An assessment of the carbon sequestration potential of ultra-mafic nickel mine waste rock: Mineral characterization and preliminary findings

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INDTRODUCTION

New Boliden's Kevitsa mineral mine provides a unique opportunity to quantify the suitability of ultra-mafic mine waste rock for mineral carbonation of atmospheric carbon dioxide. Past studies such as Pronost et al., 2011, have identified the suitability of ultra mafic mining waste in storing CO_2 which indicates that Kevitsa may be an ideal candidate for long term passive and engineered carbon sequestration schemes. This study aims to identify the elemental and mineralogical suitability of the waste mine rock produced at Kevitsa in carbon mineralization while also providing new methods of assessing carbonation rates using experimental methods of laboratory analysis.

METHODOLOGY

MINERAL AND ELEMENTAL CHARACTERIZATION

In order to assess the suitability of the mine waste rock at Kevitsa for CO_2 sequestration both the mineral and elemental characteristics were investigated. 116 samples collected from the mines waste rock dumps were analyzed using a Rigaku NEX CG ED-XRF at Swansea University. 43 of the samples were also analyzed using conventional digestion methods and ICP-MS finish at a commercial lab to confirm the ED-XRF results. 10 samples of varying physical characteristics were sent for mineralogical testing to establish the main mineral phases. This was undertaken using Mineralogic, an automated mineral characterisation software based on a Zeiss SEM with integrated Bruker EDX detectors at Petrolab Ltd.

OXI-TOP PRESSURE REDUCTION TESTS

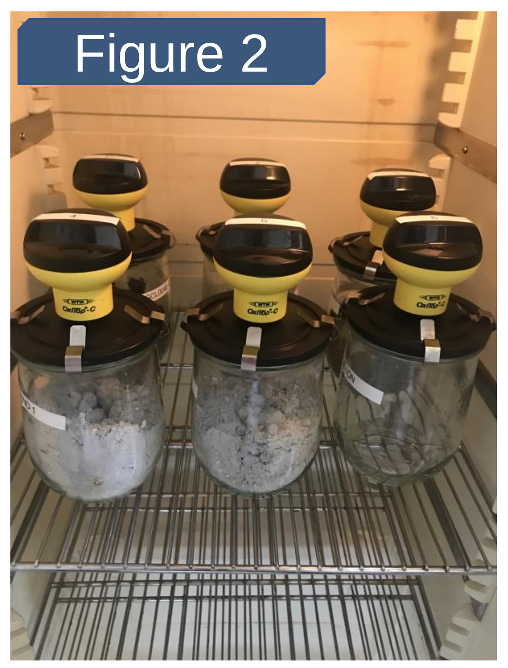
To assess carbon dioxide consumption WTW Oxi-Top vessels (Figure 2) were used in an adjusted method of assessing pressure reduction associated with CO_2 removal through mineral carbonation. Samples were purged with a pure CO_2 atmosphere within a glove box and sealed before being enclosed in a controlled temperature incubator at 25ºC. To emulate field conditions 10% moisture content was added to each dry sample. Pressure reduction was then measured over a 15 day period before being re-purged with CO_2.

ADDITIONAL EXPERIEMENTS

In addition to the Oxi-Top carbon dioxide consumption tests other laboratory tests have been implemented. A set of 6 columns containing 2 triplicates of a waste rock sample have been continuously purged with pure CO_2 or N_2 over a 2 month period to identify geochemical mineral phase changes. A set of 3 columns is being purged with CO_2 while an identical triplicate of columns is purged with N_2 for the same period of time.

Figure 1

Figure 2



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CHARACTERIZATION RESULTS

ELEMENTAL ANALYSIS - ICP-MS/ED-XRF

The average Mg content identified by ICP-MS and ED-XRF are shown in Figure 3. The average Mg concentrations were 12.4% and 13.4% respectively. Ca concentrations within the samples held averaged of 8.8% and 10.4% while S contents averaged closely at 5579.5 ppm and 5696.5 ppm.

