

I materiali di scarto delle miniere: problema o georisorsa?

Mining waste materials: problem or georesource?

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SCIENZE BIOLOGICHE,
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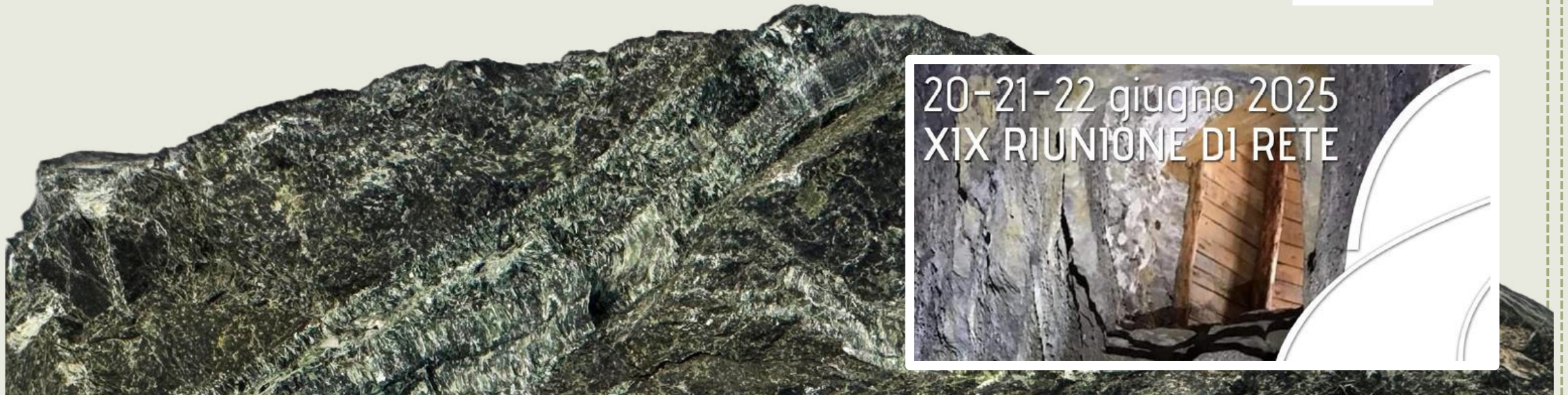
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UNIVERSITÀ
DEGLI STUDI DELLA
BASILICATA



Università
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20-21-22 giugno 2025
XIX RIUNIONE DI RETE

Le cave abbandonate di Pietra Verde

“Pietra Verde”

Complesso di rocce, dal colore variabile dal verde chiaro al verde intenso, di cui i litotipi rappresentativi sono: metabasiti e serpentiniti.

Metabasite



Serpentinite

Le **Ofioliti** sono rocce di litosfera oceanica accrete durante i processi tettonici alla crosta continentale. La litosfera oceanica è composta dalla crosta oceanica e dal mantello litosferico superficiale che rappresentano quindi i principali litotipi affioranti nelle Ofioliti

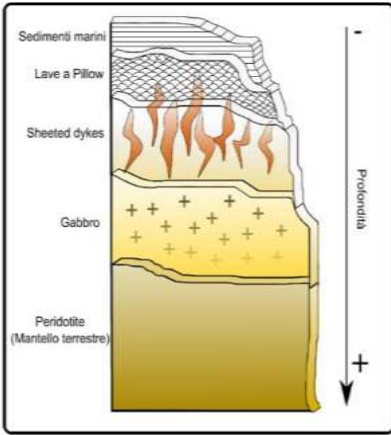
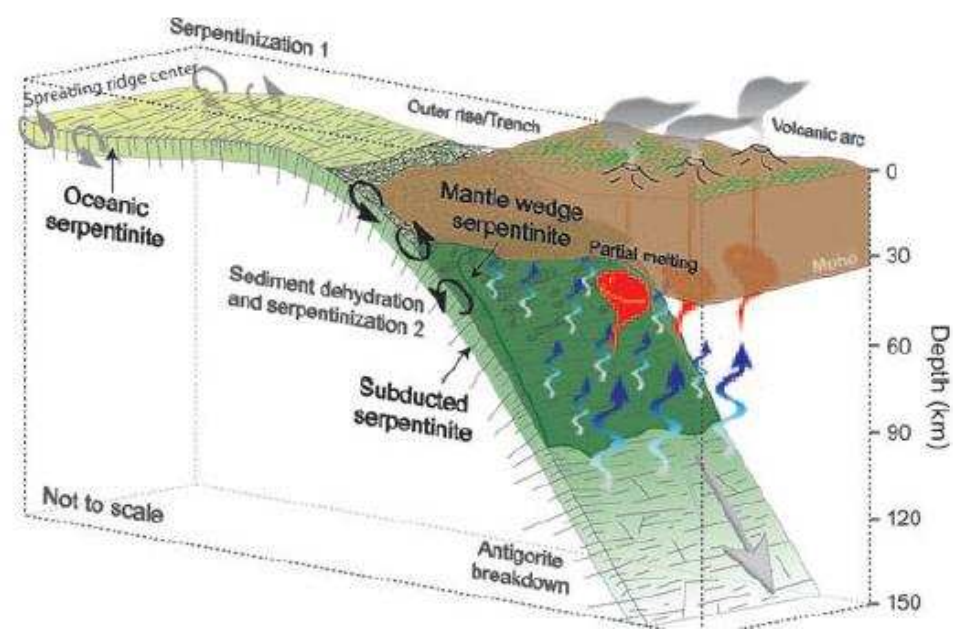
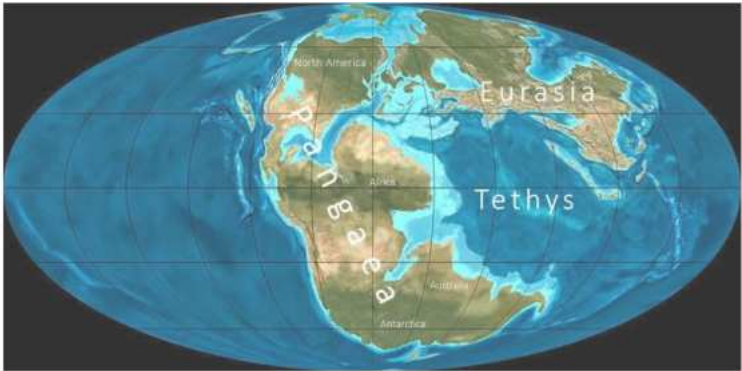


Fig. 1: struttura della litosfera oceanica.

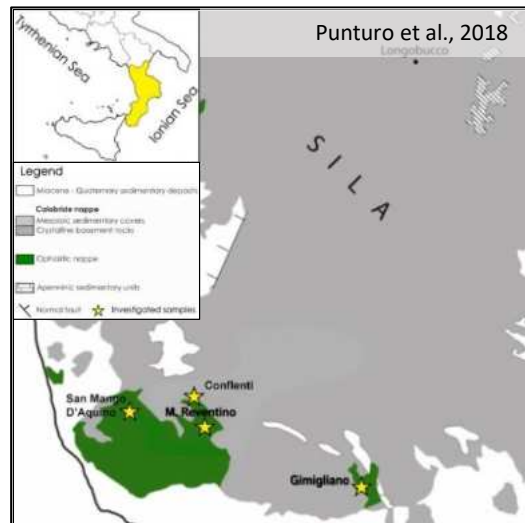


The world in Jurassic times (170 million years ago). Image: Ron Blakey-NAU Geology.

