mdru Mineral Deposit Research Unit

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Using geophysics to assess carbon mineralization capacity of ultramafic rocks in British Columbia, Canada

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CSIRO Cutting Edge Science Symposium – Locking Carbon in Minerals
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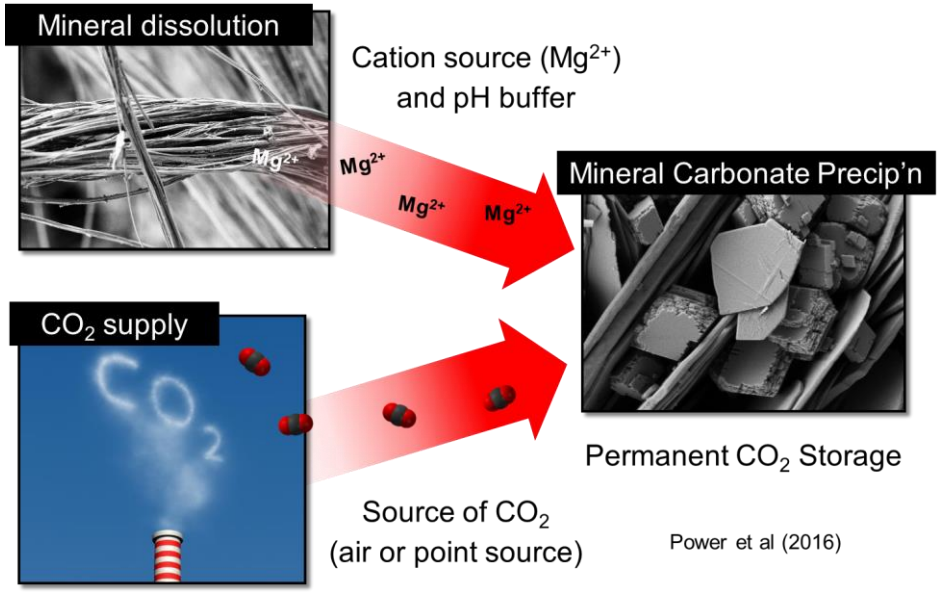
CarbMinLab Geoscience BC BRIMM BRADSHAW RESEARCH INITIATIVE FOR MINERALS & MINING mdru BRITISH COLUMBIA GEOLOGICAL SURVEY

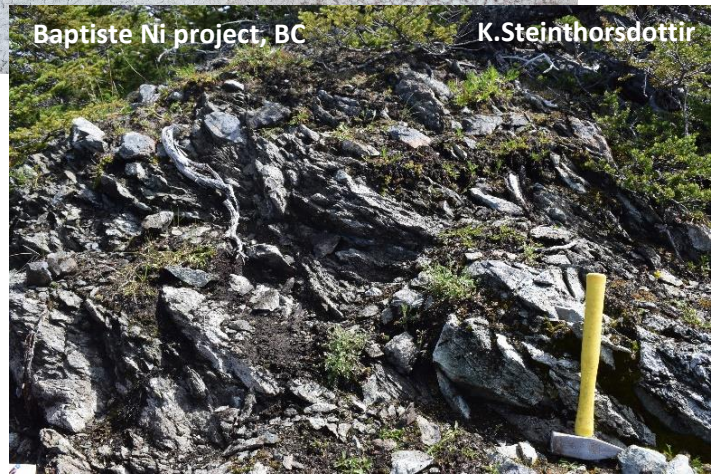
Outline

- Ultramafic rocks, CO_2 mineralization - province-scale opportunities
- Physical rock properties and geophysical signatures of ultramafic rocks
- Magnetics and 3D modelling for carbon mineralization capacity
- Challenges, ongoing work, study implications

Ultramafic rocks, CO_2 mineralization - province-scale opportunities



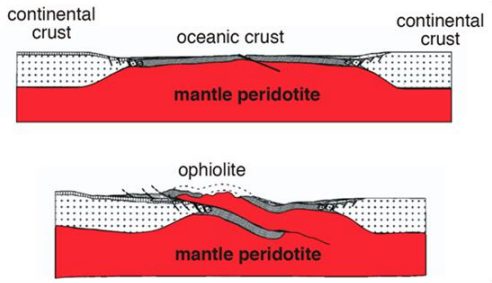
Power et al (2016)



Ultramafic rocks and battery metals in Canada and BC

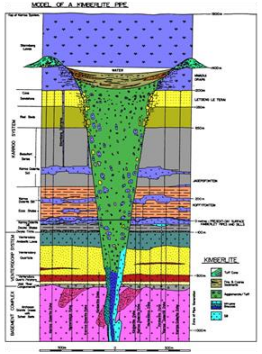
- Ni, PGE, Cr asbestos

Mantle massifs



(Kelemen after Coleman, 1977)

Kimberlite

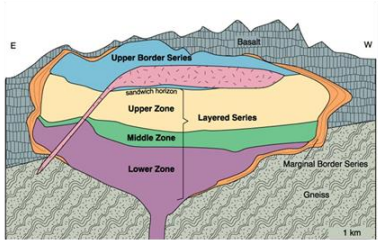


(Hawthorne, 1975)

- Diamonds

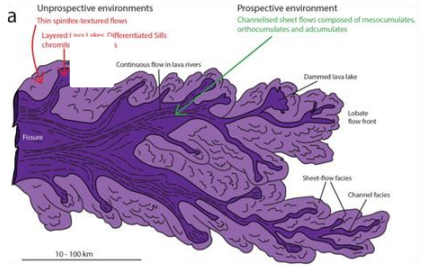
- Ni, PGE, Cr, Cu, Co

Intrusion



(Hoover, 1978)

Komatiite



(Le Vaillant et al., 2016)

- Ni, PGE, Cr, Cu, Co

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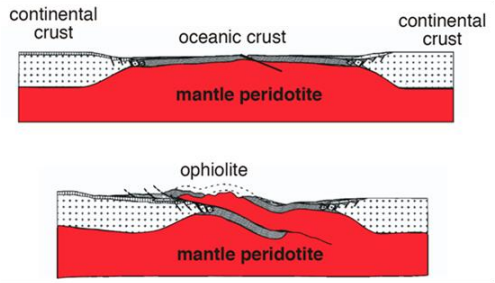

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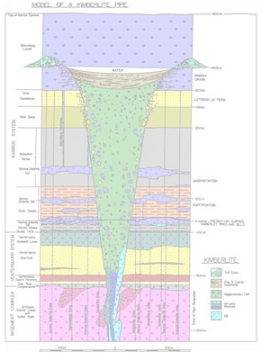
Kimberlite



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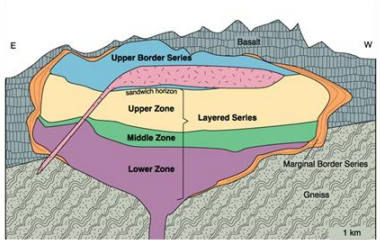
- Diamonds

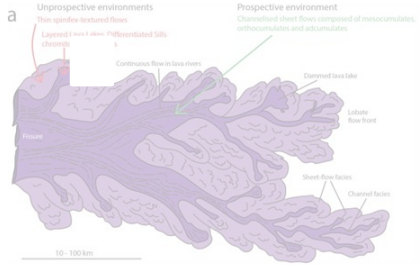
- Ni, PGE, Cr, Cu, Co

Intrusion



(Hoover, 1978)

