Carbon Mineralization in Ultramafic Tailings, Central British Columbia: A Prospect for Stabilizing Mine Waste and Reducing Greenhouse Gas Emissions

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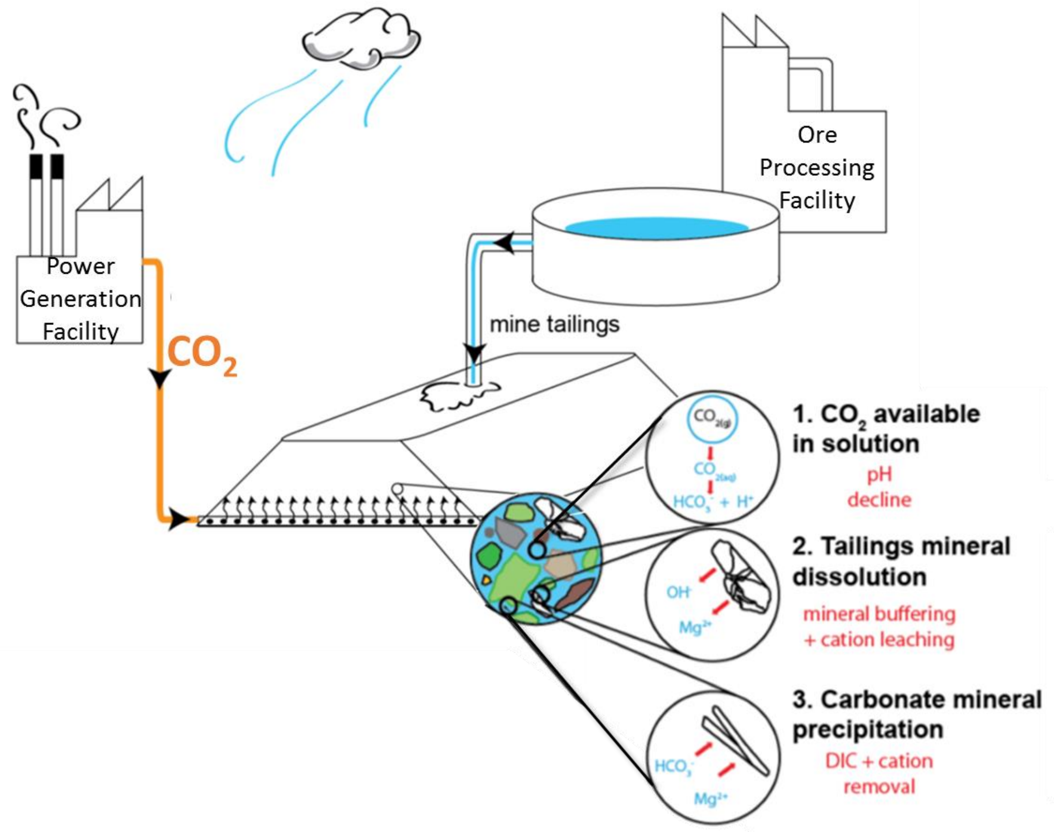
I. Abstract

The Baptiste nickel deposit, which is part of the Decar Mineral District in Central B.C., is a promising candidate for becoming the first greenhouse-gas neutral mine through *carbon mineralization*. This process sequesters carbon dioxide (CO_2) while providing the co-benefit of stabilizing the mine tailings through the precipitation of secondary magnesium-carbonate minerals ($MgCO_3 \cdot nH_2O$) that act as a cement of the tailings. The cement-forming reactions can be accelerated by targeting tailings that are naturally rich in highly reactive mineral sources of magnesium, such as brucite [$Mg(OH)_2$], and by exposing the tailings to a CO_2-rich gas, such as flue gas from onsite power generators. In this study we have developed a method to predict the variability and spatial distribution of brucite abundance within the Baptiste nickel deposit so that tailings from zones rich in brucite may be targeted for carbon mineralization. This is accomplished by projecting mineral abundance from ~10,000 assays of whole-rock elemental composition collected during the exploration drilling program. Our results suggest that the Baptiste nickel deposit has sufficient levels brucite to offset mine truck emissions and render the prospective mine greenhouse gas neutral given access to hydroelectricity for ore processing. After exposure to 10% CO_2 gas, we evaluated the stability of cemented Baptiste tailings through unconfined compressive strength measurements, strengths of up to 4,300 psi were observed, which is comparable to high-strength concrete. In combination with our map of brucite abundance throughout the nickel deposit, our suite of experiments that assessed compressive strength of cemented tailings vs. the initial brucite content suggest that 15-30% of Baptiste tailings may have potential to achieve stabilization through carbon mineralization. These results encourage the investigation of alternative and less costly tailings storage facility designs that exploit the stabilization produced by carbon mineralization.