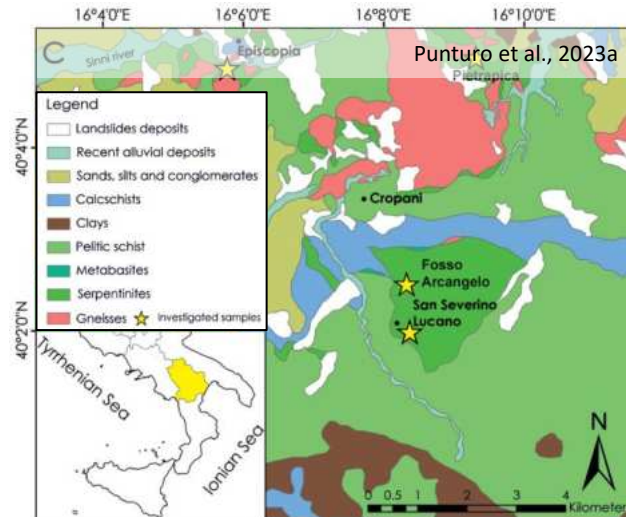


Contesto geologico

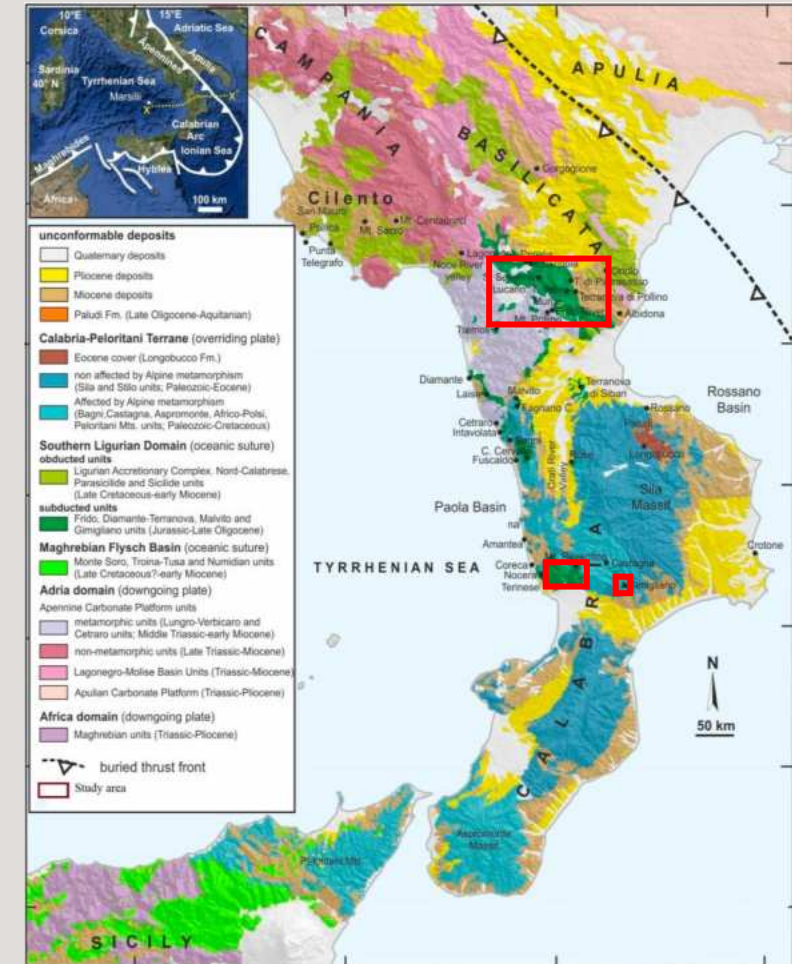
In Calabria e Basilicata, nell'Italia meridionale, si trovano estese sequenze ofiolitiche all'interno dell'orogeno calabro-peloritano e dell'Appennino meridionale. All'interno delle ofioliti, le rocce serpentinitiche affiorano in estesi affioramenti.



Calabria Region



Basilicata Region



Dichicco et al., 2019

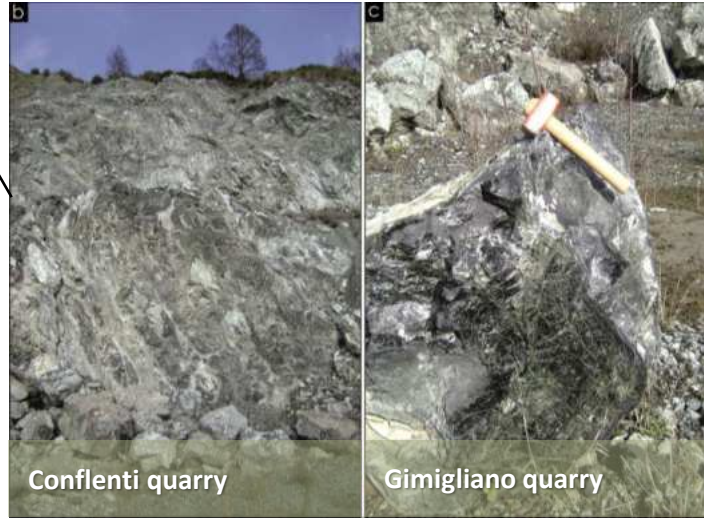


Cave abbandonate

Le cave storiche abbandonate di Pietra Verde (serpentinite) dell'Appennino meridionale

CALABRIA REGION

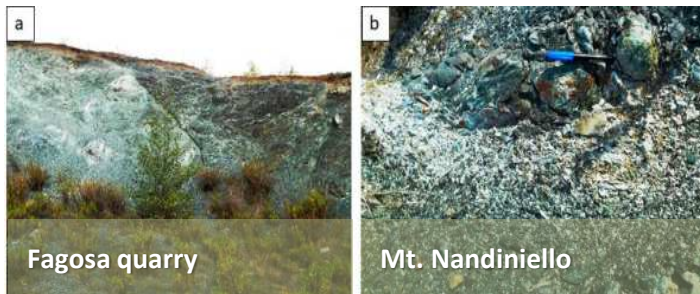
- **Massive bodies**, sometimes weakly foliated
- Crosscut by **serpentine and calcite veins**
- Presence of **large serpentinite blocks and mélange zones**



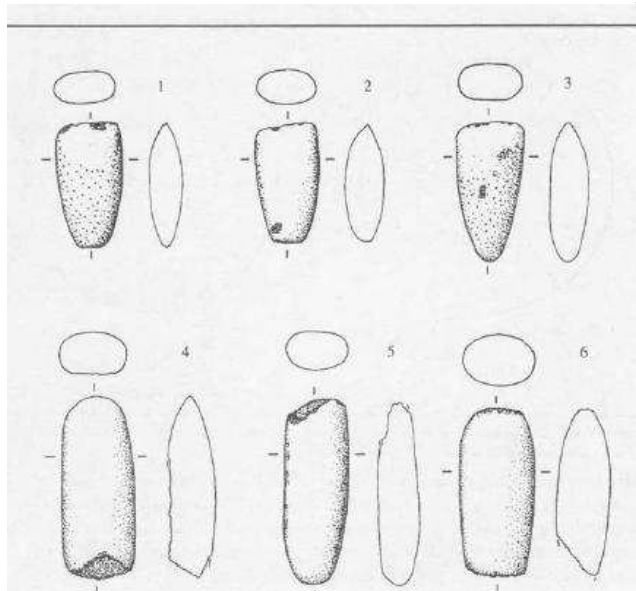
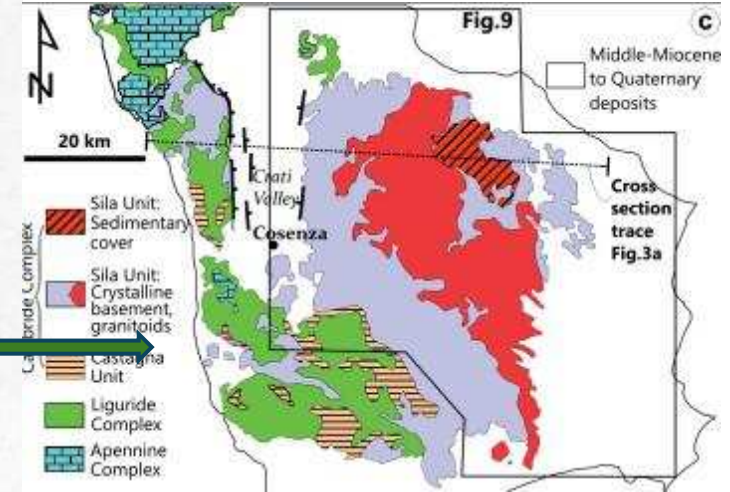
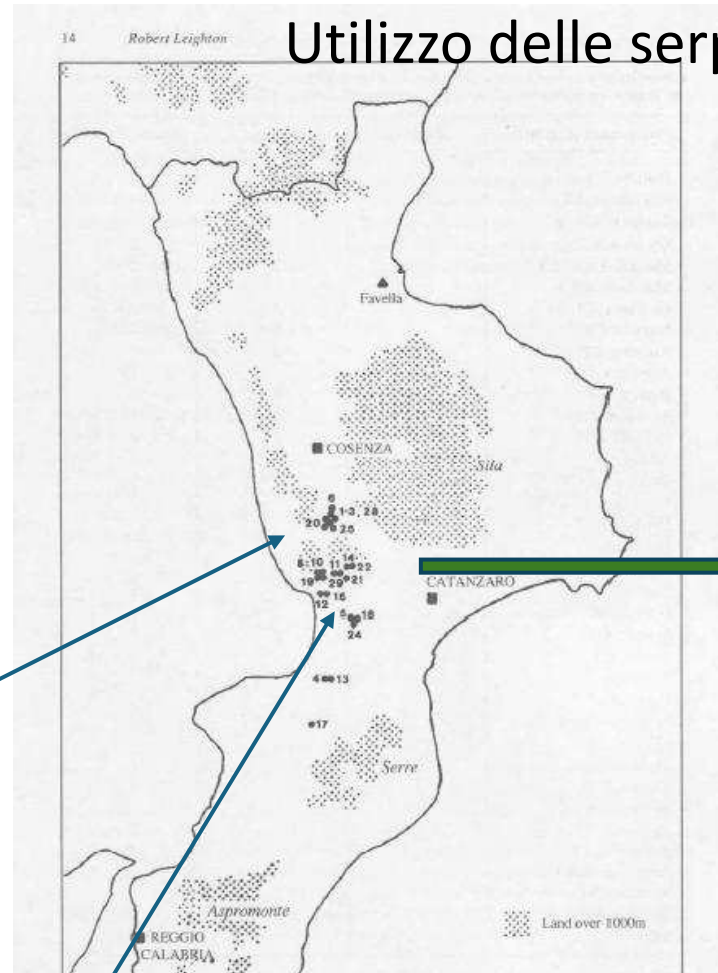
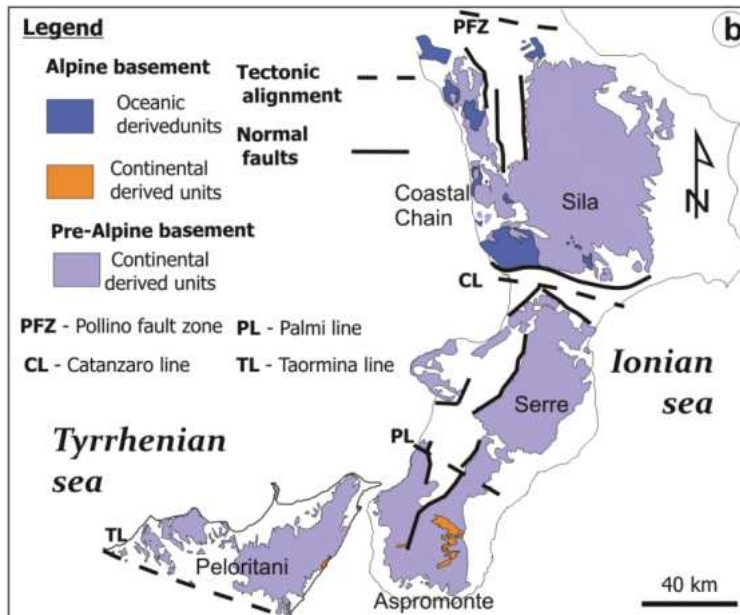
BASILICATA REGION

