VALORIZATION OF MINING RESOURCES THROUGH A TRANSDISCIPLINARY, CIRCULAR, AND ENVIRONMENTALLY-SOUND APPROACH (VIRTUS)

CNR DSSTTA

Consiglio Nazionale delle Ricerche

BACKGROUND AND RATIONALE

The **SARs-CoV2 pandemic crisis and the geo-political instabilities** at an international level have highlighted the **fragility** of Europe with regards to **the supply of raw materials**, which is **fundamental** for satisfying the industrial needs of the Member Countries, including Italy

With the presentation of the **Critical Raw Materials Act** (2023), the European Commission proposes a series of **actions** aimed at guaranteeing **safe and sustainable access to raw materials** fundamental for the economic development of the European Union

March, 2023

← Post

Ursula von der Leyen
@vonderleyen

Without critical raw materials, there is no green transition and digital transition.

The Critical Raw Materials Act will improve Europe's refining, processing and recycling of raw materials.

And create a Critical Raw Materials Club with reliable partners to diversify supply.

Traduci post

December, 2023

The European Parliament and the Council, the grouping of EU governments, needed to agree on a common text. They did this on Monday, parties from both sides said, paving the way for the law to enter force in early 2024.

Negotiators upgraded the recycling target to at least 25%. Parliament negotiators also said the European Commission would pass a related act in 2027 that set a recycling target related to annual waste collected, rather than consumption.

May, 2024

Today marks the entry into force of the European Critical Raw Materials Act, which aims at ensuring a diverse, secure, and sustainable supply of critical raw materials for the EU's industry. Secured access to critical raw materials is essential for strategic sectors including clean technologies, digital, defence and aerospace industries.

Setting benchmarks by 2030 for domestic capacities

The Act sets these benchmarks along the strategic raw materials value chain and for the diversification of the EU supplies

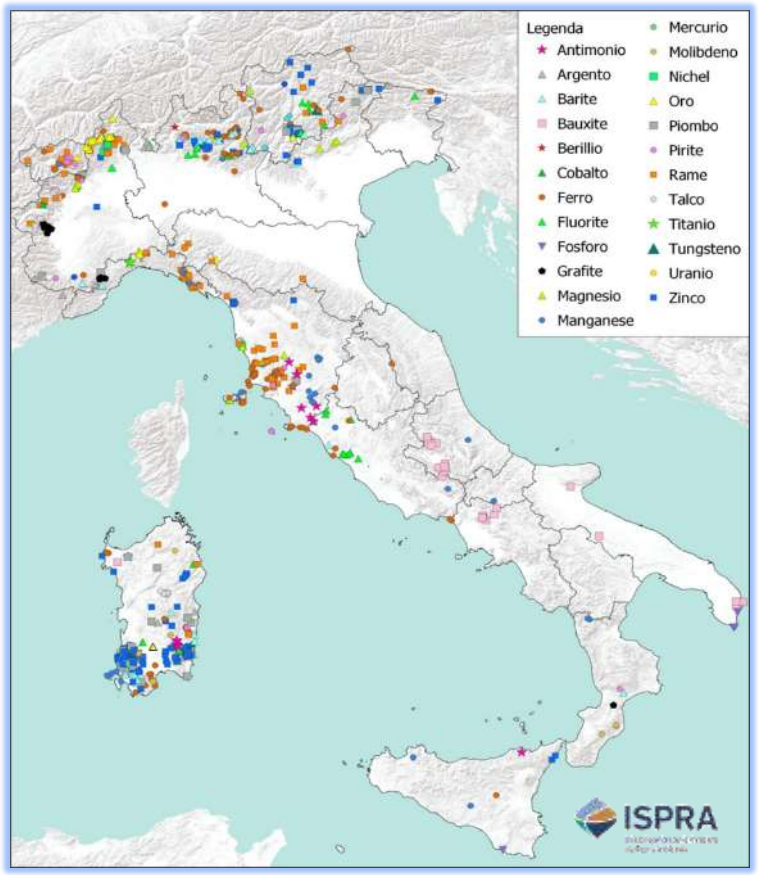
- at least 10% of the EU's annual consumption for extraction
- at least 40% of the EU's annual consumption for processing
- at least 25% of the EU's annual consumption for recycling
- no more than 65% of the EU's annual consumption from a single third country