II. Carbon mineralization at a mine site

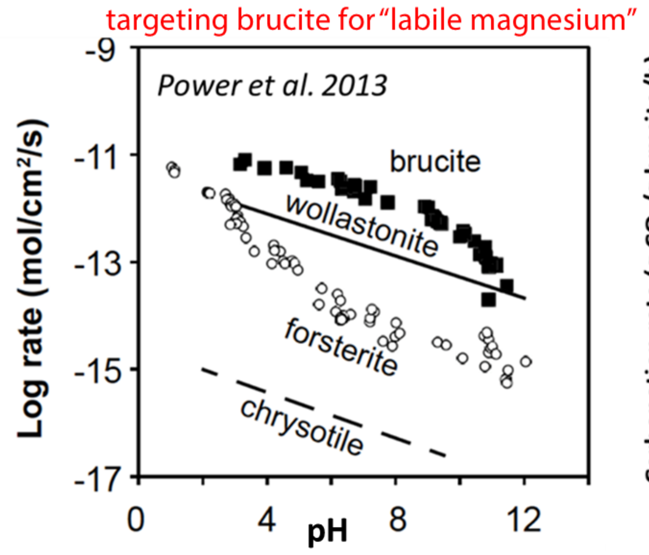


Brucite $Mg(OH)_2 + HCO_3^- + H^+ + H_2O \rightarrow MgCO_3 \cdot 3H_2O$

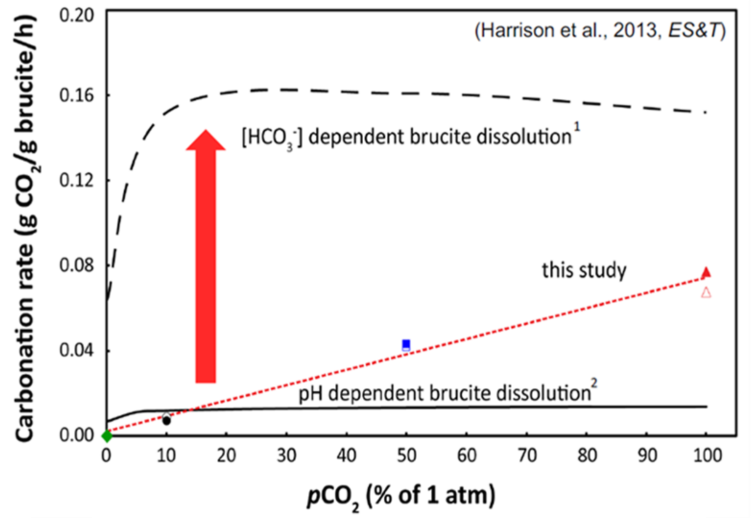
Serpentine $Mg_3Si_2O_5(OH)_4 + 3HCO_3^- + 3H^+ + 4H_2O \rightarrow 3(MgCO_3 \cdot 3H_2O) + 2SiO_2$

Stabilize tailings by forming carbonate cement through reaction with CO_2

III. Acceleration strategies



The pH-dependent dissolution rate of various minerals



The influence of CO_2 concentration on reaction rate

"Labile Magnesium" Easily leached from highly reactive minerals (brucite and hydrotalcite) and mineral surfaces. A cheap and fast source of Mg^{2+} for cementing tailings though the precipitation of secondary magnesium carbonate minerals.

