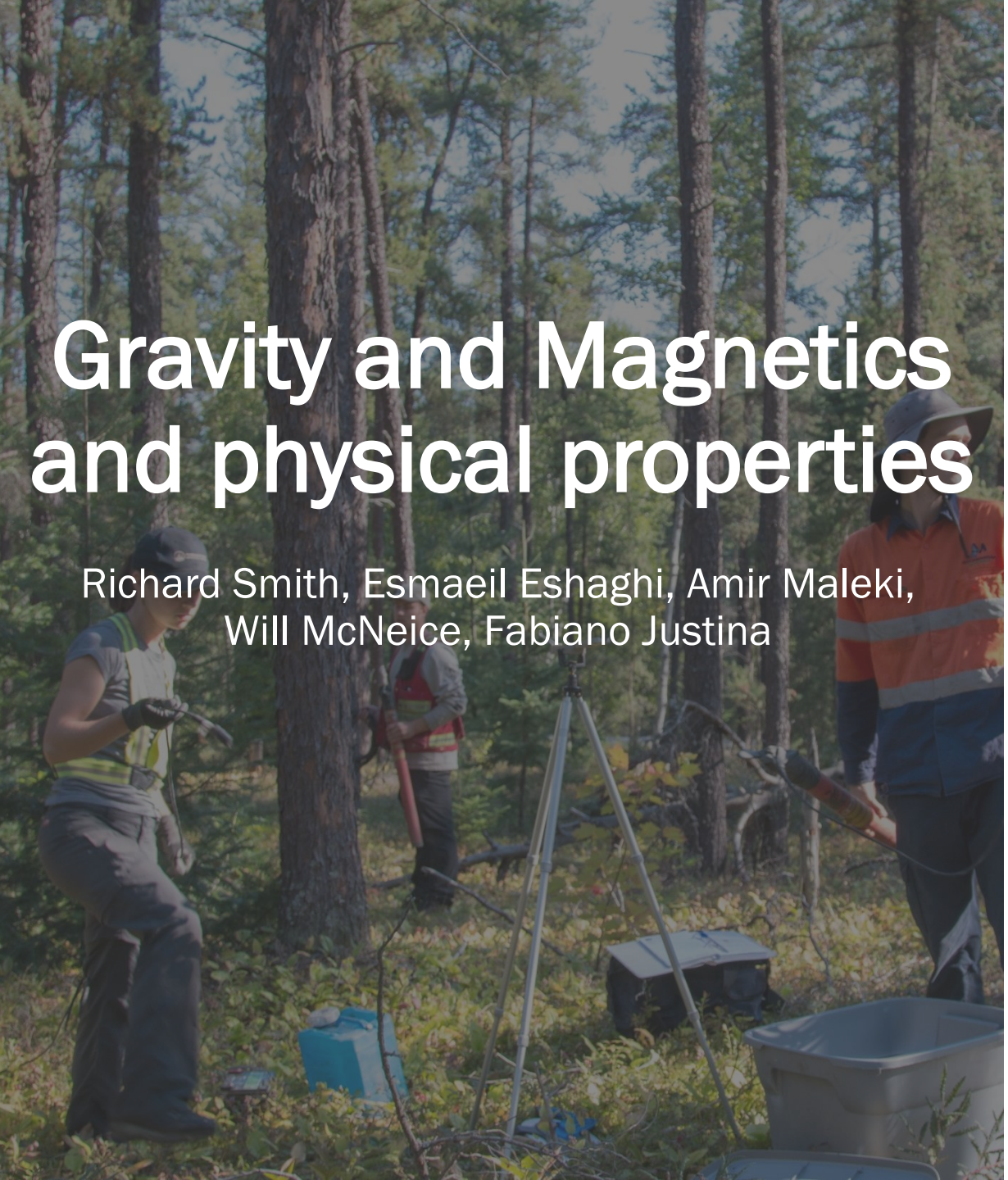


Gravity and Magnetics and physical properties

Richard Smith, Esmaeil Eshaghi, Amir Maleki,
Will McNeice, Fabiano Justina

METAL EARTH

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

CANADA FIRST RESEARCH EXCELLENCE FUND

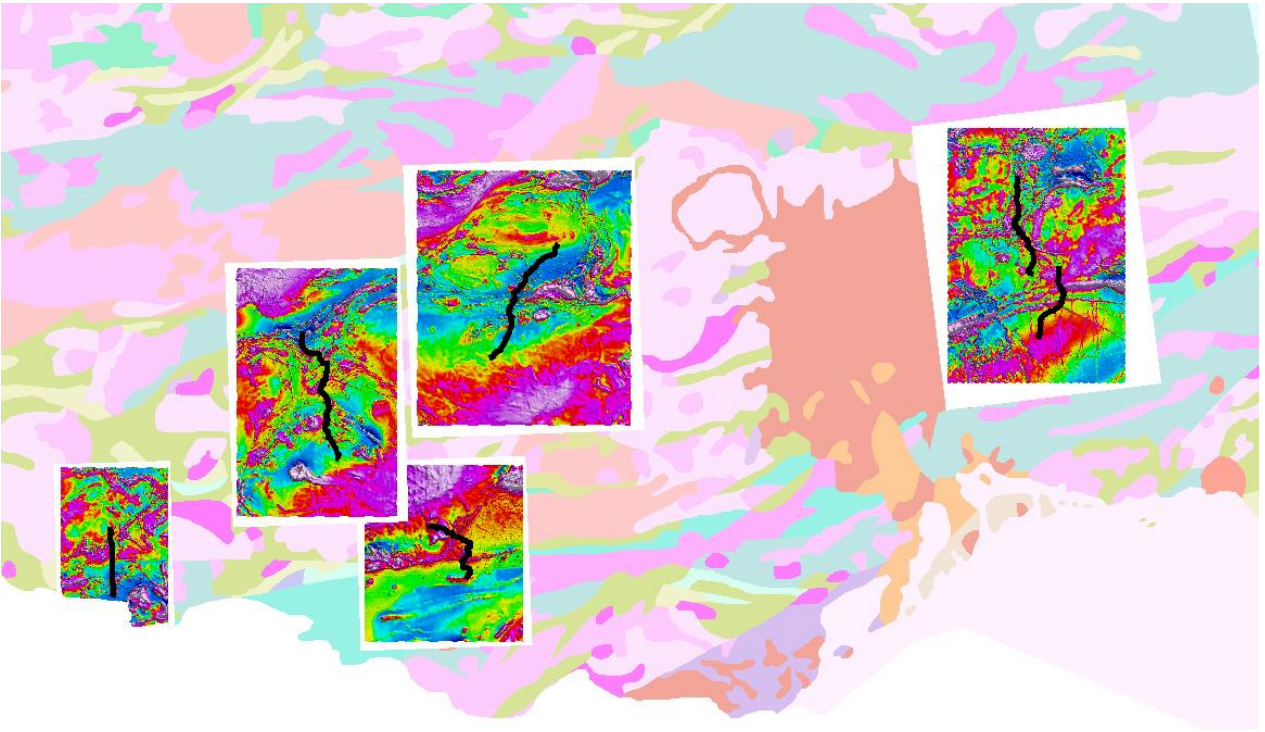
Canada

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

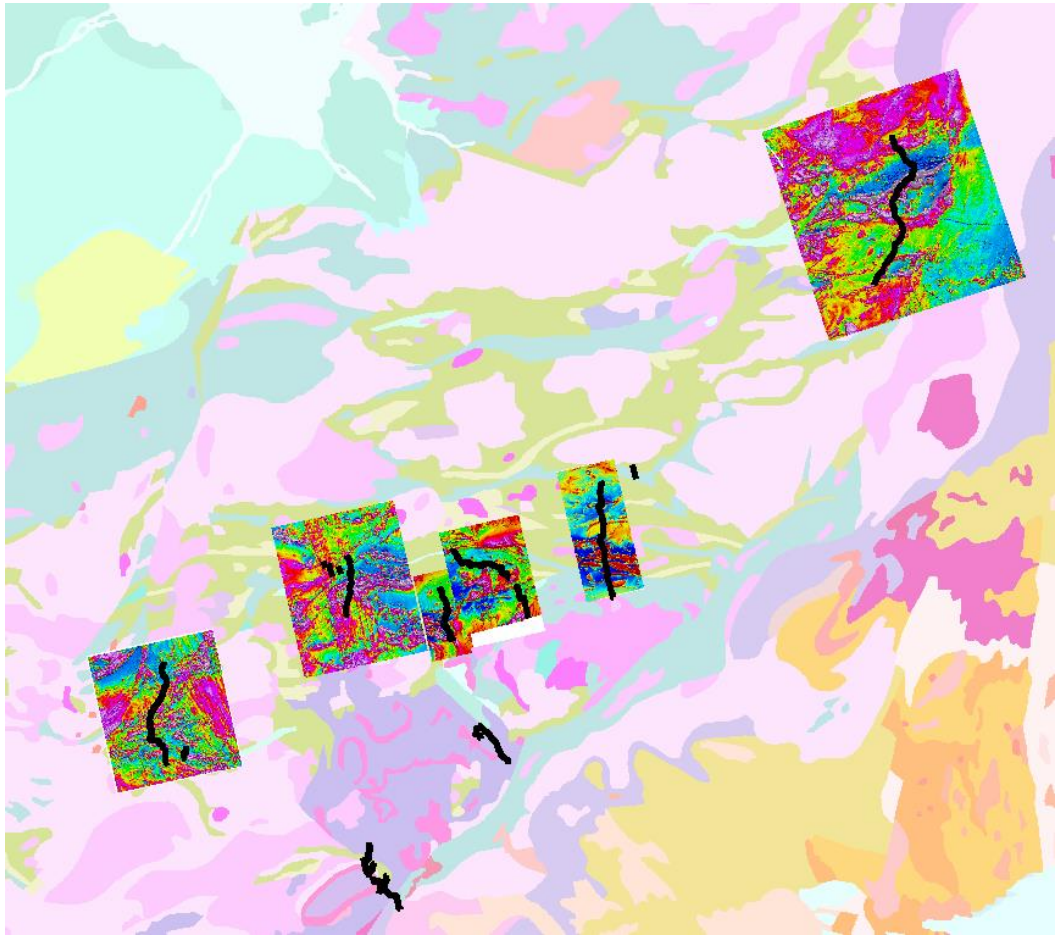
MERC
Mineral Exploration Research Centre

Magnetic data (compiled, levelled, interpreted)

Western Superior



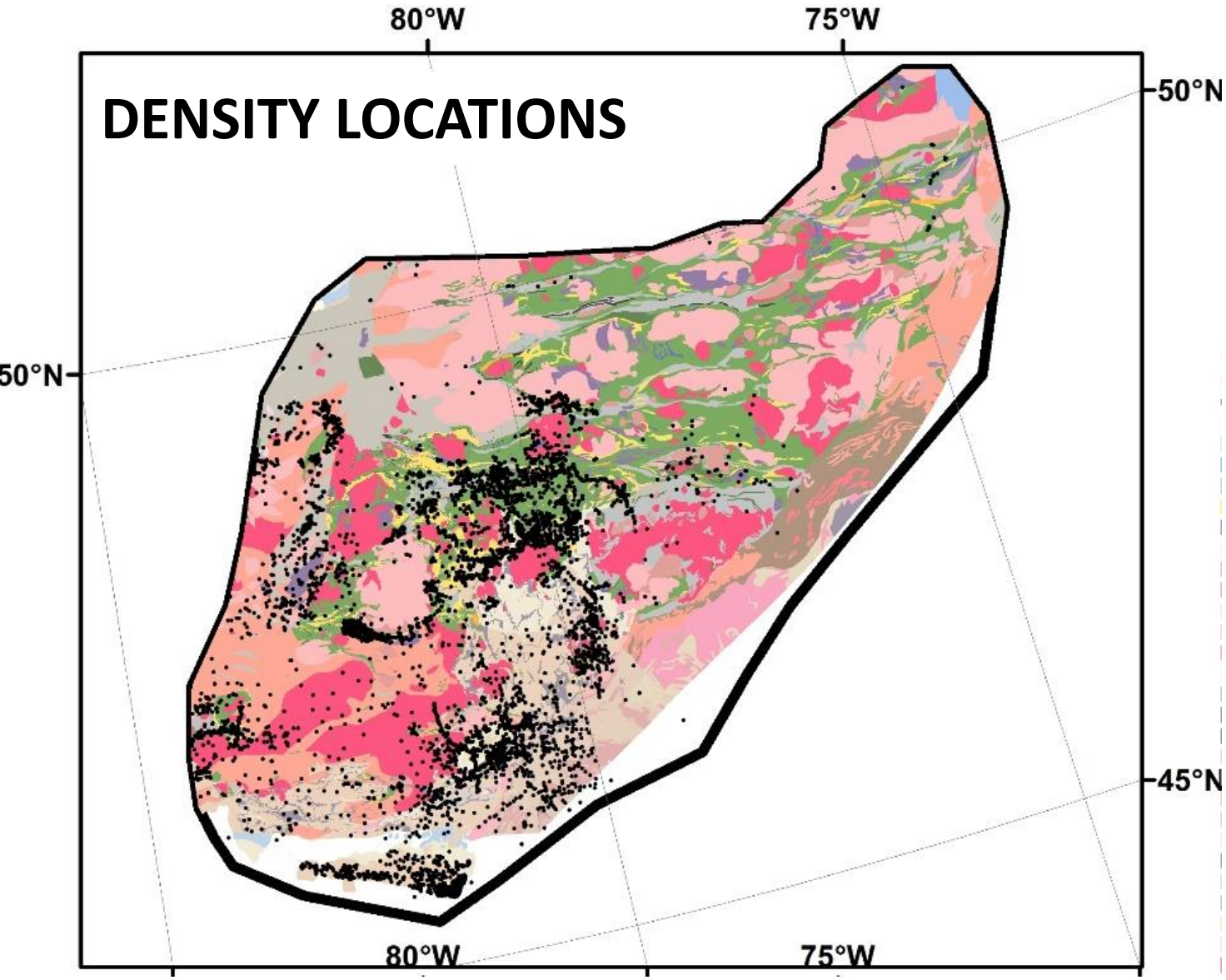
Eastern Superior



METAL EARTH

Eshaghi

Petrophysical measurements



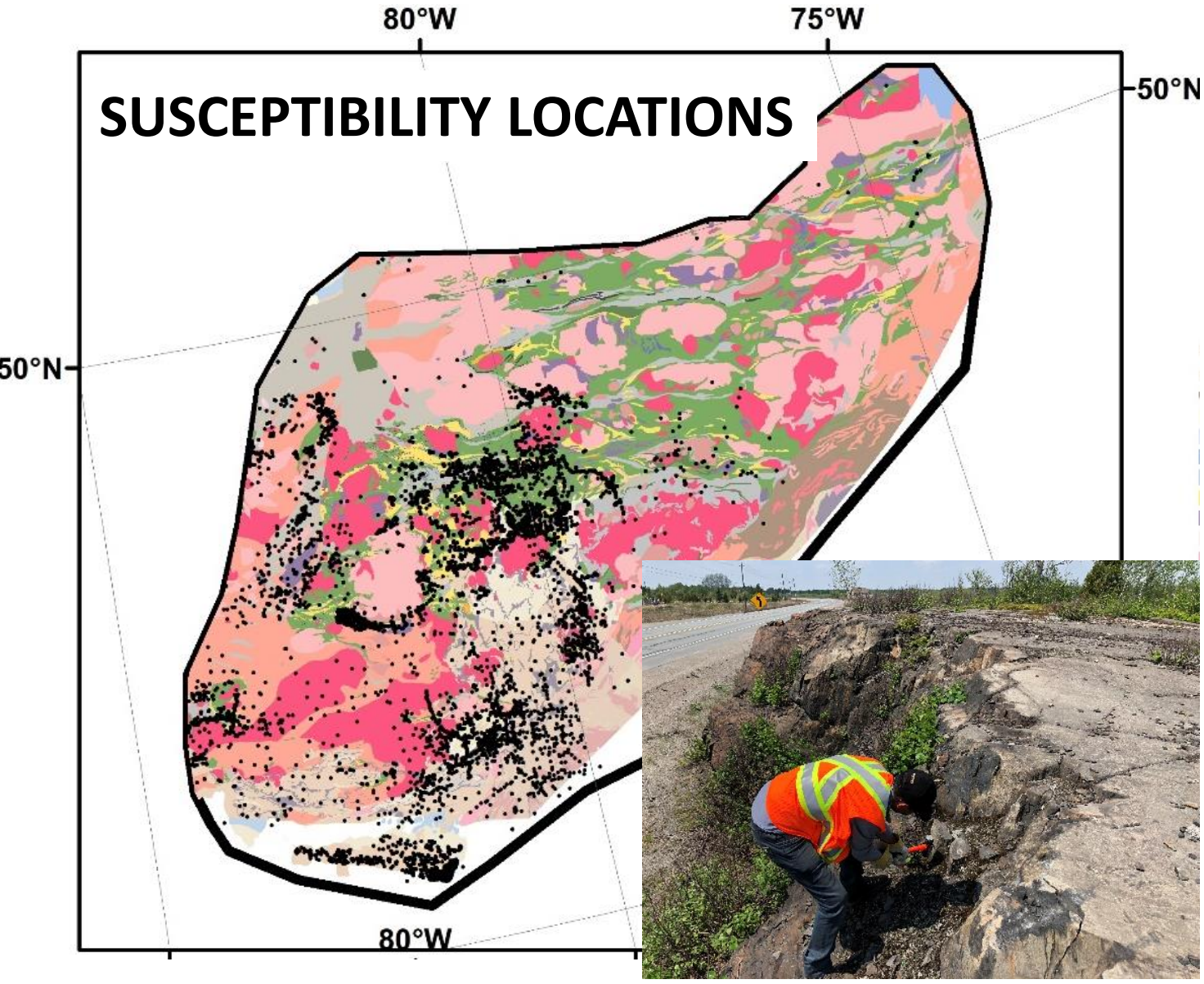
Density will be used to constrain inversions