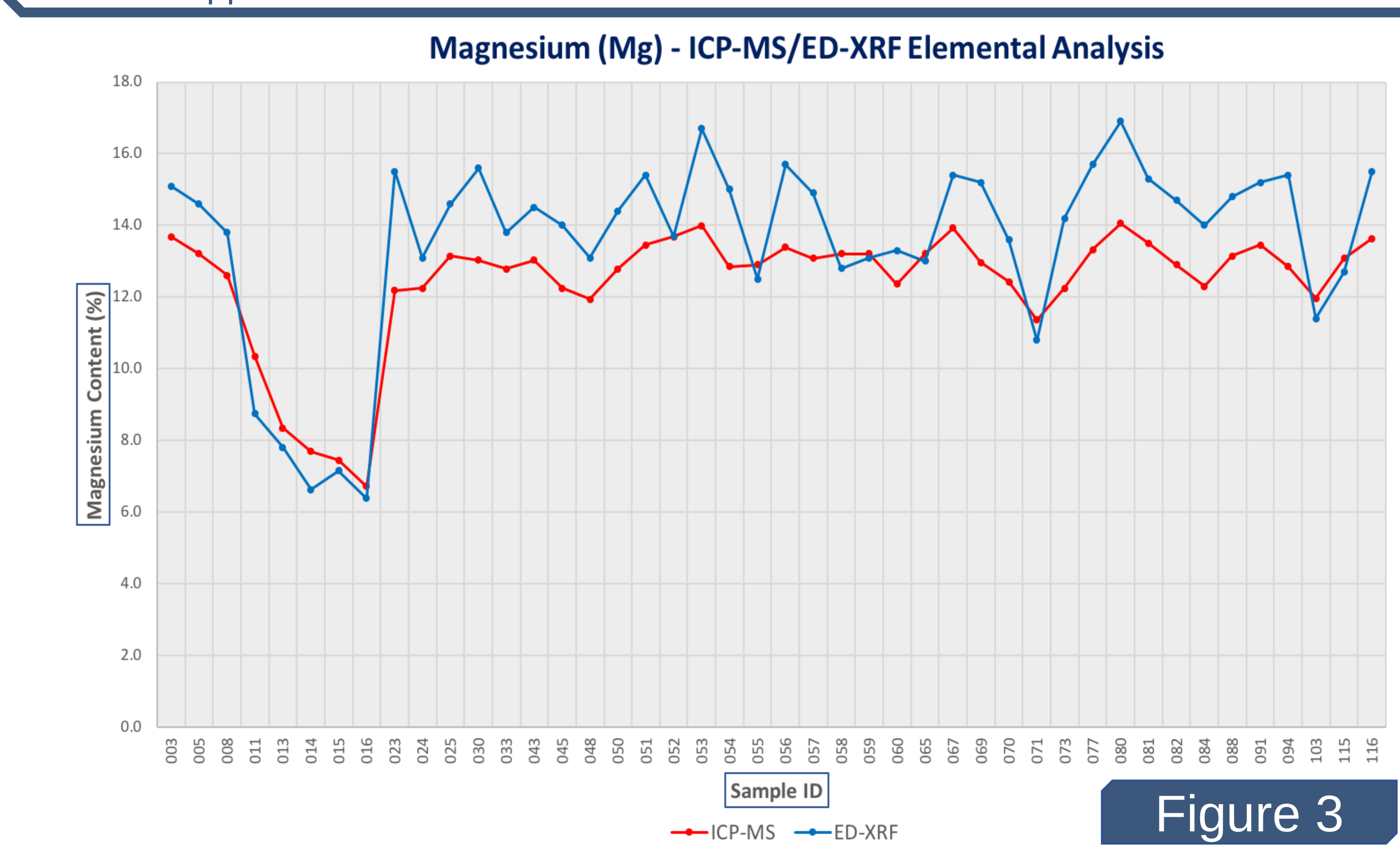

Figure 3

MINERALOGY ANALYSIS – SEM-EDX

The 10 samples sent for mineralogical determination were all found to be dominated by Pigeonite (Low-Ca Clinopyroxene) and Diopside (High-Ca clinopyroxene) with less significant mineral phases of Olivine, Iron Oxides, Amphibole, Orthopyroxene and chlorite (Figure 4). Magnesium rich clinopyroxenes and olivine assemblages have been found to be well suited in long term carbon capture due to rapid mineral dissolution rates and release of divalent cations. The average Pigeonite mineral weight within these samples was 27.27% while the average Olivine content was 6.43% with a maximum of 9.9%.