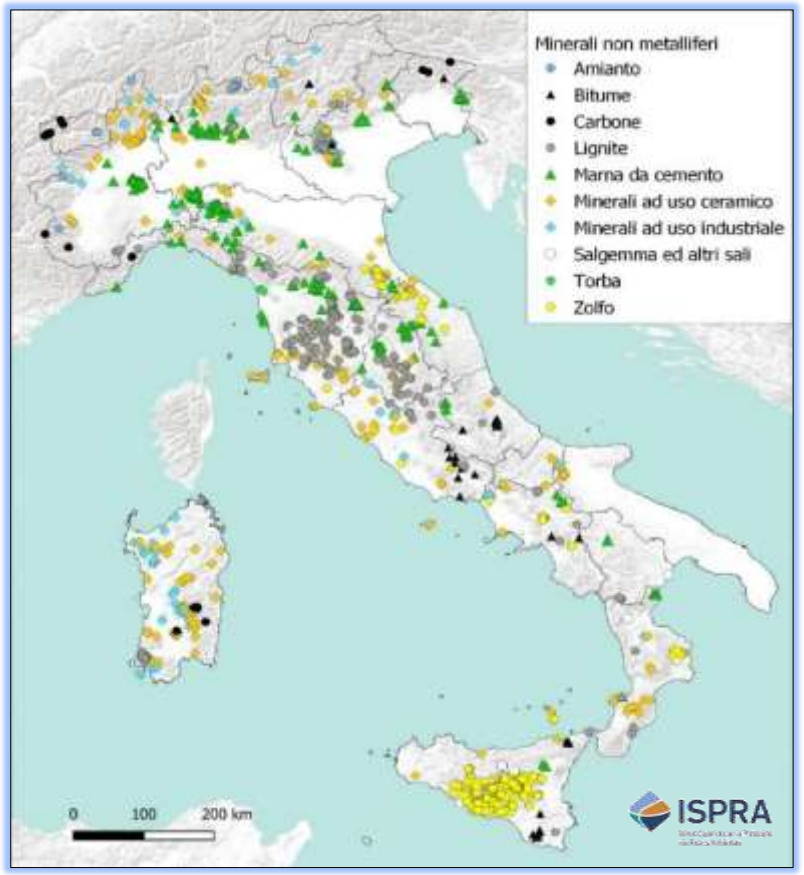
BACKGROUND AND RATIONALE

ITALY? Re-evaluation of national resources: Italian mining sites 1870-2023

June/August, 2024

Decree-Law No. 84/2024 establishes **urgent measures** to **ensure the secure and sustainable supply** of strategic critical **raw materials**, in implementation of the Critical Raw Materials Act. It was subsequently converted into **Law No. 115/2024**.





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BACKGROUND AND RATIONALE

July, 2025

The **National Mineral Exploration Program** has been approved.

Approvato il Programma nazionale di esplorazione mineraria. Al via le indagini in tutta Italia

Sono 14 i progetti di ricerca contenuti nel Programma Nazionale di Esplorazione Mineraria generale appena approvato dal Comitato Interministeriale per la Transizione Ecologica (CITE), distribuiti su tutto il territorio nazionale, in regioni chiave come Lombardia, Piemonte, Trentino-Alto Adige, Liguria, Toscana, Lazio, Campania, Calabria, Emilia-Romagna, Marche e Sardegna, ai quali si aggiunge la mappatura nazionale dei depositi dei rifiuti estrattivi prevista dal progetto PNRR URBES.

ITALIAN MINING MAP – ISPRA
GEMMA Database (2024)

Main goal(s)

- ✓ Developing and validating a **multidisciplinary strategy** for the comprehensive **assessment of CRM potential** in a **representative mining site**:
  - i. advanced methods for **site characterization, mapping and classification** based on the availability, quality, and accessibility of CRMs in terms of **"primary" exploitation** and **recovery of "secondary resources"**
  - ii. the development of **novel environmentally-sound technologies** for the **extraction and recovery of CRM** from tailings,
  - iii. the **understanding/modelling of water-rock interactions**, including bio-based processes, which influence the **environmental footprint** of mine sites.
- ✓ Promoting a **transdisciplinary approach** to involve **local communities, policymakers**, and **stakeholders** to gather insights, ensure regulatory compliance, and foster sustainable mining partnerships.

SPECIFIC OBJECTIVES OF THE VIRTUS PROJECT

S.O. 1: *Targeting of **primary CRM** resources in base metal deposits.*

i. better defining the minerogenetic and geological controls that gave rise to the deposits and the concentration of CRM in the ores, which are far from being understood

ii. defining advanced criteria and guidelines for future CRM exploration at district and regional scales

iii. providing essential mineralogical and petrographic information of primary resources for advanced mining waste characterization, reprocessing, and metal recovery

S.O. 2: *Characterizing, mapping, and classifying **mining residues**.*

i. Integrating field surveys and laboratory analytical techniques with satellite imagery, supervised classification, and cluster analysis

ii. creating a dataset useful for mining residues classification, and mapping of exploitable CRMs

SPECIFIC OBJECTIVES OF THE VIRTUS PROJECT

S.O. 3: *Developing* ***technologies for the sustainable recovery of CRM*** *from mining waste.*

i. integrating **bio-based technologies** and **advanced hydrometallurgical methods** for CRM extraction and subsequent recovery.

S.O. 4: *Understanding* ***CRM fluxes in waters*** *from underground to river catchment and their* ***biogeochemical processes****.*

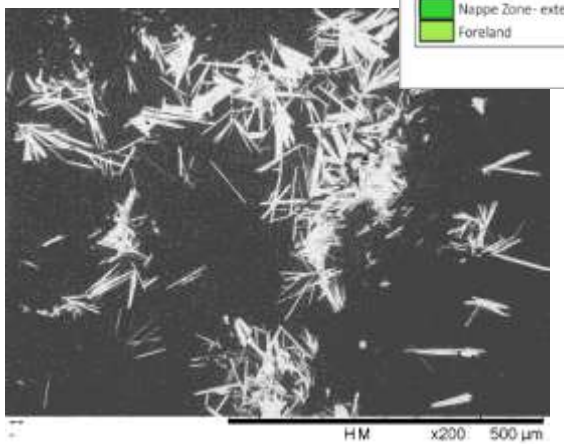
i. characterizing the entire water path from infiltration areas through underground workings and drainage tunnels to the river catchment, enhancing knowledge of environmental interactions in mining areas.