Komatiite



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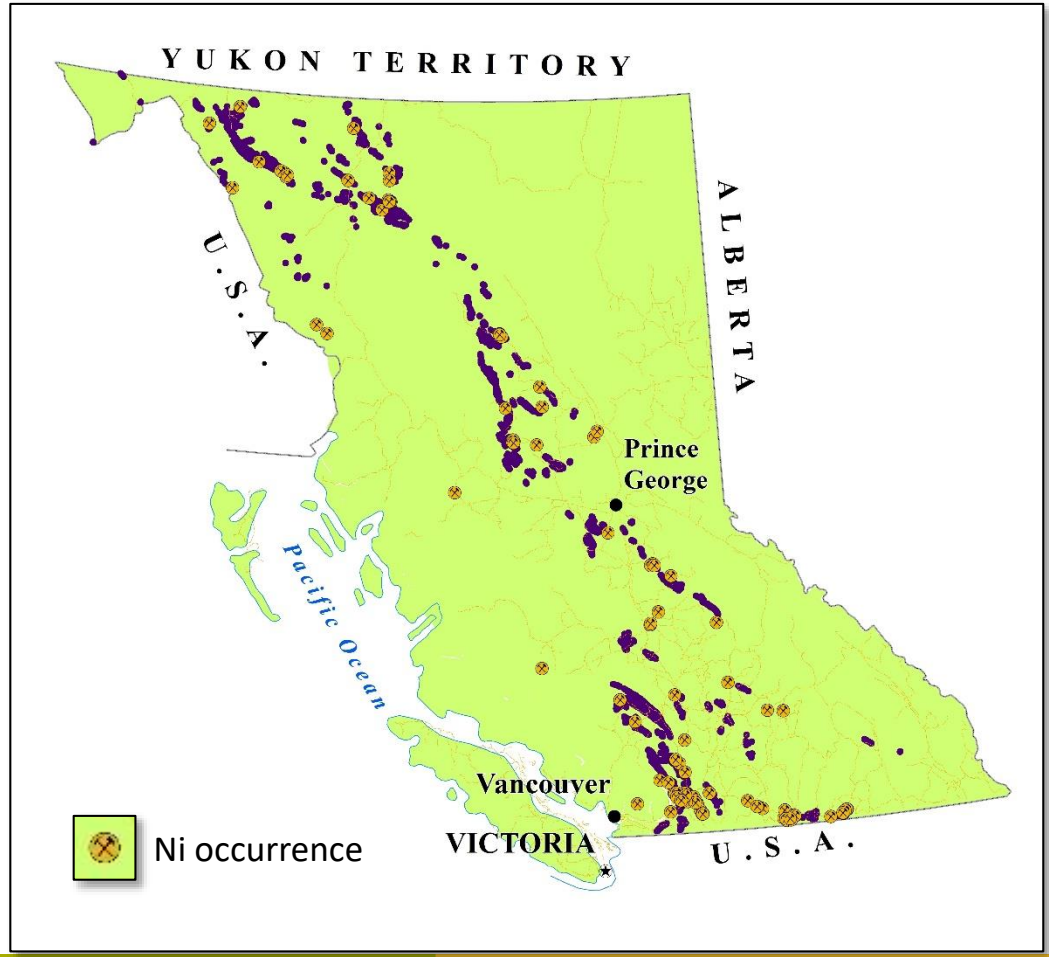
- Ni, PGE, Cr, Cu, Co

Ultramafic rocks in British Columbia

Geology.com

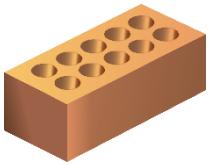


The CaMP project – British Columbia

CarbMinLab

- **A University of British Columbia CarbMin Lab project**
- **CarbMin Lab** – over two decades of research on carbon mineralization in mine tailings and technologies to accelerate carbon mineralization at mine sites
- **CaMP** = **Ca**rbon **M**ineralization **P**otential of British Columbia
- **CaMP Project goal:** use British Columbia geophysical data and geophysical inversion modelling techniques to remotely determine the capacity for carbon mineralization of ultramafic rocks, and create regional prospectivity guides and rankings for potential CO_2 offset sites, in BC

Mineralogy to physical properties



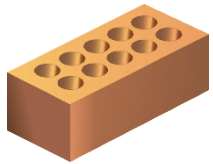
$$\text{R1: olivine} \pm \text{orthopyroxene} + H_2O \rightarrow \text{serpentine} \pm \text{brucite} \pm \text{magnetite}$$

Magnesium hydroxide - $Mg(OH)_2$

$$\text{R2: olivine} + \text{brucite} + CO_2 + H_2O \rightarrow \text{serpentine} + \text{magnesite} + H_2O$$

$$\text{R3: serpentine} + CO_2 \rightarrow \text{magnesite} + \text{talc} + H_2O$$

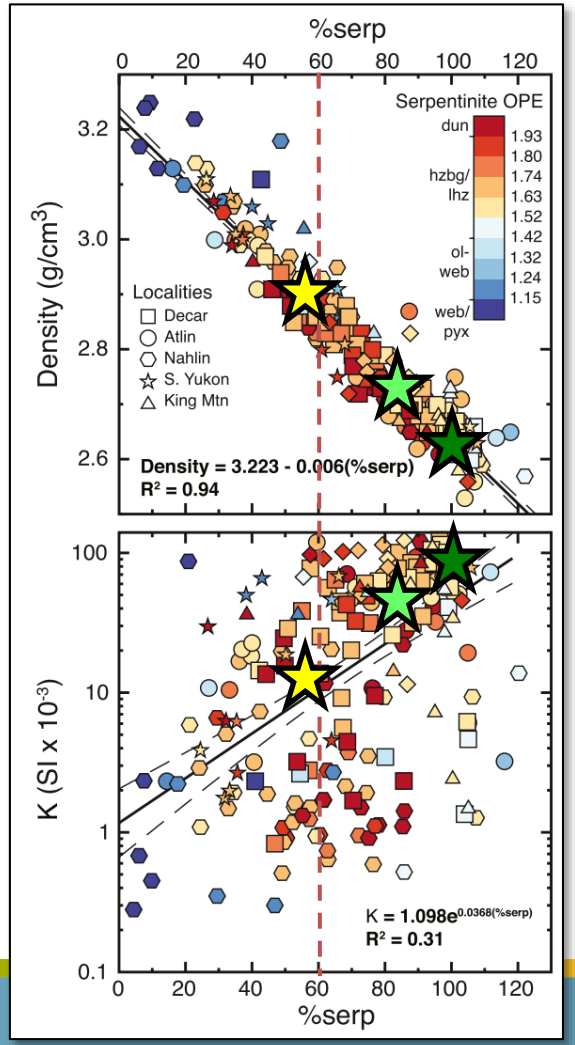
$$\text{R4: talc} + CO_2 \rightarrow \text{magnesite} + \text{quartz} + H_2O$$

