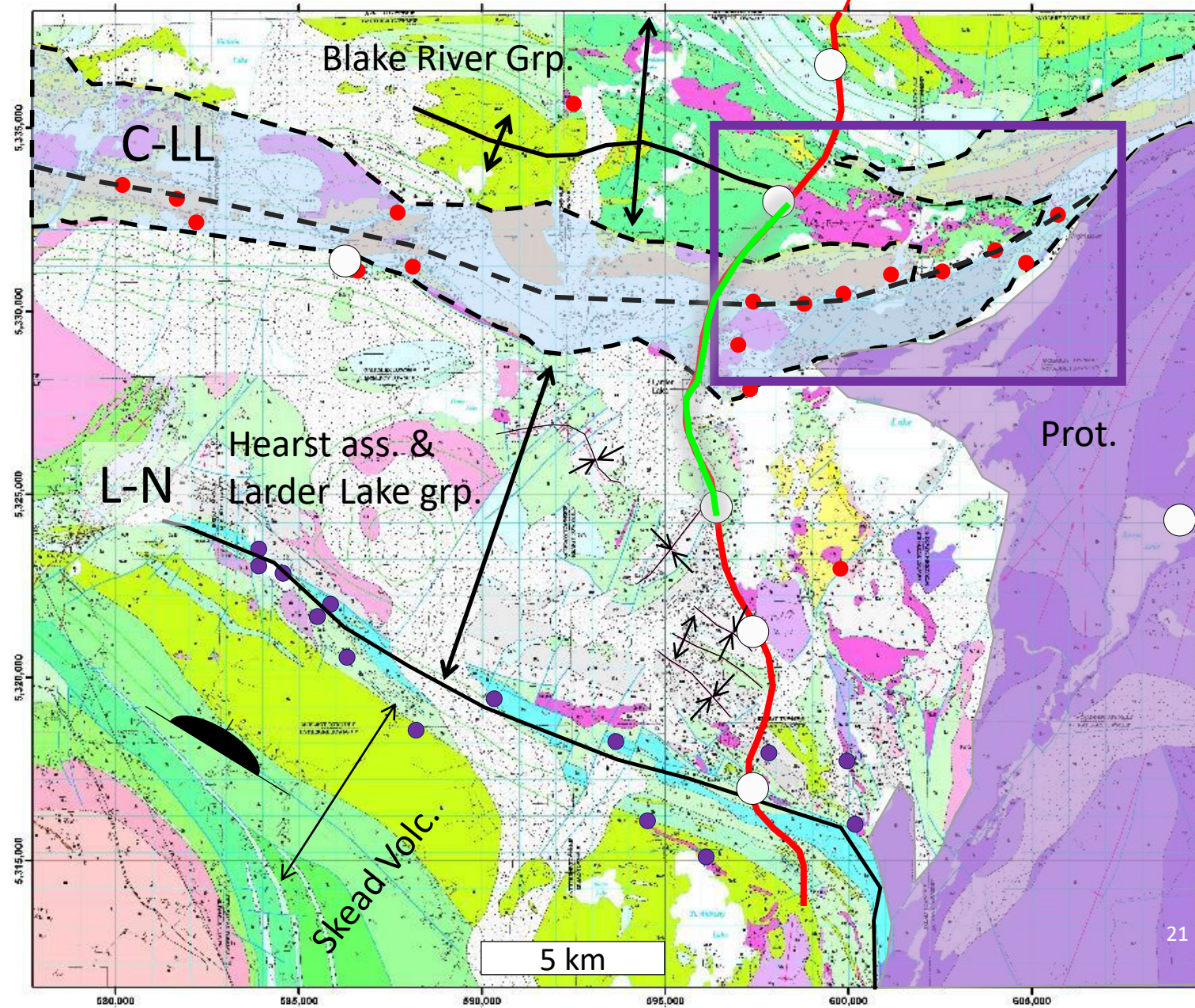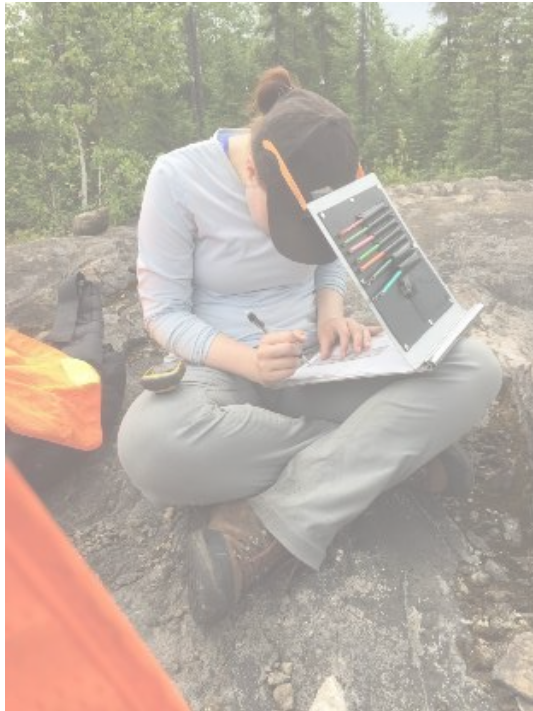
Larder Lake area

Cadillac-Larder Lake break

Extends Matachewan-Val d'Or (250 km)

Contact between Blake River grp. and Timiskaming ass. unconformity.

Contact between Timiskaming ass. and Larder Lake grp. Is C-LL break

Cross section through the C-LL break

N
S

Larder Lake grp. (Piche equivalent) (ca. 2710-2704 Ma)

unconformity

Timiskaming (2679–2669 Ma)

unconformity

Level of exposure

Timiskaming (2679–2669 Ma)

Blake River (2704–2696 Ma)

Cadillac-Larder Lake Break
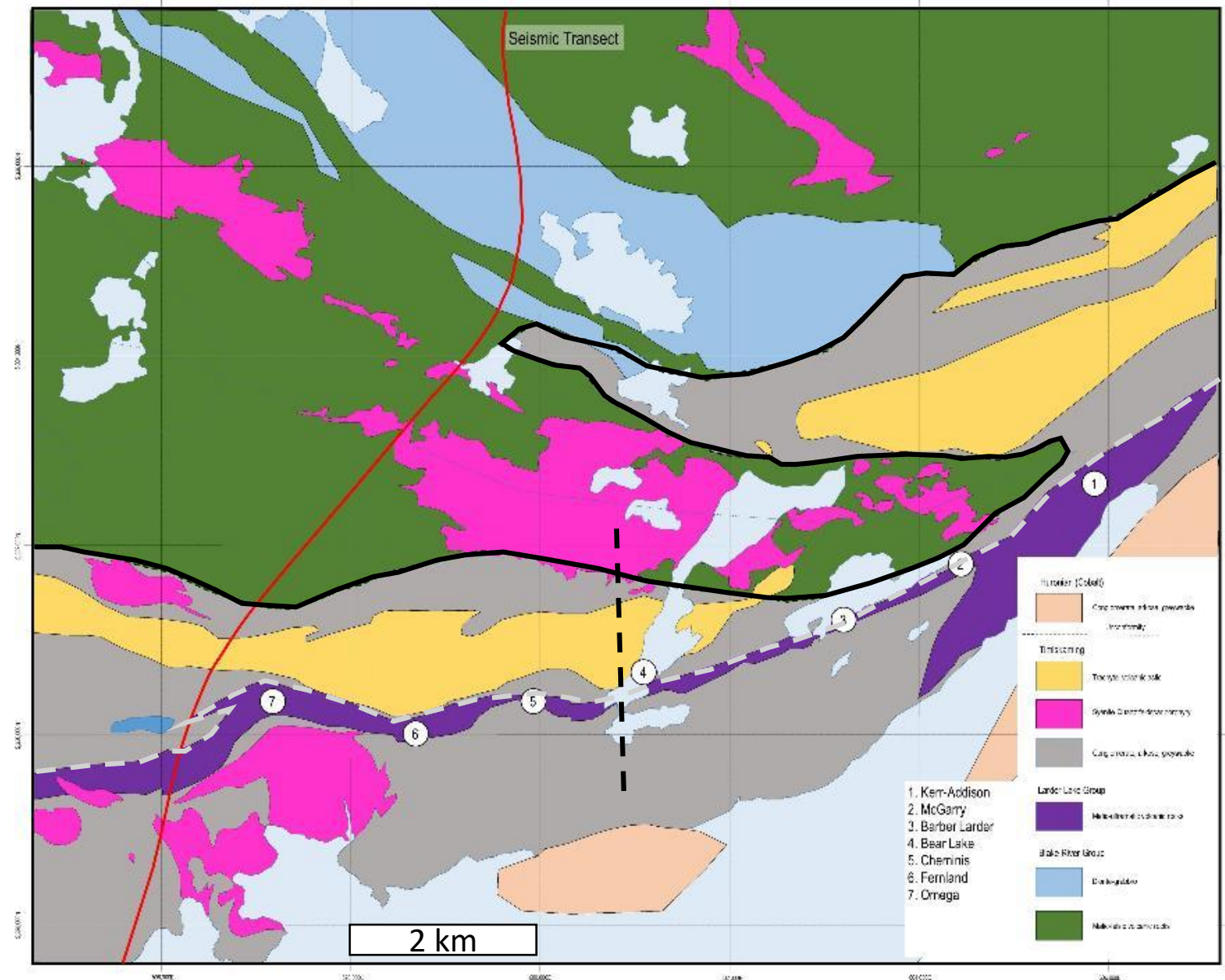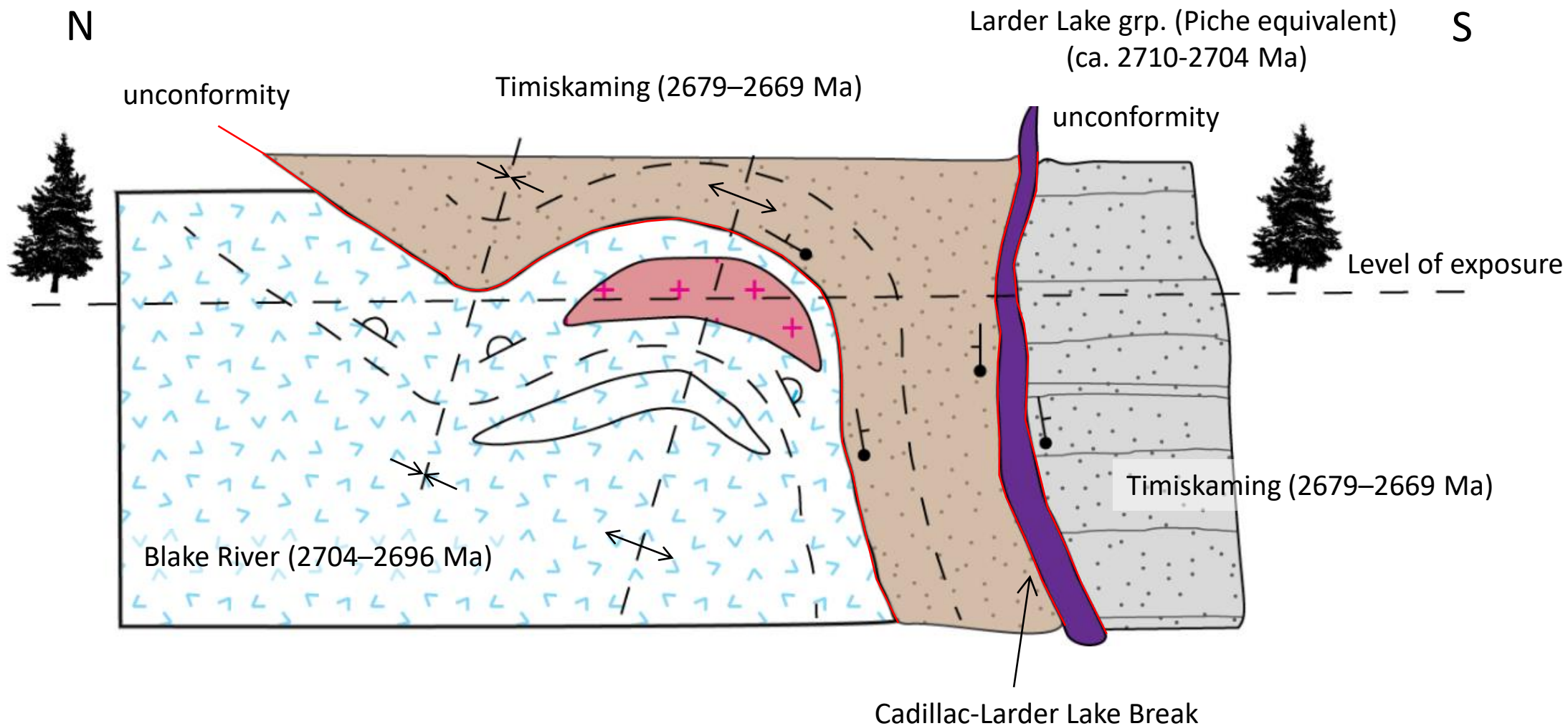
Contact between Larder Lake group and Timiskaming assemblage was initially sedimentary, unconformity