Punturo et al., 2023 b

- **Cataclastic**: fractures with exposed fibrous minerals
- **Massive**: low fracturing and no exposed fibers
- **amphibole-bearing serpentinites**



Utilizzo delle serpentinitì calabre dalla Preistoria





Monastero di Sant'Anna,
Valverde (CT)



Altare di Sant'Agata, Chiesa
di San Nicolò L'arena (CT)



Santuario San Francesco Di
Paola (CS)



Fonte Battesimale;
Martirano LOMbarDO (CZ)



Particolare della
pavimentazione della Chiesa
di San Nicolò L'Arena (CT)

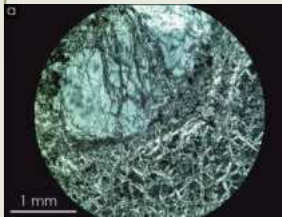
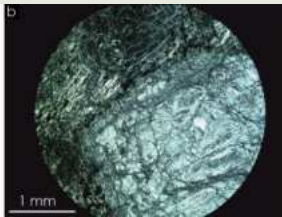
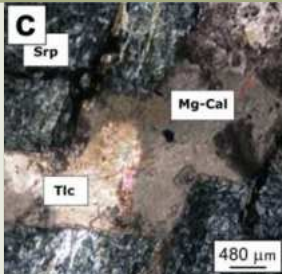
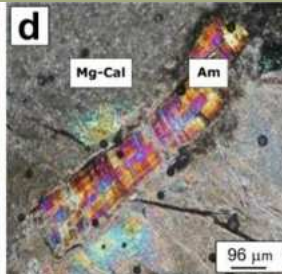


Chiesa del Gesù (Napoli)

Serpentine: caratteri petrografici e mineralogici



Both Calabrian and Basilicata serpentinites contain **serpentine group minerals**, amphiboles, pyroxene, chlorite, talc, titanite, magnetite, and carbonates. Basilicata serpentinites also include quartz, dolomite, and **edenite** (Punturo et al., 2015; Dichicco et al., 2019).

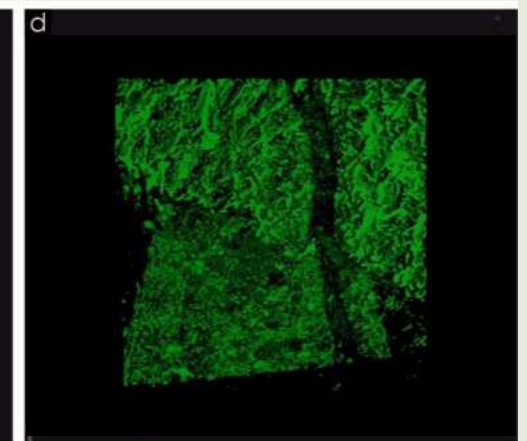
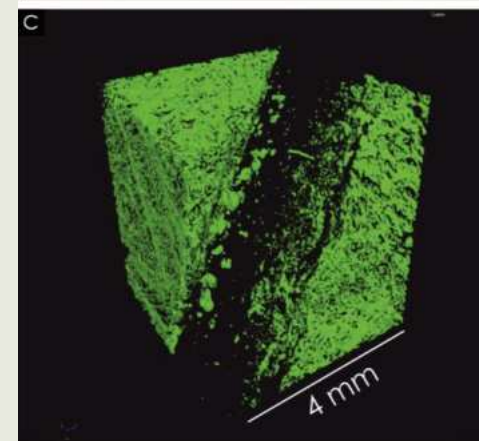
Locality	Texture	Mineral Assemblage	Fibrous Minerals	Petrography
Sila Piccola Massif (CAL)	Mesh microstructure and pseudomorphic texture	$\text{Srp} \pm \text{Mag} \pm \text{Tr} - \text{Act} \pm \text{Chl} \pm \text{Cpx} \pm \text{Spl} \pm \text{Cal} \pm \text{Tlc}$	Tremolite, antigorite, chrysotile	  Punturo et al., 2023b
Pollino Massif (BAS)	Pseudomorphic texture and mylonitic-cataclastic structures	$\text{Srp} \pm \text{Mag} \pm \text{Tr} - \text{Act} - \text{Ed} - \text{Hbl} \pm \text{Clc} \pm \text{Cpc} \pm \text{Spl} \pm \text{Ttn} \pm \text{Cal} \pm \text{Dol} \pm \text{Tcl} \pm \text{Qz}$	Tremolite, antigorite, chrysotile, edenite	  Rizzo et al., 2023

Serpentine: Proprietà petrofisiche e fisico-meccaniche

On Calabrian serpentinites, salt crystallization tests, seismic analysis (Vp) and compressional strength measurements (UCS) was performed to understand the relationship between compositional and microstructural features and the behavior of such rocks:

	Non-crystallization test (NCT):	Post Crystallization test (PCT):
Vp	6.0 - 7.5 km/s	5.2 - 6.8 km/s
UCS*	77 - 191 MPa	81 - 159 MPa

*American ASTM standards for building materials (UCS > 69 MPa)



Puturo et al., 2023



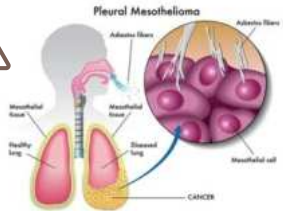
SYRMEP (SYnchrotron Radiation for MEdical Physics) beamline