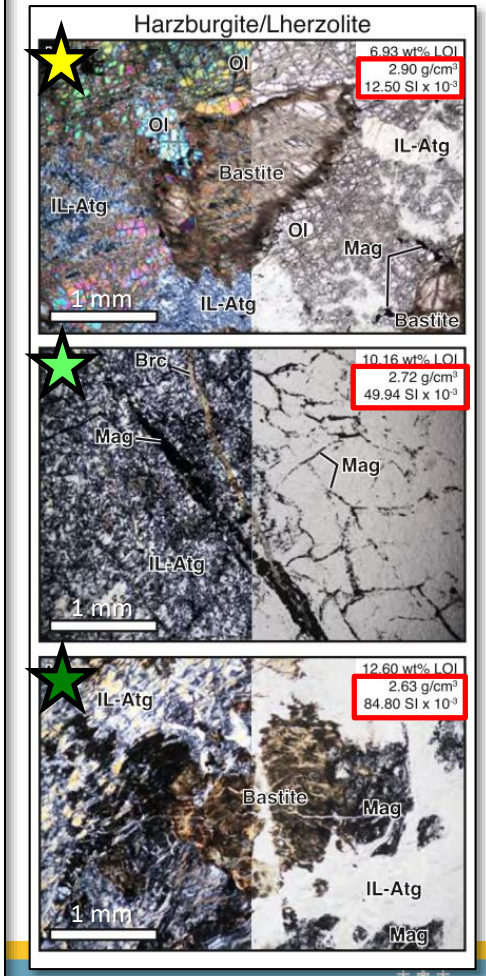


Cutts et al., 2021

Physical properties of serpentinized ultramafic rocks

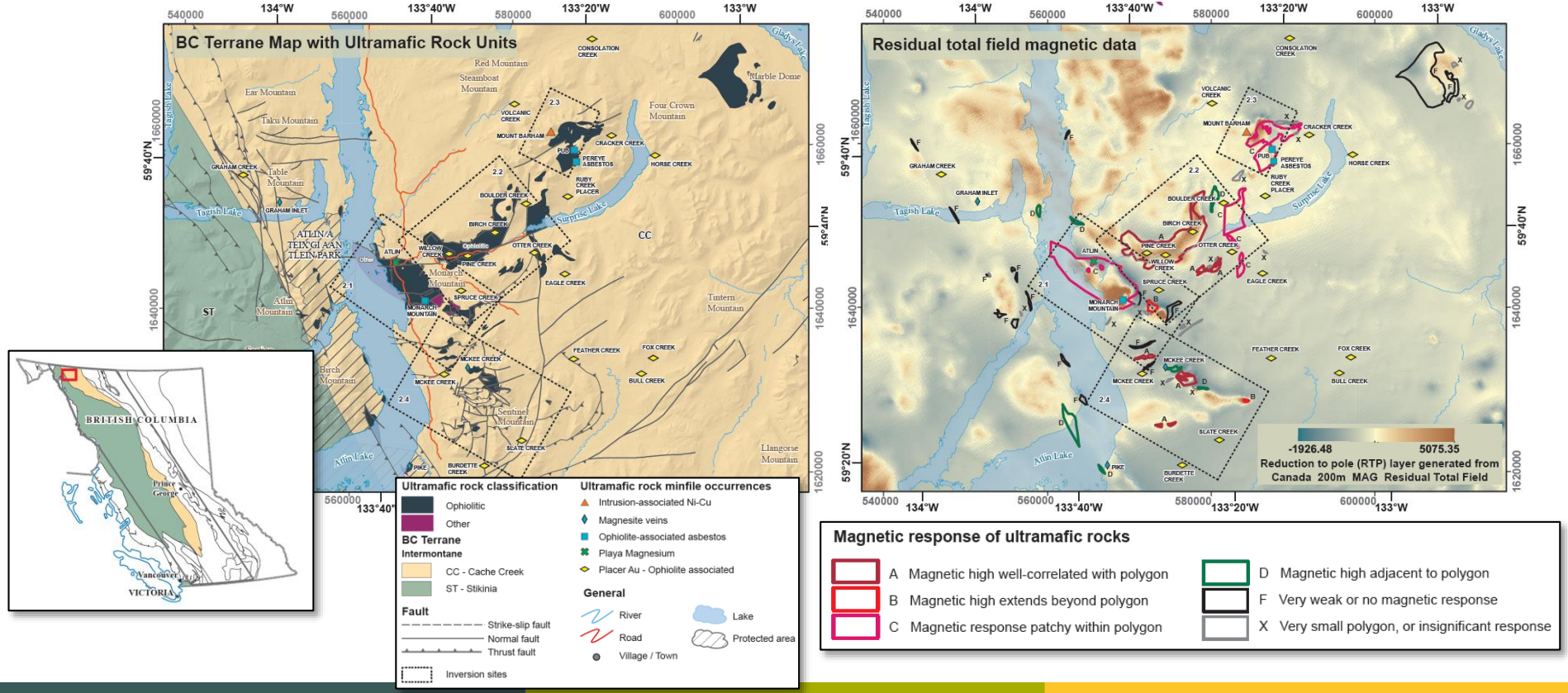
- **Decrease in density** with serpentinization – due to destruction of higher density olivine and pyroxene, and increased porosity
- **Increase in magnetic susceptibility** due to formation of magnetite during serpentinization
- Highest susceptibilities and lowest densities found in the most strongly serpentinized (most highly reactive) rocks