Subsequently modified by several deformation events (D_3)

Mineralization syn-D_2, associated with K-alteration in green carbonate and albite alteration in mafic volcanic rocks

E
W

•LLG mafic to ultramafic fragments

iskaming siltstone

5 mm
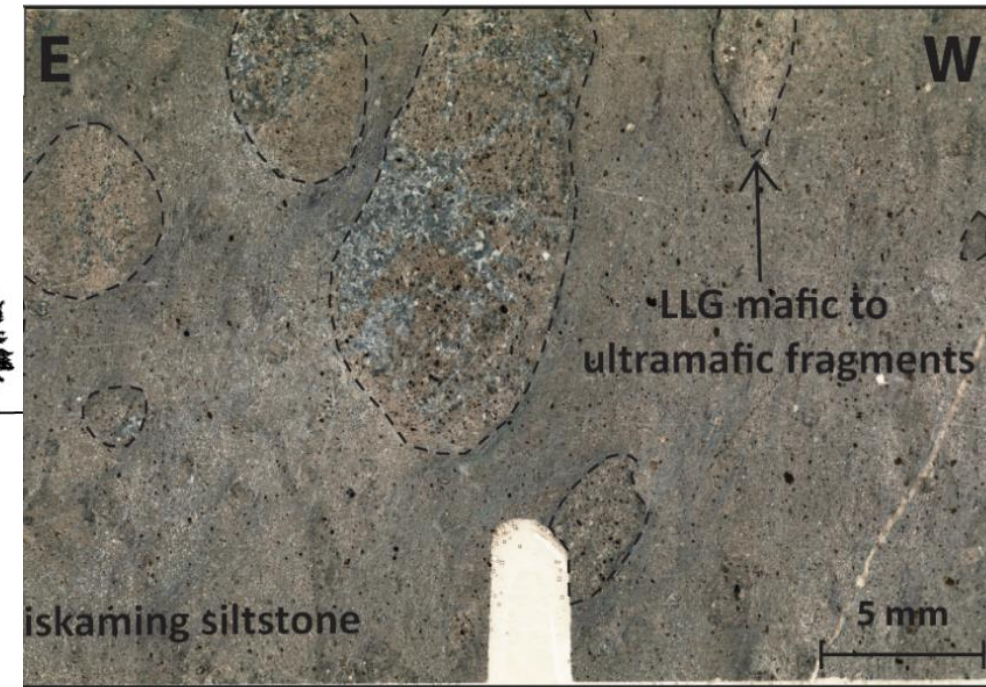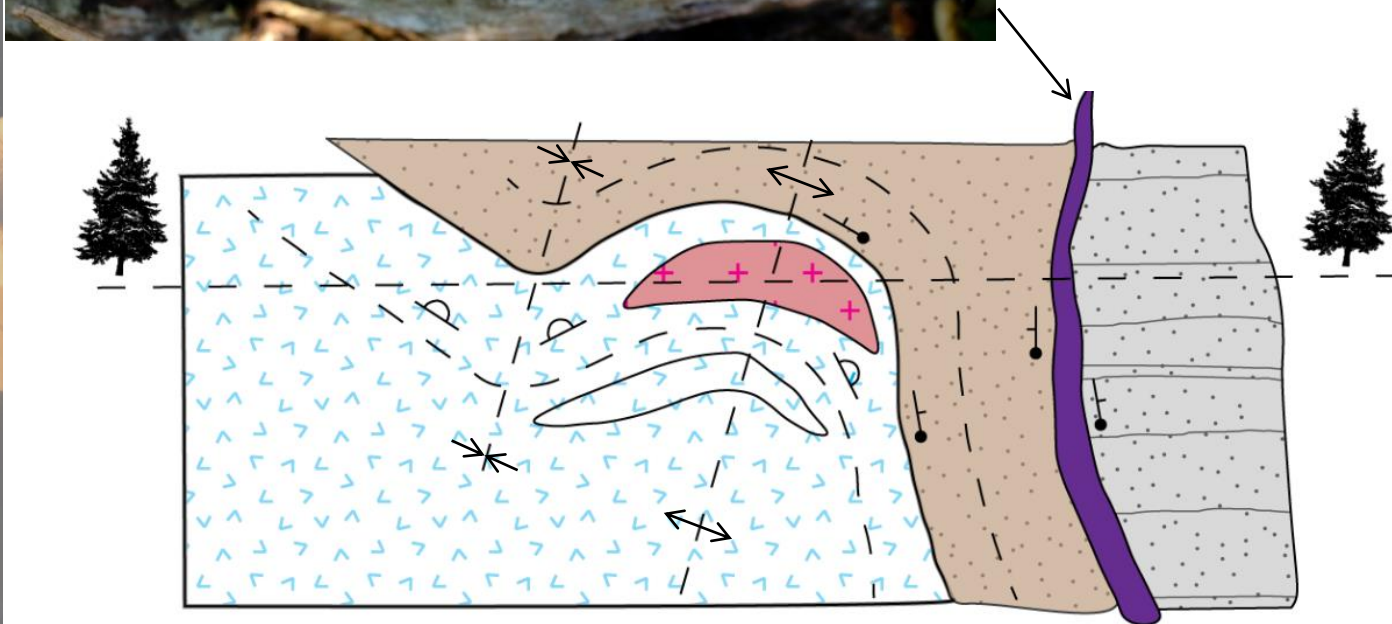
Photos from Nadia St-Jean MSc thesis