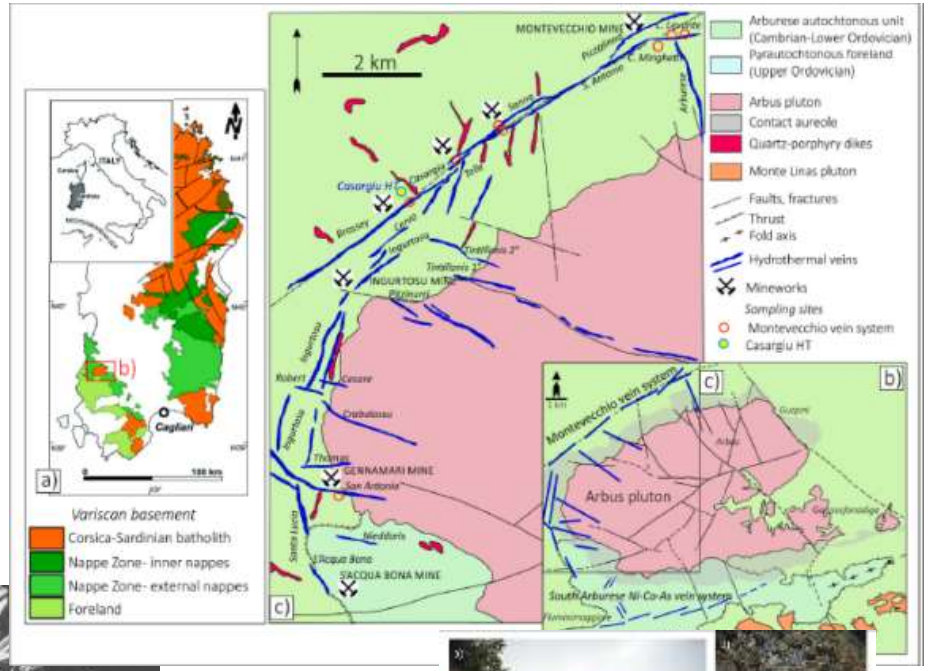
S.O. 5: *Ensuring effective* ***dissemination/communication****, and* ***public engagement****.*

THE REPRESENTATIVE MINING DISTRICT

Montevecchio-Gennamari-Ingurtosu

- ✓ Montevecchio, Ingurtosu and Gennamari have been among the largest lead and zinc mines in Italy . Mining ceased in 1991. Historical production: > 3Mt of metallic Pb+Zn
- ✓ High contents of accessory metals in the ore: Ag, **Bi**, **Sb**, **Cu**, Cd, **Ni**, **Co**, **Ga**, **Ge**, In were recovered in the past in the mining company's metallurgical plants. Recent studies in the ore minerals confirmed the presence of Ni-Co minerals and locally high Ga, Ge, In contents. **REE minerals** were recently discovered.





REE fluorocarbonates in quartz gangue – south from Gennamari

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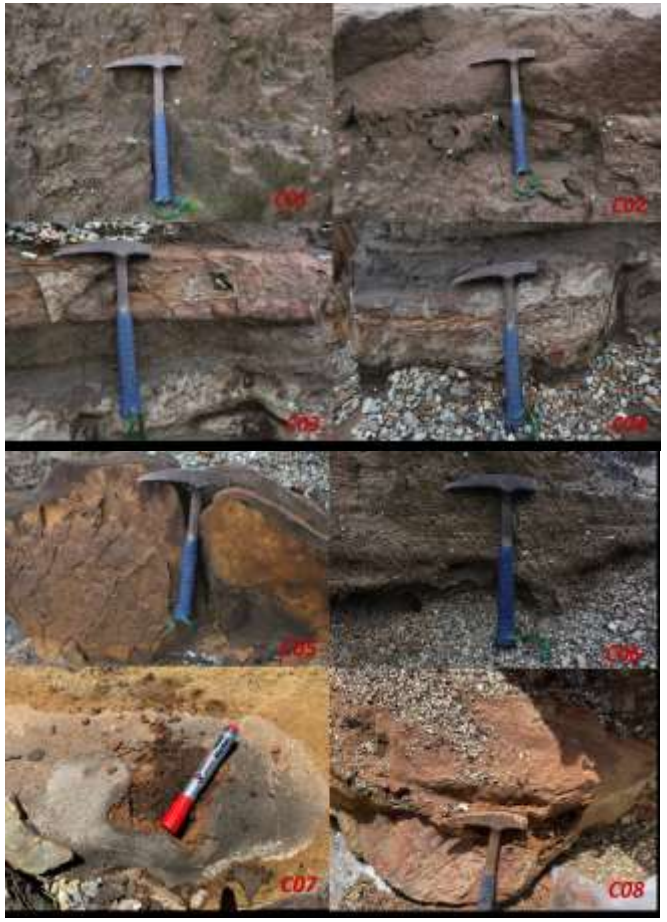
THE REPRESENTATIVE MINING DISTRICT



Ponente plant: tailing stratigraphy in the tailing dam

- ✓ Over **10 Mm³** of hydrogravimetric and flotation tailings are present close to the main processing plants. In the western part of the district ("ponente" processing plant) high **Zn** (over 2.5%), **Pb** (over 1%) and interesting **REE** contents (up to **600 ppm**) have been found in **flotation tailings from the old tailing dam**

Ponente processing plant and mine waste deposits

THE VIRTUS RESEARCH TEAM (VRT)

The VRT have a strong, multidisciplinary background which will be fully exploited to achieve VIRTUS' main goals.