Cutts et al., 2021

Using magnetic data to locate serpentinized ultramafic rocks in BC



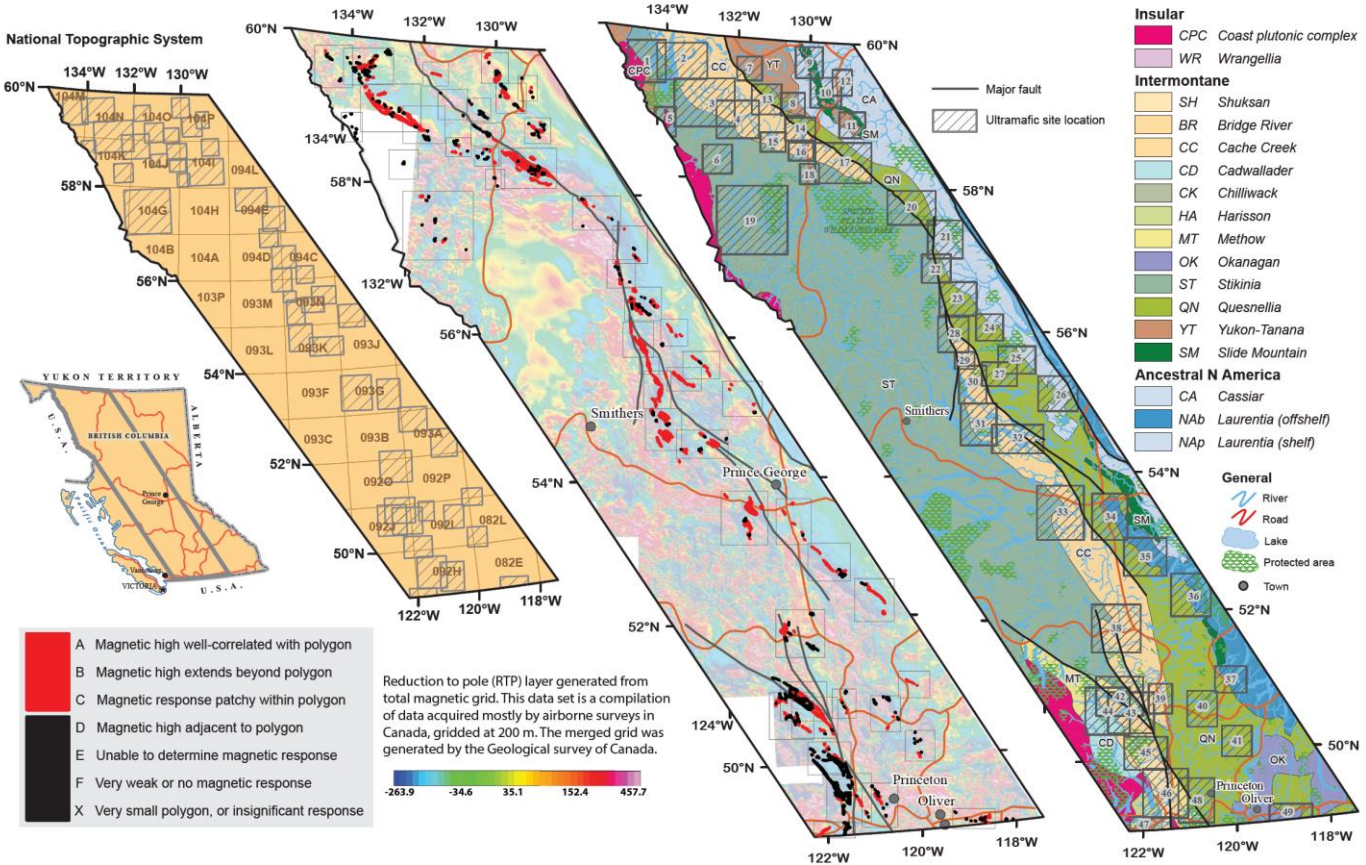
BC ultramafic body magnetic classification

Classification	Description	Confidence that magnetic anomaly is related to mapped ultramafic unit	Number of polygons represented	Total Area (km^2) of mapped polygons within class
A	Positive magnetic anomaly well-correlated spatially to mapped ultramafic polygon	High	78	1681
B	Positive magnetic anomaly extends beyond mapped ultramafic polygon	High	105	232
C	Irregular or patchy positive magnetic anomaly contained within a mapped ultramafic polygon	High	158	958
D	Polygon with offset positive magnetic anomaly (may be due to the ultramafic or adjacent unit)	Low	39	119
E	Can't isolate/differentiate a distinct magnatic signal from surrounding magnetic material	Low	38	39
F	Very weak to no magnetic signal correlated to the mapped ultramafic polygon	None	95	733
X	Generally small polygon of varied magnetic response, overall insignificant contribution to ultramafic rock volume	None	210	56
ND	No magnetic data coverage	None	23	9
		Total	**746**	**3827**

2871 km^2

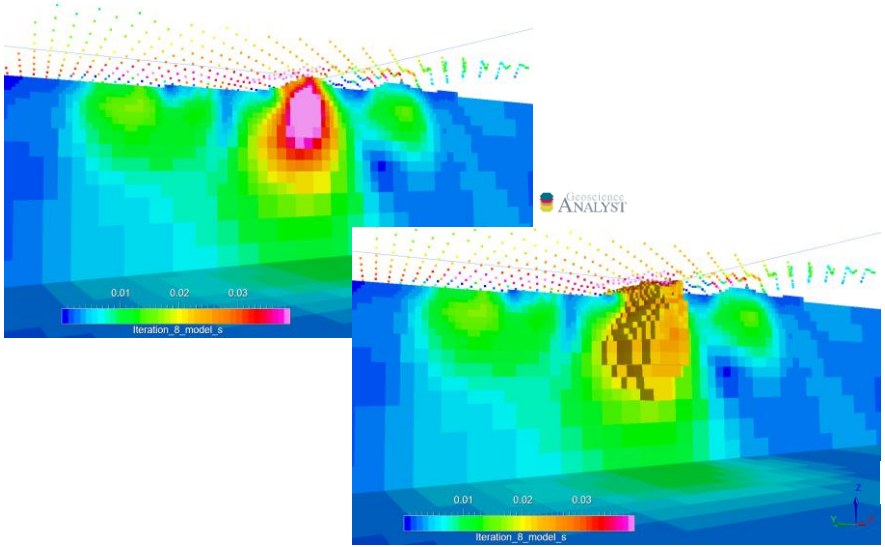
Estimating amount of serpentinized ultramafic rocks

- **46 %** of ultramafic rock polygons have magnetic anomalies
- **75 %** of the total areal extent of mapped ultramafic rocks are associated with magnetic anomalies



3D magnetic inversion modelling for serpentinized rock volumes

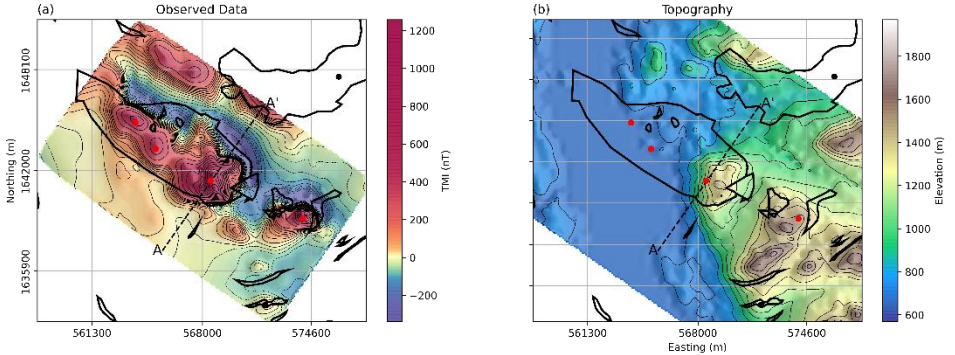
- Magnetic inversion finds the 3D physical property (magnetic susceptibility) model that fits the observed magnetic data

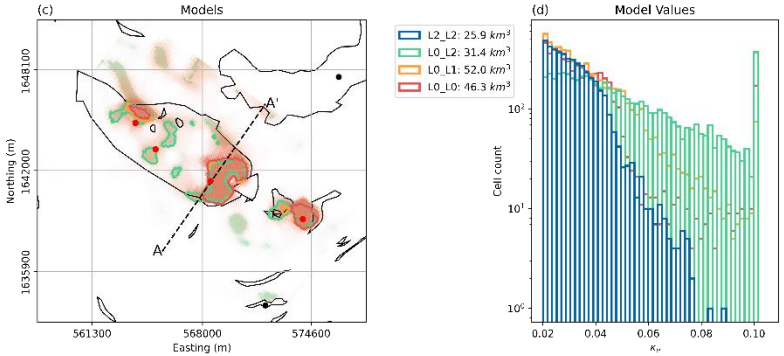


- 50 ultramafic localities, 99 inversions (x4)
- <u>Code</u>
  - MVI (magnetic vector inversion) code from SimPEG (Simulation and Parameter Estimation in Geophysics) open source geophysical inversion package
- <u>Data</u>
  - Natural Resources Canada 200 m gridded data compilation
- <u>Constraints/Lp-norms</u>
  - Four combinations of Lp norms (determine the smoothness of the inversion model) were used to assess variability in possible models

