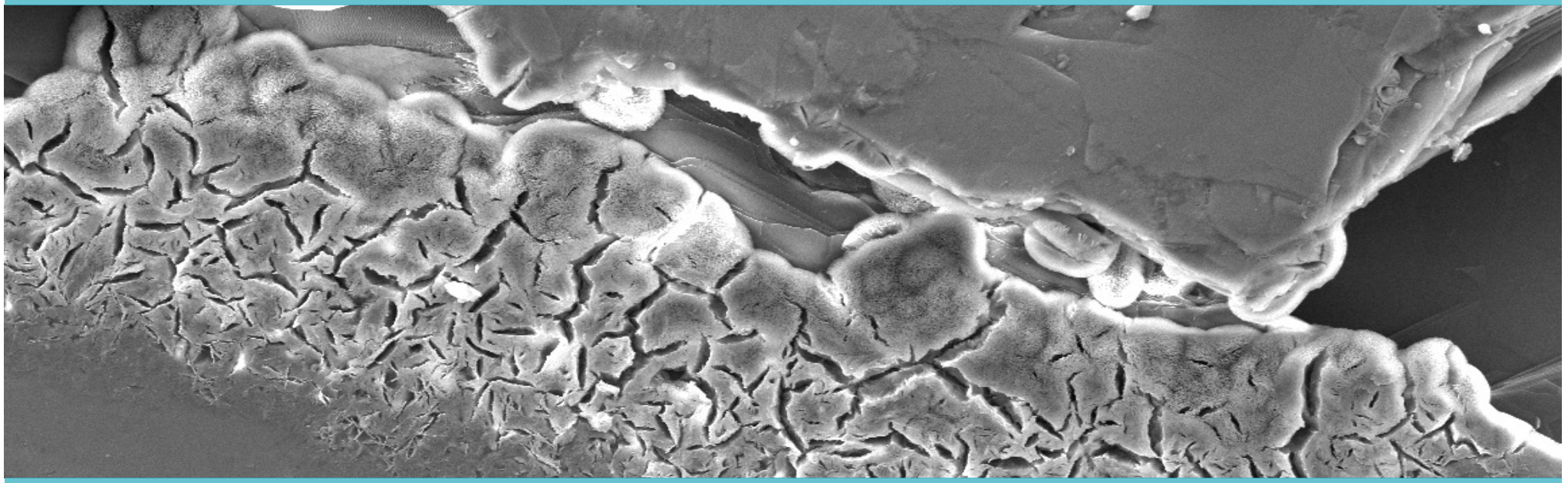
CarboStoreUltra: Efficiency of CO_2 storage by ex situ mineralization with Swiss rocks



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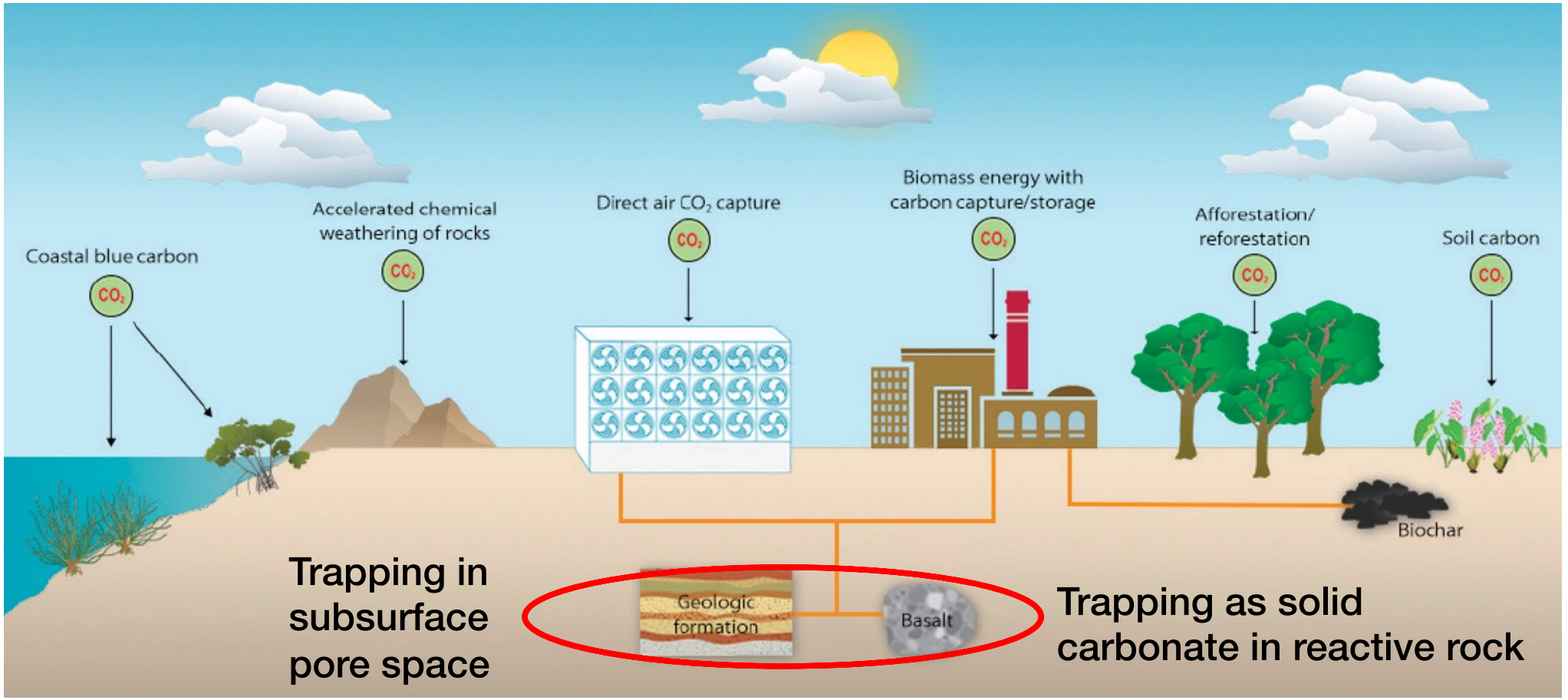
Captured CO_2 must be stored

