

Assessment of Kazakhstan Ultramafic-Mafic Complexes for CO2 Sequestration:

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Abstract

In this work, the abilities of various minerals and complexes in **carbonization** of carbon dioxide were assessed. The work was of an exclusively **qualitative nature**, which allowed us to focus on qualitative changes and close our eyes to possible inaccuracies, such as the loss of certain masses. The main mineral tested in this study was the **ultramafic complexes**, which showed positive and satisfactory results in **X-Ray Diffraction(XRD)** analysis. (Presented in the **Results Section**). The main work was carried out on a **Batch reactor experiment**, the details of which are presented in the **Methodology Section**.

Introduction

Climate change and the Greenhouse, strongly affected by the considerable increase in the emissions of greenhouse gases like CO_2 , are undeniably the most concerning environmental problems of contemporary world. Such detrimental environmental changes come hand in hand with a general progress, especially in Asian region.

The Asian region is becoming increasingly important; in the previous 20 years, there has been a noticeable shift in the global economic dominance.According to Bhatti(2020), with an increase of a Asia's share in purchasing power parity in terms of World income (gross domestic product) has grown from 34.4% in 2000 to 48.4% in 2017, Asian CO_2 emissions from fuel combustion grew from 8.2 Gt to 17.9 Gt, a change of 119.3%, in the period of 2000-2017. The global tendency of an increase in CO_2 emissions remains the same, and failure to act on this issue will have large-scale negative effects on many important areas of human activity.

Recently, the Intergovernmental Panel on Climate Change (IPCC) and other authoritative sources have concluded that annual removal of more than ten gigatons (Gt) CO_2 from air (CDR, aka "negative emis- sions") will be required by mid-century to keep global warming below 1.5 to 2 °C (e.g., IPCC, 2014; IPCC, 2018; UNEP, 2018).

World is seeking for immediate actions and effective solutions. One of such ways to deal with the problem of high amount of emitted CO_2 is a carbon mineralization by utilising materials as Ultramafic-Mafic Complexes, in

which CO_2 in air and water react with Mg- and Ca-rich rocks (ultra- mafic rocks) and industrial wastes of similar composition to form solid carbonate minerals. This process occurs naturally during weathering of Mg- and/or Ca- rich, Al-poor materials (e.g., "ultramafic rocks" composed mainly of the minerals olivine, serpentine, brucite, and/or wollastonite, and/or industrial wastes with similar, ultramafic compositions). Engineered carbon mineralization is better known as a potential technology for storing CO_2 captured elsewhere. Storing CO_2 via reaction with common rocks and minerals has been considered for 30 years (Lackner et al., 1995; Seifritz, 1990).

In carbon mineralization, CO_2 reacts with minerals rich in Ca andMgg to form carbonates, such as calcite ($Ca(CO_3)$), magnesite ($MgCO_3$), and dolomite ($CaMg(CO_3)_2$), and a host of metastable, hydrated carbonate minerals: hydromagnesite ($Mg_5(CO_3)_4(OH)_2\,4\,H_2O$), nesquehonite ($Mg(HCO_3)(OH)\,2\,(H_2O)$), dypingite ($Mg_5(CO_3)_4(OH)_2\,5\,H_2O$), hydrotalcite ($Mg_6Al_2CO_3(OH)_{16}\,4\,H_2O$), and so on. Reaction of olivine and pyroxene with aqueous fluids at upper crustal pressures and tempera- tures less than 300 °C converts silicate minerals to brucite ($Mg(OH)_2$), serpentine ($Mg_3Si_2O_5(OH)_4$), talc ($Mg_3Si_4O_{12}(OH)_2$), and various other hydrous phases. In rocks with Mg/Si ¿ 1.5, excess Mg forms brucite ($Mg(OH)_2$). In turn, hydrous silicates and brucite can also react with CO_2 to form carbonates.

Some idealized reactions are as follows:

- **Wollastonite** $CaSiO_3 + CO_2 \longleftrightarrow CaCO_3$
- **Olivine** $Mg_2SiO_4 + 2\,CO_2 \longleftrightarrow 2\,MgCO_3 + SiO_2$
- **Pyrtoxenes** $CaMgSi_2O_6 + 2\,CO_2 \longleftrightarrow CaMg(CO_3)_2 + 2\,SiO_2$
- **Serpentine Polytypes** $Mg_3Si_2O_5(OH)_4 + 3\,CO_2 \longleftrightarrow 3\,MgCO_3 + 2\,SiO_2 + 2\,H_2O$
- **Brucite** $Mg(OH)_2 + CO_2 \longleftrightarrow MgCO_3 + H_{20}$

Mine tailings and some alkaline industrial wastes provide "low- hanging fruit" as rock reactants for CO2 removal from air (CDR) and storage via carbon mineralization. Tailings and some wastes have high surface area to volume ratios compared to subsurface geological for- mations, and are currently produced for other reasons, thus providing nearly "cost-free" feedstock for CDR. In such way, CO_2 carbonization is an effective and universal way to coap with both problems of production waste and CO_2 high level of emissions.

