CO_2 storage through mineral carbonation

Fostering ICT collaboration in innovative technologies

Jorge Pedro

Geosciences Department, University of Évora, Portugal
Institute of Earth Sciences (ICT)

Instituto de Ciências da Terra
Institute of Earth Sciences

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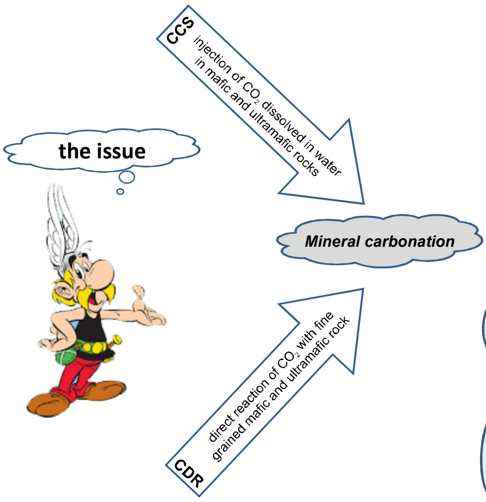
1. Mineral carbonation



- **Carbon, Capture and Storage (CCS)** is a technology in which captured CO_2 is dissolved in water and injected into mafic and ultramafic rocks (***in situ*** process), or when mafic and ultramafic rocks are mined and the mineral carbonation takes place in plants under optimized pressure and temperature conditions ***(ex situ*** process).
- **Carbon, Dioxide Removal (CDR)** is a technology in which fine-grained mafic and ultramafic rocks deliver "negative emissions", through **enhanced weathering** by the removing and sequestering CO_2 directly from the atmosphere and oceans.
- ***Mineral carbonation*** allows for both CCS and CDR technologies and corresponds to a set of geochemical reactions related with the exposure of mafic and ultramafic rocks to the CO_2, allowing for permanent carbon storage in solid phase. The silicate minerals react with CO_2 and precipitate carbonate minerals like calcite ($CaCO_3$), dolomite ($CaMg(CO_3)_2$), magnesite ($MgCO_3$) and siderite ($FeCO_3$), leading to the trapping of the CO_2 at a much faster rate than can be expected in sedimentary silicate rocks, and provide an alternative to the conventional CO_2 storage in subsurface sedimentary formations.

Main reactions in mineral carbonation

CO_2 solubility

$CO_{2\,(aq)} + H_2O = H_2CO_3 = H^+ + HCO_3^-$

Silicate solubility

$(Mg,Fe)_2SiO_4 + 4H^+ = 2(Mg2^+ + Fe2^+) + SiO_{2\,(aq)} + 2H_2O$

$CaAl_2Si_2O_8 + 8H^+ = Ca2^+ + 2Al^{3+} + 2SiO_{2(aq)} + 4H_2O$

$CaMgSi_2O_6 + 4H^+ = Ca^{2+} + Mg^{2+} + 2SiO_{2(aq)} + 2H_2O$

Carbonate precipitation

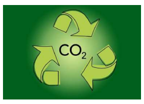
$Mg^{2+} + HCO_3^- = MgCO_3 + H^+$

$Fe2^+ + HCO_3^- = FeCO_3 + H^+$

$Ca2^+ + HCO3^- = CaCO_3 + H^+$

$Mg^{2+} + Ca^{2+} + 2HCO_3^- = (Ca,Mg)CO_3 + 2H^+$

2. ICT strategy



Mineral carbonation is a Research Theme (RT) align with the Scientific Challenge (SC) "***Georesources for circular economy and energy transition***", of the ICT strategy for 2025-2029 period.

Mineral carbonation aims to assess CO_2 emissions-reduction, to remove greenhouse gasses from the atmosphere or ocean and is aligned with the European and National policies, strategies and goals, specifically the European Green Deal and the Net-Zero Industry Act, which establishes a prosperous and carbon-neutral Europe for 2050, and the national Roadmap for Carbon Neutrality 2050.