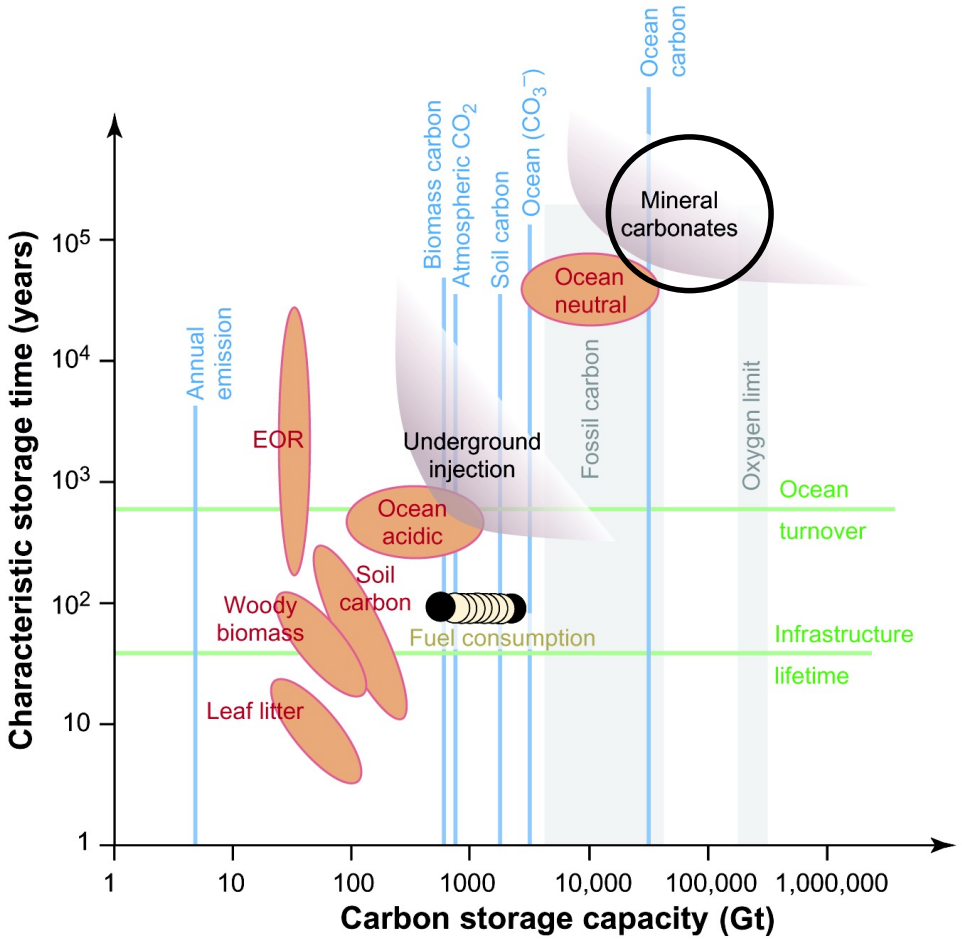


- CO_2 storage in Switzerland's porous geological formations (Chevalier et al., 2010) is still not quantified; needs 5–10 yr and high exploration investment

- What about by carbonation of chemically reactive rocks?

(National Academies of Sciences, Engineering, and Medicine (NASEM), 2019)

Advantages of mineral carbonation



Mineral carbonation offers advantages:

- stable over millennia
- very large capacity
- geologic setting differs from "conventional" Carbon capture and storage (CCS) so there may be opportunities in regions without appropriate sandstone reservoirs

A major drawback?

- Reaction rates are slow

Lackner (2003) Science

Promising rocks identified

Previous project (CarboStore) screened geological formations available in Switzerland that could potentially be suitable for mineral carbonation

Project partners:
Geotest + UniBe

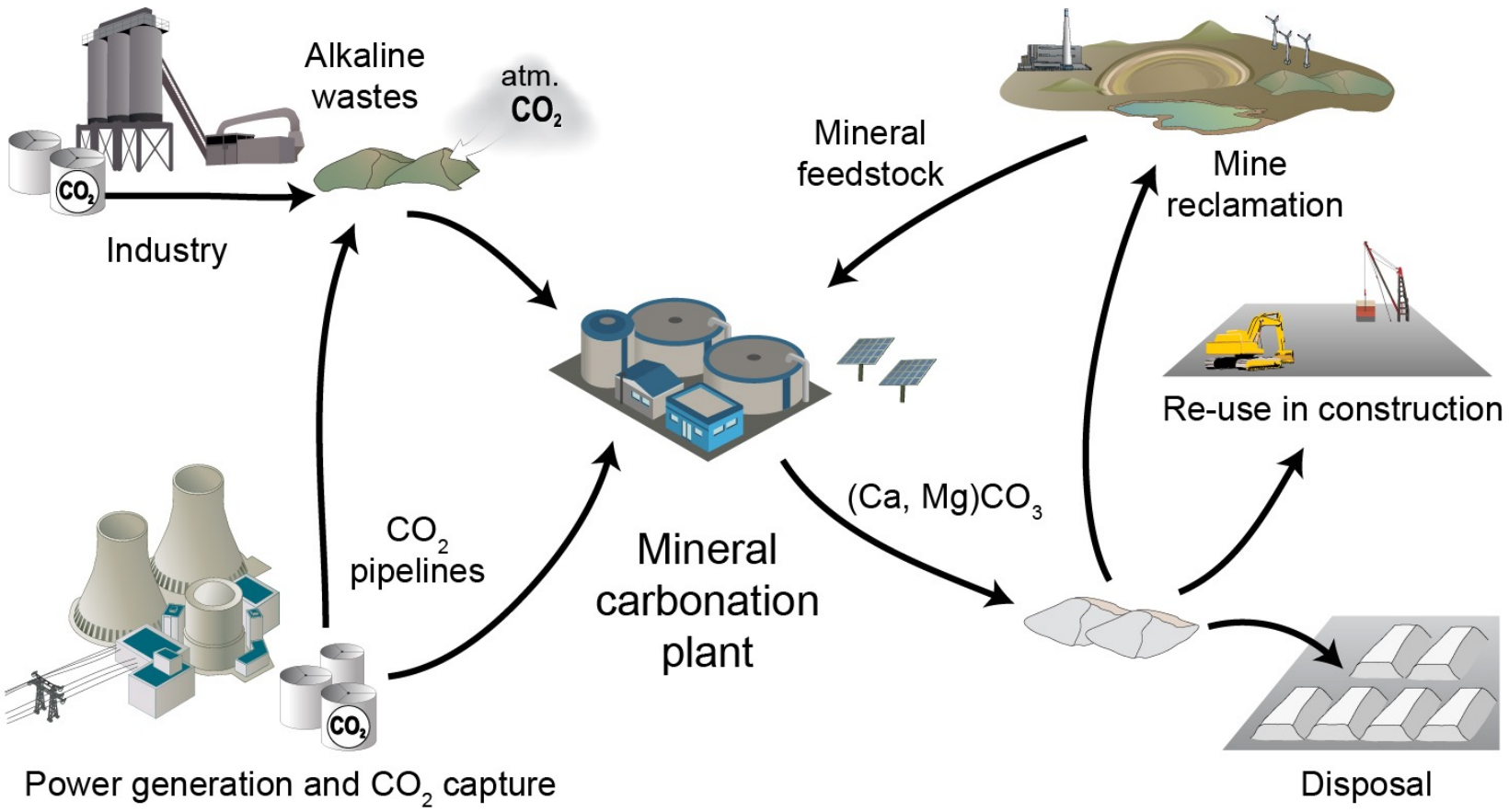
Funding:
BFE + VBSA

Take-home messages:

