Simulations and Geophysical Inversions of Ultramafic Rock Magnetic Anomalies in BC to Inform Carbon Sequestration Opportunities

Authors: *Annika Naylor[1], Dianne Mitchensen[2], Dominique Fournier[3], Jamie Cutts[1], Greg Dipple[1]

[1]CarbMin Lab, Department of Earth, Ocean, and Atmospheric Sciences, University of British Columbia: 2207 – 2020 Main Mall, Vancouver, BC, V6T 1Z4 (https://carbmin.ca/)

[2]Mineral Deposit Research Unit, Department of Earth, Ocean, and Atmospheric Sciences, University of British Columbia: 2207 – 2020 Main Mall, Vancouver, BC, V6T 1Z4 (https://www.mdru.ubc.ca/)

[3]Mira Geosciences: 409 – 512B Granville St, Vancouver, BC, V6C 1T2 (https://mirageoscience.com/)

*Corresponding Author: annikan24@gmail.com

Abstract:

Serpentinized ultramafic rocks have the potential to mineralize and sequester carbon dioxide at Earth surface conditions. The widespread occurrence of ultramafic rocks in British Columbia provides the opportunity for significant sequestration of carbon if these rocks are mined. The Carbon Mineralization Potential Project for British Columbia (CaMP-BC) was initiated in 2019 to quantify the carbon mineralization prospectivity of ultramafic rocks in BC. Highly-serpentinized ultramafic rocks have the greatest potential to mineralize and capture carbon dioxide. Serpentinization produces magnetite, leading to increased magnetic susceptibility and reduced rock density. High resolution magnetic data is available for key serpentinized localities across BC. Thus, it should be possible to estimate the volumes of serpentinized rock from inverted geophysical data and rock physical properties. To test volume recovery, block simulations were built for one case study area: the Decar Ni deposit. In general, recovered high susceptibility volumes match sample data and distributions, and inversions of synthetic models are consistent with inversions of real data.However, remanently magnetized rock interacts constructively with induced fields and creates higher magnetic anomalies, which could yield an overestimated volume total. The field direction from inversion results was compared with the overall field strength to constrain the strength of remanence, then compared with the natural remanent magnetization (NRM) and Koenigsberger ratio (q-ratio) of samples. Future work will focus on differences in real and synthetic data to identify priorities within the nearly 1000 km^3 of serpentinized rock in BC to advance mining and carbon sequestration opportunities at the gigatonne scale.

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Mineral Deposit Research Unit and Bradshaw Research Initiative for Minerals and Mining, University of British Columbia, Vancouver, BC
*Corresponding Author: annikan24@gmail.com

1 - Abstract

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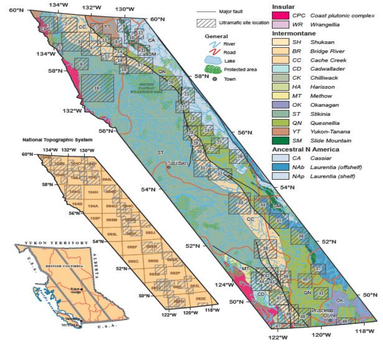
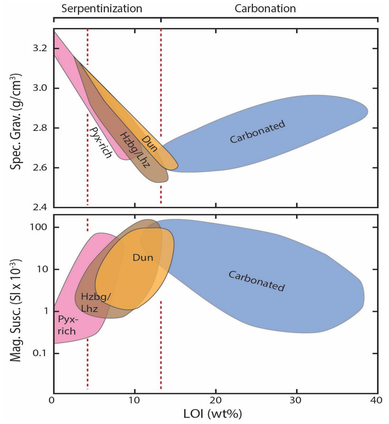


2 - Physical Properties of Serpentinized & Carbonated Rock

Serpentinization and carbonation reflect hydration and carbonation of rock, respectively. They can be tracked through bulk rock loss on ignition (L.O.I.).