- >43000 density measurements were compiled from various sources (e.g. ME, GSC, OGS, MGS, Footprint).
  - >15000 were from Abitibi
- Few in Chibougamau

METAL EARTH

Eshaghi

Petrophysical measurements

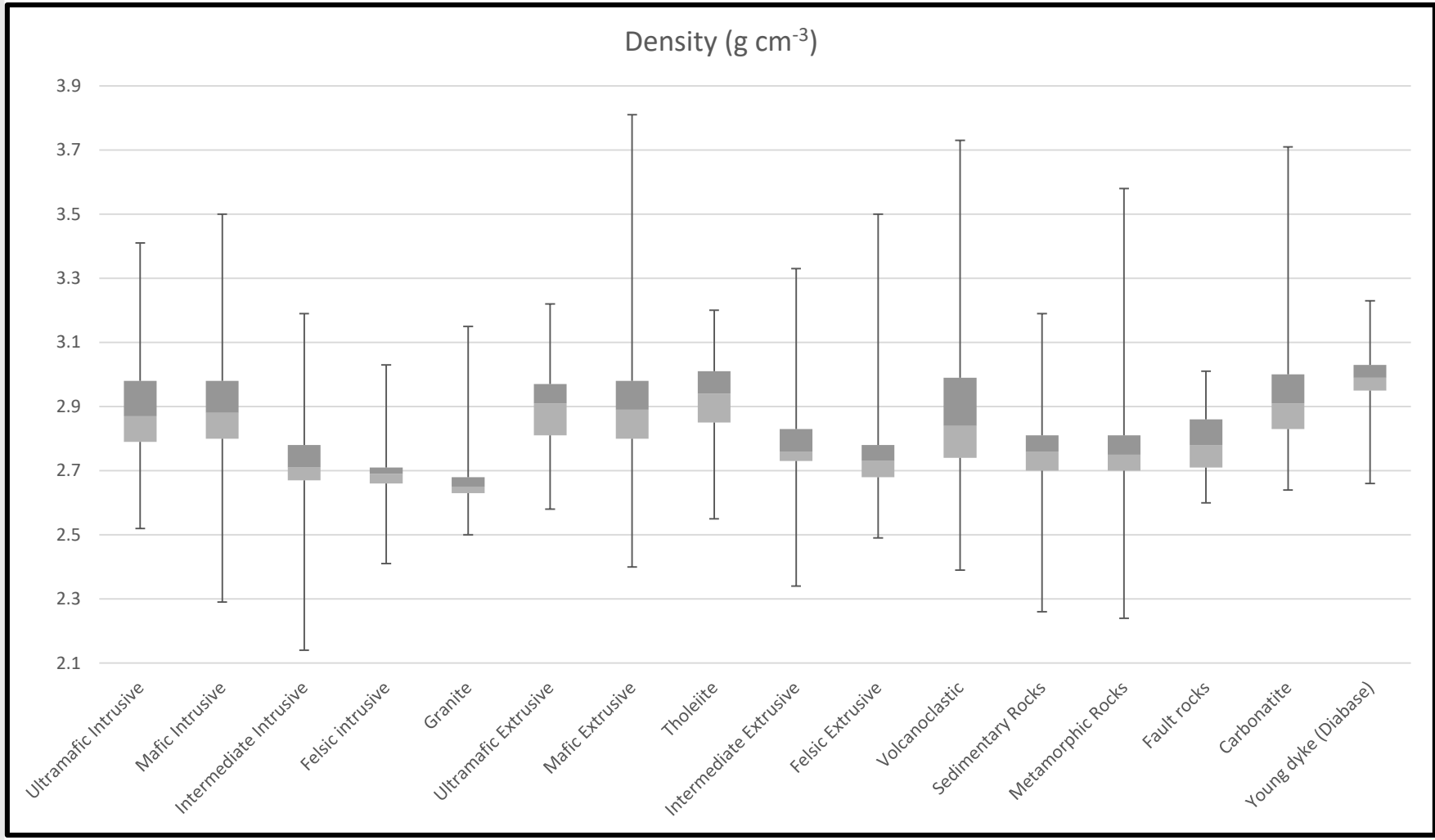


Mag susceptibility will be used to constrain inversions

- ~36000 mag sus) were compiled from various sources (e.g. ME, GSC, OGS, MGS, Footprint).
  - >13500 were from Abitibi
- Two sets of datasets are compiled (Abitibi and Wabigoon subprovinces)
- Petrophysical data are systematically characterised by mapped lithology.

Density of each major lithological unit

- Density characterisation allows assigning representative density properties to each major lithological unit for gravity data modelling



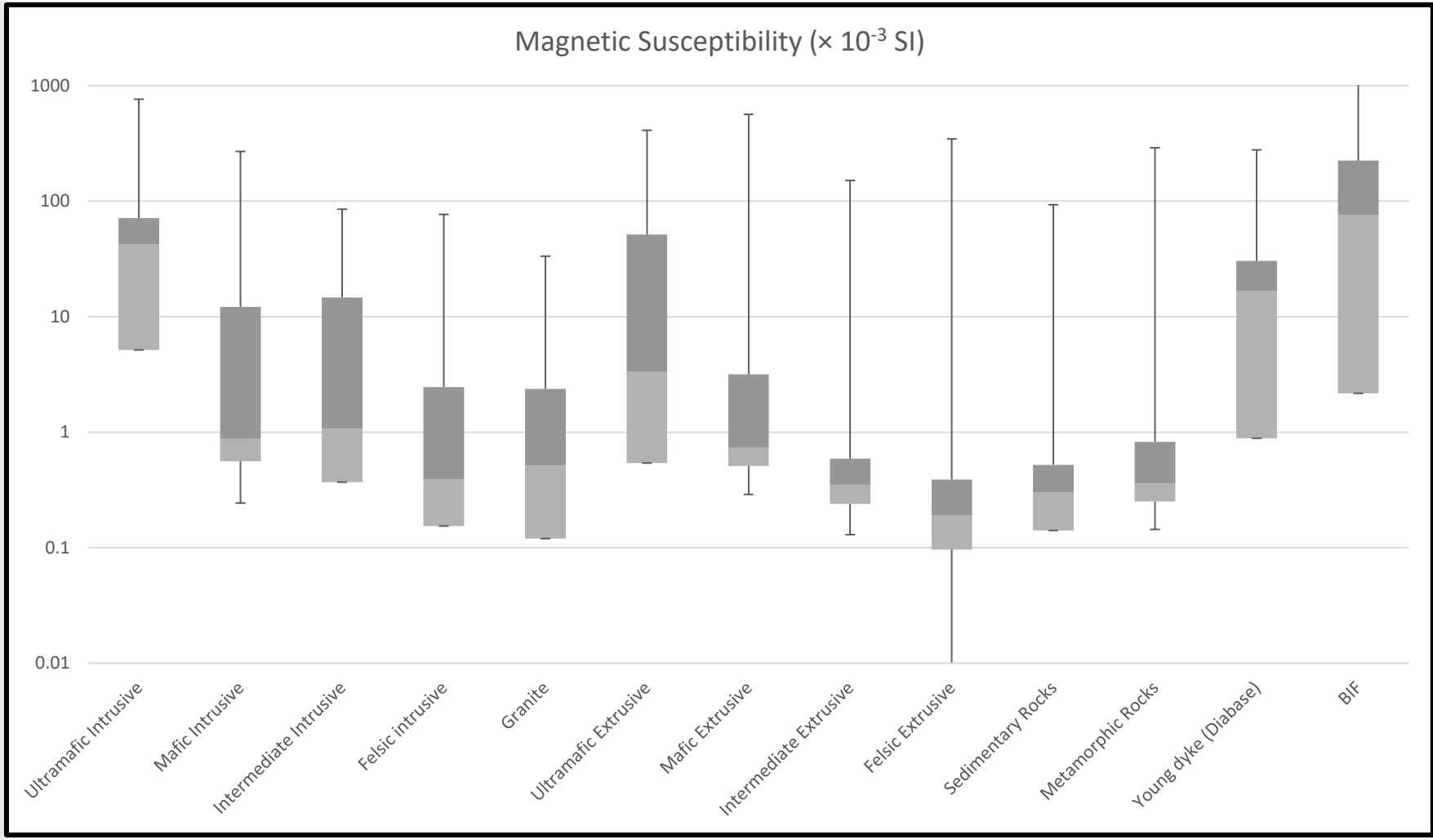
Boxplot analysis of density values of major lithological units within Abitibi Greenstone Belt

METAL EARTH

Eshaghi

Susceptibility of each major lithological unit

- Density characterisation allows assigning representative density properties for gravity data modelling

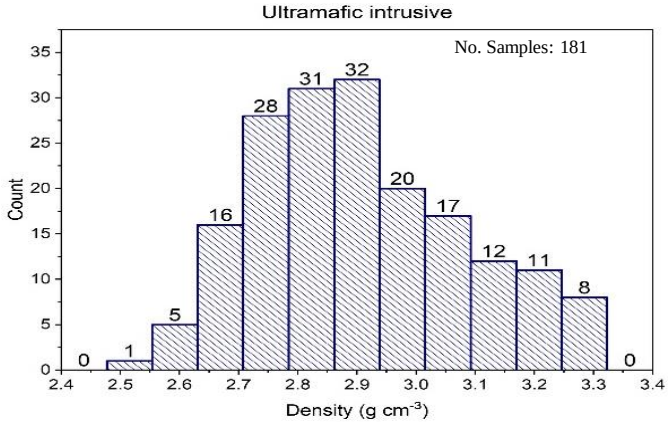


Boxplot analysis of density values of major lithological units within Abitibi Greenstone Belt

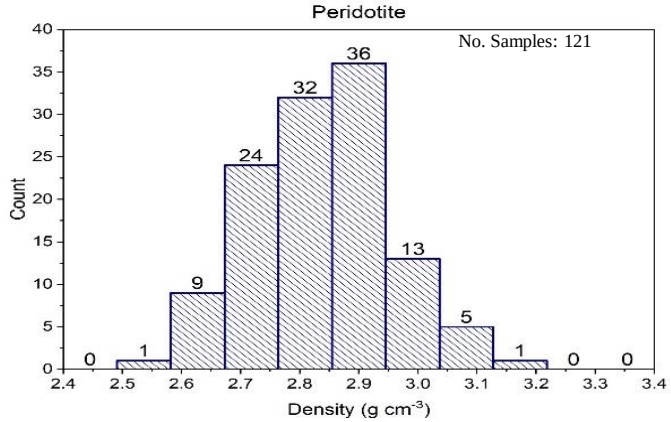
Ultramafic intrusives

Density

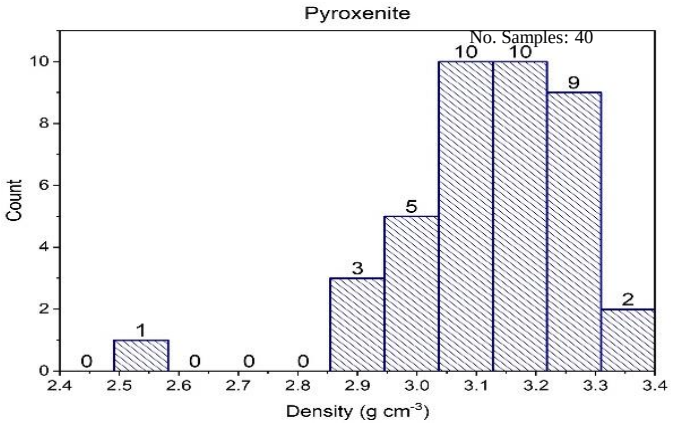
- Breakdown of major rock types into sub-classes



All ultramafic intrusives



Peridotite



Pyroxenite

Density measurements of ultramafic intrusive rocks and major lithological units of this hierarchy in the Abitibi Greenstone Belt. The left column displays histograms of the values and the right column shows the quartile-quartile (QQ) plots.

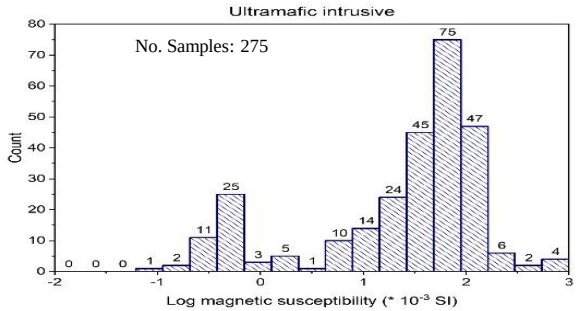
METAL EARTH

Eshaghi

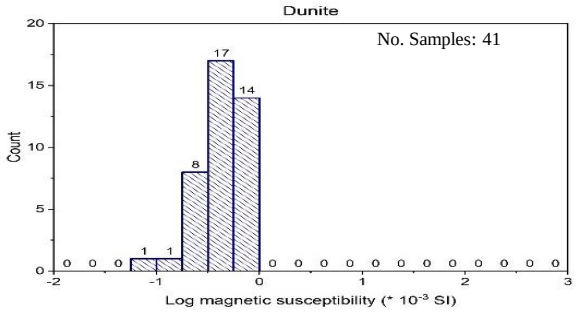
Ultramafic intrusives

Magnetic susceptibility

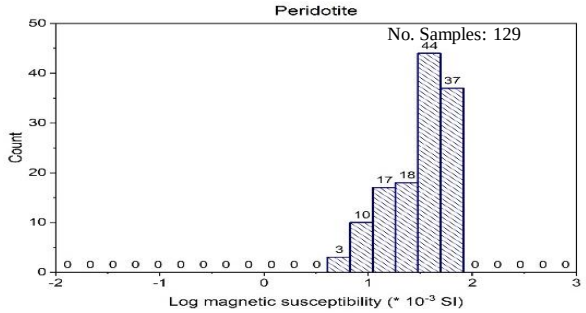
- Breakdown of major rock types into sub-classes



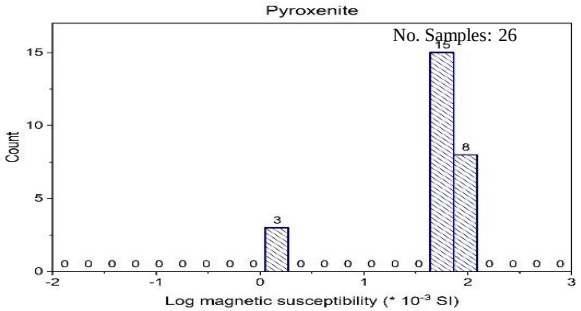
All ultramafic intrusives



Dunite



Peridotite



Pyroxenite

Magnetic susceptibility measurements of ultramafic intrusive rocks and major lithological units of this hierarchy in the Abitibi Greenstone Belt shown on a $\log_{10}$ scale. The left column displays histograms of the values ($\times 10^{-3}$ SI) and the right column shows the quartile-quartile (QQ) plots.