Cross section through the C-LL break

unconformity

Level of exposure

Blake River (2704–2696 Ma)
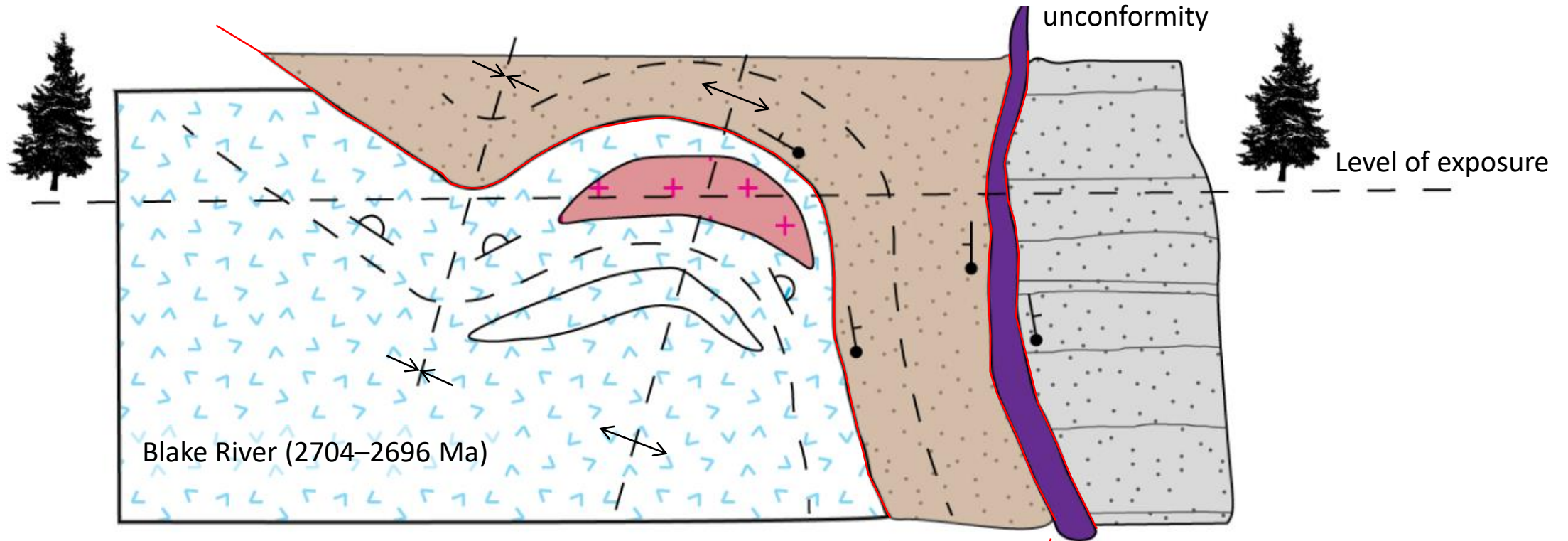
Cadillac-Larder Lake Break

Structural juxtaposition between the Blake River and Larder Lake grps.

Larder Lake area

Series of gold deposits localized along the Larder Lake grp/ (equivalent of the Piche in Quebec)
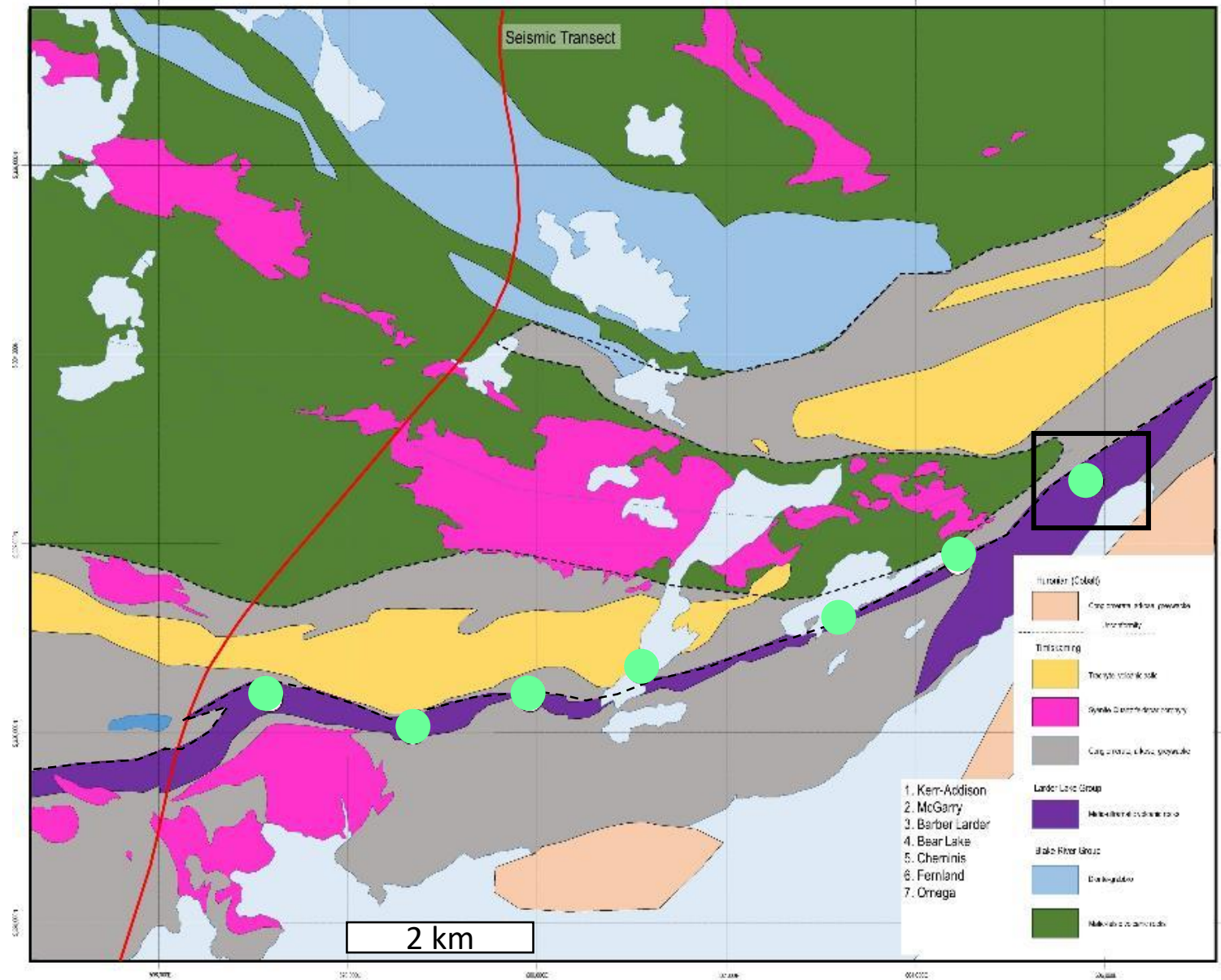
Kerr-Addison

Approx. 11 Mozs of high grade gold (~9 g/t) was produced over a 58 year period; operations ceased in 1996

Immediate FW of "C-LL break"