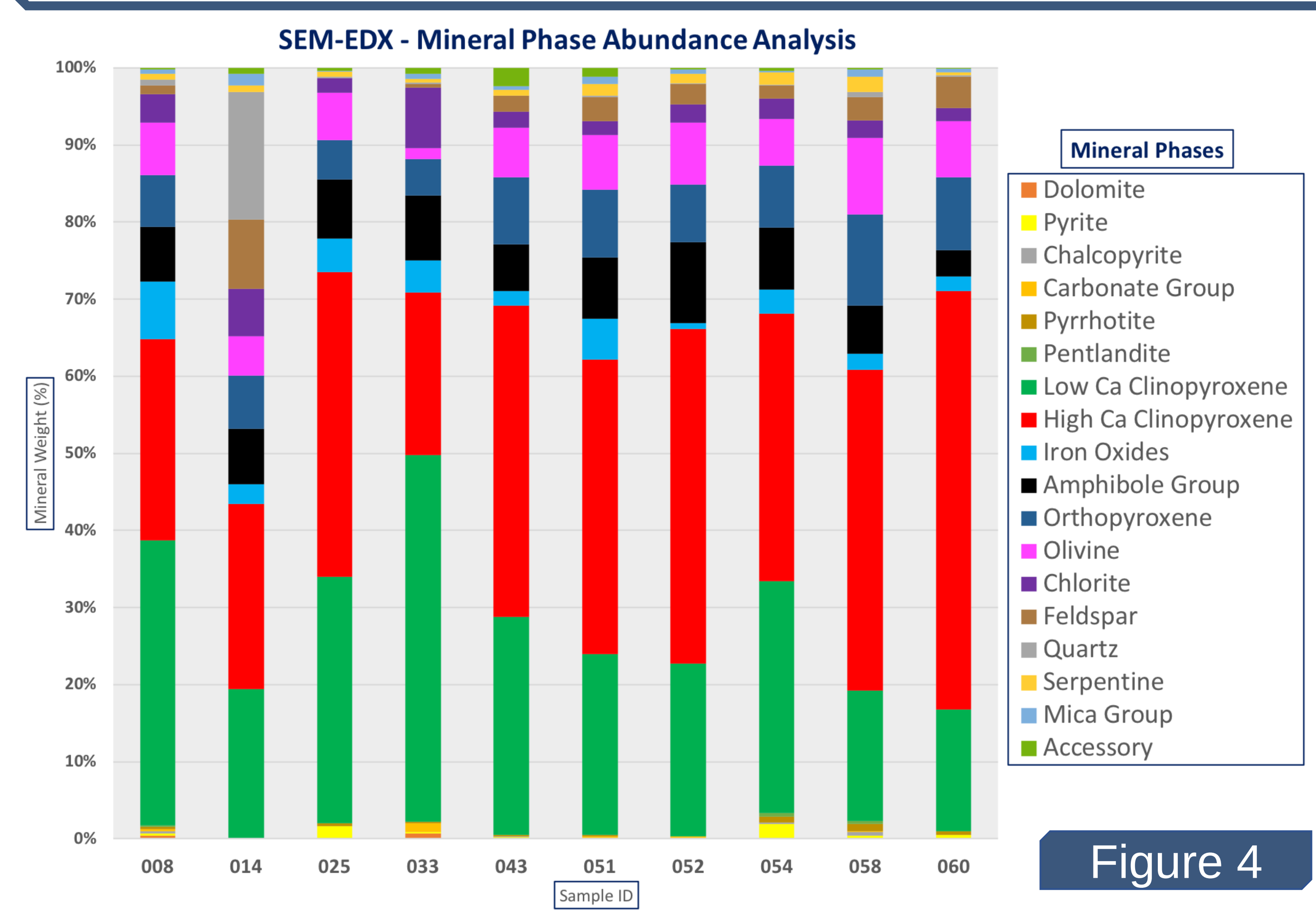

Figure 4

MAXIMUM CARBON CAPTURE POTENTIAL

Using the elemental characterization data collected through ED-XRF and ICP-MS analysis the maximum carbon capture potential rate could be assessed using the following equation, adjusted from the Steinour formula shown in in Gunning, Hills and Carey (2010).

$$\left(\frac{1000}{100}\right)\cdot\left(\frac{CaO}{M_{W\ (CaO)}}+\frac{MgO}{M_{W\ (MgO)}}+\frac{Na_2O}{M_{W\ (Na_2O)}}+\frac{K_2O}{M_{W\ (K_2O)}}-\frac{SO_4}{M_{W\ (SO_4)}}-\frac{P_2O_5}{M_{W\ (P_2O_5)}}\right)\cdot M_{W\ (CO_2)} = Corrected\ CCP\left(\frac{kg_{CO_2}}{tonne_{(Mine\ waste)}}\right)$$

$Where\ M_{W\ (Oxide)}\ is\ the\ molecular\ weight\ of the\ Oxide$

Adjusted Steinour CCP Formula

The use of this adjusted formula allows assessment of the maximum carbon capture potential of the waste mine rock based solely on elemental analysis. The mean CCP of the 43 samples that underwent ICP-MS and XRF analysis is 317.38 kg of CO_2 per tonne of mine waste rock.