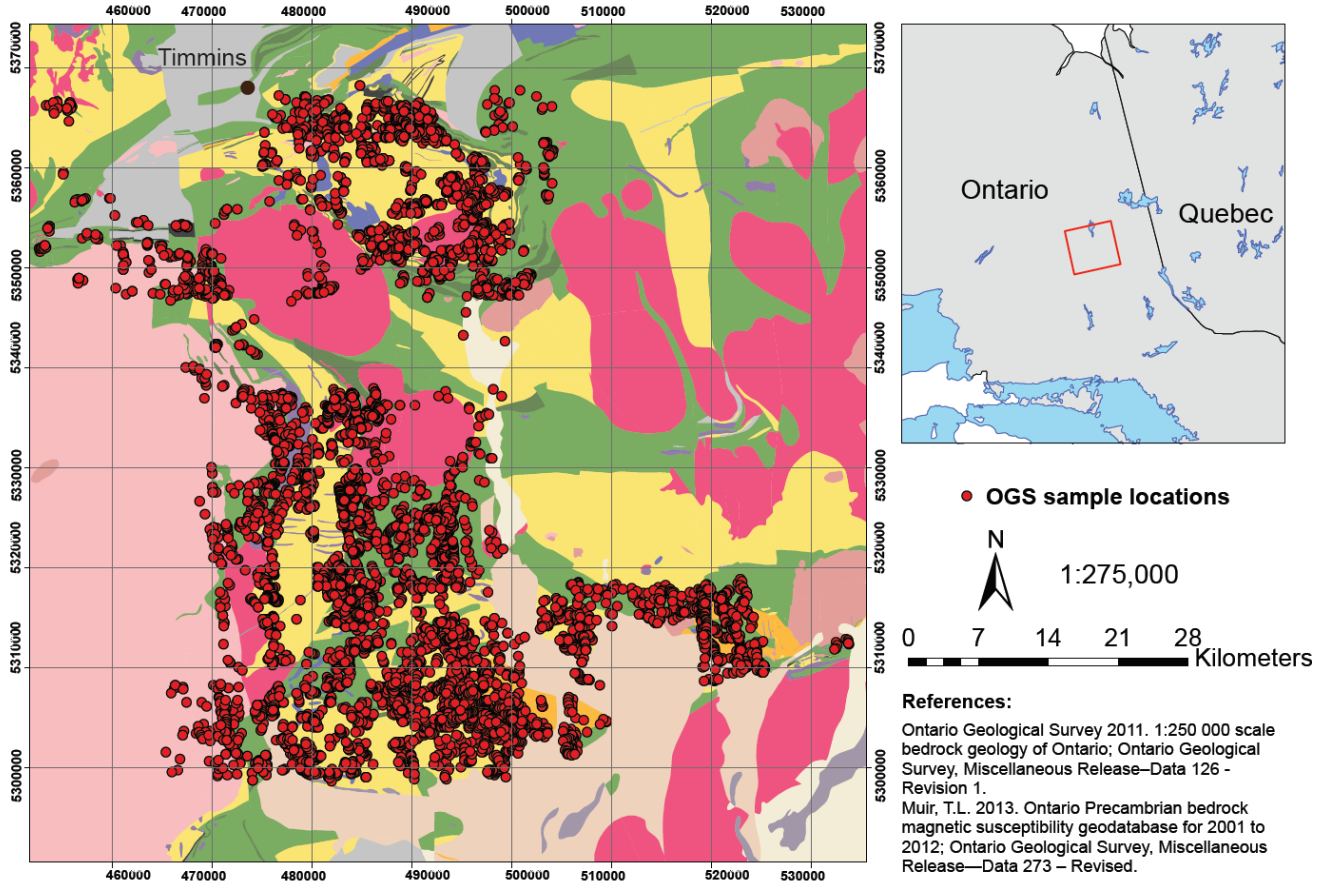
Physical properties measurements

Uses

- Geophysicists: Characterizing rock properties for modelling
- Geologists: Identifying anomalous locations
  - Why is property different from elsewhere
    - Alteration (clays or magnetite destroyed or created)
    - Vein density (Byrne et al., 2019)
    - Metamorphic grade changes
    - Deformation (magnetite fractures into single domains)
    - Different magma source

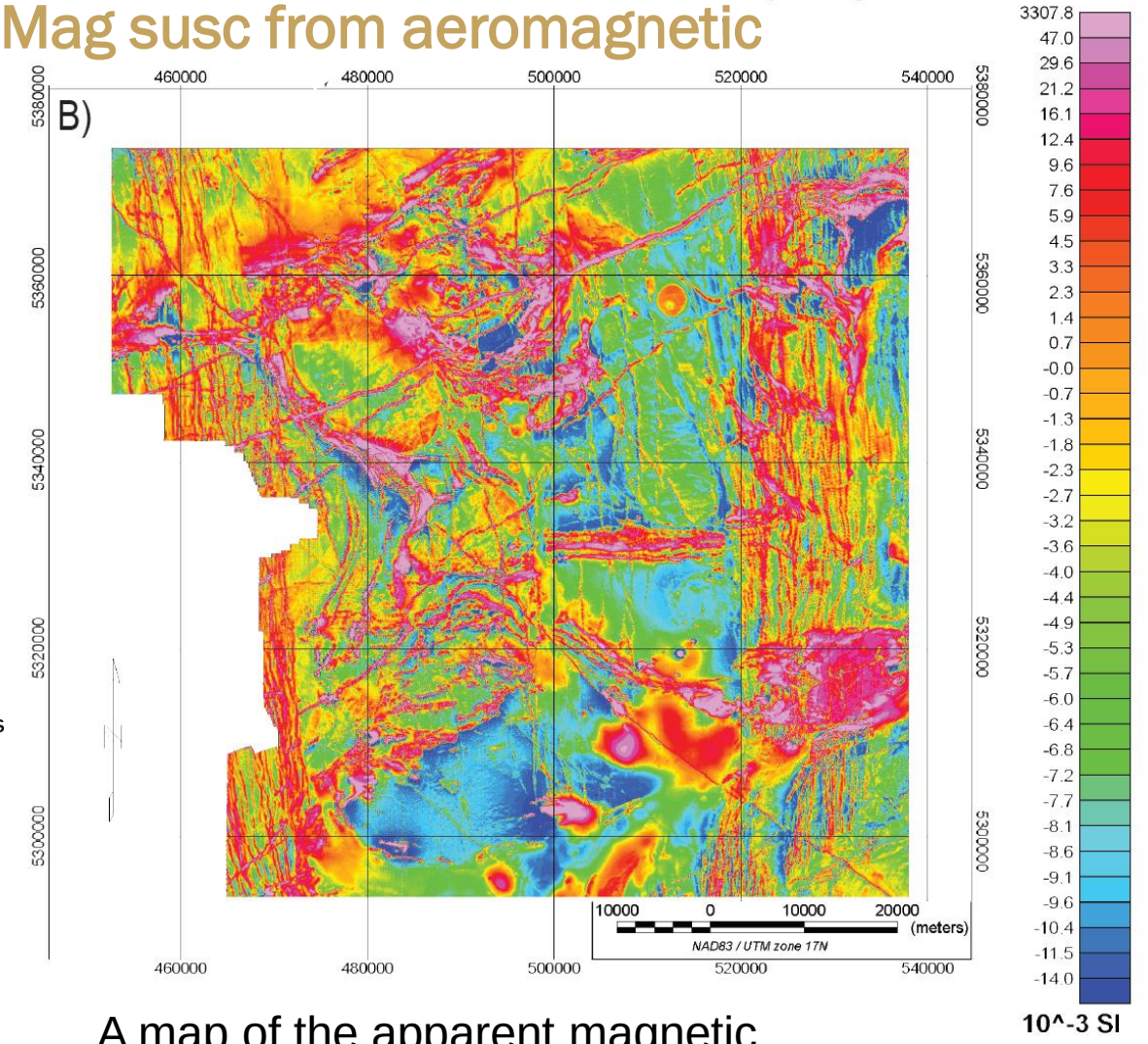
How accurate are mag susc for geophysical modelling

Mag susc from outcrop (OGS)



Map of the study area located in the western Abitibi region. The red points indicate where Ontario Geological Survey crews have taken on-average ten magnetic susceptibility measurements on one outcrop using a KT-10 magnetic susceptibility meter.

Mag susc from aeromagnetic



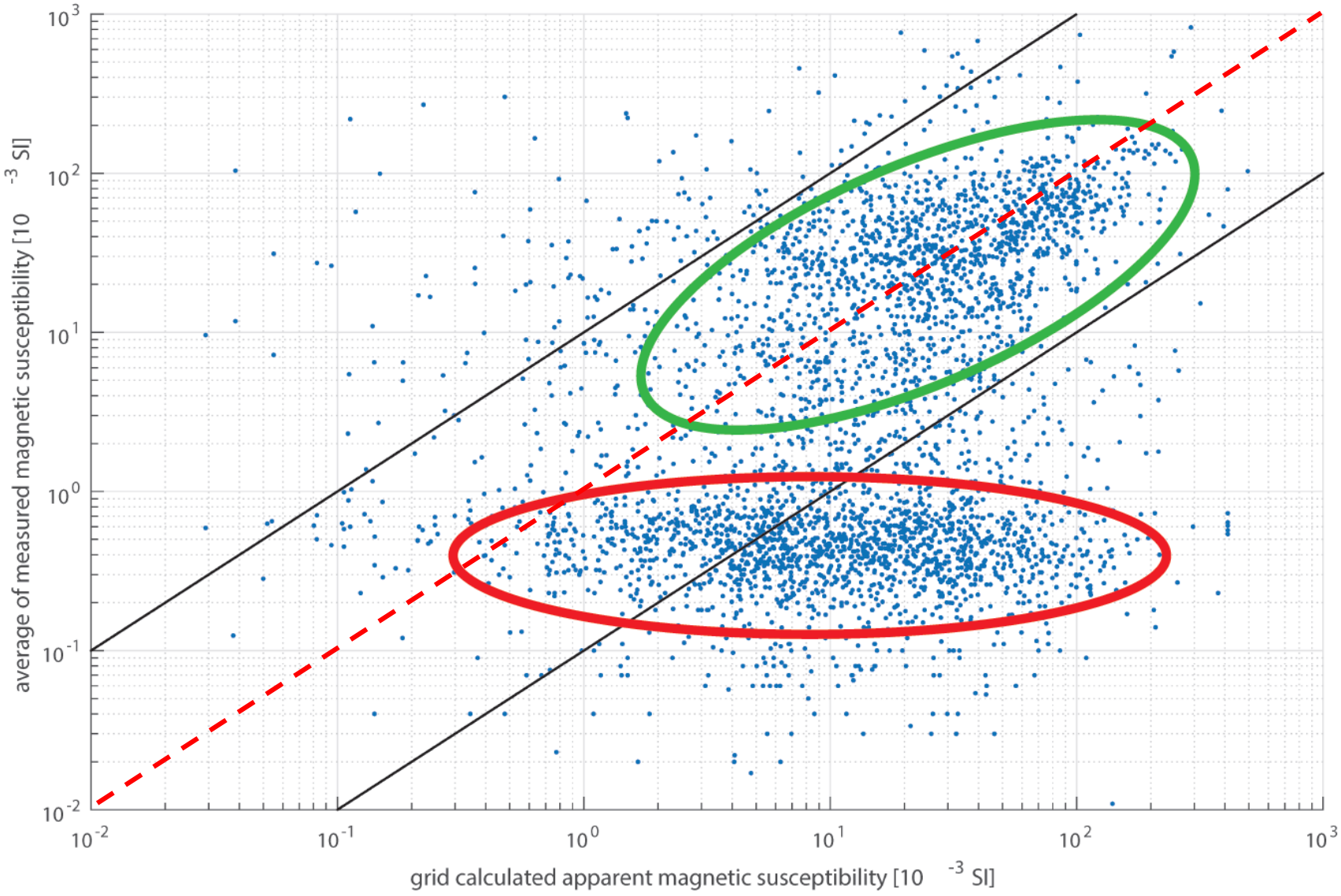
A map of the apparent magnetic susceptibility of the study area derived from the RTP map.