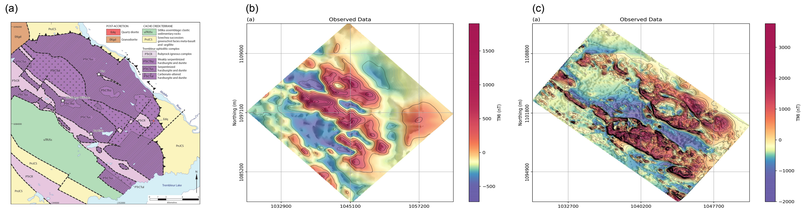
<u>Serpentinization:</u> Net volume-increasing reaction, involving the production of serpentine and magnetite
- Increased magnetic susceptibility
- Decreased specific gravity

<u>Carbonation:</u> Consumes magnetite, brucite, and serpentine to form rocks dominated by magnesite
- Increased specific gravity
- Decreased magnetic susceptibility



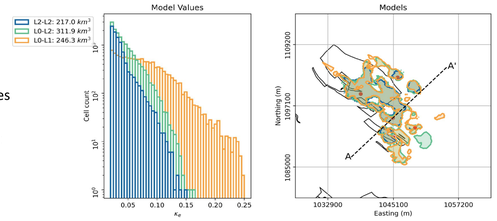
3 - Case Study: Decar Nickel District

CaMP uses Magnetic Data of the (a) Decar Locality from (b) NRCAN (200m spacing) and (c) Aeroquest (100m spacing).



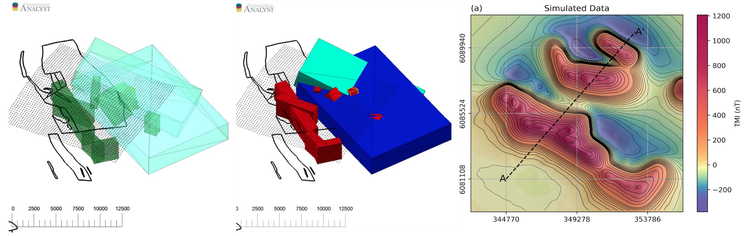
3a - Inversions

- Inversions of magnetic data show depth, 3D shape of deposit
- ℓp norms determine the ultimate blockiness/smoothness
  - Shown in histograms of magnetic susceptibility
- L2-L2 and L0-L2 were most reasonable in susceptibility values
  - Volume returned matches geological field estimate
- A map view of three inversion models compare well against the geologic map



3b - Block Simulations

- Synthetic susceptibility magnitudes are much lower than survey data (see data above for magnitudes)
- Could not match sample susceptibilities without:
  - Impossibly high susceptibility values and/or geologically nonsensical block depth

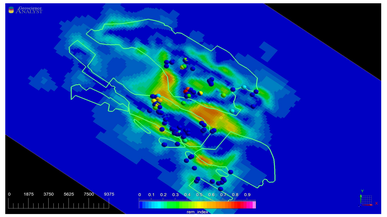


4 - Magnetic Remanence

The magnetic field direction was taken from inverted data. The direction of highest magnitude of magnetic field (B_mag) may not equal the inducing Earth's field (B_ind) at every position in 3D space.

$$\text{Remanence Index} = (\theta_{B\_mag} - \theta_{B\_ind})/|B\_mag|$$

$$\text{Q Ratio} = B\_mag/B\_ind$$



- A high Remanence Index indicates both:
  - Large magnitude
  - Large incidence angle relative to inducing field
- High remanence index areas seem to surround mapped serpentinized rock, with some highs also found within
  - The close proximity of high remanence could be impacting the magnitude of magnetic susceptibility values in the Decar Nickel District
- The points represent Koenigsberger ratios (Q-ratios) at sample points
  - Orientated samples would assist in confirming remanence values

5 - Conclusions + Implications

- Remanence plays a large role in the apparent susceptibility in Decar
- Other localities in BC could be impacted by the same remanent magnetization
- Impact on assessing the carbon sequestration potential of ultramafic occurrences in BC:
  - Magnetic (and gravity) geophysical data can be used to identify zones of serpentinization
  - Inversion shape and volume may change if not remanence is not accounted for

6 - Future Work

- Oriented magnetic samples
  - Confirm field directions
  - Confirm remanence field magnitudes
- Gravity data - more widespread surveys required
  - Further differentiate between carbonates and serpentinized rock
- Volume confirmation
  - Considering gravity data and remanence

Read more about it in our pre-liminary Geoscience BC report!

7 - Acknowledgements + References

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Mitchinson, D., Cutts, J., Fournier, D., Naylor, A., Dipple, G., Hart, C.J.R., Turvey, C., Rahimi, M., Milidragovic, D. (2020). The Carbon Mineralization Potential of Ultramafic Rocks in British Columbia: A Preliminary Assessment. Geoscience BC Report 2020-15/MDRU Publication 452, 25 p.