PRELIMINARY LABROTORY RESULTS

WTW OXI-TOP CO_2 CONSUMPTION RESULTS

Pressure reduction within the Oxi-Top measuring cells were converted from units of pressure to a mass CO_2 consumption rate using the ideal gas equation. The results are shown in Figure 5. After 15 days the triplicate samples showed a consumption of between 0.8 and 0.9 kg of CO_2 per tonne of mine waste rock. Following the 15 days, samples were re-purged with CO_2 and have entered a second phase of testing

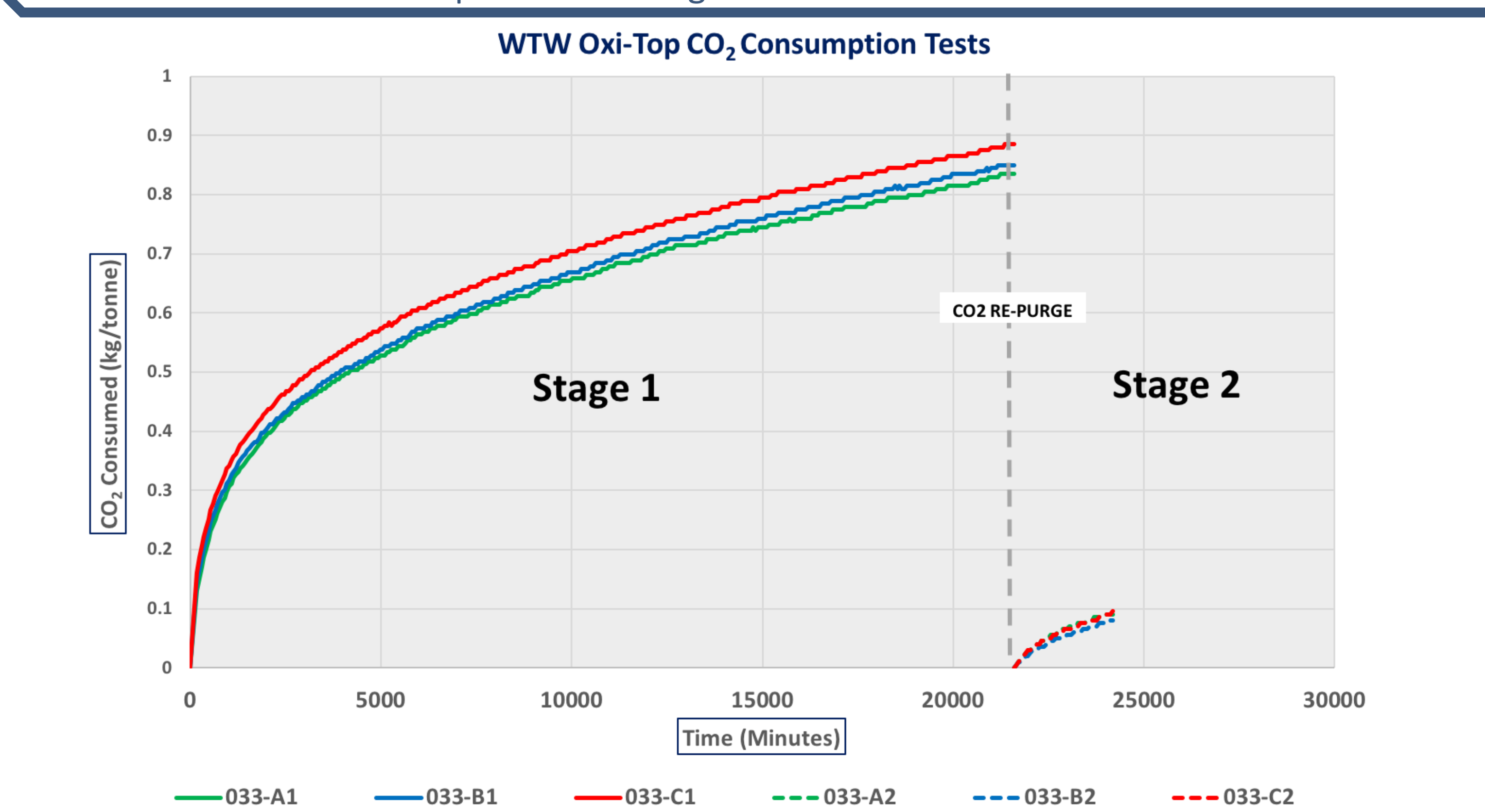

Figure 5

FURTHER RESEARCH POTENTIAL

The initial preliminary Oxi-top results presented in figure 5 do seem promising for the potential to sequestrate significant amounts of atmospheric CO_2 using the mine rock waste at Kevitsa. Studies into other magnesium rich mine wastes such as kimberlites suggest that offsetting mine carbon emissions is possible even within a sub-arctic climate (Mervine et al., 2018). Future tests could look to assess the impact of colder temperatures on the mine waste through emulating climate conditions to provide a field rate of carbonation as well as assessing surface area availability. Such tests would provide a quantifiable measure of the atmospheric carbon sequestration potential of such ultra-mafic mine waste material as well as provide a basis for assessing waste rock dump engineering design to promote maximum carbon capture potential.