METAL EARTH

McNeice

Comparison of mag susc

- Results should agree and points lie along red dashed line

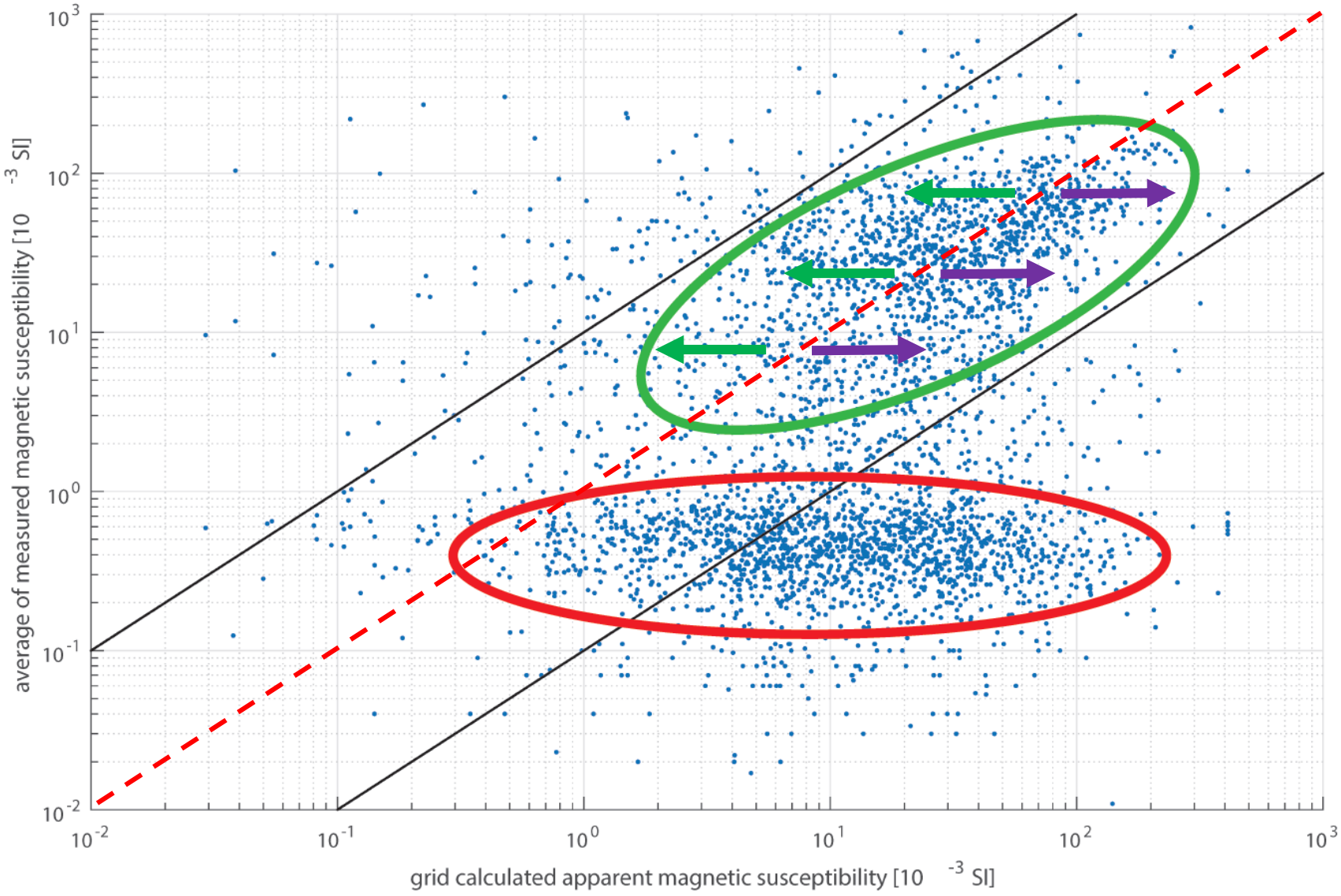


METAL EARTH

McNeice

Comparison of mag susc

- Results should agree and points lie along red dashed line
- In areas of high mag susc, remanent magnetization will increase (or decrease) the apparent susceptibility estimate

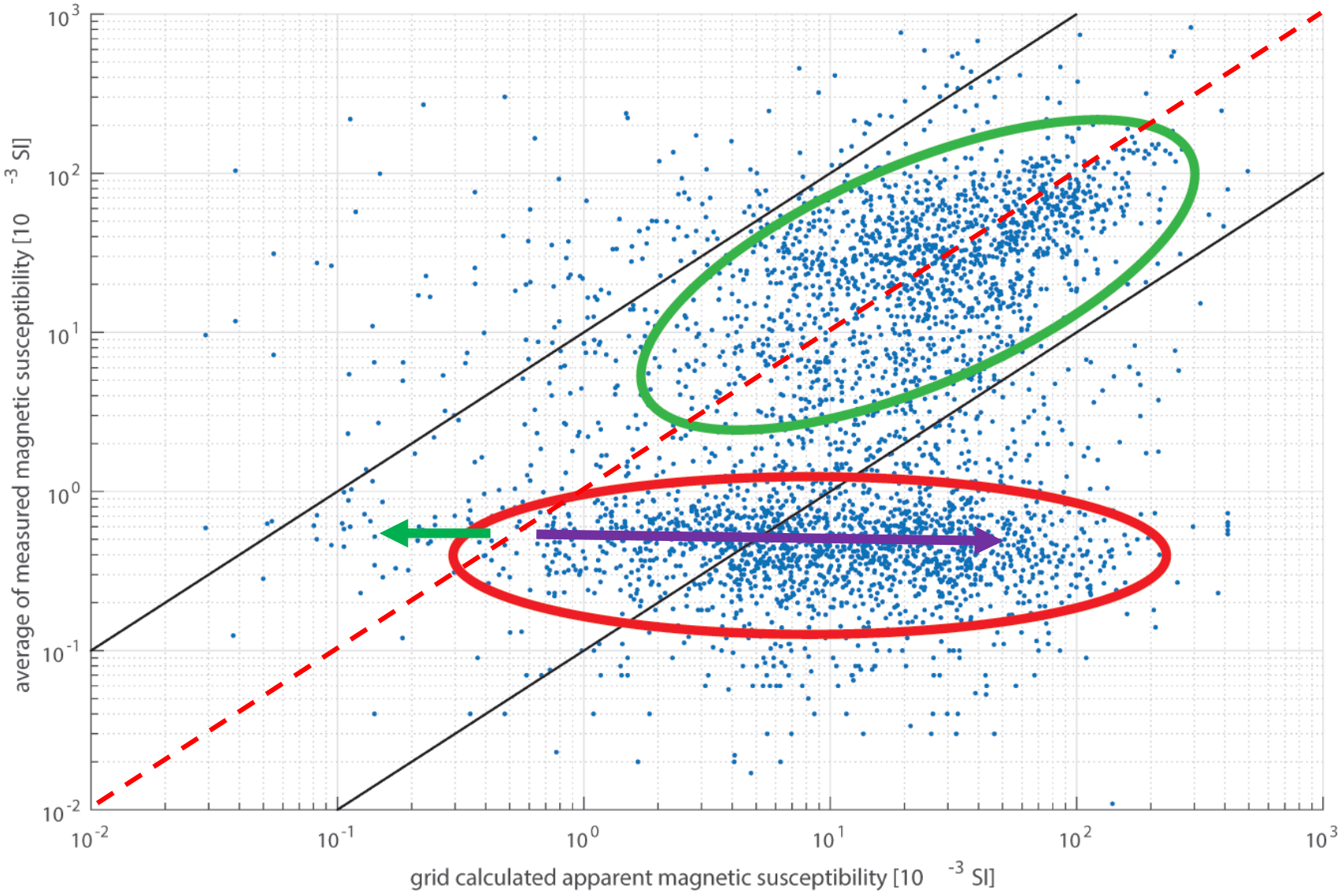


METAL EARTH

McNeice

Comparison of mag susc

- Results should agree and points lie along red dashed line
- In areas of low mag susc, nearby anomalies will increase (or decrease) the apparent susceptibility estimate

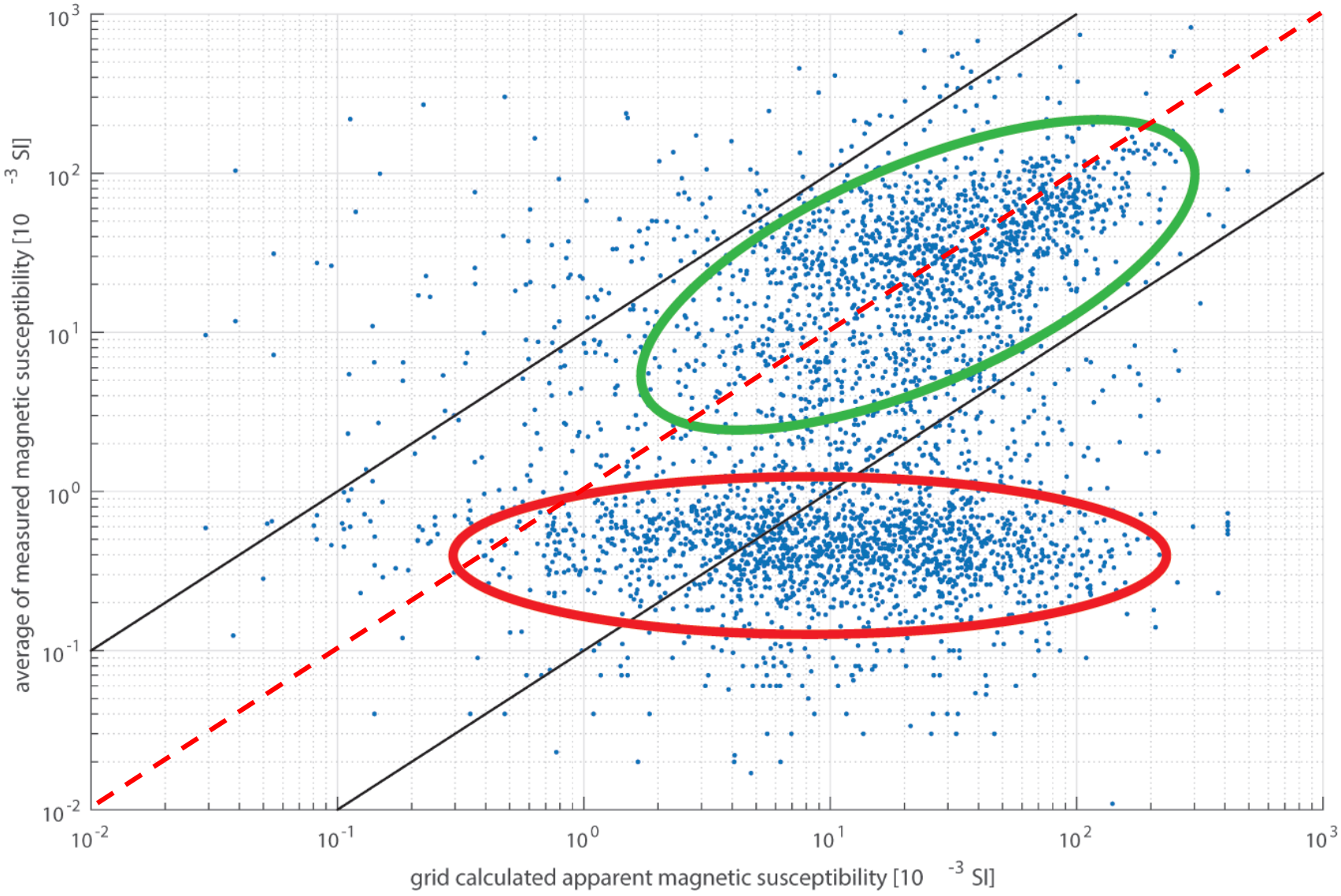


METAL EARTH

McNeice

Comparison of mag susc

- Results should agree and points lie along red dashed line
- Other reasons for variability
  - Transcription errors
  - Operator error
  - Weathering
  - Geometric effects
  - Poor technique
- **Conclusion:**
  - Mag susceptibilities that are required to explain magnetic data can vary by up to a factor of 10 from outcrop measured value
  - Outcrop values can be varied by a factor of ten to explain the magnetic data.

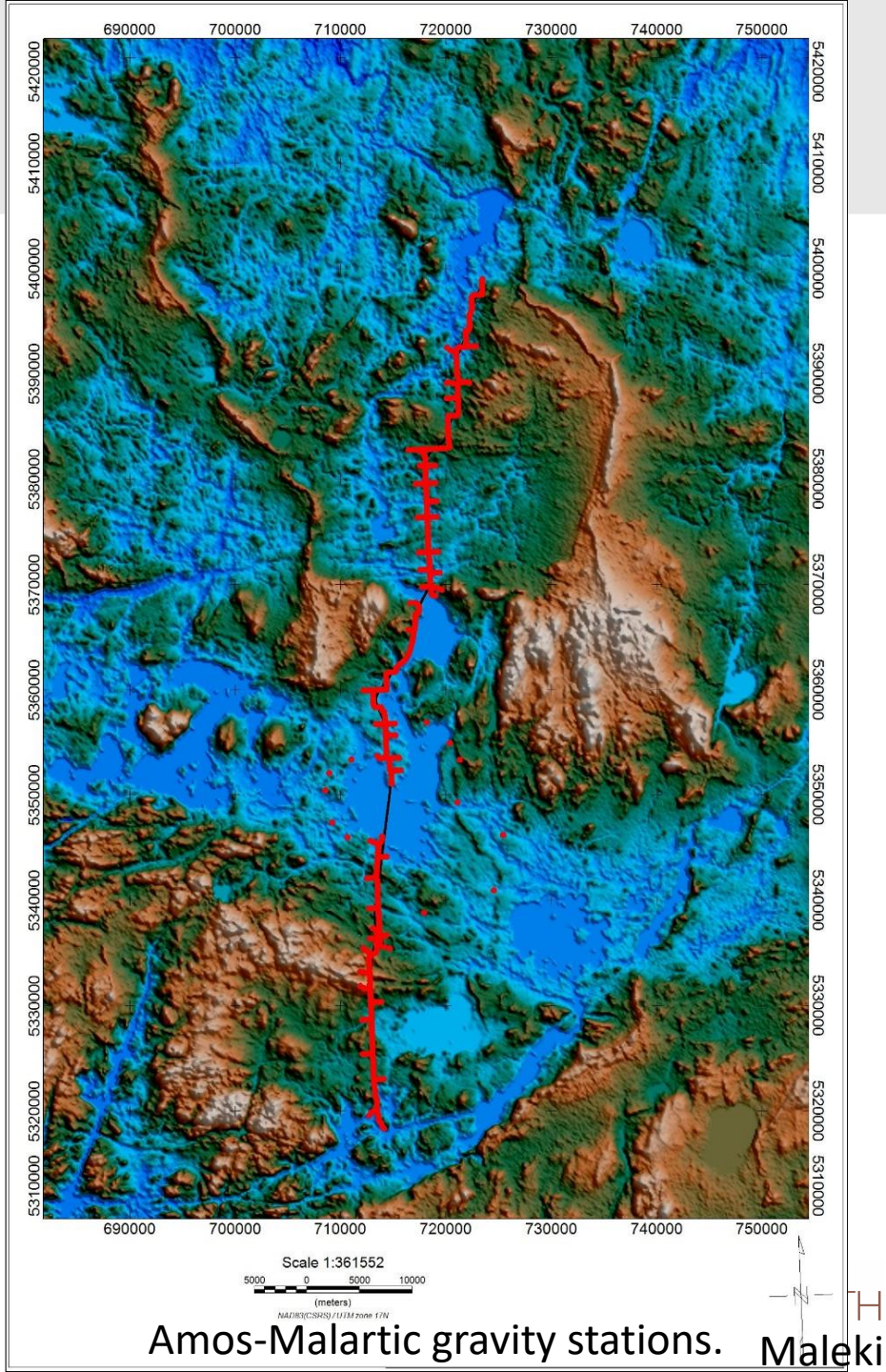


METAL EARTH

McNeice

Gravity data collection

2974 stations (June 2017-August 2018)



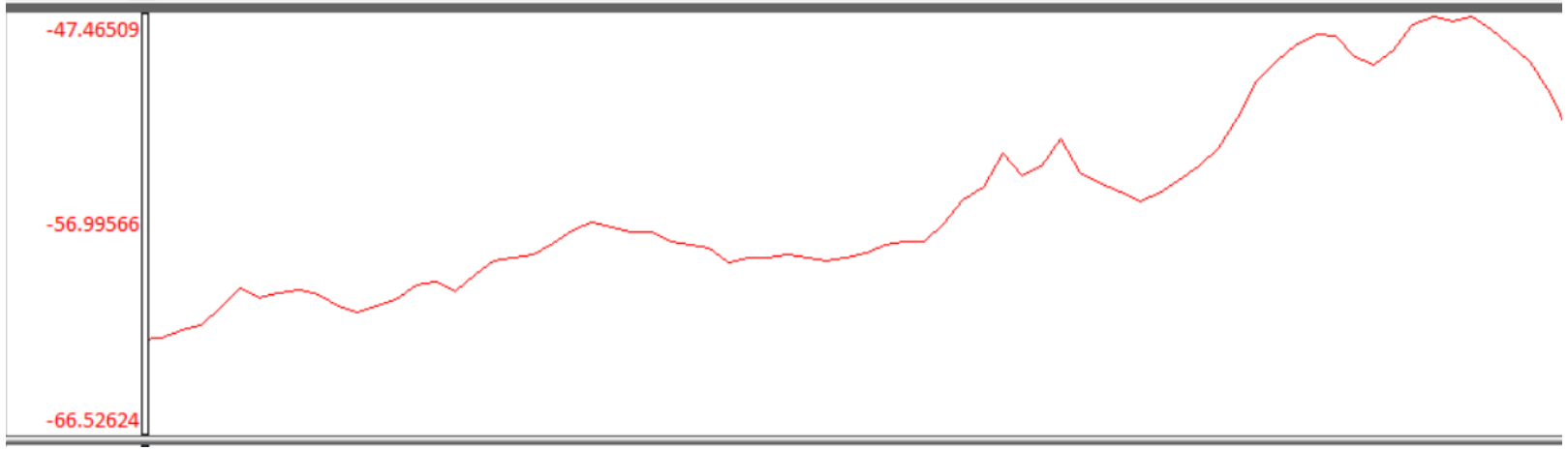
Amos-Malartic gravity stations.