Reaction rate often limited by CO_2 supply when labile magnesium is available

IV. Target highly reactive phases (brucite) through mineral abundance predictions

Identify characteristic minerals within the deposit by X-ray Diffraction. Use these mineral to explain the whole-rock geochemistry exploration data of other samples.

Rietveld X-ray Diffraction Results

Sample ID	(wt%) brucite	(wt%) magnetite	(wt%) olivine	(wt%) serpentine	(wt%) diopside
1423082	12.6	3.6	4.8	78.4	0.7
1423084	12.6	6.5	4.2	76.3	0.5
1423083	12.2	4.8	3.5	79.0	0.6
1423091	10.8	6.7	4.5	77.7	0.3
1423086	10.8	4.5	5.5	78.9	0.4
1423094	10.7	2.8	3.5	82.3	0.7
1423073	10.7	5.9	3.0	79.9	0.5
1423072	10.1	4.1	3.4	81.8	0.5
1423092	9.8	2.5	2.9	83.5	1.3
1423079	9.6	3.4	6.4	80.1	0.4
1423096	9.6	4.3	7.4	78.3	0.4
1423088	7.5	3.0	13.3	76.2	0.0
1423128	6.8	3.6	8.3	81.3	0.0
1423078	5.8	2.0	20.5	71.4	0.3
1423134	5.0	3.1	7.3	83.9	0.7
1423127	4.6	2.2	11.6	81.7	0.0
1423132	1.8	2.7	4.4	90.0	1.1
1423090	1.8	1.8	11.0	84.6	0.8
1423106	1.4	1.7	11.0	85.6	0.2
1423149	1.2	1.3	17.6	79.0	1.0
1423167	1.1	1.5	10.5	84.4	2.5
1423189	0.9	2.4	9.5	83.9	3.2
1423178	0.8	2.8	4.9	88.1	3.4
1423188	0.8	2.7	8.9	84.6	3.0
1423162	0.7	2.7	7.8	87.1	1.7
1423117	0.7	3.4	4.2	90.1	1.6
1423116	0.6	4.2	2.7	90.4	2.1
1423108	0.5	3.1	5.9	87.5	3.0
1423118	0.3	3.1	5.3	89.6	1.7
1423111	0.2	4.6	3.9	88.9	2.4

Exploration Data

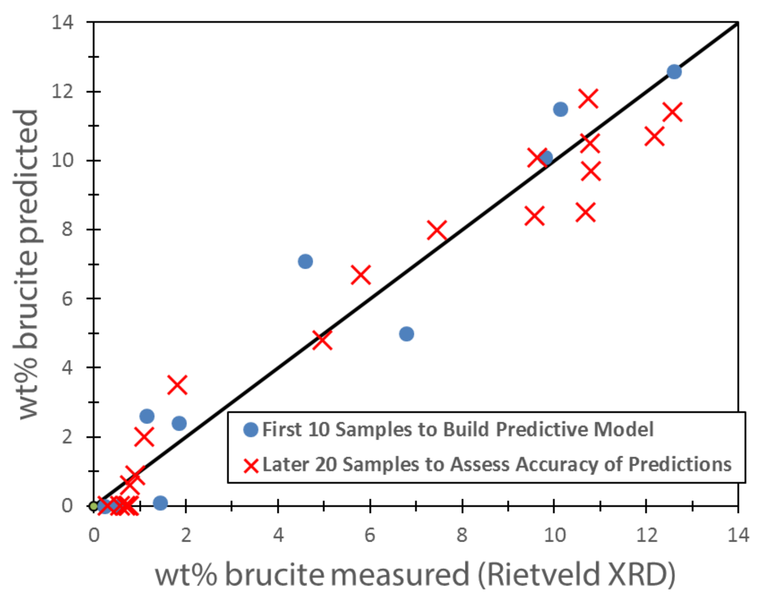
Wt%
MgO
SiO_2
Fe_2O_3
Al_2O_3
CaO
Loss on Ignition