The VRT consist of researchers, technologists, technical staff, full and associate professors from different research and academic institutions:

- ✓ Institute of Environmental Geology and Geoengineering (CNR-IGAG)
- ✓ Institute of Geosciences and Earth Resources (CNR-IGG)
- ✓ University of Cagliari (UniCA)
- ✓ National University of Cuyo (Argentina)

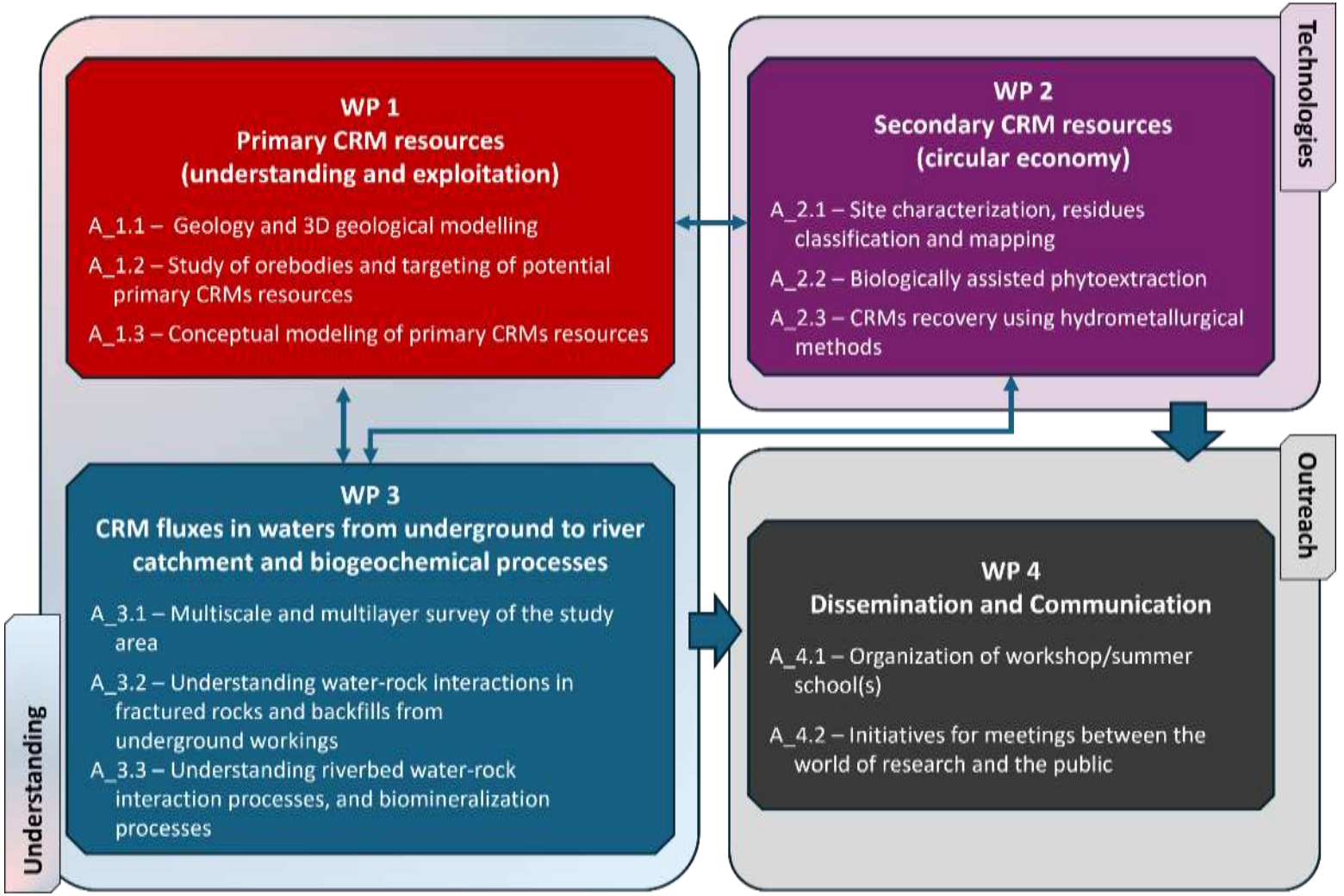
More than 10 research projects on VIRTUS-related topics

Some of the **key disciplines involved**

environmental mineralogy and geochemistry, ore geology, analytical and environmental chemistry, remote sensing and geospatial analysis, biotechnology, hydrometallurgy, …

THE VIRTUS' STRUCTURE

- **Three grouping boxes**
  1. *Understanding*
  2. *Technologies*
  3. *Outreach*
- **Four interconnected WPs**
  1. *Primary CRM resources*
  2. *Secondary CRM resources*
  3. *CRM fluxes in waters from underground to river catchment and biogeochemical processes*
  4. *Dissemination and communication*