Methods

During the laboratory work, **Qualitative** methods have been followed. All practical part of the research have been done within the limits of safety precautions.

Rocks and minerals of different origins and compositions were collected from different parts of the world, including Kazakhstan, the United States and China. This approach to selecting minerals allows us to learn and compare their effectiveness for use in capturing gaseous CO_2. However, this research paper will discuss only results of the main mineral of **Ultramafic complex**. Ultramafic complex is an igneous rock with extremely low silica composition, being made of almost all olivine and pyroxene. Ultramafic rocks contain very low amount of silica and are common in the mantle. Primary ultramafic rocks are komatiite (extrusive) and peridotite (intrusive). Main part of the work is being conducted in the **experiment of batch reactor**, which requires minerals and rocks to be powdered to micro sizes. Thus, reactor, dispalyed in the Figure 1, becomes less susceptible for mechanical damages, and duration of the reaction is being shortened by increasing the surface area of the mineral.



Figure 1: Reactor

Reactions between minerals and CO_2 are conducted in the **deionized water** under **super-critical** conditions(CO_2 is between the gaseous and liquid states), which is reached by a special heating equipment shown in the

Figure 2. Approximate temperature and pressure used in the reactions are 100 °C and 120 psi, respectively. The duration of the reaction depends on factors such as the reactivity of the ions in the mineral and can range from **1 to 50 days**.



Figure 2: Heating Equipment

During the batch reactor experiment, a gradual change in the colour in the **"Reactor Window"**, which indicates the change in pH of the solution within the reactor, is clearly visible to an observer.(Colours and their pH equivalents are shown in the Figure 3). Thus, the **release of cations** and the possible decrease of cations due to the fact of carbonization process ignition.

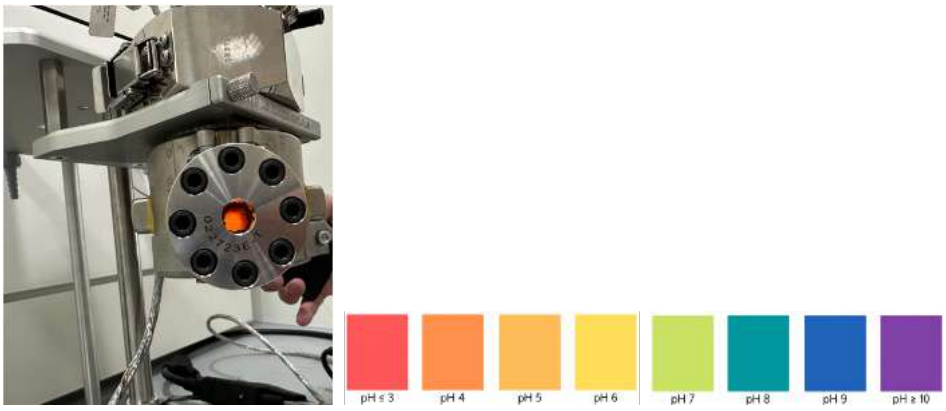


Figure 3: "Reactor window" on the left; pH equivalents on centre and right

To analyze the change in the composition of deionized water and check for traces of CO2 carbonation, after the preliminary experiment, samples are taken from the post-experimental water and the resulting sediment (shown in Figure 4). To perform the analysis, **X-Ray Diffraction(XRD)** method has been utilised. This method is as specifically effective due to its possibility to show compositions of different complex minerals and molecules. The process of XRD analysis is shown in the Figure 5