Problema I

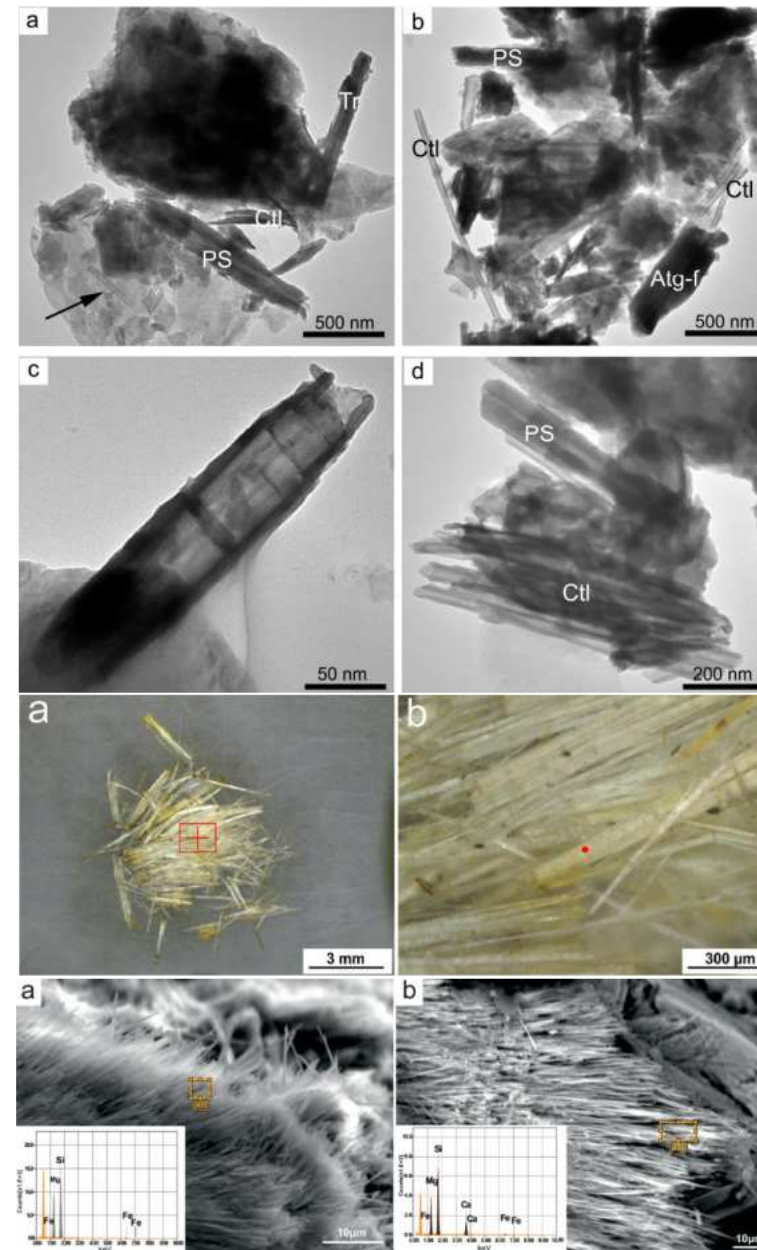
Serpentine: Presenza di Asbesto (NOA) negli scarti

La letteratura esistente segnala la presenza di NOA (amianto e minerali asbestiformi), potenzialmente dannosi per la salute umana e per l'ambiente.

Pollino Massif (BAS):	Sila Massif (CAL):
Chrysotile fibres within the veins - Rare fibrous tremolite in carbonate veins - Fibrous edenite* crystals aggregates often associated with serpentine, diopside, and calcite	Chrysotile fibres within the veins - Lamellar lizardite inside the massive serpentinite - Fibres arranged perpendicular to the vein elongation - Locally splitting of larger bundles into thinner
<i>*not regulated</i>	



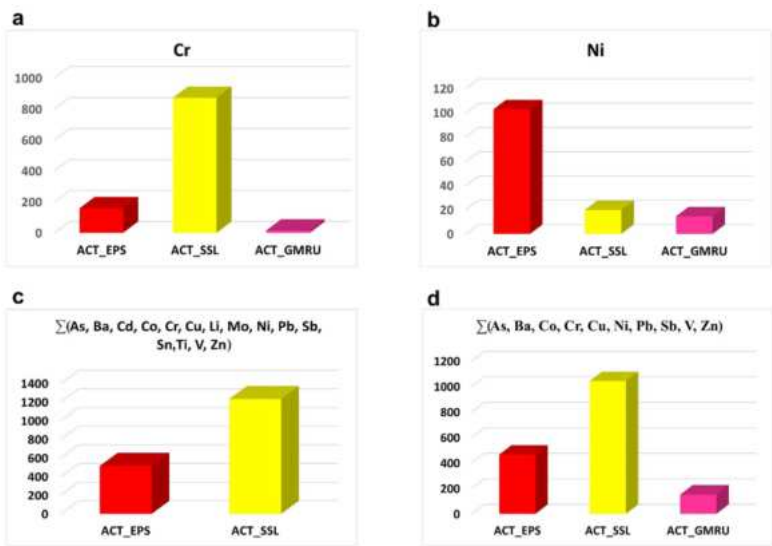
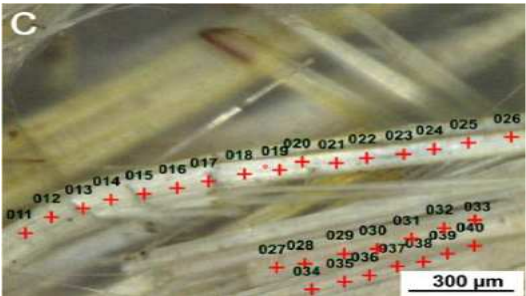
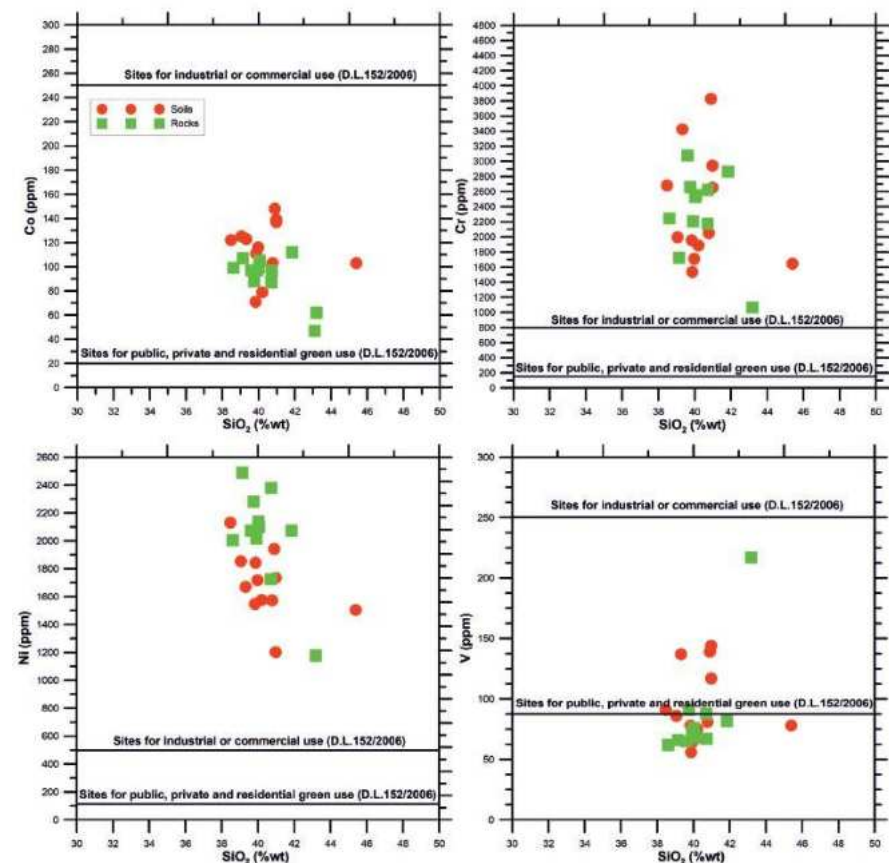
“All types of asbestos cause **lung cancer**, **mesothelioma**, **cancer of the larynx and ovary**, and **asbestosis** (fibrosis of the lungs)”
([World Health Organization WHO](http://www.who.int))



Problema II

Serpentine: Presenza di alte concentrazioni di Metalli potenzialmente tossici (PTE)

Roccia e suoli



Punturo et al., 2023a

V, Cr e Co superano le soglie consentite dalla Legge per l'uso verde pubblico, privato e residenziale, mentre anche il Ni supera il limite legale per l'uso industriale e commerciale.