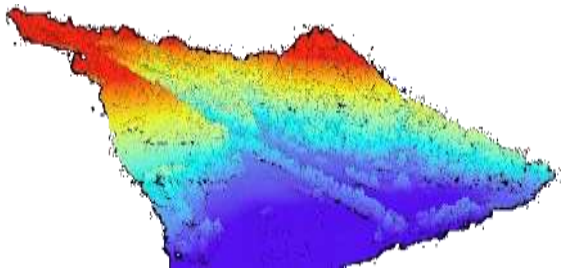


WP1 – PRIMARY CRM RESOURCES (UNDERSTANDING AND EXPLOITATION)

Andrea Dini (a.dini@igg.cnr.it)
Stefano Naitza (snaitza@unica.it)

A_1.1: *Geology and 3D geological modelling (CNR-IGAG, UniCA; SO_1; TRL 4)*

- ✓ *A geological-structural map and 3D geological model of a test site will be developed.*
- ✓ *A 3D GIS database will be created, incorporating geological, stratigraphic, structural, petrographic, geophysical, geochemical, mining, and well log data from literature, previous mining operations, and the GeMMA database by ISPRA*



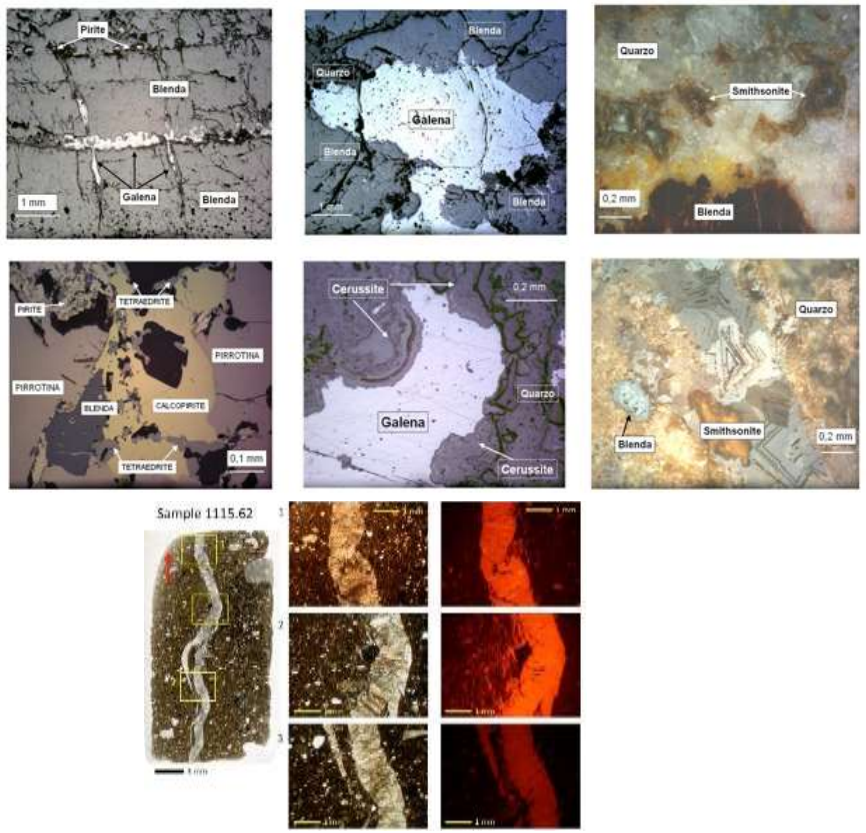
Outcropping ore in Sanna mine excavations

WP1 – PRIMARY CRM RESOURCES (UNDERSTANDING AND EXPLOITATION)

Andrea Dini (a.dini@igg.cnr.it)
Stefano Naitza (snaitza@unica.it)

***A_1.2**: Study of the orebodies and targeting of potential primary CRMs resources*
(UniCA, CNR-IGG, CNR-IGAG; *SO_1*)

- ✓ *Selected geological samples will undergo detailed microtextural and microstructural characterization*
- ✓ *The ore grade and total CRM contents will be estimated, and the characterization of host rocks will aid in modeling the physicochemical conditions that produced the ores*
- ✓ *A specific focus will be on studying CRM mobility and entrapment under supergene conditions*



WP1 – PRIMARY CRM RESOURCES (UNDERSTANDING AND EXPLOITATION)

Andrea Dini (a.dini@igg.cnr.it)
Stefano Naitza (snaitza@unica.it)

A_1.3: *Conceptual modeling of CRMs sources*

(CNR-IGG, UniCA; *SO_1-2*; TRL 3)

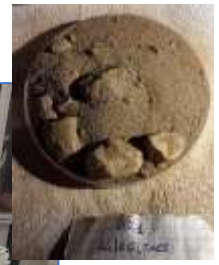
- ✓ *The results of A_1.1-2 will be synthesized into new conceptual models of the studied deposits:*
  - ✓ *essential data for CRMs targeting actions and characterization of materials in mining waste deposits*
  - ✓ *new exploration criteria for future projects on CRMs at the regional scale*
  - ✓ *analytical elements and interpretative tools to clarify some geological and genetic aspects still unresolved, and to overcome the current classification schemes of ore deposits*

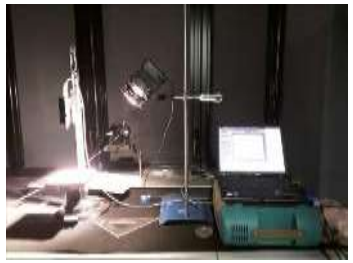
WP2 – SECONDARY CRM RESOURCES (CIRCULAR ECONOMY)