Associated with main D_2 event
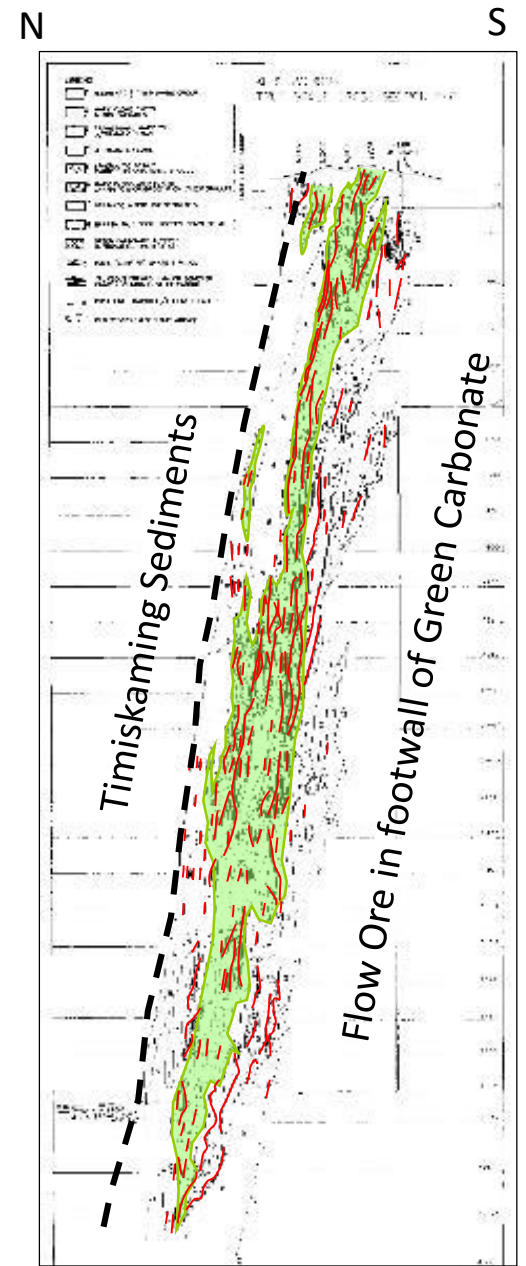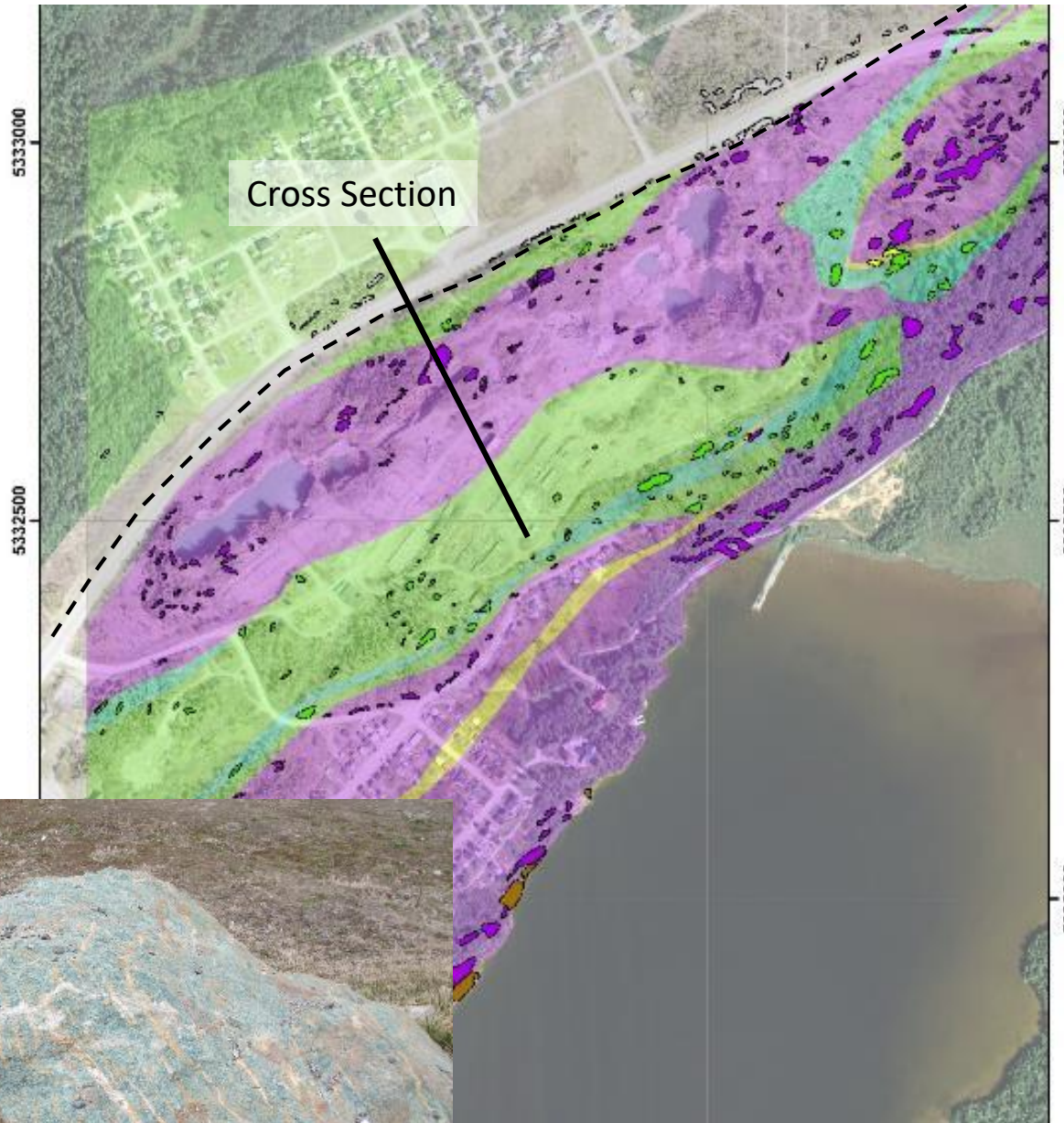
Large Deformation Zones

Cadillac-Larder lake break, marked by Timiskaming clastic sedimentary and alkali volcanic rocks

Hosts gold systems in altered mafic and um rocks

Lincoln Nippising shear zone separates the Skead volcanics from the Larder Lake grp. and the Hearst clastic sediments

Intruded by small-volume stocks and associated gold mineralization
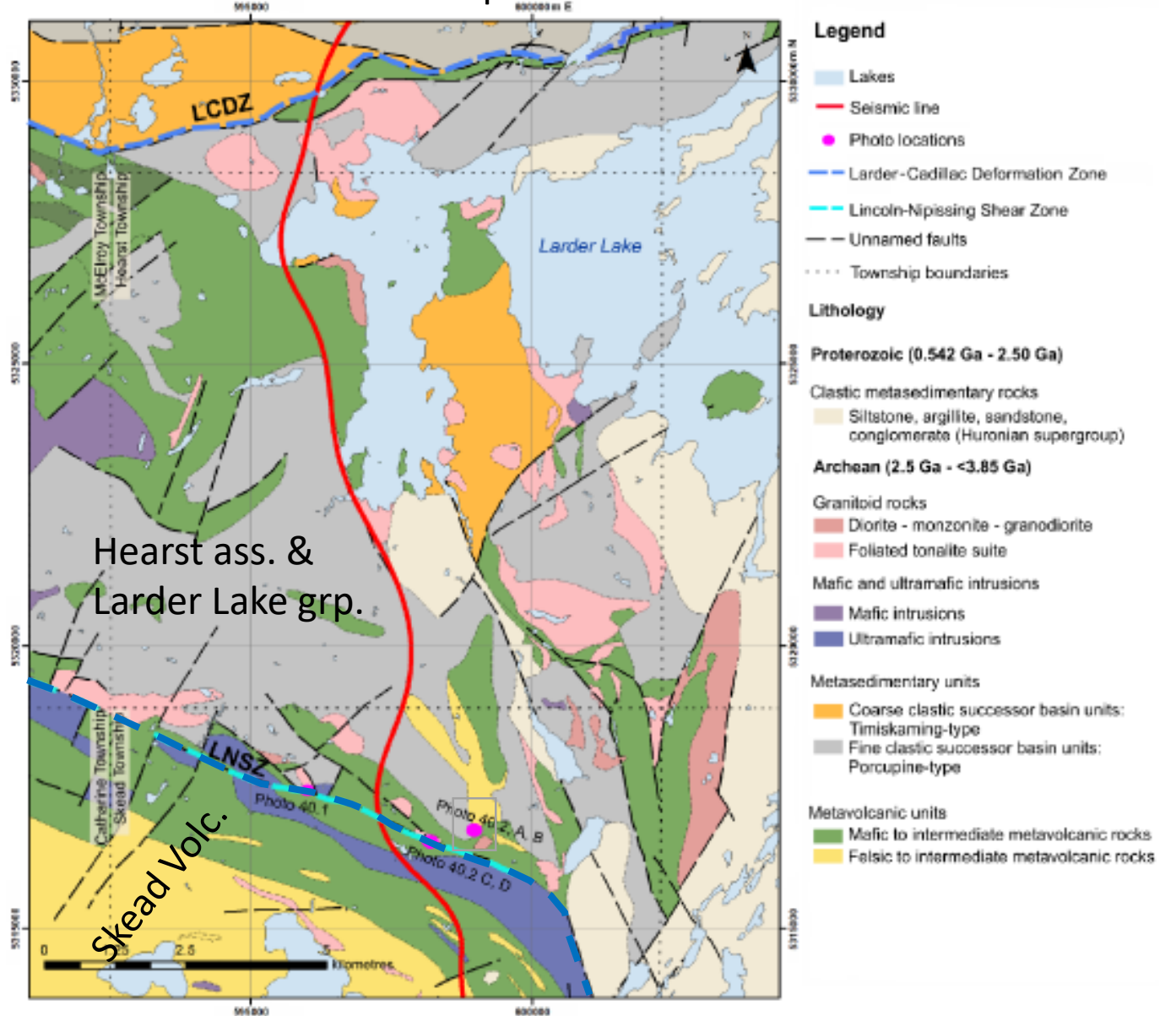
Lincoln Nippising shear zone

Basal unconformity developed between (a) the Larder Lake grp. (ca. 2710-2704 Ma)
and (B) the Hearst ass. (> ca. 2700 Ma)

Similar structural / stratigraphic relationships as the Cadillac-Larder Lake break

Komatiite (serpentinized polyhedral joints)

Basal conglomerate (matrix-supported, unsorted, angular clasts of veined granitoid and spinifex-textured komatiites)

Komatiite clast
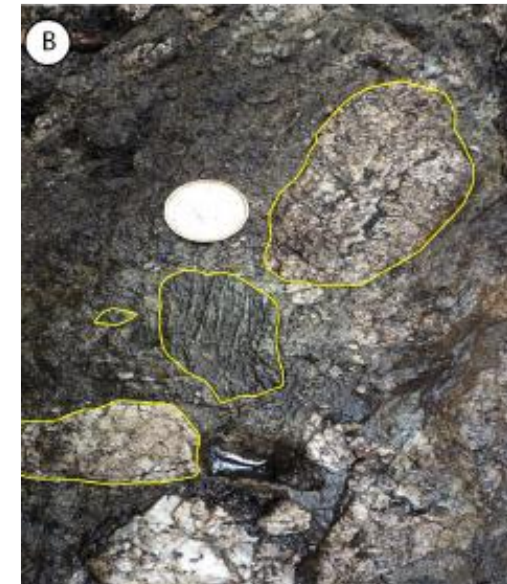
Lincoln Nippising shear zone