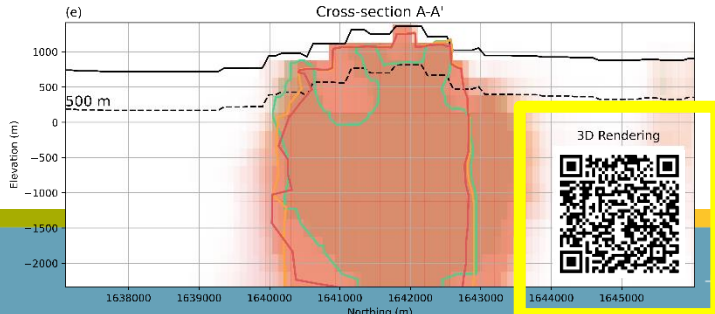
3D magnetic inversion modelling for serpentinized rock volumes

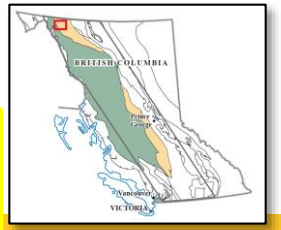
- Volume determination from 20 x 10^{-3} SI threshold value (based on physical property studies)
- Volume calculated for each of the four different Lp-norm models to explore the range
- Median of Lp-norm volumes used for carbon mineralization capacities at each location





Atlin (Northern Cache Creek Terrane)





Serpentinized volume and carbon mineralization capacities

Sequestration capacity of serpentinized ophiolites in BC

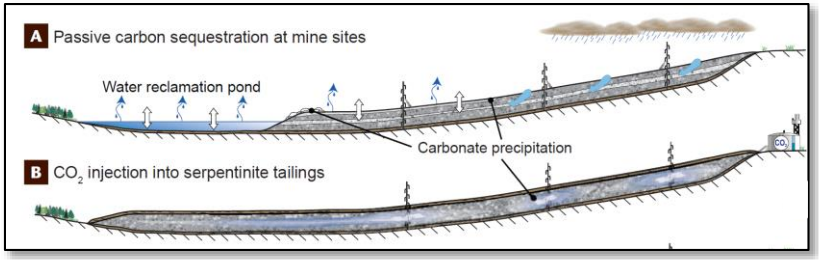
Depth interval (km)	Serp volume (km^3)	Sequestration Capacity (Gt CO_2)	Method	Yrs of BC emissions*
0 to 0.5	139	8	*ex situ*	115
0 to 1	547	31	*ex situ*	452
0 to 2	1812	102	*ex situ*	1499
2 to 4	2,045	2,526	*in situ*	37144

2018 rates of 68 Mt CO^2 annually*

For ex-situ carbon mineralization
Labile MgO 2.3 weight % available for reaction (Vanderzee et al, 2019)
CO_2 reaction capacity: 0.020 tonne CO_2 per tonne rock

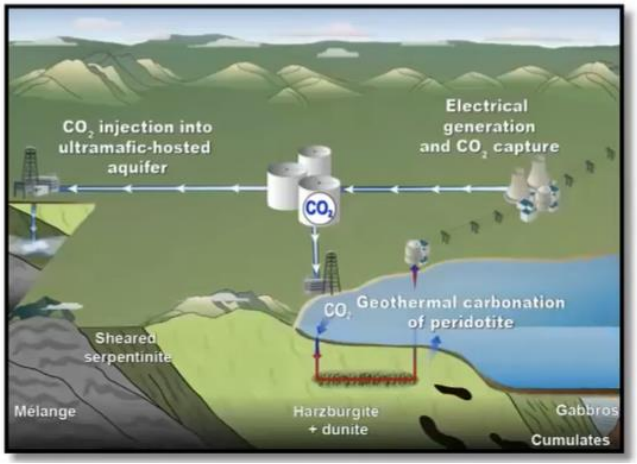
For in-situ carbon mineralization >2 km depth
100% Mg reacted

***Ex-situ* carbon mineralization**



Power et al., 2013

***In-situ* carbon mineralization**

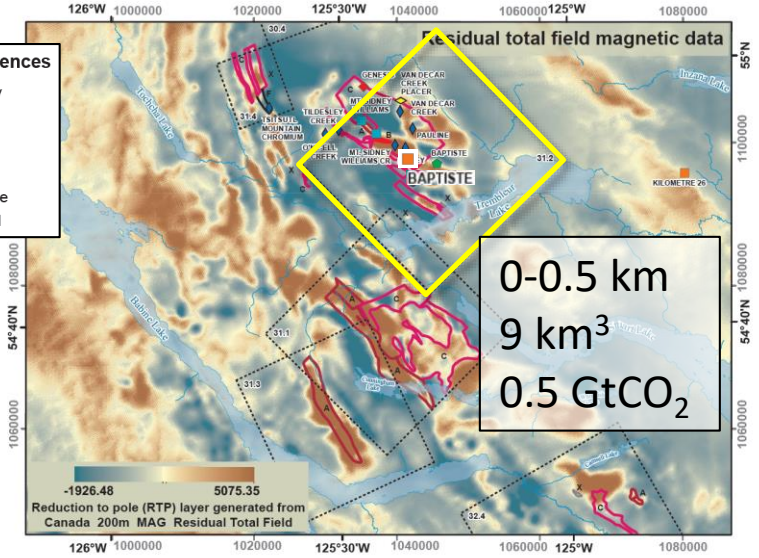


Power et al., 2013, after Kelemen and Matter 2008

High CO_2 mineralization capacity sites in BC

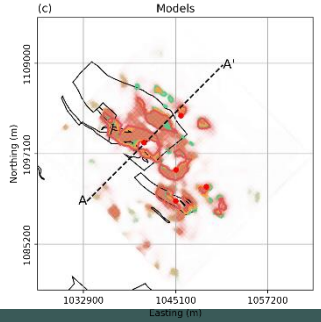
Ultramafic rock minfile occurrences

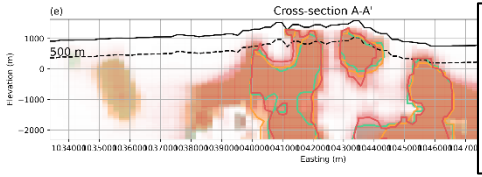
- Ophiolite-associated nickel alloy
- Ophiolite-associated asbestos
- Jade
- Podiform chromite
- Ultramafic-hosted talc-magnesite
- Placer Au - Ophiolite associated