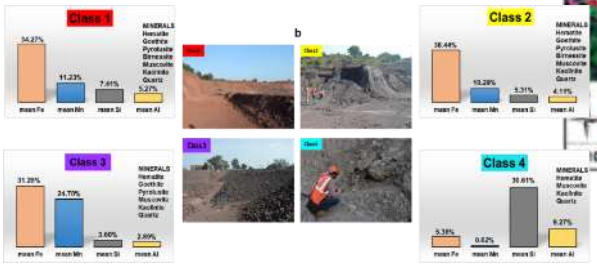
Stefano Milia (stefano.milia@cnr.it)
Giovanna Cappai (gcappai@unica.it)

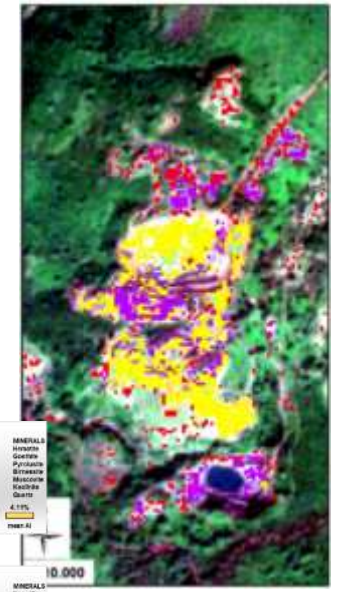
A_2.1: *Site characterization, residues classification and mapping (CNR-IGAG, UniCA; S.O. 2: TRL 3-4).*

- ✓ *Preliminary CRM assessment, sampling and mineralogical, chemical, and physical characterization.*
- ✓ *The sampling sites will be recognized on **satellite images**, and the corresponding spectral signature will be coupled with the sample spectra acquired by spectrometer.*
- ✓ *The **maps of exploitable CRMs** will be used to select mining residues suitable to be treated by phytoremediation and/or hydrometallurgical methods*









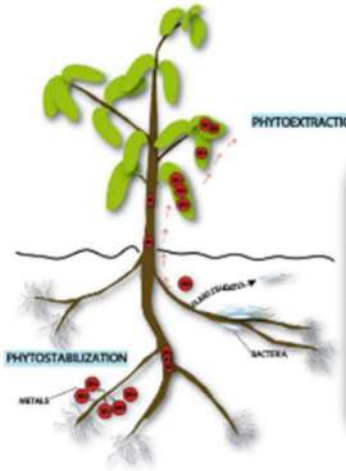
WP2 – SECONDARY CRM RESOURCES (CIRCULAR ECONOMY)

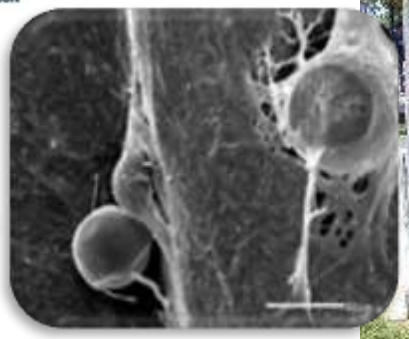
Stefano Milia (stefano.milia@cnr.it)
Giovanna Cappai (gcappai@unica.it)

A_2.2: *Biologically assisted phytoextraction*

(CNR-IGAG, UniCA, UniCuyo; SO_3; TRL 4)

- ✓ *The joint application of selected microorganisms, organic conditioners and plants will be explored in bioreactors at the laboratory scale.*
- ✓ *Representative plant samples will be collected and processed to evaluate process performance in terms of growth and survival rates, and CRMs extraction (uptake) potential.*



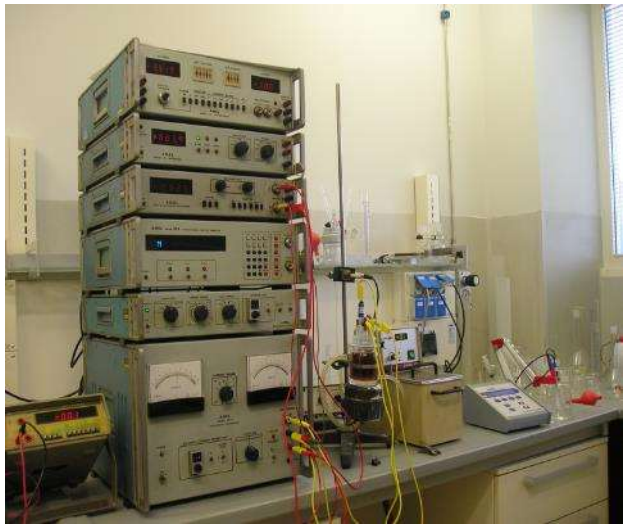


WP2 – SECONDARY CRM RESOURCES (CIRCULAR ECONOMY)

Stefano Milia (stefano.milia@cnr.it)
Giovanna Cappai (gcappai@unica.it)

A_2.3: *CRMs recovery using hydrometallurgical methods (CNR-IGAG; SO_3; TRL 4)*

- ✓ *The leaching of metals from the ash of heat-treated vegetable biomass using acidic or basic solutions will be carried out.*
- ✓ *Purification/concentration of filtered leaching solutions will be performed by advanced and environmentally friendly technologies.*
- ✓ *Finally, the recovery of metals from the final solution will be carried out*