Gold prospects associated with small volume intrusive rocks and quartz-carbonate veins
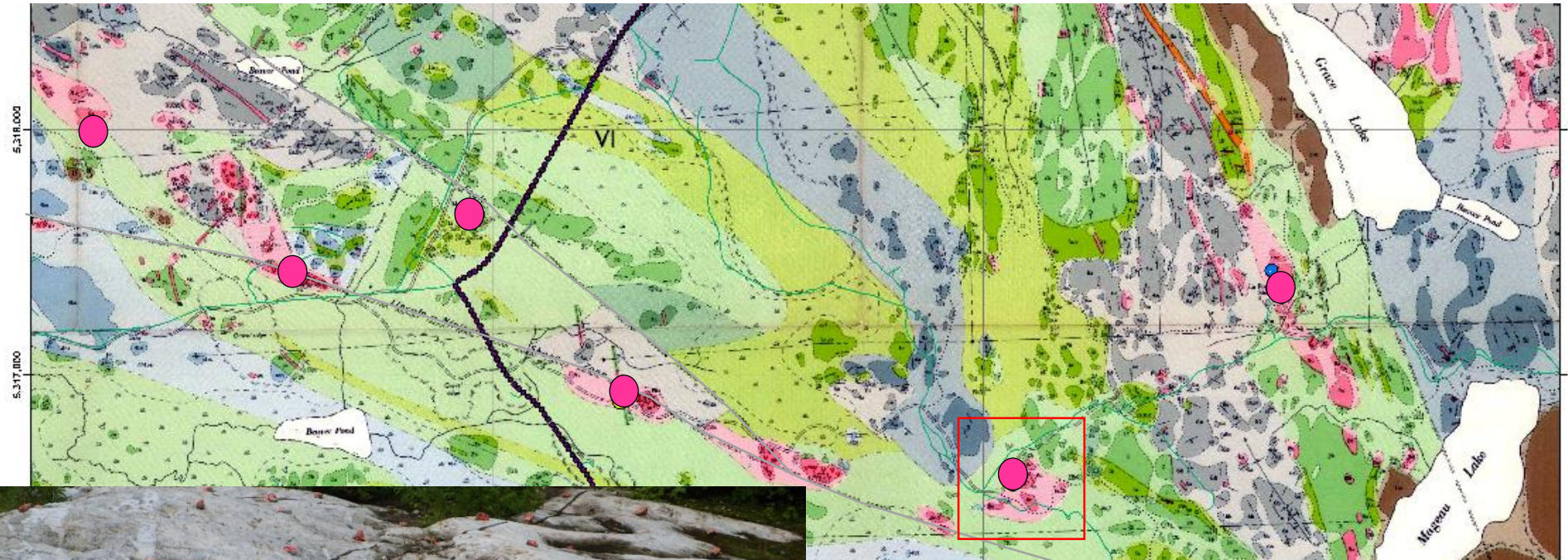
Metal Earth

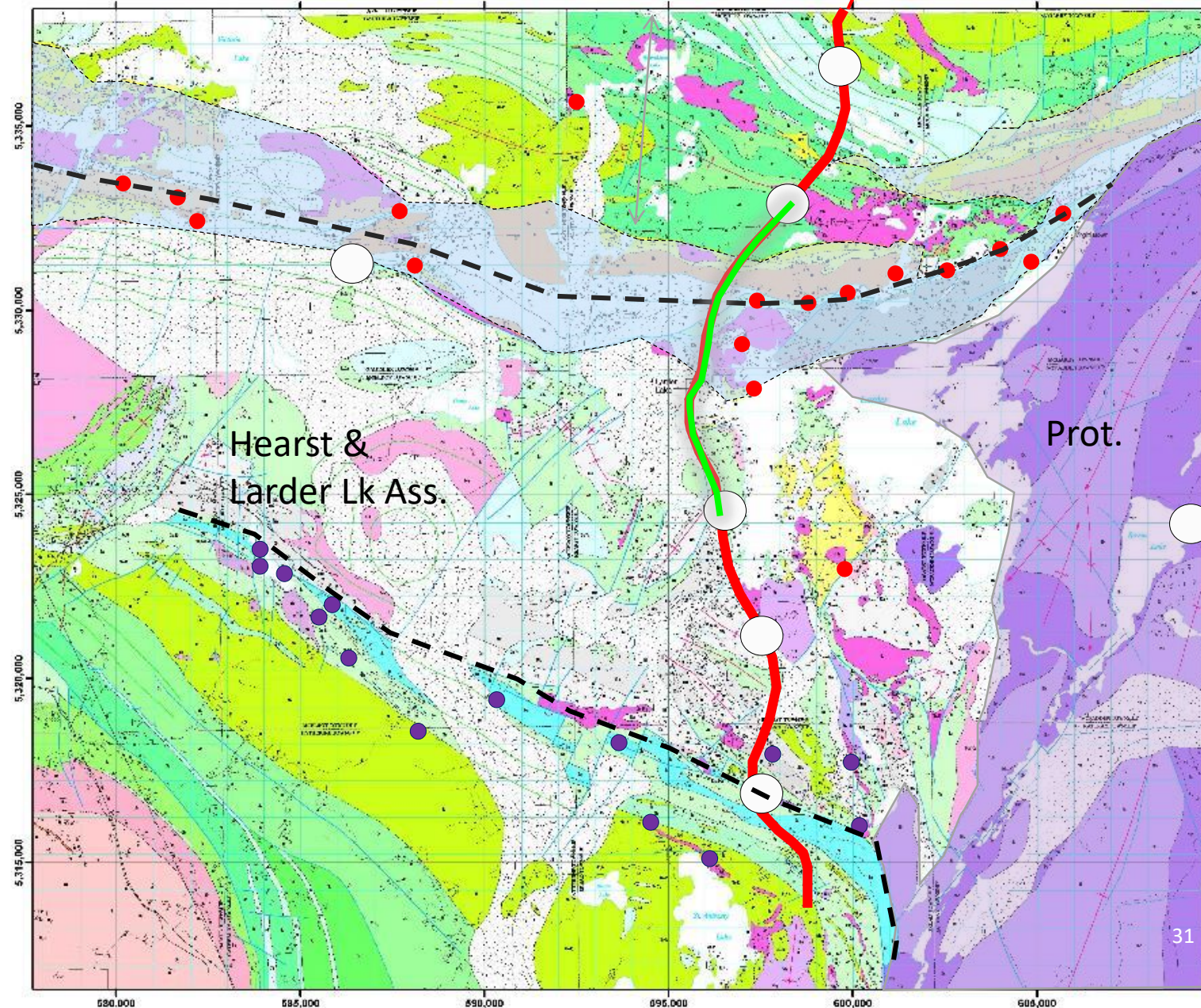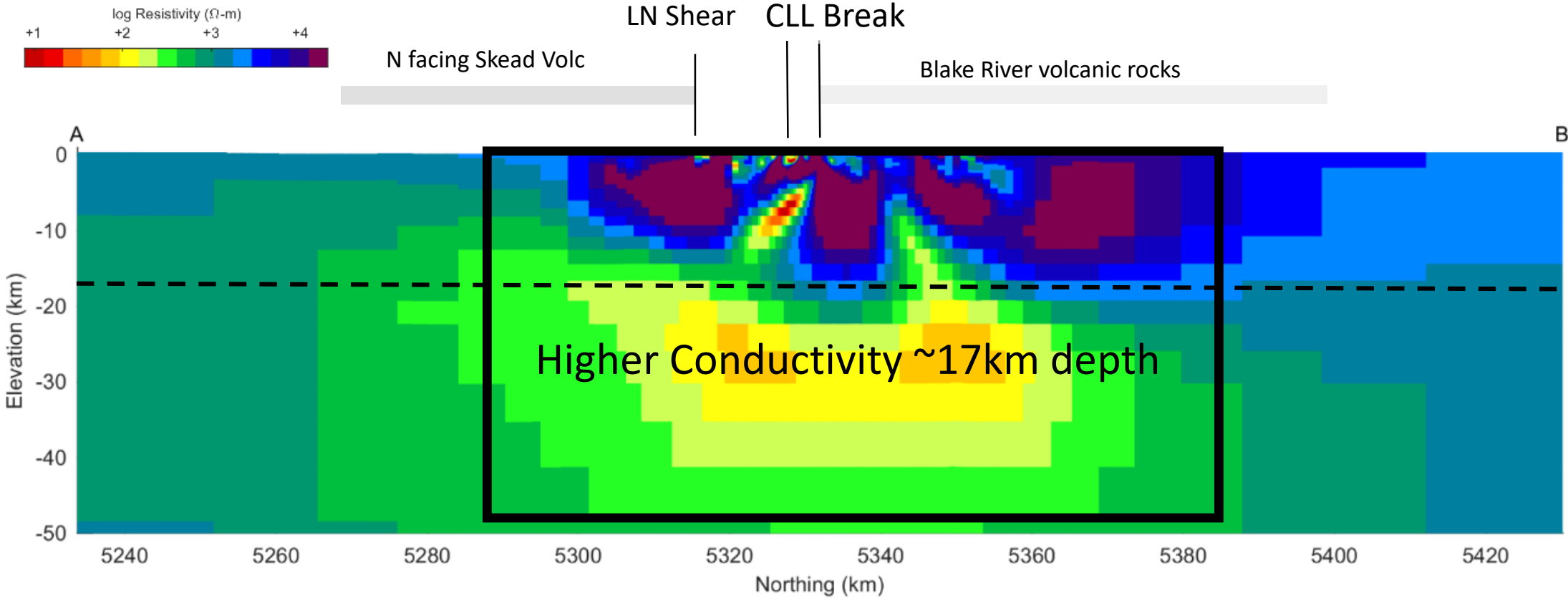Transect Scale Research

Larder Lake Transect

Seismic & MT

Hearst &
Larder Lk Ass.

Prot.

Metal Earth

Larder Lake MT – AMT section, 3D inversion

LL181112-allmdls : Model 11: ice=53 South-North View

log Resistivity (Ω-m)

LN Shear   CLL Break

N facing Skead Volc   Blake River volcanic rocks

Higher Conductivity ~17km depth

Graham Hill, Personal Com..