Maleki

Gravity data reduction and compilation

- Geosoft oasis montaj used for processing
  - Free-air
  - Bouguer slab
  - Terrain correction
  - Yields "complete Bouguer anomaly"
- Existing GSC gravity data compiled, reprocessed, QCQA and combined with ME gravity data.

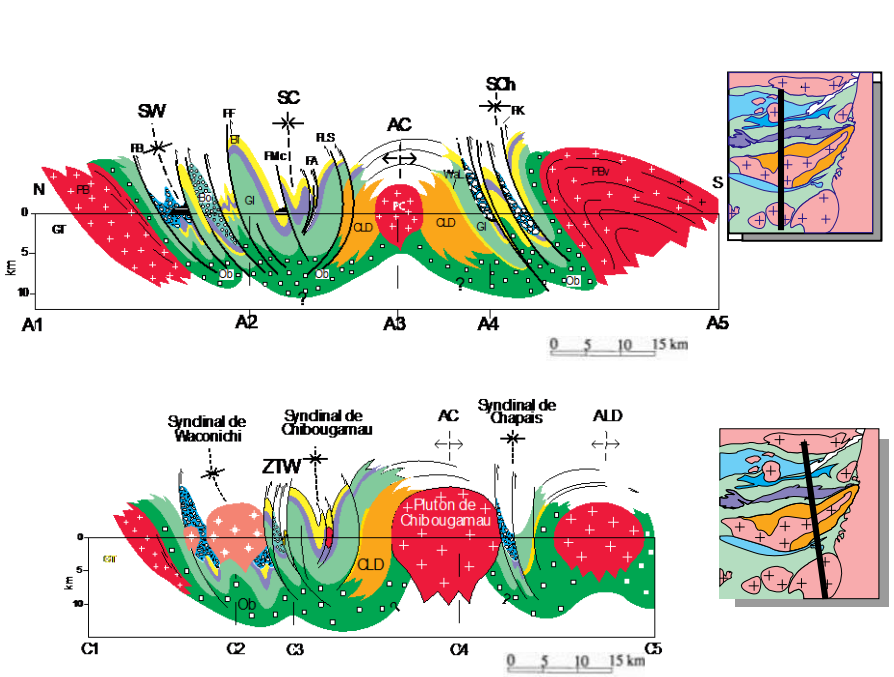
LSouth	Longitude	Elevation	Date	Observe_gravity	Terrain	Free_Air	Bouguer_Anomaly	Complete_Bouguer_Anomaly
11.0	-78.14	298.75	20170809	980767.6899	0.1332	-31.17448	-65.0100	-64.87678
12.0	-78.14	299.83	20170809	980768.3115	0.0702	-30.43424	-64.3916	-64.32146
13.0	-78.14	299.62	20170809	980768.8540	0.0584	-30.20908	-64.1426	-64.08423
14.0	-78.14	306.09	20170809	980768.1244	0.0504	-29.17661	-63.8425	-63.79213
15.0	-78.14	308.60	20170809	980768.4773	0.0284	-28.31455	-63.2641	-63.23569



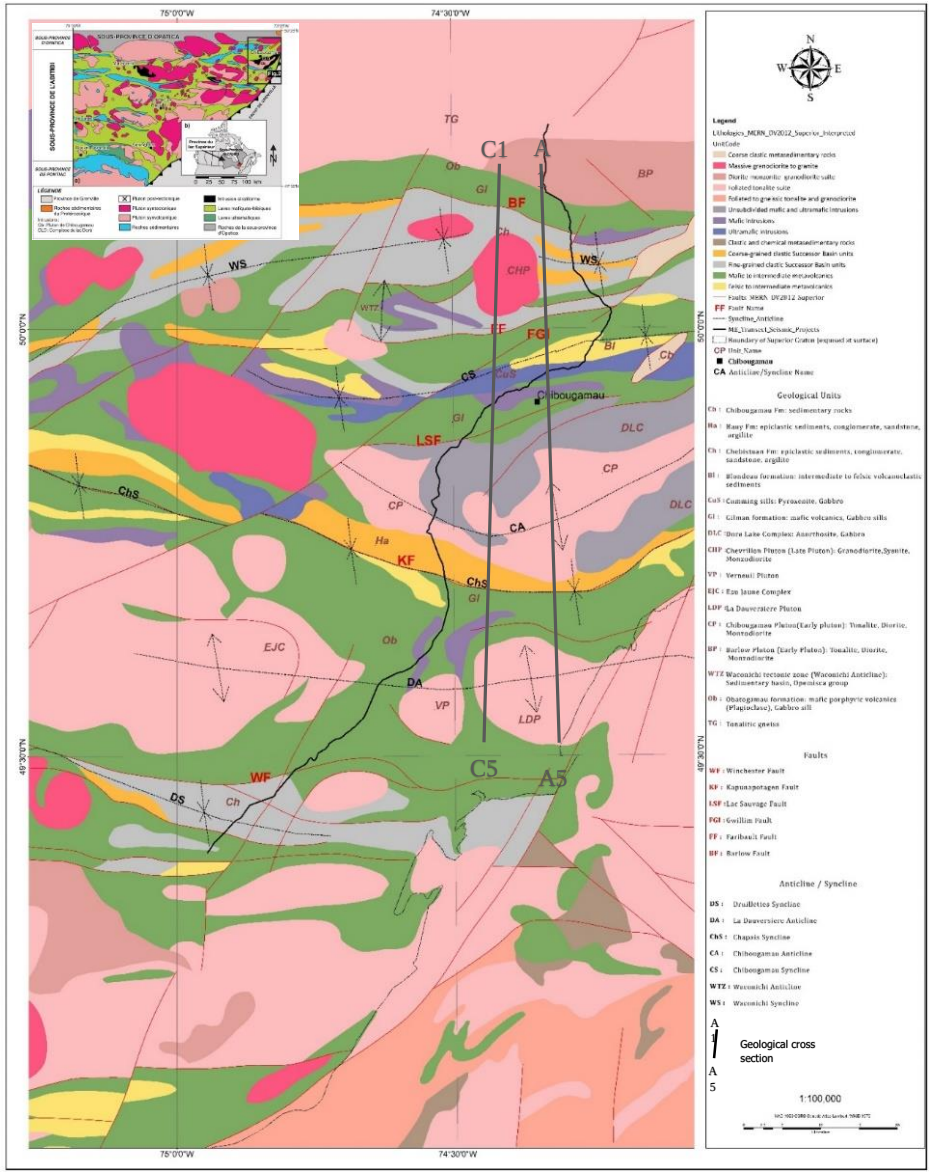
METAL EARTH
Maleki

Chibougamau transect

Previous geological work



Detailed cross-section of the Chibougamau area. See Fig.1 for abbreviations and the location of the cross sections (after Daigneault et al. 1990).



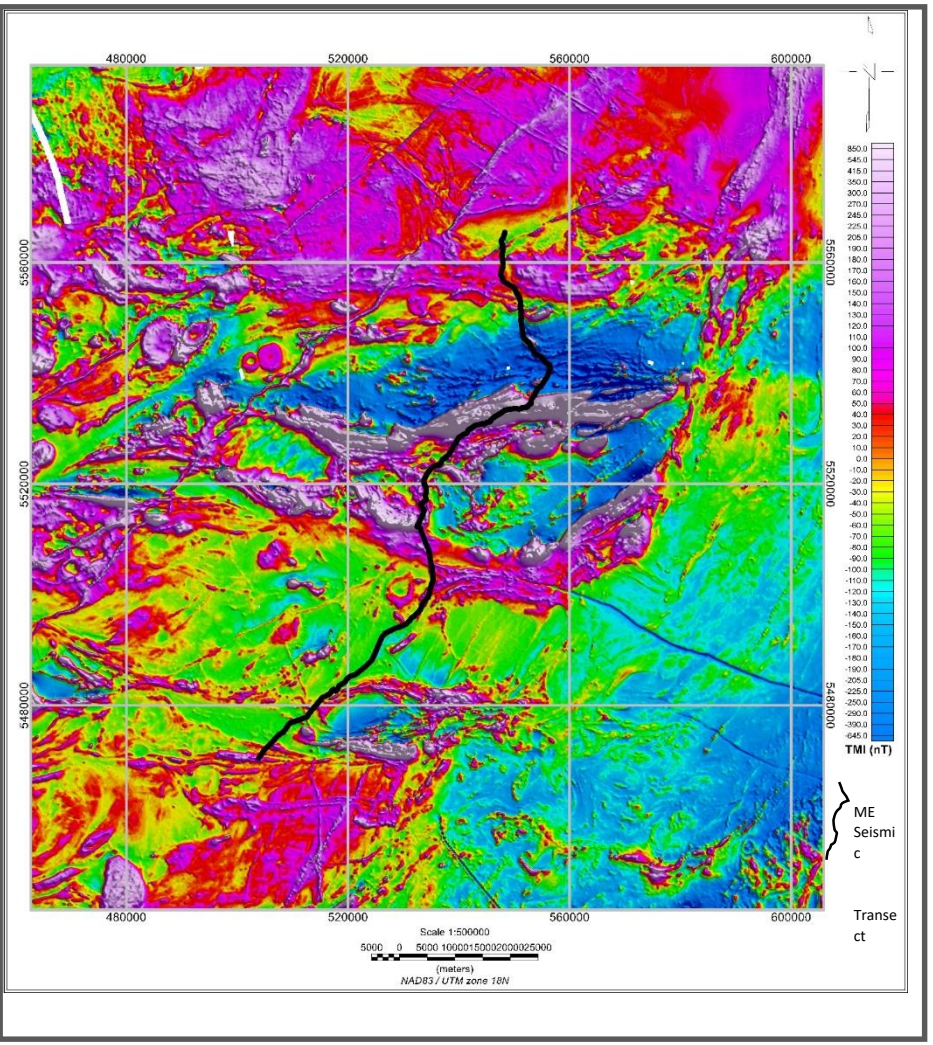
Geological map of the Chibougamau area, showing the distribution of the folds produced during the D2 regional deformation. The location of two detailed cross-sections (A5 and C5; see Fig. 2) is shown with thick straight black (modified from Montsion et al. 2017, Daigneault et al. 1990, Leclerc 2008)