10,000 Samples Assayed

Mineral Abundance Predictions

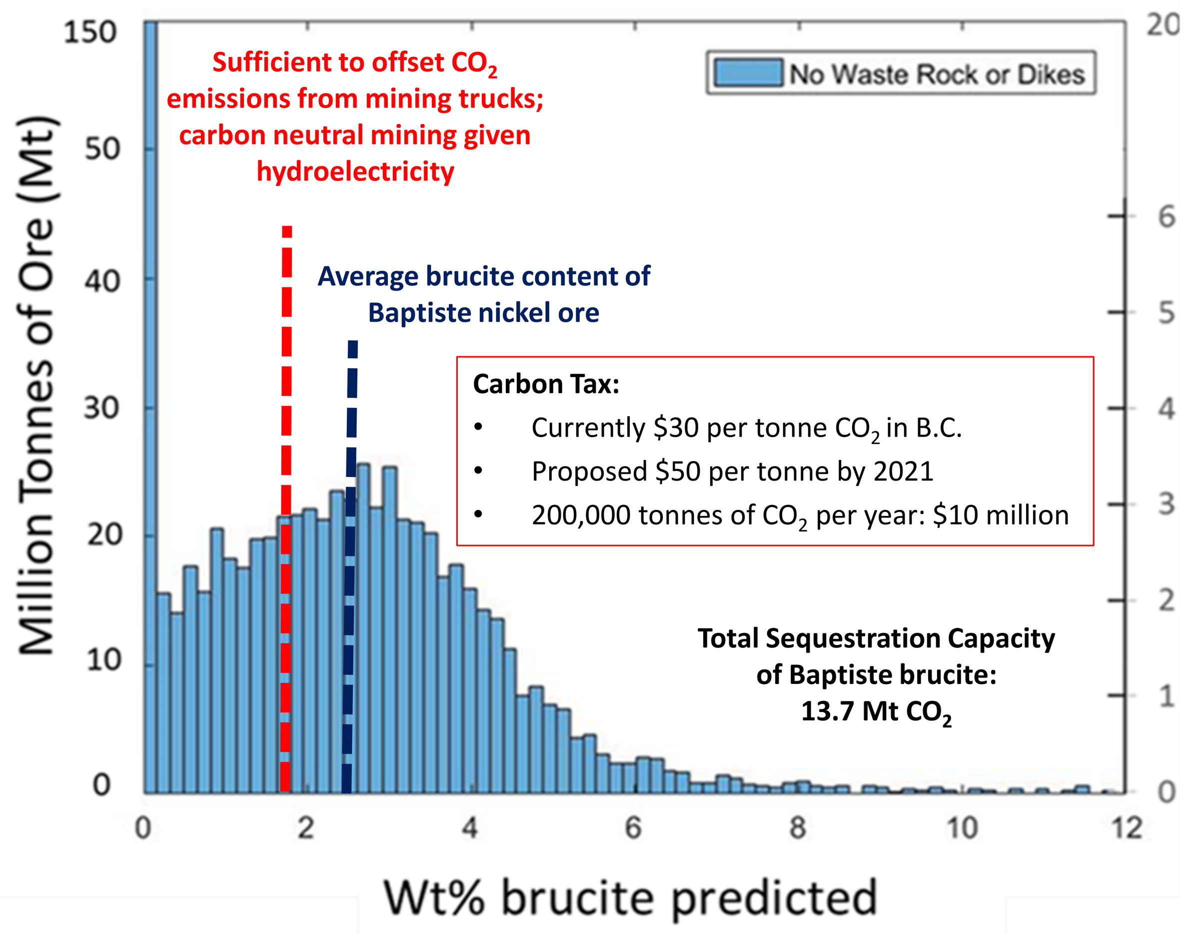
Wt%
$(Mg,Fe)(OH)_2$ [brucite]
$(Mg,Fe)_3(Si,Fe,Al)_2O_5(OH)_4$ [serpentine]
$(Mg,Fe)_2SiO_4$ [olivine]
$Ca(Mg,Fe)Si_2O_6$ [diopside]
Fe_3O_4 [magnetite]