Larder Lake MT – AMT section, 3D inversion

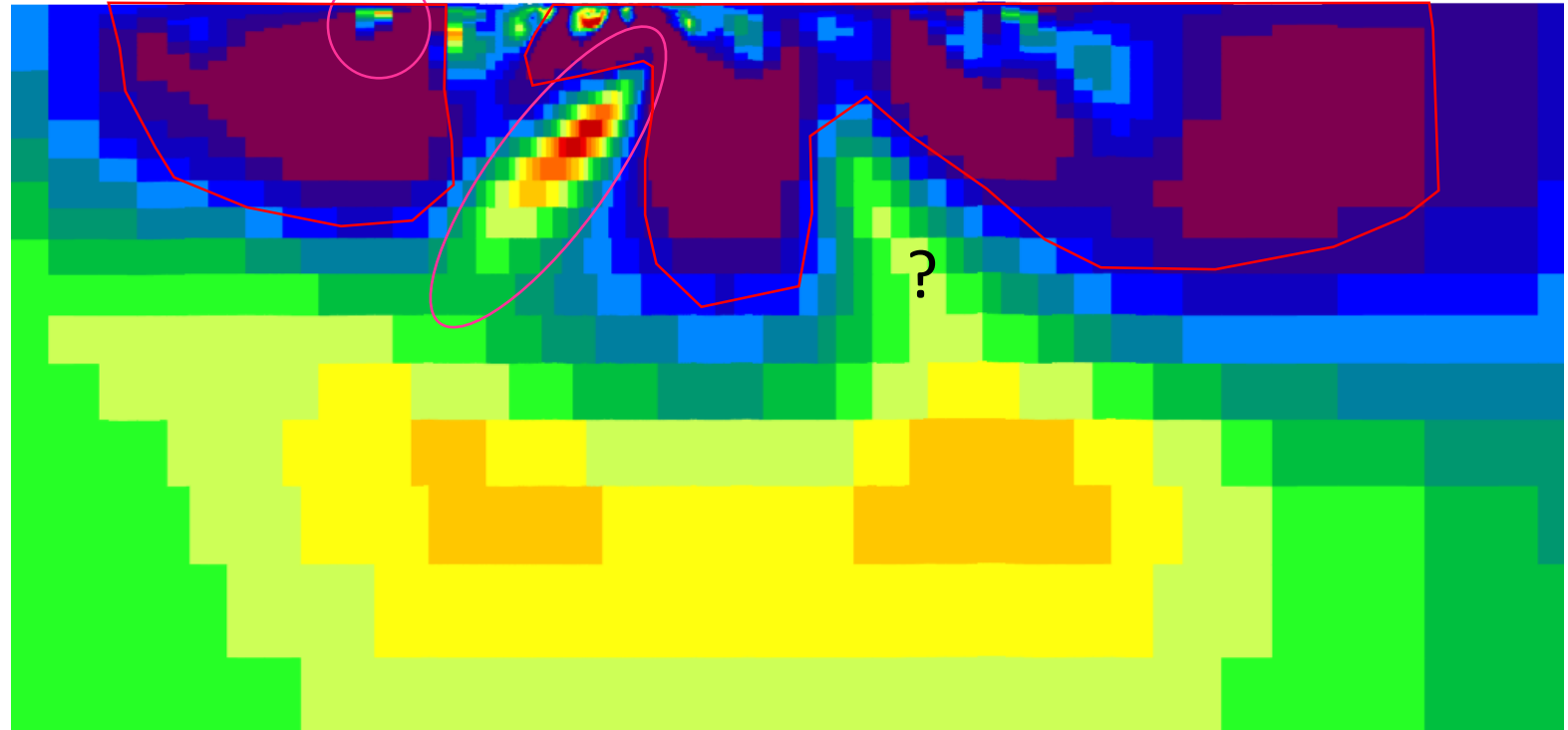LL181112-allmdls : Model 11: ice=53 South-North View
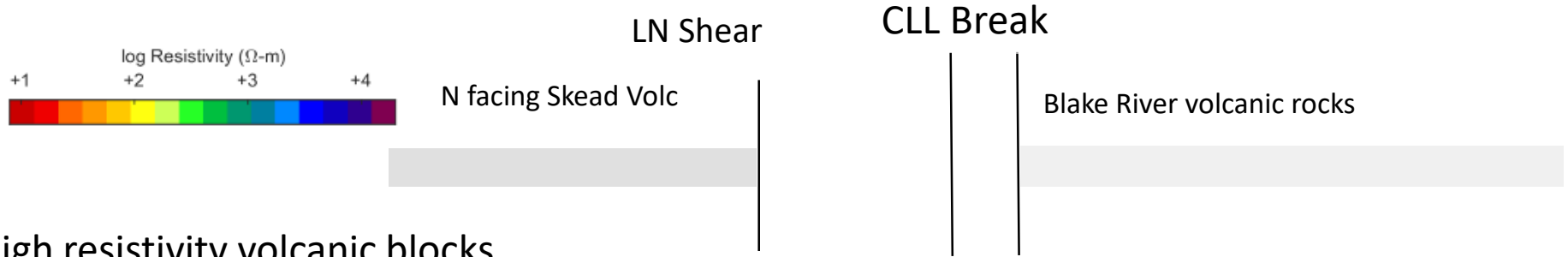
Mapping high resistivity volcanic blocks

C-LL break has conductivity contrast traced to +30km

LN shear very minor conductivity contrast to under 3km

Contrast typically considered alteration effect

LN Shear

CLL Break

N facing Skead Volc

Blake River volcanic rocks

log Resistivity (Ω-m)
+1   +2   +3   +4
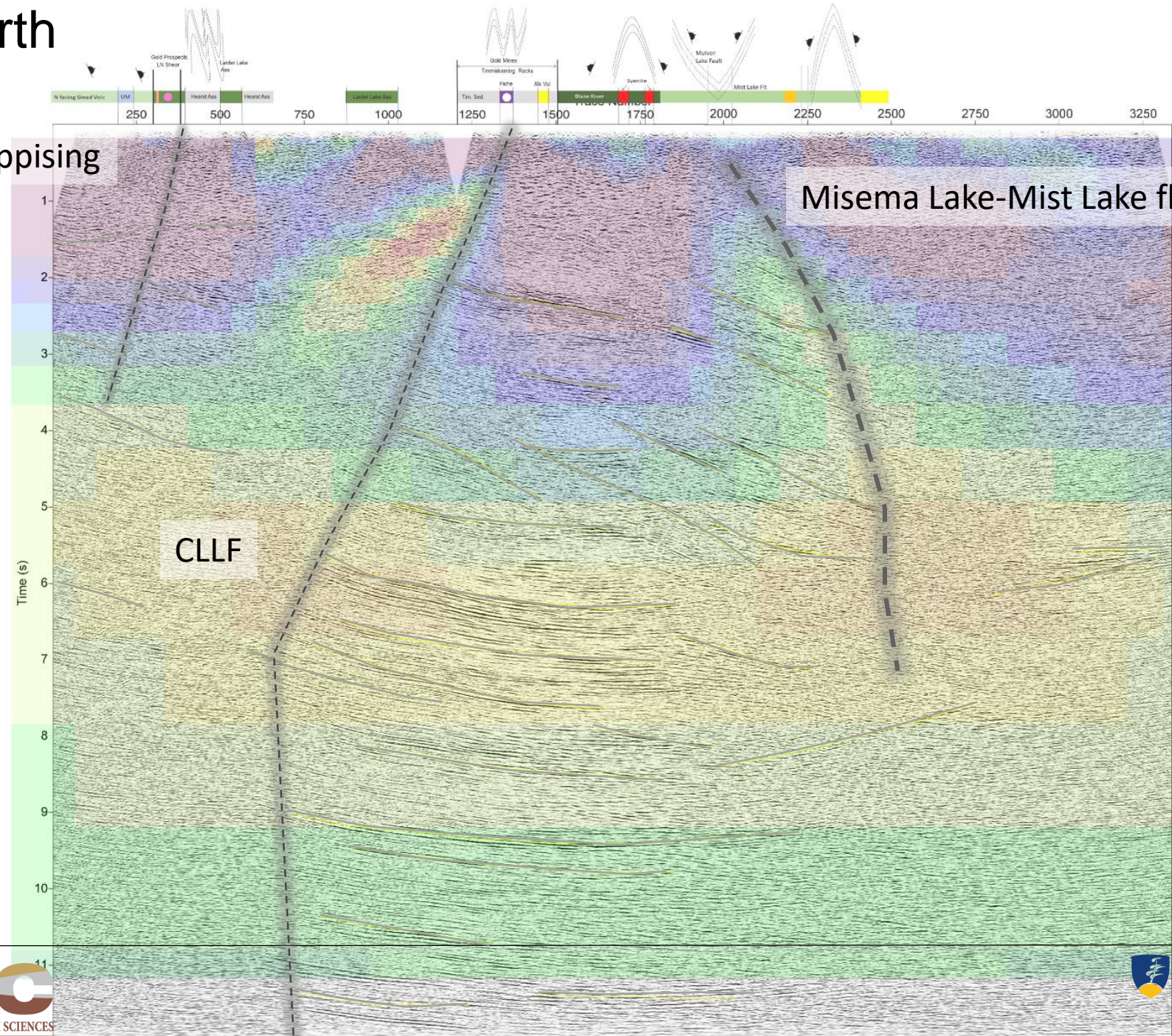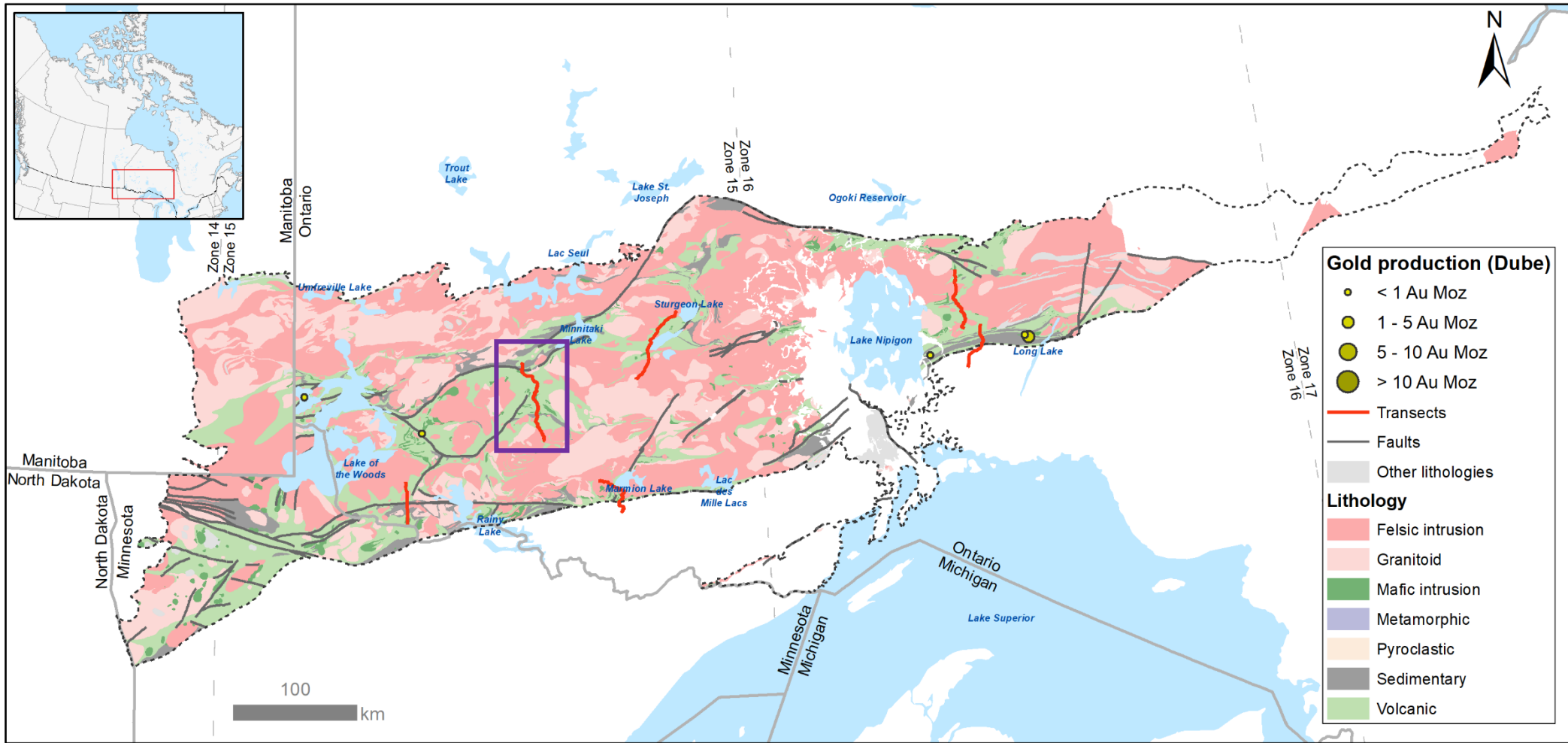
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Graham Hill, Personal Com..