Problema III

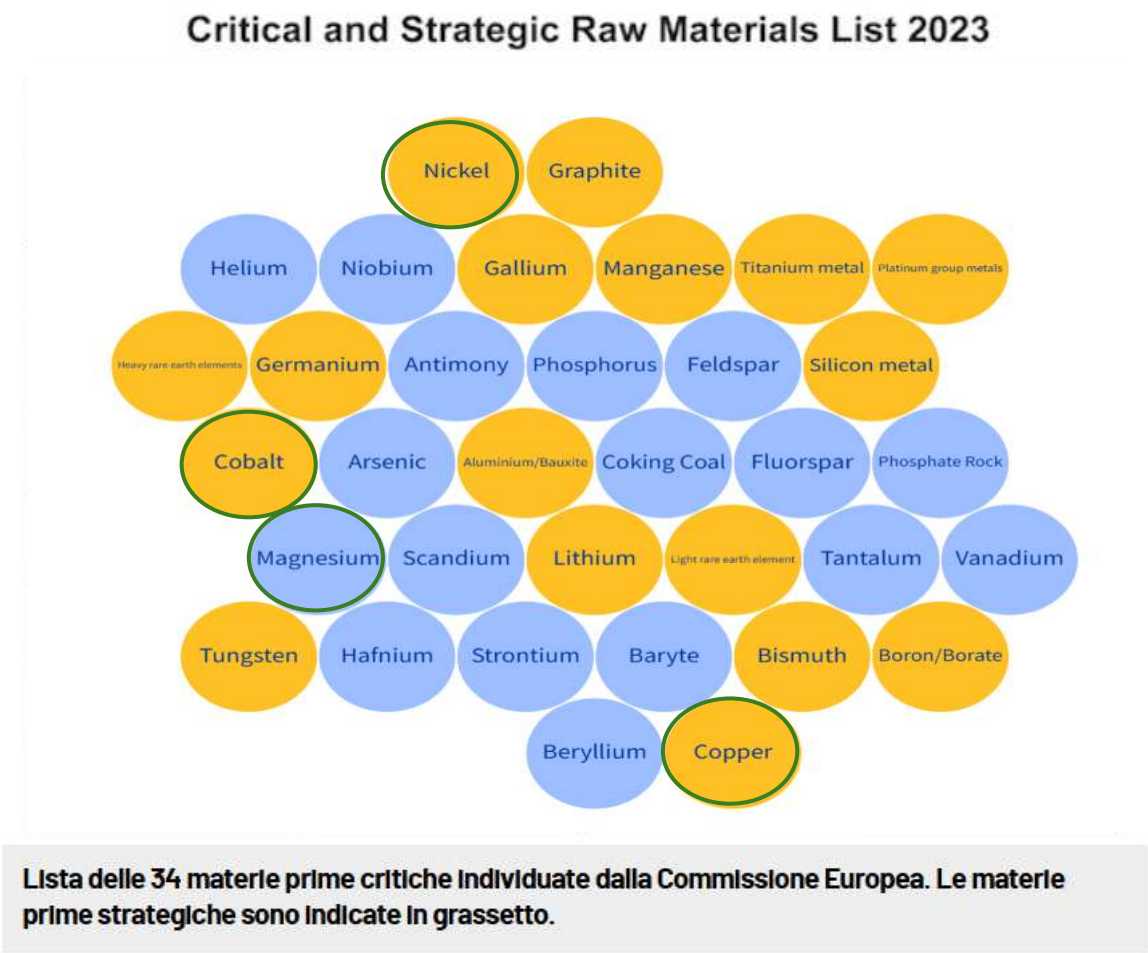
Inquinamento dei suoli in prossimità delle cave abbandonate



Serpentiniti: da **problema** a georisorsa

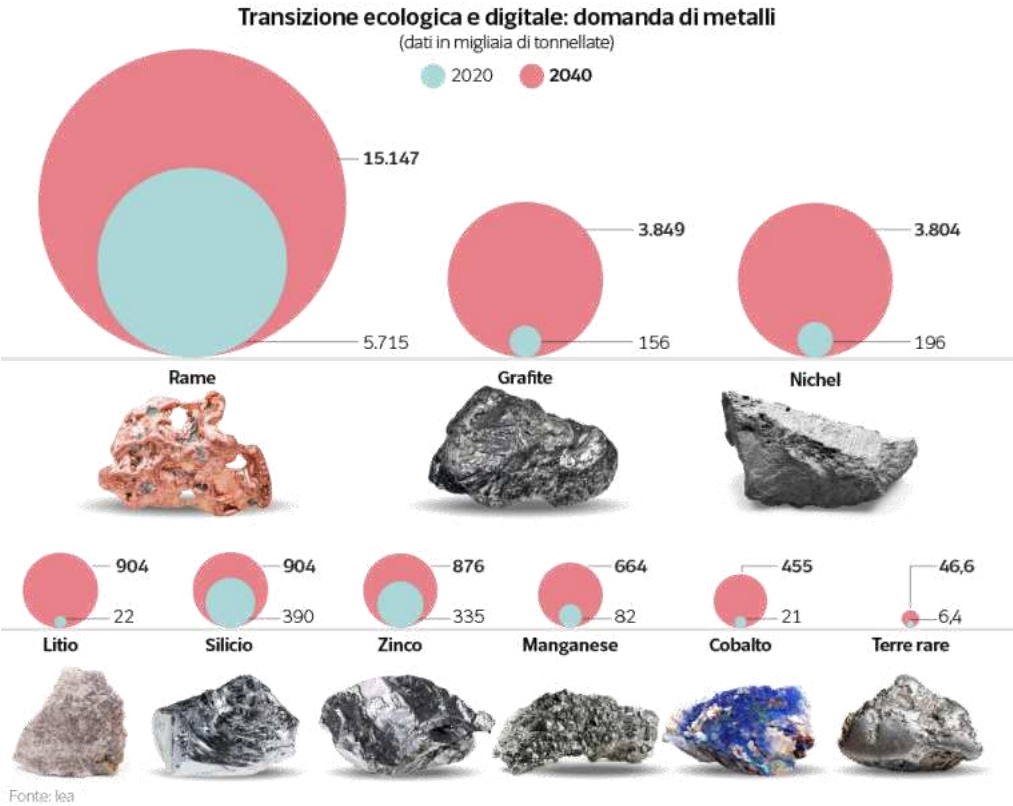
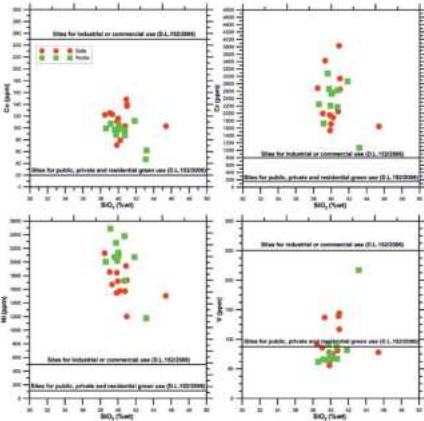


Serpentiniti: da problema a georisorsa



<https://www.consilium.europa.eu/en/infographics/critical-raw-materials/>

Alte Concentrazioni di metalli



Serpentiniti: da **problema** a **georisorsa**

Le serpentiniti offrono una materia prima altamente reattiva per le reazioni di carbonatazione e la capacità di sequestrare l'anidride carbonica (CO_2) su scala globale. La CO_2 può essere sequestrata nella serpentinite estratta utilizzando reattori di carbonatazione ad alta temperatura, carbonatando rifiuti minerali alcalini o mediante reazione sotterranea attraverso l'iniezione di CO_2 in falde acquifere contenenti serpentinite e peridotiti serpentinite.

L'ampliamento delle tecnologie esistenti che accelerano la carbonatazione della serpentinite potrebbe rivelarsi sufficiente per compensare le emissioni industriali locali, ma l'implementazione su scala globale richiederà incentivi considerevoli e ulteriore ricerca e sviluppo.

Da Rizzo et al., 2024 (Periodico di Mineralogia)