- **Rocks suitable to bind CO_2 through mineral carbonation are present in Switzerland**
- **Due to low porosity and permeability they are unlikely suitable for in situ carbonation**
- **The suitability of these materials for ex situ carbonation should be investigated**

Ladner et al (2023)

Ex situ carbonation



Power et al (2013)

Target rocks for CarboStoreUltra

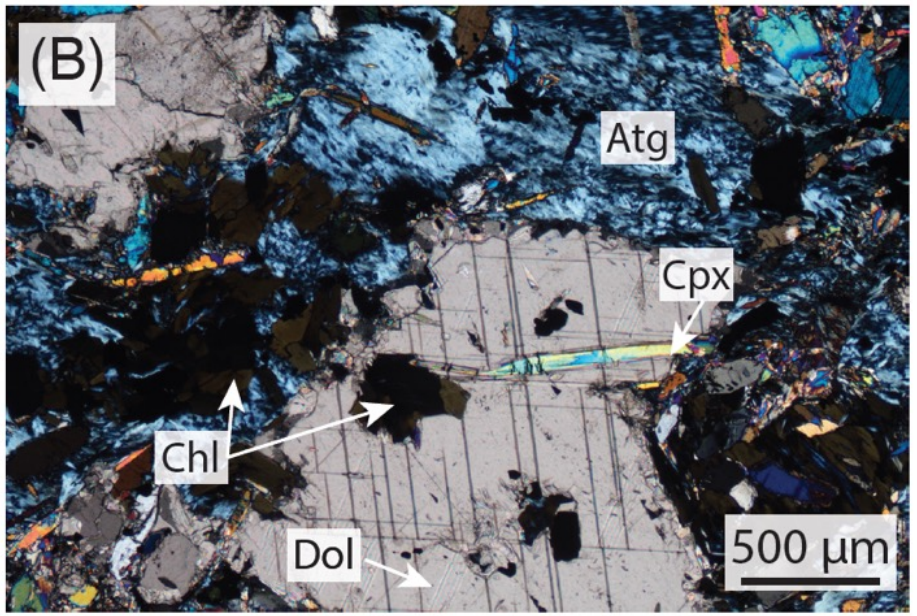
The most promising rocks in Switzerland for *ex situ* carbonation are Mg-rich rocks termed “ultramafic” by geologists (hence “Ultra” in our project name)

Ultramafic rocks relevant to our study:

Rock types	Peridotite (Earth’s mantle)	Serpentinite (hydrated peridotite)
Constituent minerals	Olivine (Mg_2SiO_4) + Enstatite + Diopside + Spinel	Lizardite [$Mg_3Si_2O_5(OH)_4$] (low *T*) or Chrysotile [$Mg_3Si_2O_5(OH)_4$] or Antigorite [$Mg_3Si_2O_5(OH)_4$] (high *T*) + Magnetite
Theoretical capacity	0.63 t CO_2/t olivine	0.48 t CO_2/t serpentine

Real rocks are not pure!

- Mineralogical and chemical compositions deviate from ideal
- What is the realistic achievable CO_2 storage capacity given the complexity of natural rocks?
- Material-specific properties will determine suitability, capacity, and efficiency
  - Remains to be determined for Switzerland

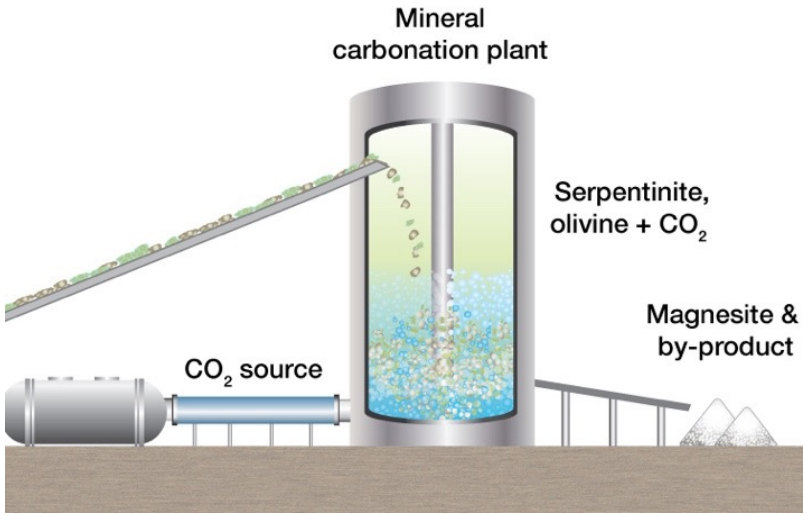


Piccoli et al. *(in review)*

CarboStoreUltra

Objective:

Determine whether ex situ carbonation of rocks available in Switzerland (e.g. as powdered feedstock) could be a viable part of the Swiss Climate Strategy based on current knowledge of mineralization reactions.