0-0.5 km
9 km^3
0.5 $GtCO_2$

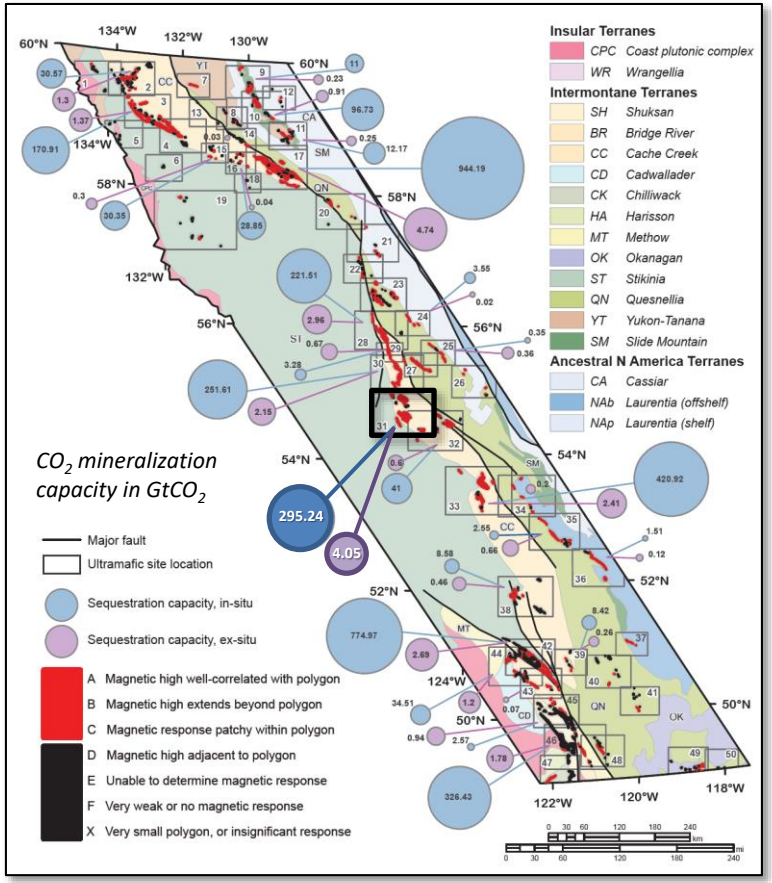
Cache Creek Complex – Trembleur UM Unit (Southern Cache Creek Terrane)





L2_L2: 197.7 km^3
L0_L2: 197.7 km^3
L0_L1: 216.9 km^3
L0_L0: 220.4 km^3

FPX Nickel Corp.
TSX-V:FPX



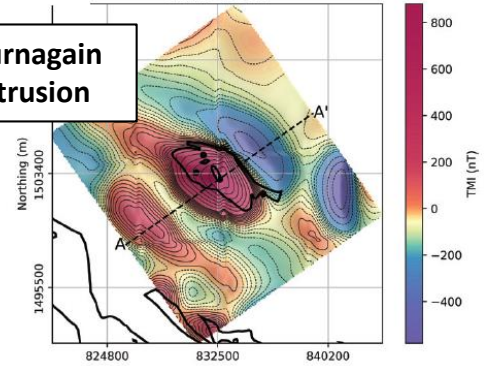
Challenges

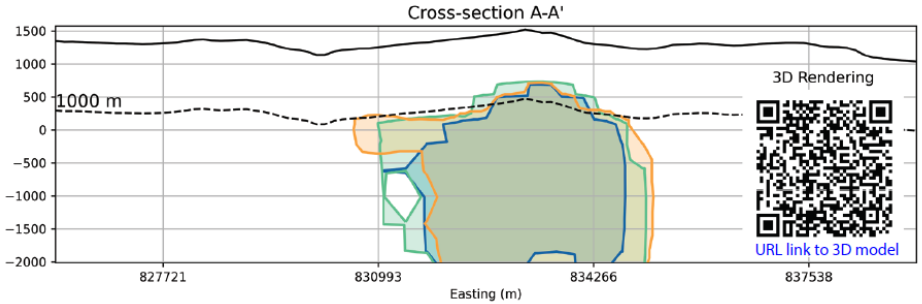
- **Magnetic data resolution** – public data resolution ok for estimates, but may not be enough to most accurately model depths and detail of serpentinized bodies

Magnetic inversions – testing resolution and variability

Observed public NRCan 200 m

Turnagain intrusion

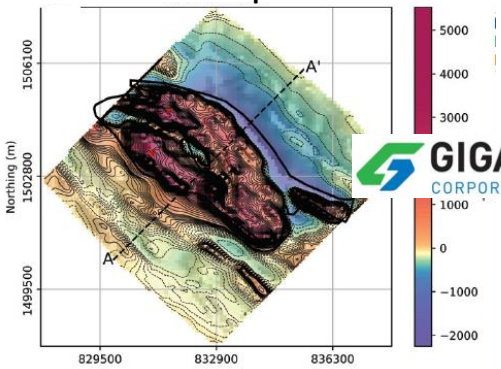




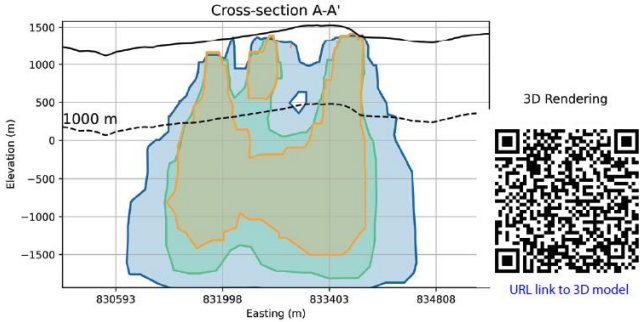
Volumes at 0.02 SI mag sus cut-off

- L2-L2: 33.1 km^3
- L0-L2: 53.3 km^3
- L0-L1: 60.9 km^3

Observed Aeroquest 100 m



GIGAMETALS CORPORATION



Volumes at 0.02 SI mag sus cut-off

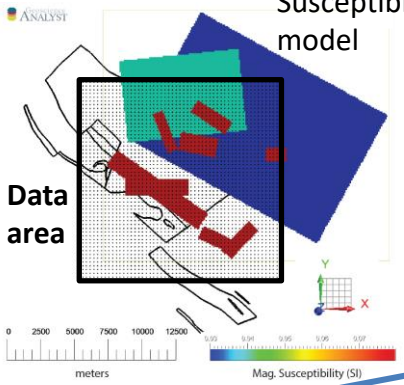
- L2-L2: 95.4 km^3
- L0-L2: 45.2 km^3
- L0-L1: 29.1 km^3

Challenges

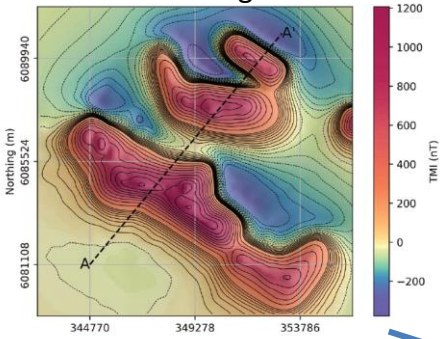
- **Magnetic remanence** – not specifically accounted for in the inversion modelling and clearly affecting estimated volumes and depths in some locations