METAL EARTH
Maleki

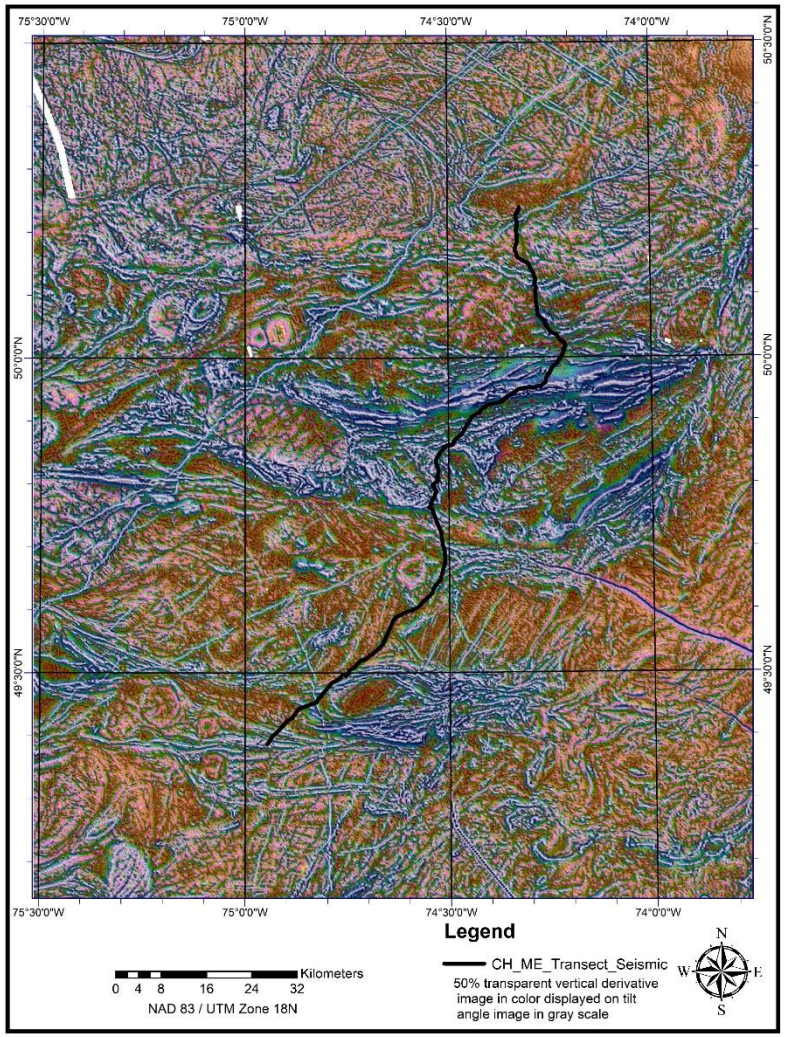
Geophysical Setting

- Qualitative interpretation of the airborne magnetic data

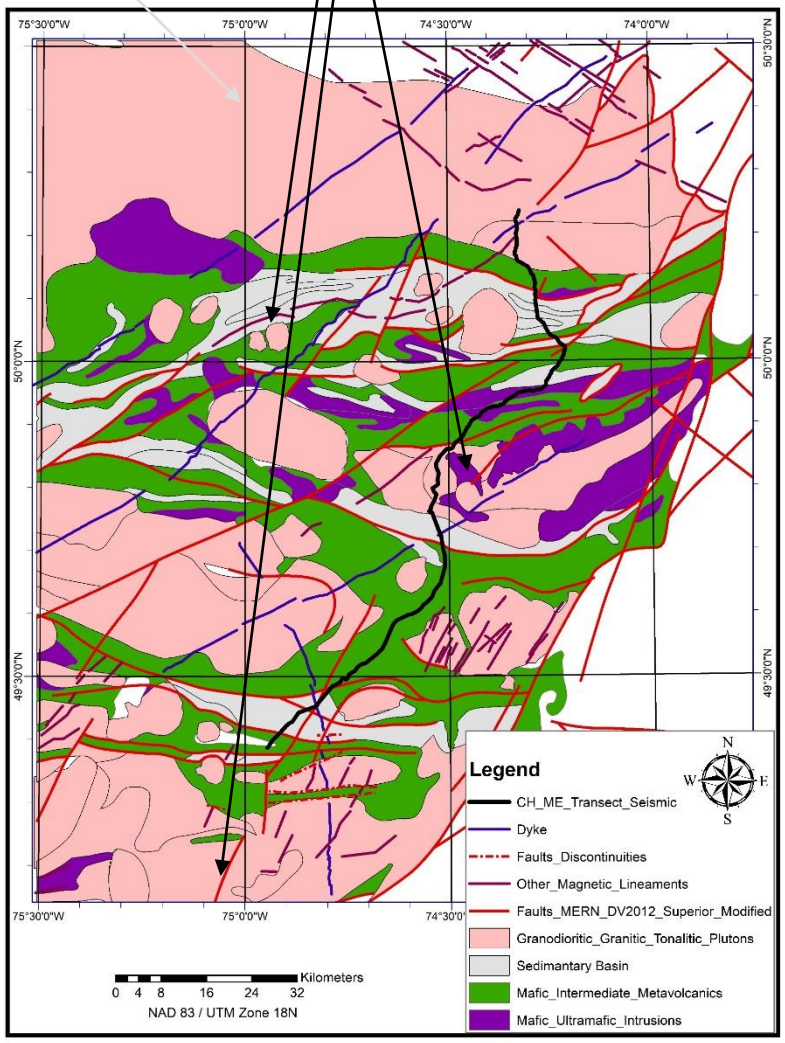
Different from geological map



Total magnetic intensity map



Combination of 2nd vertical derivative and tilt angle images

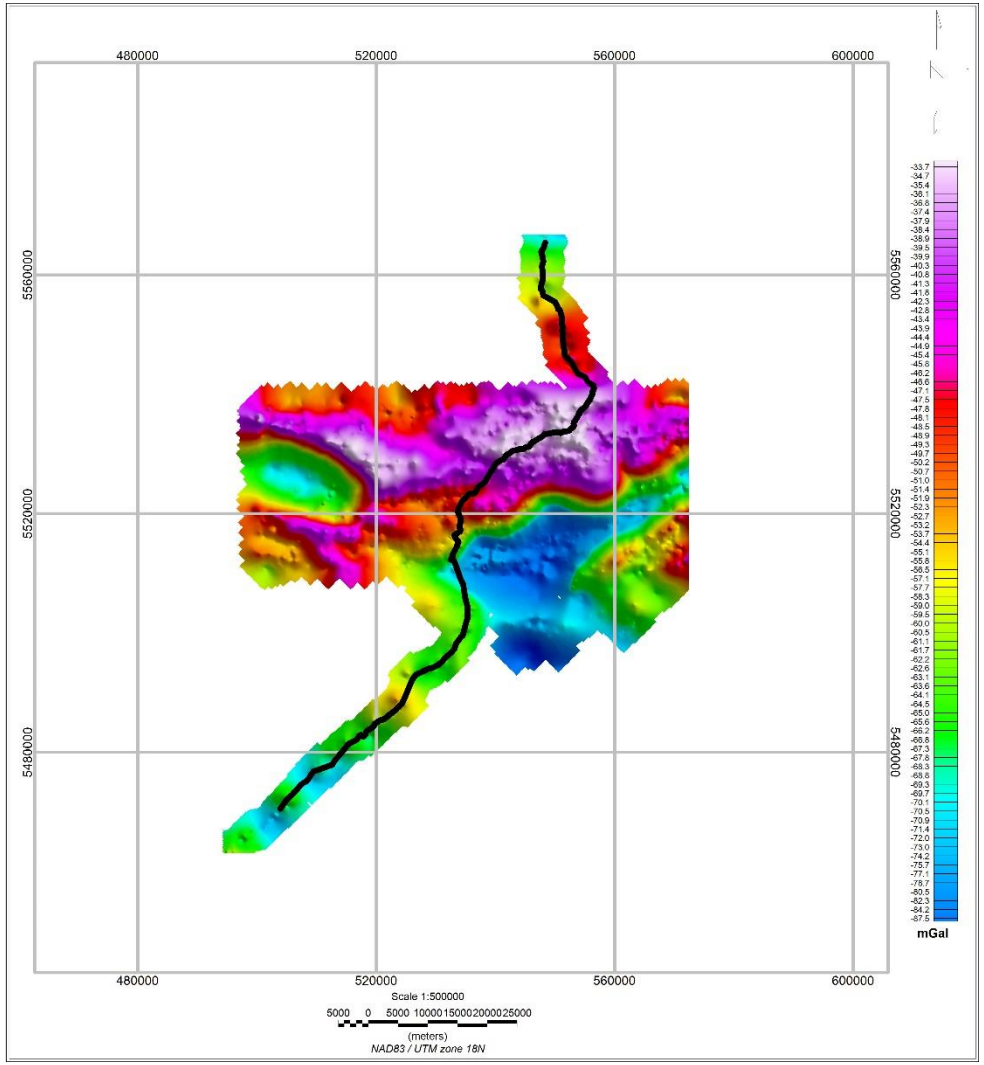


The magnetic interpretation map

Maleki

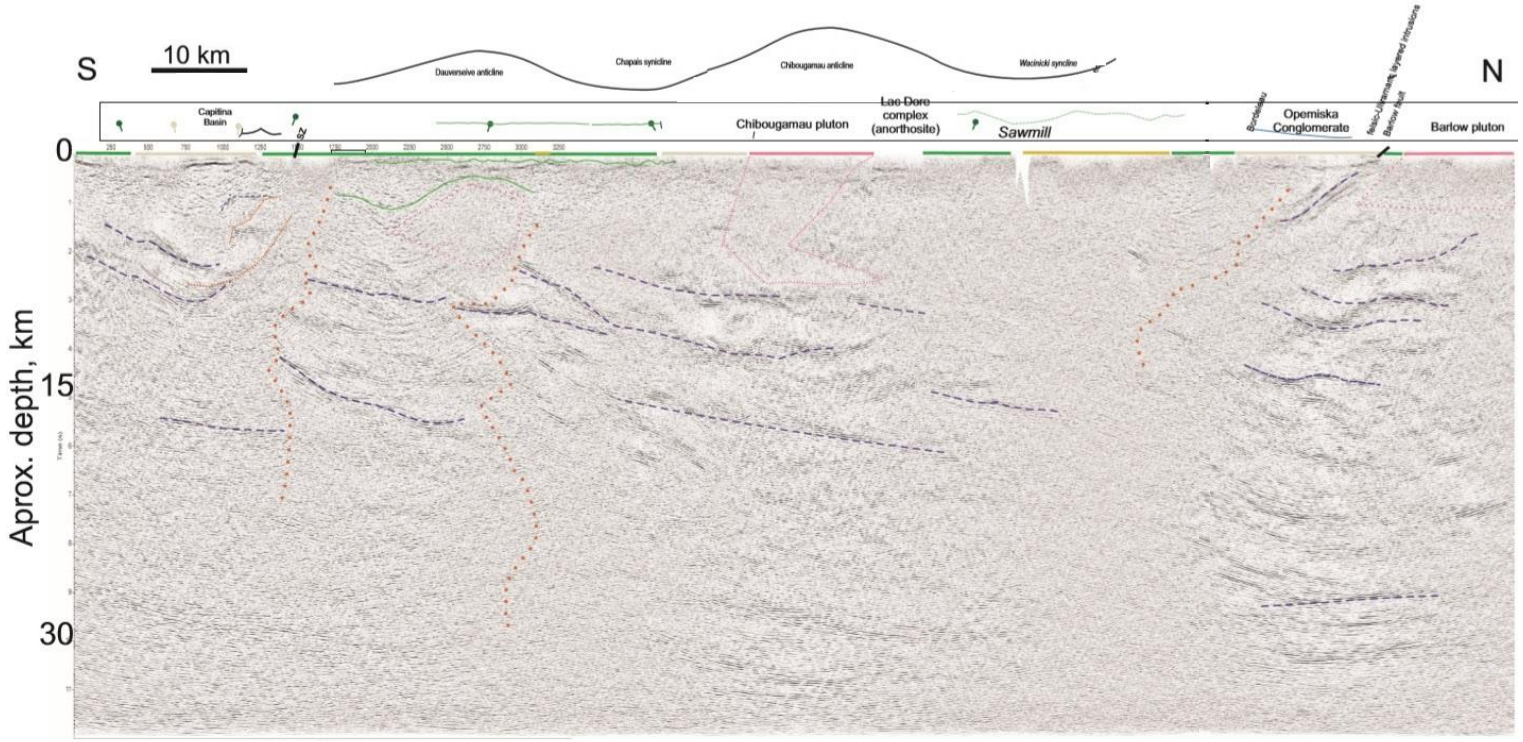
Geophysical Setting

The gravity data



Complete Bouguer anomaly map of combined ME and GSC gravity data

Qualitative interpretation of the seismic data

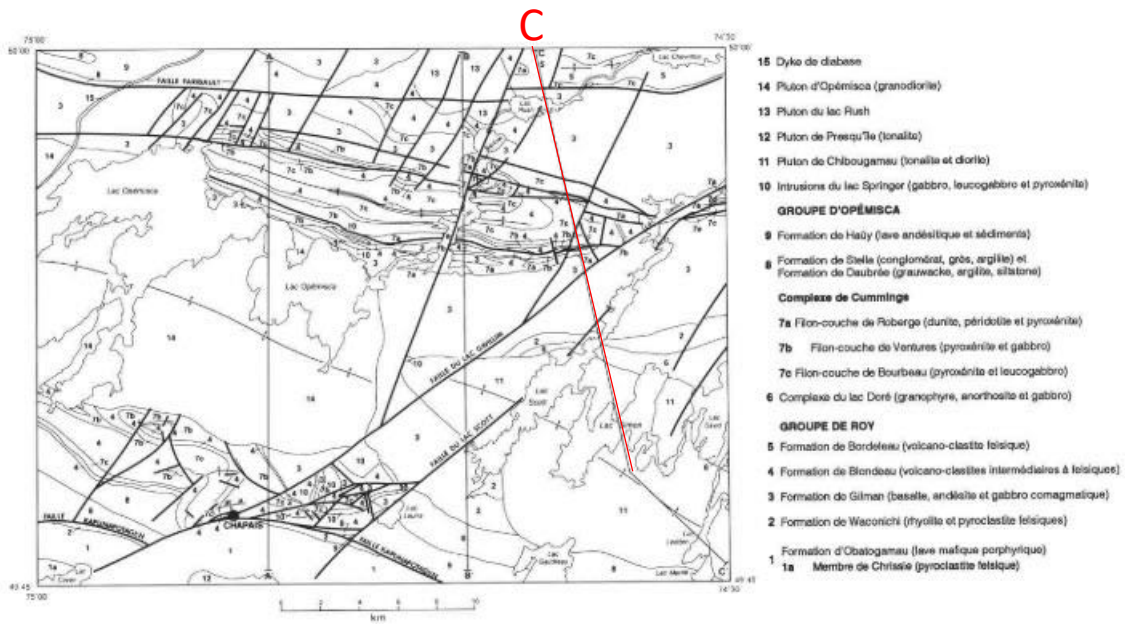


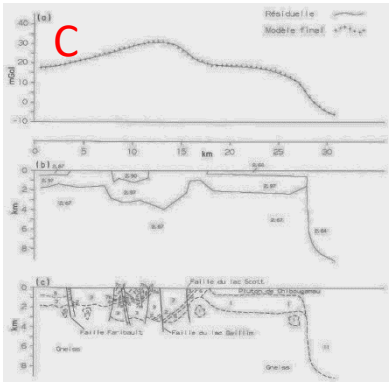
Preliminary interpretation of ME seismic section, dotted pink lines show plutons, Dotted purple lines are more continuous reflectors, orange lines mark breaks in reflectors (After Snyder and Mathieu)

Maleki

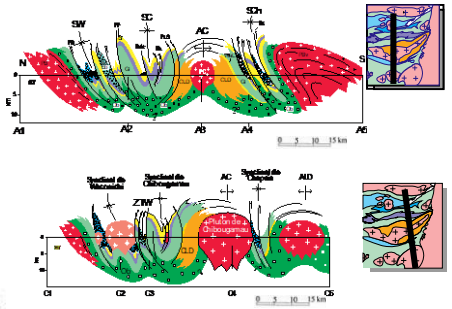
2.5-D potential-field data modelling (constraints on the 2.5-D model)

Geological Constraints





Geological sections from previous geological and geophysical studies (Dion et al. 1991)



(Daigneault et al. 1990)

Petrophysical properties

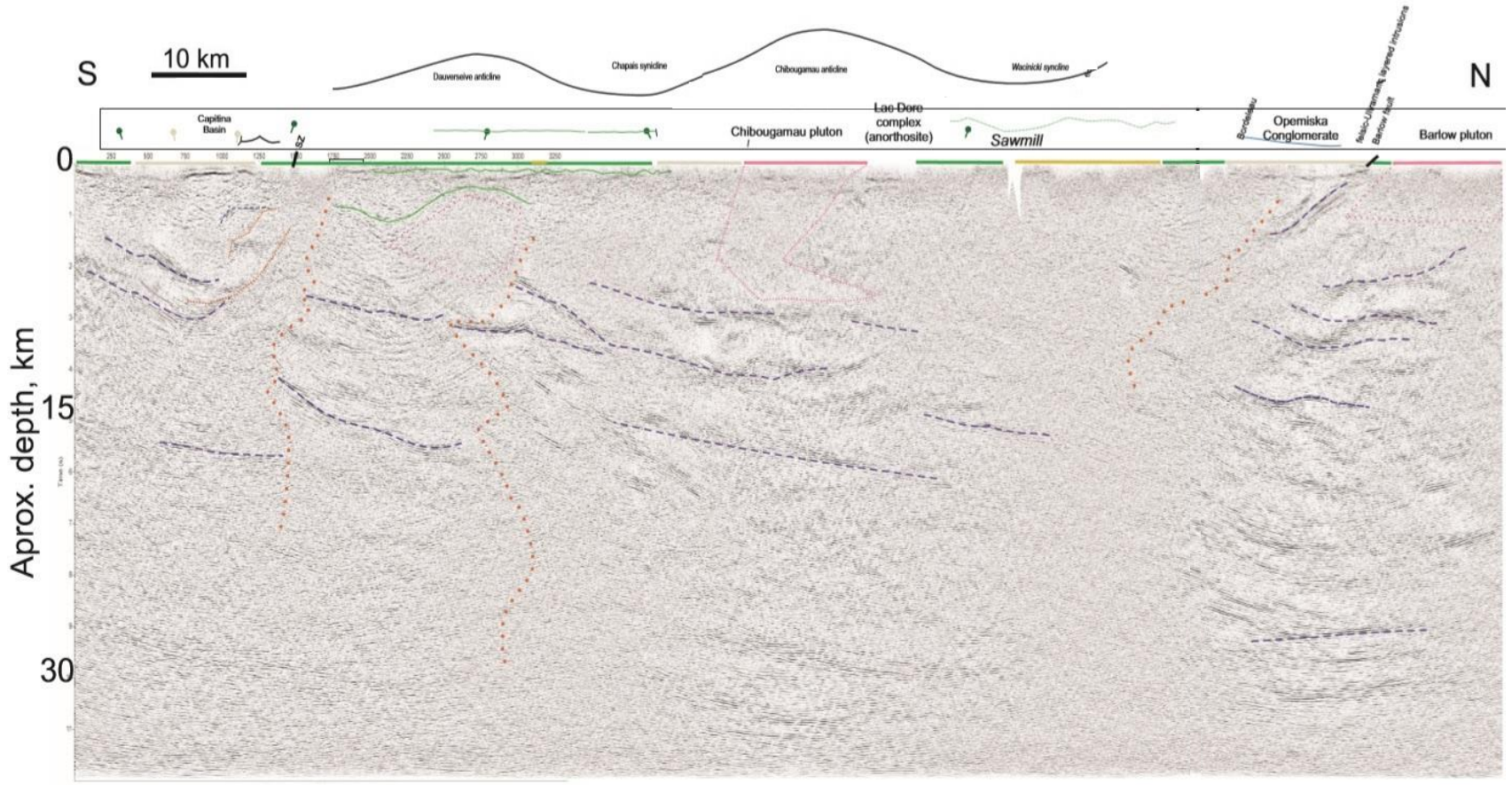
Lithologie	N	Densité (g/cm³) Intervalle	Densité (g/cm³) Moyenne ± écart type	Susceptibilité magnétique (×10⁻³ SI), intervalle
Pluton d'Opémisca				
Monzonite	6	2,62–2,64	2,63±0,008	0,01–0,8; 2,4–4,3
Pluton de Presqu'île				
Tonalite	3	2,74–2,82	2,77±0,04	0,01; 0,2
Pluton de Chibougamau				
Tonalite	12	2,60–2,73	2,67±0,04	0,01–2,3; 10–40
Diorite	21	2,73–3,06	2,93±0,1	0,01–2,3; 18–53
Groupe d'Opémisca				
Formation de Haüy	10	2,72–2,97	2,87±0,07	0,1–0,5; 1,4–3,4
Formation de Stella	4	2,71–2,76	2,74±0,02	0,1–0,5; 6,3–6,5
Formation de Daubrée	4	2,73–2,99	2,88±0,11	0,01; 0,6
Complexe de cummings				
Gabbro de Bourbeau	9	2,83–3,05	2,97±0,07	0,01–0,6; 3–8
Gabbro de Ventures	7	2,92–3,04	2,99±0,05	0,01–1,6; 12–45
Dunite	2	2,72–2,74	2,73	110; 190
Péridotite	6	2,66–2,79	2,73±0,04	72–130
Pyroxénite	5	3,12–3,27	3,21±0,06	0,8–8; 100
Complexe du lac Doré				
Anorthosite	2	2,99–3,00	2,99	0,01
Granophyre	1	2,61	2,61	0,2
Groupe de Roy				
Formation de Blondeau				
Sédiments–tufs	24	2,66–2,91	2,79±0,06	0,01; 1,2
Andésite	8	2,75–2,83	2,79±0,04	0,01; 1,4
Dyke de gabbro	6	2,85–2,98	2,90±0,05	17–100
Formation de Gilman				
Basalte	11	2,80–3,23	2,99±0,13	0,01–1,6; 5–11
Gabbro	5	2,90–3,12	3,00±0,08	0,01–1,4; 6
Andésite	3	2,71–2,79	2,76±0,04	0,01; 0,4
Pyroclastite felsique	3	2,64–2,74	2,69±0,05	0,01; 0,1
Formation de Waconichi				
Rhyolite	2	2,63–2,66	2,65	0,01; 0,1
Formation d'Obatogamau				
Basalte	27	2,73–3,10	2,95±0,12	0,01; 1,2
Gabbro	4	2,82–3,05	2,99±0,11	0,01; 1,4
Andésite	1	2,65	2,65	0,05
Membre de Chrissie	2	2,68–2,74	2,71	0,01; 0,5
Gneiss tonalitique (socle)	22	2,56–2,77	2,67±0,05	—