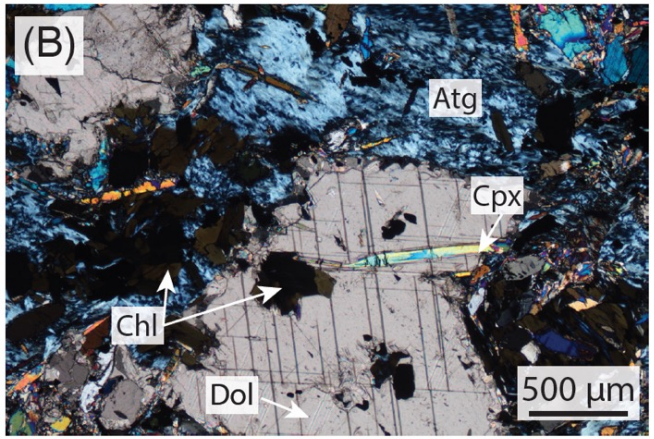


CarboStoreUltra

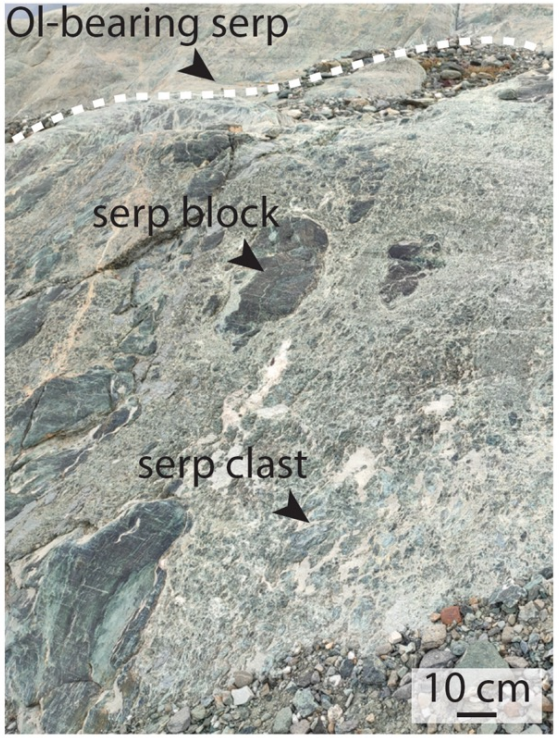
Task 1:

Characterize the properties of the rocks identified as the most promising in Switzerland for ex situ carbonation.

Lab based characterization



Field based characterization



Zermatt Serpentinite

Piccoli et al. *(in review)*

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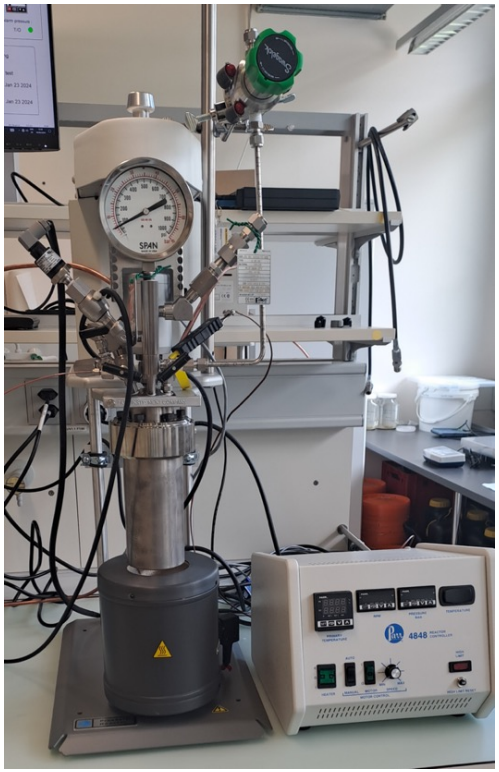
Task 2:

Determine by laboratory experiments the rate and capacity of CO_2 storage by ex situ carbonation at process conditions relevant to local industrial CO_2 emitters.

Serpentine

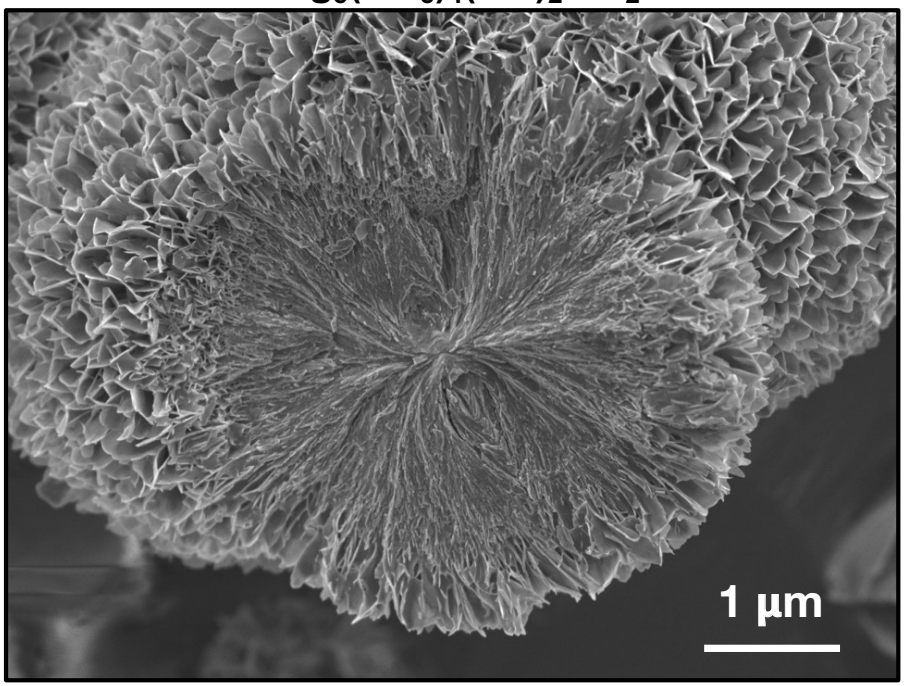
$Mg_3Si_2O_5(OH)_4$

Experimental apparatus (UniBern)