Magnetic inversions – synthetic tests

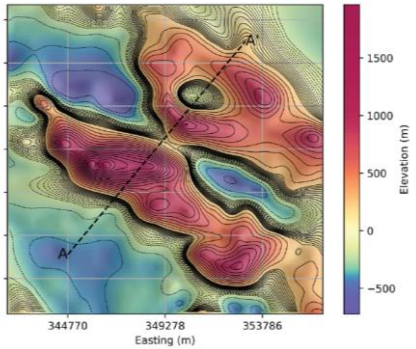
Susceptibility model

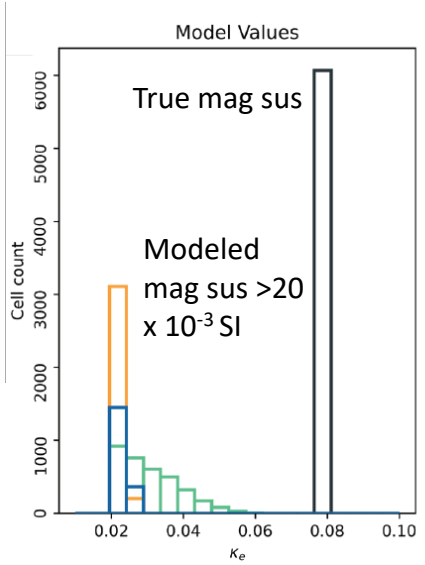


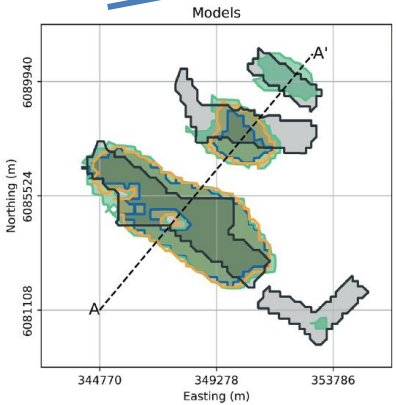
Simulated mag data

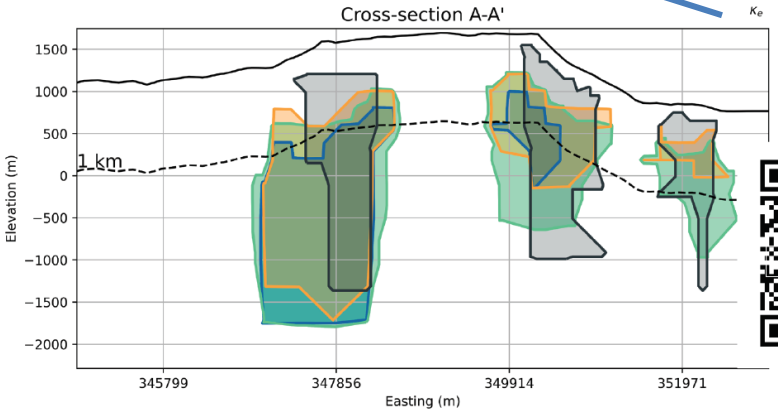


Observed mag data









3D Rendering

URL link to 3D model

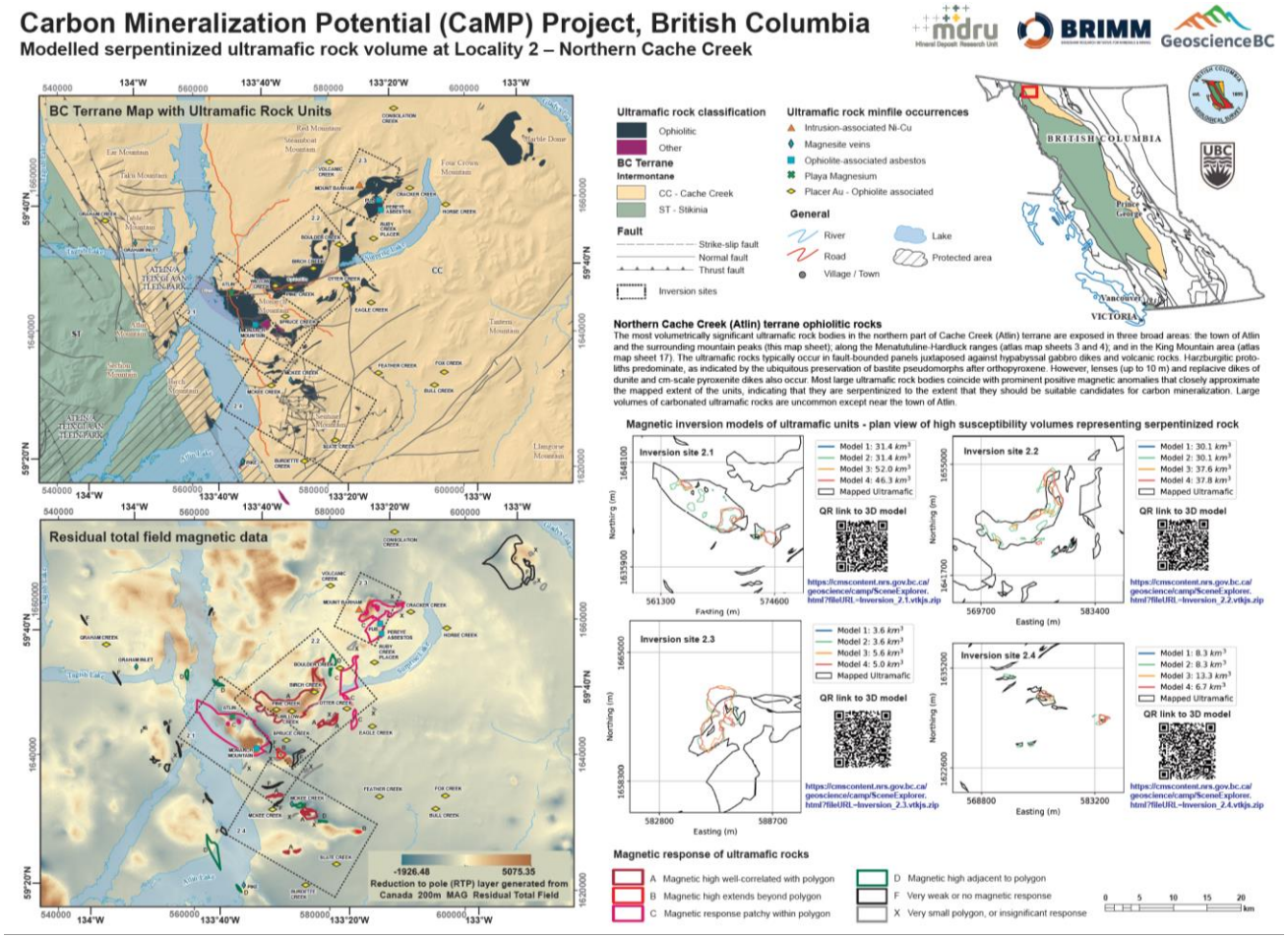
L2-L2: 45.7 km^3
L0-L2: 65.2 km^3
L1-L1: 47.5 km^3
True: 77.8 km^3

Challenges

- **More physical property data needed** – ophiolites focused on, more data are needed to better understand typical physical properties of intrusive ultramafic rocks
- **Lack of high res gravity** – clear and excellent correlation between density and serpentinization, but public gravity datasets are too low resolution to use for modelling at the scale we need