Petrophysical properties from previous studies (Dion et al. 1991)

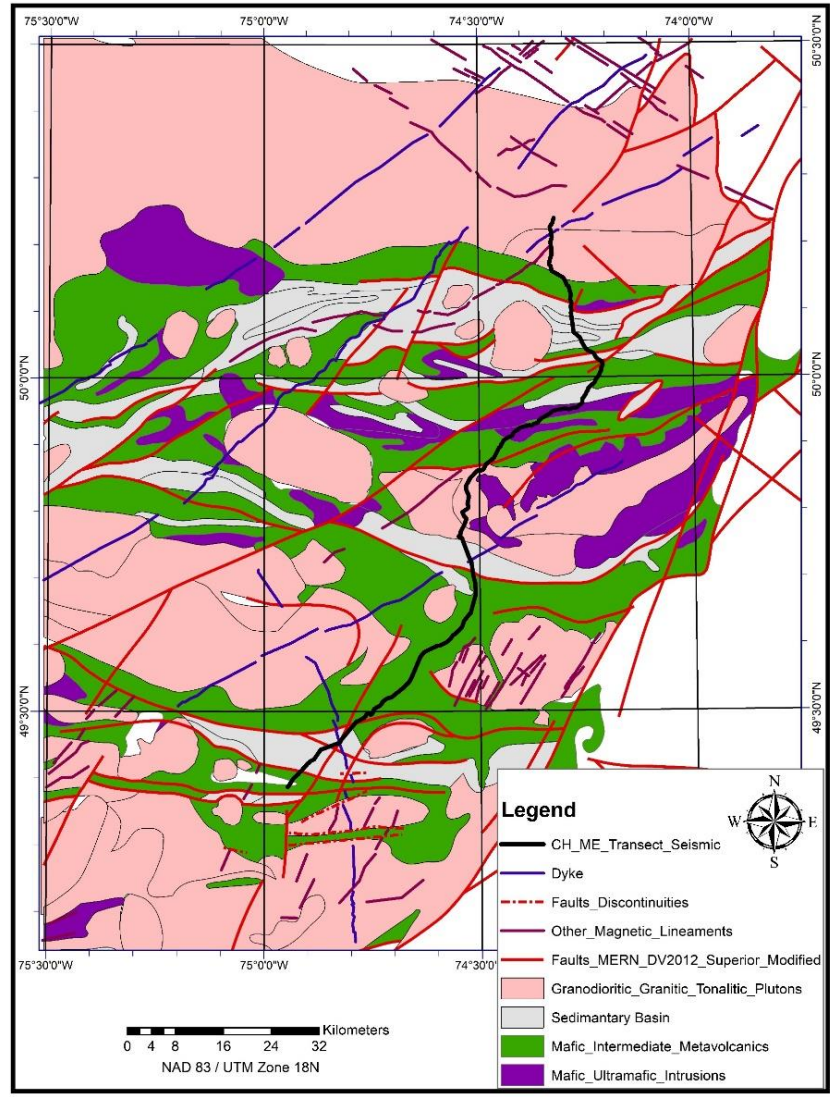
Maleki

2.5-D potential-field data modelling (constraints on the 2.5-D model)