10,000 Predictions



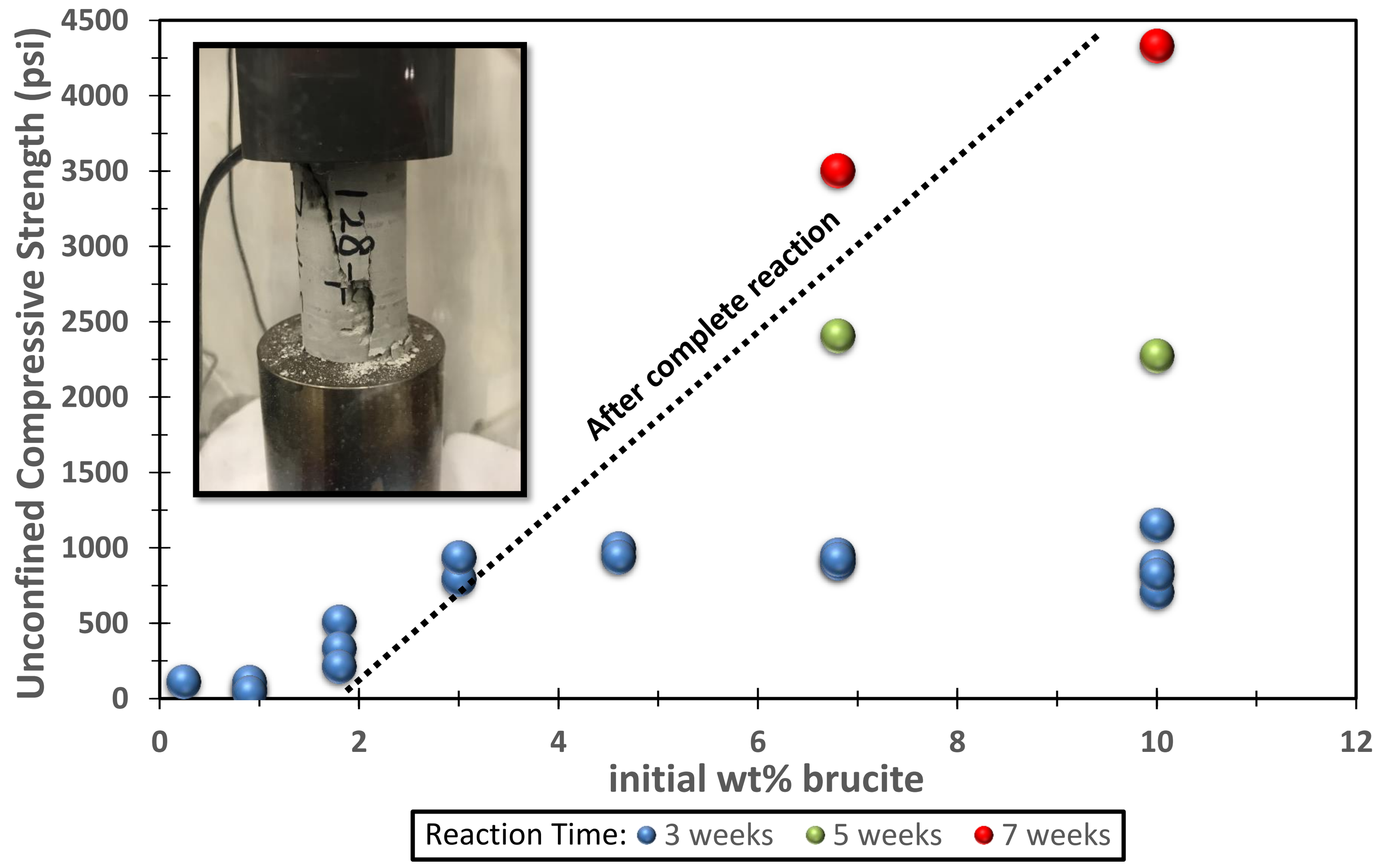
Convert whole-rock geochemistry data from exploration program into mineral abundance predictions through mass balance calculations