Mg-carbonate

$Mg_5(CO_3)_4(OH)_2 \cdot 4H_2O$

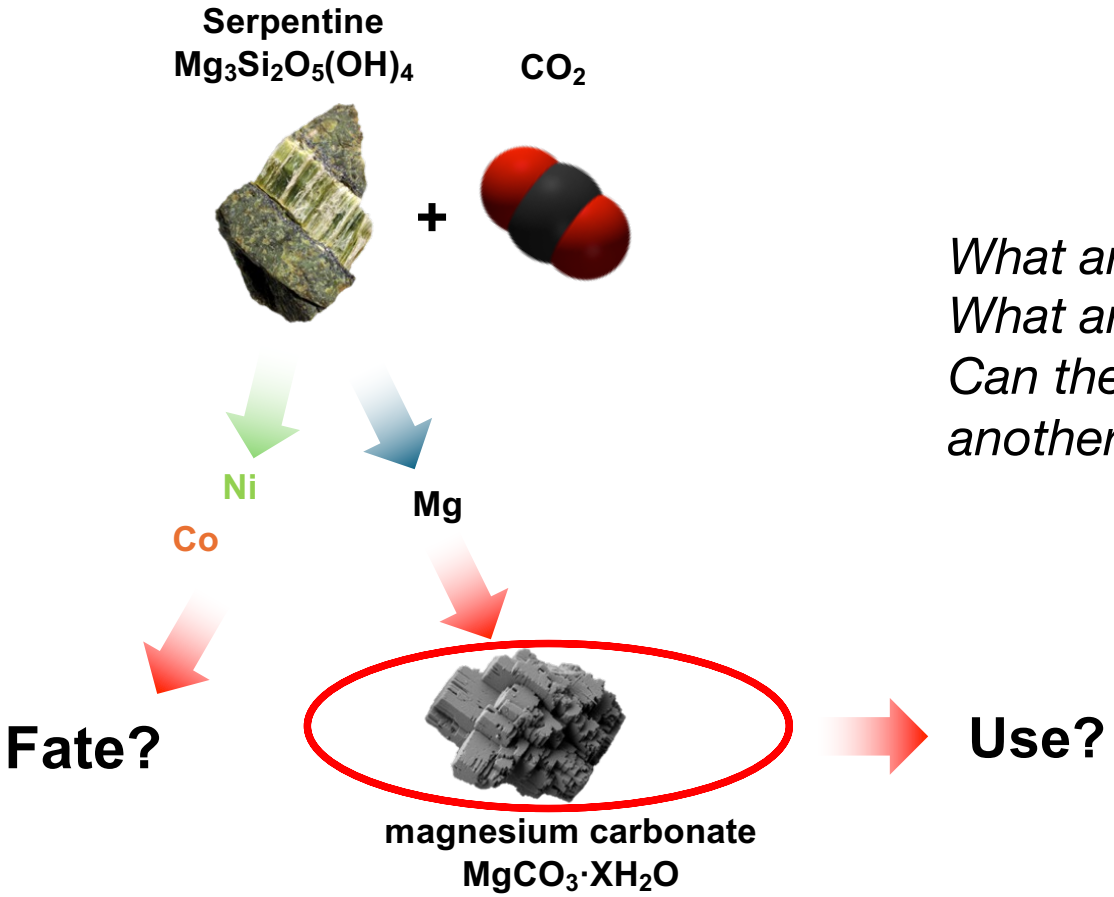


Harrison et al

CarboStoreUltra

Task 3:

Characterize reaction products and fate of trace metals during ex situ carbonation of Swiss rocks as a preliminary assessment of potential valuable byproducts.



What are the products?
What are their compositions?
Can these products be used for another purpose (e.g., aggregate?)

CarboStoreUltra Team

University of Bern

Anna Harrison

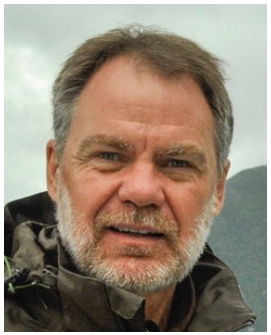
(coordinator; carbon mineralization expert)

Daniela van den Heuvel

(Swiss geology; mineral-fluid interaction)

Vasileios Mavromatis

(Carbonate formation; experimental geochemistry)



Larryn Diamond

(thermodynamics of carbonation)

Francesca Piccoli

(Swiss geology and analytics)

Postdoctoral fellow

(starting in Feb 2025; *conducting experiments)*

Funding partners

Robin Quartier (VBSA)

(industry requirements)

CemSuisse

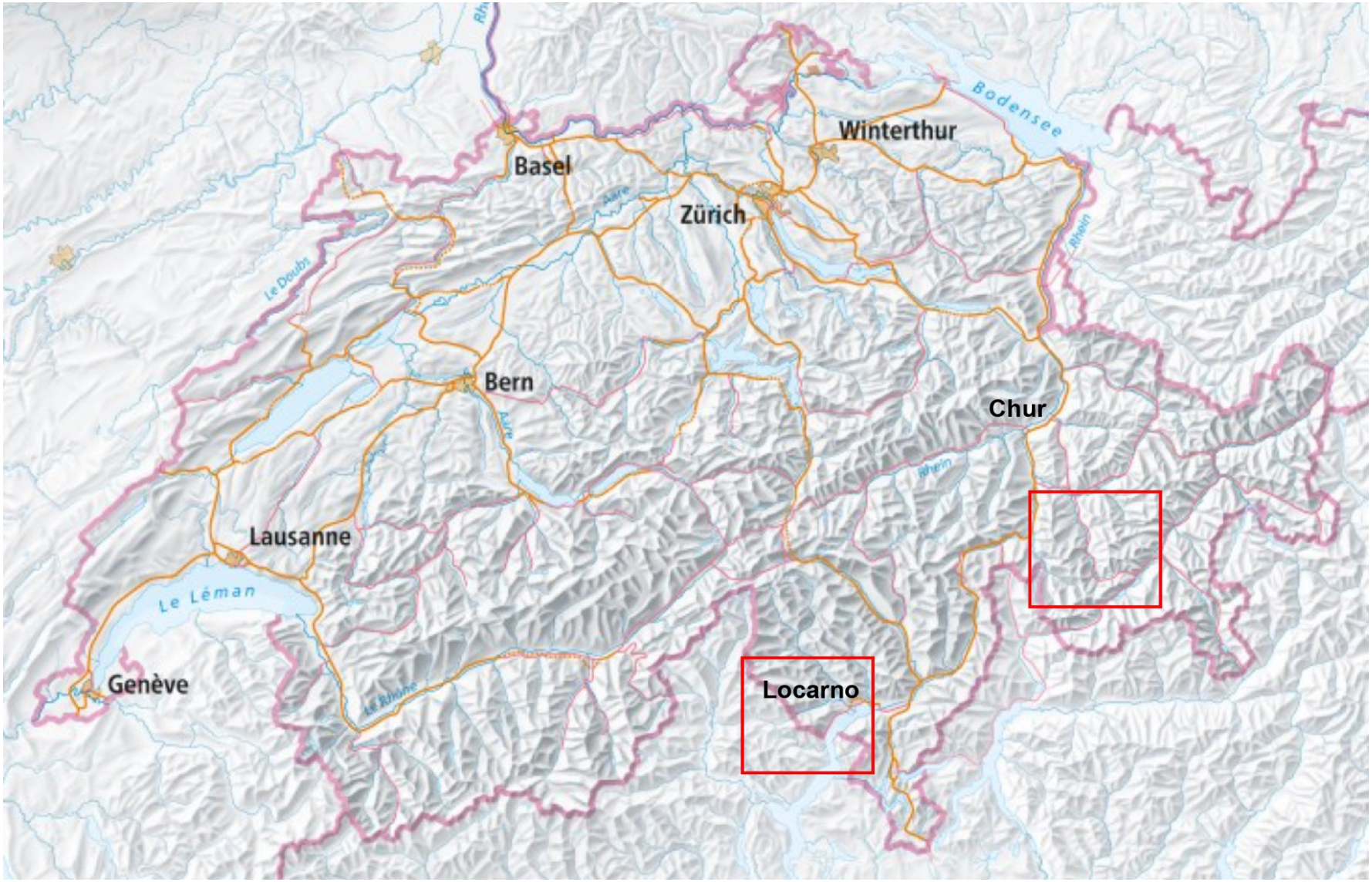
(industry requirements)