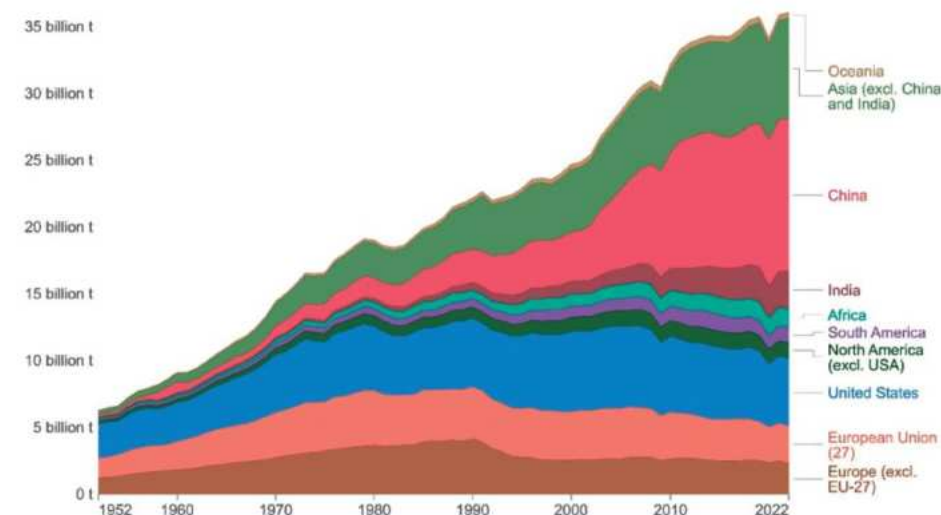
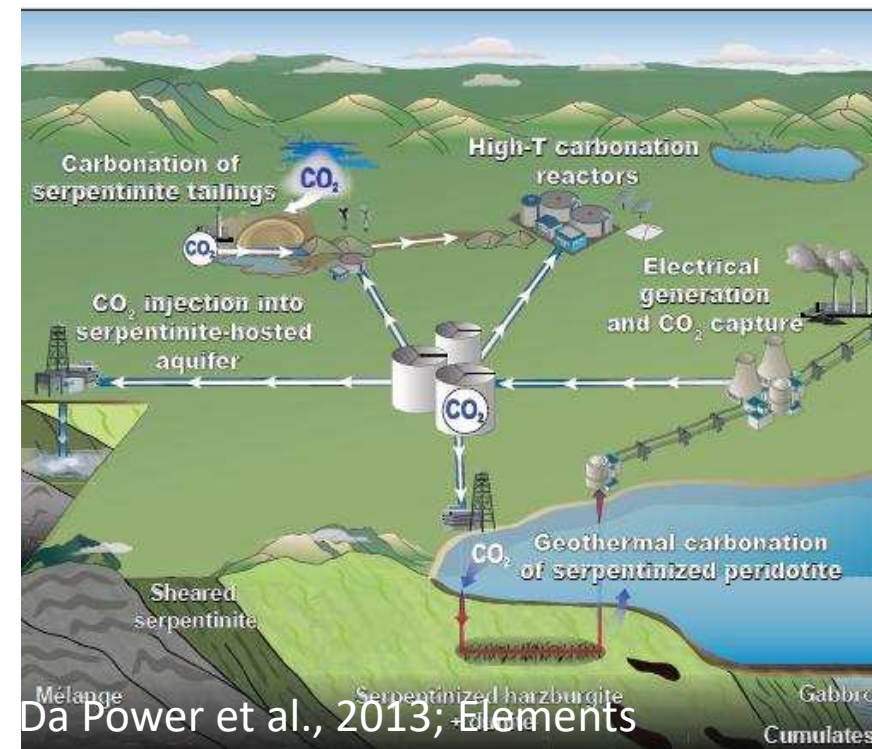


Figure 1. Annual CO_2 emissions by world region (modified after Global Carbon Budget, 2023).

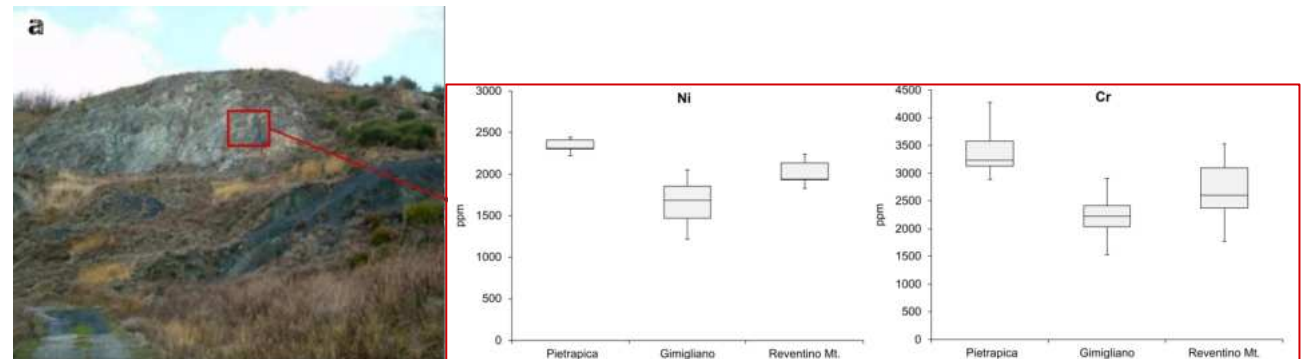
Serpentiniti: da **problema** a **georisorsa**

Ridefinizione dei geomateriali contenenti amianto come georisorse. Ad esempio, le serpentiniti dell'Appennino meridionale (BASILICATA) possono essere utilizzate per lo stoccaggio e il sequestro di CO₂, e le cave abbandonate nella regione sono oggetto di studio come potenziali fonti di materie prime critiche (CRM).

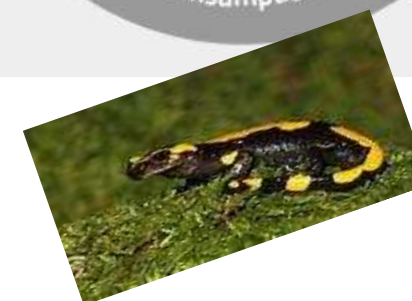
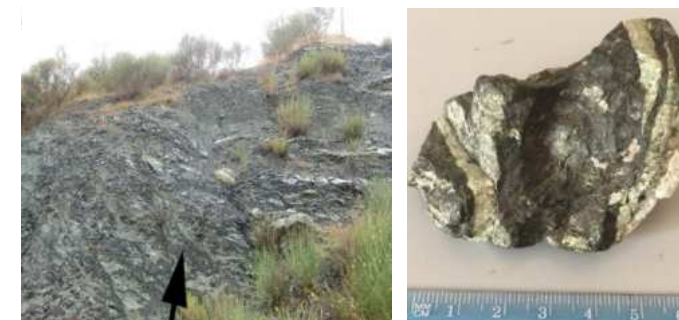
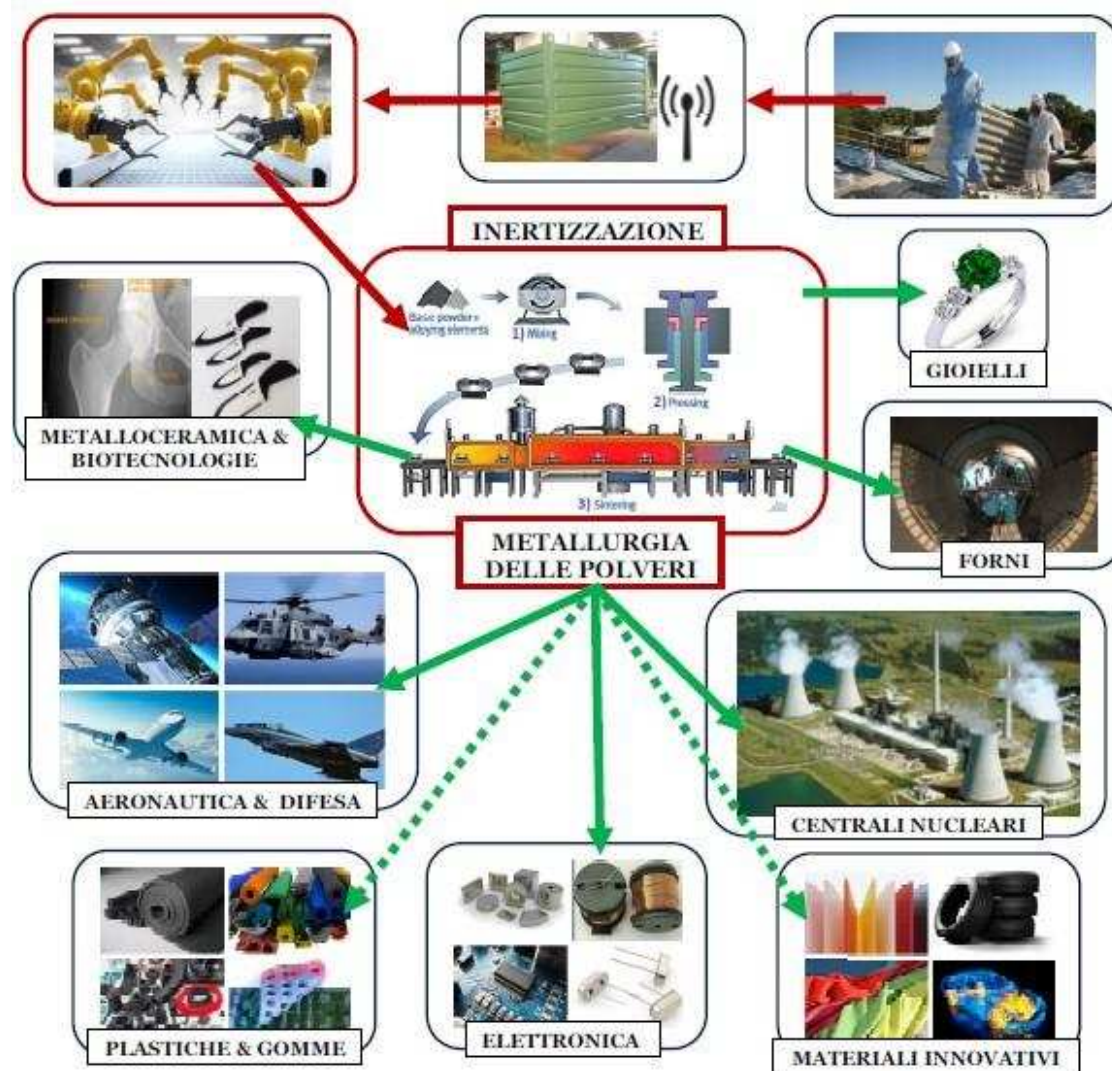


Pietrapica serpentinite quarry, Basilicata (Rizzo et al., 2024).

