Sustainable Mining – To Integrate Critical Element Recovery and CO_2 Mineralization using Mining Waste

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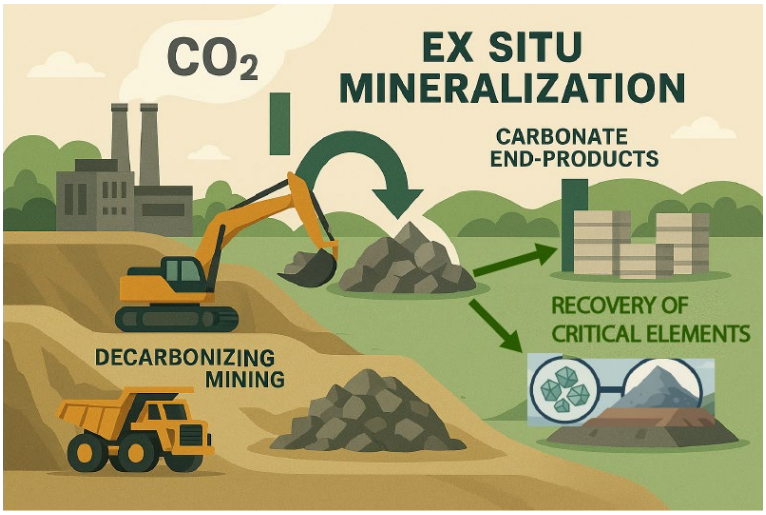
The mining of critical elements (CEs), e.g. lithium (Li), cobalt (Co), nickel (Ni), and rare earth elements (REEs), is paramount for the development of advanced renewable energy generation and storage systems. CEs are usually found in ores located only in a few areas around the world and extracted through inefficient and environmentally unsustainable processes. Moreover, their current supply will not be able to meet future demand. In addition, Europe is heavily dependent on imports from third countries for CEs and should develop its mining industry sustainably. Therefore, CEs mining with innovative and green solutions from alternative and more widespread resources is envisaged.

Potential alternative resources are mining waste such as mine tailings and gangue minerals, and brines. Mining waste holds a legacy of earlier mining activities with recognized negative impact on the environment and at the same time they are often naturally enriched in CEs. They provide geographically distributed potential resources for CEs within Italy and worldwide. Some mining wastes do not only contain CEs but also high concentrations of alkaline Earth elements such as calcium (Ca) and magnesium (Mg), which can react with carbon dioxide (CO_2) through the CO_2 mineralization process fixing CO_2 into stable carbonate minerals. The composition of these alternative resources opens the unique opportunity to combine CMs recovery with CO_2 mineralization making mining a sustainable and carbon neutral operation.



In this project, the Ph.D. student will work on the development of a new process that integrates CEs recovery with CO_2 mineralization using tailings. The mine waste will be provided by the industrial partner Minerali Industriali S.r.l. which has access to several mining sites in Italy and abroad. The integrated process comprises enhanced mineral dissolution/leaching followed by a CEs selective separation unit based on either electro-membrane extraction, ion-sieve membrane, or even a combination of them, and carbonate precipitation for CO_2 removal and residues stabilization. Organic acids (e.g., citric acid, oxalic acid, acetic acid, and formic acid) as bacteria by-products will be considered to enhance dissolution/leaching at circumneutral pH and low temperature. Seeded carbonate precipitation will be carried out with the residues from dissolution/leaching enhancing the CO_2 mineralization step while stabilizing residual mining waste. The carbonated product will be tested for re-use as a construction material. A model of the entire process will be developed and validated with experiments performed in the lab using a set-up fully monitored with in-line and on-line sensors.

In the three-year research period, the specific tasks to be conducted include laboratory experiments of extraction and recovery and process modeling. In particular, tests of of dissolution/leaching, carbonate precipitation, and recovery will be carried out. The experimental data will be used to validate a model for process simulation and control and scale-up. Moreover, the Ph.D. student will have the opportunity to spend time at the end of the second year of the Ph.D. program abroad in a research institution.

The PI's laboratory is in the Department of Geosciences and is equipped with set-ups and computational tools for the proposed activities (https://www.geoscienze.unipd.it/en/valentina-prigiobbe).
Interested candidates can contact the PI directly by email: valentina.prigiobbe@unipd.it.

Broader Impact
In the effort to mitigate CO_2 emissions during the transition to renewable energy systems, one of the most promising pathways for CO_2 sequestration includes decarbonizing the mining industry while recovering critical elements, producing marketable carbonated end-products, and improving tailings management. Integrating these strategies could make mining, as well as other hard-to-abate industries, more sustainable in the coming decades. This research will result in a framework for this integrated approach, facilitating custom design of the extraction of CEs together with CO_2 removal.

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