WP3 – CRM FLUXES IN WATERS FROM UNDERGROUNDS TO RIVER CATCHMENT AND THEIR BIOGEOCHEMICAL PROCESSES

Giovanni De Giudici
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Simone Vezzoni
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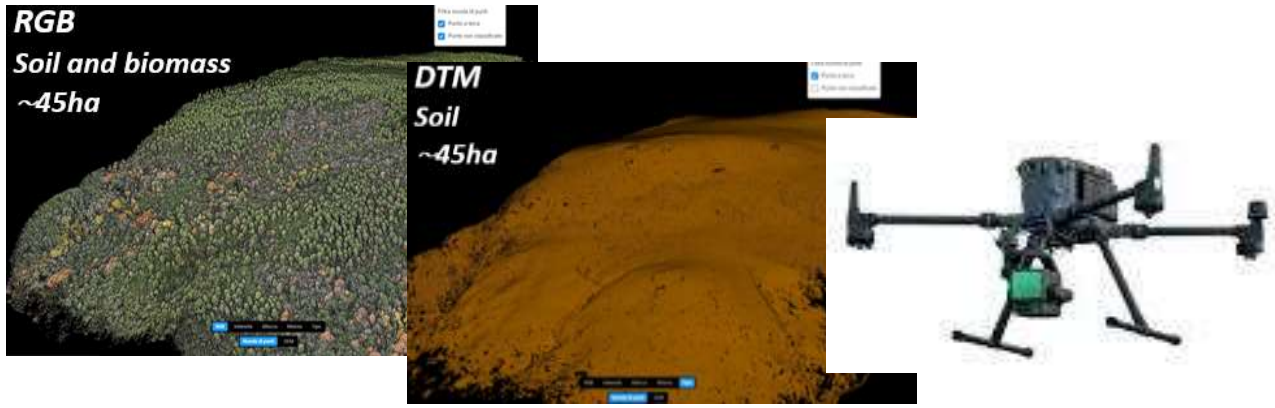
A_3.1: *Multiscale and multilayer survey of the study area (CNR-IGG; UniCA; SO_4; TRL 3-4)*

- ✓ *Visual recognition, fly-, ground- and underground-methods for the observation of the study area*
- ✓ *A 3D, geomorphological digital model will be generated for the analyses of water circulation and CRM fluxes based on high-resolution remote sensing (reliefs, mining works and wastes)*
- ✓ *Cross-calibration of multilayer survey with mineralogical and geochemical data in selected key areas - continuous description of the total study area*



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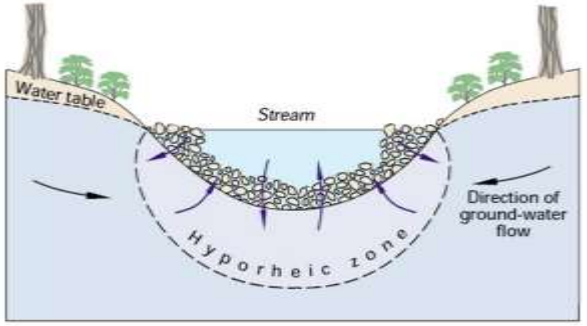
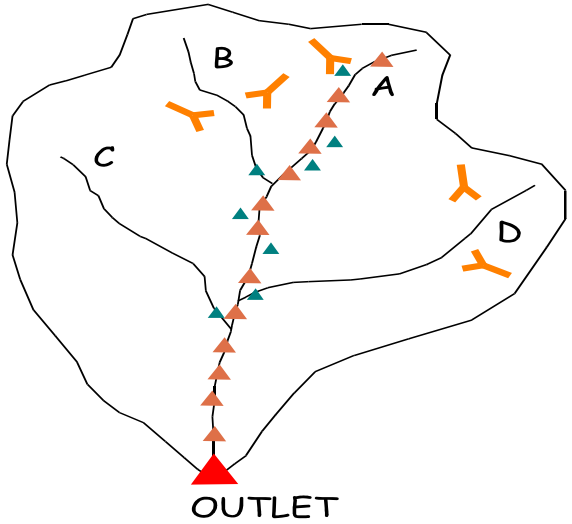
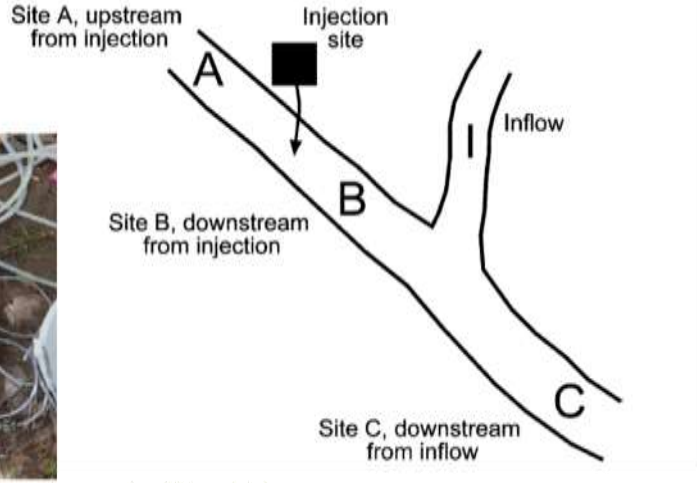
***A_3.2**: Understanding water-rock interaction in fractured rocks and backfills from underground workings*

(CNR-IGG; UniCA; SO_4; TRL 3-4).