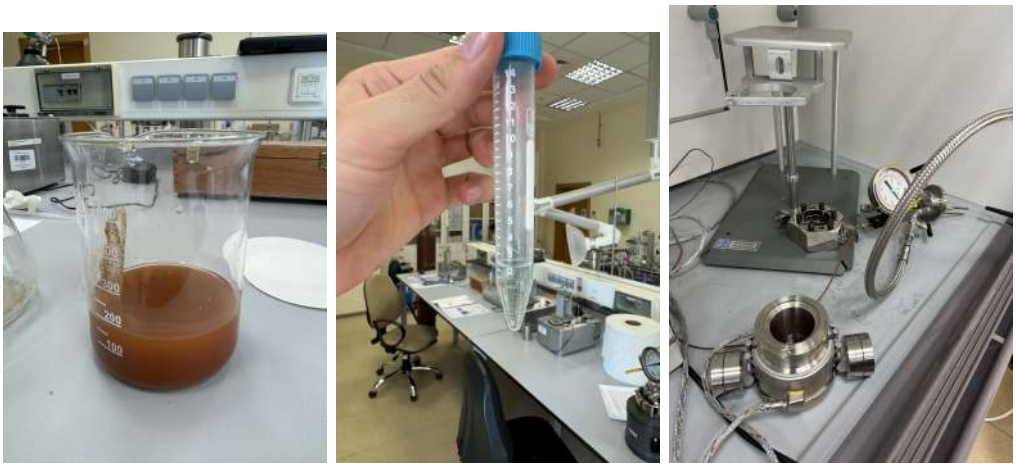


Figure 4: Getting the samples



Figure 5: XRD analysis process

For this, basic sediment filtration methods are used using chemical glassware and filter paper (shown in Figure 6). These samples undergo a drying process in an oven and qualitative analysis.

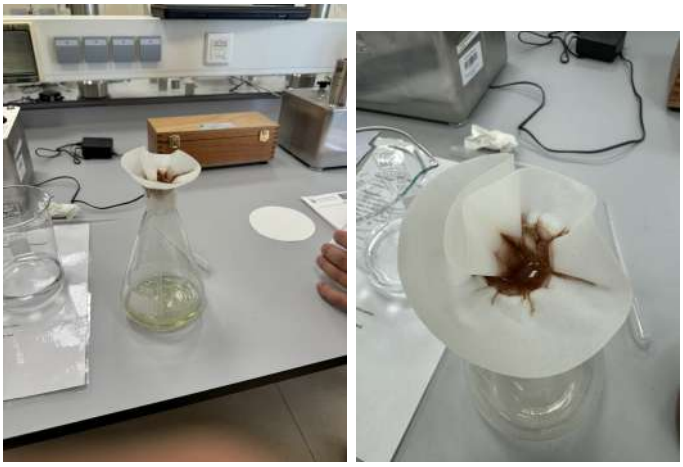


Figure 6: Filtering Process

For the note, it is worth noting that the work has only qualitative significance, which allows us to close our eyes to minor losses in mass of samples and etc.

Results

In general, speaking about the results of the work, they can be confidently assessed as positive and satisfactory.

As was said in the methodology section, the complexes were analyzed before and after the batch reactor experiment. The comparison of these analyses is presented in Figure 7.

Figure 7: Confidential

According to the graph in Figure 7, obtained as a result of XRD, one can notice strong jumps in the red curve compared to the blue curve. The **red curve** implies the analyzes of the sample AFTER THE BATCH REACTOR EXPERIMENT, while the **blue curve** implies the analyzes of the sample BEFORE THE REACTOR EXPERIMENT. Comparing the two curves, the red curve has higher peaks than the blue one. This is a direct proof of the presence of carbonization during the **batch reactor experiment**. Thus, these indicators allow us to understand the high efficiency of the ultramafic complexes in CO_2 carbonization process

Conclusion

In conclusion, It is worth noting the fact of high efficiency of minerals, especially ultramafic complexes, in carbonization of carbon dioxide. Kazakhstan's potential in the development of this sphere is very high. Geochemical simulation and batch reactor experiment confirm the great potential for ultramafic massifs in Kazakhstan as fast sequestration sites for CO2. Given the 70% lizardite (the least reactive) content of peridotite massifs in Western Kazakhstan. 829 m tons of lizardite will suffice for complete carbonation of Kazakhstan's annual CO2 emissions. Considering the volume of peridotite massifs in Western Kazakhstan alone, they have the capacity to sequester the total yearly CO2 emissions in Kazakhstan for at least 15 years.

However, there are still some possible improvement that may be considered in the future studies on this topic:

- The impact of the experimental conditions (T, P, ionic strength) on the reaction rate should be identified. The experiment should be conducted with a template of conditions to assist in optimization and determination of reaction kinetic and thermodynamic parameters useful in modeling large scale and dynamic scenarios.

- The impact of particle size on the carbonation process and CO2 conversion rate should be evaluated experimentally, especially as we approach the nanoparticle regime to document any super-reactivity.

- The batch experiment was conducted on whole rock sample containing a mixture of minerals. Experiments should be conducted on isolated mineral phases in order to determine the optimum conditions for CO2 mineralization and possible role of minerals processing to accelerate CO2 conversion.

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