Ongoing work

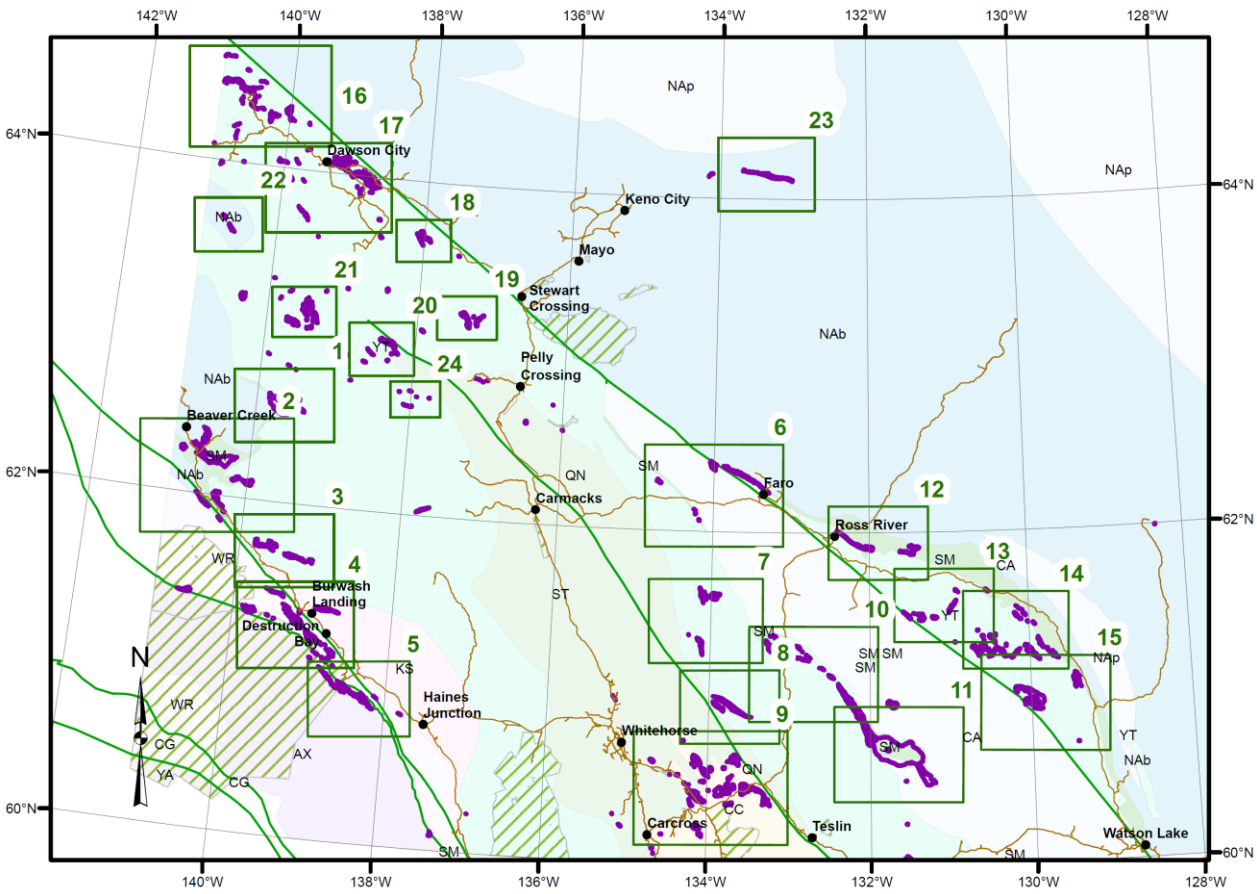
- BC CaMP atlas



Ongoing work

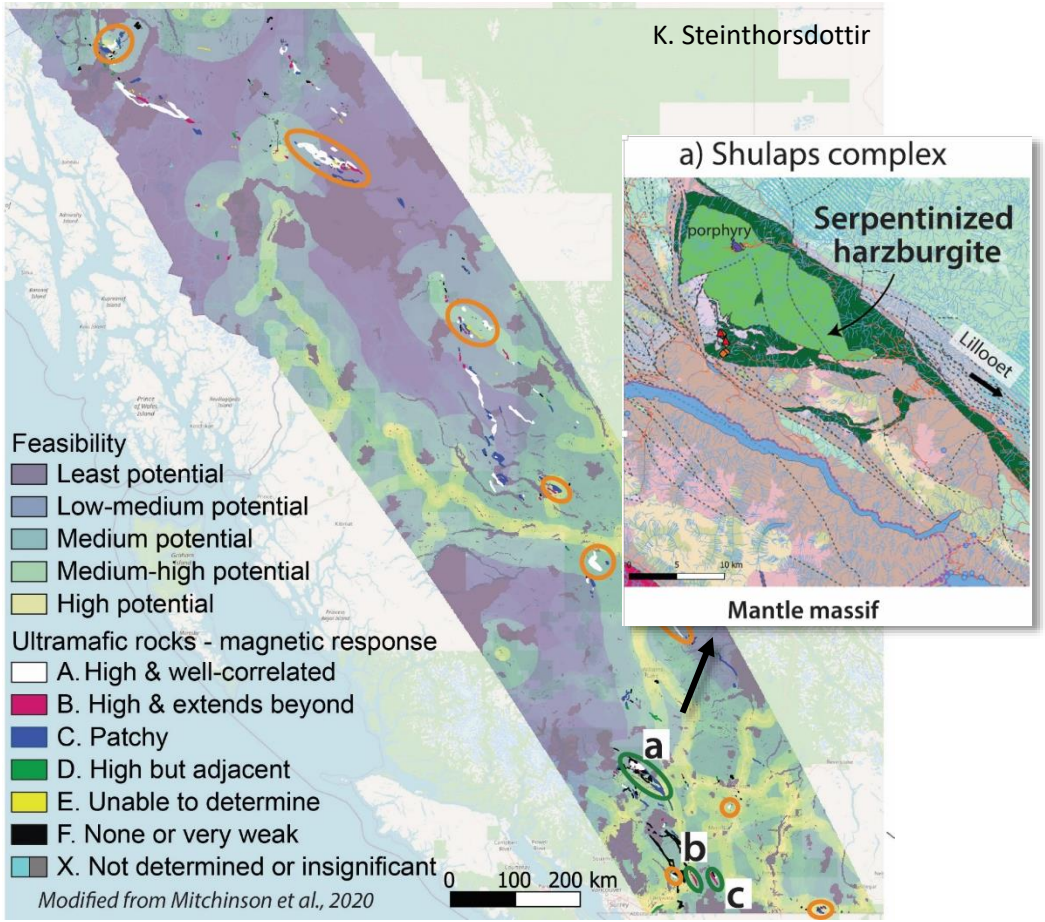
- BC CaMP atlas
- CaMP Yukon

Geology.com



Ongoing work

- BC CaMP atlas
- CaMP Yukon
- Feasibility of in-situ carbon mineralization in serpentinite in BC



Study implications

- Results provide:
  - An opportunity for exploration and carbon capture companies to prioritize sites based on estimated carbon capture potential
  - Encouragement to sample and analyze for CO_2 mineralization capacities
  - An understanding of preliminary estimated volumes of serpentinization and an opportunity to plan for refined modeling (e.g. other geophysical surveys)
  - An opportunity to plan for future mine and tailings design, and carbon capture infrastructure

Acknowledgements

- Geoscience B.C.
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Thank You!