- ✓ *Hydrological tracer techniques will be applied to at least one catchment in order to know the mass balance of metals and CRM **(what the impact of specific mine waste/body is?)***







Giovanni De Giudici
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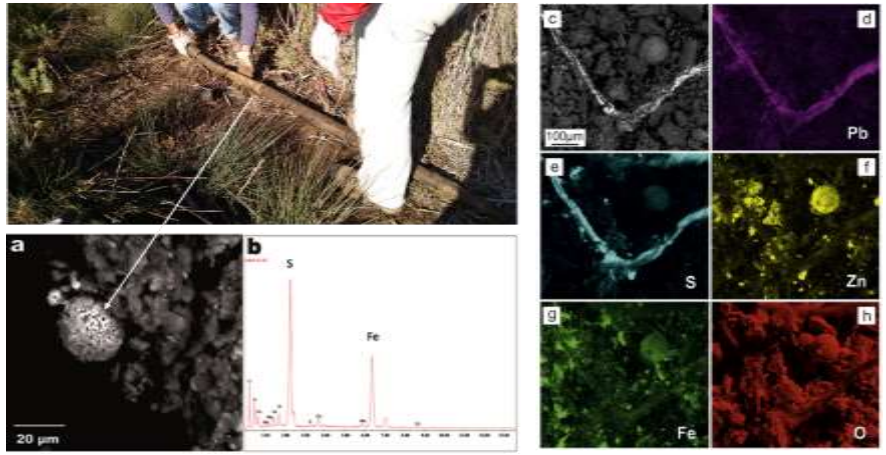
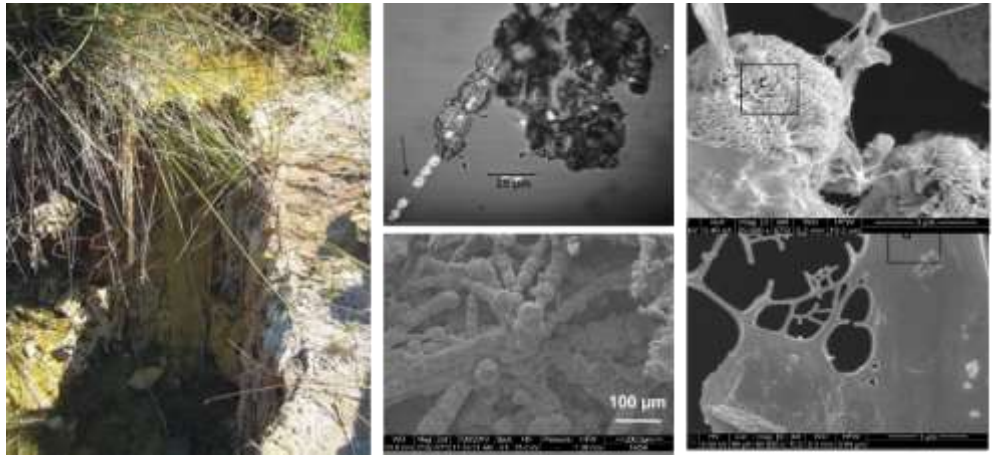
A_3.3: *Investigating riverbed water-rock interaction processes and understanding biomineralization processes*

(UniCA; *SO_4*; TRL 3-4)

- ✓ *Biomineralization processes in riverbed will be investigated by on site survey and sampling, and then by applying XRD-XRF-SEM-TEM-FTIR and synchrotron techniques in order to know the chemical composition, morphological features and structural details* ***(what the formation mechanism is?)***





WP4 – DISSEMINATION AND COMMUNICATION

Daniela Guglietta
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A_4.1: *Organization of workshop/summer school (All Partners; SO_5)*

- ✓ *A three-day workshop will be devised at the University of Cagliari to specifically involve students, technical staff and stakeholders and increase awareness on the topics of VIRTUS project*

4.2: *Initiatives for meetings between the world of research and the public* (All Partners; *SO_5)*

- ✓ *At least three half-day meetings will be devised in different towns in Italy to increase awareness on the topics of VIRTUS project and our project results*

MAIN OUTPUTS, OUTCOMES, IMPACTS OF VIRTUS

OutP – tangible and measurable

*A **multidisciplinary strategy** for the sustainable assessment and valorization of **CRM potential** in **mine sites** for primary and secondary resources, **proactive involvement of stakeholders** within a transdisciplinary approach*

OutC – setting the basis for further scientific developments of the proposed activities and technologies in similar contexts at the national and international level

Enhanced resource utilization, adoption of sustainable practices, improved understanding of environmental interactions

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I – long-term impacts of the VIRTUS project will target various aspects of society, economy, and environment

Economic growth and sustainability, Environmental protection and circular economy

Consiglio Nazionale delle Ricerche

"Valorization of mIning Resources through a Transdisciplinary, circUlar, and environmentally-Sound approach (VIRTUS) "
Rome, 16th July 2025


Tratta da «Storie di Miniera» - L'Unione Sarda


Tratta da «Storie di Miniera»
L'Unione Sarda

Thank you for your attention!
Questions?

Presented by Stefano Milia (stefano.milia@cnr.it)