The goals of mineral carbonation are transversal to the other ICT Scientific Challenges, requires cooperation and **encouraging collaborative work** within the ICT community.

3. Skills

The screening, ranking and characterization of mafic and ultramafic rocks requires preliminary geological and geophysical field work.

The main research issues in mineral carbonation are in petrography and geochemistry, to characterize samples before and after CO_2 exposure, and modelling to simulate volumes of carbon sequestration for long periods of time.

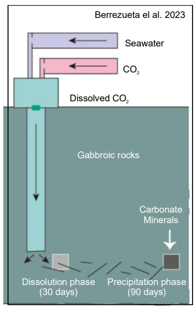
This is achieved by laboratory multi-analytical approaches and numerical studies with PHREEQC or CMG-GEMS codes.

Analytical methods used in mineral carbonation characterization

4. Know-how

InCarbon

ICT researchers have experience in mineral carbonation (Abdoulghafour et al. 2021; Berrezueta et al. 2023; Carneiro et al. 2019, 2022; Marques et al. 2022; Moita et al. 2020, 2022; Pedro et al. 2020), through the **InCarbon – *In situ Carbonation for reduction of CO_2 emissions from energy and industrial sources in Alentejo –*** project, funded by FCT (PTDC/CTA-GEO/31853/2017).

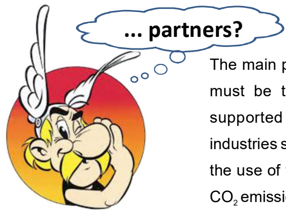


Replication of CO_2 injection/ mineralization at 800m depth

During the InCarbon project the research team developed an experimental procedure replicating real conditions of CO_2 injection and mineralization at 800m depth, by submitting gabbroic rocks to supercritical CO_2-rich brine (seawater), inside an autoclave (80bar and 40°C).

After 120 days of experiment to supercritical CO_2-rich brine, the gabbro samples were analysed with X-ray diffraction scanning area, to visualise the occurrence of salt deposition and mineral carbonation with the precipitation of dolomite crystals.

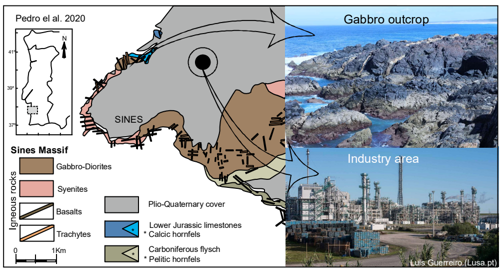
5. Opportunity



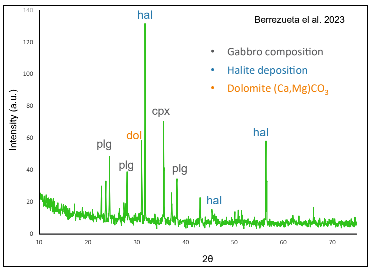
The main path for a carbon-neutral society must be the renewable energy sources supported by energy storage. In some industries such conditions may not exist and the use of fossil fuels, with the consequent CO_2 emissions are inevitable.

The implementation of CO_2 geological storage technologies is crucial to decarbonize the industry. Recently ICT researchers of "***Georesources for circular economy and energy transition***" and "***Earth Dynamics, life-support systems, and global changes***" Scientific Challenges submitted to the FCT the **MadeDecarb - *Mineral carbonation to reduce CO_2 emissions and decarbonize the Madeira Island* -** project, that aims to present solutions to reduce CO_2 emissions and promote the decarbonization of the energy system of Madeira Island, by assessing the potential of CO_2 sequestration through mineral carbonation in basalts.

Despite the progress in recent years, mineral carbonation and other CDR techniques, such as enhanced weathering, remain challenging but promising technologies. Field work, laboratory, numerical studies, and high screening data analysis are required to address these issues and are an opportunity for interaction among ICT researchers and students.



InCarbon field work area



Diffractogram on the surface of the gabbro

6. References

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