V. Assess potential for CO_2 Sequestration



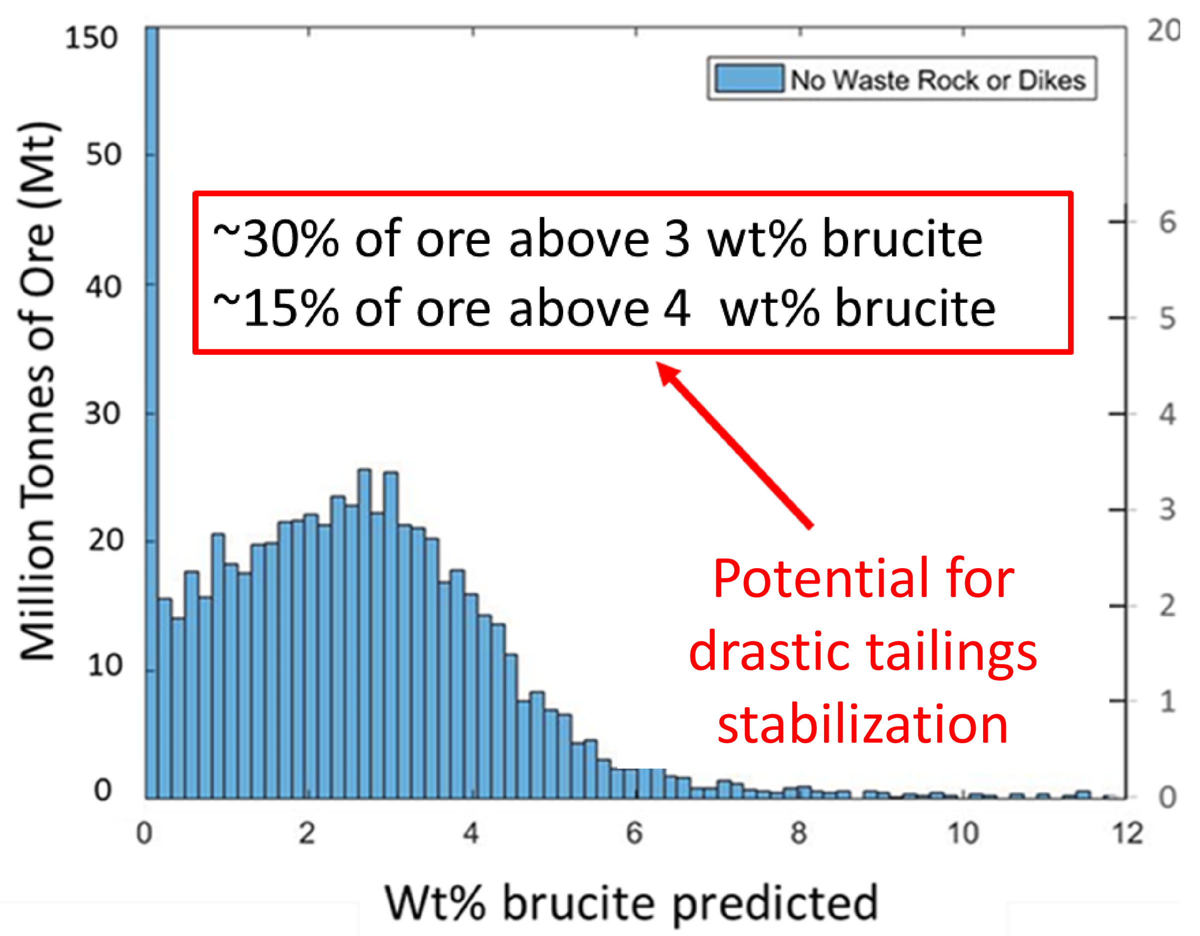
Histogram of the predicted wt% brucite throughout the Baptiste Nickel Deposit, extrapolated over the Decar Mineral District.