Metal Earth

Lincoln Nippising

Misema Lake-Mist Lake flt
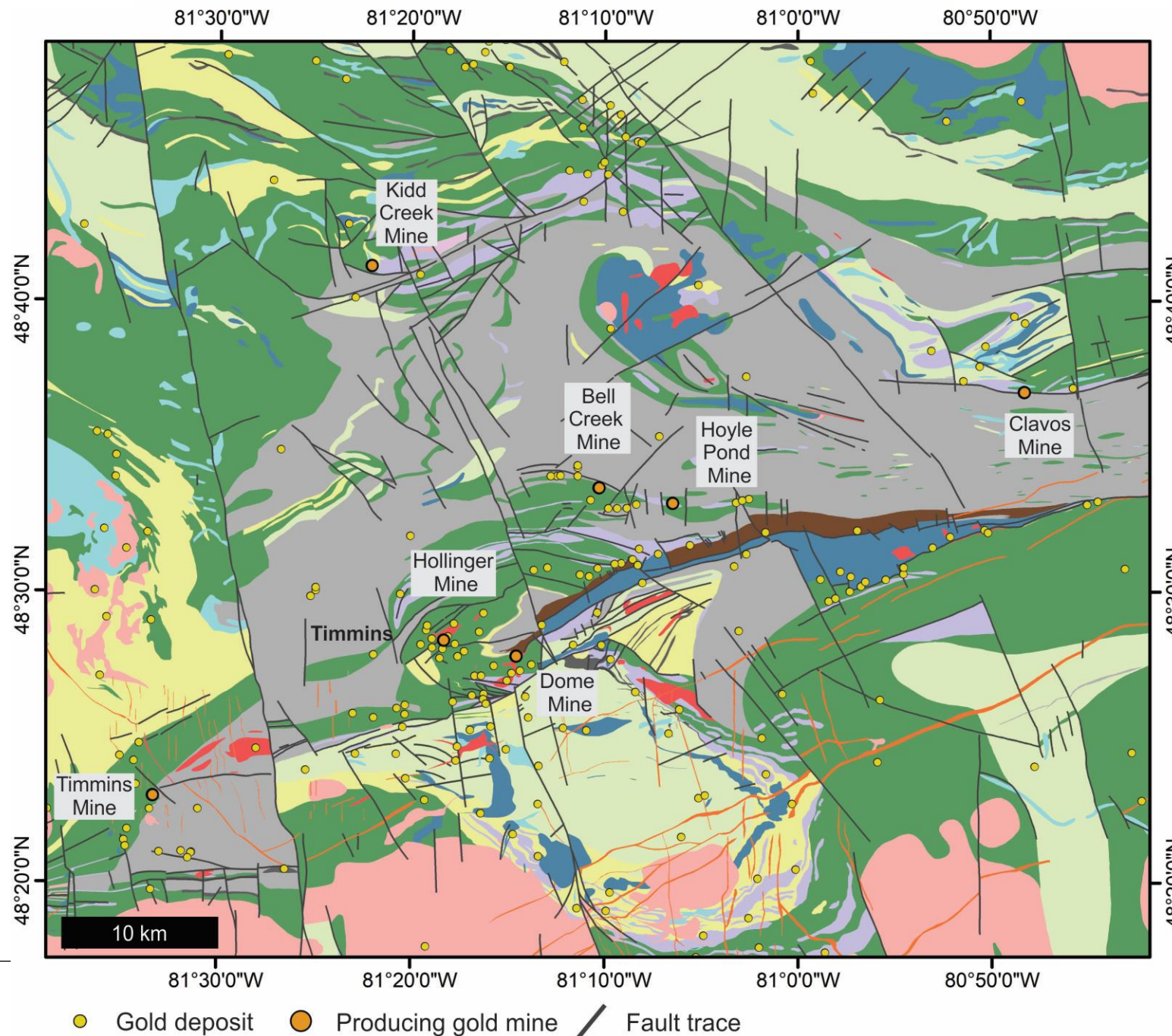
CLLF

Waibigoon Transects

Metal Earth

New reprocessed magnetics

Plus geologic compilation and
two field seasons of mapping

New geologic framework

Use as a basis for comparison/ data
analytics / prospectivity

To Timmins camp, same scale to examine
processes and variations in deposit styles
and endowment

Metal Earth Summary Oct. 2019
Year 4 of 7

o Completed work on Malartic, Noranda, Swayze and Matheson, currently in write up stage. Data release spring 2020

o Completed field work on Chibougamau, Larder Lake, Cobalt, Geraldton and Dryden. Write up in 2019-2020. data release in spring 2021

o Summer 2020 will have field programs at Rainy River (2nd year) Sturgeon (2nd year) and Attikokan (1st year)

o Thematic study on VMS deposits and upcoming studies on Gold and Tectonics

Metal Earth Analytical Capacity

o LA-ICP-MS functioning well. Nearing capacity with ME and HES
- o Invoicing to create a legacy fund to support the machine post-ME
o New SEM in place and booking time for started in mid-Feb 2019
o Moved old HES, LAICP-MS into same room to allow for better configuration of instruments
o Two new petrographic scopes and 2 new binocular scopes for mineral picking
o Update and rehab of HES sample prep facility, new polishing setup

Metal Earth Partners


MEYER WERFT / Hero Lang©

Metal Earth MOU

o MOU with Geological Survey of Canada, NRCan

- Provides a framework for cooperation, research, students, short courses etc.
- Patrick Mercier-Langevin part of Metal Ocean
- Benoît Dubé, Science Advisor
- Possible collaboration on Seismic processing, MT surveys, mantle xenolith work and craton scale metallogeny research