(a) Pietrapica serpentinite quarry; (b) box and whiskers plot for trace elements in the Pietrapica, Gimigliano and Reventino Mt. Serpentinities (Rizzo et al., 2023)



Asbesto e Serpentiniti: da **problema** a **georisorsa**



Cortesia di Paolo Tuccitto

Alcune considerazioni.....

Mappatura di dettaglio degli scarti: L'importanza degli studi multidisciplinari



remote sensing

an Open Access Journal by MDPI

Hyperspectral Investigation of an Abandoned Waste Mining Site: The Case of Sidi Bou Azzouz (Morocco)

Daniela Guglietta; Roberto Salzano; Amina Wafik; Aida M. Conte; Matteo Paciucci; Rosalda Punturo; Rosamaria Salvatori; Giorgio S. Senesi; Carmela Vaccaro

Remote Sens. 2025, Volume 17, Issue 11, 1838



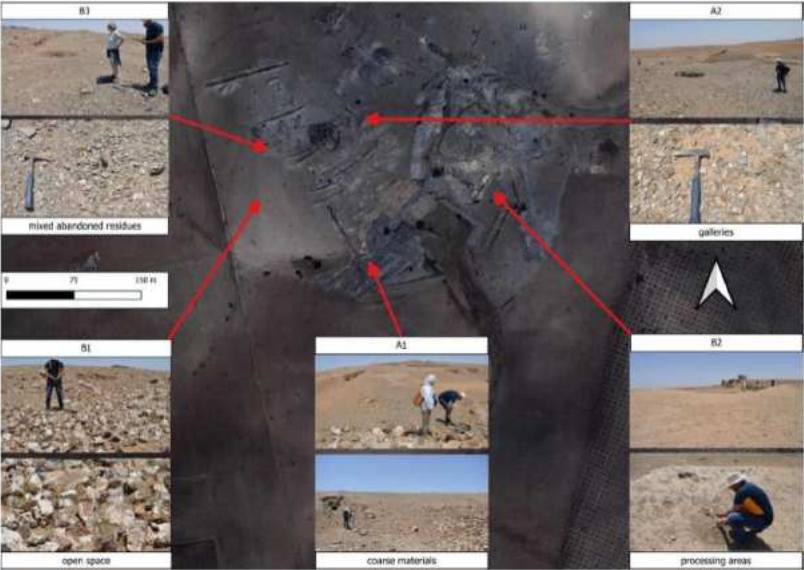


Figure 10. The spatial distribution of mining residue classes identifying different zones (red arrows) with varying mineralogical compositions in the Sidi Bou Azzouz abandoned mine (Google Earth Pro-Image © Airbus 2025, acquired on 2 February 2022).

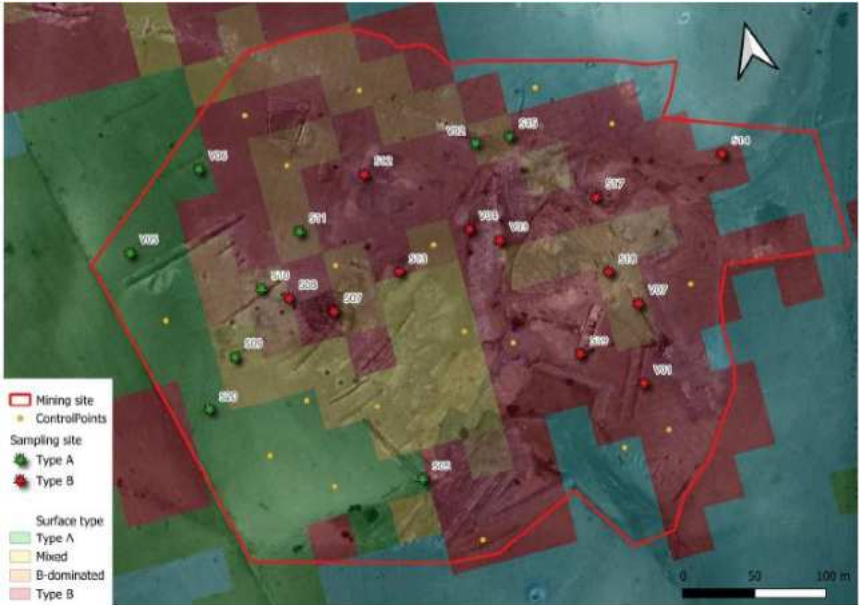
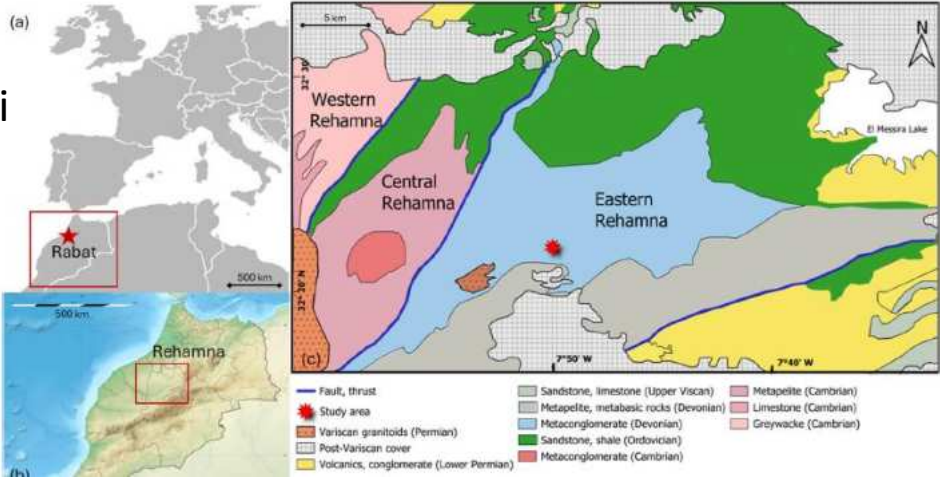
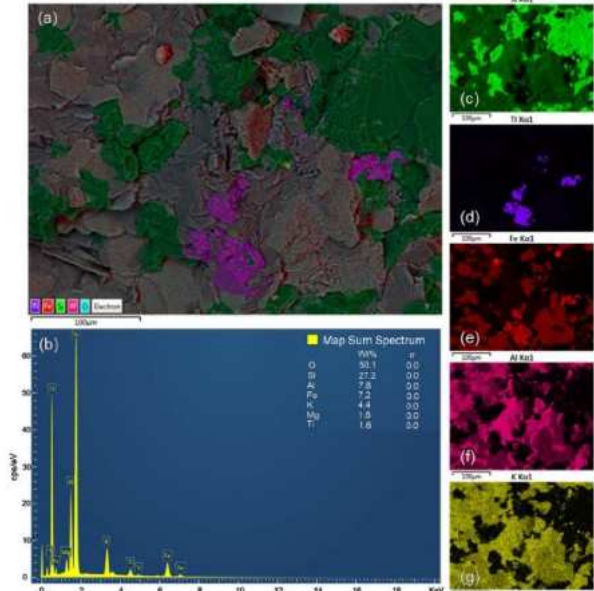
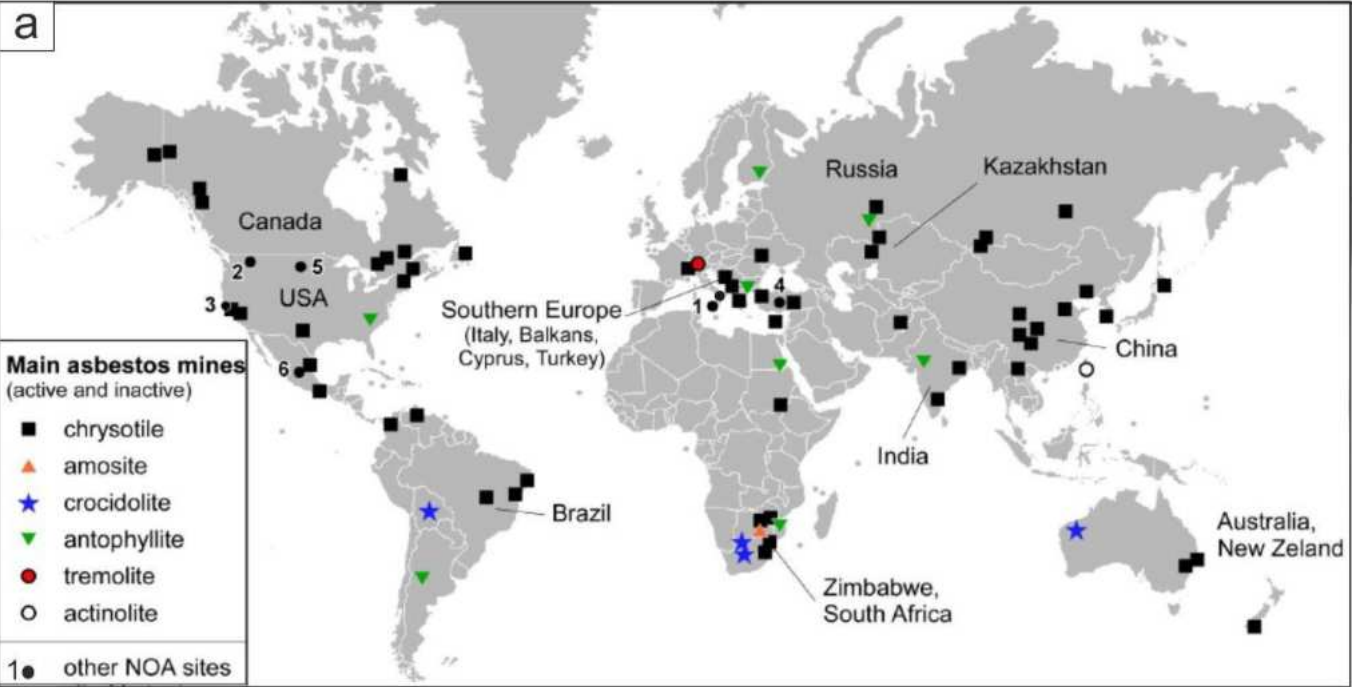
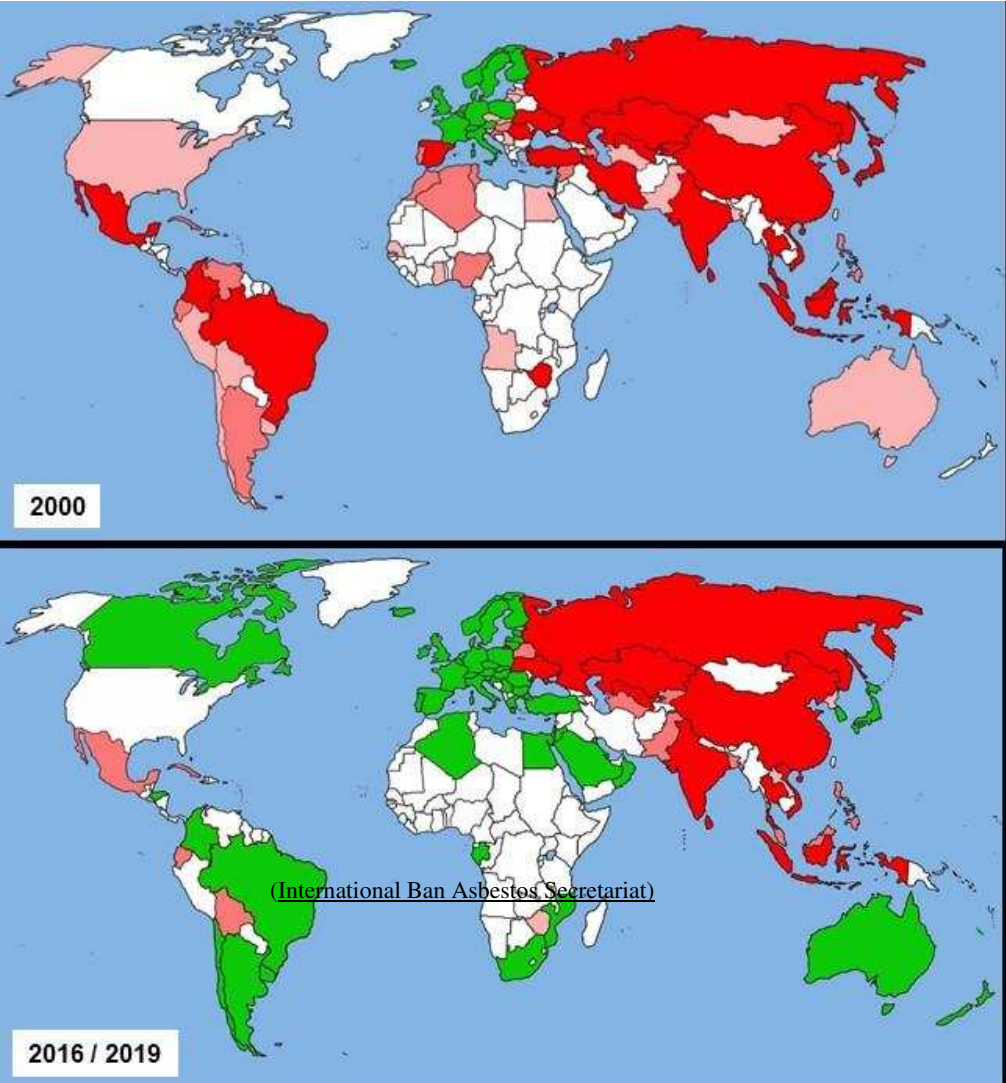