seismic section

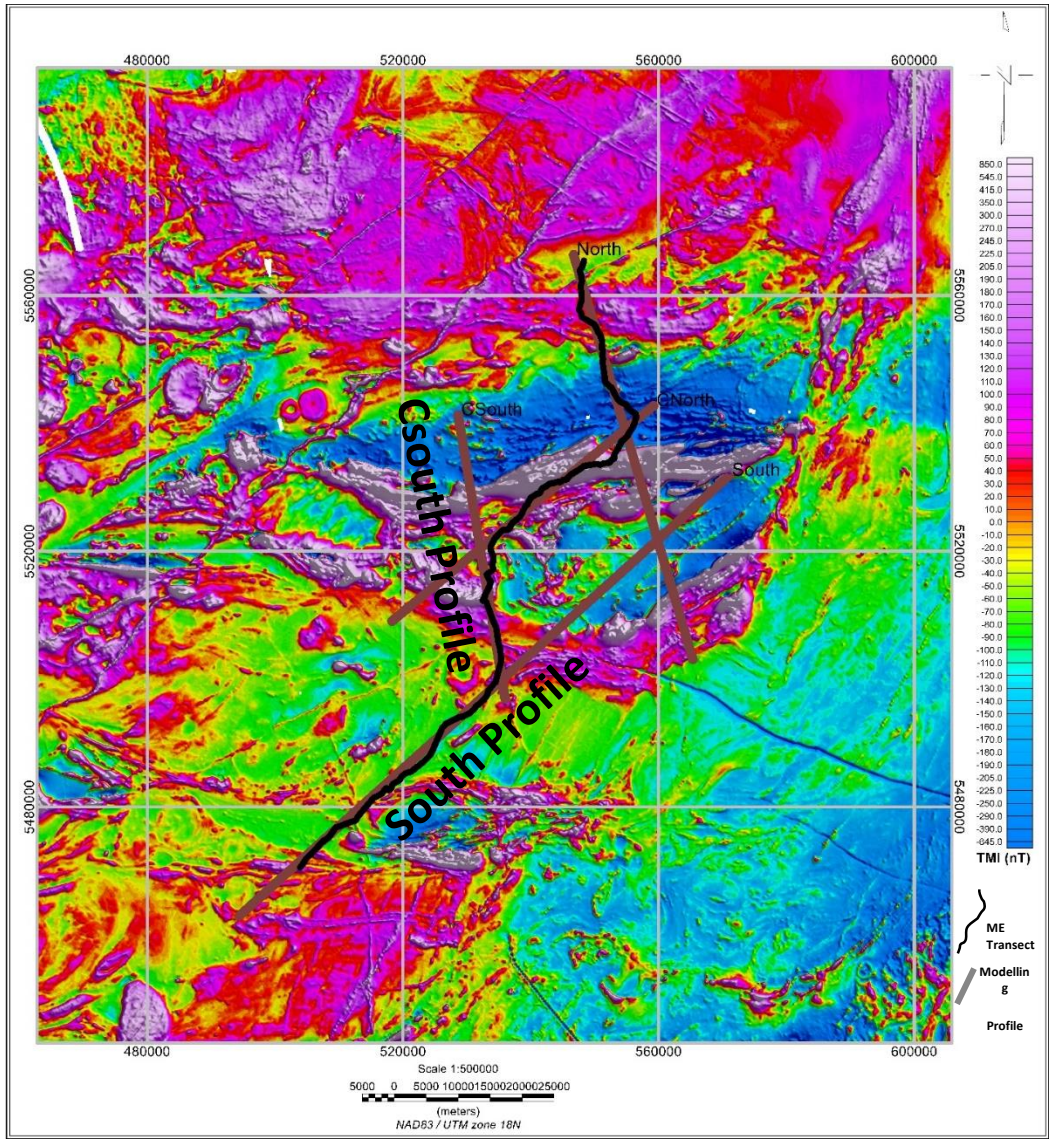


Magneto-stratigraphic map



Maleki

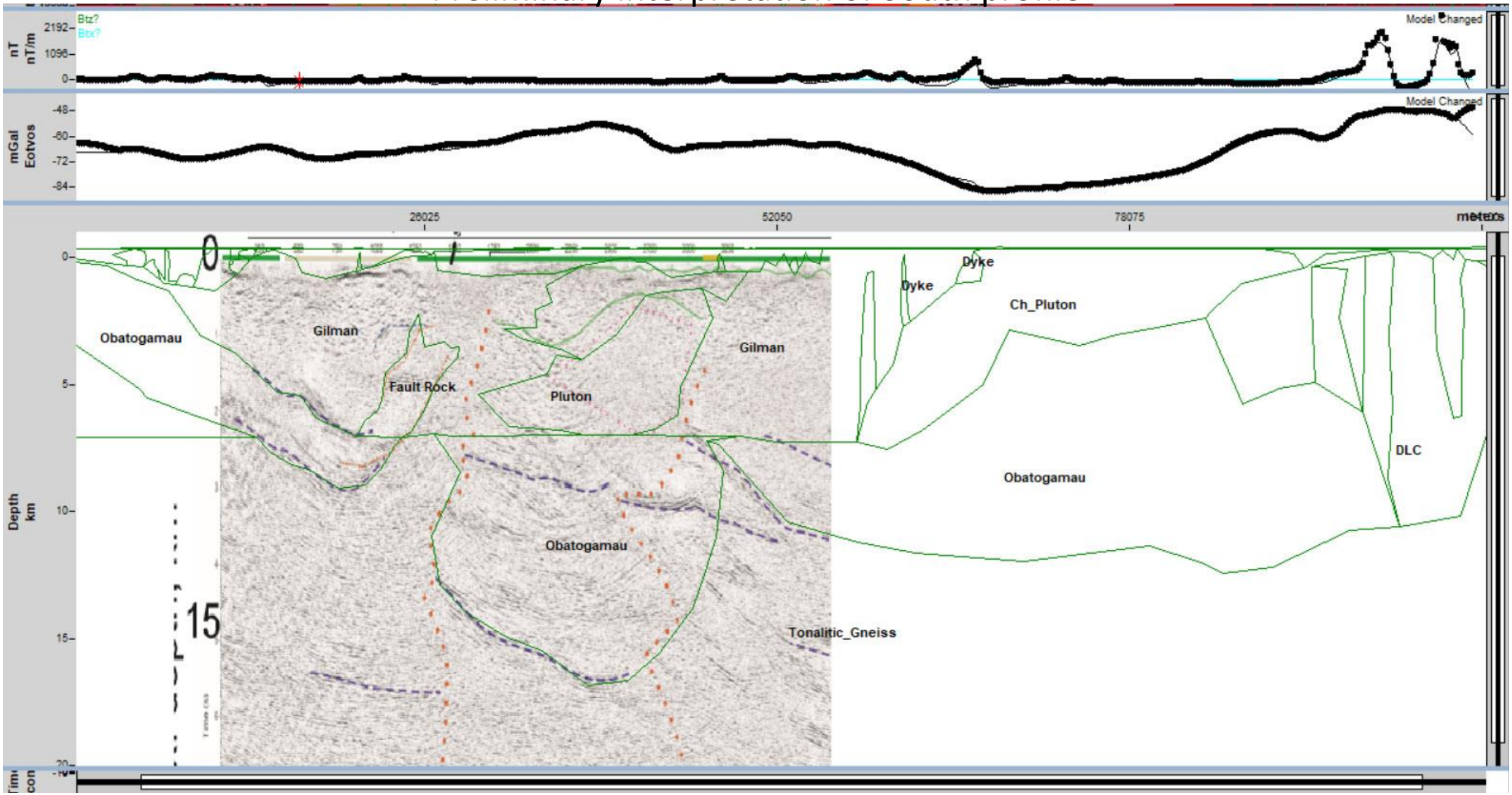
2.5-D potential-field data modelling



The location of the modelled sections on TMI map

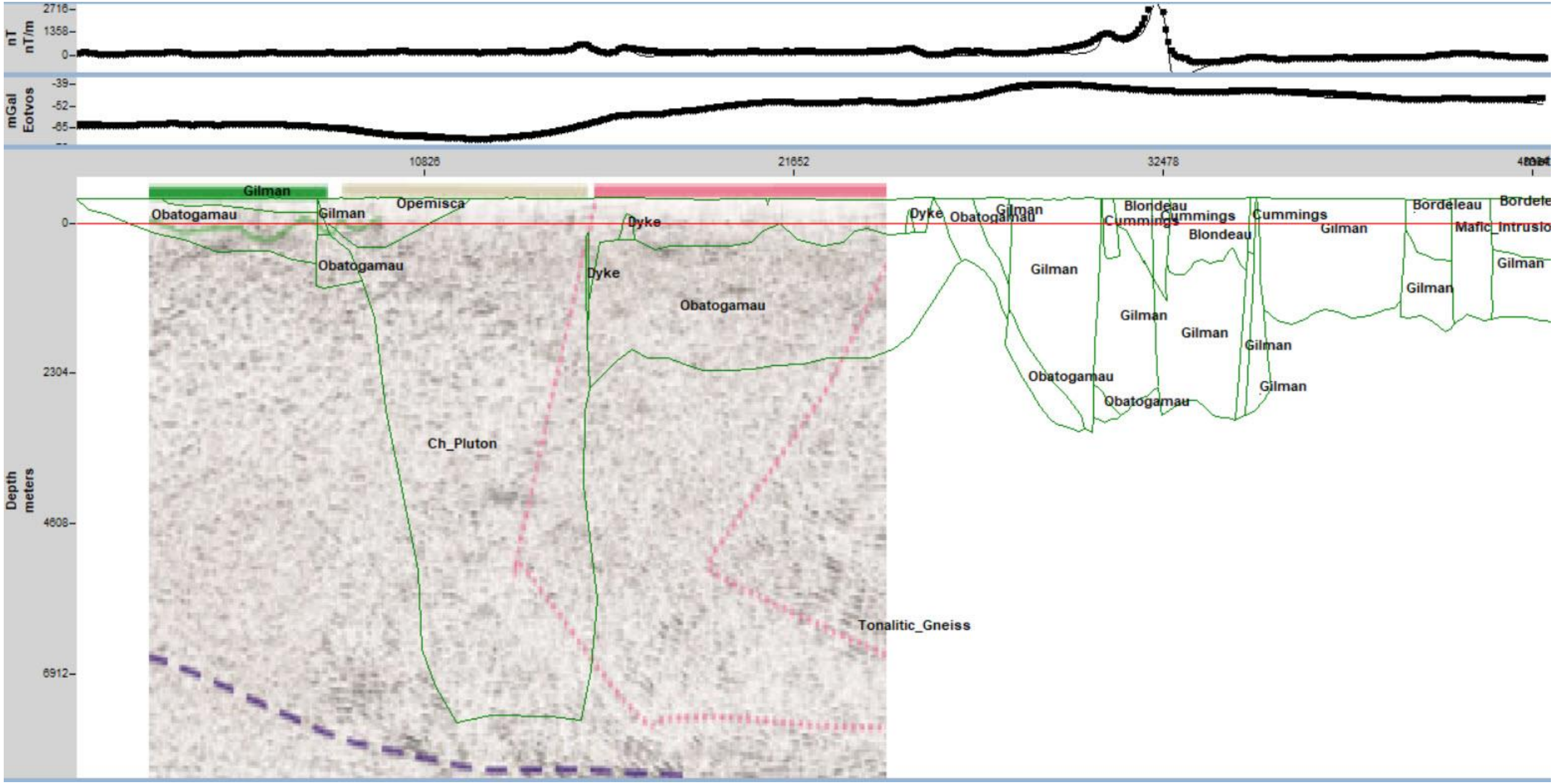
Maleki

Preliminary interpretation of South profile



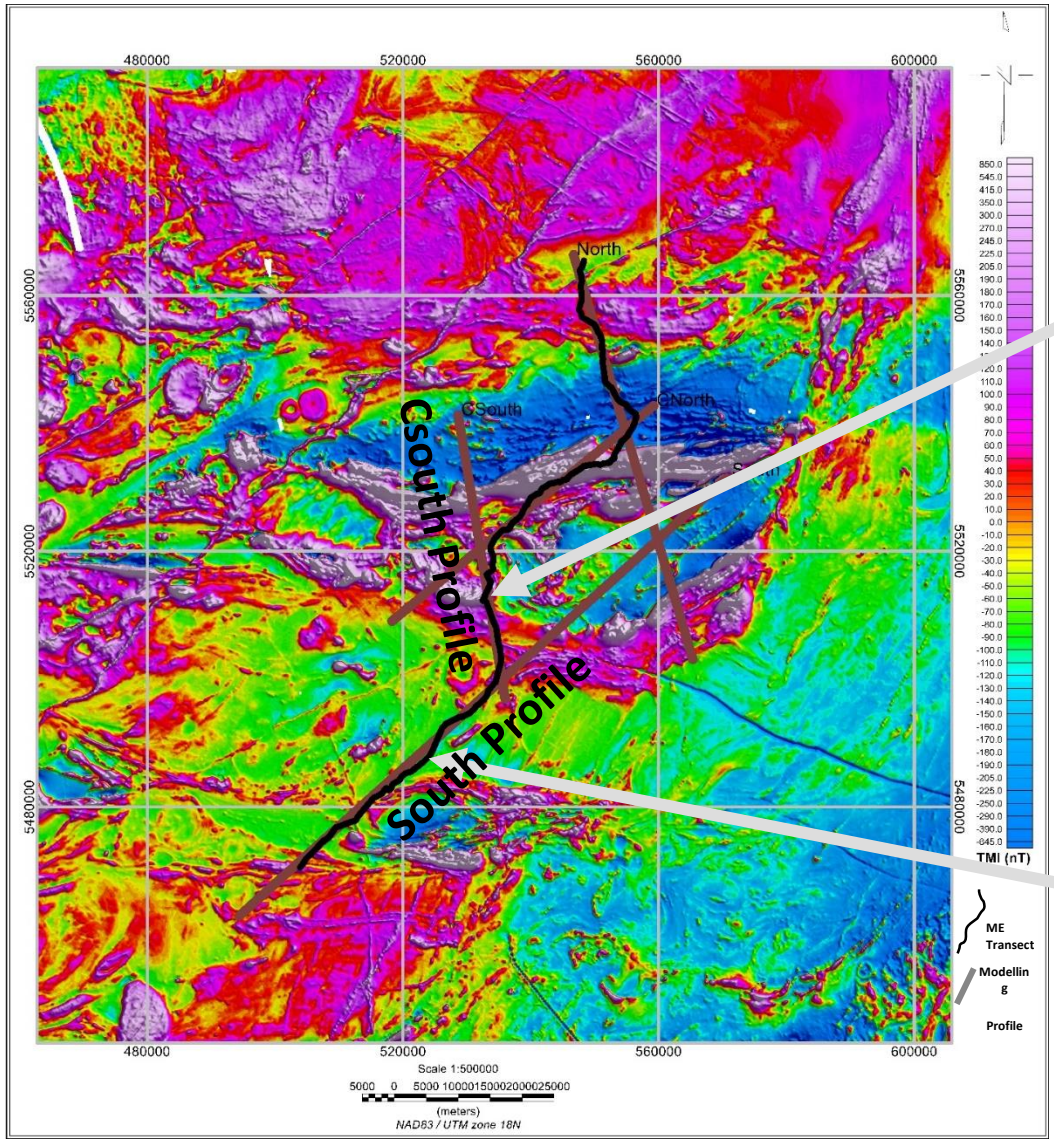
Maleki

Preliminary interpretation of Csouth profile

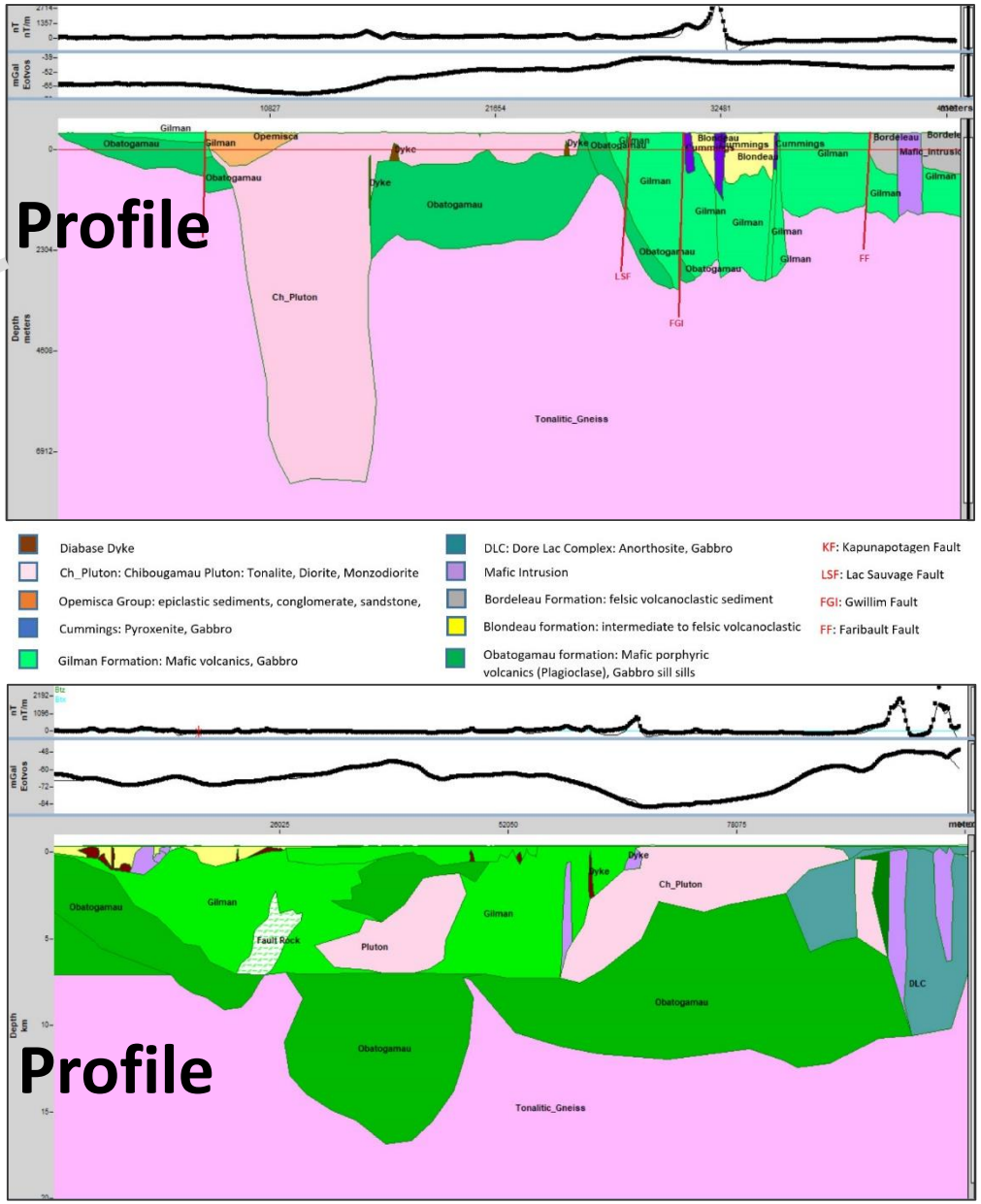


Maleki

2.5-D potential-field data modelling



The location of the modelled sections on TMI map



Potential-field data modelled along a) Csouth and b) South profiles

Maleki

Conclusions

Tasks

- Magnetic data compilation and processing – done 100%
- Physical properties acquisition – in progress 80%
- Physical properties compilation – in progress 80%
- Gravity data acquisition – in progress 80%
- Gravity and magnetic constrained 2D modelling – in progress 8%
- Gravity and magnetic constrained 3D modelling – to start 0%

METAL EARTH

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

KINROSS

Teck

IAMGOLD

IVANHOE MINES
NEW HORIZONS

Laurentian University Université Laurentienne
GOODMAN SCHOOL OF MINES ÉCOLE DES MINES

ALAMOS GOLD INC.

MERC Tier 2 Members

Tr Transition Metals

SUDBURY INTEGRATED NICKEL OPERATIONS
A GLENCORE COMPANY

NORTHERN SUPERIOR RESOURCES

VALE

KGHM
POLSKA MIEDŹ

Exiro
MINERALS

McEWEN MINING
NYSE MUX TSX

PELANGIO

HIGHLAND
Copper Company Inc.

PHOENIX GEOPHYSICS

BAT+E-RY
MINERAL RESOURCES

FIRST COBALT

MERC
AT THE HARQUAIL SCHOOL OF EARTH SCIENCES

METAL EARTH

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

Metal Earth Partners

UQAC Université du Québec à Chicoutimi

uOttawa

Geological Survey Canada 1842 Commission Géologique

Université Laval

University of Alberta

UNSW The University of New South Wales

Carnegie Institution for Science

University of Toronto

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

125 Anniversary Ontario Geological Survey

Mirarco Mining Innovation

CEMI Centre for Excellence in Mining Innovation

DIVEX Diversification de l'exploration minérale au Québec

CODES ARC Centre of Excellence in Ore Deposits

Centre for Exploration Targeting

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

CERM Centre d'études sur les ressources minérales

Northwest Territories

Manitoba

NxGold Ltd.

MAC Resources

First Cobalt

Cobalt Power Group

Canada-Nunavut Geoscience Office / Bureau géoscientifique Canada-Nunavut / ᑲᓇᑕᒥ-ᓄᓇᕗᒥ ᐅᔭᕆᐊᓕᕆᓂᖅ / Kanatami-Nunavumi Geoscience Titigakviit

Noront

KL Kirkland Lake Gold

Yorbeau Resources Inc

Sudbury Integrated Nickel Operations A Glencore Company

Metal Earth Software Partners

Adobe

Clarivate Analytics

Emerson

esri

Geosoft

GLOBE Claritas seismic processing software

Intrepid Geophysics

MathWorks

Mira Geoscience ...modelling the earth

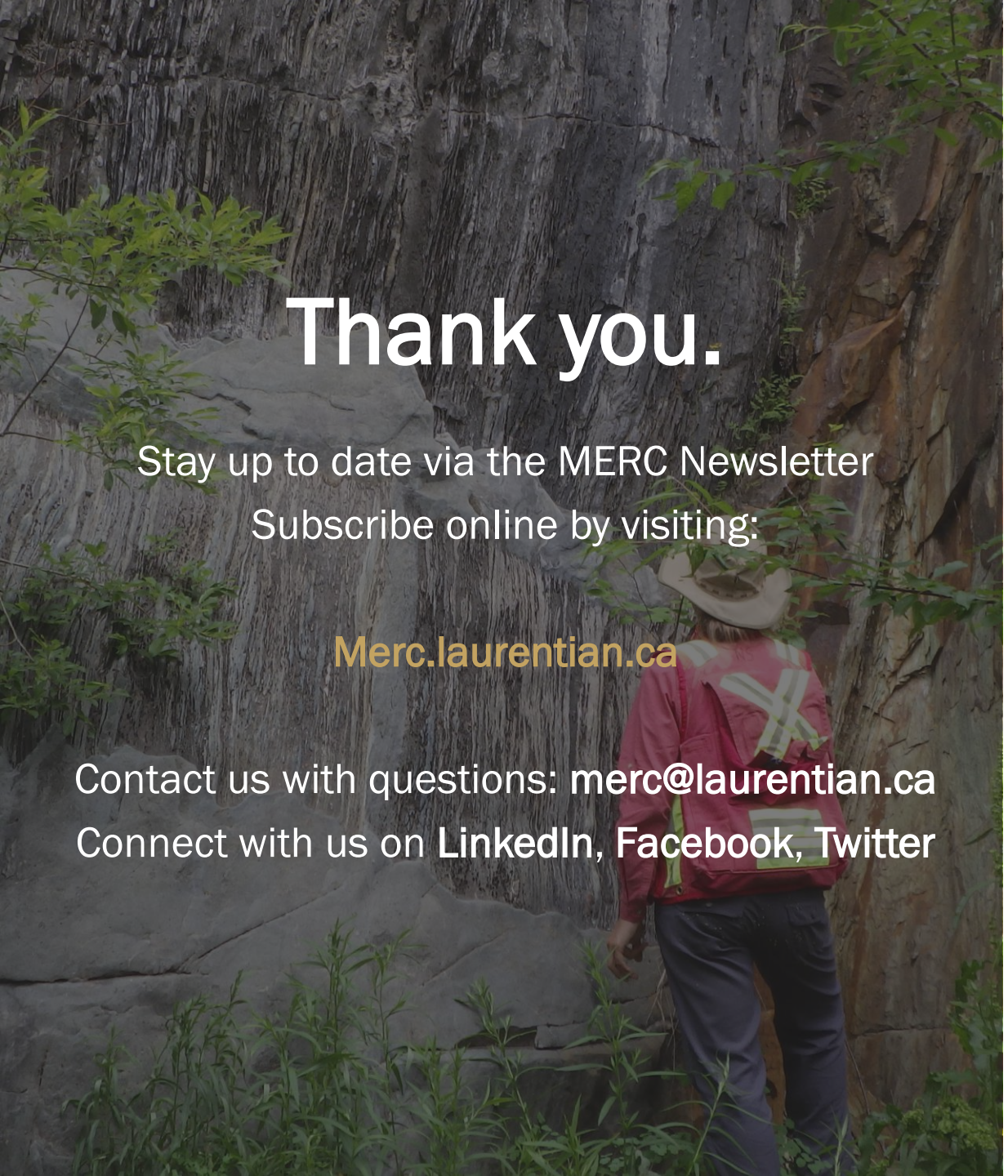
Reflex Intelligence on Demand

Scooter Software

MERC at the Harquail School of Earth Sciences

Metal Earth

Laurentian University Université Laurentienne Harquail School of Earth Sciences École des sciences de la terre



Thank you.

Stay up to date via the MERC Newsletter
Subscribe online by visiting:

Merc.laurentian.ca

Contact us with questions: **merc@laurentian.ca**
Connect with us on **LinkedIn, Facebook, Twitter**

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