Florence Bégué (SFOE)

Stefano Benato (SFOE)

The hunt for peridotite and serpentinite

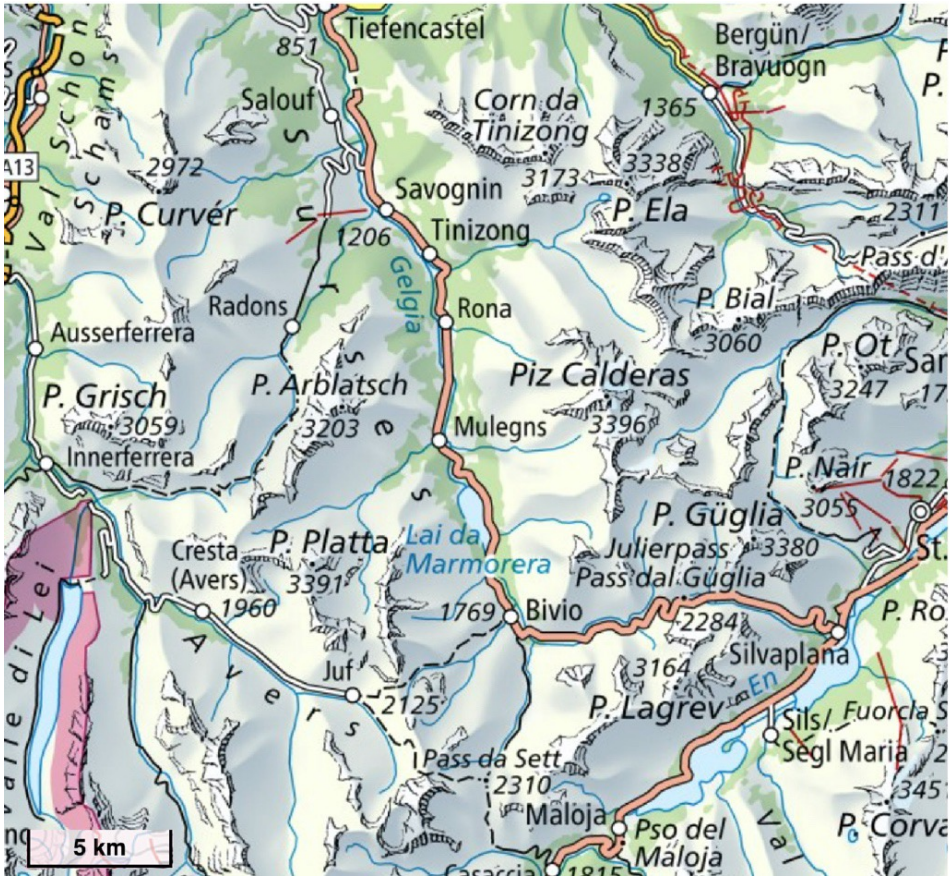
Two localities visited in Graubünden & Ticino



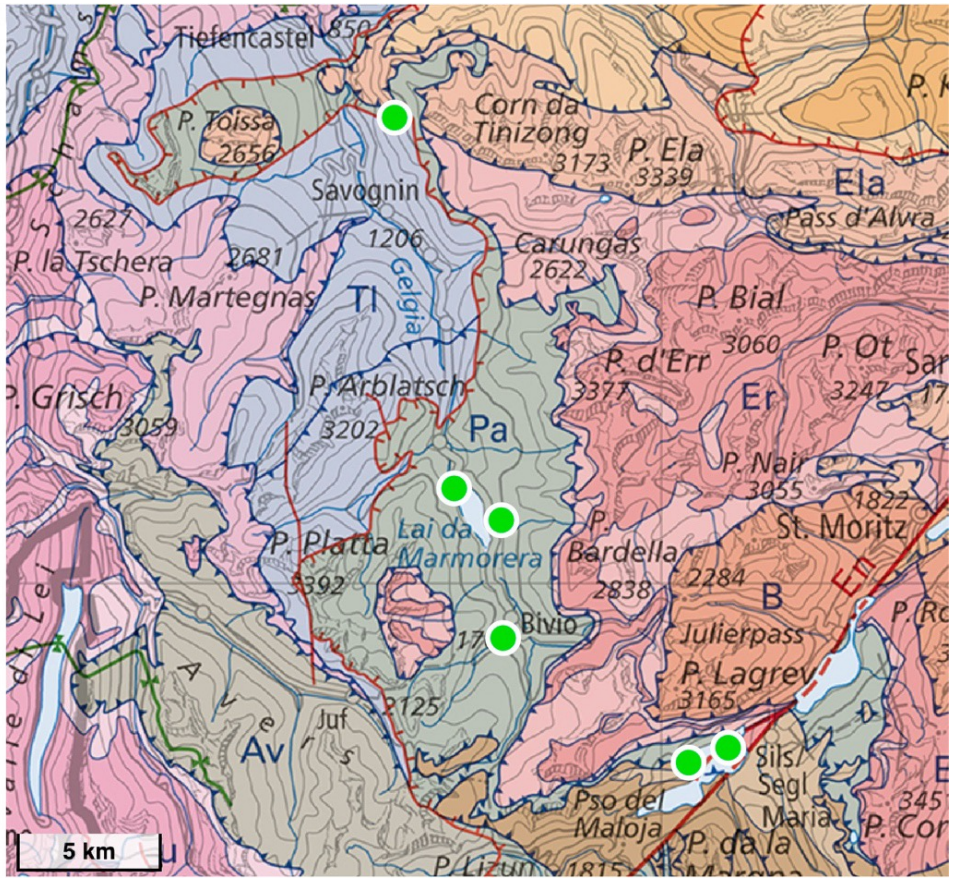
Reconnaissance sampling: Serpentinite

14 + 15 Oct 2024, Graubünden (Oberhalbstein and Engadine Valley)

Topographic map



Geologic map



Serpentinites

Reconnaissance sampling: Serpentinite

14 + 15 Oct 2024, Graubünden (Oberhalbstein and Engadine Valley)