VI. Determine wt% brucite needed for tailings stabilization through carbon mineralization



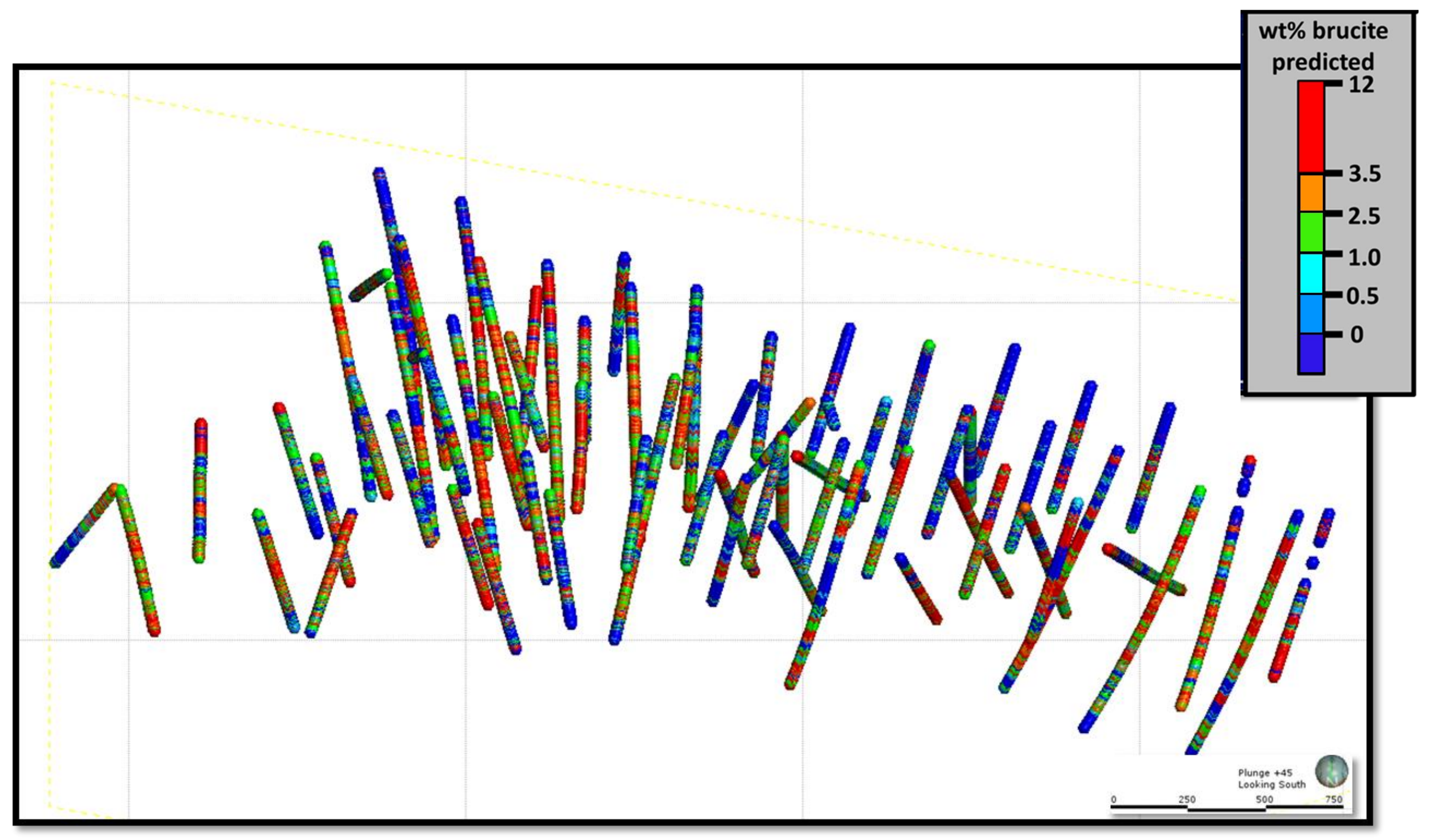
The unconfined compressive strength of Baptiste tailings after stabilization through carbon mineralization by exposure to a 10% CO_2 gas.

VII. Assess potential for tailings stabilization



Histogram of the predicted wt% brucite throughout the Baptiste Nickel Deposit, extrapolated over the Decar Mineral District.

VIII. Create a 3D map of predicted brucite abundance for use in mine waste management



The spatial distribution of the predicted brucite abundance throughout the Baptiste nickel deposit, part of the Decar Mineral District.

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FPX Nickel Corp. TSX-V:FPX

Geoscience BC

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