Figure 13. Spatial distribution of the mining residue classes. Identified classes are overlaid on a high-resolution image obtained by using Google Earth Pro-Image © Airbus 2025, acquired on 2 February 2022.

Distribuzione delle miniere di asbesto nel mondo



Asbesto bandito



Riassumendo

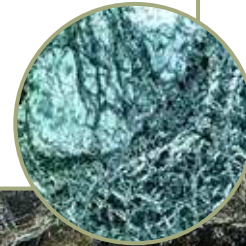
- Fragments of the **Neotethyan Ocean**, uplifted during **Apennine orogenesis**
- **Metamorphic grade higher in Calabria** (blueschist facies) **than in Basilicata** (greenschist facies) serpentinites
- Commonly associated with **metabasites**

Geological Context:



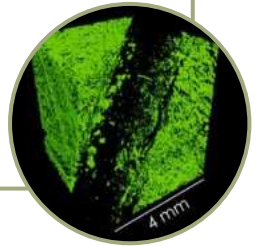
- Both regions contain **serpentine-group minerals** (lizardite, antigorite, chrysotile), **amphiboles, pyroxenes, chlorite, talc, titanite, magnetite, and carbonates**
- Basilicata serpentinites also include **quartz, dolomite, and edenite**

Mineralogical Composition:



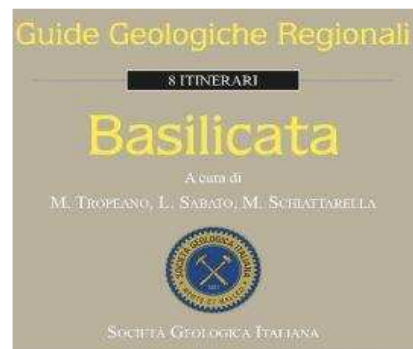
- Calabrian serpentinites show **mechanical properties suitable for building materials**, meeting ASTM standards (UCS > 69 MPa)
- **Presence of NOA** (naturally occurring asbestos) **and PTEs** (potentially toxic elements) highlights the need for detailed study

Petrophysical & Environmental Considerations:



Da **problema** a **georisorsa**: prospettive future

Geological site accessibility



Promote geotourism by enhancing access to key geological site

Encourage **public engagement** through educational itineraries and responsible exploration

Sustainable Applications



Potential for use in **construction, restoration, and innovative materials**

Ensuring **worker safety** and **exposure prevention**

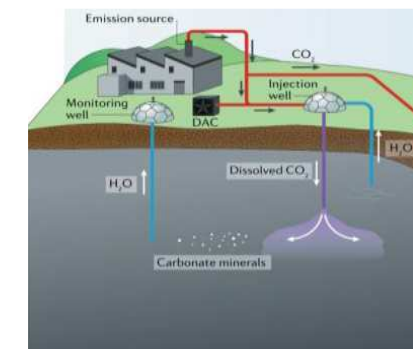
Strategic Resource for the EU



Potential source of **Critical Raw Materials (CRM)**, supporting the **Critical Raw Materials Act (CRMA)**

Valorization of **extractive waste** through circular economy models

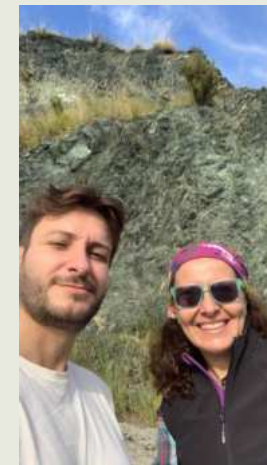
CO₂ Capture & Storage



Natural **carbon sequestration** potential through **mineral carbonation**

Investigating **Pollino Massif serpentinites** for **Carbon Capture & Storage (CCS)** applications

Grazie per l'attenzione!



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