Université du Québec à Chicoutimi (UQAC)
Partners at Chibougamau

o Four MSc, and 1 RA to start field work in Chibougamau camp, summer 2018. Focused on intrusion and VMS related base metal systems and intrusive geochemistry.
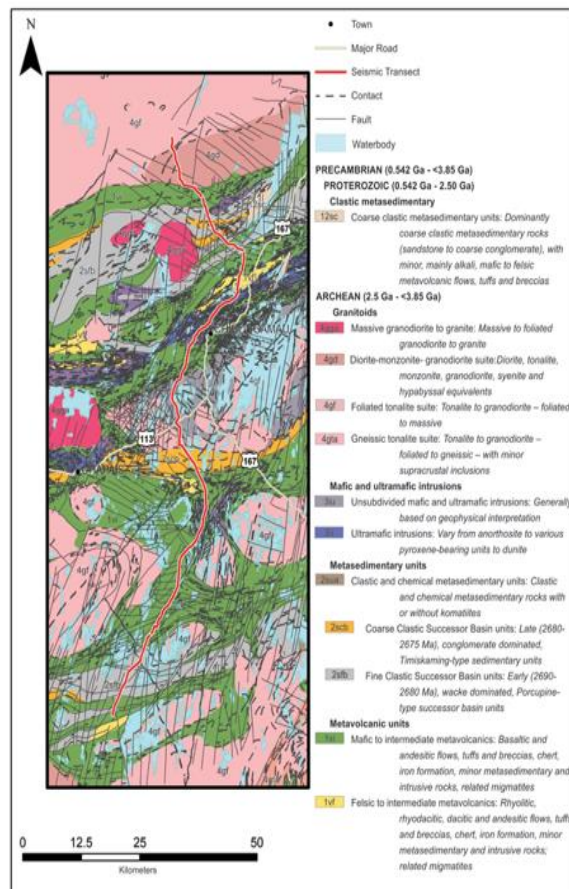
The Chibougamau area, when compared to the rest of the Abitibi Subprovince, has several unique characteristics: fold-dominated architecture, lack of komatiites, unusual intrusions (layered complex and polyphased pluton), and a large amount of "intrusion-related" copper dominated mineralization.
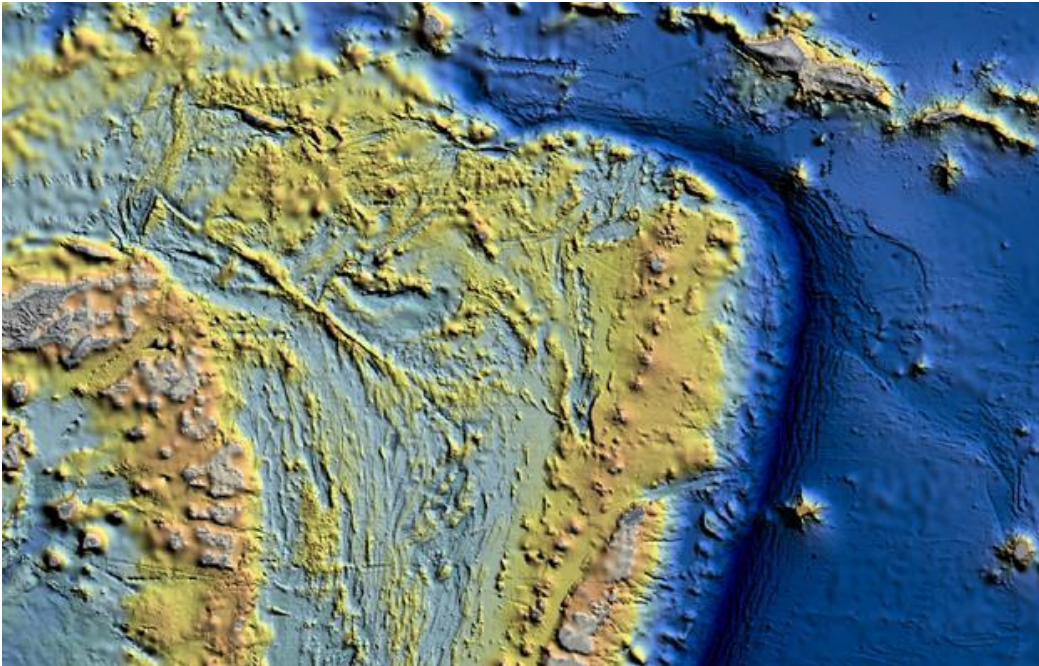
Research will focus on the geologic architecture of deformation corridors, the Chibougamau pluton, the Abitibi-Opatica contact, as well as the contact between Formations.

Dr. Lucie Mathieu

University of Ottawa Modern - Ancient Subgroup

o Microplate tectonic processes, metallogeny of submarine and subaerial ocean and continental arcs, plate boundaries

o Margaret Stewart, PDF, technician position advertised, First Cruise for seismic survey December 2018. Patrick Mercier-Langevin GSC participation.
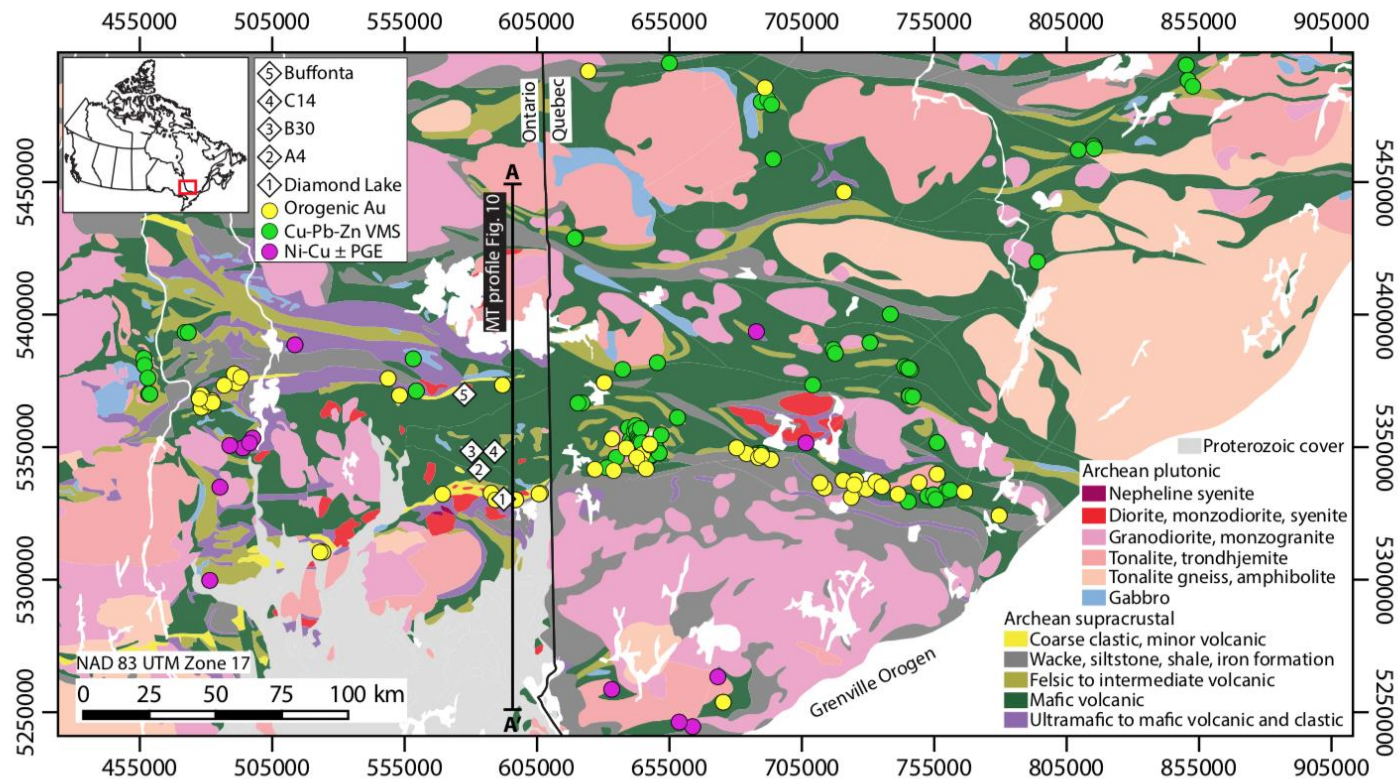

Metal Oceans is a subproject of Metal Earth focusing on the comparison of modern ocean crust and its evolution with the structure and composition of Archean greenstone belts. The primary objective is to investigate the relationship between microplate formation and the emergence of magmatic-hydrothermal systems in modern convergent-margin settings in order to better understand crustal growth and metal endowment in Archean greenstone belts.

Bathymetric map of the northern Lau Basin showing its complex geology and structure.
(Source: Global Multi-Resolution Topography Data Synthesis)

Mantle Group (U of A, Carnegie Institution and U of Maryland)

o The primary objective for 2017/2018 will be to analyse mantle xenolith samples from an extensive mantle xenolith sample suite (Kirkland Lake and Wawa) that documents the mantle beneath the Superior craton.

The Mantle Group research, for this subproject of Metal Earth, focuses on the generation and evolution of sub-continental mantle underpinning both the Superior and Slave cratons and its relationship to the formation and evolution of the greenstone belts and Archean crust.

Metal Earth

Université of Laval (Georges Beaudoin)
Stable Isotopes

o   Have not started collaborative work, lab completion in fall 2018.
o   Post-doc in field July and August

University of Toronto (Mike Hamilton)
Geochronology (TIMS)

o   Completed 30 TIMS in 2017 and targeting 50-60 TIMS analysis in 2018
o   Integrate Mike into aspects of field work and interpretation

Thank you.

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METAL EARTH

A new Canadian research initiative funded by Canada First Research Excellence Fund.

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