Lizardite

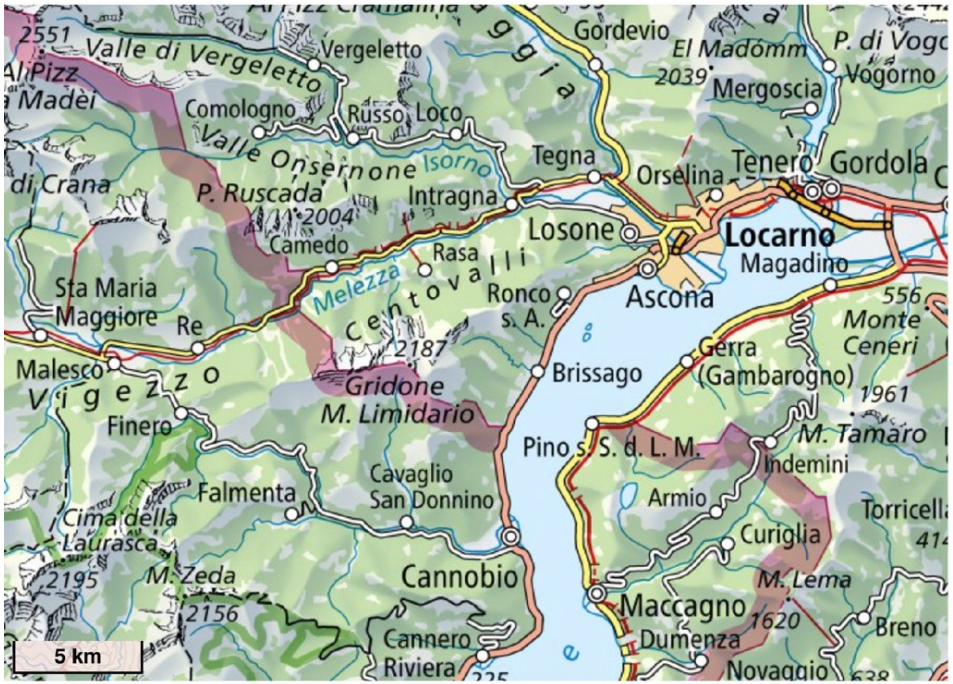

Antigorite


Lizardite, Lake Marmorera

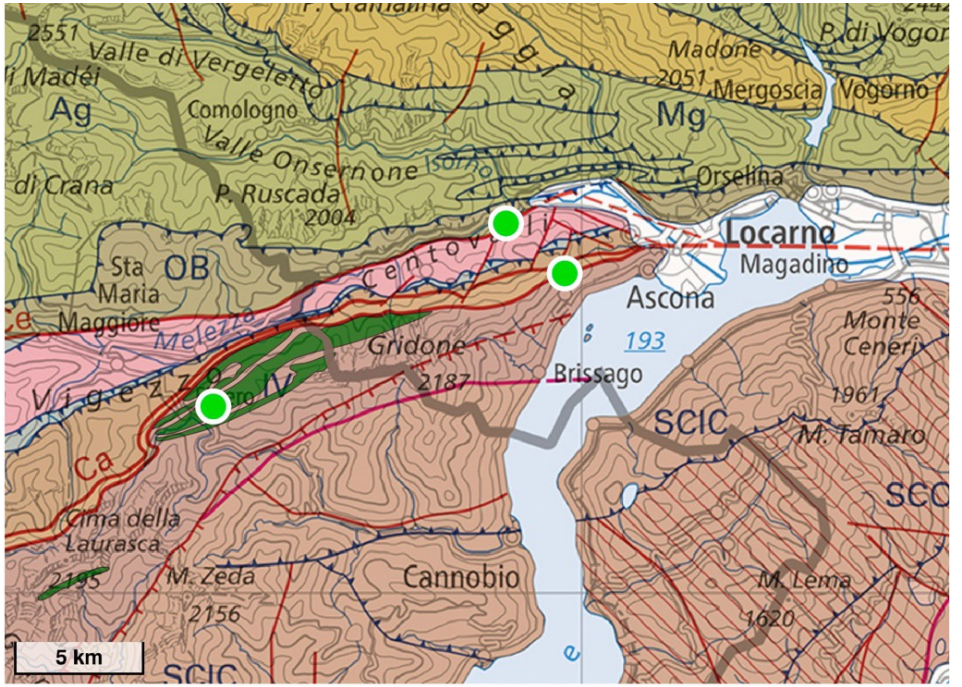
Reconnaissance sampling: Peridotite

Field work: 12 + 13 Nov 2024, Locarno, Ticino

Topographic map



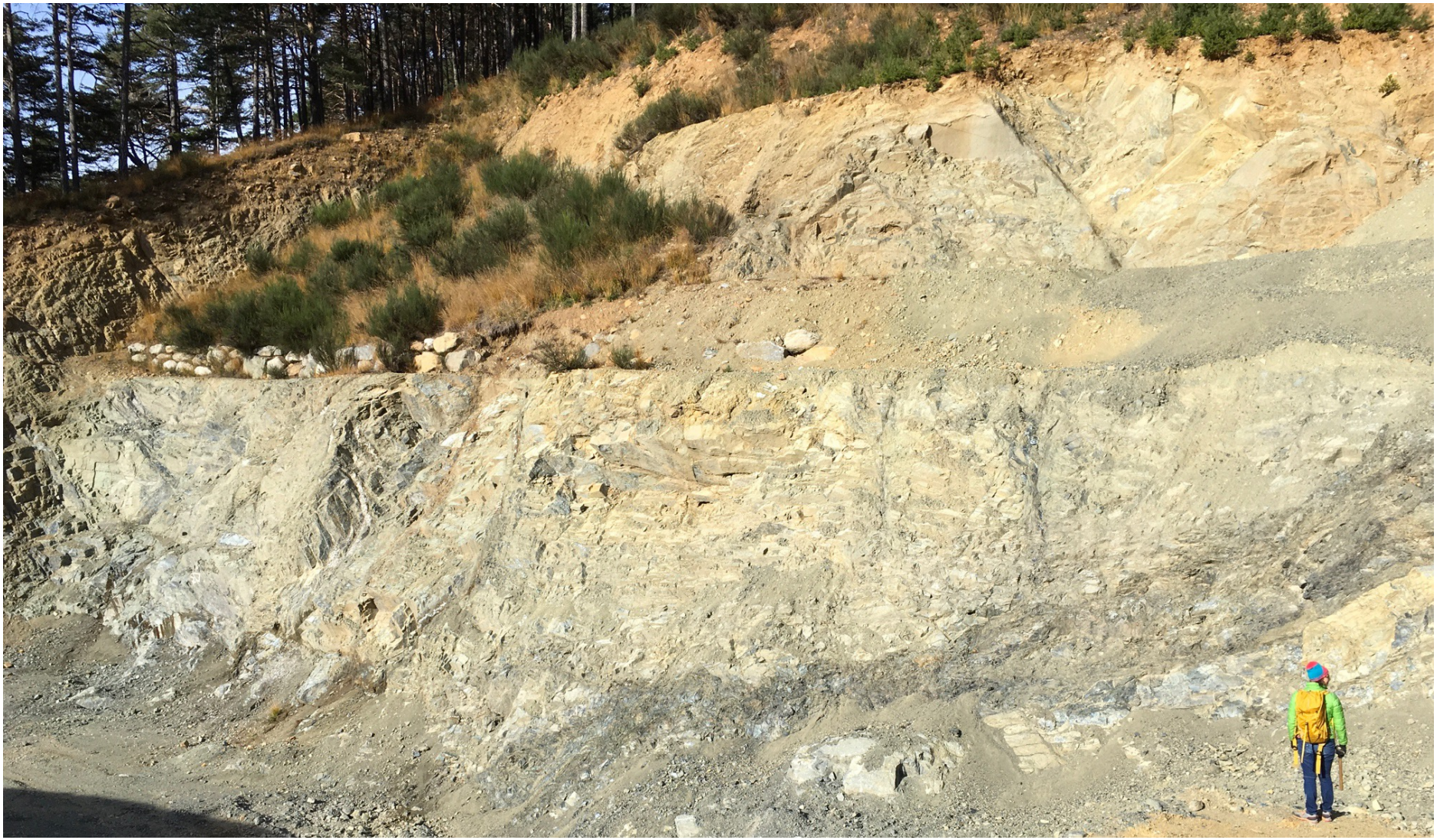
Tectonic map



Peridotite (~20 km^2)

Reconnaissance sampling: Peridotite

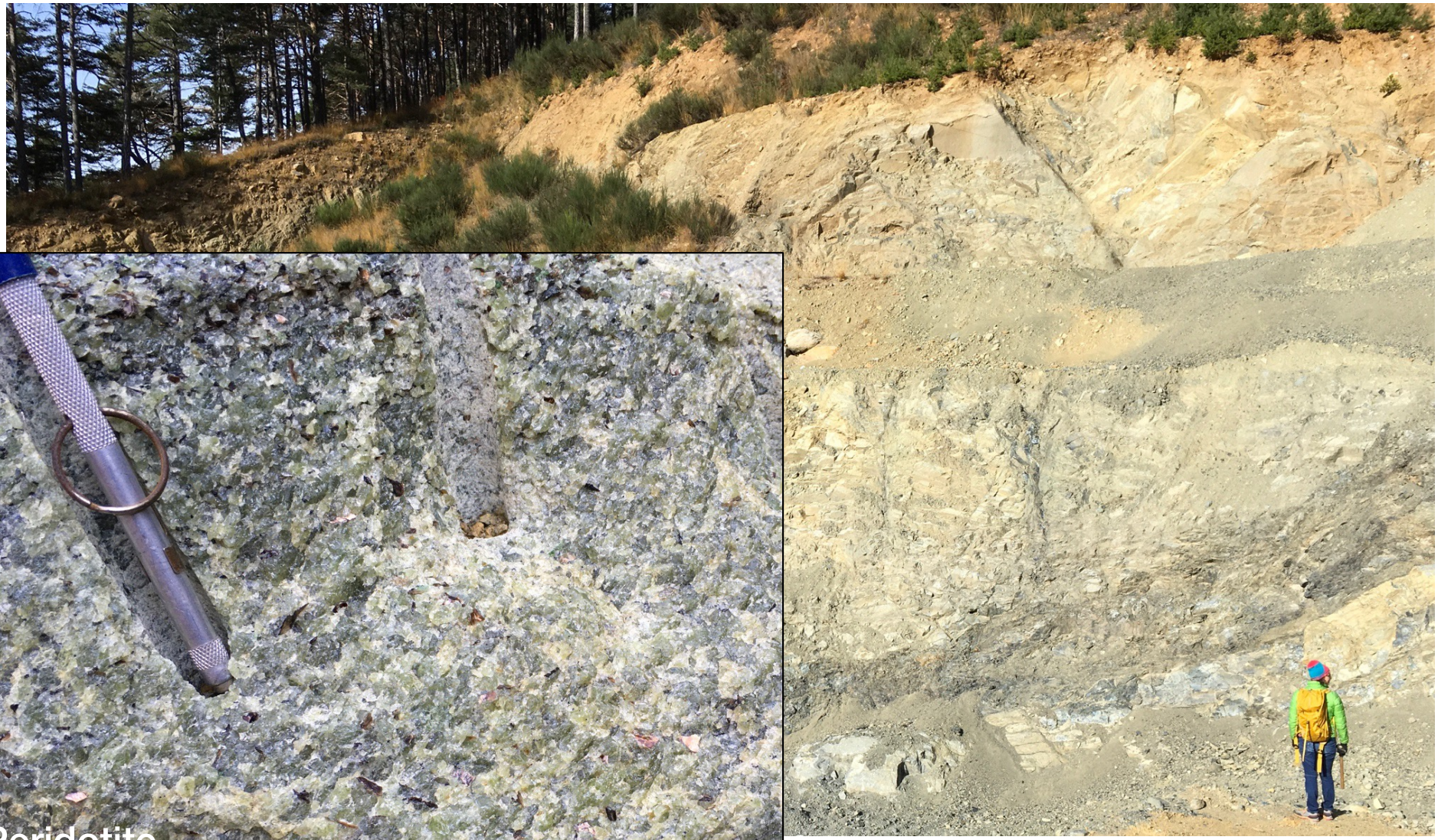
12 + 13 Nov 2024, Locarno, Ticino



Finero quarry (Italy)

Reconnaissance sampling: Peridotite

12 + 13 Nov 2024, Locarno, Ticino



Peridotite

Finero quarry (Italy)

CarboStoreUltra

Work packages (WP)

Phase 1: 2024-2027 (2.5 years)

WP1: Literature review of ex situ carbonation processes and selection of experimental conditions

- In progress

WP 2: Collection and characterization of promising Swiss materials.

- In progress

WP 3. Experiments to determine ex situ carbonation rates and capacity (“efficiency”).

- To begin in early 2025 after arrival of post doc

WP 4: Preliminary assessment of valuable by-products produced during ex situ carbonation.

Thanks for your attention